The Circulation of Ideas: Firms versus Markets

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Abstract

We describe new ideas as incomplete concepts requiring feedback from agents with complementary expertise. Once shared, ideas may be stolen. We compare how different contractual environments support invention and implementation. Markets, as open exchange systems, are good for circulation and thus elaboration, but may fail to reward idea generation. Firms, as controlled idea exchange systems, can reward idea generation but restrict their circulation. This identifies a basic trade-off between protecting the rights of invention and the best implementation of ideas. An environment that allows ideas to cross firm boundaries enhances the rate of innovation and creates a symbiotic relationship between markets and firms.

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1 Introduction

The role of innovation in economic growth is well recognized (Romer, 1990), yet the process of generating innovative ideas is still a novel field of inquiry. The literature has focused on the role of intellectual property rights as incentive for invention (Nordhaus, 1969, Gallini and Scotchmer, 2001). We focus here on an early stage in the innovation process, where ideas are still half-baked (so they cannot yet be patented), and need to be shared in order to be further screened and elaborated. We study how different contracting environments promote the development of novel concepts, when communicating them exposes the inventor to the risk that they will be stolen (Arrow, 1962; Anton and Yao, 1994). In the process we explore the notion that a free circulation of ideas may be as critical for generating innovation as their protection.

There is a strong presumption that market interaction and new firms drive innovation. Yet, most R&D is performed in established firms.[1] While the technological success of new ventures in Silicon Valley is often taken as evidence that innovation thrives in a free market environment, it is remarkable how any history of the Silicon Valley experience resembles a long list of talented people leaving large firms with novel ideas. Clearly, large established firms play a critical role as incubators for innovation.

We start with a simple definition of a novel idea. Schumpeter (1926, 1942) argued that new ideas are original combinations of existing factors (Weitzman, 1998). Most random combinations are useless. Valuable ideas are combinations which "fit" together, aggregating the component resources in a novel, functional way (Biais and Perotti, 2003). Accordingly, we define an early stage idea as an incompletely specified combination, which requires elaboration along some dimension. If the concept has some merit, it will become implementable once elaborated.

Because the idea is both incomplete and novel, it is not obvious who may be the agent with the right skills to complement it. Thus elaborating an idea requires sharing it with various agents, seeking the right match. A broad circulation of ideas is thus critical for the process of innovation, as it allows maximum scope for any concept to find the right complementary match.[2] Yet there is a fundamental problem with an open circulation of ideas, namely that information can be appropriated. We assume that an incomplete idea is too vague for an independent patent office to grant exclusive property rights.[3] Following Arrow (1962), we assume that agents will not contract to cooperate on an idea without knowing its content in advance. We then study the relative merit of hierarchies (firms) versus markets in the trade-off between

[1]For 2003, the National Science Foundation estimated private industrial R&D spending at $180 billion. In comparison, the National Venture Capital Association reported investments in venture capital backed companies amounting to $18 billion, i.e., one tenth the amount.

[2]Saxenian (1994) emphasizes "cross-pollination" and open networking as a central aspect of Silicon Valley's innovative potential.

[3]The well-known Yale survey found that patent protection is only one among many ways that firms protect their intellectual property, and that patents only matter for a limited set of industries (Levin et. al., 1987).

the need to circulate ideas and to reward their generation, when ideas must be shared before contracting.

In our model, an inventor who has developed an incomplete idea screens other agents on competence, seeking the partner with matching skills (a "complementor") to assess and complete her concept. If the inventor shares his idea with a complementor, this agent receives an informative signal, which he can either report it truthfully, or not. If the idea has potential, the complementor can either steal the idea or give feedback to complete the idea, which identifies its type. Since both parties have valuable implementation skills, an immediate agreement on a partnership is efficient.

However, often the inventor will present the idea to an agent whose skills essentially replicate his own. We call such an agent a "substitute". A substitute is unable to elaborate the idea, but understands it and can match the implementation skills of the inventor. Our first result is that as a substitute has nothing to gain from truthful reporting, he will steal the idea while giving negative feedback. The effect is to discourage the inventor, who cannot distinguish a false from a truthful negative response. As a result, an idea may circulate through a sequence of agents until matched to a complementor, who will "resolve" it by either recognizing it as hopeless, or by completing it if valuable.[4] Thus from a social perspective, a free circulation of ideas in an open exchange environment is efficient in ensuring a complete screening and implementation of all ideas. The problem is that idea stealing may deny the inventor a sufficient reward for invention. In such circumstances, no ideas will be shared in an open exchange system.[5]

In our model, firms emerge as a solution to this market failure. Specifically, agents accepting employment in a firm join a closed or "structured" exchange system. As part of their employment contract, employees sign a broad non-compete agreement on ideas generated inside the firm. In exchange, the firm owner commits to a performance-based reward system (which relies on an significant investment in reputation). Firms thus can control idea stealing and guarantee a reward for invention, and may thrive even as markets fail to generate ideas. However, firms have two drawbacks. Controlling the flow of ideas requires costly monitoring. Moreover, containing ideas within the firm's boundary limits the set of possible matching opportunities.

Although the owner does not control directly her employees' ideas, she can induce their reporting in exchange for a promised reward. An inventor chooses to disclose his idea as he obtains internal protection, and because he is allocated the task of "internal champion" or "intrapreneur" to seek to implement it internally. The owner "registers" the idea as a firm project and monitor its circulation by an internal recording

[4]This distinguish our model from the dissemination models in Dennis and Yao (1994) and Baccara and Razin (2002, 2004).

[5]This results echoes Grossman and Stiglitz (1980), who derive the impossibility of perfectly informative financial prices in a frictionless environment, as there are no incentives to generate information.

system (read: a "bureaucracy"), in order to create a verifiable paper trail of internal projects. This supports a mutual guarantee: once an idea is recorded, the owner cannot expropriate it, nor can any employee take it outside the firm. Our theory thus provides a justification for the frequently bemoaned bureaucracy associated with large hierarchical firms.[6]

But why would an agent trust a firm, if he would refuse to sign a "blind" contract with another individual? How can firms commit to reward rather than expropriate ideas? In our setting, any individual can set up a firm, by investing enough resources into building a reputation (see Kreps, 1986). With an infinite time horizon, a reputation for fairness is valuable to firms for capturing the residual value of multiple ideas. A large sunk investment in reputation, which would be lost in the case of idea expropriation, convince employees about the firm's incentive to reward inventors, as well as to fight idea stealing by employees.

Comparing idea generation by individual entrepreneurs and within firms, we offer a rationale for why individuals often pursue opportunities that require modest budgets, and may account for a larger fraction of radical innovations, whereas firms focus on larger scale, complex ideas which require substantial investments. Interestingly, this result is not a consequence of greater financial constraints faced by individuals (as is often assumed), but of the need to offer adequate rewards to inventors.

After studying idea circulation in markets and firms in isolation, we consider the possibility that ideas may move across firm boundaries. We study two possible forms of mobility: when firms condone the departure of an employee, after internal completion has failed; and when the employee with an idea may leave the firm without reporting it internally first. In the first case, allowing mobility may be efficient for firms, since it allows them to capture part of the value of ideas they cannot develop by reducing the required reward to inventors (Lewis and Yao (2003) consider a similar issue). This increased mobility also produces a general equilibrium effect: namely, it increases the reservation utility for joining a firm, since the flow of ideas out of firms makes it more attractive for agents to be active in the open system. In the second case, inventors prefer to develop their ideas externally when they are outside the firm's core competence. The firm may not be willing to incur the cost to reward retention of all possible ideas, as this may force a high compensation to all inventors.[7]

In general, the mobility of ideas from firms to markets enhances efficiency: firms promote idea generation, while markets increase their chances of completion, thus raising the rate of innovation. Thus our main conclusion is that markets and firms are in a natural symbiosis, complementing each other's weakness. This approach allows to interpret the high rate of innovation in Silicon Valley as the result of a symbiotic relationship of 'porous' firms and markets.

[6]Of course, an internal recording does not protect the idea against non employees. However, any employee who shares an internal idea with an outsider would not be able to legally profit from it.

[7]This also helps explaining why firms pursue "narrow" strategies, focusing employee initiatives towards a defined set of competencies (Rotemberg and Saloner, 1994).

Recent empirical evidence confirms that the flow of ideas out of established firms generates many innovative start-ups. According to Bhidé (2000), over 70 % of the founders of firms in the Inc. 500 list of fast growing young firms replicated or modified ideas encountered in their previous employment. Gompers, Lerner and Scharfstein (2004) show how a very high number of new entrepreneurs in high tech firms started their firm after leaving large firms.

The paper contributes some new perspective on the theory of the firm. The literature has made significant progress by looking at the role of corporate ownership of assets (Hart, 1995). Ideas are in principle intangible real assets, and in our approach their distinctive feature is that are neither verifiable ex ante (i.e. prior to disclosure) nor excludable ex post (prior to completion and patenting). Holmström and Roberts (1998) suggest that ideas and people should belong at the core of any theory of the firm. Our approach partially integrate this view with the asset ownership approach, as it views individual choices as essential to the specification of ownership rights on intangible assets.

In our model, firms are defined as boundaries around people and their ideas. As in the general literature, this boundary emerges because of a market failure, namely to protect against idea appropriation by controlling the circulation of ideas. But limiting the flow of ideas generates its own inefficiencies, which markets can contribute to resolve. Even when idea generation is not viable in markets, they can complement the incubating role of firms by refining those ideas that could not be completed within them. Our theory of the firm therefore points to an important symbiotic relationship between firms and markets, a novel perspective on the long-standing debate of firms versus markets (Williamson, 1975).

This paper also contributes to the recent theory literature on innovation. The optimal allocation of control over innovative ideas is analyzed in Aghion and Tirole (1994). Anton and Yao (1994) show that inventor can secure some rents by threatening to transmit the idea further, creating more competitors. Anton and Yao (2002, 2004) considers partial disclosure of ideas, as also in Bhattacharya and Guriev (2004) and Cestone and White (2003). Baccara and Razin (2002) examine a complex bargaining game where there is a team of investors who consider whether to buy out all idea holders, other whether to allow some leakage of ideas. Baccara and Razin (2004) extend that model by examining how a firm can provide additional incentive to prevent idea leakages. Rajan and Zingales (2001) examine how a hierarchy may prevent idea-stealing by granting access to its technology only to dedicated employees. Gromb and Scharfstein (2001) argue that firms have an advantage at knowing an employee's track record, which reduces the cost of innovation failures. Ueda (2004) and Chemmanur and Chen (2003) examines the trade-off of talking to uninformed investors who cannot appropriate an idea, versus venture capitalists who can. Finally, a recent literature on the open source movement addresses the question of voluntary exchange of ideas. Lerner and Tirole (2002) argue that career concerns induce people to contribute to open source code, while Johnson (2002) emphasizes the private provision of a public good. Biais and Perotti (2003) show that an early stage, unpatentable idea may be safely shared with experts for screening when their expertise is highly complementary. The current paper pursues this notion of complementarity one step further - or rather earlier - by allowing the complementary agent also to elaborate the idea.

Our model of coexistence is consistent with the evidence on firms spawning innovative ventures gathered by Gompers, Lerner and Scharfstein (2004). In particular, they show that more 'porous' firms (those backed by venture capitalists) tend to spawn less related firms. This is consistent with our result that more open firms attract employees by allowing them to leave to develop ideas which do not fit the current firm strategy. Klepper and Sleeper (2002) provide some evidence from the laser industry. Azoulay (2003) finds that pharmaceutical firms, while actively outsourcing in many other areas, maintain strong firm boundaries around knowledge intensive projects. Kremp and Mairesse (2004) find a positive relationship between firms' internal knowledge management systems and their innovative performance.

In section 2 we explain the basic setup. In section 3 we contrast open systems (markets) and closed systems (firms). In section 4 we present the model of interaction of firms and markets, and we study the mobility of ideas across firm boundaries. Section 5 discusses the implication of the extensive model, and is followed by some conclusions and thoughts for further research.

2 The Base Model

2.1 Ideas and Agents

In our model, incomplete ideas are generated by individuals at some cost. Ideas are private information, and are yet too incomplete to be patentable. To be elaborated, they need feedback by someone with a set of skills complementary to those of the inventor. Since these ideas are novel and incomplete, it is not obvious what the complementary skills are, or who might have them. So inventors need to seek agents with the right match of skills. By incurring a search cost, inventors can identify 'competent' agents, who a priori have a chance to be able to elaborate the idea.

Competent agents can be of two types, which cannot be distinguished ex ante. The first type are "complementors," who understand whether the idea is good, and if so are able to complete it. The second type are "substitutes," who do not know whether the idea is good, or how it can be completed. However, once they hear the idea, they have the same implementation skills as the inventor. Whether an agent is a complementor or substitute is idea-specific, and cannot be ascertained by his history. Our basic result will be that because substitutes have nothing to contribute, they have no incentive to report truthfully their ignorance, and they are likely to steal the idea.

2.2 Contracting in Firms and Markets

We contrast sharing ideas in open idea exchanges (markets) and within closed idea exchanges (such as firms). Market interaction offers inventors unrestricted matching with an infinite set of free agents, not subject to any governance structure. Within a closed system such as a firm, ideas circulate only inside a boundary, subject to some rules.

Idea appropriation is sometimes explained by assuming that ideas are not contractible. This is not convincing, since any idea which can be communicated can presumably be written down, and thus be put into a contract. In contrast, contractual commitments not to use information which will be disclosed only ex post are difficult to specify. In practice, so called "non-disclosure agreements" or NDAs are rarely used. Anton and Yao (1994) report that they are difficult to enforce, and that many institutions involved in the circulation of ideas, such as venture capitalists, routinely refuse to sign them. The work by Arrow (1962) and Anton and Yao (1994, 2002) suggests a reason. Individuals will not agree to sign a contract that forfeits their right to use some idea, before they have seen its content. Signing such a blind contract may unduly restrict the agent's future opportunities and/or expose him to extortion risks. For instance, a contract may contain ideas and knowledge that the agent already possesses, thus preventing him from pursuing his regular activities. We thus assume that agents are unwilling to sign such blind contracts, so that incomplete ideas must be shared before any contractual commitments are made. Once agents agree to cooperate on developing a specific idea, they can create a reliable partnership with properly specified NDA clauses. Before that, however, there is no contractual protection for ideas which are shared .

Agents can also interact within firms (intended as established multi-project firms, rather than single-project start-ups). The boundaries of the firm is given by the set of individuals who contract with the firm owner to become employees. The employment contract specifies that the owner has an ownership claim on all the ideas of all employees. Thus employees sign away the right to use any of the ideas circulating within the firm or to transfer them across its boundary.

The firm owner has two important tasks. First, she must monitor the generation and use of ideas. Yet claiming ownership requires that inventors report their ideas to the firm. Thus the second task is that the firm must commit to attribute ideas to their true inventors, and reward successful ideas. We argue that firms keep records of internal initiatives to produce verifiable evidence (a "paper trail") on what ideas are generated within the firm, and who generated them. Thus "bureaucracy" helps the firm to both claim internally generated ideas, and to commit to a compensation system for inventors.

We argue that the ability of a firm to commit to a reward for inventors stems from a desire to uphold its reputation. A sufficiently large sunk investment in reputation guarantees that the firm does not want to steal an employee's idea, or withhold his reward. Thus the fixed cost of setting up a firm K includes the sunk cost of establishing a reputation (in addition to setting up a bureaucracy that tracks the generation and use of ideas). In addition, we assume that every period the firms incurs monitoring costs $m(E)$, where E is the number of employees in the firm, with $m' > 0$ and $m'' > 0$ for sufficiently large E. Thus monitoring costs are (eventually) convex, reflecting an increasing complexity of managing a large organization, as the need to monitor any external use of internal ideas.[8] A free entry condition determines the number of firms as the number of agents who choose to invest in the necessary reputation, so the number of firms is endogenous.

2.3 Stage game

Table 1 summarizes the notation used throughout the paper. Our model has an infinite sequence of dates in which agents interact. We assume there is a unit mass of agents whose discount factor is δ.

The assumptions for our stage game are chosen to keep it sufficiently simple to retain stationarity. We assume that agents can only carry one idea from one period to the next. They can thus talk at most about one idea, and listen at most to one idea. This structure allows us to treat talking and listening as independent activities.

Figure 1 illustrates the structure of the stage game. At the beginning of each period, an agent may try to generate an idea at a private cost ψ, and finds an (incomplete) idea with probability γ. The idea may be good, with prior chance p, or bad. A completed good idea generates a payoff z; a bad one is worthless. Ex ante, it is not known what the complementary piece is, so the idea must circulate among potentially competent agents to find those with the matching skills. Since competence is idea-specific rather than an individual quality, the carrier of an idea incurs some search cost c to identify knowledgeable agents. We assume that it is optimal to incur this cost to avoid being matched with agents who certainly lack the necessary skills.[9] Thus c is a measure of the (local) frequency of competent agents. After hearing the idea, the listener receives a private signal on its quality and gives a report (feedback). The idea is then implemented, or dropped, or taken to other listeners next period by one or both agents. If the idea is jointly implemented, we assume that agents negotiate on sharing the return under Nash bargaining.[10]

Competent listeners understand the idea, but only some of them are able to see whether it can be completed. With probability ϕ the listener has the right complemen-

[8] We do not model explicitly the nature of the convex costs, interpreting them bradly as reflecting increasing complexity (e.g., a firm with E employees has to manage E (E-1) interactions). To the extent that these costs determine the boundary of the firm, we do attempt to model their underlying determinants.

[9] Since the talker discounts future payoffs, he is willing to incur some search costs to screen ideas faster. The screening also avoids that incompetent agents may circulate an idea which they do not understand to potential competitors.

[10] In the appendix we also show that our result do not depend on Nash bargaining, and continue to hold for outside option bargaining a la Rubinstein (1986).

tary expertise, and receives a precise signal. We term such an agent a complementor. If the idea is good, this agent knows how to complete it, and can identify his own type by describing the completed concept. With probability $\overline{\phi}$[11] the listener understands the idea, but receives an uninformative signal about its quality. At this point, this agent has the same skills and the same information as the inventor. We term such agents substitutes. In order to implement an idea, both types of skills (those of any complementor, and of the generator or any of his substitutes) are required. We call an idea "resolved" if has been either abandoned or implemented.

Because signals are private information, both complementors and substitutes may lie. A substitute who reports truthfully admits that he has nothing to contribute to the idea. We will show that as a result, he has an incentive to steal the idea and seek for a complementor himself (so in the next period he will become a talker). In contrast, a complementor has something to offer as well as something to gain, as he needs the skills of the speaker.

A complementor who reports truthfully a good signal reveals the idea to be good. In other words, successful idea elaboration makes it self-evident that the idea is viable and that the listener is a complementor. Since both types of skills are needed to implement an idea, the complementor can either offer the talker to collaborate on the implementation, or steal the idea and look for another substitute. If a complementor recognizes the idea as bad, he has no reason to pursue it further, and gives a (correct) negative feedback. We assume that a negative report by a complementor cannot be distinguished from that of a substitute.[12] Finally, when two teams implement an idea simultaneously, they engage in Bertrand competition, so both teams get zero returns. Also, once an idea has been implemented, everybody knows about it, and no one else tries it again.

Throughout the paper we denote the per period utilities of agents with lower cases u and v, and lifetime utilities (i.e., the net present value of the current and all future per-period utilities) with upper cases U and V. u and U pertain to agents in the open system, while v and V pertain to agents inside firms.

3 Analysis of the model

3.1 Analysis of markets

3.1.1 Analysis of the stage game

We now introduce an intuitive assumption to maintain a stationary process of idea circulation. Basically, we restrict attention to circumstances when in equilibrium, an idea is circulated in each period by only one agent. Specifically, we impose a so-called

[11]Throughout the paper, a bar over any variable signifies $1-$ that variable, so $\overline{\phi} \equiv 1 - \phi$.

[12]Intuitively, it may be possible to test a proposed solution, while it may be impossible to review all the possible solutions to show that the concept could never work.

discouragement condition, so that the talker stops pursuing the idea after a negative report. In this case, as we show in Lemma 1 below, negative feedback could either come from a honest complementor or a dishonest substitute. Negative feedback is always informative, and leads to a downward revision in the talker's beliefs on the quality of the idea.

A talker receiving negative feedback may be discouraged and abandon the idea when the utility of generating a new idea is greater than the utility of further pursuing the current idea. This discouragement condition, which is formally derived in the appendix, is always satisfied for ϕ sufficiently low, and also for ϕ sufficiently large. Since discouragement happens after the first negative feedback, it prevents parallel dissemination and allows us to maintain a stationary stage game. The intuition for a large ϕ is that it makes the response very informative. In contrast, a low ϕ discourages further searching because it is difficult to find a match.

We now examine the listener's choice of either providing honest or false feedback under such a condition.

Lemma 1:

(i) A substitute always provides false negative feedback and steals the idea.

(ii) A complementor always provides honest feedback and cooperates with the talker.

The proof of Lemma 1 is instructive, so we derive it in the main text. Consider first a substitute listener. He understand the concept, but cannot complete it by himself. He can either provide false negative feedback, or else disclose his ignorance. If he provides false feedback, the discouragement condition guarantees that he can take the idea forward alone. The substitute then becomes a talker next period, and gets a utility δu_T (derived below). If the substitute discloses his ignorance to the talker, then both are equally capable of taking it forward. Consider the most favorable outcome for the listener, which is when they do not compete, It is then efficient to flip a fair coin, to determine who is to take the idea forward. The utility of disclosing ignorance is thus given by $\frac{1}{2}\delta u_T$. This is always less than the utility of stealing the idea by providing false negative feedback.

Consider next the choice facing a complementor, who knows whether the project is good or bad. If the project is bad, he has no interest in pursuing it, and he is willing to provide honest negative feedback to the talker. The interesting case is when the project is good. Suppose first that the complementor provides honest positive feedback, which reveals that he and the talker can implement the project together. Below we derive the equilibrium bargaining shares, denoted by a for the talker and $\overline{a}$ for the complementor. If instead the complementor provides false negative feedback, the talker is discouraged. We denote the complementor's utility of taking the idea forward into the next period by ζ_C. In the next period, the complementor talks to a substitute with probability $\overline{\phi}$ (who has the complementary skills to the complementor) or to another complementor (which is a competitor in terms of skills). Finding a substitute leads to bargaining over the division of the return which yields a utility $\overline{a}z$. Finding another complementor creates a dilemma, since both agents are equally capable, but they need the skills of a substitute to implement the idea. Once again it is efficient to flip an even coin, to determine who may take the idea further. The utility of providing negative feedback and taking the idea further alone is thus given by

$$\zeta_C = \delta(\phi\frac{\zeta_C}{2} + \overline{\phi}\overline{a}z - c) \Leftrightarrow \zeta_C = \frac{\delta(\overline{\phi}\overline{a}z - c)}{1 - \delta\frac{\phi}{2}}$$

To see that the complementor always prefers to give honest feedback, it is easy to verify that $\overline{a}z > \zeta_C$. In fact, we can rewrite this inequality as follows: $\overline{a}z > \delta(\frac{\phi}{2}\overline{a}z + \overline{\phi}\overline{a}z - c)$. This helps us to see why stealing has several disadvantages for a complementor: it causes delay (as captured by δ), it requires additional search (as captured by c), it is risky, since he may talk to a rival complementor (as captured by $\frac{\phi}{2}\overline{a}z$), and at best it only leads to meeting another substitute (as captured by $\overline{\phi}\overline{a}z$). This completes the proof of Lemma 1.

Lemma 1 explains the fundamental problem of talking about an idea in an open exchange. Interestingly, substitutes are the talker's biggest problem. They have nothing to add, and so are eager to steal the idea. Complementors actually need a partner with the talker's skills, so cooperation is efficient. Provided they receive an attractive share of returns which compares well with their alternative, they will provide honest feedback and cooperate.

We are now in a position to examine the bargaining game between a talker and a complementor who has just revealed his type by completing the idea. To derive the outside options, we consider the continuation game if the talker and complementor fail to agree. Depending on parameters, this continuation game may have three types of equilibria. In one equilibrium, the complementor takes the idea further. Knowing this, the talker prefers to stop.[13] In a second equilibrium, it is the talker that takes the idea further, and knowing this, the complementor prefers to stop. Finally, in a third equilibrium, both talker and complementor take the idea further, even though there may be competition. Unlike the first two equilibria, the third equilibrium is no longer stationary, and is analytically not tractable. We thus identify parameter ranges where the third equilibrium can be excluded. For this we obtain sufficient conditions by placing an upper bound on the utilities associated to the non-stationary continuation game.

[13] This is similar to the discouragement, except that here the talker actually knows that the idea is good. What is stopping him here is the threat of competition from the complementor.

Lemma 2:

(i) If ϕ is sufficiently small, the only equilibrium of the continuation game has the complementor continuing, and the talker stopping.

(ii) If ϕ is sufficiently large, the only equilibrium of the continuation game has the talker continuing, and the complementor stopping.

The proof is in the appendix. The key intuition is that the agent with the scarcer skill is in the stronger position, since he is more likely to win the race of finding a suitable partner. The weaker partner prefers to stop, rather than incurring search costs.

We are now in a position to solve the continuation game, which determines the outside options for the bargaining game between the talker and the complementor. For ϕ sufficiently small, the talker has an outside option of 0, and the complementor has an outside option of ζ_C.[14] Using Nash bargaining, the talker gets $az = \frac{z - \zeta_C}{2}$ and complementor gets $\overline{a}z = \frac{z + \zeta_C}{2}$. For ϕ sufficiently large, the talker's outside option is denoted by ζ_T. The talker gets $az = \frac{z + \zeta_T}{2}$ and complementor gets $\overline{a}z = \frac{z - \zeta_T}{2}$.

Lemma 3:

(i) For ϕ sufficiently small, the Nash bargaining share of talker is given by

$$a = \frac{1}{2} - \frac{\zeta_C}{2z} \text{ where } \zeta_C = \frac{\delta(\overline{\phi}z - 2c)}{2 - \delta}.$$

Note that a is larger when the chance of meeting another complementor is higher (higher ϕ), when search costs are higher (higher c), and when the delay costs are larger (lower δ).

(ii) For ϕ sufficiently large, the Nash bargaining share of talker is given by

$$a = \frac{1}{2} + \frac{\zeta_T}{2z} \text{ where } \zeta_T = \frac{\delta(\phi z - 2c)}{2 - \delta}.$$

Here, a is larger when the chance of encountering another complementor is higher (higher ϕ), when search costs are lower (lower c), and when the delay costs are smaller (higher δ).

[14] To exclude trivial cases, we assume that search costs c are not too high to prevent the party in question from wanting to continue. Formally, this requires $\zeta_C > 0 \Leftrightarrow c < \frac{\overline{\phi}z}{2}$ (for the case where ϕ sufficiently low) and $\zeta_T > 0 \Leftrightarrow c < \frac{\phi z}{2}$ (for the case where ϕ sufficiently high).

The proof is in the appendix.

Lemma 3 shows that bargaining shares depend on the relative scarcity of skills. If complementors are sufficiently rare, the open system rewards them more than the generators of ideas (i.e. $a < \frac{1}{2}$). Moreover, the sharing of rents does not depend on the cost of generating ideas. Thus the reward for the inventor does not depend on its ex ante investment, but only on his ex post bargaining strength.

3.1.2 Equilibrium behavior

We now compute the return to generating and stealing ideas. Conditional on having an idea, the utility of the talker is equal to her share of the profits conditional on meeting a complementor and the idea being good.

$$u_T = \phi p a z - c$$

The expected period utility of an idea inventor is given by

$$u_G = \gamma u_T - \psi$$

Part of the expected benefit of being a listener comes from the chance of becoming a complementor, which equals

$$u_L = \phi p \bar{a} z$$

Below we derive the total benefit of being a listener, which also includes the benefit of stealing the idea. To derive the steady state properties of the open system, denote by s the fraction of agents who just stole an idea. The number of people who have an idea are all those who stole an idea (s), and those who generated a new one ($\bar{s}\gamma$). Thus the number of people talking is given by $t = s + \bar{s}\gamma$. Naturally, this is also the number of people listening.

In any period, $tp\phi$ projects get implemented, and $t\bar{p}\phi$ projects get dropped because complementors realize they are not feasible. Finally, in any period, $t\bar{\phi}$ projects get stolen. Thus $s = t\bar{\phi}$. Using $t = s + \bar{s}\gamma$ we get the following result.

Lemma 4: The steady state number of agents talking (t) and stealing (s) are given by

$$t = \frac{\gamma}{\phi + \gamma - \gamma\phi} \text{ and } s = \frac{\gamma - \gamma\phi}{\phi + \gamma - \gamma\phi}.$$

Both t and s are increasing in the probability of generating an idea (γ), and decreasing in the probability of finding a complementor (ϕ).

Consider now the ex-ante utility of an agent in such a system, assuming that everyone invests in generating ideas. With probability s the agent steals an idea, and gets u_T. With probability $\overline{s}\gamma$, the agent has a new idea and also gets u_T. With probability $\overline{s\gamma}$, the agent has no idea and gets nothing. In addition, with probability t, an agent becomes a listener and gets u_L. We therefore get:[15]

$$U = \frac{\overline{s}u_G + su_T + tu_L}{1-\delta}$$

U is increasing in p, z, δ, ϕ and γ, which is very intuitive.

The open exchange system is an efficient environment to resolve ideas, as they circulate until they find a complementary match; they are then either implemented if good, or dropped if bad. However, in such a system an inventor may receive only a small fraction of the payoff from his own idea. Thus in an open system, listening is very attractive: it may lead to becoming a complementor, or to stealing an idea. But if agents have no incentive to generate ideas, no ideas are generated and circulate within the open system. The critical cost threshold such that investors break even is given by

$$\psi_M \equiv \gamma u_T = \gamma(\phi paz - c)$$

Proposition 1 *Consider an open exchange system.*

- *For $\psi < \psi_M$, the open system achieves a first-best outcome, where all ideas are resolved (i.e. they circulate until they are either implemented if good, or dropped if bad).*
- *For $\psi > \psi_M$, the expected reward of generating an idea is too low because of idea stealing. No ideas are generated and no ideas circulate.*
- *The open exchange system is more likely to fail to support idea generation:*
  1. *if finding an idea is rare (low γ),*
  2. *if the idea is unlikely to be good (low p),*
  3. *if ideas have little value (low z),*
  4. *if finding a right match is rare (low ϕ),*
  5. *if it is costly to search for a match (high c)*

[15] To see this, denote the lifetime utility with a stolen idea by U_T and without a stolen idea by U_G, then $U_T = u_T + tu_L + \overline{s}\delta U_G + s\delta U_T$ and $U_G = u_G + tu_L + \overline{s}\delta U_G + s\delta U_T$. Using $U = \overline{s}U_G + sU_T$, we rewrite this as $U_T = u_T + tu_L + \delta U$ and $U_G = u_G + tu_L + \delta U$, so that $U = \overline{s}(u_G + tu_L + \delta U) + s(u_T + tu_L + \delta U) \Leftrightarrow U(1-\delta) = \overline{s}u_G + su_T + tu_L$.

The proof is in the appendix.

In summary, the generation of ideas in an open system is harder to achieve when ideas are less valuable, when inventors have less bargaining power (in particular, when their skills are more common), and when there are high search costs (perhaps because there are few competent agents).

3.2 Analysis of firms

We now introduce the firm as a possible solution to the weakness of the open exchange system when $\psi > \psi_M$. As defined, a firm is a closed exchange system in which employees sign away their rights to all internally registered ideas. We assume that the firm boundaries are perfectly monitored, so that no idea ever escapes.

Employees can register their ideas with the firm, who rewards their generation and completion. Let b be the percentage share of profits from implemented ideas offered as reward to an inventor. To ensure registration of ideas, the firm needs only to cover the inventor's generation cost. This is because he would not wish to hide an idea and leave the firm, as his reward in the open system is too low. Once an inventor registers an idea, he receives the task of finding an internal match. In managerial terms, he becomes an "internal project champion" or "intrapreneur." Since the idea is now registered as an internal project, the firm can ensure that no employee can profit from leaking it outside the firm.[16] This allows the champion to obtain reliable feedback from all internal listeners. Note also that the firm does not need to compensate complementors, since they cannot take ideas elsewhere. The utility of listening to ideas inside the firm is therefore zero.

We first assume that the inventor must abandon the idea if no internal match is found (later we relax this assumption). For comparability with the open system, we assume that the search cost inside firms is the same as in market although in practice it may well be lower. (Such a cost differential would by itself constitute a reason for firms). We simplify the closure of the internal search by assuming that it is known when the whole set of competent employees has been consulted.[17]

We denote the per period utility by v and the lifetime utility by V. The expected utility of being a talker in any period is given by

$$v_T = \phi pbz - c.$$

To calculate the lifetime utility, we need to take into account how long an idea has

[16] We assume that randomly generated, costless ideas are easily identified and dismissed.

[17] More explicitly, suppose that incurring a search cost always identifies the next most competent agent within the firm. It makes little difference to the results whether the last competent employee is identified in advance or not.

already circulated.[18] Let V_G denote the agent's utility when he does not have an idea, and thus needs to generate a new one. Let e be the e^{th} round of talking about an idea, so V_T^e is the lifetime utility of an employee who is about to talk to the e^{th} listener. For any e with $1 \leq e < E$, we have

$$V_T^e = \upsilon_T + \phi\delta V_G + \overline{\phi}\delta V_T^{e+1}$$

This says that in the e^{th} round an agent has an expect per-period return of υ_T. With probability ϕ the idea is resolved (the idea is either implemented or dropped). The agent then gets V_G, i.e., he has to start afresh and generate a new idea. With probability $\overline{\phi}$ the idea is still unresolved. The agent continues to circulate his idea, and gets V_T^{e+1}. At $e = E$, the agent has no one left to talk to, so

$$V_T^E = V_G \text{ where } V_G = -\psi + \gamma V_T^1 + \overline{\gamma}\delta V_G$$

Clearly, these utilities form a recursive system. The following lemma characterizes their solution.

Lemma 5:
(i) The life-time utility of newly joining a firm is given by $V_G = \rho_T \upsilon_T - \rho_G \psi$ where

$$\rho_T = \frac{\gamma \sum_{i=0}^{i=E-2} (\overline{\phi}\delta)^i}{1 - [\overline{\gamma}\delta + \gamma(\overline{\phi}\delta)^{E-1} + \gamma\phi\delta \sum_{i=0}^{i=E-2} (\overline{\phi}\delta)^i]}$$
$$\rho_G = \frac{1}{1 - [\overline{\gamma}\delta + \gamma(\overline{\phi}\delta)^{E-1} + \gamma\phi\delta \sum_{i=0}^{i=E-2} (\overline{\phi}\delta)^i]}$$

(ii) V_G is increasing in E.
(iii) $V_T^1 > V_T^2 > ... > V_T^{E-1} > V_T^E = V_G$.

The proof is in the appendix. ρ_T is the discounted number of times that an employee has an idea to talk about. ρ_G is the discounted number of times that an employee generates an idea. V_G thus equals the discounted value of talking about ideas, minus the cost of generating them.

The intuition why V_G is increasing in E is that a larger firm provides more matching opportunities, increasing the expected value of generating an idea. The intuition why $V_T^e > V_T^{e+1}$ is that having more people left to talk to is better for the inventor, since there is a greater probability of completion.

[18]For notational simplicity we assume that all employees in the firm are competent. It is conceptually easy to assume that only a fraction of the firm's employees are sufficiently knowledgeable. We return to this issue in the section on mobility of ideas.

Given this utility structure of the employees, consider now a firm's optimization problem. The owner maximizes the value of the firm by choosing the optimal number of employees E. The firm's net present value of profits (excluding the fixed cost K) is given by

$$\Pi = E(1-b)\rho_T \phi p z - \frac{m(E)}{1-\delta}$$

The firm's objective is to maximize Π, subject to the agent's incentive constraint. For this, she chooses the optimal size E, as well as a compensation package b.

The incentive constraint requires that employees are willing to generate ideas, and is given by $V_G \geq 0$. V_G is increasing in b (through v_T). Since the firm wants to minimize b, we get

$$V_G = 0 \Leftrightarrow b^* = \frac{c + \psi \frac{\rho_G}{\rho_T}}{\phi p z}$$

Substituting b^* into Π yields

$$\Pi = E\rho_T(\phi p z - c) - E\rho_G\psi - \frac{m(E)}{1-\delta}$$

where $E\rho_T(\phi p z - c)$ is the number of employees times the fraction with an idea, times the expected value of an idea (net of search costs), and $E\rho_G\psi$ is the total cost of generating ideas. Note that Π also represents the joint utility of the firm and all its employees.

Proposition 2 *The firm's optimal choice of E is*

- *decreasing in the marginal cost of monitoring (m').*
- *decreasing in the cost of generating ideas (ψ)*
- *decreasing in the internal search cost (c)*
- *and increasing in the profitability of new ideas (p and z).*

The optimal compensation b^* is

- *increasing in the cost of generating ideas (ψ)*
- *increasing in the internal search cost (c)*
- *decreasing in the profitability of new ideas (p and z).*

The proof is in the appendix.

The optimal size of the firm thus decreases in the cost of monitoring employees and in the cost of generating ideas (high ψ), as the marginal benefit of having another employee is lower. In contrast, the more profitable are agents' ideas (higher p or z), the larger are firms. Finally, higher (internal) search costs (c) reduce firm size.

The comparative statics of b^* are also intuitive. If the cost of generating an idea is greater (higher ψ, lower γ), inventors need to be compensated more. Interestingly, in addition to this direct effect, there is also an indirect effect. Higher generation costs reduce the optimal firm size E^*, which in turn reduces the return to generating an idea. The change in the optimal reward b^* must take this into account.

To close the model, we derive the number of firms endogenously. Suppose there is free entry, and agents have different (but known) costs, drawn from a general distribution of sunk costs $\Omega(K)$. The number of firms is given by an indifference condition for the marginal firm owner, who is indifferent between being an employee versus setting up a firm. The number of agents n_F who become firm owners is then given by

$$n_F = \Omega(\widehat{K}) \text{ where } \Pi - \widehat{K} = 0$$

The reputational component of the cost K has to be large enough to dissuade owners from reneging on their commitment to inventors. An owner could appropriate all reported ideas and implement them outside the firm. This is actually a dominated strategy, since the owner would still need to find complementors in the open system. The best reneging strategy is to appropriate all returns from successful innovations by refusing to pay the generator his share b. A sufficient condition for firms to maintain their reputation is thus given by

$$\Pi > Ebz.$$

implying that the value of firms exceeds the maximum gain from reneging in the extreme case where all E employees implement a good project at the same time.[19]

3.3 Comparative advantages of firms and markets

Under what circumstances do firms emerge? As long as markets can support idea generation ($\psi \leq \psi_M$), there is no role for firms, since markets are more efficient at implementing ideas. Firms emerge only when markets fail. Naturally, whether or not firms emerge depends on their own viability, since Π is also decreasing in ψ. If we define ψ_F so that $\Pi(E^*, \psi_F) = K$, where E^* is the optimal choice of E, ψ_F is a critical value above which firms are also not viable.

[19] This condition can be relaxed, e.g. the firm could commit to a capacity constraint of never implementing more than $\widetilde{E} < E$ projects per period, by delaying the implementation of some project.

In general, we cannot say whether ψ_F is greater or smaller than ψ_M, since this depends on the costs of monitoring (m), as well as the fixed costs (K). We will focus on the case where the costs of operating firms are not preventive.

Figure 2 depicts the feasible regions of firm and market governance. The vertical axis measures generation costs (ψ), while the horizontal axis measures the value of ideas (z). Higher values of z make idea generation more profitable and allow therefore enable a higher value of ψ_M. Similar for ψ_F. The following proposition distills the main insights from Figure 2.

Proposition 3

- *For a given generation cost (ψ), markets work well for valuable ideas (high z), while firms are necessary for less valuable idea.*
- *For a given value of ideas (z), markets work well for low generation costs (low ψ), while firms are necessary for higher generation costs (higher ψ).*

This result provides some interesting insights into the comparative advantages of firms versus markets. Markets work well for very promising but not too expensive ideas (high z, low ψ). This correspond to a common perception that radical innovations are often developed outside firms, while incremental innovations fall into the realm of established corporations. In addition, entrepreneurs may be able to develop only ideas that are simple to generate, whereas companies are better positioned to develop ideas that require substantial investment. Intuitively, individual entrepreneurs pursue opportunities that require modest budgets, whereas firms focus on larger scale, complex ideas which require substantial investments. Yet in our model this result is not, as it is often assumed, a consequence of financial constraints faced by individuals.

Notice that we do not imply that markets are better than firms. A lower return to ideas inside firms is not a sign of inefficiency, rather a sign of market failure. Firms emerge precisely when the return to ideas is not high enough for markets to function.

4 Coexistence of firms and markets

4.1 Motivation

The previous section compares firms and markets in isolation. We now discuss how firms and markets may interact, in particular so that some ideas may flow across firm boundaries.

In our basic model, employees commit not to take any internal idea outside the firm. Such a simple rule has the benefit of simplicity, and may keep monitoring costs down. Yet the rule is also inefficient, as it implies that some idea will not be allowed to be resolved. Because the firm has a finite size, the champion may not find an internal match for some good idea, and be forced to give it up.[20]

Consider now the case of more flexible rules, where a firm may permit an internal champion to pursue his idea outside the firm, once he has exhausted all potential matches with his colleagues. By allowing the agent to pursue the idea in the open system, the firm can improve incentives to generate ideas, and thus capture some of their value by reducing his compensation, or by retaining some stake in the spin off. Since letting employees bring internal ideas to other firms creates potential competition, we assume that while firms cannot block departing employees from joining competitors or to start their own venture, firms are able to stop them to implement an internally generated idea within any other firm.

This coexistence of firms and markets creates an interesting symbiotic relationship between firms and market. We maintain our assumption that $\psi > \psi_M$ (since otherwise firms would be strictly dominated by markets), so that the open system is unable by itself to sustain idea generation. Yet employee mobility allow the open system to feed off ideas generated inside firms. So, while firms emerge to compensate for market failure, markets can thrive by compensating for the limited efficiency of firms. Thus in the model firms and markets truly complement one another, each compensating for the inefficiency of the other.

4.2 The coexistence equilibrium

In the model there are three types of agents, namely firm owners, employees and agents in the free market. Their respective numbers are denoted by n_F, n_E and n_M ($= 1 - n_F - n_E$, given unit mass). We focus on stationary equilibria where firm size is constant, so that the flow of agents leaving firms must equal the flow of agent joining firms to maintain the optimal firm size.[21] The new employees are recruited from the open system. We characterize the equilibrium flow of agents from firms to markets and vice versa.

Let λ be the fraction of employees that on average leave a firm every period, a value endogenous to the model. Let Q_0 be the expected number of employees without an idea at the beginning of the period. With probability $\gamma\overline{\phi}$ they generate a new idea which is not resolved within the period, so that in steady state $Q_0\gamma\overline{\phi}$ employees start with an idea that is exactly one period old. Similarly, $Q_0\gamma\overline{\phi}^e$ (for $e < E-1$) employees have an idea that is exactly e periods old. Adding up the total number of employees, we obtain $Q_0(1+\gamma\overline{\phi}+\gamma\overline{\phi}^2 ... +\gamma\overline{\phi}^{E-2}) = E \Leftrightarrow Q_0 = \dfrac{E}{\overline{\gamma}+\gamma\sum_{i=0}^{E-2}\overline{\phi}^i}$.

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[20] Formally, the probability that an internal idea cannot get resolved is given by $1 - \sum_{i=0}^{i=E-2}\phi(\overline{\phi})^i > 0$.

[21] For simplicity we abstract from the possibility that a new employee could revisit an internal idea that the departing employee was previously unable to resolve.

The number of employees that leave because they cannot find a match inside the firm is thus $Q_0\gamma\overline{\phi}^{E-1}$. The fraction λ is therefore given by

$$\lambda = \frac{Q_0\gamma\overline{\phi}^{E-1}}{E} = \frac{\gamma\overline{\phi}^{E-1}}{\overline{\gamma} + \gamma\sum_{i=0}^{E-2}\overline{\phi}^i}. \tag{1}$$

Thus, since λn_E is the fraction of employees leaving firms to explore their ideas in the open system, firms must rehire in each period the same number.

Of the λn_E new ideas moving every period to the open system, a fraction ϕ gets resolved (either implemented or stopped), while a fraction $\overline{\phi}$ continues to circulate. The number of ideas that circulated for exactly one period is thus $\lambda n_E\overline{\phi}$. Similarly, the number of ideas that have circulated for i periods is $\lambda n_E\overline{\phi}^i$. Of course, the total number of ideas circulating in the open system must is the same as the number of people talking. That number is given by

$$t = \lambda n_E \sum_{i=0}^{i=\infty}\overline{\phi}^i = \frac{\lambda n_E}{\phi}. \tag{2}$$

Consider now the probability that an agent in the open system is approached by another agent with an idea. Since there are t ideas, and n_M people to talk to, the probability of becoming a listener is $\frac{t}{n_M}$. We focus on the case where are always more potential listeners than talkers, i.e., where $t < n_M$.[22] If an agent gets to listen to an idea, he either complements it or steals it.

The utility of a free market agent, who has no idea of his own, is thus given by

$$U = \frac{t}{n_M}\phi(p\overline{\alpha}z + \delta U) + \frac{t}{n_M}\overline{\phi}(\delta p\alpha z - c + \delta U) + (1 - \frac{t}{n_M})\delta U$$

After transformations this yields

$$U = \frac{t}{n_M}\frac{\phi p\overline{\alpha}z + \delta(\overline{\phi}p\alpha z - c)}{1-\delta} \tag{3}$$

Next, consider the utilities of departing employees. We assume employees are allowed to retain any profits from ideas they take out of firms. Thus V_T^E now includes these expected payoff. Since the idea may now be expropriated by a substitute, a departing employee receives the expected returns as any inventor in the open system, given by $u_T = \phi paz - c$.

[22] For $t > n_M$, the model is the same, except that $U = \frac{\phi p\overline{\alpha}z + \delta(\overline{\phi}p\alpha z - c)}{1-\delta}$ in equation (3) below, and $u_T = \frac{n_M}{t}\phi paz + \frac{n_M}{t}\delta u_T - c \Leftrightarrow u_T = \frac{\frac{n_M}{t}\phi paz - c}{1 - \frac{n_M}{t}\delta}$ in equation (4) below.

The utility of the departing employee is first to get the opportunity to talk about his idea (u_T), and then to reside in the open system. Let U be the lifetime utility of an agent that currently resides in the open system and does not have any idea to pursue (which we derive it below). Formally, we have

$$V_T^E = u_T + U \text{ where } u_T = \phi paz - c. \tag{4}$$

The expressions for V_T^e and V_G are the same as before, i.e.,

$$V_T^e = v_T + \phi\delta V_G + \overline{\phi}\delta V_T^{e+1} \text{ and } V_G = -\psi + \gamma V_T^1 + \overline{\gamma}\delta V_G \text{ where } v_T = \phi pbz - c. \tag{5}$$

In order to hire employees, firms have to match their utility of being in the open system. The utility of a fresh hire is given by V_G, which is increasing in the compensation parameter b. Firms must set their compensation b^* to match the utility of being in the open system, so that

$$V_G = U. \tag{6}$$

Thus employee compensation inside firms now depends on the utility of agents in the open system. We will exploit this insight below.

Next we determine the equilibrium size and number of firms. The optimal size of the firm is found as before, i.e., E maximizes

$$\Pi = E(1-b)\rho_T \phi pz - \frac{m(E)}{1-\delta}. \tag{7}$$

The number of firms is given by the same free entry condition as before, except that the marginal firm owner is now indifferent between spending the fixed costs of setting up a firm versus operating as an agent in the open system. Formally, we have

$$n_F = \Omega(\widehat{K}) \text{ where } \Pi - \widehat{K} = U. \tag{8}$$

Finally, with the assumption of a unit mass of agents, the number of employees and free market agent is given by

$$n_E = En_F \text{ and } n_M = 1 - n_E - n_F = 1 - (1+E)n_F. \tag{9}$$

4.3 The consequences of coexistence

Equations (1) through (9) describe the coexistence equilibrium. We now establish some of its properties.

Proposition 4

- *In the coexistence equilibrium, all ideas are generated within firms.*

- *Employee mobility eliminates the main inefficiency of firms, namely a limited circulation of ideas.*

- *In equilibrium, all ideas are resolved, and all good ideas get implemented, either within firms or within the market.*

This proposition shows that the coexistence of firms and markets is efficient. Markets complement firms by resolving ideas taken out of firms by departing employees.

This result offers a provocative view on the role of markets, playing a complementary, almost subordinate role to firms. Agents in open exchange systems receive, and often appropriate, ideas generated (but not resolved) inside firms. Their role is symbiotic, in the sense that free agents complete those ideas that the firms could not resolve.

Proposition 5

- *The flow of ideas to the market (λn_E) is increasing in the number of firms (n_E), and the rate of idea generation in firms (γ),*

- *The total number of ideas circulating in the open system (t) and the utility of residing in the open system (U) are also increasing in n_E and γ.*

This proposition further highlights the symbiotic relationship between firms and markets. The greater is firm density, and the more ideas are generated in firms, the more active the market becomes, with more number circulating (t), generating higher benefit for free agents (U).

Consider now the benefits of employee mobility for firms. From the perspective of an individual firm, it is attractive to let employees go after they exhausted all internal matching opportunities. (We are ignoring any additional costs due to employee turnover). Employee mobility adds a positive term to V_G in equation (4), increasing the return to generating ideas. Since the firm sets the compensation b such that $V_G = U$, the additional term in V_G allows the firm to lower its reward to internal completion b. Thus giving employees the benefit of taking their ideas with them reduces the cost of hiring them ex-ante, and is individually efficient for any firm to do so.

However, there is also a general equilibrium effect of employee mobility, since the flow of ideas to the market create rents for free agents. This raises the utility in the open system, which in raises the costs of attracting new employees.

To see this formally, we adapt Lemma 5 to the coexistence model. Straightforward calculations shows that equations (2), (3) and (4) can be combined to yield

$$V_G = \rho_T v_T - \rho_G \psi + \rho_\lambda u_T \qquad (3')$$

where ρ_T and ρ_G as before, and where $\rho_\lambda = \dfrac{\gamma(\overline{\phi}\delta)^{E-1}}{1-[\overline{\gamma}\delta+\gamma(\overline{\phi}\delta)^{E-1}+\gamma\phi\delta\sum_{i=0}^{i=E-2}(\overline{\phi}\delta)^i]}$. Adding $V_G - U(=0)$ to $\Pi = E(1-b)\rho_T\phi pz - \dfrac{m(E)}{1-\delta}$, and using (3') we obtain after standard transformations

$$\Pi = E\rho_T(\phi pz - c) - E\rho_G\psi - \frac{m(E)}{1-\delta} + E\rho_\lambda u_T - EU.$$

As before, Π represents the joint utility of the firm and all its employees. It is given by the expected value of internally completing ideas (first term), minus the cost of generating ideas (second term), minus the costs of monitoring (third term), plus the opportunity to take an unresolved idea into the market (fourth term), minus the opportunity cost of having employees work in the firm rather than the market (fifth term). The main difference to the model of section 3 is the addition of the last two terms. Whether the fourth term is larger than the fifth depends on many parameters. Low values of u_T (e.g., because of high search costs c), or high values of U (e.g., because of high values of n_E) lead to a general equilibrium increase in required compensation. We summarize this observation as follows.[23]

Proposition 6 *If, in general equilibrium, $U < \rho_\lambda u_T$, then employee mobility is beneficial to firms, and increases their optimal size E^*. Otherwise, employee mobility, while beneficial at the individual firm level, reduces profitability and the optimal size for all firms.*

Under what circumstances is U likely to be larger than $\rho_\lambda u_T$? Note that an increase in the number of firms n_F, say because of lower fixed costs K, increases n_E (holding E constant).[24] This raises the number of ideas leaving firms and thus the number of people t talking about ideas in the open system. From equation (6), this increases U as well. Firm entry thus has a positive externality for market agents. On the other hand, a greater firm density does not affect $\rho_\lambda u_T$, i.e., it does not affect the utility that an employee gets from taking an internally generated idea to the market. The condition $U > \rho_\lambda u_T$ therefore holds for larger values of n_F. In other words, the negative wage effect dominates when there are sufficiently many "porous" firms (i.e., which allow their employees to explore unresolved ideas in the market).

This result offers a new perspective on employee mobility, on which the literature (e.g., Pakes and Nitzan (1983)) often takes a partial equilibrium perspective. This result suggests that, ceteris paribus, there might be negative indirect effects from other firms. Employees mobility and high firm density creates rents for agents in the

[23] The result about optimal size of the firm follows from the fact that firm owners choose firm size according to a simple cost benefit trade-off.

[24] This follows from Equation (9), provided E^* does not change too much, which is a weak condition.

open system, making it more attractive to remain there, and so raises the cost of hiring new employees. This is consistent with the famously high labor costs in Silicon Valley, associated with its remarkable employee turnover rates.

The negative effect of firm density on other firms stands against the empirical tendency of innovative firms to concentrate geographically. Yet the high (local) return to free agents may also produce some positive externalities. An active market of ideas which produce high returns may naturally attract more talented employees to the region. The availability of better employees may also increase (specific) competence in innovative sector, and reduce search costs. Krugman (1991) suggests that it may lead to better matching of firms and employee skills.[25] Under such circumstances, entry of new firms can benefit incumbent firms as well.

4.4 Opportunistic mobility

So far we considered a form of mobility which is condoned by firms, because they individually gain from allowing mobility of ideas which could not be resolved internally. We briefly sketch an alternative form of employee mobility, without fully deriving the equilibrium.

In reality, employees seem to often leave their employers to pursue an idea that they obtained during employment, but never disclosed to their employer. This possibility also exists in our model, since undisclosed ideas cannot be claimed by firms. Under our assumptions so far, this was not a problem, since employees with a new idea always prefer to disclose their ideas internally, as the firm, unlike the market, grants them sufficient protection from expropriation.

Consider now a model where ideas differ in their fit with the firm. Ideas which fit well with the firm's competencies have a high probability of finding an internal match (ϕ_G). Other ideas may fall outside of the firm focus, so that the probability of finding a match is lower ($\phi_B < \phi_G$). For simplicity, let the probability of finding a good match in the market to be always ϕ_G - all that matters is that it sufficiently higher than ϕ_B.

We assume that the fit of the idea is observable to the inventor but not to the firm, so that the reward is not contingent on idea type. Clearly, the inventor of a good-fitting idea prefers to look for an internal match. Otherwise, looking for an internal match may be dominated, as it is more expensive in terms of search effort. Anticipating this, employees may prefer to leave rather than disclosing any poorly-fitting idea.

To see more formally when an inventor may not want to disclose a poorly fitting ideas, note that the employee's utility from disclosing a poorly fitting idea is given by $V_T^1(\phi_B)$, where $V_T^e(\phi_B) = v_T(\phi_B) + \phi_B \delta V_G + \overline{\phi_B} \delta V_T^{e+1}(\phi_B)$ for $1 \leq e < E$ and

[25]Note that a greater local concentration of agents with complementary skills may improve recruitment, but in turn increases the return for inventors to share ideas in the open system.

$V_T^E = u_T(\phi_G) + U$ (where u_T is evaluated at ϕ_G, the chance of a good match in the market).

The utility from leaving without disclosing the idea is then given by $u_T(\phi_G) + U$. The employee prefers not to disclose whenever $V_T^1(\phi_B) < u_T(\phi_G) + U$. Since $v_T(\phi_B) = \phi_B pbz - c$ is an increasing function of ϕ_B, this condition is always satisfied for sufficiently low values of ϕ_B. The problem of disclosing such poorly-fitting ideas is that doing the internal rounds is costly, as it delays the expected timing of finding a good match.[26]

Let us briefly sketch the equilibrium with this type of mobility. Let γ_G be the probability of finding an idea that fits well, and γ_B the probability of finding an idea that fits poorly. For a good fit, the recursive system of equation (5) continues to hold as before. The only difference concerns V_G, which is now given by

$$V_G = -\psi + \gamma_B(u_T(\phi_G) + U) + \gamma_G V_T^1(\phi_G) + (1 - \gamma_G - \gamma_B)\delta V_G$$

The firm could of course try to retain all employees by raising its bonus b. However, this could be expensive, since the firm would have to pay the higher bonus both for good or and poorly fitting ideas. As long as the ratio $\frac{\gamma_B}{\gamma_G}$ is sufficiently low, the firm will prefer to lose a few employees, rather than raising its bonus on all ideas.

In equilibrium, we have two types of employee departures. Some employees leave without ever disclosing their poorly-fitting ideas. Others leave after having tried to find an internal match. The general equilibrium properties of this model are similar to the main coexistence model discussed above.

5 Further Discussion and Open Issues

5.1 Incentives in Firms and Markets

The result that markets produce poor incentives relative to firms for idea generation may sound at first counter-intuitive. It is typically believed that the reward for developing a new venture on one's own are much greater than for an employee. Reconciling these observations with our model yields some interesting additional insights.

The open exchange offers high potential returns upon successful completion, but the model identifies two important caveats. First, there is a high risk of idea expropriation. Indeed, in the model the inventor gets a single shot at presenting the idea: it either finds a match or gives up. Second, the rewards in the open system may go disproportionately to the complementor. This is consistent with observing highly successful entrepreneurs in the market (who are not necessarily the idea generator), while at the same time many entrepreneurs fail to achieve an adequate return

[26] Informally we may add that the problem of employees not disclosing ideas is likely to be higher for larger firms, and also for firms that are less flexible letting employees depart after they have not found an internal match.

(Moskowitz and Vissing-Jorgensen, 2002). Contrast this with the rewards inside firms. The compensation of so-called "intrapreneurs" may look less generous, but is presumably more reliable as they have better protection against idea stealing; they may thus be able to champion their ideas for a longer time.[27] Overall, the rewards for intrapreneurs are less risky, but possibly more attractive on average, than for many potential entrepreneurs, many of whom will not manage to develop a good idea to their advantage.

Another observation is that the optimal firm policy may reward inventors, while giving lower rents to complementors. In the model, being a complementor is idea-specific, and all agents have an equal chance of becoming a complementor. Yet if there are agents who a priori are particularly good at idea completion (i.e. they are more likely to be complementors), they may prefer to reside in the open system. Firms may find it difficult to properly compensate them, becasue there is only a limited flow of ideas inside firms. Strong complementors would prefer the open system where they may draw from a large pool of idea generators. There are several real world analogies to these strong complementors: particularly venture capitalists, but also experienced entrepreneurs/mentors, and professionals such as specialized lawyers and consultants. They may specialize in working with inventors, helping them to turn their ideas into viable businesses (Lee et al., 2000).

5.2 Circulation of Ideas Across Firm Boundaries: Route 128 versus Silicon Valley

Our description of the interaction between firms and markets seem to fit many features of the open circulation of ideas in Silicon Valley, an environment in which many innovative start ups have emerged. Because many such independent ventures have been quite successful, agents in the open market appear as promoting more innovation than large firms. Our approach suggests a few qualifications. Many innovations (or at least some important preliminary concepts) may have been originally developed in large firms, which markets were best at implementing. Independent entrepreneurs may often not be the original inventors, but rather those who took a promising idea from an inventors. Thus large firms should be seen as a crucial feature of any highly innovative environment, as critical incubators of novel complex ideas, and independent agents may be often partners with a capacity for idea elaboration. Of course, such a contribution is sometimes as significant as the initial vague concept.

In fact, large firms are an important component of the productive structure in Silicon Valley.[28] Any account of its success starts with a long list of the remarkable

[27]Porter (1978), for example, describes the seemingly endless quest, and eventual success, of an intrapreneur inside the Bendix Corporation, to develop the first electronic fuel injection for automobiles.

[28]In 1997, Silicon Valley accounted for a remarkable 20% of the *largest* high tech firms in the world (Business Week, 1997).

number of novel ventures started by individuals who left employment with a larger firm, and in turn spawned further ventures by departing employees. Gompers, Lerner and Scharfstein (2004) provide evidence on the role that large corporations play in entrepreneurial spawning. Consistently with our mobility model, they find that more open firms tend to spawn more ventures, which also tend to be on average in less related areas. Enterprises with porous boundaries may create a symbiotic relationship with free agents operating in an open exchange market. In contrast, a secretive corporate culture which resists interaction with markets may suffocate the circulation and thus subsequent elaboration of internally generated ideas.

The hierarchical approach to R&D in Japan and Europe, as well as in the large high tech companies on Route 128 in Massachusetts, has been unfavorably contrasted with the loosely organized open environment of Silicon Valley in California (Saxenian, 1994; Aoki, 2001), whose success is attributed to a free movement of ideas and individuals creating innovative ventures via informal arrangements. Yet the intense exchange of ideas in Silicon Valley is puzzling, since California actually has a fairly weak tradition of protecting intellectual property (see also Gilson, 1999 and Hyde, 1998), so is not clear how idea generation may be rewarded. Our model offers some insight, by showing that entrepreneurial firm formation and large multi-product firms are actually symbiotic. Large firms are a natural source of innovative ideas, yet many of these ideas can find realization only if they are allowed to move to a free exchange system; in turn, a dynamic open market will attract skilled, entrepreneurial individuals only if there are enough firms from which ideas may leave, seeking elaboration or completion. The open environment in Silicon Valley may thus thrive thanks to the historical presence in the area of large firms, which have acted as incubators of new ideas, particularly those which were costly to develop.[29]

The role that venture capitalists play in supporting entrepreneurs who leave firms seems also consistent with the notion suggested (if not fully modelled) in our approach, that agents in open exchange systems may specialize in implementation rather than origination, while inventors may prefer a more protected corporate (or academic) environment. In fact, academic researchers, who have an independent reward system for novel ideas, seem to play a prominent role in creating innovative ventures.

The model also suggests that high wages in Silicon Valley may result from a general equilibrium effect of mobility in the presence of a high density of innovative firms, where operating in the market becomes an attractive outside option for employees.

5.3 Firms as Long Term Bureaucracies

In our model, firms are long term, multi-project institutions. Firms can solve contracting failures better than arm's length transacting individuals thanks to their sunk investment in reputation capital, which underlies a commitment not to expro-

[29] Hellmann (2003) provides a theoretical analysis of how intellectual property rights affect the incentives of employees to take ideas out of firms.

priate inventors, and to prosecute idea stealing by employees, i.e. to enforce the firm boundary. To sustain these tasks, the firm needs a formal organizational structure for recording and managing internal initiatives. Its role is to create a formal "paper trail" which facilitates the verifiability by a third party of idea stealing, either by the firm or by employees. Thus the "bureaucratic" nature of firms, while adding costs and possibly slowing down initiatives relative to more informal arrangements, have an essential function in ensuring that ideas are better protected in firms than in an open exchange.

An open question is what set of rules governs idea circulation inside firms. In the base model, the optimal rule is simple, since ideas are homogenous. Yet many ideas which fit poorly with the firm's competencies may be taken outside firms without ever been disclosed, precisely to avoid wasting time with the "bureaucratic" process of seeking an unlikely internal match (see section 4.3). This suggests a simple intuitive reason for why firms choose to pursue "narrow" strategies (see Rotemberg and Saloner, 1994) and may have some implications for internal flexibility. If firms adopt a rigid approach about forcing inventors to seek all possible internal matches before they may leave the firm, they may discourage reporting when employees are better able to assess specific competence. Flexible rules which allow employees some discretion on how long to search internally would improve incentives to generate and report ideas. In general, the optimal internal organization will depend on the relative frequency of general and firm specific ideas, and on firms' specific cluster of competence.

5.4 Other Governance Structures

We have considered only extreme organizational forms, either unstructured or hierarchical ones. We have also assumed that in an open system containing an infinite number of agents, no individual reputation process will be enforceable without a large sunk investment. In practice, market exchange include informal arrangements which can protect to some extent the individual return to invention.

Suppose that agents earn extra rents from belonging to a close, non hierarchical system (perhaps because its participants generate on average a larger number of ideas than outsiders). A reputation game may be sustainable if individual behavior is observed by others "within sight" so that opportunistic actions may be punished by ostracism from this group. This would presumably involve some monitoring costs, although less than in a firm. To the extent that such costs increase with size, it will also have a limited scope, producing an outcome similar to a hierarchical system.[30] In fact, precise monitoring may not be feasible except in small, geographically localized circles. In future work we plan to consider different versions of non hierarchical closed systems based on peer monitoring, such as networks and partnerships. Our

[30]It may be harder for third parties to identify idea stealing than other forms of opportunistic action, if the identity of the talker is unobservable.

conjecture is that such organizational forms, while less precise than firms in controlling attribution of invention, may support idea generation at a lower cost than firms, and/or may support interaction among a larger set of free agents.

6 Conclusions

We have proposed a novel trade-off between the necessity to protect idea generation and the need to share ideas in order to screen and elaborate them. The free circulation of ideas is efficient for the elaboration of incomplete concepts, but fails to reward personal effort for generating novel concepts. Individuals may then voluntarily join close exchange systems, such as firms to ensure that their initiatives receive support and feedback without being appropriated. Firm ownership thus represent a claim on the use of registered ideas vis-a-vis employees. This creates a legal firm boundary which discourages the escape of ideas. The internal structure of the firm is designed to ensure a controlled circulation of ideas and a reliable reward system.

Our model also suggests that there is a natural symbiosis between the ability of firms to sustain exploration in ambitious ideas and the comparative advantage of open market partners, such as venture capitalists, in screening, elaborating and implementing ideas which leave firms.

Much further work is needed to elaborate further this important theme of the circulation of ideas among individuals and institutions. We have sketched some questions and outlined some directions of research we intend to pursue. Beyond firms and markets, this paper does not examine many other important institutions for the circulation of ideas. We are currently examining the case of networks and partnerships. Another compelling question concerns idea generation and circulation among academics. Although academic researchers rarely capture the value created by their discoveries, the academic publication system may ensure some alternative reward mechanism. This suggests that other institutional arrangements may endogenously arise to preserve the free circulation of ideas, which constitutes a valuable public good.

7 References

- Aghion, P. and J. Tirole, 1994, "On the management of innovation", Quarterly Journal of Economics, 1185–207.

- Anton, J., and D. Yao, 1994, "Expropriation and Inventions", American Economic Review, 190–209.

- Anton, J., and D. Yao, 2002, "The sale of ideas: Strategic disclosure, property rights and contracting" Review of Economic Studies, 69, 513-531.

- Anton, J., and D. Yao, 2004, "Little Patents and Big Secrets: Managing Intellectual Property" Rand Journal of Economics 35(1), 1-22, Spring

- Aoki, M., 2001, Towards a Comparative Institutional Analysis, MIT Press

- Arrow, K., 1962, Economic Welfare and the Allocation of Resources for Inventions, in R. Nelson, Ed., The rate and direction of inventive activity: economic and social factors, Princeton University Press, Princeton.

- Azoulay, P., 2004, "Acquiring knowledge within and across firm boundaries: evidence from clinical development" Working paper, Columbia University.

- Baccara, and Razin, 2002, "From thought to practice: Appropriation and endogenous market structure with imperfect intellectual property rights," Working paper, Princeton University.

- Baccara, and Razin, 2004, "Curb your innovation: corporate conservatism in the presence of imperfect intellectual property rights" Working paper, Princeton University.

- Biais, Bruno and Enrico Perotti, 2003, "Entrepreneurs and New Ideas", CEPR Discussion Paper no 3864, London

- Binmore K., A. Rubinstein and A. Wolinsky, 1986, "The Nash bargaining solution in economic modelling." Rand Journal of Economics, Summer, 17(2), 176-188.

- Bhattacharya, S. and S. Guriev, 2004, "Knowledge disclosure, patents and optimal organization of research and development" CEPR Working paper 4513

- Bhidé, Amar V., 2000, "The Origin and Evolution of New Businesses", Oxford University Press

- Cestone, G., and L. White, 2003, "Anti-Competitive Financial Contracting: the Design of Financial Claims." Journal of Finance 58(5), 2109-2141

- Chemmanur, T. and Z. Chen, 2003, "Angels, Venture Capitalists, and Entrepreneurs: A Dynamic Model of Private Equity Financing", Boston College Mimeo
- Fosfuri, Andrea and Thomas Ronde, 2004, "High Tech Clusters, Technology Spillovers, and Trade Secret Laws", International Journal of Industrial Organization no 22, 45-65
- Gallini N., and S. Scotchmer, "Intellectual property: when is it the best incentive system?" chapter 2 in "Innovation policy and the economy", Vol. 2., eds. A. Jaffee, J. Lerner and S. Stern, MIT Press, Cambridge, Massachusetts, 51-77
- Gilson, R., 1999, "The Legal Infrastructure of High Technology Industrial Districts: Silicon Valley, Route 128, and Covenants Not to Compete," New York University Law Review, June, Vol. 74(3), 575-629
- Gompers, P., J. Lerner, and D. Scharfstein, 2004, "Entrepreneurial Spawning: Public Corporations and the Genesis of New Ventures: 1986-1999" forthcoming, Journal of Finance
- Gromb, D., and D. Scharfstein, "Entrepreneurial Activity in Equilibrium," Mimeo, Massachusetts Institute of Technology, May 2001
- Grossman S., and J. E. Stiglitz, 1980, "On the impossibility of informationally efficient markets," American Economic Review, 70, 393-408.
- Hart. O. "Firms, Contracts and Financial Structure," Clarendon Press, Oxford, 1995.
- Hellmann, Thomas, 2003, "When do Employees Become Entrepreneurs", Mimeo, Stanford University
- Hellmann, Thomas, and Enrico Perotti, 2004, "Circulation of Ideas in Networks and Partnerships", Mimeo
- Holmström B., and J. Roberts, 1998, "The boundaries of the firm revisited" Journal of Economic Perspectives, 12(4), 73-94, Fall
- Hyde, A., 1988, "Silicon Valley's High-Velocity Labor Market," Journal of Applied Corporate Finance, Vol. 11(2), Summer, 28-37
- Johnson, J., 2002, "Open Source Software: Private Provision of a Public Good, " Journal of Economics and Management Strategy, Winter, 11(4), 637-663
- Klepper, S., and S. Sleeper, 2002, "Entry by Spin-offs," Mimeo, Carnegy Mellon University

- Kremp, E. and J. Mairesse, 2004, "Knowledge management, innovation and productivity: a firm level exploration based on French manufacturing CIS3 data" NBER Working paper 10237, January
- Kreps, D., 1986, "Corporate Culture and Economic Theory," in Alt and Shepsle, editors, Rational Perspectives on Political Science
- Lee, Chong-Moon, William F. Miller, Marguerite Gong Hancock and Henry S. Rowen, 2000, The Silicon Valley Edge, Stanford University Press, Stanford, California
- Lerner, J., and J. Tirole, 2002, "Some simple economics of open source" Journal of Industrial Economics, 52, 197-234
- Levin, Richard, Alvin K. Kelvorick, Richard R. Nelson and Sidney G. Winter, 1987, "Appropriating the Returns from Industrial R&D," Brooking Papers on Economic Activity, 3, 785-832
- Lewis, Tracy and Dennis Yao, 2003, "Innovation, Knowledge Flow, and Worker Mobility", Mimeo, University of Pennsylvania, Philadelphia
- Moskowitz, Paul and Annette Vissing-Jorgensen, 2002, "The Return to Entrepreneurial Investment: A Private Equity Puzzle?", American Economic Review, Vol. 92 no. 4, 745-778
- Nordhaus, W., 1969, "Invention, growth and welfare: a theoretical treatment of technological change" MIT Press, Cambridge
- Pakes, A., and S. Nitzan, "Optimum Contract for Research Personnel, Research Employment, and the Establishment of Rival Enterprises," Journal of Labor Economics, Vol. 1(4), 1983, 345-365
- Porter, M., 1978, "Bendix Corporation" Harvard Business School, Case Study 9-378-257
- Rajan, R. and L. Zingales, 2001, "The Firm as a Dedicated Hierarchy", Quarterly Journal of Economics
- Rubinstein A. "Perfect Equilibrium in a Bargaining Model" Econometrica, 1982, 50, 97-110.
- Romer, P., 1990, Endogenous Technological Change, Journal of Political Economy, Vol. 98
- Rotemberg, J., and G. Saloner, 1994, "Benefits of Narrow Business Strategy," American Economic Review, Vol. 84(5), December, 1330-1349

- Saxenian, Anna Lee, 1994, "Regional Advantage: Culture and Competition in Silicon Valley and Route 128" Harvard Business School Press
- Schumpeter, J., 1926, Theorie der wirtschaftlichen Entwicklung, Duncker and Humbolt, Berlin.
- Schumpeter, J., 1942, Capitalism, Socialism and Democracy, George Allen and Unwin, London.
- Ueda, M., 2004, "Banks versus Venture Capital: Project Evaluation, Screening, and Expropriation," April, Journal of Finance
- Weitzman, M., 1998, "Recombinant growth," , Quarterly Journal of Economics, 331–360.
- Williamson, O., 1975, "Markets and hierarchies: Analysis and Antitrust Implications" The Free Press, New York, New York

8 Appendix

8.1 Discouragement condition

To derive the discouragement condition, consider the continuation game after negative feedback. If the talker pursues the idea one more period, he always incurs the search cost c. With probability $\frac{\phi\overline{p}}{\phi\overline{p}+\overline{\phi}}$ the reported negative signal was honest, and he simply wastes his time. With probability $\frac{\overline{\phi}}{\phi\overline{p}+\overline{\phi}}$ the negative signal was dishonest. With probability $\overline{\phi}$ the original talker finds no match, and gets no benefits. With probability ϕ^2 both the talker and the substitute listener find their respective match, each getting the Bertrand payoff, which is zero. And with probability $\phi\overline{\phi}$ the talker finds a match, but the substitute listener does not. In this case the talker gets paz. Thus the expected return for the talker from pursuing an idea one more period after negative feedback is $\frac{\overline{\phi}}{\phi\overline{p}+\overline{\phi}}\phi\overline{\phi}paz-c$. The discouragement condition ensures that an agent prefers to generate a new idea (obtaining $\gamma(\phi paz-c)-\psi$), rather than pursuing an old idea on which he has received negative feedback. Formally, the condition is therefore given by

$$\frac{\phi\overline{\phi}^2 paz}{\phi\overline{p}+\overline{\phi}}-c<\gamma(\phi paz-c)-\psi$$

Note that since we are only concerned with $\gamma(\phi paz-c)\geq\psi$, a simpler sufficient condition is $c>\frac{\phi\overline{\phi}^2 apz}{\phi\overline{p}+\overline{\phi}}$. This condition is always satisfied both for ϕ sufficiently small, and sufficiently large.

8.2 Proof of Lemma 2

Let S be the substitute and C be the complementor. The continuation game has three possible equilibria, that we call "C continues alone," "S continues alone" and "both C and S continue."

We first show that for ϕ sufficiently small, "C continues alone" is the only equilibrium. For this, we derive a set of sufficient conditions that are always satisfied for ϕ sufficiently small. Note that we focus on sufficient conditions. Deriving tighter necessary conditions is not tractable, since it would require solving a non-stationary subgame. The sufficient conditions avoid this problem by using appropriate bounds on the utilities of this non-stationary subgame.

To show that "C continues alone" is the unique equilibrium, we provide two conditions. The first condition ensures that "both C and S continue" is not an equilibrium. We show this by providing a sufficient condition for S not to want to continue if C continues. The second condition ensures that "S continues alone" is also not an equilibrium. We show this by providing a sufficient condition for C to still want to continue if S continues.

Consider first the case where both C and S continue. With probability ϕ^2, C finds a another complementor and S also finds a complementor. In this case, S wins and gets a payoff az. With probability $\overline{\phi}^2$, C finds a substitute and S also finds a substitute. In this case C wins and gets a payoff $\overline{a}z$. With probability $\phi\overline{\phi}$, C finds a substitute and S finds a complementor. In this case, they compete Bertrand and receive no returns at all. Finally, with $\phi\overline{\phi}$, C finds a complementor and S finds a substitute. In this case, the continuation value is difficult to assess, since it depends on the next continuation game, which is no longer stationary. We therefore find some appropriate bounds on the utilities.

The first condition is harder to satisfy the higher S's utility in the equilibrium where both C and S continue. We therefore use an upper bound on the S's expected utility in that equilibrium. For this, we use S's utility under the lucky scenario that C never finds a match. The upper bound is then given by $(az-c)[\delta\phi + (\delta\phi)^2 + ...] = \frac{(az-c)\delta\phi}{1-\delta\phi}$.

The second condition is harder to satisfy the lower C's utility in the equilibrium where both C and S continue. We therefore use a lower bound on the C's utility in that equilibrium. We use 0 as a lower bound.

With this, the first sufficient condition requires that if C is continuing, S does not want to continue. The upper bound on S's expected utility from also continuing is given by $\phi^2 az + \phi\overline{\phi}\frac{(az-c)\delta\phi}{1-\delta\phi} - c$. The first sufficient condition is thus given by

$$\phi^2[az + \overline{\phi}\frac{(az-c)\delta}{1-\delta\phi}] < c.$$

This condition is always satisfied for sufficiently small ϕ, i.e., if complementors are sufficiently rare.

The second sufficient condition requires that C still wants to continue even if S continues. The lower bound on C's expected utility from also continuing is given by $\overline{\phi}^2\overline{a}z - c$. The second sufficient condition is thus given by

$$\phi < 1 - \sqrt{\frac{c}{\overline{a}z}}.$$

Again, this condition is always satisfied for sufficiently small ϕ. Taken together, these two conditions ensure that for sufficiently small ϕ, "C continues alone" is the unique equilibrium of the continuation game.

The analysis for the second part of the lemma, namely that "S continues alone" is the unique equilibrium for ϕ sufficiently large is analogous. All we need to do is switch the lower and upper bounds. Straightforward calculations reveal that the two sufficient conditions are now given by

$$\overline{\phi}^2[\overline{a}z + \phi\frac{(\overline{a}z - c)\delta}{1 - \delta\overline{\phi}}] < c \text{ and } \phi > \sqrt{\frac{c}{az}}.$$

Both of these conditions are satisfied for sufficiently large ϕ.

8.3 Proof of Lemma 3

Consider first the case of ϕ sufficiently small. Replacing $\overline{a}z = \frac{z + \zeta_C}{2}$ into $\zeta_C = \delta(\phi\frac{\zeta_C}{2} + \overline{\phi}\overline{a}z - c)$ we get after simple transformations $\zeta_C = \frac{\delta(\overline{\phi}z - 2c)}{(2 - \delta)}$. From $az = \frac{z - \zeta_C}{2}$ we thus obtain $a = \frac{1}{2} - \frac{\delta}{2 - \delta}(\frac{\overline{\phi}}{2} - \frac{c}{z})$.

If ϕ sufficiently large, then the complementor has no outside option. The talker's outside option is given by $\zeta_T = \delta(\phi az + \overline{\phi}\frac{\zeta_T}{2} - c)$. Note that the talker can no longer be discouraged at this point. Using $az = \frac{z + \zeta_T}{2}$ we get $\zeta_T = \frac{\delta(\phi z - 2c)}{2 - \delta}$, and thus $a = \frac{1}{2} + \frac{\delta}{2 - \delta}(\frac{\phi}{2} - \frac{c}{z})$.

It should be noted that our results do not rely on the use of the Nash bargaining solution. Binmore, Rubinstein and Wolinsky (1986) provide an extensive form game to justify the use of the Nash bargaining solution. However, there exist other reasonable bargaining solutions, such as "outside option" bargaining (Rubinstein 1986). Let us focus on the case of ϕ sufficiently small. With "outside option" bargaining, the complementor's share is given by $\overline{a}z = Max[\frac{z}{2}, \zeta_C]$ where ζ_C as before. For $\zeta_C > \frac{z}{2} \Leftrightarrow \frac{c}{z} < \frac{2\delta\overline{\phi} - 2 + \delta}{4\delta}$ we get $\overline{a}z = \zeta_C = \frac{\delta(\overline{\phi}z - 2c)}{(2 - \delta)}$. For $\zeta_C < \frac{z}{2}$ we get $a = \overline{a} = \frac{1}{2}$. The complementor gets at least half, and possibly more of the surplus.

8.4 Proof of Proposition 1

The only part of Proposition 1 that requires a proof are the comparative statics on $\psi_M = \gamma(\phi paz - c)$. This depends on a, which in turn depends on the bargaining equilibrium. Since a does not depend on γ and p, those comparative statics are straightforward. For z we simply note that even though a may be decreasing in z, az is always increasing in z, so that ψ_M is increasing in z. Next, a is always an increasing function of ϕ, so that ψ_M is increasing in ϕ. Finally, for c we note that for ϕ sufficiently large, a is decreasing in c, so that ψ_M is decreasing in c. And for ϕ sufficiently small we have $\frac{d\psi_M}{dc} = \gamma(\phi pz\frac{da}{dc} - 1) = \gamma(\phi p\frac{\delta}{2 - \delta} - 1) = \frac{\gamma}{2 - \delta}(\delta(1 + \phi p) - 2) < 0$.

8.5 Proof of Lemma 5

For part (i) consider first the case of $E = 3$ then $V_T^2 = v_T + \delta V_G$, $V_T^1 = v_T + \phi\delta V_G + \overline{\phi}\delta V_T^2$ and $V_G = -\psi + \gamma V_T^1 + \overline{\gamma}\delta V_G$. This is a system of three variables and three unknown. Solving it, we find that $V_G = -\psi + \overline{\gamma}\delta V_G + \gamma V_T^1 = -\psi + \overline{\gamma}\delta V_G + \gamma v_T + \gamma\phi\delta V_G + \gamma\overline{\phi}\delta V_T^2$ $= -\psi + \overline{\gamma}\delta V_G + \gamma v_T + \gamma\phi\delta V_G + \gamma\overline{\phi}\delta v_T + \gamma\overline{\phi}\delta\delta V_G = -\psi + \gamma v_T + \gamma\overline{\phi}\delta v_T + \overline{\gamma}\delta V_G + \gamma\phi\delta V_G + \gamma\overline{\phi}\delta\delta V_G$ so that

$$V_G = \frac{-\psi + \gamma v_T + \gamma\overline{\phi}\delta v_T}{1 - (\overline{\gamma}\delta + \gamma\phi\delta + \gamma\overline{\phi}\delta\delta)}$$

Consider next the case of $E = 4$, where $V_T^3 = v_T + \delta V_G$, $V_T^2 = v_T + \phi\delta V_G + \overline{\phi}\delta V_T^3$, $V_T^1 = v_T + \phi\delta V_G + \overline{\phi}\delta V_T^2$ and $V_G = -\psi + \gamma V_T^1 + \overline{\gamma}\delta V_G$. From $V_G = -\psi + \overline{\gamma}\delta V_G + \gamma V_T^1$ $= -\psi + \overline{\gamma}\delta V_G + \gamma v_T + \gamma\phi\delta V_G + \gamma\overline{\phi}\delta V_T^2 = -\psi + \overline{\gamma}\delta V_G + \gamma v_T + \gamma\phi\delta V_G + \gamma\overline{\phi}\delta v_T + \gamma\overline{\phi}\delta\phi\delta V_G +$ $\gamma\overline{\phi}\delta\overline{\phi}\delta V_T^3 = -\psi + \overline{\gamma}\delta V_G + \gamma v_T + \gamma\phi\delta V_G + \gamma\overline{\phi}\delta v_T + \gamma\overline{\phi}\delta\phi\delta V_G + \gamma\overline{\phi}\delta\overline{\phi}\delta v_T + \gamma\overline{\phi}\delta\overline{\phi}\delta\delta V_G$ $= -\psi + \gamma v_T + \gamma\overline{\phi}\delta v_T + \gamma\overline{\phi}\delta\overline{\phi}\delta v_T + \overline{\gamma}\delta V_G + \gamma\phi\delta V_G + \gamma\overline{\phi}\delta\phi\delta V_G + \gamma\overline{\phi}\delta\overline{\phi}\delta\delta V_G$ we obtain

$$V_G = \frac{-\psi + \gamma v_T + \gamma\overline{\phi}\delta v_T + \gamma\overline{\phi}\delta\overline{\phi}\delta v_T}{1 - (\overline{\gamma}\delta + \gamma\phi\delta + \gamma\overline{\phi}\delta\phi\delta + \gamma\overline{\phi}\delta\overline{\phi}\delta\delta)}$$

For the general case, it is now easy to see that

$$V_G = \frac{-\psi + \gamma v_T \sum_{i=0}^{i=E-2} (\overline{\phi}\delta)^i}{1 - [\overline{\gamma}\delta + \gamma(\overline{\phi}\delta)^{E-1} + \gamma\phi\delta \sum_{i=0}^{i=E-2} (\overline{\phi}\delta)^i]}$$

where for the denominator we use $[\overline{\gamma}\delta + \gamma\delta(\overline{\phi}\delta)^{E-2} + \gamma\phi\delta \sum_{i=0}^{i=E-3} (\overline{\phi}\delta)^i] = [\overline{\gamma}\delta + \overline{\phi}\gamma\delta(\overline{\phi}\delta)^{E-2} + \gamma\phi\delta \sum_{i=0}^{i=E-2} (\overline{\phi}\delta)^i] = [\overline{\gamma}\delta + \gamma(\overline{\phi}\delta)^{E-1} + \gamma\phi\delta \sum_{i=0}^{i=E-2} (\overline{\phi}\delta)^i]$. Naturally, this maps directly into $V_G = \rho_T v_T - \rho_G \psi$ where

$$\rho_T = \frac{\gamma \sum_{i=0}^{i=E-2} (\overline{\phi}\delta)^i}{1 - [\overline{\gamma}\delta + \gamma(\overline{\phi}\delta)^{E-1} + \gamma\phi\delta \sum_{i=0}^{i=E-2} (\overline{\phi}\delta)^i]}$$

$$\rho_G = \frac{1}{1 - [\overline{\gamma}\delta + \gamma(\overline{\phi}\delta)^{E-1} + \gamma\phi\delta \sum_{i=0}^{i=E-2} (\overline{\phi}\delta)^i]}$$

For part (ii) we simply note that the numerator of V_G is increasing in E (since $\sum_{i=0}^{i=E-2} (\overline{\phi}\delta)^i$ increases with E) and the numerator is decreasing in E (since $\gamma(\overline{\phi}\delta)^{E-1} + \gamma\phi\delta \sum_{i=0}^{i=E-2} (\overline{\phi}\delta)^i$ increases with E). Note also that for the same reasons, both ρ_T and ρ_G are increasing in E.

For part (iii) we consider again the case of $E = 4$. To see that $V_T^3 > V_G$, assume to the contrary that $V_T^3 < V_G$. Then we have $V_T^2 = v_T + \phi\delta V_G + \overline{\phi}\delta V_T^3 < v_T + \delta V_G = V_T^3$, so that $V_T^1 = v_T + \phi\delta V_G + \overline{\phi}\delta V_T^2 < v_T + \phi\delta V_G + \overline{\phi}\delta V_T^3 < v_T + \delta V_G = V_T^3$ and thus $V_G = -\psi + \gamma V_T^1 + \overline{\gamma}\delta V_G < -\psi + \gamma V_T^3 + \overline{\gamma}\delta V_G = -\psi + \gamma v_T + \delta V_G \Leftrightarrow V_G < \dfrac{\gamma v_T - \psi}{1-\delta}$. But this is not possible, since $V_G(E) > V_G(E=2) = \dfrac{\gamma v_T - \psi}{1-\delta}$. Thus $V_T^3 > V_G$. To see that $V_T^2 > V_T^3$, note that $V_T^2 - V_T^3 = v_T + \phi\delta V_G + \overline{\phi}\delta V_T^3 - v_T - \delta V_G = \overline{\phi}\delta(V_T^3 - V_G) > 0$. For $V_T^1 > V_T^2$ note that $V_T^1 - V_T^2 = v_T + \phi\delta V_G + \overline{\phi}\delta V_T^2 - v_T - \phi\delta V_G - \overline{\phi}\delta V_T^3 = \overline{\phi}\delta(V_T^2 - V_T^3) > 0$. Thus $V_T^1 > V_T^2 > V_T^3 > V_G$. The proof for $E > 4$ is analogous.

8.6 Proof of Proposition 2

For the comparative statics of the optimal E, we use $\dfrac{dE}{d\psi} = \dfrac{d^2\Pi}{dEd\psi}/(-\dfrac{d^2\Pi}{dE^2})$. Since $\dfrac{d^2\Pi}{dE^2} < 0$ and $\dfrac{d^2\Pi}{dEd\psi} = -\dfrac{dE\rho_G}{dE} < 0$, we have $\dfrac{dE}{d\psi} < 0$. Similarly, since $\dfrac{d^2\Pi}{dEdc} = -\dfrac{dE\rho_T}{dE} < 0$, we have $\dfrac{dE}{dc} < 0$; since $\dfrac{d^2\Pi}{dEdpz} = \dfrac{d\phi E\rho_T}{dE} < 0$, we have $\dfrac{dE}{dp} > 0$ and $\dfrac{dE}{dz} > 0$. Finally, since $\dfrac{d^2\Pi}{dEdm'} = \dfrac{-1}{1-\delta} < 0$ we have $\dfrac{dE}{dm'} < 0$. The comparative for b^* are obtained directly from $b^* = \dfrac{c + \psi\frac{\rho_G}{\rho_T}}{\phi pz}$.

Figure 1: The Stage Game

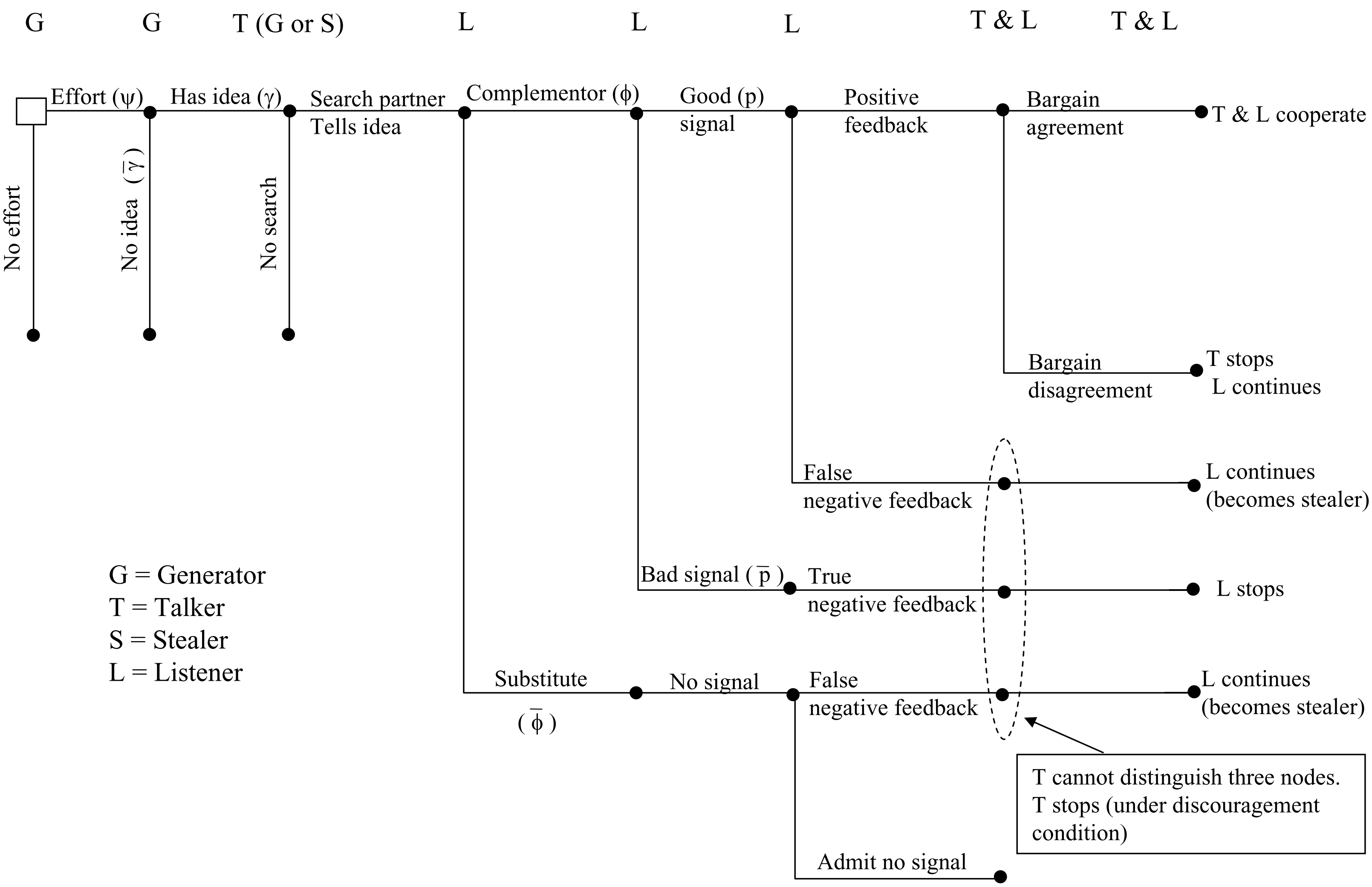

Figure 2: Feasible regions

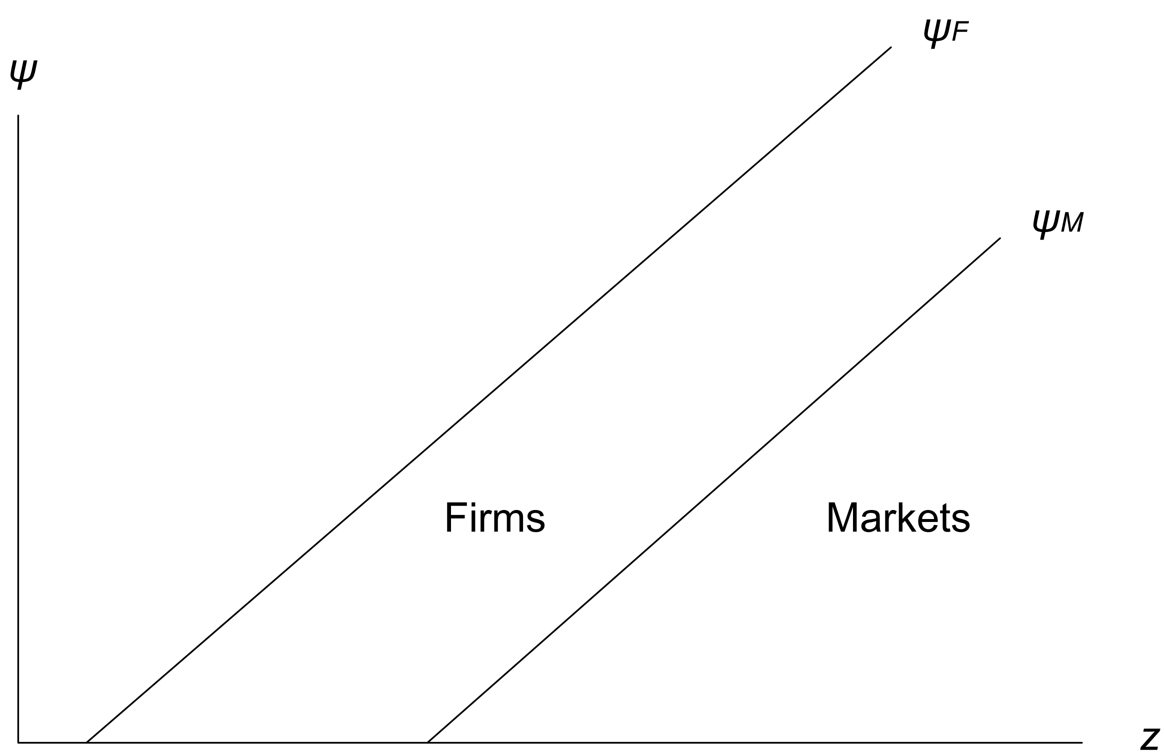

Table 1: Key notation

a	Talker's share in market returns
b	Generator's share in firm returns
c	Search costs
E	Number of employees within a firm
K	Fixed cost of starting a firm
m	Monitoring cost
n_F,n_E,n_M	Number of firm owners, employees and market agents
p	Probability that idea is good
s	Fraction of agents stealing an idea in the market
t	Fraction of agents talking about an idea in the market
u	Per period return in the market
U	Lifetime utility in the market
v	Per period return inside a firm
V	Lifetime utility inside a firm
z	Net value of good idea
ψ	Private idea generation costs
δ	Discount factor
ϕ	Probability that listener is complementor
γ	Probability of finding an idea
λ	Fraction of employees leaving with ideas
Π	Lifetime profits of a firm
ρ_G	Discounted number of times an employee generates idea
ρ_T	Discounted number of times an employee talks about idea
ζ_C	Complementor's outside option from continuation game
ζ_T	Talker's outside option from continuation game

Common subscripts

F	Subscript for firms
G	Subscript for generator
L	Subscript for listener
M	Subscript for markets
T	Subscript for talker