Preventing Employee Departure: A Human Capital Model with Innovation[*]

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Abstract

In his seminal paper, Becker (1962) argues that firms never invest in general human capital of their employees, as firms cannot extract any returns from it. Nevertheless, empirical evidence shows that many firms invest in general human capital. This paper sheds light on this puzzle by developing a principal-agent model where both firm and employee can invest in the employee's human capital. The novel feature of the model is that specific human capital investment helps the employee generate an innovation. From the employee's perspective, innovation brings the opportunity of entrepreneurship. From the firm's perspective, entrepreneurship represents the departure of a skilled employee. The key insight is that the firm may invest in the employee's general human capital to discourage innovation, and thus to reduce the risk of employee departure. Therefore, this paper offers a new explanation on optimal human capital investments, which goes beyond Becker's seminal work.

JEL Codes: J24, L26, O31

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1   Introduction

In his seminal paper, Becker (1962) categorizes human capital into two groups, general human capital and firm-specific human capital, based on which employers value them. While general human capital is equally valuable in any firm, firm-specific human capital is only valuable to the current employer. Because all firms value the employee's general human capital equally, the employee realizes all the returns to general human capital investment. Consequently, firms never invest in general human capital. On the other hand, because no other firm values the employee's specific human capital, the current firm captures all the returns to specific human capital investment. Hence, employees never invest in specific human capital. Yet, empirical evidence (e.g. Capelli, 2004; Flaherty, 2007) shows that many firms invest in general human capital of their employees and many employees invest in firm-specific human capital. This paper aims to shed light on this puzzle by analyzing the optimal human capital investments in a principal-agent framework. The key departure from Becker's work is that I introduce "generating an innovative idea" as the new effect of human capital investment.

I develop a two-period principal-agent model in which first the principal (she) and then the agent (he) can invest in the agent's human capital during the first period. The human capital investment can be in the form of general or specific human capital. While general human capital only increases the agent's second period output, specific human capital increases both the agent's second period output and his probability to innovate.[1] At the end of the first period, the agent may generate an innovative idea. If he has no innovative idea, he can work for the principal or another firm in the second period. In such case, his second period wage is the full return to his general human capital. If, however, the agent has an innovative idea, he implements the innovation outside the firm as an entrepreneur.[2]

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[1] The positive effect of human capital accumulation on innovation is well-documented in the literature. There is both theoretical (e.g. Nelson & Phelps, 1966; Aghion & Howitt, 1998) and empirical evidence (e.g. Ballot, Fakhfakh & Taymaz, 2001; Pauline-Gallié & Legros, 2012) supporting this argument.

[2] Empirical evidence supports the notion that some employees choose entrepreneurship as a career path if

The first important result of this model is that the agent invests in his specific human capital in equilibrium. The intuition behind this result can be explained as follows: Because the return from entrepreneurship is higher than the employment wage, the agent is interested in becoming an entrepreneur. However, in order to become an entrepreneur, he needs to generate an innovative idea. Therefore, the agent invests in his specific human capital because it increases his chances to innovate and thus, to become an entrepreneur.

From the principal's perspective, innovation represents the departure of a skilled agent. If the agent leaves, the principal benefits from neither his output nor his innovative idea so she invests in the agent's human capital strategically to reduce the risk of departure. Because the principal invests in the agent's human capital before the agent does, she captures the first-mover advantage in the game. This advantage allows her to alter the agent's human capital investments. This brings us the second important result which explains how the principal's and the agent's human capital investments interact. If the principal invests in specific human capital, the agent's probability to innovate increases. This reduces the agent's willingness to stay so the agent reduces his general human capital investment. At the same time, because the agent is less willing to stay and more willing to become an entrepreneur, he increases his specific human capital investment. If the principal invests in general human capital of the agent, the agent's willingness to and return from staying increases. This reduces the agent's motivation to innovate. As a result, the agent reduces his specific human capital investment and increases his general human capital investment.

The third important result of the paper pertains to the principal's human capital investments. The principal knows that the agent's specific human capital investment increases as the entrepreneurial income (i.e., R) rises. This reduces the marginal benefit (henceforth MB) of investing in the agent's specific human capital for the principal because the agent's probability to stay in the firm reduces with higher specific human capital investment. When R

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they identify an opportunity or generate an innovative idea (e.g. Cooper, 1985; Bhide, 1994; Gompers, Lerner & Scharfstein; 2005; Ganco, 2013).

reaches a certain threshold, the MB of investing in the agent's specific human capital reduces to zero for the principal so she stops the investment. If R exceeds this threshold, this time the MB of investing in the agent's general human capital becomes positive. This is because the agent's probability to stay in the firm becomes very low and the principal needs to make staying more attractive. By investing in the agent's general human capital, the principal raises his second period wage in the firm so the agent's probability to stay increases.

This paper relates to several strands of the economics literature. First and foremost, this paper is a part of the human capital literature which examines why firms (employees) invest in general (specific) human capital. The papers focusing on why firms invest in general human capital offer three alternative explanations. First, the information asymmetry between the principal and other firms allows the principal to capture some return to general human capital investment (Katz & Ziderman, 1990; Chang & Wang, 1996). Second, the principal can enjoy some return to general human capital investment thanks to labor market frictions as suggested by Acemoglu & Pischke (1998, 1999). Third, the principal can benefit from the strategic complementarity between general and specific human capital which incentivizes her to invest in general human capital (Balmaceda, 2005; Kessler & Lülfesmann, 2006). The papers focusing on why employees invest in specific human capital also offer several explanations. Some of these explanations are promotion based on seniority (Carmichael, 1983), up-or-out contracts (Kahn & Huberman, 1988), promotion to another job (Prendergast, 1993), sales-based incentives (Zabojnik, 1998), and reduction in the probability of being laid off (Bernhardt & Mongrain, 2010).

Within this strand of literature, Sevilir's (2010) work is closest to this study in terms of its context. Sevilir's paper investigates the effect of firm-sponsored general human capital investment on the agent's ability to innovate and start a new venture. It shows that firm's investment in general human capital motivates the agent to exert more effort. Higher effort increases the agent's probability to generate a firm-specific innovation which

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boosts the principal's profit. This study differs in the following aspects: First, Sevilir (2010) assumes that firm can only invest in general human capital. In this paper, firm can invest in general and/or specific human capitals. Second, Sevilir (2010) uses the innovation as the only outcome of human capital investment. This paper simultaneously studies the effect of human capital investment on both the agent's production and his probability to innovate. Finally, Sevilir (2010)'s result on general human capital stems from the principal's probability to capture the rent from firm-specific innovation. In this paper, the principal never captures any returns from innovation and she invests in general human capital just to increase the probability of retention. In other words, this study offers a novel explanation of why the principal invests in the agent's general human capital.

The second related strand of literature studies the effects of innovation, allocation of IP rights, and labor mobility on corporate strategies. Kim & Marschke (2005) study the R&D investment of a firm under the risk of employee departure. They find that higher patenting rate and/or reduction in R&D spending are the optimal responses against this risk. Hellmann (2007) investigates the corporate strategies in a multi-tasking environment where employees allocate effort between the innovation opportunities and the core task. He shows that the agent's decision on following innovative opportunities and becoming an entrepreneur depends on the incentive scheme for the core task, allocation of IP rights, and the availability of venture capital. Hellmann & Thiele (2011) derive the optimal incentive contract for the standard task when the innovation is unplanned and its rent can only be shared through ex-post bargaining. Their results show that the firm-specificity of the innovation plays a crucial role in the optimal incentive contract: The higher the firm-specificity of the innovation, the lower the incentives for the standard task. Bettignies & Chemla (2008) investigate why corporate venturing emerges. They show that corporate venturing helps firms retain their star employees who have innovative ideas. Campbell et al. (2012) compare the effect of employee mobility and employee entrepreneurship on the parent firm. Their results indicate

that employee entrepreneurship has a larger negative effect on the parent firm even after controlling for observable employee quality.

The contribution of this paper to the literature is three-fold. First, this paper introduces innovation and entrepreneurship into the human capital theory and provides a new explanation for why firms (employees) invest in general (specific) human capital. Importantly, unlike previous frameworks, this model does not rely on imperfections.[3] Second, this paper highlights the difference between sequential and simultaneous human capital investments. Third, this paper provides a theoretical explanation for the empirical observation of firm-provided general human capital's positive effect on employee retention (see e.g. Capelli, 2004; Flaherty, 2007; Gicheva, 2012).[4]

The rest of the paper is organized as follows: Section 2 presents the basic setup for the principal-agent framework. Section 3 analyzes the human capital model without innovation as benchmark. Section 4 introduces innovation into the human capital model and derives the equilibrium human capital investments. Section 5 considers some extensions to the model. Section 6 discusses empirical implications of the model. Section 7 concludes.

All derivations and proofs are in the appendix.

2   Basic Setup

Consider an employment relationship between a risk-neutral principal (she) and a risk-neutral and wealth-constrained agent (he). There are two periods: In the first period, the agent accumulates human capital, which is required for production. In the second period, the agent uses his human capital to produce output.

Human capital investment can be in the form of general training or specific training.

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[3]The imperfections used in the previous literature are labor market frictions, information asymmetry, and hold-up problem as a result of human capital investment.

[4]Capelli (2004) and Flaherty (2007) show that employer provided general training – in the form of tuition reimbursement – increases the employee retention rate. Moreover, the results in Gicheva (2012) support the same argument by indicating employer-sponsored MBA reduces the turnover probability.

After the training, the agent's human capital levels are $\mathbf{g} \in [0, \bar{\mathbf{g}}]$ and $\mathbf{s} \in [0, \bar{\mathbf{s}}]$. There are two ways to invest in the agent's human capital: Contractible training (e.g. education) which is financed by the principal and non-contractible training (e.g. on-the-job training) level of which is determined by the agent. The cost of training is $c(z) = z^2/2$ with $z = g_A, g_P, s_A, s_P$ where the subscripts P and A stand for the principal and the agent, respectively.

Investments in human capital have two effects: First, it increases the agent's second period output if he stays with the firm. The agent's production is represented by the following function:

$$F(\mathbf{g}, \mathbf{s}) = f(\mathbf{g}) + h(\mathbf{s})$$

where $f(\mathbf{g}) = g_A + g_P$, and $h(\mathbf{s}) = s_A + s_P$.[5]

The second effect is that specific human capital increases the agent's probability to innovate. This is a key and novel feature of this model. The agent's probability to innovate depends on the agent's specific human capital and is given by:

$$p(\mathbf{s}) = \gamma(s_A + s_P)$$

where γ defines the marginal contribution of specific human capital and $\gamma \in \left(0, \dfrac{1}{\bar{\mathbf{s}}}\right]$.[6]

This probability of innovation function captures the notion that he agent gets a better understanding of the production process with human capital investment. This allows him to determine possible inefficiencies in the production. As a result, the agent can generate an innovative idea which is also an entrepreneurial opportunity for him. The empirical findings of Corbett (2007) also support this assumption, by showing that investment in specific human capital increases the entrepreneurial opportunities identified by the employee.

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[5] When combined with the convex cost functions, linear production functions guarantee an interior solution. Moreover, they are used by several papers (e.g. Hashimoto, 1981; Benhardt & Mongrain, 2010) in the human capital literature.

[6] I assume a linear probability of innovation for the sake of simplicity.

Figure 1 illustrates the timing of this game:

[Figure 1 About Here]

At date 0, the principal offers the agent a contract which specifies the firm-sponsored training level. If the agent accepts the offer, the training stage starts.

At date 1/2, the firm-sponsored training ends and the agent decides how much non-contractible training effort to exert.

An important feature of this game is that the training is in sequential form. Sequential investment is consistent with the idea that many firms offer training and orientation to new employees before they start working.

At date 1, the agent becomes aware of the possible innovative idea. If the agent has an innovative idea, he implements it outside the firm as an entrepreneur and earns the entrepreneurial income of R.[7] In this case, the principal hires a new unskilled agent. However, if the agent has no innovative idea, he can work for the principal or another firm in the second period and earn the employment wage (w). To ensure that the agent chooses entrepreneurship over employment, I assume that the return from entrepreneurship is higher than the maximum employment wage he can earn in any firm (i.e., $R > w$).

At date 2, the agent gets the income of R and the principal gets nothing if the agent innovated at date 1. Otherwise, the agent gets the wage (w) and the principal claims the residual amount.[8]

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[7]The agent does not share the innovative idea with the principal due to the risk of appropriation. Put differently, once the principal learns about the innovative idea, she can benefit from it without compensating the agent. This story also fits well to the real world. As mentioned in Hellmann & Thiele (2011), overwhelming majority of innovative employees get no or very small reward after sharing their innovative ideas with their employers in the real world.

[8]The residual amount is the difference between the agent's total production and his wage.

3   Benchmark: No-innovation Case

First, I consider the benchmark case which is in the spirit of Becker (1962).

3.1   First-Best Outcome

In the first-best scenario, the principal and the agent invest in the agent's human capital to maximize the total surplus:

$$Max \ \ (g_A + g_P + s_A + s_P) - \frac{(g_A)^2}{2} - \frac{(g_P)^2}{2} - \frac{(s_A)^2}{2} - \frac{(s_P)^2}{2}$$

The socially optimal human capital investments are then as follows:

$$g_A^{FB} = 1 \text{ and } s_A^{FB} = 1$$

$$g_P^{FB} = 1 \text{ and } s_P^{FB} = 1$$

These investments will be used to assess whether the equilibrium outcome is socially efficient.

3.2   Second-Best Outcome

In order to find the equilibrium human capital investments, I proceed by backward induction.

At date 2, the principal pays the wage w to the agent.

At date 1, the agent receives wage offers from the principal and another firm (henceforth competitor). While his general human capital is equally valuable in both firms, his specific human capital has no value for the competitor. For that reason, the competitor offers $f(\mathbf{g}^*)$, the returns to general human capital, to the agent. In order to retain the agent,

the principal's wage offer must be at least as high as the competitor's offer. Thus, the principal also offers $f(\mathbf{g}^*)$ as the second period wage and her payoff becomes $h(\mathbf{s}^*)$, the returns to specific human capital.

At date 1/2, the agent chooses g_A and s_A to maximize his net payoff:

$$Max \quad (g_A + g_P) - \frac{(g_A)^2}{2} - \frac{(s_A)^2}{2}$$

The agent's equilibrium human capital investments become:

$$g_A^* = g_A^{FB} = 1$$

At date 0, the principal chooses g_P and s_P to maximize her net payoff:

$$Max \quad (s_A + s_P) - \frac{(g_P)^2}{2} - \frac{(s_P)^2}{2}$$

The principal's equilibrium human capital investments become:

$$s_P^* = s_P^{FB} = 1$$

Proposition 1 : *In the human capital model without innovation, the agent (principal) invests in general (specific) human capital at the first-best level. On the other hand, the agent (principal) does not invest in specific (general) human capital in equilibrium.*

This proposition shows that without the innovation, the human capital model in this paper generates the same insights as Becker (1962).

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4   Human Capital Model with Innovation

The novel feature of this model is that the agent can generate an innovative idea as a result of specific human capital investment. Having an innovative idea matters to the agent because he can become an entrepreneur and earn a higher income. On the other hand, because it leads to the departure of a skilled agent, the principal's payoff reduces.

I proceed by backward induction in order to find the equilibrium human capital investments:

At date 2, both parties receive their payoffs and the game ends.

At date 1, the agent realizes whether he has an innovative idea. If he has an innovative idea, he implements it outside the firm as an entrepreneur. The agent's payoff is then given by R. If he has no innovative idea, the game goes back to the standard human capital model where the agent gets $f(\mathbf{g}^*)$ as his payoff and the principal gets $h(\mathbf{s}^*)$ as her payoff.

At date 1/2, the agent decides on his human capital investment. This investment affects his second period payoff in two ways: Investing in general human capital increases his second period wage if he stays in the firm and investing in specific human capital increases his probability to innovate and earn the entrepreneurial income. Therefore, the agent chooses g_A and s_A to maximize his utility:

$$Max\ U_I = \gamma\left(s_A + s_P\right)R + \left[1 - \gamma\left(s_A + s_P\right)\right]\left(g_A + g_P\right) - \frac{(g_A)^2}{2} - \frac{(s_A)^2}{2}$$

At the optimal choice of s_A and g_A, the marginal benefits are equal to the marginal costs of these investments:

$$s_A^* = \gamma\left[R - (g_A + g_P)\right] \tag{1}$$

$$g_A^* = 1 - \gamma \left(s_A + s_P \right) \tag{2}$$

As shown in the appendix, the agent's equilibrium human capital investments are as follows:

$$g_A^* = \frac{1 - \gamma^2 R - \gamma s_P + \gamma^2 g_P}{1 - \gamma^2} \tag{3}$$

$$s_A^* = \frac{\gamma \left(R - 1 \right) + \gamma^2 s_P - \gamma g_P}{1 - \gamma^2} \tag{4}$$

Proposition 2 : *In the innovation environment, the agent invests in his specific human capital in equilibrium as long as $\gamma > 0$. Moreover, the agent's investment in specific human capital (general human capital) is increasing (decreasing) in the entrepreneurial income (i.e., R).*

The logic behind this proposition is straightforward: Because the entrepreneurial income is higher than the employment wage (i.e., $R > w = g_A + g_P$), the agent prefers to become an entrepreneur. However, in order to become an entrepreneur, the agent must innovate. Because his probability to innovate is increasing in specific human capital, the agent invests in this human capital in equilibrium. The explanation of the second part of this proposition is as follows: Because the entrepreneurial income is the agent's reward for innovating, any increase in this income also increases the agent's willingness to innovate. In

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such case, in order to increase his probability to innovate, the agent increases his specific human capital investment. On the other hand, the agent's general human capital increases neither his entrepreneurial income nor his probability to innovate. Therefore, the agent reduces his general human capital investment. Even though the agent reduces his general human capital investment, he continues to invest in it as long as his probability to innovate is less than one. This is because he may still be an employee in the second period and if so, his income comes from his general human capital.

Proposition 3 : *In the innovation environment,*

(i) The principal's general human capital investment positively affects the agent's general human capital investment (i.e., $\dfrac{\partial g_A}{\partial g_P} > 0$) and it negatively affects the agent's specific human capital investment (i.e., $\dfrac{\partial s_A}{\partial g_P} < 0$),

(ii) The principal's specific human capital investment positively affects the agent's specific human capital investment (i.e., $\dfrac{\partial s_A}{\partial s_P} > 0$) and it negatively affects the agent's general human capital investment (i.e., $\dfrac{\partial g_A}{\partial s_P} < 0$).

The rationale behind these interactions is as follows: When the principal invests in the agent's general human capital, the agent's reward for staying with the principal increases. As a result, the agent reduces his specific human capital investment. As he reduces his specific human capital investment, his probability to stay with the principal increases. This means he is more likely to earn the return to his general human capital in the second period. For that reason, the agent increases his general human capital investment.

When the principal invests in the agent's specific human capital, the agent's probability to stay with the principal decreases. This means the agent is less likely to earn the return to his general human capital so he decreases his general human capital investment. As

he reduces his general human capital investment, the relative reward of innovation increases. For that reason, the agent increases his specific human capital investment.

The human capital interactions arise in this game because the principal and agent invest in the agent's human capital sequentially. This brings an important strategic advantage to the principal: Even though the agent's human capital investments are not contractible, the principal can alter the agent's investments thanks to these interactions.

At date 0, the principal chooses g_P and s_P to maximize her utility:

$$Max\ V_I = [1 - \gamma s_A(g_P, s_P) - \gamma s_P][s_A(g_P, s_P) + s_P] - \frac{(g_P)^2}{2} - \frac{(s_P)^2}{2}$$

At the optimal choice of g_P, the marginal benefit is equal to the marginal cost of investment:

$$\frac{\partial s_A}{\partial g_P}[1 - \gamma s_A - \gamma s_P] - \gamma \frac{\partial s_A}{\partial g_P}(s_A + s_P) = g_P \tag{5}$$

What this equality shows can be interpreted in the following way: As discussed in proposition 3, the principal's general human capital investment reduces the agent's specific human capital investment (i.e., $\frac{\partial s_A}{\partial g_P} < 0$). This interaction has two consequences for the principal. First, if the agent does not generate an innovative idea, the principal's payoff becomes the full return to specific human capital. Thus, the principal's payoff decreases as the agent reduces his specific human capital investment. The first term on the LHS of this equality shows this negative effect. Second, the agent's specific human capital investment increases his probability to innovate. If the agent innovates, the principal's payoff becomes

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zero because the agent becomes an entrepreneur. Thus, the agent's probability to stay with the principal increases as he reduces his specific human capital investment. The second term on the LHS of this equality shows this positive effect. This means g_P^* becomes positive if and only if the positive effect (i.e., increasing the agent's probability to stay) dominates the negative effect (i.e., reducing the agent's specific human capital output) of general human capital investment.

At the optimal choice of s_P, the marginal benefit is also equal to the marginal cost of investment:

$$\left[1 + \frac{\partial s_A}{\partial s_P}\right][1 - \gamma s_A - \gamma s_P] - \gamma \left[1 + \frac{\partial s_A}{\partial s_P}\right](s_A + s_P) = s_P \tag{6}$$

The interpretation of this equality is similar to the principal's general human capital investment: The principal's specific human capital investment has one positive and one negative effect: If the agent does not innovate, the principal's second period payoff increases both directly and indirectly (through increasing s_A) as a result of this investment. The first term on the LHS of this equality shows this positive effect. On the negative side, the principal's specific human capital investment reduces the agent's probability to stay with her both directly and indirectly. The second term on the LHS of this equality shows this negative effect. This means s_P^* becomes positive if and only if the positive effect (i.e., increasing the agent's specific human capital output) dominates the negative effect (i.e., reducing the agent's probability to stay).

As shown in the appendix, the equilibrium human capital investments by the principal are given by:

$$s_P^* = Max\left\{0, \frac{-\left[2\gamma^2 R - \gamma^2 - 1\right]}{1 + 2\gamma - 2\gamma^2 + 2\gamma^3 + \gamma^4}\right\} \tag{7}$$

$$g_P^* = Max\left\{0, \frac{\gamma\left[2\gamma^2 R - \gamma^2 - 1\right]}{1 + 2\gamma - 2\gamma^2 + 2\gamma^3 + \gamma^4}\right\} \tag{8}$$

Proposition 4 *: In the innovation environment, there exists a threshold for the entrepreneurial income, $\bar{R} = \dfrac{1 + \gamma^2}{2\gamma^2}$, such that*

(i) The principal does not invest in general human capital and her specific human capital investment reduces as R increases (i.e., $\dfrac{\partial s_P^*}{\partial R} < 0$) when $R < \bar{R}$,

(ii) The principal invests in neither general nor specific human capital when $R = \bar{R}$, and

(iii) The principal does not invest in specific human capital and her general human capital investment increases as R increases (i.e., $\dfrac{\partial g_P^*}{\partial R} > 0$) when $R > \bar{R}$.

Figure 2 illustrates the relationship between the entrepreneurial income and the principal's human capital investments (as discussed in Proposition 4).

[Figure 2 About Here]

The intuition behind this proposition is as follows: First of all, if the entrepreneurial income is below a certain threshold (i.e., $\underline{R}$)[9] , the agent do not consider becoming an

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[9]This minimum threshold for entrepreneurial income is equal to the wage obtained in no-innovation case: $\underline{R} = w^* = g_A^* + g_P^* = 1$.

entrepreneur and he invests in his human capital exactly as in no-innovation case. For that reason, the horizontal axis in Figure 2 starts from this threshold value, not zero. If the entrepreneurial income is above this threshold, entrepreneurship becomes a viable career option in the second period so the agent starts investing in his specific human capital investment. We know from proposition 2 that the agent increases his specific human capital investment as the entrepreneurial income rises. As the agent increases $s_A^*(g_P, s_P)$, the marginal benefit of investing in s_P^* decreases for the principal. This is because when s_A^* increases, the agent's probability to stay with the principal decreases. When the entrepreneurial income reaches the threshold $\bar{R}$, the agent's specific human capital investment becomes $s_A^* = \dfrac{1}{2\gamma}$. This reduces the marginal benefit of investing in s_P^* to zero so the principal chooses not to invest (i.e., $s_P^* = 0$).[10]

When the entrepreneurial income exceeds the threshold $\bar{R}$, the agent's specific human capital investment increases above $\dfrac{1}{2\gamma}$ which makes the marginal benefit of investing in s_P^* negative. Because the principal cannot reduce specific human capital investment below zero, her equilibrium investment stays at $s_P^* = 0$. At the same time, the marginal benefit of investing in g_P^* becomes positive as $s_A^* > \dfrac{1}{2\gamma}$. This is because the agent's probability to innovate is above the optimal level for the principal and reducing this probability will increase the principal's payoff. Due to the negative interaction between g_P^* and s_A^*, the principal can achieve this goal with general human capital investment. Thus, the principal starts investing in the agent's general human capital when $R > \bar{R}$.

The first part of proposition 4 (i.e., when $R < \bar{R}$) is consistent with the findings of Kim & Marschke (2005). They show that when a scientist's departure risk rises, the firm reduces its innovation budget. This helps the firm reduce the probability of the scientist walking away with the innovation. In this model, when the entrepreneurial income rises, the

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[10]The principal's payoff is maximized when the agent's probability to innovate reaches 0.5 and this probability level is reached when $s_A^* = \dfrac{1}{2\gamma}$. Thus, investing in s_P^* only reduces the principal's payoff after this point.

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agent's departure risk increases. In order to reduce this risk, the principal reduces specific human capital investment.

The second part of proposition 4 (i.e., when $R > \bar{R}$) presents a novel result. According to Becker (1962), the principal never invests in general human capital of the agent because the agent captures all the return to general human capital investment. However, this paper shows that the principal can invest in general human capital even if the agent gets the full return to this investment. The principal makes such an investment because the bigger threat for her (in terms of labor mobility) comes from entrepreneurship, not other firms. According to the model, the principal can match the wage offers from other firms so the agent stays with her in the second period. However, the principal cannot match the entrepreneurial income in the model (i.e., $R > w$). As mentioned in Bettignies & Chemla (2008), a firm's concern to retain its skilled employees is stronger when those employees have access to better compensation outside the firm. This situation forces the principal to increase the attractiveness of staying. In this model, the principal makes staying more attractive by investing in general human capital of the agent which raises his second period wage within the firm.

5   Extensions

5.1   Simultaneous Human Capital Investments

In the previous sections, I assumed that the principal invests in the agent's human capital first. As the first-mover, she could invest strategically to alter the agent's human capital investments. In this section, I analyze the scenario in which both parties simultaneously invest in the agent's human capital.

At date 2, both parties receive their payoffs and the game ends.

At date 1, the agent potentially observes an innovation opportunity. If he has an

innovative idea, he implements it as an entrepreneur and earns the payoff of R. If he has no innovative idea, he stays with the principal in return for the payment of $f(\mathbf{g}^*)$.

At date 0, the agent chooses g_A and s_A to maximize his expected utility:

$$Max\ U_I = \gamma\left(s_A + s_P\right)R + \left[1 - \gamma\left(s_A + s_P\right)\right]\left(g_A + g_P\right) - \frac{(g_A)^2}{2} - \frac{(s_A)^2}{2}$$

As shown in the appendix, the agent's equilibrium human capitals investments are given by:

$$g_A^* = \frac{1 - \gamma^2 R - \gamma s_P + \gamma^2 g_P}{1 - \gamma^2} \tag{9}$$

$$s_A^* = \frac{\gamma\left(R - 1\right) + \gamma^2 s_P - \gamma g_P}{1 - \gamma^2} \tag{10}$$

Again at date 0, the principal chooses g_P and s_P to maximize her expected utility:

$$Max\ V_I = \left[1 - \gamma s_A - \gamma s_P\right]\left(s_A + s_P\right) - \frac{(g_P)^2}{2} - \frac{(s_P)^2}{2}$$

As shown in the appendix, the equilibrium human capital investments by the principal are given by:

$$g_P^* = 0 \tag{11}$$

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$$s_P^* = Max \left\{ 0, \frac{-\left[2\gamma^2 R - \gamma^2 - 1 \right]}{1 + 2\gamma - \gamma^2} \right\} \tag{12}$$

Proposition 5 : *In the innovation environment with simultaneous human capital invest-ments, there exists a threshold for the entrepreneurial income, $\bar{R} = \dfrac{1 + \gamma^2}{2\gamma^2}$, such that*

(i) The principal invests in the agent's specific human capital when $R < \bar{R}$, where s_P^* is decreasing in R (i.e., $\dfrac{\partial s_P^*}{\partial R} < 0$),

(ii) The principal does not invest in the agent's specific human capital when $R \geq \bar{R}$, and

Moreover, the principal never invests in the agent's general human capital.

Figure 3 illustrates the relationship between the entrepreneurial income and the prin-cipal's human capital investments in simultaneous investment game:

[Figure 3 About Here]

The rationale behind this proposition is as follows: When investments are made simultaneously, the principal's first-mover advantage disappears. In other words, the principal cannot influence the agent's human capital investments. For that reason, the principal never invests in the agent's general human capital. On the other hand, both parties' expected payoffs are affected by their specific human capital investments. That is why the principal and the agent take each other's specific human capital investment into account when they make their investment decisions. The agent's specific human capital investment increases as

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the entrepreneurial income increases (i.e., $\frac{\partial s_A^*}{\partial R} > 0$). This reduces the principal's probability to retain the agent. Therefore, the principal reduces the specific human capital investment as the agent's return from entrepreneurship increases. If the return from entrepreneurship exceeds the threshold value, the agent's probability to innovate becomes sufficiently high so any investment by the principal only reduces her expected payoff. For that reason, the principal does not invest in the agent's specific human capital when $R \geq \bar{R}$.

5.2   General Human Capital and Probability of Innovation

The human capital model in section 4 assumed that the agent's probability to innovate is only a function of his specific human capital. In this section, I relax this assumption and use a probability function which increases in both general and specific human capital[11]:

$$p(\mathbf{g}, \mathbf{s}) = \gamma \mathbf{s} + \alpha \mathbf{g} = \gamma \left(s_A + s_P \right) + \alpha \left(g_A + g_P \right)$$

where $\alpha > 0$ is a parameter that measures the importance of general human capital for the agent's innovation.

I focus on the case where $\gamma > \alpha$ because the principal may still use general human capital investment as a strategic tool to retain the agent in the second period.[12]

At date 2, both parties receive their payoffs and the game ends.

At date 1, the agent observes the potential innovative idea. If he has an innovative idea, he chooses to become an entrepreneur and his payoff becomes R. If he does not have an innovative idea, he stays with the principal and his payoff becomes $f(\mathbf{g}^*)$.

At date 1/2, the agent chooses g_A and s_A to maximize his expected utility:

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[11] This type of probability function is also in line with the evidence presented in Hermann & Peine (2011).

[12] If $\alpha > \gamma > 0$, the principal would never invest in the agent's general human capital. Furthermore, the agent's willingness to invest in firm-specific human capital would also reduce. This stems from the fact that general human capital investment increases both his employment wage and his probability to innovate.

$$Max\ U_I =$$

$$[\gamma\,(s_A + s_P) + \alpha\,(g_A + g_P)]\,R + [1 - \gamma\,(s_A + s_P) - \alpha\,(g_A + g_P)]\,(g_A + g_P) - \frac{(g_A)^2}{2} - \frac{(s_A)^2}{2}$$

As I show in the appendix, the equilibrium human capital investments by the agent are given by:

$$g_A^* = \frac{1 + R\left(\alpha - \gamma^2\right) - \gamma s_P + \left(\gamma^2 - 2\alpha\right) g_P}{1 + 2\alpha - \gamma^2} \tag{13}$$

$$s_A^* = \frac{R\left(\gamma + \alpha\gamma\right) - \gamma + \gamma^2 s_P - \gamma g_P}{1 + 2\alpha - \gamma^2} \tag{14}$$

Proposition 6 *: Consider the innovation environment,*

(i) There exists a threshold for α, $\bar{\alpha} = \gamma^2$, such that the agent's general human capital investment is increasing in R when $\alpha > \bar{\alpha}$ (i.e., $\dfrac{\partial g_A}{\partial R} > 0$), and decreasing otherwise.

(ii) There exists another threshold for this marginal contribution, $\hat{\alpha} = \dfrac{\gamma^2}{2}$, such that the agent's general human capital investment is increasing in g_P^* for $\alpha < \hat{\alpha}$ (i.e., $\dfrac{\partial g_A}{\partial g_P} > 0$), and decreasing otherwise.

The first part of this proposition can intuitively be explained as follows: The agent's willingness to innovate increases with the rise in return from entrepreneurship (i.e., R). Even though investing in general human capital increases the agent's probability to innovate directly, this investment negatively affects his specific human capital investment. This

means general human capital investment reduces the agent's probability to innovate indirectly (through reducing s_A^*). If the positive effect of general human capital investment on innovation dominates the negative effect (i.e., $\alpha > \gamma^2$), the agent's probability to innovate increases in equilibrium so the agent invests more in his general human capital as R rises.

The intuition behind the second part of this proposition is also similar to the first part: The principal's general human capital investment increases the agent's probability to innovate. This means the agent's probability to stay in the firm reduces. For that reason, the agent reduces his general human capital investment. On the other hand, the principal's general human capital investment increases the employment wage so it reduces the relative attractiveness of entrepreneurship. As a result, the agent reduces his specific human capital investment. This makes it more likely that the agent stay in the firm, so his best response is to increase his general human capital investment. Therefore, the overall effect of g_P^* on g_A^* depends on α: If $\alpha > \hat{\alpha}$, the first effect dominates so the agent reduces g_A^*. If $\alpha < \hat{\alpha}$, the second effect dominates so the agent increases g_A^*.

At date 0, the principal chooses g_P and s_P to maximize her expected utility:

$$Max \ V_I = [1 - \gamma s_A\left(g_P, s_P\right) - \gamma s_P - \alpha g_A\left(g_P, s_P\right) - \alpha g_P]\left[s_A\left(g_P, s_P\right) + s_P\right] - \frac{(g_P)^2}{2} - \frac{(s_P)^2}{2}$$

At this point, I focus on the more interesting scenario where g_P^* becomes positive.

The only purpose of the principal's general human capital investment is to make the job more attractive for the agent so he is more likely to stay. However, as discussed in section 4, the principal uses general human capital investment as a last resort. In other words, the principal invests in the agent's general human capital only after her specific human capital investment reduces to zero.

Therefore, the principal chooses only g_P to maximize her expected utility:

$$Max\ V_I = [1 - \gamma s_A (g_P) - \alpha g_A (g_P) - \alpha g_P] [s_A (g_P)] - \frac{(g_P)^2}{2}$$

As I show in the appendix, the principal's equilibrium general human capital investment is given by:

$$g_P^* = Max \left\{ 0, \frac{\gamma \left[R \left(2\gamma^2 + \gamma^2 \alpha - \alpha \right) - \left(\gamma^2 + 1 \right) \right]}{\left(1 + 2\alpha - \gamma^2 \right)^2 + 2\gamma \left(\gamma^2 - \alpha \right)} \right\} \tag{15}$$

Proposition 7 : *Consider the innovation environment where both general and specific human capital investments positively affect the probability of innovation,*

(i) There exists a threshold for the entrepreneurial income, $\hat{R} = \dfrac{\left(1 + \gamma^2 \right)}{\left(2\gamma^2 + \gamma^2 \alpha - \alpha \right)}$, such that the principal does not invest in the agent's general human capital when $R < \hat{R}$. Otherwise, the principal invests in g_P^* and it is increasing in R (i.e., $\dfrac{\partial g_P}{\partial R} > 0$).

What this proposition shows can be explained as follows: The entrepreneurial income is the agent's reward for innovation. When this reward increases, the agent becomes more motivated to innovate. When the return from entrepreneurship exceeds $\hat{R}$, the agent's probability to stay becomes very low so the principal starts investing in the agent's general human capital to distract him from innovation.

Corollary 1: *As the marginal contribution of general human capital to the probability of innovation (i.e., α) increases, the threshold value for the entrepreneurial income (i.e., $\hat{R}$) increases and the equilibrium value of g_P^* decreases.*

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This corollary is easy to explain and it is self-evident: The principal's only benefit from general human capital investment is the decrease in the agent's probability to innovate (through reducing s_A^*). At the same time, general human capital investment increases the agent's probability to innovate directly. As α increases, the direct positive effect increases. This means the principal benefits less from general human capital investment. For that reason, the principal's willingness to invest in the agent's general human capital decreases as α increases.

6 Empirical Implications

This model yields several empirical predictions that provide interesting insights to human capital investments, wage structures, and employee mobility.

One of the main contributions of the model is that it explains why firms invest in their employees' general human capital. The model predicts that there is a positive relationship between firms' investment in general human capital and the employees' likelihood of staying with the firm. This prediction is in contrast with the standard human capital theory because it assumes that firms never capture any return to general human capital investment. This model argues that even though firms do not capture any return directly from general human capital investment, such investment increases the probability of retention and hence the probability of capturing the return to specific human capital. The prediction of higher retention rate is also supported by some recent empirical evidence. For example, Capelli (2004), Flaherty (2007), and Gicheva (2012) show that employer-financed general training (i.e., education) increases the employee retention rate.

Another empirical prediction of the model that is along the same line is that even though firms may reduce employee turnover by general human capital investment, the employees who leave such firms are more likely to become entrepreneurs. When the firm invests in the employee's general human capital, it increases the employee's (future) wage in the

firm because other firms also value this type of human capital. By offering a higher wage, the firm matches other firms' wage offers so the employee's probability to stay with the firm increases (see Coff, 1997; Benson, Finegold & Mohrman, 2004). However, if the employee starts a new venture, his entrepreneurial income can be higher than the firm's wage offer. For that reason, when the skilled (and better paid) employee leaves the firm, his probability to become an entrepreneur is higher than his probability to join another firm. In fact, the empirical evidence presented in Carnahan, Agarwal & Campbell (2012) support this prediction by showing that employee entrepreneurship is more plausible than employee departure if the employee is better paid in his current firm.

The third empirical prediction concerns the enforcement of non-compete clauses (henceforth NCC) as an alternative means to prevent employee departure. While NCCs are not enforceable in certain states (e.g. California), they are enforceable in others (e.g. Massachusetts). Because the employee can become an entrepreneur with the innovative idea he generated during his employment in this paper, the findings are more applicable to the states where NCCs are not enforceable. If, however, the firm is located in a state where NCCs are enforceable, employee entrepreneurship can be prevented with a contract so the firm can restructure its human capital investments. Firms in such states are expected to increase specific human capital investment and not to invest in general human capital. At the same time, employees in such states do not invest in specific human capital and they invest only in general human capital. The empirical evidence presented in Garmaise (2011) and Marx et al. (2009) support the prediction of higher (lower) specific human capital investment by firms (employees) in states where NCCs are enforceable.

The fourth empirical prediction of the model is about how the industry in which the firm competes affects human capital investments. Certain industries such as high-tech and bio-tech are more innovation oriented than others. In those industries, losing a skilled employee with an innovative idea can be more detrimental to firms. Thus, the importance of

employee retention is arguably higher in innovation oriented industries. For that reason, the model predicts higher general human capital investment by firms in those industries.

7   Conclusion

In this paper I develop a theoretical model that combines human capital investment, innovation, and entrepreneurship. The positive effect of human capital investment on employee productivity is widely-discussed and well-understood in the human capital literature since the seminal work of Becker (1962). However, the positive effect of human capital investment on employee innovativeness has not yet been studied. This paper investigates how firm's and employee's human capital investments change when employee can generate an innovative idea as a result of his acquired human capital and choose entrepreneurship over employment.

The cardinal factor that determines equilibrium human capital investments in this paper is the employee's return from entrepreneurship. Because specific human capital investment increases the employee's probability to innovate, any increase in return from entrepreneurship motivates the employee to invest more in his specific human capital. In contrast to that, the firm cuts down its own specific human capital investment in order to reduce the risk of employee departure. However, if the return from entrepreneurship exceeds a certain threshold, the employee invests even more in his specific human capital and his probability to innovate becomes substantially high. In such case, the firm chooses not to invest in the employee's specific human capital. In addition to that, the firm starts investing in the employee's general human capital. The purpose of this strategy is to decrease the relative attractiveness of entrepreneurship by increasing the employment wage. As a result, the employee reduces his specific human capital investment in equilibrium and the firm's probability to retain the employee increases. This is a novel finding which explains why firms may invest in their employees' general human capital.

Several important questions remained unanswered. For example, does empirical ev-

idence support general human capital investment by firms competing in highly innovative industries or firms located in areas with high new firm creation rates? How do firm's human capital investments change in a multi-agent environment especially when employees are heterogeneous in terms of productivity and ability to innovate? These are promising areas for future research which can provide additional insights on human capital investment.

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Appendices

Appendix 1: Human Capital Model with Innovation

Date 1/2:

$$Max \ U_I = \gamma \left(s_A + s_P\right) R + \left[1 - \gamma \left(s_A + s_P\right)\right] \left(g_A + g_P\right) - \frac{\left(g_A\right)^2}{2} - \frac{\left(s_A\right)^2}{2}$$

The first-order condition for s_A and g_A yield:

$$s_A^* = \gamma \left[R - \left(g_A + g_P\right)\right] \tag{1}$$

$$g_A^* = \left[1 - \gamma \left(s_A + s_P\right)\right] \tag{2}$$

Substituting s_A^* into g_A^* and g_A^* into s_A^* yield:

$$g_A^* = \frac{1 - \gamma^2 R - \gamma s_P + \gamma^2 g_P}{1 - \gamma^2} \tag{3}$$

$$s_A^* = \frac{\gamma \left(R - 1\right) + \gamma^2 s_P - \gamma g_P}{1 - \gamma^2} \tag{4}$$

Date 0:

$$Max \ V_I = \left[1 - \gamma s_A \left(g_P, s_P\right) - \gamma s_P\right] \left[s_A \left(g_P, s_P\right) + s_P\right] - \frac{\left(g_P\right)^2}{2} - \frac{\left(s_P\right)^2}{2}$$

The first-order condition for g_P yields:

$$\frac{\partial s_A}{\partial g_P}\left[1 - 2\gamma s_A - 2\gamma s_P\right] = g_P \tag{5}$$

where $\dfrac{\partial s_A}{\partial g_P} = \left(\dfrac{-\gamma}{1 - \gamma^2}\right)$.

$$\frac{2\gamma^2\left(s_A + s_P\right) - \gamma}{1 - \gamma^2} = g_P$$

Plugging equation 4 (i.e., s_A^*) into the equation above, we get:

$$\frac{2\gamma^2 s_P + 2\gamma^2\left(\dfrac{\gamma\left(R - 1\right) + \gamma^2 s_P - \gamma g_P}{1 - \gamma^2}\right) - \gamma}{1 - \gamma^2} = g_P$$

$$\left(2\gamma^2 s_P + 2\gamma^3 R - \gamma^3 - \gamma\right) = g_P\left[(1 - \gamma^2)^2 + 2\gamma^3\right]$$

Thus,

$$g_P^*(s_P) = Max\left\{0, \frac{\gamma\left[2\gamma^2 R - \gamma^2 - 1\right] + 2\gamma^2 s_P}{1 - 2\gamma^2 + 2\gamma^3 + \gamma^4}\right\}$$

The first-order condition for s_P yields:

$$\left[1 + \frac{\partial s_A}{\partial s_P}\right]\left[1 - 2\gamma s_A - 2\gamma s_P\right] = s_P \tag{6}$$

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where $\dfrac{\partial s_A}{\partial s_P} = \left[1 + \dfrac{\gamma^2}{1 - \gamma^2}\right].$

$$1 - 2\gamma s_A = s_P(1 - \gamma^2 + 2\gamma)$$

Plugging equation 4 (i.e., s_A^*) into the equation above, we get:

$$1 - 2\gamma\left(\frac{\gamma(R-1) + \gamma^2 s_P - \gamma g_P}{1 - \gamma^2}\right) = s_P(1 - \gamma^2 + 2\gamma)$$

$$s_P^* = Max\left\{0, \frac{-\left[2\gamma^2 R - \gamma^2 - 1\right] + 2\gamma^2 g_P}{1 + 2\gamma - 2\gamma^2 + \gamma^4}\right\}$$

Because g_P^* and s_P^* are functions of each other, we plug them into each other:

$$s_P^* = \frac{-\left[2\gamma^2 R - \gamma^2 - 1\right] + 2\gamma^2\left\{\dfrac{\gamma\left[2\gamma^2 R - \gamma^2 - 1\right] + 2\gamma^2 s_P}{1 - 2\gamma^2 + 2\gamma^3 + \gamma^4}\right\}}{1 + 2\gamma - 2\gamma^2 + \gamma^4}$$

As $s_P^* \geq 0$, we find:

$$s_P^* = Max\left\{0, \frac{-\left[2\gamma^2 R - \gamma^2 - 1\right]}{1 + 2\gamma - 2\gamma^2 + 2\gamma^3 + \gamma^4}\right\} \tag{7}$$

$$g_P^* = \frac{\gamma\left[2\gamma^2 R - \gamma^2 - 1\right] + 2\gamma^2\left\{\dfrac{-\left[2\gamma^2 R - \gamma^2 - 1\right]}{1 + 2\gamma - 2\gamma^2 + 2\gamma^3 + \gamma^4}\right\}}{1 - 2\gamma^2 + 2\gamma^3 + \gamma^4}$$

Because $g_P^* \geq 0$, we have:

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$$g_P^* = Max \left\{ 0, \frac{\gamma \left[2\gamma^2 R - \gamma^2 - 1 \right]}{1 + 2\gamma - 2\gamma^2 + 2\gamma^3 + \gamma^4} \right\} \tag{8}$$

Proof of Proposition 4: The denominator of both s_P^* and g_P^* are positive for $\forall \gamma > 0$. Thus, the positivity of s_P^* and g_P^* hinges upon the numerator in both human capital investments. As one can easily see from equations 5 and 6, the term that will determine the value of s_P^* and g_P^* is the term in the square bracket.

$$\left[2\gamma^2 R - \gamma^2 - 1 \right] \gtrless 0$$

$$R \gtrless \frac{1 + \gamma^2}{2\gamma^2} = \bar{R}$$

If $R < \bar{R}$, then $g_P^* = 0$ and $s_P^* > 0$ in equilibrium.

If $R = \bar{R}$, then $g_P^* = 0$ and $s_P^* = 0$ in equilibrium.

If $R > \bar{R}$, then $g_P^* > 0$ and $s_P^* = 0$ in equilibrium.

Appendix 2: The Simultaneous Human Capital Investments

Date 0 (Agent's utility):

$$Max \ U_I = \gamma \left(s_A + s_P \right) R + \left[1 - \gamma \left(s_A + s_P \right) \right] \left(g_A + g_P \right) - \frac{\left(g_A \right)^2}{2} - \frac{\left(s_A \right)^2}{2}$$

The first-order condition for s_A and g_A yield:

$$g_A^* = \left[1 - \gamma \left(s_A + s_P \right) \right]$$

$$s_A^* = \gamma \left[R - \left(g_A + g_P \right) \right]$$

Substituting s_A^* into g_A^* and g_A^* into s_A^* yield:

$$g_A^* = \frac{1 - \gamma^2 R - \gamma s_P + \gamma^2 g_P}{1 - \gamma^2} \tag{9}$$

$$s_A^* = \frac{\gamma (R - 1) + \gamma^2 s_P - \gamma g_P}{1 - \gamma^2} \tag{10}$$

Date 0 (Principal's utility):

$$Max \ V_I = [1 - \gamma s_A - \gamma s_P] (s_A + s_P) - \frac{(g_P)^2}{2} - \frac{(s_P)^2}{2}$$

The first-order condition for g_P yields:

$$\frac{\partial V_I}{\partial g_P} = g_P^* = 0 \tag{11}$$

The first-order condition for s_P yields:

$$s_P(s_A) = \frac{1 - 2\gamma s_A}{1 + 2\gamma}$$

Plugging equation 10 (i.e., s_A^*) into the equation above, we get:

$$s_P = \frac{1 - 2\gamma \left[\dfrac{\gamma(R-1) + \gamma^2 s_P}{1 - \gamma^2} \right]}{1 + 2\gamma}$$

$$s_P^* = Max \left\{ 0, \frac{-\left[2\gamma^2 R - \gamma^2 - 1\right]}{1 + 2\gamma - \gamma^2} \right\} \tag{12}$$

Proof of Proposition 5: Since the denominator of s_P^* is positive for $\forall \gamma \in (0, 2.414]$, what determines the positivity of s_P^* is the numerator of equation 10. If the square bracket term is negative, then s_P^* will be positive in equilibrium. Otherwise, s_P^* will be zero in equilibrium.

$$s_P^* = 0 \ \ \text{if} \ \ \left[2\gamma^2 R - \gamma^2 - 1\right] > 0$$

$$R \geq \frac{1 + \gamma^2}{2\gamma^2} = \bar{R}$$

Thus, when $R > \bar{R}$, then both $g_P^* = 0$ and $s_P^* = 0$ in equilibrium.

Appendix 3: General Human Capital and Probability of Innovation Model

Date 1/2:

$$Max \ U_I =$$
$$[\gamma(s_A + s_P) + \alpha(g_A + g_P)]R + [1 - \gamma(s_A + s_P) - \alpha(g_A + g_P)](g_A + g_P) - \frac{(g_A)^2}{2} - \frac{(s_A)^2}{2}$$

The first-order condition for s_A and g_A yield:

$$g_A = \frac{\alpha R + 1 - \gamma (s_A + s_P) - 2\alpha g_P}{1 + 2\alpha}$$

$$s_A = \gamma R - \gamma (g_A + g_P)$$

Substituting s_A^* into g_A^* and g_A^* into s_A^* yield:

$$g_A^* = \frac{\alpha R + 1 - \gamma s_P - \gamma \left[\gamma R - \gamma (g_A + g_P)\right] - 2\alpha g_P}{1 + 2\alpha}$$

$$g_A^* = \frac{1 + R \left(\alpha - \gamma^2\right) - \gamma s_P + \left(\gamma^2 - 2\alpha\right) g_P}{1 + 2\alpha - \gamma^2} \tag{13}$$

$$s_A = \gamma R - \gamma g_A - \gamma g_P = \gamma R - \gamma g_P - \gamma \left[\frac{1 + R \left(\alpha - \gamma^2\right) - \gamma s_P + \left(\gamma^2 - 2\alpha\right) g_P}{1 + 2\alpha - \gamma^2}\right]$$

$$s_A^* = \frac{R \left(\gamma + \alpha\gamma\right) - \gamma + \gamma^2 s_P - \gamma g_P}{1 + 2\alpha - \gamma^2} \tag{14}$$

Proof of Proposition 6: The denominator of both s_A^* and g_A^* are positive for $\forall \gamma \leq 1$ and $\forall \alpha > 0$. Thus, the positivity or negativity of the derivations depends on the numerator.

$$\frac{\partial g_A^*}{\partial R} = \frac{\alpha - \gamma^2}{1 + 2\alpha - \gamma^2} \lessgtr 0$$

If $\alpha > \gamma^2$, g_A^* increases as R increases.

If $\alpha < \gamma^2$, g_A^* decreases as R increases.

$$\frac{\partial g_A^*}{\partial g_P^*} = \frac{\gamma^2 - 2\alpha}{1 + 2\alpha - \gamma^2} \lessgtr 0$$

If $\alpha < \gamma^2/2$, g_A^* increases as g_P^* increases.

If $\alpha > \gamma^2/2$, g_A^* decreases as g_P^* increases.

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Since the focus is on when the principal finances general human capital investment, we assume that $s_P^* = 0$ in this section. This assumption stems from the finding in section 4: The principal reduces specific human capital investment first and then she starts investing in general human capital as further distraction if needed.

$$Max \ V_I = [1 - \gamma s_A(g_P) - \alpha g_A(g_P) - \alpha g_P][s_A(g_P)] - \frac{(g_P)^2}{2}$$

The first-order condition for g_P yields:

$$\frac{\partial s_A}{\partial g_P}[1 - \gamma s_A - \alpha g_A - \alpha g_P] - s_A\left[\gamma\frac{\partial s_A}{\partial g_P} + \alpha\frac{\partial g_A}{\partial g_P} + \alpha\right] = g_P$$

where $\dfrac{\partial s_A}{\partial g_P} = \left(\dfrac{-\gamma}{1 + 2\alpha - \gamma^2}\right)$ and $\dfrac{\partial g_A}{\partial g_P} = \left(\dfrac{\gamma^2 - 2\alpha}{1 + 2\alpha - \gamma^2}\right)$.

$$\left(\frac{-\gamma}{1 + 2\alpha - \gamma^2}\right)[1 - \gamma s_A - \alpha g_A] + s_A\left[\frac{\gamma^2 - \alpha}{1 + 2\alpha - \gamma^2}\right] = g_P\left[1 - \frac{\gamma\alpha}{1 + 2\alpha - \gamma^2}\right]$$

$$\left(2\gamma^2 - \alpha\right)s_A + \gamma\alpha g_A - \gamma = g_P\left(1 + 2\alpha - \gamma^2 - \gamma\alpha\right)$$

In this stage, when we plug equation 13 and 14 (i.e., the equilibrium values of g_A^* and s_A^*) into the equation above, we get:

$$\left(2\gamma^2 - \alpha\right)\left[\frac{R(\gamma + \alpha\gamma) - \gamma - \gamma g_P}{1 + 2\alpha - \gamma^2}\right] + \gamma\alpha\left[\frac{1 + R(\alpha - \gamma^2) - (\gamma^2 - 2\alpha)g_P}{1 + 2\alpha - \gamma^2}\right] - \gamma$$

$$= g_P\left(1 + 2\alpha - \gamma^2 - \gamma\alpha\right)$$

$$R\left[2\gamma^3 + \gamma^3\alpha - \gamma\alpha\right] - \gamma^3 - \gamma = g_P\left[\left(1 + 2\alpha - \gamma^2\right)^2 + 2\gamma\left(\gamma^2 - \alpha\right)\right]$$

$$g_P^* = Max\left\{0, \frac{\gamma\left[R\left(2\gamma^2 + \gamma^2\alpha - \alpha\right) - \left(\gamma^2 + 1\right)\right]}{\left(1 + 2\alpha - \gamma^2\right)^2 + 2\gamma\left(\gamma^2 - \alpha\right)}\right\} \tag{15}$$

Proof of Proposition 7: As long as the numerator is positive, general human capital investment by the principal will be positive in equilibrium as well. This means the square bracket in the numerator must be positive for g_P^* to be positive in equilibrium.

$$R\left(2\gamma^2 + \gamma^2\alpha - \alpha\right) > \left(\gamma^2 + 1\right)$$

$$R > \frac{\left(1 + \gamma^2\right)}{\left(2\gamma^2 + \gamma^2\alpha - \alpha\right)} = \hat{R}$$

If $\alpha = 0$, the positivity condition becomes identical to the main model's positivity condition (i.e., $\bar{R} = \hat{R}$).
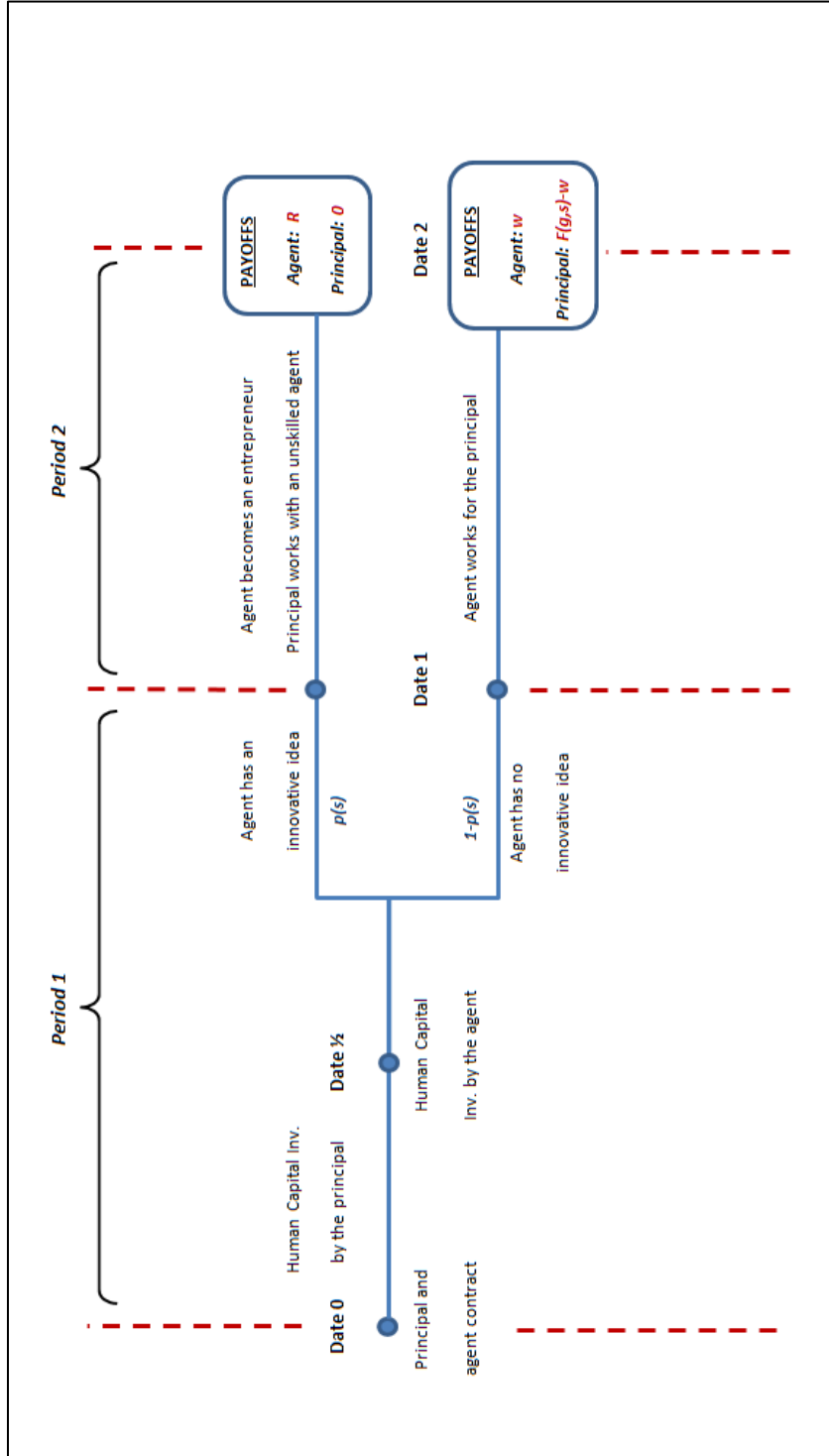
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Figures

Figure 1: Time Chart of the Game

Figure 2: Human Capital Investments by the Principal in Sequential Game
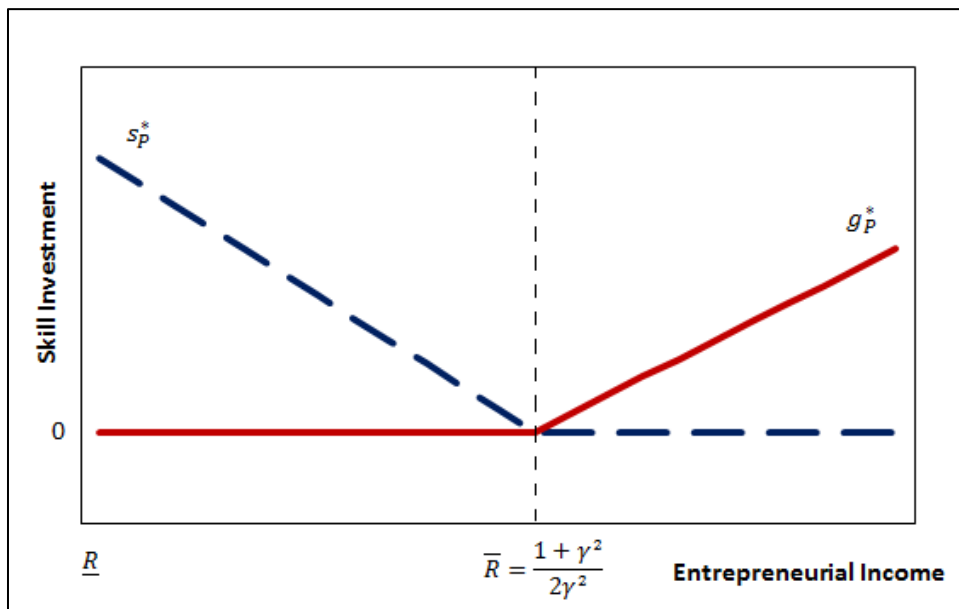

Figure 3: Human Capital Investments by the Principal in Simultaneous Game