# Optimal Project Rejection and New Firm Start-ups[1]

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**Abstract**

Entrants typically appear to be more innovative than incumbent firms. Furthermore, these innovative ideas often originate with established firms in the industry. Therefore, the established firm and the start-up firm seem to select different types of projects. We claim that this is the consequence of their optimal project allocation mechanism which depends on their comparative advantage. The start-up firm may seem more "innovative" than the established firm because the comparative advantage of the start-up firm is to commercialize "innovative" projects, i.e. projects that do not fit with the established firms' existing assets. Our model integrates various facts found in the industrial organization literature about the entry rate, firm focus, firm growth, industry growth and innovation. We also obtain some counter intuitive results such that a reduction in the cost of start-ups may actually slow down start-ups and that the firm may voluntarily give away the property rights to the inventions discovered within the firm.
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# 1 Introduction

Entry into an industry is considered to be an important driver of innovation. Scherer (1980) argue that new entrants are responsible for a disproportionate share of all really new and revolutionary industrial products and processes. Carefully observing the process of how ideas are commercialized at start ups shows that in many cases the scientists and entrepreneurs in small innovative firms tend to come from large established firms in the industry and that these inventions are actually conceived at the incumbent's R&D department, but are passed up for other opportunities. For instance, Christensen (1997) claims that "ultimately, nearly all North American disk drive manufacturers can trace their founder's genealogy to IBM's San Jose division, which developed and manufactured its magnetic recording products." Bhidé (1996) conducted a survey of 87 Harvard Business School MBAs that became entrepreneurs, and found that more than 50% of them spotted a "need" while in a previous job. He also found that, 71% of the founders of 100 of the 1989 Inc. 500 fastest growing private companies had replicated or modified an idea encountered through previous employment. These facts suggest that established firms are an important source of project ideas even though they are not commercialized where they emerge. As the following quote illustrates, start-ups frequently occur as the result of *rejected ideas* of existing firms.

> "The presumption is that employees of the big companies leave and go to venture companies to found start-ups to make more money. That's not the way. Andy Grove, Bob Noyce and others left Fairchild to found Intel, not to make more money. They left to make a product that Fairchild was either unable or unwilling to make, or for what ever reason, didn't get around to making. That's why ventures are started: from lack of responsiveness in big companies... The only reason good people leave is because they become frustrated. They want to do something they can't

do in their present environment."

Don Valentine, Venture Capitalist in Silicon Valley.[1]

Many similar stories exist: Co-founders of Apple, Steven Jobs and Steven Wozniak initially offered their personal computer to Hewlett-Packard Corporation, which turned it down; Between 1974 and 1984 HP executives were responsible for starting more than eighteen firms, including notable successes such as Rolm, Tandem, and Pyramid Technology (Saxenian, 1994); Microsoft is experiencing a similar phenomenon in the Seattle area where it has generated start-ups such as RealNetworks, Crossgain, ViAir, CheckSpace, digiMine, Avogadro, Tellme Networks to name only a few (Wall Street Journal); Mitch Kapor -founder of Lotus Development Corporation-left Digital Equipment Corporation (Kao, 1989); Finis Conner and John Squires left Seagate and set up Conner Peripherals in order to develop small hard disk drives for notebook computers (Christensen, 1997, Chesbrough, 1997); Sam Walton's idea to locate discount stores in small towns of the Southwest of the US was rejected by the management of Ben Franklin; Freemarkets' founder was an engineer at GE where he proposed the idea of creating a B2B market place for suppliers. After GE rejected his initial proposal he set up the market place from his basement.[2]

In this paper, we develop a model that addresses the question why an established firm does not commercialize a seemingly good project while a start-up firm does. We propose a comparative advantage theory of project allocation where the comparative advantage of the established firm is to commercialize the projects which fit with the firm's assets in place while the start-up has a comparative advantage commercializing the projects which do NOT fit with the assets of the established firm. As a consequence the established firm may forgo a good project due to its poor fit with

[1] Quoted in Saxenian (1994).

[2] Franco and Filson (2000) indicate that start-ups originating from employees of existing firms accounted for more than 99% of total cumulative revenues generated by the start-up group in the hard disk drive industry.

the firm's assets and may wait for a project with a better fit.[3] This theory does not need to assume that either the established firm or the start-up firm is better or more profitable than the other. But it does assume that the established firm cannot commercialize infinitely many projects simultaneously and, hence, the capacity to commercialize an additional project has a positive option value. When this option value is high, the established firm becomes cautious in adopting a new project and, therefore, many projects are passed to start-up firms.

We study the determinants of this option value by developing a stylized model. The established firm sequentially receives project proposals on product innovations from scientists that are working in the R&D department of the firm. At random points in time scientists discover projects, characteristics of which are not known in advance. Once a scientist makes a discovery, the firm and the scientist negotiate about the fate of the project and the distribution of the surplus. There are three possible decisions regarding the fate of the project: the firm undertakes the project internally, the scientist starts up a new firm and undertakes it, or the project is shelved. The fate of the project depends on the characteristics of the project and the endogenously determined value of the option that the established firm maintains for adoption opportunities in the future. The distribution of the surplus between the established firm and the scientist depends on who owns the intellectual property rights over the project. We study two extreme cases: scientist ownership and firm ownership.[4]

[3] As Teece (1986) states "A firm's history and the assets it already has in place ought to condition its R&D investment decision. It is therefore rather clear that the R&D investment decision cannot be divorced from the strategic analysis of markets and industries and the firms position within them." Shane (2001b) finds that the low importance of complementary assets such as distribution or marketing and sales, increases the likelihood that MIT patents are commercialized through a start up.

[4] These rights are regulated by the legal environment of the state or country where the established firm is located. In most US states all rights of the scientist with respect to innovations can be legally signed over to the company. In addition, non-compete and trade secret clauses are signed which allow the employer to easily block any start-up without knowing the exact specification of the innovation of the former employee. The signing over of these rights, especially the rights to innovations that the researcher developed on her own time and budget, is illegal in Europe and some US states such as California, Kansas, Minnesota, Washington, North Carolina and Illinois will not

Our model is able to organize and relate various facts found in the industrial organization literature. First, consistent with the evidence of Acs and Audretsch (1988), the model implies that when the industry to which the established firm belongs is experiencing a high rate of invention and/or is young, the option value increases and so does the start-up rate. When invention is more frequent, the established firm becomes patient in accepting an additional project since the next invention will come along soon. For this reason, the established firm rejects more projects and new firms pick up these projects. Consistent with this prediction Shane (2001b) finds that start-ups are more likely to commercialize the technology protected by MIT patents related to young technology areas. In the laser industry Klepper and Sleeper (2002) show that firms producing types of lasers that were more advanced along the product life cycle had lower spinoff rates.

Second, the R&D intensity of the established firm affects the rate of start-ups positively. Such a R&D intensive firm generates more ideas with more rejected ideas left for start-ups to pick up. Consistent with this prediction, Klepper and Sleeper (2002) show that firms that patent more intensively had higher spinoff rates.

Third, comparing the project portfolio of an established company with the projects at start-up firms, the model implies that if we identify projects with a high "fit" as "marginal" inventions, that incumbents are more likely to introduce marginal innovations, while the start-up firm is more likely to introduce "radical" innovations. This is consistent with the fact that small (start-up) firms are more "innovative" than established firms (Scherer, 1980). Silverman (1999) finds that the probability of a firm diversifying into a certain industry strongly depends on the technological proximity of this industry to the technological position of the firm *relative* to any other (tech-

enforce non-compete clauses or use a very narrow definition of trade secret. Thus, in Europe and the US states where scientists rights are protected by law it is often difficult or impossible for the established firms to appropriate all the rents from the innovations that are not commercialized by the established firm. Furthermore, by rejecting and not commercializing ideas that are not patented, the firm loses the rights to these ideas, even though the idea surged within the organization. For a thorough development of the legal environment in Silicon Valley see Hyde (1998).

nological) diversification opportunities. Consistent with this evidence Shane (2001a) shows that more important, more radical, and broader patents from MIT are more likely commercialized through the establishment of a new firm. Furthermore, in a multi-project extension of the model, we find that the hurdle rate of the firm for accepting the project increases over time and that, therefore, the firm focus increases over time. As valuable capacity is filling up, the firm becomes more selective about which projects to accept. The model thus nicely distinguishes between the effects of the age of the firm and the maturity of the market. As the firm grows older, it becomes more selective, but as the industry gets more mature, the firm becomes less selective in its choice of projects.[5]

Our model is general in allowing a new project to either cannibalize or complement the existing business of the established firm. We find some counter-intuitive results that depend on whether the cannibalization effect or the complementary effect is strong. First, we study the effects of changes in the start-up environment on the start-up rate. Contrary to common belief, we find that the development of venture capital markets and stock markets, or subsidies towards new firms does not always increase the start-up rate. This happens when the cannibalization effect is strong. When a start-up becomes less costly, the established firm expects that rejecting projects is more likely to lead to the start-up of competing firms. Because of this negative externality, the established firm reduces the size of the R&D department and consequently fewer ideas will be generated. Thus, the start-up rate may even decrease in a start-up friendly environment. This prediction is also derived by Burke and To (2001) in a different setting. Second, we find that if the complementarity effect is strong, the established firm may prefer giving scientists property rights to projects. The firm's benefit from doing so is to stand at a stronger bargaining position when negotiating on internal adoption of projects with a scientist. If the negotiation breaks

[5] Relying on a model with decreasing returns to scale Jovanovic (1982) and Hopenhayn (1992) predict the negative relation between firm age and growth. The empirical evidence, however, is mixed (Evans 1987a,b and Hall 1987).

down, the scientist externally adopts the project if she owns property rights, and *vice versa*. The firm gets more from this external adoption than from no adoption when the complementarity effect is positive. As a consequence, the firm can stand at a stronger bargaining position if a scientist has property rights rather than the firm, when the complementarity effect is positive. Finally, the model is consistent with coexistence of corporate ventures and independent ventures. We identify corporate ventures as projects rejected for internal adoption, but sponsored by the established firm. The model implies that corporate ventures tend to be less profitable than independent start-ups. Many corporate ventures are projects that are complementary to the business of the established firm, but have insufficient stand alone profitability to be organized as a start-up. Therefore, they can only be successfully organized with a subsidy from the established firm.[6]

The model in this paper belongs to the literature on irreversible investments (Pindyck, 1988). For instance, Baldwin (1982) constructs a similar project evaluation mechanism as the one presented in this paper. A firm needs to decide about sequentially arriving investment opportunities. She shows that a standard NPV analysis does not provide the correct evaluation measure for projects when accepting a project today, reduces the possibility of accepting a project tomorrow. However, in her model rejected projects have no outside opportunity while in our model rejected projects are possibly developed outside the firm as a start-up. Therefore, the occurrence of start-ups is endogenous to the incumbent's project selection mechanism in our model. This also contrasts with the literature on whether incumbents or entrants have stronger incentives to commercialize an innovation. In this literature the entrant appears exogenously. By analyzing the incentives to invest in R&D of incumbent firms compared to entrants, economists argued that entrants are more likely to introduce "drastic" innovations that displace the incumbent firm (Arrow, 1962; Reinganum,

[6] Gompers and Lerner (1998) indeed find that corporate venture capitalists tend to invest at a premium compared to other firms.

1983; Gilbert and Newbery, 1982). However, both Ghemawat (1991) and Henderson (1993) have shown that the typical innovations introduced by an entrant cannot be considered "drastic", i.e. forcing the incumbent to exit the market.

In the literature on intellectual property rights the entrant does appear endogenously, but the commercialization of the invention by the entrant is an attempt by the scientist to avoid expropriation by her employer because of the lack of protection of intellectual property (Anton and Yao, 1994, 1995). A scientist with an interesting idea would leave the company and set up her own organization without revealing the idea to her current employer. As we have indicated, most scientists in start-ups seem to have revealed their idea to their former employer before deciding to start up on their own. Both of these explanations for the R&D commercialization incentives of start-ups -the incentive theory and lack of intellectual property protection- are based on the output market effects of innovation and new entry. Contrary to the economics literature, the management literature explains the perceived innovativeness of entrant firms from an internal perspective, i.e. as the result of organizational inertia in investing in the next generation technology by the established firm. The sunk cost of learning the current technology conditions the firm to restrict attention to marginal improvements of the current technology, leaving the field wide open to entrants with radical (disruptive) new technologies (Tushman and Anderson; 1986, Henderson and Clark; 1990, Henderson, 1993; Christensen, 1997).[7] The decision of the incumbent not to pursue these radical technologies, however, is considered irrational and limited by the cognitive capabilities of the incumbent. Similarly, Scherer and Ross (1990) argue that agency and risk aversion are important reasons for the "inability to get ideas approved by higher management" driving "the most creative individuals out of large corporations laboratories to go it alone in their own ventures" (p.652). Therefore, firms generating many start-ups because of these rejections should

[7] Arrow (1974) derived similar conclusions about the effects of the information processing ability of young versus old organizations.

perform worse than firms generating few start-ups in the same industry. However, Klepper and Sleeper (2002) show that firms generating more spin-offs actually have higher survival rates.

Two related papers develop a model with the same starting point, i.e. start-ups originating from employees of existing firms.[8] Klepper and Sleeper (2002) develop a model of horizontal product differentiation where the start-up is established by a former employee producing a slightly differentiated product. By assumption a start-up will cannibalize part of the parent firm's market share. Our model is more general in allowing for a richer relation between the innovation and the position of the original firm. This allows us to explain patterns observed in the laser industry with closely related start-ups on the one hand, and, patterns in the hard disk drive industry where start-ups seem to have been less related to the product positioning of the parent firm on the other. Hellmann (2002) examines the generation and organization of innovation using a multitasking model. The firm controls innovation generation through its commitment to an incentive scheme where the employee can decide to work on the assigned task or explore a new idea. The incentive scheme also determines whether the innovations, once generated, are commercialized within the organization, as a corporate venture, as a start-up, or, are shelved. While Hellmann endogenizes the effort allocation across multiple tasks given the number of employees, our model endogenizes the number of employees in absence of the effort allocation problem. Both Hellman's and our paper suggest that intellectual property rights do not necessarily pre-determine the outcome in the sense that if the firm has the rights, it launches internal ventures, and if employees have the rights, they start their own firms. One important difference in terms of prediction between Hellman's paper and ours is about how the profitability of the established firm's core activity affects the start-up rate. We predict a positive relation because the higher the profitability (and therefore the

[8] Franco and Filson (2000) develop a general industry framework where employees are allowed to imitate their employer's know-how. However, they are more interested in the industry dynamics rather than the firm decisions.

higher option value), the more projects the established firm rejects. On the contrary, Hellmann predicts a negative relation. The higher the profitability, the lower the return to explore a new idea relative to working on the assigned task, and therefore the firm motivates the employees not to pursue a new idea.

**Structure of the Paper** In the following section we set up the baseline model and derive its implications. We assume that the scientist owns the property rights to the innovation and that the firm can adopt only one project. In Section 3, we extend the baseline model. First, we study the case in which the firm can adopt more than one project. Second, we consider the case in which the firm has the property rights to the innovation. Next we look at the effect of additional costs for the start up and examine the effect of costly replacement of scientists that leave to start up a firm. Finally, we consider the case of external acquisition of ideas and examine the effect of the stationarity assumption in our model. Section 4 concludes. All proofs are gathered in the Appendix.

## 2 The Model

We study the R&D and project selection decisions of an established firm. The firm possesses some critical asset that is lumpy and exhaustible. This asset could be the management team, the sales force, the design team, production facilities or the whole organizational structure. This resource is under-utilized and the firm is searching for a project that may exploit it. Unlike the established firm, a start-up firm does not own any of these assets initially. Good investment opportunities frequently arise in the established firm because these assets give it an option to expand cheaply whereas the start-up would need to acquire new resources to commercialize a project. A project is internally adopted if the established firm adopts the project and externally adopted if the start-up firm does so. For either type of adoption, the scientist is an essential resource to adopt the project that she discovered.[9] That is, one cannot adopt a project without consent and cooperation of the scientist. For internal adoption, the established firm is also an essential resource and one cannot adopt a project internally without consent and cooperation of the established firm.

## 2.1 Project

A project is characterized by a triplet $(a, b, u)$. We denote by $u$ as the *private* net present value of the project if the necessary resources for the project must all be acquired on the market. Because undertaking the project may affect the cash flow to existing businesses of the established firm, the social value of the project may differ from $u$. Let $b$ denote the amount of cash flow that is added to the existing businesses. This incidental effect may be positive or negative. If $b$ is positive, the project is complementary to the existing businesses and if it is negative, the new project is a substitute for or competing with the existing businesses. To summarize, $u$ accrues to the adopter of the project while $b$ accrues to the established firm no matter who, the established firm or the start-up firm, adopts the project.

We study an established firm that owns critical assets that can be physical, technological, organizational or managerial. These assets allow the firm to better appropriate value from any innovation or idea (Teece, 1986). Rather than acquiring all the resources on the market, the project may utilize excess capacity of resources present at the established firm. In this case, the project can save some costs and its value increases by $a$. Because the start-up firm does not own assets at the outset, $a$ is realized only if the established firm adopts the project. We call $a$ the "fit" of the project with the existing assets of the established firm. There are two interpretations of $a$. First, $a$ may measure the relatedness between the new project and the existing businesses of

[9] This assumption is not necessary to obtain most of the results. Nonetheless, this assumption requires the scientist, not a third party, to start-up the firm to externally adopt the innovation. Otherwise, the scientist can simply sell the innovation to a third party without leaving the original employer. Garvin (1983) argues that probably the most important condition governing spinoffs is that the industry's critical design and production techniques are embodied in skilled labor rather than in physical capital.

the established firm. The more related the new project, the more the existing assets can be used for undertaking the new project and the lower the investment the firm has to make. With this relatedness interpretation, we can say that the firm maintains its focus when adopting a high $a$ project while it diversifies when adopting a low $a$ project. Second, the fit, $a$, may be negatively related to the originality of the project. Highly original projects often embody surprising and unanticipated ideas such that the existing assets of the established firm are not readily adjustable to undertake the projects. For this reason, we will think of low $a$ projects as "innovative".[10]

The adoption capacity of the established firm is limited up to $J$ projects. In other words, scaling in the firm is limited. We think that the limited scaling is plausible since the ability of the firm's managers to coordinate all the activities of the firm is limited as noted by Penrose (1959). As an extreme case, we for now assume that the established firm can adopt only one project, that is, $J = 1$. This assumption will be relaxed later. Further we assume that the adoption decision is irreversible such that the firm may not be able to abandon an adopted project to switch to another. We are aware that this assumption is extreme but we think that it is a good approximation of reality. In reality there are many kinds of adoption costs that cannot be recovered even if the project is abandoned. Such costs are incurred when reorganizing the firm's manufacturing facility, negotiating with suppliers, working over the marketing strategies, and training the sales force. Because of these irreversible investments required for adopting a project, a firm tends to stick to a project already adopted rather than start a new project from scratch. We also believe that allowing the firm to reverse its adoption decision does not change any of the results in this paper. The irreversibility of adoption gives the firm an option value to maintain the adoption capacity. We denote $V$ as this option value of the established firm and we will derive

[10] Our model abstracts from innovation and competition from outside firms. Competition and strategic effects could be incorporated through a careful interpretation of the different parameters. However, the interpretation of $a$ as a measure of innovativeness clearly depends on what the competition is producing.

$V$ endogenously later on. Unless the firm can adopt an infinite number of projects simultaneously, the value of the option $V$ is positive. It will represent the expected value of a future project on the optimal adoption path. In sum, the social value of the project is equal to $u + b + a - V$ if the project is internally adopted.

The adoption decision is also irreversible if it is externally adopted. Thus, the start-up firm loses a chance to start another new firm. At the same time, the start-up firm acquires a chance to become an established firm in the future. For simplicity, we assume that these two effects completely cancel each other out and therefore the social value of the project is simply equal to $u + b$ if it is externally adopted.[11]

## 2.2 Project Arrival and Selection

The firm has a R&D department which consists of a team of homogeneous scientists and the number of the team members is equal to $N$. The wage cost to hire $N$ scientists per period is $c(N)$ and the total wage to maintain $N$ scientists for duration $\Delta t$ is $c(N)\Delta t$. The function $c$ is non-negative, increasing, convex and continuously differentiable, and $c(0) = 0$. At any point in time, a scientist discovers a project with time-invariant probability, $\lambda$, that is, the arrival rate of a project per scientist is $\lambda$ and the project arrival rate for the whole R&D division is $N\lambda$. According to the Poisson law of rare events, the probability with which more than one scientist discovers a project at the same time is zero. Each project is characterized by a triplet $a \in [\underline{a}, \overline{a}]$, $b \in [\underline{b}, \overline{b}]$ and $u \in [\underline{u}, \overline{u}]$. These characteristics are drawn from the stationary joint distribution, $G$ with the density, $g$. The density function is positive everywhere and continuous over the domain. Once the established firm exhausts its capacity to adopt any additional project, the R&D department will be shut down.[12]

[11] The incidental effect is interpreted as the synergy of the project with the existing businesses. As Bankman and Gilson (1999) point out, the incidental effect may also be positively related to the tax saving in case that the new project makes losses. This effect is particularly acute when returns to the existing project and the new project are less correlated. The low correlation may however have a reverse effect on $b$ by weakening the divisional managerial incentives. Therefore, we will stick to the synergy interpretation of $b$.

[12] This assumption helps simplify the model. In reality, we think, most firms retain their R&D department while the firms are too occupied to adopt more projects, because there is some probability

Once a project is discovered, the scientist and the firm negotiate about the destiny of the project, which is either internal adoption, external adoption, or "shelving". We assume that both parties are symmetrically informed about all the relevant variables and that payoffs of both parties are transferable. We thus naturally use the Nash bargaining solution as the solution concept. A Nash bargaining solution is efficient such that the joint surplus is maximized and we therefore focus on the case in which the destiny of the project is determined efficiently. The efficient destiny of the project depends on the four variables, $V, a, b$ and $u$. External adoption gives a net surplus equal to $b+u$; internal adoption, $a+b+u-V$ and shelving zero. Thus, letting $B = b+u$, the efficient destiny of the project is determined by $\max\{B, a+B-V, 0\}$ . First, note that internal adoption occurs only if $a \geq V$ because otherwise external adoption yields a higher payoff than internal adoption. This implies that the established firms will only adopt projects with a sufficiently high "fit" with the existing assets. The necessary and sufficient condition that internal adoption occurs is therefore $a \geq V$ and $a+B-V \geq 0$. External adoption occurs if $a < V$ and $B \geq 0$. Consistent with Scherer (1980), the projects adopted by start-ups are sufficiently "innovative", i.e. have low $a$. If $B < 0$ and $u < 0$, adoption by others is not profitable and never happens. Thus, the firm does not patent the project and simply forgets it. If $B < 0$, but $u \geq 0$, the firm may patent the project because if others adopt it, they would reduce the firm's profit by $b$.[13] Figure 1 graphically illustrates the efficient destiny of a project.

A crucial assumption is that the firm's adoption capacity is limited and, therefore, the option value $V$ is strictly positive. If $V$ is zero as assumed in the previous literature, the external adoption region vanishes. Given $V$, external adoption likely

an existing product will become obsolete in any period, freeing up capacity in the next period. Complicating the model in this way will neither substantially change our results nor add much insight.

[13] In our model, shelving is a broader concept than the one in Gilbert and Newbery (1983). Gilbert and Newbery (1983) restrict attention to our latter case where a firm may patent a project but not adopt it in order to exclude the adoption by others and to keep competitive pressures low.

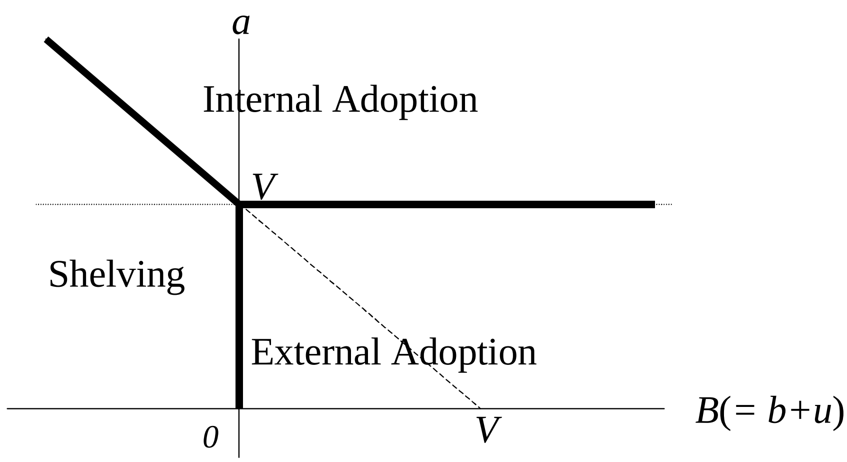


Figure 1: Efficient Destiny of Project

occurs if $a$ is low, that is, the project does not fit well with the firm's existing resources.[14] Consistent with this prediction, Shane (2001b), in a study about the commercialization of MIT patented technologies, finds that start ups are more likely to commercialize technologies whenever complementarity assets are not important, i.e. when the fit with an established firm's assets is likely low.

In what follows, we derive the option value $V$. For now, we assume that the established firm can adopt at most one more project.

### 2.3 Negotiation

The firm and the scientist divide the joint surplus according to the Nash bargaining solution. We analyze a simple negotiation environment in which there is no prior contract but ownership of the property rights of the project is given. The allocation of ownership of the project determines the outside options of the parties in case they may disagree.[15] We study two extreme cases: scientist ownership and firm ownership.

[14] Lerner and Hunt (1998) found that in Xerox managers assessed proposed product ideas using several criteria. Not only did the technology have to be promising, but the product had to match Xerox's existing delivery system (e.g. Xerox's sales force).

[15] In Aghion and Tirole (1994) the allocation of property rights affects the allocation of effort by the scientist and the firm (customer) and hence the expected success rate of different organizational forms. Rotemberg and Saloner (1994) study the incentive problem of researchers with respect to

To be concrete, scientist ownership means that without the approval of the firm the scientist can externally adopt the project and receive $u$ while firm ownership means that the scientist does need the approval of the firm before adopting the project externally. For now we study the case of scientist ownership.[16] The alternative case in which the firm owns the property rights is discussed in Section 3.

Under scientist ownership, the scientist can externally adopt the project without cooperation from the firm. This fall back option is valuable and credible only if $u > 0$. Thus, if $u > 0$, the fall back option of the firm is $b$ and the one of the scientist is $u$. Otherwise, if $u \leq 0$ the fall back option of the firm and the scientist are both zero. The negotiation about the adoption decision leads to the efficient decision described above and determines the transfer from the firm to the scientist. Let $P_S$ be the transfer that the firm makes to the scientist. We assume that the firm gets a fraction of the surplus equal to $\delta \in [0, 1]$ and the scientist gets $(1 - \delta)$.

The following lemma summarizes the equilibrium distribution of the surplus.

**Lemma 1** *Let $R_F^k$ and $R_S^k, k = 1, ..., 6$ be the cash flow of payoffs to the firm and the scientist, respectively and let $P_S$ be the transfer from the firm to the scientist. Also we define*

- $\omega^1 \equiv \{a, b, u | a - V > 0,\ a + b + u - V > 0 \text{ and } u > 0\}$
- $\omega^2 \equiv \{a, b, u | a - V > 0,\ a + b + u - V > 0 \text{ and } u \leq 0\}$
- $\omega^3 \equiv \{a, b, u | b + u \geq 0,\ a \leq V \text{ and } u > 0\}$

the organizational scope of the firm. They argue that firms might optimally limit the scope of their activities, i.e. their claims on innovations by employees, as a commitment not to implement inefficient projects ex post which distorts the incentives of the employees to come up with ideas. Hellmann (2002) applies this to the case of start-ups. In this model we abstract from any moral hazard problems affecting the effort of the scientist and therefore the arrival rate of new projects (see also Subramanian, 2001).

[16] This would be the case in Europe or the US states mentioned in footnote 4. Nevertheless, it seems that many companies have a policy of sharing the ownership of innovations with their employees as a motivational tool. As many start-ups arise as rejected ideas from the parent firm (see Klepper, 2001 and references therein), this assumption seems a reasonable first approximation.

- $\omega^4 \equiv \{a, b, u | b + u \geq 0,\ a \leq V \text{ and } u \leq 0\}$

- $\omega^5 \equiv \{a, b, u | b + u < 0,\ a + b + u - V < 0 \text{ and } u > 0\}$ *and*

- $\omega^6 \equiv \{a, b, u | b + u < 0,\ a + b + u - V < 0 \text{ and } u \leq 0\}$.

1. *If* $\{a, b, u\} \in \omega^1$, *the project is internally adopted, and* $R_F^1 = b + \delta (a - V)$ *and* $R_S^1 = P_S = u + (1 - \delta)(a - V)$.

2. *If* $\{a, b, u\} \in \omega^2$, *the project is internally adopted, and* $R_F^2 = \delta (a + b + u - V)$ *and* $R_S^2 = P_S = (1 - \delta)(a + b + u - V)$.

3. *If* $\{a, b, u\} \in \omega^3$, *the project is externally adopted, and* $R_F^3 = b$ *and* $R_S^3 = u$. *The transfer,* $P_S = 0$.

4. *If* $\{a, b, u\} \in \omega^4$, *the project is externally adopted, and* $R_F^4 = \delta (b + u)$ *and* $R_S^4 = (1 - \delta)(b + u)$. *The transfer,* $P_S = b - \delta (b + u)$.

5. *If* $\{a, b, u\} \in \omega^5$, *the project is shelved and* $R_F^5 = b - \delta (b + u)$ *and* $R_S^5 = P_S = u - (1 - \delta)(b + u)$.

6. *If* $\{a, b, u\} \in \omega^6$, *the project is shelved and* $R_F^6 = 0$ *and* $R_S^6 = 0 = P_S$.

As discussed before, a project can be internally adopted (regions $\omega^1$and $\omega^2$), externally adopted (regions $\omega^3$and $\omega^4$), or, shelved (regions $\omega^5$and $\omega^6$). The payoffs depend on the outside option of the scientist. In regions $\omega^1$, $\omega^3$and $\omega^5$ the project will be commercialized through a start up if no agreement is reached. The start up is not a viable threat in regions $\omega^2$, $\omega^4$and $\omega^6$ for the scientist. In the cases cited at the beginning of this paper, the established firms neither adopted the projects nor appropriated any returns from the projects undertaken by the new entrants, even though the original projects had emerged in the established firms. Such cases occur in region $\omega^3$, where there is no transfer payment between the scientist and the firm. The outcome for projects with characteristics falling in region $\omega^4$ has an interesting interpretation. The fit of the project $a$ is too low ($a \leq V$) for internal adoption while the project yields a positive gain by external adoption ($b + u \geq 0$). Nevertheless, the base profitability, $u$ is too low ($u \leq 0$) implying that the scientist does not want to start up without a subsidy from the firm. As a consequence, the firm subsidizes the scientist by $(1 - \delta)(b + u)$. This case resembles a corporate venture program in which the firm rejected the project for internal adoption but instead funds the scientist to undertake the project outside of the firm because of its complementarity with the firm's existing businesses. Microsoft, for example, is known for subsidizing former employees when developing complementary technologies and products.

The firm's total payoff equals the discounted sum of the cash flows associated with the arrival of projects. If the firm internally adopts a project at time $\tau$, then the firm's payoff is:

$$U = E\left[\int_0^{\tau} e^{-rt} C^F(t)\, dt\right],$$

where $r$ is discount rate and $C^F(t)$ is firm's cash flow at time $t$. Note that the cash flow is equal to $R_F$ if the project arrives and zero otherwise. We assume that the firm is risk neutral and that it chooses the adoption policy such that $U$ is maximized.

We now determine the option value of the firm, $V$. Since $G$ is time-independent and each scientist has a constant arrival rate of projects, $\lambda$, the firm's problem is also time-independent. As a consequence, the firm faces the stationary arrival rate of projects, $N\lambda$, and therefore has a stationary adoption and buyout policy for projects.

Let $V$ be the expected payoff to hold an option to adopt a project given the adoption and buyout policy described in Lemma 1, then $V$ must satisfy the following asset pricing formula:

$$rV + c(N) = N\lambda \sum_{k=1}^{6} \int_{\omega^k} R_F^k dG.$$

That is: the foregone interest ($= rV$) plus the wage rate is equal to the expected gain ($N\lambda \sum_{k=1}^{6} \int_{\omega^k} R_F^k dG$). Explicitly writing $R_F^k$, $k = 1, ..., 6$ and rearranging the terms gives:

$$
\begin{aligned}
& V \qquad (1) \\
= \; & \frac{\int_{\omega^1} (\delta a + b)\, dG + \delta \int_{\omega^2} (a+b+u)\, dG + \int_{\omega^3} b dG + \delta \int_{\omega^4} (b+u)\, dG + \int_{\omega^5} (b - \delta (b+u))\, dG - c(N)}{r/N\lambda + \delta \int_{\omega^1 \cup \omega^2} dG}.
\end{aligned}
$$

Note that the equation (1) implicitly determines $V$ because the regions $\omega$ depend on $V$.

The numerator of $V$ consists of five elements in addition to the wage rate $c(N)$. The first two parts represent the expected future profits from internally adopting the project (regions $\omega^1$and $\omega^2$). The next two integrals represent the payoffs when there is external adoption (regions $\omega^3$and $\omega^4$). The last expression before the wage rate is the expected cost of avoiding competition or to secure shelving (region $\omega^5$).

Our assumption that the project rejection rule is efficient and optimal has important implications for testing the validity of our model. First, researchers have no reason to hide their idea when deciding to organize a start-up. This contrast with the predictions of the intellectual property rights literature (Anton and Yao, 1994, 1995) where employees leave the parent firm without revealing their idea out of fear of being expropriated. Evidence suggests that researchers do reveal their ideas and only when rejected leave the parent firm to start-up a new firm (Klepper, 2001 and references therein). Second, we expect organizations that generate many start-ups to continue to perform well in their existing business given that projects are optimally rejected. This contrasts with the predictions from the models in the management literature (Tushman and Anderson; 1986, Henderson and Clark; 1990, Henderson, 1993; Christensen, 1997) where these firms have made mistakes in their evaluation decision and, hence, are expected to fare worse than other firms in the industry. Klepper and Sleeper (2002) find, however, that longer-lived firms accounted for a disproportionate number of spin-offs in the laser industry.

### 2.4 Comparative Statics

Let $N^*$ and $V^*$ be the maximizer of the firm's payoff, $U$. We are interested to know how the option value, $V^*$and $N^*$, are affected by $r, \lambda$ and $\delta$. The results of comparative statics are summarized below:

**Proposition 1** *$V^*$ is increasing in $\lambda$ and $\delta$ and decreasing in $r$ .*

This implies that the established firm becomes more selective about the projects for internal adoption as $\lambda$ and/or $\delta$ increase. The firm becomes more patient when it belongs to an industry experiencing a high rate of project generation (high $\lambda$) in general. Furthermore, the firm adopts more marginal (high $a$) projects internally and thus the proposition also implies that the established firm becomes more focused in an innovative environment. This result explains why small firms are disproportionately more innovative in high-tech industries as found by Acs and Audretsch (1988). High-tech industries experience a high rate of new project arrivals. Because of these abundant project opportunities, established -large- firms are prudent and focused in adopting projects avoiding to exhaust their adoption capacity. As a result, many new firms -presumably small- pick up the projects that those large firms rejected. Consistent with these predictions, Shane (2001b) finds that MIT patents that are classified in more recently established patent classes, are more likely commercialized by a start-up firm. Typically younger technologies spur a lot of invention. Garvin (1983) notes that as industries mature, effort to improve the production process and know-how becomes more embodied in physical capital, lowering the rate of spinoff.

The proposition also implies that the larger the firm's bargaining power, the pickier the firm becomes and more start-ups emerge. Because the firm expects to capture a larger fraction of rents from future ideas, the option value becomes bigger and thus the firm is less willing to internally adopt the project and abandon the option. Finally, the proposition tells us that as in the standard real option model, if the firm cares less about the future or the business is more risky (high $r$), it is more likely to accept the project.

**Proposition 2** *$N^*$ is increasing in $\lambda$ and decreasing in $r$. A change in $\delta$ does not change $N^*$.*

This result is intuitive. An increase in $\lambda$ and $\delta$ and a decrease in $r$ all mean that the marginal return to R&D increases. As a consequence, the firm has a stronger incentive to perform R&D. Note that $N^*$ and $V^*$ are positively related through changes of $\lambda$, $\delta$, and $r$. Hence, a firm with a larger R&D department (high $N$) is more likely to reject a project (high $V$), conditional on having the same adoption capacity. This is in line with Winter (1984) who states that small firm innovativeness should be proportional to the number of people exposed to the knowledge base from which innovative ideas might derive. Therefore, as more people within the established firm are exposed to the research ideas, the more likely innovative start-ups will arise. In our model this link is made explicit.

## 3 Extensions

In this section, we extend the baseline model presented in the previous section. First, we allow the firm to adopt more than one project. Second, we study the case in which the firm rather than the scientist owns the property rights to the project. Next, we include a cost of external adoption and discuss the effect of policy measures affecting the cost of start ups and examine the effect of costly replacement of scientists that leave to start up a firm. Finally, we extend the model to allow the established firm to scan the external environment for new projects, and, discuss the stationarity assumption of the project arrival process. In summary, the results obtained in the base-line model will turn out to be robust to such extensions.

### 3.1 Optimal Dynamic Adoption of Many Projects

So far we assumed that the firm can adopt at most one more project. We now extend the model to the case in which the firm can adopt finitely-many projects. Suppose that the firm will live infinitely long from date 0. Also suppose that the firm can possibly adopt $J$ projects, not only one project. We label the projects adopted $j = 1, 2, ..., J$, sequentially. For instance, the project adopted earliest is the first project and $j = 1$. Let $V_j$ be the value of the right to adopt up to $J - j$ projects and $\tau_j$ be the date of adopting the $j$th project. (Note that the subscript $j$ is the counter of projects that the firm has adopted, and NOT how many additional project the firm can adopt.) The firm's payoff in this case is:

$$U = E\left[\int_0^{\tau_J} e^{-rt} C^F(t)\, dt\right],$$

where $\tau_J$ is the time when the firm internally adopts the $J$th project and $C^F(t)$ is the firm's cash flow at time $t$. We also say that the firm is in period $j$ if it has adopted as many as $j$ projects. Thus, $V_j$ is the option value to adopt $J - j$ projects when the firm is in period $j$.

To make the problem tractable, we maintain the assumptions on $G$ made in the previous section. Irrespective of how many projects the firm has already adopted, $G$ is independently and identically distributed across time and period. Due to this assumption, there are only two state variables: one is $j$, in which period the firm is and $t$, the calendar time. Similar to the model in the previous section, using $t$ is to simplify the formalization since the firm's maximization problem must be stationary within a period. Different from the previous section, internal adoption leads to not only the loss of the current option value but also to the gain of the option value in the next period. Thus, when the firm is in period $j$, it adopts a project if and only if the NPV of the project is no less than $V_j - V_{j+1}$. Let $v_j$ be $V_j - V_{j+1}$, then if we rewrite $V$ by $v_j$ in Figure 1, we obtain a similar division of the regions for internal adoption, external adoption, and shelving. Lemma 2 in Appendix summarizes the equilibrium outcome of the negotiation and the value function in the jth period. The basic characteristics of the optimum and value function are similar to the one-project case. Thus, the firm still optimally rejects projects and a start-up may externally adopt them even though the firm has the capacity to accommodate several projects.

The next proposition states how the cut-off value $v_j$ evolves over time.

**Proposition 3** $v_j \geq v_{j-1}, \forall j$. *That is, the fewer the number of the adoptable projects, the pickier the firm becomes.*

Figure 2 helps to understand the intuition behind the proposition. Roughly speaking, the proposition says that the option value is concave in the number of the projects that can be adopted. The option value increases with the number of adoptable project but an increase in the option value is decreasing. This decreasing return to the number of projects occurs since the return to R&D is decreasing. As a consequence, the optimal R&D level $N^*$ is not proportional to the number of adoptable projects, and therefore, the option value is not proportional to the number of adoptable projects, either.

As a mirror image, the proposition implies that start-ups emerge if the established firm matures. Finally, the proposition also implies that the firm diversifies when young and becomes more focused in its project selection when it matures. This result should be contrasted with the effect of a change in $\lambda$. A slower innovation rate, which we associate with a more mature market results in the established firms becoming less selective in their project selection process. In the laser industry Klepper and Sleeper (2002) find indeed that firms producing types of lasers that were more advanced along the product life cycle, had lower spinoff rates, while older firms had higher spinoff rates.

**Corollary 1** $N_j^* > N_{j+1}^*, \forall j$. *That is, the fewer the number of adoptable projects, the lower the R&D level becomes.*

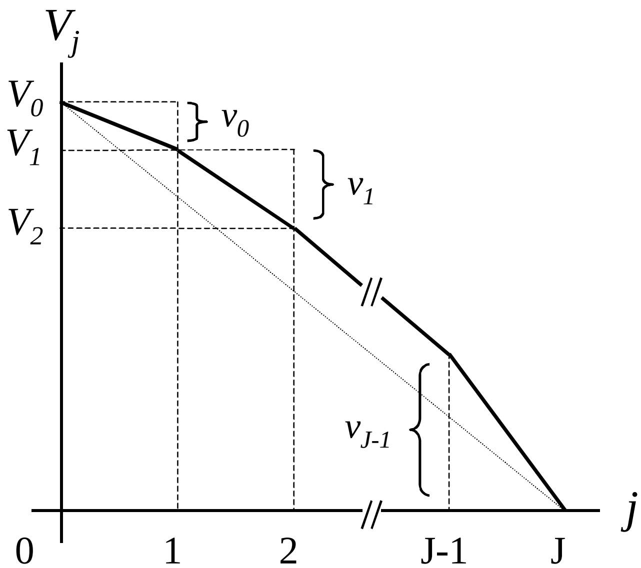


Figure 2: Option Value with Many Projects

The intuition behind this corollary is more straightforward than the one for Proposition 3. Benefits from increasing the R&D level in period $j-1$ are earlier arrivals of ideas, earlier exhaustion of one adoption capacity, and consequently earlier transition to period $j$. Earlier transition is more desirable when $V_j$ is larger. As $V_j$ decreases as the number of adoptable projects decreases, the firm has a lower incentive to perform R&D as $j$ increases.

### 3.2 The Firm Owns the Property Rights

We now study the case in which the firm owns the property rights to the projects. The key difference from the previous case in which the scientist owns the property rights is that the scientist cannot start up the firm without buying the property rights from the firm. This would be equivalent to a tight enforcement of non-compete clauses which are standard in researchers' contracts. Hence, the outside option of the firm and the scientist is zero in all cases when no agreement is reached. Because we don't need to distinguish a case in which $u > 0$, from the other, the division of the surplus becomes simpler than before.

The following lemma summarizes the outcome of the negotiation between the parties:

**Lemma 3** *Let* $\overline{R}_F^k$ *and* $\overline{R}_S^k$, $k = 1, ..., 6$ *be the payoffs of the firm and the scientist, respectively and let* $P_F$ *be the transfer from the firm to the scientist in case of the firm ownership. Then,*

1. *if* $\{a, b, u\} \in \omega^1 \cup \omega^2$, *the project is internally adopted, and* $\overline{R}_F^1 = \overline{R}_F^2 = \delta(a + b + u - V)$ *and* $\overline{R}_S^1 = \overline{R}_S^2 = (1 - \delta)(a + b + u - V)$. *The transfer* $P_F = (1 - \delta)(a + b + u - V)$.

2. *if* $\{a, b, u\} \in \omega^3 \cup \omega^4$, *the project is externally adopted, and* $\overline{R}_F^3 = \overline{R}_F^4 = \delta(b + u)$ *and* $\overline{R}_S^3 = \overline{R}_S^4 = (1 - \delta)(b + u)$. *The transfer,* $P_F = b - \delta(b + u)$.

3. *if* $\{a, b, u\} \in \omega^5 \cup \omega^6$, *the project is shelved and* $\overline{R}_F^5 = \overline{R}_F^6 = 0$ *and* $\overline{R}_S^5 = \overline{R}_S^6 = 0$. *The transfer is equal to zero.*

Proof of Lemma 3 is omitted because it is similar to the one of Lemma 1. It is interesting to compare $\overline{R}_F^k$ (firm ownership) with $R_F^k$ (scientist ownership). For the sake of exposition let us assume that the endogenously determined option value, $V$, does not differ across the two ownership cases. Comparing Lemmas 1 and 3, we see that $\overline{R}_F^k$ and $R_F^k$ have the same expression for $k = 2, 4, 6$ and that they are different for $k = 1, 3, 5$. This is intuitive. Note that $u \leq 0$ if $k$ is even ($k = 2, 4, 6$) and that $u > 0$ if $k$ is odd ($k = 1, 3, 5$). If $u \leq 0$, the allocation of the ownership does not matter because the fall back option is "not to externally adopt" for both cases. If $u > 0$, the fall back option is different across the two ownership regimes and so are the payoffs. Crucial here is that the firm can push down the scientist's as well as its own payoff to zero by leaving the negotiation table. Continuing to assume that $V$ is the same across both regimes, we get:

$$\overline{R}_F^k - R_F^k = \delta u - (1 - \delta) b, \; k = 1, 3, 5.$$

By assumption, $u$ is positive for $k = 1, 3, 5$. Thus, if $b$ is negative, that is, the project cannibalizes the existing projects of the established firm, $\overline{R}_F^k > R_F^k$. This is an intuitive case such that the party who owns the property rights can appropriate more rents. It is however important to stress that this intuitive case does not hold when $b$ is positive. Note that if $b$ is positive, scientist ownership relative to firm ownership increases the fall back payoff not only of the scientist but also of the firm. This effect is stronger for the firm's fall back payoff than the scientist's if $b$ and/or $\delta$ are large and/or $u$ is small.

The above observation suggests that *the firm may want to voluntarily give away the ownership to the property rights such that the scientists cannot commit not to externally adopt the project.* In this way, the firm may strengthen its own bargaining position relatively more than the scientist and as a consequence the firm can appropriate a bigger part of the surplus at the negotiation stage.

Noting that the problem is again time-invariant, the value function in the case of firm ownership is:

$$V = \frac{\delta \int_{\omega^1 \cup \omega^2} (a + b + u)\, dG + \delta \int_{\omega^3 \cup \omega^4} (b + u)\, dG - c\,(N)}{r/N\lambda + \delta \int_{\omega^1 \cup \omega^2} dG} \tag{2}$$

The numerator of $V$ consists of two parts: the first part represents the expected future profits from adopting the project, and the second part, the gain from selling the project to the scientist. The second part contrasts sharply with the previous case in which the scientist owns the property rights. The firm can now appropriate a part of the gain from external adoption, $b + u$ even though $u > 0$. Despite this difference, it is clear that the results on the comparative statics with respect to the option value presented in the previous section also apply to this case. Thus, changes in ownership allocation do not affect our basic results.

Let $V^F$ be the optimal cut-off value that satisfies equation (2) and $V^S$ the optimal cut-off value that satisfies equation (1). That is, $V^F$ is the equilibrium option value to the firm when it owns the property rights and $V^S$ is the one when the scientist owns the property rights. An interesting question is which option value, $V^F$ or $V^S$, is the larger one. The answer to this question is ambiguous because of the reason stated above. Scientist ownership generally strengthens the bargaining position of the scientist while it may strengthen the bargaining position of the firm even more. Which effect dominates depends on $G$ and, therefore, we don't have an unambiguous conclusion.

### 3.3 Extra cost for startup

Next, we study how the environment for start-up affects the project selection policy of the established firm. To do so, we denote $i$ as the extra loss from adopting the project externally. That is, the total gain from start-up is equal to $b + u - i$. A reduction in $i$ can be interpreted as a start-up subsidy or improved access to venture capital. The destiny of the project now depends on the five variables, $V, a, b, i$ and $u$. External adoption gives the net surplus equal to $b + u - i$; internal adoption, $a + b + u - V$ and shelving zero. Thus, again letting $B = b + u$, the efficient destiny of the project is determined by $\max\{B - i, a + B - V, 0\}$. First note that internal adoption occurs only if $a \geq V - i$ because otherwise external adoption yields a higher payoff than internal adoption. On a similar account, external adoption occurs only if $a < V - i$. The necessary and sufficient condition that internal adoption occurs is therefore $a \geq V - i$ and $a + B - V \geq 0$ and the one that external adoption occurs is $a < V - i$ and $B - i \geq 0$. Figure 3 graphically shows the efficient destiny of a project and Lemma 4 in Appendix describes the equilibrium outcome of the negotiation.

Interestingly, a decrease in $i$ may not expand the external adoption region. One can interpret a decrease in $i$ as the introduction of start-up subsidies or the development of a venture capital market. Nonetheless, such regulatory changes may not promote start-up in our model. They increase the number of profitable projects for start-ups but also make the established firms adopt more projects internally. Hence, whether such changes promote start-ups depends on which effect, the former direct

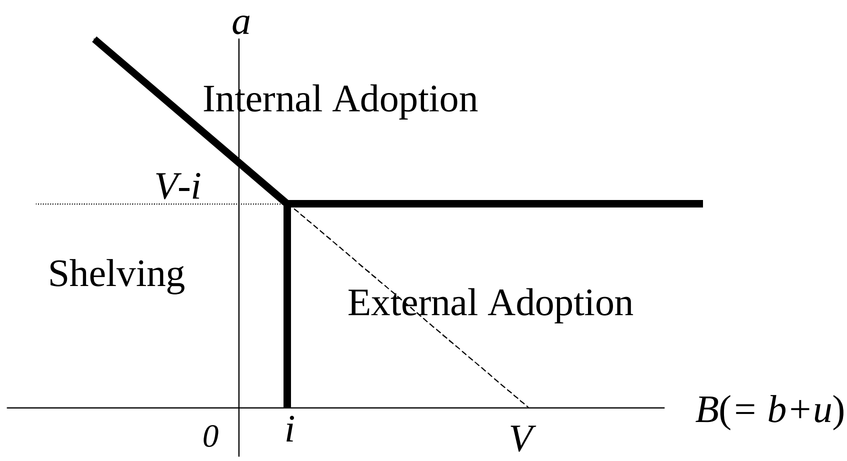


Figure 3: Extra Cost for Start-up and Efficient Destiny of Project

effect or the latter indirect, is larger.[17] Hellmann (2002) similarly finds that as the entrepreneurial environment improves start-ups might actually diminish as the parent firm adjusts its incentives for innovation and becomes more entrepreneurial itself. Burke and To (2001) derive a related result when analyzing the effect of lower entry barriers on an industry. The reduced cost of entry may lead to the reduction of entry rate and reduce economic efficiency because the incumbent limits the number of employees it hires in the first place in order to reduce the future threat of entry by employees. The proposition also implies that the established firm becomes more diversified with respect to project selection upon a positive regulatory change towards start-ups. Consistent with this prediction, Klepper and Sleeper (2002) find that unfavorable entry conditions have more effect on the spinoff rate than favorable entry conditions in the laser industry. This could be related to an endogenous adjustment of the parent's decision rule or incentives for innovation as the environment for start-ups improves.

[17] For instance, Michelacci and Suarez (1999) show that the development of a stock market increases the number of start-ups by facilitating to match entrepreneur and venture capitalists easier. This is different from our model in not considering the effect on the project adoption behavior of the established firms.

### 3.4 Cost of searching for scientists

So far we implicitly assumed that when scientists leave to adopt their project externally, the firm can find a replacement without any cost. We were implicitly assuming this by supposing that the project arrival rate $N\lambda$ won't change after any external adoption. In reality, replacing the former scientists may be costly. The firms need to advertise the vacancy, to interview candidates and to negotiate with them. Furthermore, productivity of an experienced scientist that leaves to engage in a start-up is unlikely to be the same as that of a newly hired researcher, all of which increases hiring costs. This extension is easily incorporated into the analysis however. Similar to the case above in which external adoption requires extra costs, we just need to subtract the replacement cost from the total efficiency gain. One difference from the case above is that the firm rather than the scientist must incur this cost *per se*. As a consequence, the firm stands at a weaker bargaining position and its payoff will go down.

### 3.5 Acquisition of ideas

Up to now we have restricted attention to ideas generated by the research department of the firm. However, the firm could also scan the technology space for interesting inventions to commercialize. If we assume that the scientists own the intellectual property rights to their ideas, the established firm is competing for ideas outside the firm as well as ideas developed within the firm. This has no real consequences for the optimal project rejection decision of the established firm. These inventions would then be measured against the same option value, i.e. using the scarce, critical resource of the established firm.

Our model does not include uncertainty about the commercialization of an idea. Once the idea is known, its fit and profitability are certain. In reality this is unlikely to be true. Typically the evaluation of an idea and its commercialization will involve several stages. A project could be rejected at an early stage because of the uncertainty surrounding its fit and profitability, i.e. it does not make the cut at the established firm. Nevertheless, after commercialization by a start-up firm, some of this uncertainty is resolved and the innovation might now pass the cut for one of the next evaluation stages at the established firm. In that case the established firm can consider acquiring the start-up firm in order to reintegrate the project. An interesting prediction of the multi-project model is that after an acquisition we should expect an increase in the number of start-ups generated by the firm as the hurdle for new projects has increased. This is exactly what Klepper and Sleeper (2002) find in the laser industry, where the spinoff rate for a parent firm seems to increase after an acquisition.

### 3.6 Non-Stationarity

One convenient but perhaps restrictive assumptions we made is that the arrival process of ideas is Poisson. Effectively, we have assumed that R&D is a memoryless process. However, if R&D is cumulative we would expect that the firm becomes pickier over the time without adopting any project because as time goes by it is more likely that the next idea will come earlier. Although this cumulative R&D assumption will clearly complicate the model, the basic intuition remains as long as the option value does not become zero.

## 4 Conclusions

In many industries, radical innovations are introduced by new entrants, in many cases start up firms. In the management literature this has been seen as a failure of the incumbent firms to respond to changes in their environment because of organizational inertia. Often the knowledge for the innovation is present within the firm, but the inefficient decision making by the firm results in foregoing promising projects. In the economics literature, this fact has been explained as a market failure on the one hand, and as efficient underinvestment because of diverging incentives to invest in

R&D on the other. The market failure relates to the absence of property rights over innovations. The only way that scientists can appropriate some of the returns to their ideas is by setting up their own firm. They refuse to reveal their ideas to their current employer for fear of being expropriated. The efficient underinvestment theory claims that for drastic innovations, an entrant has a higher incentive to commercialize the innovation. However, when reading the case history of many new ventures carefully, one finds that many successful entrepreneurs set up their own firms only after they did reveal their ideas to their employers and the employers declined to develop the idea within the firm. Furthermore, many of these innovations are not drastic in the economic sense, but are introduced by entrants nevertheless. If this was due to inefficient behavior by the management of incumbents firms, one would expect that over time firms correct for this mistake. But these parent firms do not seem to suffer severe consequences of these decisions in a statistically significant way.

In contrast to these existing views, our model hinges neither on inefficient decision making nor on weak protection of property rights or the existence of drastic innovations. We claim that the established firm and the start-up firm adopt different types of projects as a consequence of optimal project allocation based on a comparative advantage theory. The start-up firm may seem more "innovative" than the established firm because the comparative advantage of the start-up firm is to commercialize "innovative" projects, which do not fit with the established firms' existing assets. In addition, the model integrates various facts found in the industrial organization literature about the new firm start-up rate, firm focus, firm growth, and innovation. Contrary to common belief, we find that the development of venture capital markets and stock markets, or, subsidies toward new firms do not always increase the start-up rate. We also find that the established firm may want to give away the ownership to the project ex ante.

A number of interesting extensions of the model are left for further research. One extension is related to the growth of the firm. In order to really introduce firm growth we need to make the "fit" parameter $a$ dynamic and dependent on previously accepted projects. Our intuition, guided by the results in section 3.1, suggests that as firms grow, the fit of new projects becomes more important. Therefore, the firms are more likely to reject project proposals implying a slow down in the growth rate of the firm. In addition, we might expect that as we accept more projects, excess capacity to implement projects is reduced.

Second, we treated the adoption capacity of the firm exogenous. Nevertheless, certain firms have a very active tradition of intrapreneurship and seem to have a higher adoption capacity. Examples of these firms are 3M, Dupont, and General Electric. This begs the question why some firms have a bigger capacity to accommodate more projects than others and how firms choose this adoption capacity. Finally, although our model has a clear prediction on firm focus and diversification, we have not yet been successful in relating the results with historical data. For instance, in the late 1960s we observe the conglomerate merger wave in which many firms diversify their operations. On the contrary, in 1980s, many firms became more focused. We wish to explore if our model can shed some light on these events.

# 5 Appendix

## 5.1 Proof of Lemma 1

We distinguish four cases each of which gives different fall-back options for the firm and the scientist.

First, suppose $\{a, b, u\} \in \omega^1$, then if the firm does not buy out the innovation, the scientist's payoff is equal to $u$ and the firm's payoff is $V + b$ because the scientist does want to start up a new firm. Thus, the total surplus in this case is equal to $b + u + V$. If the firm buys out the innovation, the total surplus is $a + b + u$ . Since $a + b + u \geq V$, the buyout occurs and the payment is $u + (1 - \delta)(a - V)$. This proves the first sentence of the lemma.

Second, $\{a, b, u\} \in \omega^2$, then if the firm does not buy out the innovation, the scientist's payoff is equal to zero and the firm's payoff is $V$ because the scientist does not want to start up a new firm. Thus, the total surplus in this case is equal to $V$. If the firm buys out the innovation, the total surplus is $a+b+u$. Since $a+b+u \geq V$, the buyout occurs and the payment is $(1-\delta)(a+b+u-V)$. This proves the second sentence of the lemma.

Third, suppose that $\{a, b, u\} \in \omega^3$, then if the firm does not buy out the innovation, the scientist's payoff is equal to $u$ and the firm's payoff is $b+V$ because the scientist does want to start up a new firm. Thus, the total surplus in this case is equal to $b+u+V$. If the firm buys out the innovation, the total surplus is $V$. Hence the buyout does not occur and the payment is zero. This proves the third sentence in the lemma.

Fourth, suppose $\{a, b, u\} \in \omega^4$, then if the firm does not buy out the innovation, the scientist's payoff is equal to zero and the firm's payoff is $V$ because the scientist does not want to start up a new firm. Thus, the total surplus in this case is equal to $V$. If the scientist starts up, the total surplus is $b+u+V$. As $b+u \geq 0$, the firm subsidizes the scientist to start up by making a payment of $P_S = b - \delta(b+u)$. This proves the fourth sentence in the lemma.

Fifth, suppose that $\{a, b, u\} \in \omega^5$, then if the firm does not buy out the innovation, the scientist's payoff is equal to $u$ and the firm's payoff is $b+V$ because the scientist does want to start up a new firm. Thus, the total surplus in this case is equal to $b+u+V$. If the firm buys out the innovation, the total surplus is $V$. Hence the buyout occur and the payment is $u-(1-\delta)(b+u)$. This completes the proof of the fifth sentence in the lemma.

Sixth, suppose that $\{a, b, u\} \in \omega^6$, then if the firm does not buy out the innovation, the scientist's payoff is equal to zero and the firm's payoff is $V$ because the scientist does want to start up a new firm. Thus, the total surplus in this case is equal to $V$. If the firm buys out the innovation, the total surplus is $V$. Hence the buyout does not occur and the payment is zero. This completes the proof of the sixth sentence in the lemma.

## 5.2 Proof of Proposition 1

Rearranging the terms of the equation (1) gives:

$$\begin{aligned}
& V\left(\frac{r}{N\lambda}+\delta\int_{\omega^1\sqcup\omega^2} dG\right)+c\,(N) \\
& -\left(\int_{\omega^1}(\delta a+b)\,dG+\delta\int_{\omega^2}(a+b+u)\,dG+\int_{\omega^3} bdG+\delta\int_{\omega^4}(b+u)\,dG+\int_{\omega^5}((1-\delta)\,b-\delta u)\,dG\right) \\
= \;& 0.
\end{aligned}$$

Let $Q$ be the left hand side of the equation above. The second order condition for the optimality of $V$ implies that $sign\,(dV/dj) = sign\,(-dQ/dj)$. Since

$$-\frac{dQ}{d\lambda} = \frac{rV}{N\lambda^2} > 0,$$

$$-\frac{dQ}{dr} = -\frac{V}{N\lambda} < 0$$

and

$$-\frac{dQ}{d\delta} = \int_{\omega^1\sqcup\omega^2}(a-V)\,dG+\int_{\omega^4}(b+u)\,dG-\int_{\omega^5}(b+u)\,dG > 0,$$

then Proposition 1 follows. Q.E.D.

## 5.3 Proof of Proposition 2

The second order condition for the optimality of $N$ implies that $sign\,(dN/dj) = sign\left(-d^2Q/dNdj\right)$. Since

$$-\frac{d^2Q}{dNd\lambda} = \frac{rV}{N^2\lambda^2} > 0,$$

$$-\frac{d^2Q}{dNdr} = -\frac{V}{N^2\lambda} < 0$$

and

$$-\frac{d^2Q}{dNd\delta} = 0,$$

then Proposition 2 follows. Q.E.D.

### 5.4 Lemmas 2 and 4

**Lemma 2** *Let $V_j - V_{j+1} = v_j$ and*

- $\omega^{1j} \equiv \{a, b, u | a - v_j > 0,\ a + b + u - v_j\ > 0 \text{ and } u > 0\}$
- $\omega^{2j} \equiv \{a, b, u | a - v_j > 0,\ a + b + u - v_j\ > 0 \text{ and } u \leq 0\}$
- $\omega^{3j} \equiv \{a, b, u | b + u \geq 0,\ a \leq v_j \text{ and } u > 0\}$
- $\omega^{4j} \equiv \{a, b, u | b + u \geq 0,\ a \leq v_j \text{ and } u \leq 0\}$
- $\omega^{5j} \equiv \{a, b, u | b + u < 0,\ a + b + u - v_j < 0 \text{ and } u > 0\}$ *and*
- $\omega^{6j} \equiv \{a, b, u | b + u < 0,\ a + b + u - v_j < 0 \text{ and } u \leq 0\}$.

1. *If $\{a, b, u\} \in \omega^{1j}$, the project is internally adopted, and $R^F = b + \delta(a - v_j)$ and $R^S = P_S = u + (1 - \delta)(a - v_j)$.*

2. *If $\{a, b, u\} \in \omega^{2j}$, the project is internally adopted, and $R^F = \delta(a + b + u - v_j)$ and $R^S = P_S = (1 - \delta)(a + b + u - v_j)$.*

3. *If $\{a, b, u\} \in \omega^{3j}$, the project is externally adopted, and $R^F = b$ and $\pi^S = u$. The transfer, $P_S = 0$.*

4. *If $\{a, b, u\} \in \omega^{4j}$, the project is externally adopted, and $R^F = \delta(b + u)$ and $R^S = (1 - \delta)(b + u)$. The transfer, $P_S = b - \delta(b + u)$.*

5. *If $\{a, u\} \in \omega^{5j}$, the project is shelved and $R^F = b - \delta(b + u)$ and $R^S = P_S = u + (1 - \delta)(b + u)$.*

6. *If $\{a, u\} \in \omega^{6j}$, the project is shelved and $R^S = 0$ and $R^S = 0 = P_S$.*

**Lemma 4** *We define*

- $\omega^1 \equiv \{a, b, u | a - V + i > 0,\ a + b + u - V > 0 \text{ and } u - i > 0\}$

- $\omega^2 \equiv \{a, b, u | a - V + i > 0,\ a + b + u - V > 0 \text{ and } u - i \leq 0\}$
- $\omega^3 \equiv \{a, b, u | b + u - i \geq 0,\ a \leq V - i \text{ and } u - i > 0\}$
- $\omega^4 \equiv \{a, b, u | b + u - i \geq 0,\ a \leq V - i \text{ and } u - i \leq 0\}$
- $\omega^5 \equiv \{a, b, u | b + u - i < 0,\ a + b + u - V < 0 \text{ and } u - i > 0\}$ *and*
- $\omega^6 \equiv \{a, b, u | b + u - i < 0,\ a + b + u - V < 0 \text{ and } u - i \leq 0\}$. *Then,*

1. *If* $\{a, b, u\} \in \omega^1$, *the project is internally adopted, and* $R^F = b + \delta(a - V + i)$ *and* $R^S = P_S = u - i + (1 - \delta)(a - V + i)$.
2. *If* $\{a, b, u\} \in \omega^2$, *the project is internally adopted, and* $R^F = \delta(a + b + u - V)$ *and* $R^S = P_S = (1 - \delta)(a + b + u - V)$.
3. *If* $\{a, b, u\} \in \omega^3$, *the project is externally adopted, and* $R^F = b$ *and* $\pi^S = u - i$. *The transfer,* $P_S = 0$.
4. *If* $\{a, b, u\} \in \omega^4$, *the project is externally adopted, and* $R^F = \delta(b + u - i)$ *and* $R^S = P_S = (1 - \delta)(b + u - i)$.
5. *If* $\{a, b, u\} \in \omega^5$, *the project is shelved and* $R^F = b - \delta(b + u - i)$ *and* $R^S = P_S = u - i + (1 - \delta)(b + u - i)$.
6. *If* $\{a, b, u\} \in \omega^6$, *the project is shelved and* $R^S = 0$ *and* $R^S = 0 = P_S$.

Proof of Lemmas 2 and 4 is omitted because it is similar to the one of Lemma 1.

### 5.5 Proof of Proposition 3

We omit subscript $j$ attached to $\omega$ so as to make the following equations look simpler. According to the asset pricing formula, the firm's value function in the $j$th period is therefore:

$$\begin{aligned} & V_j \\ = \; & \frac{\int_{\omega^1} \left(\delta \left(a + V_{j+1}\right) + b\right) dG + \delta \int_{\omega^2} \left(a + b + u + V_{j+1}\right) dG}{r/N_j\lambda + \delta \int_{\omega^1 \cup \omega^2} dG} \\ & + \frac{\int_{\omega^3} bdG + \delta \int_{\omega^4} \left(b + u\right) dG + \int_{\omega^5} \left(\left(1 - \delta\right) b - \delta u\right) dG - c\left(N_j\right)}{r/N_j\lambda + \delta \int_{\omega^1 \cup \omega^2} dG} \end{aligned} \quad (3)$$

for $j = 1, ..., j - 1$ and $V_{J+1} = 0$.

Substituting $v_j = V_j - V_{j+1}$ into the equation (3) and rearranging it give:

$$\begin{aligned} & v_j + \left(1 - \frac{\delta \int_{\omega^1 \cup \omega^2} dG}{r/N_j\lambda + \delta \int_{\omega^1 \cup \omega^2} dG}\right) V_{j+1} \\ & - \frac{\int_{\omega^1} \left(\delta a + b\right) dG + \delta \int_{\omega^2} \left(a + b + u\right) dG + \int_{\omega^3} bdG + \delta \int_{\omega^4} \left(b + u\right) dG + \int_{\omega^5} \left(\left(1 - \delta\right) b - \delta u\right) dG - c\left(N\right.}{r/N_j\lambda + \delta \int_{\omega^1 \cup \omega^2} dG} \\ = \; & 0. \end{aligned} \quad (4)$$

Let $Q_j$ be the left hand side of the equation (4). The second order condition for the optimality of $V$ implies that $sign\left(dv_j/dl\right) = sign\left(-dQ_j/dl\right)$. Since

$$-\frac{dQ_j}{dV_{j+1}} < 0, \forall j < J,$$

the cut-off value $v_j$ is then increasing in $V_{j+1}$. Note that $V_j > V_{j+1}$ because otherwise one can raise $v_j$ to infinity and effectively reduce the adoption capacity by one. Therefore, $v_j > v_{j-1}$. Q.E.D.

## 5.6 Proof of Corollary

Rearranging the equation (4) gives:

$$\begin{aligned} & \left(V_{j+1} + v_j\right)\left(\frac{r}{N_j\lambda} + \delta \int_{\omega^1 \cup \omega^2} dG\right) + c\left(N_j\right) = \delta \int_{\omega^1 \cup \omega^2} dG + \int_{\omega^1} \left(\delta a + b\right) dG \\ & + \delta \int_{\omega^2} \left(a + b + u\right) dG + \int_{\omega^3} bdG + \delta \int_{\omega^4} \left(b + u\right) dG + \int_{\omega^5} \left(\left(1 - \delta\right) b - \delta u\right) dG \end{aligned} \quad (5)$$

Let $Q_j$ be the left hand side of the equation (5). As the right hand side of the equation depends neither on $V_{j+1}$ nor $N_j$, the the second order condition for the optimality of $N_j$ implies that $sign\left(dN_j/dV_{j+1}\right) = sign\left(-d^2Q_j/dN_jdV_{j+1}\right)$. Since

$$-\frac{d^2Q_j}{dN_jdV_{j+1}} = \frac{r}{N_j^2\lambda^2} > 0,$$

then Corollary 1 follows. Q.E.D.

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