The 80/20 Rule: Corporate Support for Innovation by Employees*

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Abstract

We model an employee's decision to pursue an innovative idea at his employing firm (internally) or via a start-up (externally). We characterize an idea by its market profitability and the degree of positive/negative externality that it imposes on the employing firm's profits. The innovation process consists of exploration and development. Exploring an idea internally grants the employee access to exploration support from the firm, but reduces his appropriability of the idea. We demonstrate that ideas exhibiting weak externalities are explored and developed externally whereas ideas with strong externalities are explored and developed internally. Moderate externalities are associated with internal exploration, but subsequent external development. An increase in the firm's exploration support attracts internal exploration of a wider range of ideas, but increases the likelihood of subsequent external development. Moreover, the firm's exploration support and profitability respond nonmonotonically to policies that improve its appropriability of new ideas.

Keywords: Innovation, R&D, Entrepreneurship, Exploration support.

JEL Codes: O31, O34, L51.

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1 Introduction

Evidence indicates that innovations developed by start-ups are often conceived by former employees of established firms who undertake projects that had been overlooked by their employers. These innovations are frequently related to the respective parent firms' lines of business (Bhide, 1994; Agarwal et al., 2004; Klepper and Sleeper, 2005; Franco and Filson, 2006; Cassiman and Ueda, 2006). For instance, FriendFeed, Aardvark, and Nextstop were founded by former Google employees, with each closely connected to their founders' work at Google.[1] Similarly, former Microsoft employees Rob Glaser, Gabe Newell, and Rich Barton famously went on to found RealNetworks, Valve, and Zillow, each directly connected to their past responsibilities at Microsoft (Rich Barton also co-founded Expedia.com as part of his employment at Microsoft in 1994; it was later spun off).

While innovations may eventually be developed outside of their respective parent firms, the initial exploration often occurs within. In fact, many of the firms that bear a reputation for employees leaving to form start-ups, including Amazon, Google, and Microsoft, also have in place generous policies for supporting exploration of new ideas. Firms such Chubb,[2] LinkedIn,[3] and Apple[4] followed Google in implementing generous company policies for allowing employees to explore new ideas "on the company's dime." Google's renowned 80/20 "Innovation Time Off" (ITO) policy encourages employees to take 20 percent of their time to work on company-related projects of their choosing. The policy has led to some exceptionally successful commercial products, including Gmail, AdSense, and Google News, and in-house utility tools like Google Moderator.[5]

A firm's choice to support exploration of new ideas by its employees, in lieu of negotiating exploration-contingent contracts, can be understood in light of the nature of the innovation process. Innovative ideas are frequently the result of unpredictable and non-contractible initiatives, which go beyond employees' normally prescribed tasks (Aghion and Tirole, 1994; Hellmann and Thiele, 2011). Thus, in-

[1] Numerous other start-ups that bear a relationship to Google's product line were founded by former Google employees, including Ooyala, Dasient, TellApart, Cuil, Redbeacon, Mixer Labs, Howcast, MyLikes, Weatherbill, Doapp, reMail, Hawthorne Labs, and AppJet, among others.

[2] http://sloanreview.mit.edu/article/redesigning-innovation-at-chubb/

[3] http://www.wired.com/2012/12/llinkedin-20-percent-time/

[4] http://goo.gl/42rer7

[5] http://goo.gl/CJq38

centive contracts based on measurable performance objectives studied in the literature (e.g., Holmström, 1991; Holmström and Milgrom, 1991, 1994; Gibbons, 1998) are often hard to structure and evaluate in practice. Policies for corporate innovation, such as Google's ITO policy, have attracted considerable media and practitioners' attention in recent years,[6] and their profitability has been questioned.[7] This paper aims to gain a better understanding of the relationship between a firm's support for innovation and employees' choice of whether to innovate and where to pursue new ideas.

We present an integrated model that incorporates both the firm's problem of incentivizing innovation by its employees as well as an employee's choice of pursuing an innovation internally or externally. Similar to Pakes and Nitzan (1983), a new idea in our framework can be turned into a marketable innovation in two stages — exploration and development. Exploration turns a non-verifiable and non-contractible idea into a working prototype that can be evaluated by a third party, while the development stage turns the prototype into a marketable product.

From the employee's perspective, external exploration has the advantage of a higher appropriability of the innovation. The benefit of internal exploration is twofold. First, the employee can take advantage of the firm's exploration support, which may increase the likelihood of successful exploration. Second, internal exploration and handling of an idea may be more efficient if the idea is related to the firm's line of business (e.g., due to better tailoring of new products to existing ones). Given the trade-offs that the employee faces upon coming up with an idea, he chooses whether to ignore the idea and focus on other (core) tasks, explore the idea internally, or explore the idea externally. Our objective is to understand how the firm's level of support and the conceived idea's characteristics interact with the employee's exploration and retention incentives.

Our model gives rise to the prediction that at the early exploration stage, firms tend to bleed out ideas that impose weak (positive or negative) externalities on existing profits, and retain ideas with strong externalities. This is primarily because ideas exhibiting stronger externalities are associated with higher efficiency gains from joint development. This prediction is consistent with some empirical evidence. In particular, in the semiconductor, laser and disk-drive industries, spinoffs are likely to enter new niche markets that do not significantly affect the profits of

[6] http://www.forbes.com/innovative-companies/.

[7] http://blogs.hbr.org/cs/2010/08/free_time_innovation.html

parent firms (Christensen, 1993; Klepper and Sleeper, 2005; Klepper, 2010).

Our model also incorporates heterogeneity in terms of employees' potential for entrepreneurship (e.g., due to varying abilities and access to capital), where an employee's type is private information and affects his profitability from the external pursuit of an idea. Allowing for this heterogeneity leads to interesting dynamics in the downstream once an innovation has been explored; that is, once a prototype has been completed. In particular, in the development stage, disagreements between the firm and the employee regarding the division of proceeds from an innovation may lead to the employee's departure. These disagreements are the result of the firm's inability to observe the employee's type. Our model gives rise to the prediction that internal exploration and subsequent external development occurs for ideas exhibiting moderate externalities. Employees take advantage of the firm's resources in exploring such ideas, but may later find the downstream compensation insufficient for internal development, leading to departures.

In equilibrium, since low-type employees have less attractive outside options, and consequently weaker incentives to pursue ideas externally, their initial exploration decision may signal their types. Interestingly, as the firm increases its support for exploration, the firm's ability to infer an employee's type diminishes — as all employee types find internal exploration more attractive. Therefore, while increasing its exploration support helps the firm attract more ideas for internal exploration, it can also give rise to more downstream disagreements, as the firm finds it increasingly difficult to evaluate an employee's outside option. This finding is consistent with the anecdotal evidence mentioned above, where firms which are most supportive of employees' exploration, such as Google and Amazon, are also renowned for having employees leave to form new ventures.

Thus, aside from the inherent costs associated with supporting innovation, firms face additional important trade-offs in determining their levels of support. In particular, a firm's exploration support may not only grant the firm access to new ideas, but can also facilitate a screening mechanism that enables employees to signal their types. This type of signaling can help firms retain more ideas internally at their development stage, and by doing so, realize efficiencies from joint development with their original employee innovators.

How, then, does a firm's optimal choice of support and its expected profit interact with its ability to appropriate innovation proceeds? A firm's degree of appropriability is affected by numerous factors such as the innovating employee's indispensability in the development process, the firm's control over vital production inputs, intangible benefits received by the employee from external development, and the employee's potential for independent development. We show that if a firm is seeking to attract a wide spectrum of employee types, then its optimal level of support is positively related to its degree of appropriability. That is, as its shares of the proceeds from new product innovations rise, so does its optimal level of support. The reason for this is intuitive. First, the increase in the firm's downstream profits from new ideas makes internal exploration more attractive for the firm. Second, since employees anticipate less favorable contractual terms in the downstream, they are less willing to explore new ideas in-house —unless the firm increases its level of support.

However, a higher degree of appropriability does not necessarily benefit the firm — and may in fact reduce its expected profit. This is because the cost of maintaining the flow of ideas brought internally can outweigh the gains from appropriating larger proceeds in the downstream. Furthermore, for high degrees of appropriability, the firm may find it too costly to retain ideas from high-type employees, leading to a substantial decrease in its level of exploration support. These findings give rise to the following empirical implication: Industries where firms' appropriability of employees' ideas is significant (e.g., due to high levels of intellectual property protection and/or enforceability of non-compete agreements), are also likely to be characterized by firms offering less support for innovation.

2 Related Literature

There is a significant body of literature that addresses different aspects of innovation in firms. The questions related to the employee's incentives to leave established companies to form start-ups (e.g., Pakes and Nitzan, 1983; Anton and Yao, 1995; Amador and Landier, 2003; Klepper and Sleeper, 2005; Cassiman and Ueda, 2006; Hellmann, 2007; Thompson and Chen, 2011) and inducing innovation within firms (e.g., Holmström, 1989; Holmström and Milgrom, 1991; Aghion and Tirole, 1994; Inderst and Klein, 2007; Bernardo et al., 2009; Hellmann and Thiele, 2011; Manso, 2011) have been at the forefront of the entrepreneurship literature. Interestingly, the analysis of these two important aspects of innovation in firms — inducing innovation and new venture formation — has been largely disconnected.

We bridge this gap by studying the choices of (i) exploration support by the firm, and (ii) start-up formation by employees, in an integrated model.

Some of the emerging explanations for employee departure include labor market frictions (Astebro et al., 2011); information asymmetries and overly optimistic employees (e.g., Amador and Landier, 2003; Thompson and Chen, 2011); lack of commitment by established firms to not expropriate innovative ideas (e.g., Pakes and Nitzan, 1983; Anton and Yao, 1994, 1995; Wiggins, 1995; Gans et al., 2002; Gans and Stern, 2003); firm's optimal pre-commitment to reject innovation by employees in order to incentivize effort on the firm's core business (Hellmann, 2007); know-how acquisition by employees that increases their potential for entrepreneurship (Franco and Filson, 2006); inability of the established firm to prevent the development of profit-eroding innovations (Klepper and Sleeper, 2005); and a limited capacity for internal ventures (Cassiman and Ueda, 2006).

Our paper is closest to the literature that models start-up formation as the result of informational asymmetries, including the firm's limited information about the characteristics of ideas conceived by its employees (e.g., Thompson and Chen, 2011). In line with the empirical evidence (e.g., Agarwal et al., 2004; Franco and Filson, 2006; Klepper, 2009), we allow for new ideas to interact with a firm's existing line of business — by either complementing or competing with the firm's existing offerings. This is an important aspect of our model that distinguishes our work from much of the existing literature. It allows us to characterize an employee's departure as a function of the employee's entrepreneurial ability, the market profitability of an idea, as well as the degree of externality that this idea may impose on the parent firm.

Existing literature that incorporates innovation externalities includes Gilbert and Newbery (1980), Reinganum (1983), Klepper and Sleeper (2005) and Cassiman and Ueda (2006). With the exception of Cassiman and Ueda (2006), this literature focuses only on innovations that cannibalize profits from existing products, while omitting the possibility of complementary innovations. More importantly, private agreements for joint development between potential entrants and existing firms are ruled out. This gives rise to the prediction that entrants may have stronger incentives compared to existing firms to develop substitute ideas, which goes contrary to our findings.

By allowing for both complementary and substitute ideas, and the possibility of internal handling of innovations, our work is closest to Cassiman and Ueda

(2006). However, unlike in our model, internal development in Cassiman and Ueda's model is independent of the idea's proximity to the established firm's line of business. Cassiman and Ueda conjecture that the firm possesses superior commercialization capability, which is unaffected by the idea's closeness to the firm's existing offerings. This makes the established firm more willing to develop ideas with wider range of profitability. As a result, Cassiman and Ueda predict that internally-commercialized ideas are on average more cannibalizing and less profitable compared to externally commercialized ideas. In contrast, a defining feature of our model is the firm's superiority in handling ideas related to the firm's line of business. As a result, we find that the firm retains ideas that exhibit significant negative or positive externalities, giving rise to the prediction that start-ups develop products that are weakly related to the parent firm's existing offerings. This finding is more in line with the empirical regularities observed in the literature (e.g., Franco and Filson, 2006; Christensen, 1993; Klepper and Sleeper, 2005; Klepper, 2010).

Our paper is also closely related to the growing literature on motivating innovation within established firms. While much of this literature (e.g., Holmström, 1989; Inderst and Klein, 2007; Bernardo et al., 2009; Manso, 2011) takes a mechanism-design approach of characterizing optimal innovation-inducing contracts, some papers (e.g., Aghion and Tirole, 1994; Hellmann and Thiele, 2011) characterize innovation activity as unplanned, non-contractible, and not subject to the standard incentive contract. The closest paper to ours on this topic is Hellmann and Thiele (2011), who consider a multitask incentive problem with one planned contractible activity (the standard, core task) and one unplanned non-contractible activity (innovation). A defining feature of their model is the mutual exclusiveness of the two activities, which allows for the contractual terms of the planned activity to influence an employee's non-contractual innovation incentives. In contrast, our multi-tasking model allows for co-existence of the two activities. Our focus is on how a firm's unconditional policy to support exploration, along the lines of policies championed by Google, interacts with an employees' choice of whether and how to explore innovative ideas.

The remainder of the paper is organized as follows. Section 3 formally sets up the model. Section 4 consists of equilibrium analysis with the following subsections: 4.1 and 4.2 solve for the expected payoffs from internal exploration and characterize an employee's optimal exploration strategy; 4.3 addresses the employee's development strategy as a function of the firm's exploration support; 4.4 characterizes the firm's optimal level of support and derives comparative statics results. Section 5 concludes. Proofs are relegated to an Appendix. For convenience, Table 1 contains a summary of the notation and is provided on the last page of the Appendix.

3 Model

The model consists of a firm (denoted by f) and a research employee (denoted by e, where we make use of the terms researcher and employee interchangeably). The researcher receives a competitive wage, w, to work on a "core task" assigned by the firm. Consistent with the literature (e.g., Pakes and Nitzan, 1983; Cassiman and Ueda, 2006; Hellmann, 2007), we assume that in the course of his work, the researcher may serendipitously come up with an innovative idea. The idea is characterized by two components: (i) market profitability, v_i, and (ii) an externality, Δ, that is imposed on the firm's existing profit. The market profitability is drawn from a Bernoulli distribution taking a high value $v_i = v$ with probability ψ and a low value $v_i = 0$ with probability $1 - \psi$. The externality imposed on the firm is drawn from a conditional distribution $F(\Delta|v_i)$ with support $[\underline{\Delta}, \overline{\Delta}]$, where $\underline{\Delta} < 0$ and $\overline{\Delta} > 0$, allowing for both positive and negative externalities (complementary and substitute ideas, respectively). Moreover, the general specification of $F(\Delta|v_i)$ allows us to capture possible correlation between market profitability and the externality to the firm.[8]

The innovation process consists of two stages: exploration and development. At the exploration stage, the employee privately observes (v_i, Δ). The probability of successful exploration is given by $p(L)$, where L denotes the pre-committed exploration support by the firm on the likelihood of successful exploration. We assume that $p'(L) > 0$ and $p''(L) \leq 0$, reflecting the positive and diminishing effect of L. External exploration succeeds with probability p_o. Successful exploration results in a working prototype. If exploration takes place internally, the characteristics of the prototype are also observed by the firm. The subsequent development

[8]For instance, a close substitute to the firm's existing products is likely to exhibit both high negative externality to the firm as well as low market profitability as market competition erodes profits. The relationship between market value and the degree of externality to the firm is less clear for complementary products.

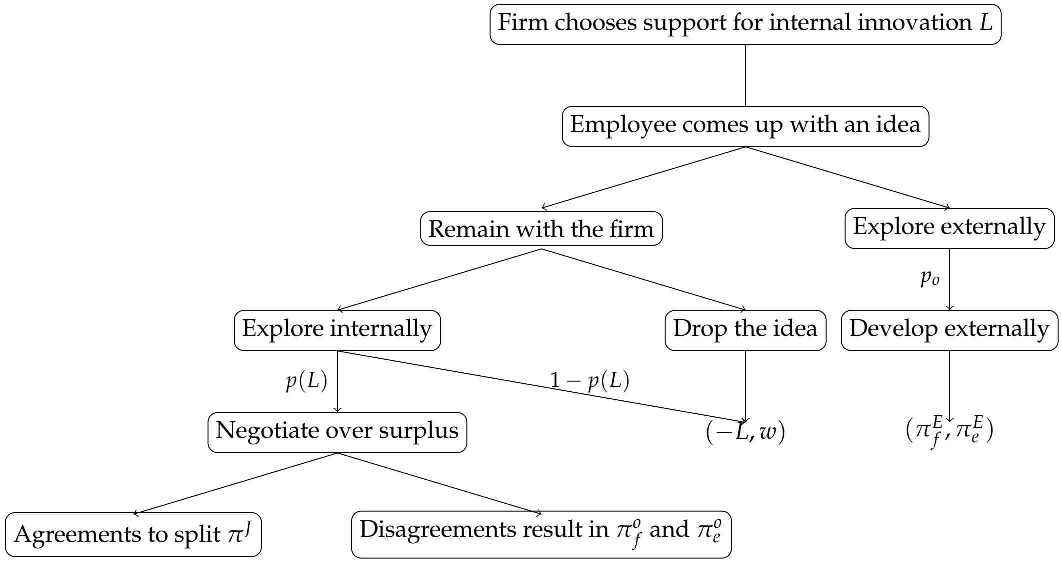


Figure 1: Timing of the game.

stage transforms a prototype into a marketable product. In either stage, the employee may choose to leave the firm to independently pursue the innovation.

The timing of the game is illustrated in Figure 1. At the onset, the firm chooses its level of exploration support L. Upon coming up with an idea for an innovation, the employee can choose to (1) remain within the firm (denoted by R) and explore internally or drop the idea and work on his core task for the wage w; or (2) explore his idea externally (denoted by E).[9]

Successful external exploration results in a prototype with market profitability v_i. The extent to which the employee appropriates this value externally depends on his privately known type, β, which reflects the subsequent share of start-up proceeds retained by the employee. We allow for high (β_H) and low (β_L) types, with $1 \geq \beta_H > \beta_L \geq 0$, and a prior $\Pr\{\beta = \beta_H\} = \theta \in (0, 1)$. Therefore, given an externality of level Δ, the respective expected payoffs for the employee and the firm from external exploration are $\pi_e^E(v_i, \beta) = p_o \beta v_i$ and $\pi_f^E(v_i, \Delta) = p_o \Delta \mathbf{1}(v_i =$

[9] It is possible that the firm's support can also provide the employee with benefits that can be used by non-innovating employees. For instance, the employee may use "Innovation Time Off" support for leisure purposes. Our model can be easily extended to incorporate such additional benefits of the firm's support. However, since an increase in the base wage would have the same impact in our model, we focus only on the type of exploration support that affects the incentives for internal exploration.

v), where $\mathbf{1}(\cdot)$ denotes the indicator function.

Successful *internal* exploration reveals the characteristics of an idea, (v_i, Δ), to the firm and allows it to gain some control over its intellectual property.[10] Consequently, the firm and the employee negotiate over the division of potential proceeds from the development stage. The outcome of this negotiation depends both on the surplus from joint development and on the two parties' outside options.

The surplus from joint development is denoted by $\pi^J(v_i, \Delta) = \max\{g\Delta + v_i, 0\}$, where the parameter g captures any efficiencies from joint development (with $g_s < 1$ for substitutes and $g_c > 1$ for complements) resulting from the efficient management of the externality Δ. Such synergies may be due to reduced competitive pressure or superior technological and commercialization ability of the firm to better position the new product with the firm's existing offerings. [11] Thus, internal development results in the highest surplus.

The disagreement payoffs of the employee and the firm in the development stage are given by $\pi_e^o(v_i, \beta) = \beta\alpha_e v_i$ and $\pi_f^o(v_i, \Delta) = (\alpha_f v_i + \Delta)\mathbf{1}(v_i = v) + \max\{0, \Delta\}\mathbf{1}(v_i = 0)$. The parameters α_e and α_f, which denote respective resultant market shares for the employee and the firm, are assumed to be common knowledge. To incorporate the profit-eroding effects of possible competition or property-rights disputes between the firm and the employee, we assume $\alpha_e + \alpha_f \leq 1$. For low-profitability ideas, we have $\pi_e^o(v_i = 0, \beta) < w$. Henceforth, we assume that for high-profitability ideas, $\pi_e^o(v_i = v, \beta) \geq w$ holds, making external development a credible outside option for the employee.

Disagreements over the joint development of an innovation may arise in equilibrium due to the unobservability of the employee's type. The negotiation stage is modeled as a random-proposer bargaining game, with γ denoting the probability that the firm makes a take-it-or-leave-it offer. The parameter γ captures factors that would interact with the firm's relative bargaining position, such as corporate policies the firm has put in place for tracking the exploration of new ideas and defending its intellectual property, contractual policies for allocating proceeds from

[10]Internal exploration may allow the firm to gain access to the know-how from the exploration stage and establish an intellectual property claim over the idea.

[11]For explicit treatment of externality management through integration see Economides and Salop (1992). A defining feature of integration is the integrated firm's internalization of externalities when making output decisions. This results in reducing the negative externality stemming from substitutes and enhancing the positive externality stemming from complements. We capture this effect in a reduced form though the parameter g.

innovations, and factors pertaining to the firm's organizational structure (for instance, hierarchical vs. flat).

Remarks: The absence of exploration-contingent contracts in our model is consistent with common corporate policies, such as Innovation-Time-Off, and reflects the difficulty of structuring and enforcing contingent contracts as they pertain to innovation. We focus on unconditional corporate exploration support as a primary mechanism affecting employees' exploration choice. While other mechanisms, such as varying the wage compensation for the core task, may also serve as an instrument to impact employees' exploration choices, extending the model in this dimension brings no added qualitative benefits.[12] The assumption of a common belief about the likelihood of the researcher's exploration success, coupled with an informational advantage by the researcher pertaining to his type, can be explained with the different set of skills required for successful research and commercialization. While the employee's research skills may be revealed in the course of his employment, his ability to successfully manage an external venture may be more difficult to observe.[13] Our approach to modeling the effect of the employee's type on his outside option is consistent with a well-functioning market, where successfully prototyped valuable ideas realize their market value — but the extent to which the researcher appropriates this value is affected by his type (e.g., entrepreneurial ability and/or accessibility to human capital via, for example, the employee's "network," and accessibility to financing). For instance, a researcher with costlier access to financing may be inclined to surrender a larger equity stake to a venture capitalist; similarly, a researcher who lacks entrepreneurial skills may need to partner with additional co-founders, increasing dilution.

[12] A higher base wage for the employee can reduce both external exploration and development by the employee and has similar a effect to a higher level of support. Allowing for both instruments would result in similar qualitative insights as long as high-value ideas and high-type employees are sufficiently scarce. This is because it would be too costly for the firm to fully prevent employee departure.

[13] Our model assumes that the value of the employee's idea and his type are independent. However, the model can easily account for correlation, as long as it is not perfect. The reason is that in such cases, there will be residual uncertainty regarding the employee's outside option, giving rise to disagreements that are analogous to our setting.

4 Equilibrium characterization

We solve for the Perfect-Bayesian equilibrium of the game. We begin by examining the negotiation subgame that follows the employee's decision to explore internally. We are specifically interested in the expected payoffs for the firm and the employee given internal exploration. Armed with these payoffs, we next determine how the level of exploration support L, the employee's type β, and the parameters of a newly conceived idea (v_i, Δ), interact with the employee's incentives for exploration. Then, by weighing in the costs and benefits of widening the spectrum of ideas that the firm attracts for internal exploration, we characterize the firm's optimal level of exploration support and derive comparative statics.

4.1 Internal Exploration: Negotiation Subgame

In the negotiation subgame, the firm and the employee bargain over the proceeds from joint development of the innovation. This stage determines the extent to which internally explored ideas are ultimately retained by the firm. We recall that following internal exploration, ideas are completely revealed to the firm; however, the employee is still privately informed about his type. Thus, disagreements may arise if the firm fails to sufficiently compensate high-ability employees. The firm's willingness to pay in order to retain an employee depends on the parameters of the idea, v_i and Δ, and on the firm's posterior belief regarding facing a high type — conditional on an internally explored idea. Let θ_I denote this posterior belief. We note that this belief may be different from the prior, given by θ, since the employee's choice of internal exploration may serve as a signal about his type. The following Proposition characterizes the type of ideas that may give rise to disagreements.

Proposition 1 *There exist cutoffs $\Delta_s^d(v_i, \theta_I)$ and $\Delta_c^d(v_i, \theta_I)$ such that disagreements occur if and only if $\beta = \beta_H$, $v_i = v$ and $\Delta \in (\Delta_s^d(v, \theta_I), \Delta_c^d(v, \theta_I))$. Furthermore, $\Delta_s^d(v, \theta_I)$ ($\Delta_c^d(v, \theta_I)$) is increasing (decreasing) in θ_I and $\Delta_s^d(v, \theta_I) = \Delta_c^d(v, \theta_I) = 0$ for $\theta_I \geq \frac{(\beta_H - \beta_L)\alpha_e}{1-\alpha_f-\beta_L\alpha_e} \in (0, 1)$.*

Proposition 1 states that the firm may fail to reach an agreement with a high-type employee over ideas characterized by high market values and weak relationships to the firm's existing offerings. In such cases, the probability of a disagreement is given by $\gamma\theta_I$; that is, negotiations will break down over some ideas (a fraction $\gamma\theta_I$) that fall into this group.

To glean some insight into this result, let us consider the case of complementary ideas. A weakly complementary idea has little interaction with the firm's existing profits. Consequently, the firm makes a low compensation offer of $\beta_L\alpha_e v$ to the researcher, which is subsequently rejected if the researcher is a high type. As the externality of the idea strengthens, the firm has more to lose from failing to reach an agreement and increases its offer to $\beta_H\alpha_e v$, which in turn is accepted by both high and low employee types. Furthermore, the disagreement region for complementary ideas, $[0, \Delta_c^d(v, \theta_I)]$, shrinks in the firm's posterior θ_I. That is, as it becomes more likely for the employee to be a high type, the firm's expected payoff from making a low compensation offer decreases; in turn, the firm is induced to increase its offer over a wider range of complementary ideas, thereby reducing disagreements.

The intuition for substitute ideas is analogous. In this case, the firm is concerned about losing ideas that would result in substantial profit erosion when developed externally. Consequently, the firm makes high compensation offers whenever faced with ideas that exhibit large negative externalities. As the likelihood of facing a high type increases, the firm in turn increases its offer over a wider range of substitute ideas.

Proposition 1 further notes that there exists a cutoff value for the firm's posterior belief, θ_I, specified by $\frac{(\beta_H - \beta_L)\alpha_e}{1-\alpha_f - \beta_L\alpha_e} < 1$, above which no ideas are lost in the downstream. In other words, despite incomplete information about the employee's type, disagreements are avoided entirely when the firm puts sufficient weight on facing a high-type employee.

Armed with the equilibrium characterization of the negotiation subgame, we can derive the employee's and the firm's expected payoffs — both of which are important determinants of the incentives for internal exploration and the level of support offered by the firm. The following Corollary characterizes the interaction between these payoffs and the degree of externality imposed by an innovation, Δ.

Corollary 1 *Let $\pi_f^N(v_i, \Delta, \theta_I)$ and $\pi_e^N(v_i, \Delta, \beta, \theta_I)$ denote the firm's and the employee's ex-ante expected continuation payoffs in the negotiation subgame.*

1. *If $\Delta > 0$, then $\frac{d\pi_f^N(v_i,\Delta,\theta_I)}{d\Delta} > 0$ and $\frac{d\pi_e^N(v_i,\Delta,\beta,\theta_I)}{d\Delta} \geq 0$ with strict inequality for*

$$\Delta > \hat{\Delta}(v_i) = \begin{cases} 0 & \textit{for} \quad v_i = v \\ \frac{w}{g_c - 1} & \textit{for} \quad v_i = 0 \end{cases}$$

2. *If* $\Delta < 0$*, then:*

   a) $\pi_f^N(0, \Delta, \theta_I) = \pi_e^N(0, \Delta, \beta, \theta_I) = 0$, *and*

   b) $\frac{d\pi_f^N(v,\Delta,\theta_I)}{d\Delta} > 0$*, while* $\frac{d\pi_e^N(v,\Delta,\beta,\theta_I)}{d\Delta} < 0$.

Henceforth, it will be useful to define the *bargaining surplus* from an idea as the additional surplus gained from joint development relative to independent pursuits by the (now former) employee and the firm. That is, the bargaining surplus is given by $\pi^J - \pi_f^o - \pi_e^o$.

We observe that a consequence of Corollary 1 is that the employee and the firm both benefit from an idea being a stronger complement. As the magnitude of the externality of an idea rises, the bargaining surplus and the firm's outside option π_f^o both increase, leading to an overall increase in both the firm's and the employee's expected continuation payoffs.

For substitute ideas, the employee benefits from having the outside option of pursuing an idea with a stronger negative externality, since the firm then has a greater incentive to retain the innovation. If the idea has a low market profitability, the employee no longer possesses the credible threat of independently pursuing the idea, whereby the bargaining surplus is 0. In contrast, for high-profit ideas, external development is feasible and the bargaining surplus shrinks as Δ increases (that is, as the externality of a substitute idea weakens), since a weaker substitute idea constitutes less of a threat to the firm's existing profit. Consequently, for substitute ideas, the firm's (employee's) expected payoff from the negotiation subgame is increasing (decreasing) in Δ.

To summarize, Corollary 1 highlights the observation that the employee benefits from ideas that impose stronger externalities on the firm. In turn, the employee requires weaker incentives to choose to explore such ideas within the firm — an observation that will be key in characterizing the employee's exploration strategy.

4.2 Optimal Exploration Strategy

Upon coming up with an idea, the employee considers the level of support offered by the firm and chooses whether to explore the idea externally (E) or remain with the firm (R). Recall that external exploration results in $\pi_e^E(v_i, \beta) = p_o \beta v_i$. Internally, the employee can either drop the idea (D), resulting in a payoff of $\pi_e^D(L) = w$, or explore the idea internally (I), giving rise to a payoff $\pi_e^I(v_i, \Delta, \beta, \theta_I, L) = p(L)(\pi_e^N(v_i, \Delta, \beta, \theta_I) - w) + w$. The employee chooses the exploration strategy that maximizes his expected payoff. Thus, he will choose to remain with the firm when

$$\max\{\pi_e^D(L), \pi_e^I(v_i, \Delta, \beta, \theta_I, L)\} \geq \pi_e^E(v_i, \beta) \tag{1}$$

We assume that the employee breaks indifferences in favor of exploring internally over externally and in favor of dropping the idea over exploring.[14]

Consider first the case of low-profit ideas; that is, $v_i = 0$. We observe that the employee would not choose to pursue low-profit ideas externally since $\pi_e^E(0, \beta) = 0$; thus the employee either chooses to drop such ideas (D) or to explore them internally (I). Internal exploration occurs only if $\pi_e^I(v_i, \Delta, \beta, \theta_I, L) > \pi_e^D(L)$. From the employee's payoffs specified above, this implies that $\pi_e^N(0, \Delta, \theta_I) > w$ and requires the idea to be complementary. Corollary 1 shows that $\pi_e^N(0, \Delta, \theta_I)$ is increasing in the degree of complementarity. Thus, for ideas with $v_i = 0$, the employee would only consider internal exploration if the ideas are sufficiently complementary, and would drop them otherwise.

Proposition 2 *Let $v_i = 0$. Then, both employee types choose to ignore an idea if $\Delta \leq \frac{w}{g_c - 1}$ and explore internally otherwise.*

In contrast, high-profit ideas are always profitable to explore because of our assumption that $\pi_e^o(v, \beta) > w$. Thus, internal exploration occurs if $\pi_e^I(v, \Delta, \beta, \theta_I, L) \geq \pi_e^E(v, \beta)$. From Corollary 1, the employee's continuation payoff, $\pi_e^I(v, \Delta, \beta, \theta_I, L)$, is strictly increasing in the magnitude of the externality, Δ. Thus, if $\pi_e^I(v, 0, \beta, \theta_I, L) \geq \pi_e^E(v, \beta)$, then all ideas will be explored internally. Otherwise, let $\tilde{\Delta}_j(L, v, \beta, \theta_I)$ denote the solution of

$$\pi_e^I(v, \tilde{\Delta}_j, \beta, \theta_I, L) = \pi_e^E(v, \beta) \; for \; j = \{s, c\} \tag{2}$$

Because of the strict monotonicity of $\pi_e^I(v, \Delta, \beta, \theta_I, L)$ in Δ for both complements and substitutes, there exists a unique $\tilde{\Delta}_j(L, v, \beta, \theta_I)$ for each $j = \{s, c\}$.

[14] Such a tie breaking rule is efficient whenever exploration is associated with a non-negligible cost. For technical simplicity and because the qualitative nature of the results is unchanged, we abstract from incorporating costly exploration.

Moreover, the employee prefers internal exploration for ideas with an externality stronger than $\tilde{\Delta}_j(L, v, \beta, \theta_I)$ and prefers external exploration otherwise. The following Proposition formalizes this observation and describes how the firm's level of support, L, the employee's type, β, and the firm's posterior, θ_I, interact with the employee's exploration strategy.

Proposition 3 *Let $v_i = v$. There exist cutoffs $\Delta_s^I(L, v, \beta, \theta_I)$ and $\Delta_c^I(L, v, \beta, \theta_I)$ such that the employee explores internally if $\Delta \notin (\Delta_s^I(L, v, \beta, \theta_I), \Delta_c^I(L, v, \beta, \theta_I))$ and explores externally otherwise. These cutoffs have the following properties:*

(1) $\frac{\partial \Delta_s^I(L,v,\beta,\theta_I)}{\partial L} > 0$ *for* $\Delta_s^I(L, v, \beta, \theta_I) < 0$.

(2) $\frac{\partial \Delta_c^I(L,v,\beta,\theta_I)}{\partial L} < 0$ *for* $\Delta_c^I(L, v, \beta, \theta_I) > 0$.

(3) $\Delta_s^I(L, v, \beta_H)$ *and* $\Delta_c^I(L, v, \beta_H)$ *are independent of* θ_I.

(4) $\Delta_s^I(L, v, \beta_L, \theta_I)$ *is non-decreasing in* θ_I *and* $\Delta_c^I(L, v, \beta_L, \theta_I)$ *is non-increasing in* θ_I.

(5) $\Delta_s^I(L, v, \beta_H) \leq \Delta_s^I(L, v, \beta_L, \theta_I)$ *with strict inequality for* $\Delta_s^I(L, v, \beta_H) < 0$.

(6) $\Delta_c^I(L, v, \beta_H) \geq \Delta_c^I(L, v, \beta_L, \theta_I)$ *with strict inequality for* $\Delta_c^I(L, v, \beta_H) > 0$.

Proposition 3 states that the employee chooses internal exploration of high-profit ideas that are sufficiently close to the firm's existing offerings. Properties (1) and (2) reveal the impact of increased exploration support on employee's choice of an exploration venue. As expected, a higher support for exploration by the firm has a positive effect on the employee's incentive to choose internal exploration. Thus, by increasing its support, the firm is able to attract a wider range of ideas inside the firm.

Properties (3) and (4) reveal how the employee's exploration incentives are impacted by the firm's posterior. Notice that a high-type employee's outside option serves as an upper bound on the firm's offer in the negotiation stage. Thus, the high type's payoff is not impacted by the firm's belief θ_I. In contrast, a low-type employee may benefit from a higher posterior, since the firm may increase its offer in the downstream above the low type's outside option. As a result, for higher posteriors, a low-type employee would be more likely to bring ideas in-house.

Properties (5) and (6) reveal that for any given idea, a high-type employee is less willing to pursue internal exploration due to his higher outside option. In turn, the firm needs to provide higher-powered incentives to attract internal exploration by high types.

Internal exploration may also provide an opportunity for the firm to update its prior belief regarding the employee's type. This occurs for ideas exhibiting relatively weak externalities since then the exploration strategies by the two types diverge. The following result characterizes the unique equilibrium exploration strategies by the two employee types and the corresponding equilibrium posterior.

Proposition 4 *Let $v_i = v$. Then, for a given level of support L:*

1) If $\Delta \notin (\Delta_s^I(L, v, \beta_H), \Delta_c^I(L, v, \beta_H))$, then both employee types explore internally and $\theta_I^* = \theta$ is the unique equilibrium belief.

2) If $\Delta \in (\Delta_s^I(L, v, \beta_H), \Delta_s^I(L, v, \beta_L, 0)]$ or $\Delta \in [\Delta_c^I(L, v, \beta_L, 0), \Delta_c^I(L, v, \beta_H))$, a high-type employee explores externally while a low type explores internally and $\theta_I^* = 0$ is the unique equilibrium belief.

3) If $\Delta \in (\Delta_s^I(L, v, \beta_L, 0), \Delta_c^I(L, v, \beta_L, 0))$, then both employee types explore externally and the equilibrium is supported by $\theta_I^* = 0$.

It follows from Proposition 4 that strongly complementary and substitute ideas are explored internally by both employee types; consequently, for ideas in this parameter range, no new information about the employee's type is conveyed to the firm, whereby $\theta_I = \theta$. Since a low type is more inclined to explore ideas internally, ideas with intermediate level of externalities would only be explored internally by low-type employees, whereby their type is revealed to the firm. In contrast, ideas that are weakly related to the firm's existing offerings are explored externally by both employee types. For ideas in this parameter range, an off-equilibrium belief $\theta_I^* = 0$ ensures no deviation by the low type.

Combining the findings from Propositions 1-4, the model gives rise to the predictions that employees who leave their employment to form start-ups pursue high-profit ideas that are likely to be weakly related to their firm's existing offerings. Moreover, an employee may end up leaving his firm either at the initial exploration stage or prior to the downstream development stage.

The next subsection examines how the firm's level of exploration support interacts with the likelihood and timing of an employee's potential pursuit of a start-up.

4.3 Timing of the Researcher's Departure

The firm's chosen level of exploration support has a direct impact on the employee's choice of an exploration venue, where a higher level of support leads to an increase in exploration activity within the firm. However, as pointed out by Proposition 1, not all internally explored ideas are subsequently retained within the firm. Building on this result, the following finding indicates that increasing the level of support indeed results in the internal exploration of a wider range of ideas. However, doing so may also lead to a higher rate of disagreements in the downstream, as it becomes increasingly difficult for the firm to distinguish between high- and low-type employees.

Proposition 5 *The likelihood of internal exploration is (weakly) increasing in L. For* $\theta \geq \frac{(\beta_H - \beta_L)\alpha_e}{1-\alpha_f - \beta_L \alpha_e}$*, no downstream disagreements occur. For* $\theta < \frac{(\beta_H - \beta_L)\alpha_e}{1-\alpha_f - \beta_L \alpha_e}$*, there exists a cutoff* $\tilde{L} \geq 0$*, such that for* $L > \tilde{L}$*, the likelihood of downstream disagreements is increasing in L.*

An increase in the level of support, L, makes internal exploration more attractive for both employee types. Thus, the cutoff $\Delta_s^I(L, v, \beta, \theta_I^*)$ is increasing in L and the cutoff $\Delta_c^I(L, v, \beta, \theta_I^*)$ is decreasing in L, reducing the range of ideas explored outside the firm. The likelihood of downstream disagreement depends on the firm's ability to distinguish between the employee's types.

Proposition 5 states that if a high-type employee is sufficiently likely (that is, $\theta \geq \frac{(\beta_H - \beta_L)\alpha_e}{1-\alpha_f - \beta_L \alpha_e}$), then identifying the employee's type is not an issue, since the firm always finds it optimal to make a generous offer in the downstream. However, for $\theta < \frac{(\beta_H - \beta_L)\alpha_e}{1-\alpha_f - \beta_L \alpha_e}$, the firm may choose to make a low price offer if the idea is weakly related to its existing offerings.

Recall that disagreements can only occur for high-profit ideas. Given low levels of support, a high-type employee leaves the firm at the exploration stage, whereby the firm is able to perfectly screen out the employee's type over a wide range of ideas exhibiting weak externalities, $\Delta \in (\Delta_s^I(L, v, \beta_H), \Delta_c^I(L, v, \beta_H))$. However, as the level of support increases, internal exploration becomes more attractive to the high types. As a result, disagreements occur for moderate complements and substitutes; that is, in cases where $\Delta \in (\Delta_s^d(v, \theta), \Delta_s^I(L, v, \beta_H))$ and where $\Delta \in (\Delta_c^I(L, v, \beta_H), \Delta_c^d(v, \theta))$. Disagreements occur because the low likelihood of a high type and the moderate externality of these ideas make it optimal for the firm to make low offers in the negotiation subgame.

From the above, it follows that the firm may never be able to implement an exploration-support strategy that completely eliminates departures by its employees. All else being equal, our findings predict that firms with higher levels of exploration support will experience more exploration activity within the firm, but will also be more susceptible to losing innovations in their development stage as a result of disagreements over surplus division. As previously mentioned, this empirical prediction is consistent with anecdotal evidence from highly innovative firms that are known both for their generous exploration support policies — and for a relatively large number of employee departures to pursue new ventures.

4.4 Optimal Support for Exploration

Having identified the characteristics of ideas explored and/or developed inside and outside of the firm, and the corresponding timing of an employee's departure, we now turn our focus to the firm's choice of exploration support. At the time of choosing its support, the firm has incomplete information about the characteristics of the ideas that are likely to emerge. Hence, the firm's decision is based on its prior beliefs about the likely characteristics of new ideas and about the distribution of employee types.

Our focus in this subsection is to examine policy variables that could impact the firm's willingness to offer support. Among the policy variables of interest are the firm's relative bargaining position vis-à-vis employees, captured by γ, and the parameters α_f and α_e, capturing relative market strengths and development capabilities for the firm and employees respectively. These variables are impacted by a variety of legal and institutional factors and affect the outcomes of negotiations over internal handling of innovations. Some of these factors include the allocation of property rights as determined by local laws and by firm-specific legal frameworks and policies, the indispensability of the employee's expertise in the development process, and institutional structures that help determine the firm's and the employee's shares of the realized surplus.

Let $\pi_f^R(v_i, \Delta, \beta, L)$ denote the firm's downstream payoff following a β-type employee's decision to keep an idea with characteristics (v_i, Δ) inside the firm. If the employee explores the idea, then $\pi_f^R(v_i, \Delta, \beta, \theta_I^*, L) = p(L)\pi_f^N(v_i, \Delta, \beta, \theta_I^*)$, where $\pi_f^N(v_i, \Delta, \beta, \theta_I^*)$ denotes the firm's expected payoff from the negotiation subgame conditional on a β-type employee. If the employee instead chooses to ignore the idea, then $\pi_f^R(v_i, \Delta, \beta, L) = 0$. The firm's payoff from external exploration is given by $\pi_f^E(v_i, \Delta) = p_0 \Delta \mathbf{1}(v_i = v)$. We recall from Propositions 2 and 4 that the firm retains ideas with externality $\Delta \notin (\Delta_s^I(L, v_i, \beta, \theta_I^*), \Delta_c^I(L, v_i, \beta, \theta_I^*))$, where we have $\Delta_s^I(L, 0, \beta, \theta_I^*) = \Delta_c^I(L, 0, \beta, \theta_I^*) = 0$ for low-profit ideas (since they are always retained within the firm).

Let $S_f(v_i, \Delta, \beta, L) = \pi_f^R(v_i, \Delta, \beta, L) - \pi_f^E(v_i, \Delta)$ denote the firm's retention surplus. Then, the firm's expected profit from offering a level of support L at the outset of the game is given by

$$\Pi_f(L) =$$
$$E[S_f(v_i, \Delta, \beta, L) \,|\, \Delta \notin \Delta_s^I(L, v_i, \beta, \theta_I^*), \Delta_c^I(L, v_i, \beta, \theta_I^*)] + E[\pi_f^E(v, \Delta)] - L \quad (3)$$

Hence, the firm's expected payoff consists of the expected externality that an idea would impose on the firm, captured by $E[\pi_f^E(v, \Delta)]$, plus the additional surplus generated from retaining ideas with strong externalities within the firm. The impact of the level of support L on the firm's profit is given by

$$\begin{aligned} \frac{\partial \Pi_f(L)}{\partial L} &= E\left[\frac{\partial S_f(v_i, \Delta, \beta, L)}{\partial L}\bigg| \Delta \notin \left(\Delta_s^I, \Delta_c^I\right)\right] - 1 && (4) \\ &\quad + \psi E\left[S_f\left(v, \Delta_s^I, \beta, L\right) f\left(\Delta_s^I | v\right) \frac{\partial \Delta_s^I}{\partial L}\bigg| v\right] && (5) \\ &\quad - \psi E\left[S_f\left(v, \Delta_c^I, \beta, L\right) f\left(\Delta_c^I | v\right) \frac{\partial \Delta_c^I}{\partial L}\bigg| v\right] \end{aligned}$$

The level of support thus has a twofold effect on the firm's profit. The first term in equation (4) captures the *productivity effect* of L via its impact on the likelihood of successful exploration, $p(L)$. The last two terms capture the *retention effect* of L (that is, its effect on the employee's incentives) via its impact on the cutoffs $\Delta_s^I(L, v, \beta, \theta_I^*)$ and $\Delta_c^I(L, v, \beta, \theta_I^*)$. The retention effect is positive for substitutes (complements) as long as $\Delta_s^I(L, v, \beta, \theta_I^*) \in (\underline{\Delta}, 0)$ $(\Delta_c^I(L, v, \beta, \theta_I^*) \in (0, \overline{\Delta}))$.

In the remainder of this subsection, we make the following technical assumption on the retention effect.

Assumption 1: For $j = \{s, c\}$, $\frac{d[S_f(v, \Delta_j^I, \beta, L) f(\Delta_j^I | v)]}{dL} \leq 0$ and $\Delta_j^I(L, v, \beta, \theta_I^*) \neq 0$.[15]

[15] Assumption 1 is a sufficient and not a necessary condition for our analytical analysis in Subsection 4.4 and is made for analytical tractability. We do not impose this restriction on our proceeding numerical simulations.

Assumption 1 guarantees that whenever the retention effect is positive, it is diminishing in the firm's level of support. Since $\Delta_s^I(L, v, \beta, \theta_I^*)$ ($\Delta_c^I(L, v, \beta, \theta_I^*)$) is increasing (decreasing) in L, it is then straightforward to verify that there exists a finite range of L for which the retention effect is positive. The following Lemma formalizes this observation.

Lemma 1 *For every v_i and β, there exist $L_j^{\min}(v, \beta) \leq L_j^{\max}(v, \beta) \in [0, \infty)$ for $j = \{s, c\}$, such that $\frac{\partial \Delta_s^I(L, v, \beta, \theta_I^*)}{\partial L} > 0$ and $\frac{\partial \Delta_c^I(L, v, \beta, \theta_I^*)}{\partial L} < 0$ for $L \in [L_j^{\min}(v, \beta), L_j^{\max}(v, \beta))$ and zero otherwise, with the following properties:*

1. $L_j^{\min}(v, \beta_H) \geq L_j^{\min}(v, \beta_L) \geq 0$,
2. $L_j^{\max}(v, \beta_H) \geq L_j^{\max}(v, \beta_L) \geq 0$.

Lemma 1 states that the retention effect is non-monotonic in L. For low levels of support, $L < L_j^{\min}(v, \beta)$, the retention effect is zero, since the employee always chooses external exploration. For high levels, $L \geq L_j^{\min}(v, \beta)$, the firm successfully induces the internal exploration of all ideas, causing the retention effect to go down to zero again. Only for intermediate levels of support does the firm have an impact on the employee's exploration strategy. The discrete increase in the retention effect at $L_j^{\min}(v, \beta)$ generates a local convexity of the objective function, as the marginal benefit of L increases discretely at this point. Consequently, the objective function specified by equation (3) may exhibit multiple local maxima, as illustrated in the following example.

Example 1 *In the following example, $v = 40$, $\psi = 0.7$, $\underline{\Delta} = -80$, $\overline{\Delta} = 40$, $\lambda_0 = 0.2$ and $\lambda_v = 0.5$. The employee's type is captured by $\beta_L = 0.1$, $\beta_H = 0.7$, and $\theta = 0.7$. The probability of a successful exploration outside the firm is $p_o = 1 - e^{-0.4}$. The effect of L on the employee is captured by $p(L) = 0.1\left(1 - e^{-0.1L-0.4}\right)$ and the employee's base pay is $w = 0.3$. Efficiencies from joint-development are captured by $g_c = 1.1$ (complements) and $g_s = .9$ (substitutes). The relative bargaining positions are given by $\gamma = 0.4$, $\alpha_f = 0.5$, and $\alpha_e = 0.4$, with $L_c^{min}(v, \beta_L) = L_s^{min}(v, \beta_L) = L_s^{min}(v, \beta_H) = 0$ and $L_c^{min}(v, \beta_H) \approx 2$. Figure 2 plots $\Pi_f(L)$. Note that the objective function exhibits local convexity at $L_c^{min}(v, \beta_H)$. There are two local maxima at $L_1 = 0$ and $L_2 = 3.5$ corresponding to only substitute ideas being attracted from the high type and both types of ideas being attracted from the high type with positive probability. The global maximum is at $L^* = L_2$.*

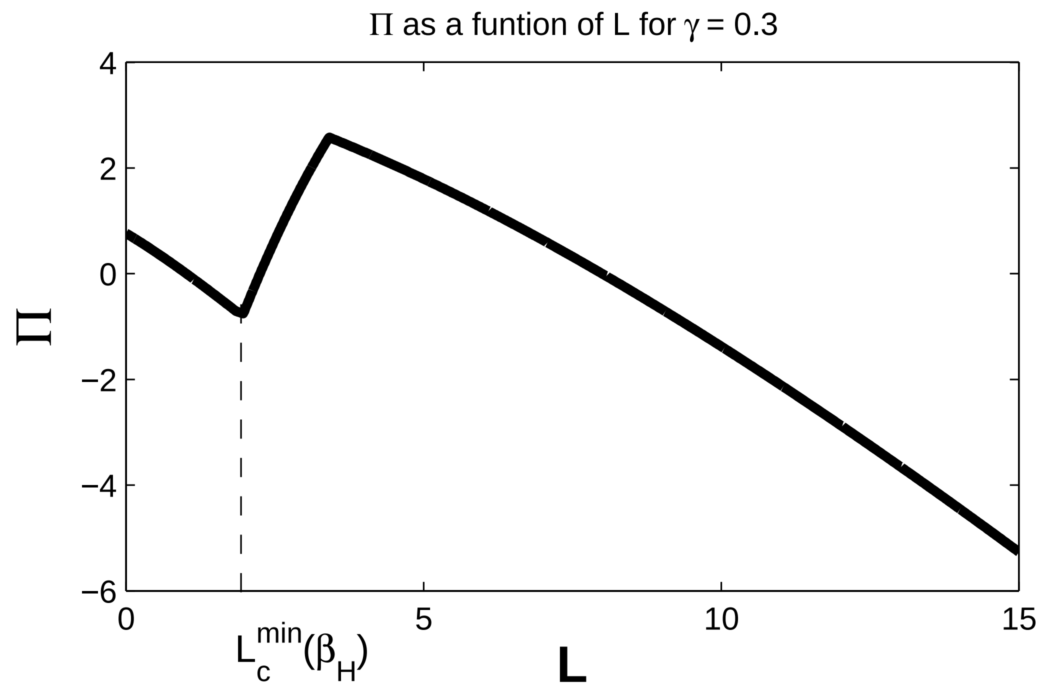


Figure 2: Firm's ex-ante expected profit as a function of the level of support.

The presence of convex regions in the objective function $\Pi_f(L)$ complicates our analysis. It gives rise to the possibility of multiple local maxima and a global maximum that switches from one local maximum to another, as illustrated by Example 3 at the end of this section. We focus our theoretical analysis on the case where the local maximum for the region $L \geq \max\{L_s^{\min}(v, \beta_H), L_c^{\min}(v, \beta_H)\}$ is also the global maximum. A level of support exceeding this cutoff involves internal exploration of both complementary and substitute ideas by both employee types with positive probabilities.[16] Thus, we focus on the case in which it is optimal for the firm to attract both employee types with complementary as well as competing ideas. This assumption is relaxed in Example 3.

Given $L^* \geq \max\{L_s^{\min}(v, \beta_H), L_c^{\min}(v, \beta_H)\}$, we are interested in the effect of changes in the relative bargaining power of the firm, γ, and in the firm's and em-

[16]Our focus on the region $L^* \geq \max\{L_s^{\min}(v, \beta_H), L_c^{\min}(v, \beta_H)\}$ is for expositional ease. Our analysis readily extends to the more general case where the global maximum does not switch from one local maximum to another. In the context of our model, this implies that if the firm finds it optimal to attract an employee of certain type with positive probability, changing the parameter values would not drive this probability down to 0.

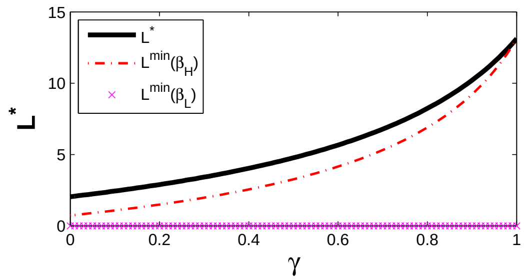
ployee's independent development capabilities, α_f and α_e. The following Proposition characterizes these comparative statics.

Proposition 6 *Let $L^*(\gamma, \alpha_f, \alpha_e) \geq \max\{L_s^{\min}(v, \beta_H), L_c^{\min}(v, \beta_H)\}$. Then, the firm's optimal level of support for exploration is increasing in γ and α_f and decreasing in α_e.*

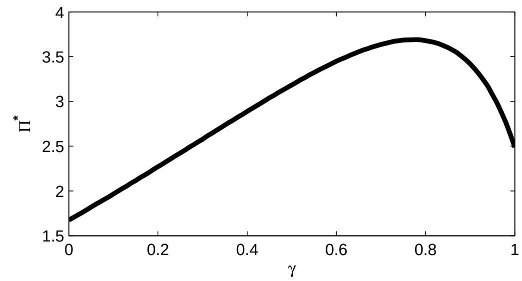
An improvement in the firm's outside option in the negotiation subgame, either through an increase γ or α_f, has two effects. First, it increases the firm's surplus from internally explored ideas, which induces the firm to increase its support. Second, it diminishes the employee's willingness to explore ideas within the firm due to a reduction in his expected downstream payoff — a negative retention effect. To mitigate the employee's reduced incentive to explore internally, the firm further increases its level of support. In contrast, an improvement in the outside option of the employee, through an increase in α_e, decreases both the firm's surplus from internal exploration, as well as the employee's incentive to explore externally, whereby the firm reduces its support.

In addition to examining how the above policy and market parameters impact the level of support offered by the firm, we are also interested in their impact on the firm's profitability, particularly since some of their variability may be directly linked to the firm's organizational structure and policies. For instance, closely monitoring an employee's exploration efforts can reduce the cost of replicating emerging ideas, thereby increasing γ and α_f and strengthening the firm's position in negotiations. Similarly, a more hierarchical organizational structure can strengthen the firm's relative bargaining power, while a flatter structure can provide employees with more autonomy.

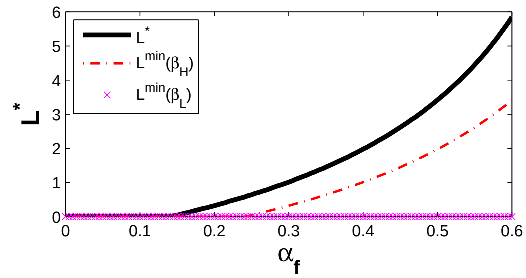
Note that in absence of a retention effect, the firm's profit is always increasing as its downstream bargaining position improves, since an increase in γ, α_f, and/or a decrease in α_e all increase the firm's surplus for every level of support L. However, strengthening the firm's bargaining position also has an indirect effect on the ability of the firm to retain ideas in-house. In particular, all else being equal, higher γ and α_f reduce the employee's incentive for internal exploration and widen the region of ideas that will be taken outside the firm, $(\Delta_s^I(L, v, \beta, \theta_I^*), \Delta_c^I(L, v, \beta, \theta_I^*))$. Consequently, it becomes increasingly costly for the firm to provide sufficient retention incentives for the employee. Thus, the retention effect tends to reduce the firm's profit. Interestingly, the negative impact of the retention effect on the firm's profit may dominate, as the following example illustrates.



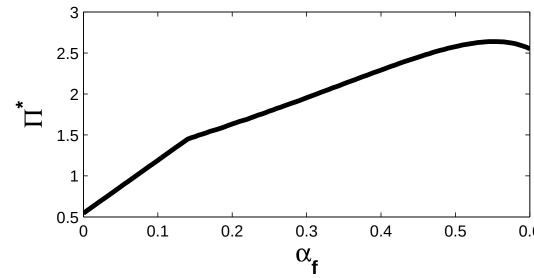
(a) Optimal support as a function of γ



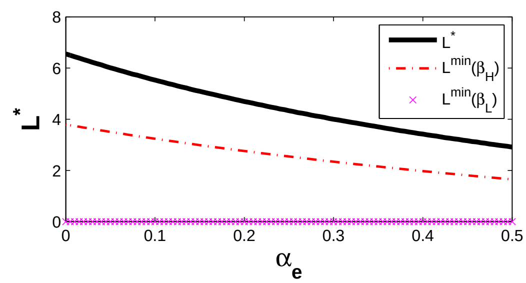
(b) Expected profit as a function of γ



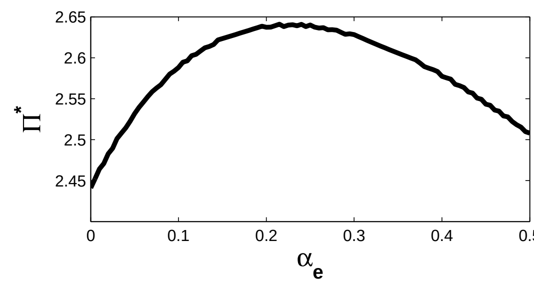
(c) Optimal support as a function of α_f



(d) Expected profit as a function of α_f



(e) Optimal support as a function of α_e



(f) Expected profit as a function of α_e

Figure 3: Firm's optimal support and expected profit as functions of γ, α_f, and α_e.

Example 2 *Consider the parameter values specified in Example 1. Let* $L^{\min}(\beta) = \max\{L_s^{\min}(v,\beta), L_c^{\min}(v,\beta)\}$*. Figure 3 illustrates the effect of increasing* γ *,* α_f *and* α_e *on the optimal level of support and on the firm's profitability for the case in which both types are attracted with positive probability for both complementary and substitute ideas, i.e.* $L^*(\gamma,\alpha_f,\alpha_e) \geq L^{\min}(\beta)$ *for all* β*. In this case,* $L^*(\gamma,\alpha_f,\alpha_e)$ *is continuously increasing in* γ *and* α_f *and continuously decreasing in* α_e*, but the firm's optimal profit is non-monotonic in these variables.*

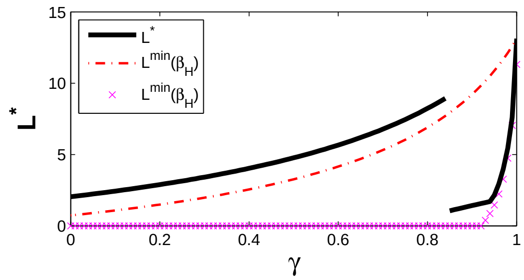
Example 2 illustrates that a firm may wish to willingly surrender some of its control over employees' innovations in order to retain ideas in-house. This finding can help explain why certain innovation-focused institutions, such as academia, have adopted a flat organizational structure, giving employees significant autonomy and control over their ideas.

It is also important to point out that while a weaker bargaining position vis-à-vis the employee may be ex-ante optimal for the firm, it is not ex-post incentive compatible. In the absence of credible commitment mechanisms, a firm would have incentives to improve its bargaining position once it gains access to innovations. This observation highlights the importance of well-specified and enforceable mechanisms, such as a well functioning legal system to govern the allocation of property rights and market competition. It further suggests that laws strengthening firms' claims over ideas emerging from their employees might actually hurt profitability by making it more difficult to induce internal exploration.

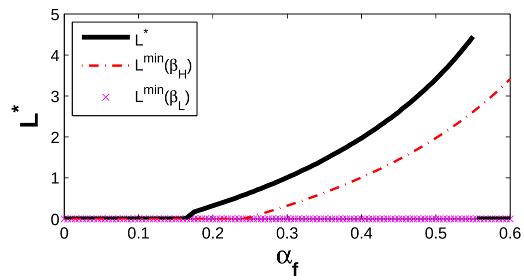
In the remainder of this subsection, we briefly examine the possibility that the firm may choose *not* to attract internal exploration of some ideas by high-type employees. The following example modifies Example 2 by reducing the prior likelihood that an employee is a high type. This makes it less profitable to incentivize internal exploration by high types, which can cause the firm to discontinuously reduce its level of support for high values of γ and α_f.

Example 3 *The parameter values are the same as in Example 2, except $\theta = 0.3$. Figures 4(a) and 4(b) plot the optimal level of support L^* as γ and α_f vary. As the figures illustrate, $L^*(\gamma, \alpha_f, \alpha_e) \geq L^{\min}(\beta_H)$ does not hold for very high values of γ and/or α_f. Instead, the firm chooses to reduce its level of support below the threshold required to attract complementary ideas by high types.*

Example 3 illustrates that for high values of γ and α_f, the optimal level of support exhibits a downward jump. This jump is due to the fact that it becomes increasingly costly to induce internal exploration of complementary ideas by high-type employees. Thus, the global maximum switches from the local maximum that retains both complementary and substitute ideas by high-type employees (with positive probability) to the local maximum under which only substitute ideas by high-type employees are possibly retained. As mentioned previously, low-type employees always choose to remain with the firm. This example illustrates that while the level of exploration support is locally increasing in the firm's bargaining position, there may exist a point at which it becomes too costly for the firm to induce high-type employees to explore internally. Consequently, the firm "gives up" on bringing in some of their ideas and discontinuously reduces its level of support.



(a) Optimal support as a function of γ



(b) Optimal support as a function of α_f

Figure 4: The firm's chosen level of support as functions of γ and α_f.

5 Conclusions

We show that employees who leave their employment to pursue new ventures tend to develop products that are weakly related to their former employers' lines of business. While increasing the level of support for innovation can induce the internal exploration of a wider range of ideas, we find that such policies may also increase employee turnover in downstream development stages. Hence, consistent with anecdotal evidence, our findings suggest that firms with generous policies for supporting innovation are also likely to have a significant number of employees leaving to form new ventures.

When choosing its optimal level of support, the firm in our model balances the benefits of inducing higher levels of exploration in-house with the cost of supporting this exploration activity. We showed that as the firm's relative bargaining position vis-à-vis an employee strengthens, its chosen level of support is likely to increase, but its ex-ante expected profits may decrease. This suggests that the firm is likely to favor policies that enable employees to retain some control over their internally explored ideas. Policies of this sort can include a flatter organizational structure and a balanced allocation of property rights between the firm and its employees.

Future work can incorporate a mechanism-design framework, where the firm is able to structure roles for employees in order to make the discovery of certain innovations more likely (e.g., innovations that are more complementary to the firm's existing line of products). Another direction is to consider the firm's incentives for committing ex ante to a development strategy in order to affect the employee's exploration choice. One may also consider a competitive landscape where outside investors, as well as other firms, are competing for attracting new ideas and their development by the firm's employees, and a framework where employees choose a subset of ideas to pursue from a larger set of ideas.

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Appendix

Proof of Proposition 1. We consider the case of $v_i = 0$ and $v_i = v$ separately.

1. Let $v_i = 0$. Then, the employee's outside option is common knowledge and equal to $\pi_e^E = 0$. Thus, disagreements do not arise in equilibrium and the efficient outcome is implemented. Joint development of the idea is efficient if and only if $\pi^J = \max\{g\Delta, 0\} \geq \max\{\Delta, 0\} + w = \pi_f^o + w$ or $\Delta > \frac{w}{g_c - 1} > 0$. In this case, if negotiations favor the firm, then it makes an offer of w. Otherwise, if negotiations favor the employee, then he makes an offer of π_f^o. For $\Delta \in \left(0, \frac{w}{g_c-1}\right]$, the efficient outcome is for the firm to develop independently and for the employee to focus on the core task resulting in Δ for the firm and w for the employee. For $\Delta \leq 0$, the efficient outcome is shelving resulting in payoffs of 0 for the firm and w for the employee.

2. Next, we consider the case of $v_i = v$. The employee makes a take-it-or-leave-it offer of π_f^o with probability $(1 - \gamma)$, which is subsequently accepted by the firm. If, instead, negotiations favor the firm, occurring with probability γ, the firm has two options:

i) Offer $\beta_H \alpha_e v$, which is accepted with probability 1, resulting in an expected payoff of $\pi^J - \beta_H \alpha_e v$ for the firm; or ii) Offer $\beta_L \alpha_e v$, which is accepted with probability θ_I, resulting in an expected payoff of $(1 - \theta_I)(\pi^J - \beta_L \alpha_e v) + \theta_I \pi_f^o$ for the firm. It is optimal for the firm to offer $\beta_H \alpha_e v$ if and only if its expected payoff from doing so exceeds its expected payoff from offering $\beta_L \alpha_e v$. That is,

$$\pi^J \geq \pi_f^o + \beta_L \alpha_e v + \frac{(\beta_H - \beta_L)\,\alpha_e v}{\theta_I} \tag{A-1}$$

For $\Delta \geq 0$, it is straightforward to check that the above inequality is satisfied if and only if $\Delta \geq \frac{\theta_I(\alpha_f + \beta_L \alpha_e - 1) + (\beta_H - \beta_L)\alpha_e}{\theta_I(g_c - 1)} v$. Then, we can define $\Delta_c^d(v, \theta_I) \equiv \max\left\{\frac{\theta_I(\alpha_f + \beta_L \alpha_e - 1) + (\beta_H - \beta_L)\alpha_e}{\theta_I(g_c - 1)} v, 0\right\}$. Clearly, $\Delta_c^d(v, \theta_I)$ is non-increasing in θ_I. Further, $\Delta_c^d(v, \theta_I) > 0$ if and only if $\theta_I < \frac{(\beta_H - \beta_L)\alpha_e}{1 - \alpha_f - \beta_L \alpha_e}$.

For $\Delta \leq 0$, there are two cases to consider:

- $\Delta \geq -\frac{1}{g_s}v$, in which case equation A-1 is satisfied if and only if

$$\Delta \leq -\frac{\theta_I(\alpha_f+\beta_L\alpha_e-1)+(\beta_H-\beta_L)\,\alpha_e}{\theta_I(1-g_s)}v \equiv \Delta_1(v,\theta_I).$$

- $\Delta < -\frac{1}{g_s}v$, in which case equation A-1 is satisfied if and only if

$$\Delta \leq -\frac{\theta_I\left(\alpha_f+\beta_L\alpha_e\right)+(\beta_H-\beta_L)\,\alpha_e}{\theta_I}v \equiv \Delta_2(v,\theta_I).$$

Combining the above inequalities, it can be verified that given $\Delta < 0$, equation A-1 is satisfied for $\Delta \leq \max\{\Delta_1(v,\theta_I),\Delta_2(v,\theta_I)\}$. Therefore, $\Delta_s^d(v,\theta_I) \equiv \min\{\max\{\Delta_1(v,\theta_I),\Delta_2(v,\theta_I)\},0\}$. It can be readily verified that $\Delta_s^d\,(v,\theta_I)$ is non-decreasing in θ_I and that $\Delta_s^d(v,\theta_I) < 0$ if and only if $\theta_I < \frac{(\beta_H-\beta_L)\alpha_e}{1-\alpha_f-\beta_L\alpha_e}$. ■

Proof of Corollary 1. We consider $v_i = 0$ and $v_i = v$ separately.

1. Consider $v_i = 0$. From the proof of Proposition 1, we know that joint development takes place if $\Delta > \frac{w}{g_c-1}$. In this case, the firm makes a take-it-or-leave-it offer of w to the employee with probability γ and the employee makes a take-it-or-leave-it offer to the firm of π_f^o with probability $(1-\gamma)$. For $\Delta \leq \frac{w}{g_c-1}$, the employee focuses on the core task and the firm develops independently whenever optimal. Therefore,

$$\pi_e^N(0,\Delta,\beta,\theta_I) = \begin{cases} w & if \quad \Delta \leq \frac{w}{g_c-1} \\ \gamma w + (1-\gamma)(\pi^J - \pi_f^o) & if \quad \Delta > \frac{w}{g_c-1} \end{cases} \tag{A-2}$$

$$\pi_f^N(0,\Delta,\theta_I) = \begin{cases} \max\{0,\Delta\} & if \quad \Delta \leq \frac{w}{g_c-1} \\ \gamma(\pi^J - w) + (1-\gamma)\pi_f^o & if \quad \Delta > \frac{w}{g_c-1} \end{cases} \tag{A-3}$$

Therefore, $\frac{d\pi_e^N(0,\Delta,\beta,\theta_I)}{d\Delta} = 0$ for $\Delta \leq \frac{w}{g_c-1}$ and $\frac{d\pi_e^N(0,\Delta,\beta,\theta_I)}{d\Delta} = (1-\gamma)(g_c-1) > 0$

for $\Delta > \frac{w}{g_c - 1}$. For the firm, $\frac{d\pi_f^N(0,\Delta,\theta_I)}{d\Delta} = 0$ for $\Delta \leq 0$, and

$$\frac{d\pi_f^N(0,\Delta,\theta_I)}{d\Delta} = \begin{cases} 1 & if \quad \Delta \in \left(0, \frac{w}{g_c-1}\right] \\ \gamma g_c + (1-\gamma) & if \quad \Delta > \frac{w}{g_c-1} \end{cases} > 0$$

2. Consider $v_i = v$. In this case, the employee has a credible option of developing independently resulting in π_e^o, while the firm's outside option is π_f^o. In the agreement region $\Delta \notin (\Delta_s^d(v), \Delta_c^d(v))$, the firm makes a take-it-or-leave-it offer of $\beta_H \alpha_e v$, which is accepted with probability 1 by the employee. In the disagreement region, $\Delta \in (\Delta_s^d(v), \Delta_c^d(v))$, the firm makes a take-it-or-leave-it offer of $\beta_L \alpha_e v$, which is accepted by the low type and rejected by the high type. Let $\tilde{\pi}_e^o$ be defined as

$$\tilde{\pi}_e^o(v, \beta_H) = \alpha_e \beta_H v \tag{A-4}$$

$$\tilde{\pi}_e^o(v, \beta_L) = \begin{cases} \beta_H \alpha_e v & if \quad \Delta \notin (\Delta_s^d(v,\theta_I), \Delta_c^d(v,\theta_I)) \\ \beta_L \alpha_e v & if \quad otherwise \end{cases} \tag{A-5}$$

Then the employee's expected payoff from the negotiation stage is given by

$$\pi_e^N(v,\Delta,\beta,\theta_I) = \gamma \tilde{\pi}_e^o + (1-\gamma)(\pi^J - \pi_f^o) \tag{A-6}$$

Thus,

$$\frac{d\pi_e^N(v,\Delta,\beta,\theta_I)}{d\Delta} = \begin{cases} -(1-\gamma)(1-g_s) & if \quad \Delta < 0 \\ (1-\gamma)(g_c - 1) & if \quad \Delta > 0 \end{cases}$$

The firm's expected payoff is given by

$$\pi_f^N(v,\Delta,\theta_I) = \begin{cases} (1-\gamma)\pi_f^o + \gamma(\pi^J - \beta_H \alpha_e v) & \text{if } \Delta \notin (\Delta_s^d, \Delta_c^d) \\ (1-\gamma)\pi_f^o + \gamma[\theta_I \pi_f^o + (1-\theta_I)(\pi^J - \beta_L \alpha_e v)] & \text{otherwise} \end{cases}$$

Since both π_f^o and π^J are increasing in Δ, it follows that $\frac{d\pi_f^N(v,\Delta,\theta_I)}{d\Delta} > 0$. ■

Proof of Proposition 2. Consider $v_i = 0$. From the proof of Corollary 1, the employee's expected payoff from internal exploration is given by

$$\pi_e^I = \begin{cases} 0 & \text{if} \quad \Delta \leq \frac{w}{g_c - 1} \\ p(L)[\pi_e^N(0, \Delta, \beta, \theta_I) - w] + w & \text{if} \quad \Delta > \frac{w}{g_c - 1} \end{cases}$$

The employee's payoff from focusing on his core task is $\pi_e^D = w$, and his payoff from external exploration is $\pi_e^E = 0$. Given that $\pi_e^N(0, \Delta, \beta, \theta_I) > w$ for $\Delta > \frac{w}{g_c - 1}$, the result follows immediately. ■

Proof of Proposition 3. Consider $v_i = v$. The employee's payoff from internal exploration is $\pi_e^I = p(L)[\pi_e^N(v, \Delta, \beta, \theta_I) - w] + w$, where $\pi_e^N(v, \Delta, \beta, \theta_I)$ is given by (A-6). Since $\pi_e^N(v, \Delta, \beta, \theta_I) > w$, payoff from internal exploration exceeds the payoff from pursuing the core task and the employee chooses between internal and external exploration. Moreover, from the proof of Corollary 1, we have

$$\frac{d\pi_e^N(v, \Delta, \beta, \theta_I)}{d\Delta} = \begin{cases} -(1-\gamma)(1-g_s) & if \quad \Delta < 0 \\ (1-\gamma)(g_c - 1) & if \quad \Delta > 0 \end{cases}$$

Thus, $\frac{d\pi_e^I}{d\Delta} < 0$ for $\Delta < 0$ and $\frac{d\pi_e^I}{d\Delta} > 0$ for $\Delta > 0$. Then, if $\pi_e^I(v, 0, \beta, \theta_I, L) \geq \pi_e^E(v, \beta)$, the payoff from internal exploration always exceeds the payoff from external exploration, and $\Delta_s^I = \Delta_c^I = 0$. Otherwise, Δ_s^I and Δ_c^I are defined as the solutions of equation (2). Note that since $\frac{d\pi_e^I}{d\Delta} < 0$ for $\Delta < 0$, Δ_s^I is unique and $\pi_e^I(v, \Delta, \beta, \theta_I, L) > \pi_e^E(v, \beta)$ for $\Delta < \Delta_s^I$. By the same token, since $\frac{d\pi_e^I}{d\Delta} > 0$ for $\Delta > 0$, Δ_c^I is unique and $\pi_e^I(v, \Delta, \beta, \theta_I, L) > \pi_e^E(v, \beta)$ for $\Delta > \Delta_c^I$.

To establish Properties 1 and 2, let $\Delta_j^I \neq 0$. It then follows that $D(v, \Delta_j^I, \beta, \theta_I, L) \equiv \pi_e^I(v, \Delta_j^I, \beta, \theta_I, L) - \pi_e^E(v, \beta) = 0$. Then, by Implicit Function theorem, we have $d\Delta_j^I / dL = -\frac{p'(L)(\pi_e^N - w)}{p(L)\partial\pi_e^N/\partial\Delta}$. The numerator is positive due to $p'(L) > 0$ and $\pi_e^N > w$. The denominator is positive for complements and negative for substitutes. Therefore, $\frac{d\Delta_s^I}{dL} > 0$ and $\frac{d\Delta_c^I}{dL} < 0$.

For Properties 3 and 4, note that $\pi_e^N(v, \Delta, \beta_H)$, as given by equation (A-6), is not a function of θ_I, establishing Property 3. To establish Property 4, recall from Proposition 1 that $\Delta_s^d(v, \theta_I)$ ($\Delta_c^d(v, \theta_I)$) is increasing (decreasing) in θ_I. This implies that $\frac{d\Delta_s^I(L,v,\beta_L,\theta_I)}{d\theta_I} = -\frac{p(L)\partial\pi_e^N/\partial\theta_I}{p(L)\partial\pi_e^N/\partial\Delta} \geq (\leq) 0$ for substitutes (complements).

For Properties 5 and 6, note that $D(v, \Delta, \beta, \theta_I, L) = 0$ can be written as

$$p(L)(1-\gamma)(\pi^J - \pi_f^o) + (1 - p(L))w = p_o\beta v - p(L)\gamma\tilde{\pi}_e^o(v, \beta)$$

where $\tilde{\pi}_e^o(v, \beta)$ is defined by equations (A-4) and (A-5). Note that for $p_o\beta v \leq p(L)\gamma\tilde{\pi}_e^o(v, \beta)$, $\Delta_j^I(L, v, \beta, \theta_I) = 0$. Therefore, we consider the case of $p_o\beta v > p(L)\gamma\tilde{\pi}_e^o(v, \beta)$ for at least one of the types. In this case, it is sufficient to show that the right-hand side is increasing in β. This is straightforward to establish since $\beta_H(p_o - p(L)\gamma\alpha_e)v > \beta_L(p_o - p(L)\gamma\alpha_e)v$. ■

Proof of Proposition 4. By Proposition 3, we have that $\Delta_j^I(L, v, \beta_H)$ is independent of θ_I. We also have that $\Delta_c(L, v, \beta_L, \theta_I) \leq \Delta_c(L, v, \beta_H)$ and $\Delta_s(L, v, \beta_L, \theta_I) \geq \Delta_s(L, v, \beta_H)$ for all θ_I. This implies that both employee types choose internal exploration for $\Delta \notin (\Delta_s^I(L, v, \beta_H), \Delta_c^I(L, v, \beta_H))$. By Bayes' Rule, this implies that the equilibrium belief is $\theta_I^* = \theta$. For $\Delta \in (\Delta_s^I(L, v, \beta_H), \Delta_c^I(L, v, \beta_H))$ the high type always explores externally. Thus, the low type is the only one that may have strict incentives to explore inside the firm.

Given $\theta_I = 0$, the low type would choose internal exploration provided $\Delta \notin (\Delta_s^I(L, v, \beta_L, 0), \Delta_c^I(L, v, \beta_L, 0))$. By Proposition 3, $\Delta_s^I(L, v, \beta_L, \theta_I)$ is non-decreasing in θ_I and $\Delta_c^I(L, v, \beta_L, \theta_I)$ is non-increasing in θ_I, indicating that the incentives for internal exploration are weakly increasing in θ_I. Therefore, $\theta_I^* = 0$ is the unique equilibrium belief that can be supported over regions $\Delta \in (\Delta_s^I(L, v, \beta_H), \Delta_s^I(L, v, \beta_L, 0)]$ and $\Delta \in [\Delta_c^I(L, v, \beta_L, 0), \Delta_c^I(L, v, \beta_H))$.

For $\Delta \in (\Delta_s^I(L, v, \beta_L, 0), \Delta_c^I(L, v, \beta_L, 0))$, the only possible equilibrium is for both types to explore externally. To see this, note that any belief θ_I that results in internal exploration by the low type in the region $\Delta \notin (\Delta_s(L, v, \beta_L, \theta_I), \Delta_c(L, v, \beta_L, \theta_I))$ cannot be supported as an equilibrium — in equilibrium, Bayes' Rule requires $\theta_I = 0$, a contradiction. An off-equilibrium belief $\theta_I^* = 0$ in this region guarantees no deviation incentives by the low type. ■

Proof of Proposition 5. Let $F(\cdot|v_i)$ denote the conditional distribution of Δ for a given realization of v_i. Then the probability of internal exploration is given by

$$\begin{aligned} P(L) &= \left[(1-\psi)\left(1-F\left(\frac{w}{g_c-1}\middle|0\right)\right)\right]+ \\ &\quad +\psi\sum_{\beta}\Pr(\beta)\left[1-\Big(F(\Delta_c^I(L,v,\beta,\theta_I^*)|v)-F(\Delta_s^*(L,v,\beta,\theta_I^*)|v)\Big)\right]. \end{aligned}$$

From Proposition 3, $\frac{\partial\Delta_s^I(L,v,\beta,\theta_I^*)}{\partial L}\geq 0$ and $\frac{\partial\Delta_c^I(L,v,\beta,\theta_I^*)}{\partial L}\leq 0$. Thus,

$$\frac{dP}{dL}=\psi\sum_{\beta}\Pr(\beta)\left[f(\Delta_s^I|v)\frac{\partial\Delta_s^I}{\partial L}-f(\Delta_c^I|v)\frac{\partial\Delta_c^I}{\partial L}\right]\geq 0$$

Next, we consider the likelihood of downstream disagreements. Note that a necessary condition for disagreements to take place is $\Delta\notin(\Delta_s^I(L,v,\beta_H),\Delta_c^I(L,v,\beta_H))$ since otherwise the high type explores externally and the negotiations never fail. By Proposition 4, $\theta_I^*=\theta$ in this region. Proposition 1 then implies that downstream disagreements are not possible for $\theta_I^*=\theta\geq\frac{(\beta_H-\beta_L)\alpha_e}{1-\alpha_f-\beta_L\alpha_e}$ since it then holds that $\Delta_s^d(v,\theta_I^*)=\Delta_c^d(v,\theta_I^*)=0$. For $\theta_I^*=\theta<\frac{(\beta_H-\beta_L)\alpha_e}{1-\alpha_f-\beta_L\alpha_e}$, $\Delta_s^d(v,\theta)<0$ and $\Delta_c^d(v,\theta)>0$. Downstream disagreements occur if and only if $\Delta\in(\Delta_s^d(v,\theta),\Delta_s^I(L,v,\beta_H,\theta))\cup(\Delta_c^I(L,v,\beta_H,\theta),\Delta_c^d(v,\theta))$. By Proposition 3, $\Delta_s^I(L,v,\beta_H)$ is increasing in L and $\Delta_c^I(L,v,\beta_H)$ is decreasing in L. Therefore, there exists $\tilde{L}\geq 0$ such that the region of downstream disagreements is non-empty and increasing in L. ■

Proof of Lemma 1. The proof for complements and substitutes is analogous; we show the case of complements, $\Delta\geq 0$.

For $\Delta\geq 0$, $\pi_e^I(v,\Delta,\theta_I,L)$ is strictly increasing in L and Δ. $L_c^{\min}(v,\beta)$ is defined as the smallest level of exploration support L such that $\pi_e^I(v,\overline{\Delta},\theta_I,L)\geq\pi_e^E(v,\beta)$. Similarly, $L_c^{\max}(v,\beta)$ is defined as the smallest level of L such that $\pi_e^I(v,0,\theta_I,L)\geq\pi_e^E(v_i,\beta)$. Clearly, $L_c^{\max}(v,\beta)\geq L_c^{\min}(v,\beta)$ since $\pi_e^I(v,\Delta,\theta_I,L)$ is increasing in L

and Δ for $\Delta \geq 0$. For $L_c^{\min}(v,\beta) = 0$ and $L_c^{\max}(v,\beta) = 0$, Properties 2 and 3 trivially hold. Therefore, we focus on $L_c^{\min}(v,\beta) > 0$ and $L_c^{\max}(v,\beta) > 0$, where $L_c^{\min}(v,\beta)$ is the solution of

$$\pi_e^I(v_i, \overline{\Delta}, \theta_I, L_c^{\min}) = \pi_e^E(v_i, \beta), \tag{A-7}$$

and $L_c^{\max}(v,\beta)$ is the solution of

$$\pi_e^I(v_i, 0, \theta_I, L_c^{\max}) = \pi_e^E(v_i, \beta). \tag{A-8}$$

To see that $L_c^{\min}(v,\beta_H) \geq L_c^{\min}(v,\beta_L)$, note that equation (A-7) can be rewritten as

$$p(L_c^{\min})[\gamma \tilde{\pi}_e^o(v,\beta) + (1-\gamma)(g_c\overline{\Delta} + v - \overline{\Delta} - \alpha_f v) - w] + w - p_o\beta v = 0$$

where $\tilde{\pi}_e^o(v,\beta)$ is defined by equations (A-4) and (A-5). Note that the left-hand side is increasing in L since $\gamma\tilde{\pi}_e^o + (1-\gamma)(g_c\overline{\Delta} + v - \overline{\Delta} - \alpha_f v) > w$ and $p'(L) > 0$. Moreover, $p(L_c^{\min})\gamma\tilde{\pi}_e^o(v,\beta) - p_o\beta v < 0$; otherwise the left-hand side will be strictly greater than 0. This implies that the left-hand side is decreasing in β, since $0 > p(L)\gamma\tilde{\pi}_e^o(v,\beta_L) - p_o\beta_L v > p(L)\gamma\tilde{\pi}_e^o(v,\beta_H) - p_o\beta_H v$ holds for $L \leq L_c^{\min}(v,\beta_H)$. It follows that $L_c^{\min}(v,\beta_H) > L_c^{\min}(v,\beta_L)$. To show that $L_c^{\max}(v,\beta_H) \geq L_c^{\max}(v,\beta_L)$, note that equation (A-8) can be rewritten as

$$p(L_c^{\max})[\gamma\tilde{\pi}_e^o(v,\beta) + (1-\gamma)(1-\alpha_f)v - w] + w - p_o\beta v = 0$$

Using an argument analogous to the case of $L_c^{\min}(v,\beta)$, it can be readily shown that $L_c^{\max}(v,\beta_H) \geq L_c^{\max}(v,\beta_L)$. ■

Proof of Proposition 6. Consider $L^*(\gamma,\alpha_e,\alpha_f) > \max\{L_s^{\min}(v,\beta), L_c^{\min}(v,\beta)\}$. Then, $L^*(\gamma,\alpha_e,\alpha_f)$ is defined as the solution of $\frac{\partial\Pi_f(L^*)}{\partial L} = 0$, where $\frac{\partial\Pi_f(L)}{\partial L}$ is defined by equation (4). By Implicit function theorem, it is sufficient to establish $\frac{\partial\Pi_f(L^*)}{\partial L\partial\gamma} > 0$, $\frac{\partial\Pi_f(L^*)}{\partial L\partial\alpha_f} > 0$ and $\frac{\partial\Pi_f(L^*)}{\partial L\partial\alpha_e} < 0$. Let $x \in \{\gamma, \alpha_f, \alpha_e\}$. Then,

$$\begin{aligned}
\frac{\partial \Pi_f(L)}{\partial L \partial x} &= E\left[\left.\frac{\partial S_f(v_i,\Delta,\beta,L)}{\partial L\partial x}\right| \Delta \notin \left(\Delta_s^I,\Delta_c^I\right)\right] + \\
&+\psi E\left[\left.\frac{\partial S_f\left(v,\Delta_s^I,\beta,L\right)}{\partial x} f(\Delta_s^I|v)\frac{\partial \Delta_s^I}{\partial L} - \frac{\partial S_f\left(v,\Delta_c^I,\beta,L\right)}{\partial x} f(\Delta_c^I|v)\frac{\partial \Delta_c^I}{\partial L}\right| v\right] + \\
&+\psi E\left[\left.\frac{d[S_f\left(v,\Delta_s^I,\beta,L\right) f(\Delta_s^I|v)]}{dL}\frac{\partial \Delta_s^I}{\partial x}\frac{\partial \Delta_s^I}{\partial L} + S_f(v,\Delta_s^I,\beta,L) f(\Delta_s^I|v)\frac{\partial^2 \Delta_s^I}{\partial L\partial x}\right| v\right] - \\
&-\psi E\left[\left.\frac{d[S_f\left(v,\Delta_c^I,\beta,L\right) f(\Delta_c^I|v)]}{dL}\frac{\partial \Delta_c^I}{\partial x}\frac{\partial \Delta_c^I}{\partial L} - S_f(v,\Delta_c^I,\beta,L) f(\Delta_c^I|v)\frac{\partial^2 \Delta_c^I}{\partial L\partial x}\right| v\right]
\end{aligned}$$

Recall from Proposition 3 that $\frac{\partial \Delta_s^I}{\partial L} \geq 0$ and $\frac{\partial \Delta_c^I}{\partial L} \leq 0$. Given Assumption 1, $\frac{d[S_f\left(v,\Delta_j^I,\beta,L\right) f(v,\Delta_j^I,\beta,L|v)]}{dL} \leq 0$ for $j = \{s,c\}$. We proceed in sequence to establish the signs of the remaining variables:

- $\frac{\partial S_f(v_i,\Delta,\beta,L)}{\partial L\partial x} = p'(L)\frac{\partial \pi_f^N(v_i,\Delta,\beta,\theta_I^*)}{\partial x}$, where it can be readily established that $\frac{\partial \pi_f^N(v_i,\Delta,\beta,\theta_I^*)}{\partial \gamma} > 0$, $\frac{\partial \pi_f^N(v_i,\Delta,\beta,\theta_I^*)}{\partial \alpha_f} > 0$ and $\frac{\partial \pi_f^N(v_i,\Delta,\beta,\theta_I^*)}{\partial \alpha e} < 0$
- $\frac{\partial S_f\left(v,\Delta_j^I,\beta,L\right)}{\partial x} = p(L)\frac{\partial \pi_f^N(v_i,\Delta,\beta,\theta_I^*)}{\partial x}$.
- $\frac{\partial \Delta_j^I}{\partial x} = -\frac{\partial D/\partial x}{\partial D/\partial \Delta}$ for $\Delta_s^I \in [\underline{\Delta},0)$ and $\Delta_c^I \in [0,\overline{\Delta})$ where $D(v,\Delta,\beta,\theta_I^*,L) \equiv \pi_e^I(v,\Delta,\beta,\theta_I^*,L) - \pi_e^E(v,\beta)$. Given $\pi_e^I(v,\Delta,\beta,\theta_I^*,L) = p(L)(\pi_e^N(v,\Delta,\beta,\theta_I^*) - w) + w$, we have $\frac{\partial \Delta_j^I}{\partial x} = -\frac{\partial \pi_e^N/\partial x}{\partial \pi_e^N/\partial \Delta}$. It is straightforward to establish that $\frac{\partial \pi_e^N(v,\Delta,\beta,\theta_I^*)}{\partial \gamma} < 0$, $\frac{\partial \pi_e^N(v,\Delta,\beta,\theta_I^*)}{\partial \alpha_f} < 0$ and $\frac{\partial \pi_e^N(v,\Delta,\beta,\theta_I^*)}{\partial \alpha e} > 0$. Moreover, from Corollary 1, $\frac{\partial \pi_e^N(v,\Delta,\beta,\theta_I^*)}{\partial \Delta} > 0$ for complements and $\frac{\partial \pi_e^N(v,\Delta,\beta,\theta_I^*)}{\partial \Delta} < 0$ for substitutes. Therefore, $\frac{\partial \Delta_c^I}{\partial \gamma} > 0$, $\frac{\partial \Delta_s^I}{\partial \gamma} < 0$, $\frac{\partial \Delta_c^I}{\partial \alpha_f} > 0$, $\frac{\partial \Delta_s^I}{\partial \alpha_f} < 0$, $\frac{\partial \Delta_c^I}{\partial \alpha_e} < 0$, and $\frac{\partial \Delta_s^I}{\partial \alpha_e} > 0$.
- $\frac{\partial \Delta_j^I}{\partial L\partial x} = \frac{\partial \Delta_j^I}{\partial x\partial L} = \frac{\partial}{\partial L}\left[-\frac{\partial \pi_e^N/\partial x}{\partial \pi_e^N/\partial \Delta}\right] = 0$, since π_e^N is not a function of L.

Given the signs of the variables above, it is straightforward to establish that $\frac{\partial \Pi_f(L^*)}{\partial L\partial \gamma} > 0$, $\frac{\partial \Pi_f(L^*)}{\partial L\partial \alpha_f} > 0$, and $\frac{\partial \Pi_f(L^*)}{\partial L\partial \alpha_e} < 0$. ■

Notation Table

e	research employee
f	firm
w	competitive wage
$v_i \in \{0, v\}$	stand alone valuation of the idea
Δ	externality imposed by the idea
ψ	probability that $v_i = v$
$\beta \in \{\beta_H, \beta_L\}$	employee's entrepreneurial ability
θ	firm's prior belief that $\beta = \beta_H$
$g \in \{g_c, g_s\}$	synergies from joint development
α_e, α_f	profit eroding effect of competition
γ	probability that firm makes an offer in negotiation stage
E, R	employee's choice: External exploration vs. Remain with firm
$\{D, I\} \in R$	employee's choice given R: Drop the idea vs. Internal exploration
p_o	likelihood of successful exploration if idea is pursued outside the firm
L	level of exploration support offered by the firm
$p(L)$	likelihood of successful exploration if idea is pursued inside the firm
π_e^D	employee's payoff from dropping the idea
$\pi^J(.)$	surplus from internal (joint) handling of an explored idea
$\pi_e^E(.), \pi_f^E(.)$	expected payoffs from external exploration
$\pi_e^I(.), \pi_f^I(.)$	expected payoffs from internal exploration
$\pi_e^o(.), \pi_f^o(.)$	expected payoffs from independent development after internal exploration

Table 1: A summary of the notation.