# A Reciprocity Model of Innovation in Teams: An Agent's Choice

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**Abstract**

Several theories have been offered by economists on how innovation drives technological growth. Macroeconomics considers innovation mostly as an exogenous growth factor and, less frequently, as endogenous technology that is developed under contract. It sees only the aggregate outcome of agents inventing in response to market incentives; it does not see the actions of an agent. Agents function in a micro-environment. Economics sees the innovating process in R&D facilities where agents are specifically contracted to invent. Agents of neoclassical economic theories contracting for non-R&D functions won't innovate because innovation is beyond the contract. Un-contracted innovating is a loss to the agent. However, whether an agent innovates is dependent on more than financial incentives and alternate opportunities. Here I introduce a model that captures additional incentives the agent considers when choosing whether to innovate in a particular firm; agents have non-monetary utility concerns as well.

It is possible to motivate agents to share their knowledge without financial incentives, i.e. Wikipedia. The model in this paper allows an agent to calculate whether to stay with the firm and innovate or start her own company. It also provides a useful model to firms to see at what point an innovating agent will leave the firm.

## Introduction

Most studies about the firm are "firm-centric" in that the decision the principal and the agent makes is described based on the perspective of the firm. The problems is that of moral hazard in which the agent offers to expend effort $e$ in exchange for contract wages $w$ but provides effort $e-\delta$, $\delta > 0$. The principal, knowing this, spends a great deal of money on monitoring to ensure that the agent performs according to contract. However, even if the agent performs according to contract every task, if the firm is in equilibrium market, the firm cannot grow unless something changes exogenously to the firm.

In equilibrium market the firm sells exactly as much as what is demanded and the only way it can make additional profit if it can reduce the cost of its supplies, increase its product quality, or if the market shifts and tastes change. However, given that the agent performs as contracted, quality improvement is not possible—the agent works at the maximum quality level she is willing to provide for the particular contract. Although cost reduction for supplies is possible, such cost-reduction is available for the firm's competition, equalizing the market once more.

Furthermore, assume a firm in the knowledge industry, such as Microsoft. In a company like this, the supply is the education-level and knowledge of the employees. The cost reduction of this supply is not to the advantage of the firm. The economically most advantages way this type of firm may decrease the costs of its supply is by getting more value from each already contracted employee. Classical economic theories suggest that the employee is contracted to a particular effort level, and unless additional monetary incentives are offered, the agent will not innovate. Hence this type of firm could not grow, which is in conflict with real life experience.

Wikipedia, for example, is an Internet-based free encyclopedia that is created by the people for the people. All work on Wikipedia is un-contracted, unpaid, and voluntary but it offers non-financial agent-utility incentives, such as fame, pride, accomplishment, and satisfaction. It is an inexhaustible public good that is created by the innovative processes of individuals who have the knowledge to share and are willing to share it without contract. Wikipedia improves the working processes of everyone who uses it. As Wikipedia provides an un-contracted good, free-riding is not within its scope. It provides measurable growth both at micro and macro-level. Wikipedia shows us that it is possible to motivate agents to share their knowledge without financial incentives.

Experiments show that the agents' assessment of their happiness can be influenced. For example, researchers asked subjects to fill out surveys about their general state of happiness but first they were asked to photocopy something for the researcher. About half of the agents found a coin on top of the copy machine and the other half did not. Those agents who found a coin reported to be significantly happier than those agents who did not (Schwarz, 1987, as reported by (1)). Subjects' behavior is influenced by their moods, the weather (2), hormonal fluctuations (3-6), and their gender (7). A key element of agent-behavior is the level of trust the agent feels in his or her environment. Trust has shown to be important in how wealthy nations are (8).

A firm has two types of supplies: tangible and intangible. Raw materials, human head-count, and equipment for widget manufacturing are tangible; employee-knowledge is intangible. Tangible supplies are tradable and replaceable and neither provide inimitable benefits nor unique advantage to the firm. In equilibrium widget markets, so long as agents perform to contracted level, the firm stands still with only tangible supplies because those are available to all of its competitors. The firm's biggest asset is in its intangible capital of agent-knowledge that is not contracted but can be provided by the agents for the right incentive. How does a firm encourage its agents to share their un-contracted knowledge?

There are two types of knowledge-sharing in firms: R&D and non-R&D. In R&D's employees contract to "manufacture knowledge" and so this is equivalent to contracting to "manufacture widgets," only the output is different. In an R&D knowledge-manufacturing is tangible because it is a planned and contracted action. The type of innovation this paper discusses is not made in R&D's; it is neither planned to be innovated, nor contracted; it is voluntary.

Agent behavior literature describes innovation as increased sales (9), work in R&D's (10), or spinouts (11-14). Spinouts are formed by agents that often take the existing knowledge of the firm before the firm is able to implement it or when there is a disagreement between the management whether a particular product should be developed. When an agent forms a spinout, by definition the agent has left the firm. Some innovations are small and don't make it as spinouts because the value of the innovation is too small to stand alone. This innovation is harder to predict than an impending spinout because it is hidden and the agents won't advance the knowledge if the inter-firm environment does not have an appropriate "climate" for knowledge-sharing. This paper addresses the time *before* the agent leaves.

I base my principal argument of agent behavior on experimental findings in the ultimatum game (6, 15-19), public good games (20-23), trust games (3, 5, 24), and other behavioral and neuroeconomics experiments that show that human agents use feelings and emotions (21, 25-30) in their decision-making with non-monetary utility considerations (27, 31). This paper updates a model developed by Paul Romer (10) and improved by Ramon Marimon and Vincenzo Quadrini (2006).

### Agent – in Neoclassical Economic Theories

Neoclassical economics sees the agent as a "unit of labor force" who chooses a particular effort level for each contract, noted as high-effort $e_h$ and low-effort $e_l$. An important aspect of the principal-agent theory is that "effort" *per se* is neither visible nor contractible and thus it should fall outside of the theory of economics as it is neither measurable nor predictable. The level of effort an agent will use is calculated using probability and backward induction; it cannot be optimized per se. Effort is more approachable through behavioral and experimental economic methods and it becomes contractible when human relations of reciprocity are considered, particularly in repeated interactions (21). As agents expect benefits for everything they do for the firm, informal institutions and local cultural norms enforce the particular relationship that is between the firm and the agent as well as among the agents who work for the firm. It benefits the firm to create indebtedness and accountability in its agents by creating an environment that begets reciprocity. An environment in which reputation matters (32, 33), where punishment is an option that team members may use to enforce cooperation (34-36), and where trust begets trustworthy behavior, *effort* becomes contractible and predictable (8).

### Concepts of Knowledge, Innovation, and the Firm

The firm does not own the knowledge of its employees. Yet this knowledge is what makes the firm grow. How can something that does not belong to the firm make the firm experience growth it can later measure? Resource-based views of the firm see the agent as resource but increasing human capital alone does not imply "growth" *per se*. Indeed, firms periodically reduce their human capital by reorganizing, reengineering, or redesigning the firm and laying people off.

In some human capital models, knowledge becomes analogous to the skills of human capital; skills that are measurable by years of education and other similar factors (37). However, skill alone does not become a firm asset. An agent may contract below her skill as skill is not visible. Secondly, an agent may contract for a particular skill and associated effort but, as principal-agent theory suggests, may not use her skills as contracted. Thus skill-level is not convertible to effort-level and so skill is not convertible to firm growth.

There is no model that is able to predict under what condition an agent might *want* to innovate without contract. This "want" to innovate is analogous to an agent giving her innovation to the firm in exchange for some future yet un-contracted benefit. What motivates exempt salaried employees who don't earn any pay for overtime to work overtime (38)?

**The Human Agent**

An agent has choices in her life. One of these choices is whether she wants to work for a firm or work as a sole proprietor. The external market presents risks, ambiguity, and tradeoffs for agents who choose to be sole proprietors. Agents who choose to work for a firm are shielded from market risks and ambiguities and have alternate opportunities, including the choice of working for another firm or start a sole proprietorship. A sole proprietor agent may join a firm.

**Risk**: in economic theories, an agent knows the distribution of the external market conditions and all her alternatives. When a human agent "knows" the particular market probability of success, it is based on her belief. Choosing to be a sole proprietor has significant risks, ambiguity, and costs of investment associated with it.

An agent working for a firm is typically considered to be risk averse and the principal is risk neutral. In this paper, I am analyzing a single agent who must choose to either be an employee, i.e. risk averse, or become a sole proprietor (principal), i.e. risk neutral. An agent's aversion to risk changes over time (18, 39).

Market risk varies between [0, 1]. Having risk equal to 0 implies working in an absolute non-risk environment, a guaranteed success, which is a trivial corner solution. Risk of 1 implies certain failure, which is also a trivial corner solution. Therefore, the range of interest for this paper is restricted to when the risk is believed to be between (0, 1) by the agent.

**Effort level:** In the principal-agent definition the agent chooses between her effort levels and contracts accordingly. In the model developed here, the agent chooses her effort level differently. She chooses between two working options (firm or sole proprietor) based on the costs of her effort she estimates given the type of effort that she has already spent in collecting her knowledge. The effort that is left to be chosen is specific to the implementation of her innovation. Because her knowledge-to-be-shared is equivalent in the firm to what it is in the sole proprietorship, her effort with respect to the firm or sole proprietor are the same[1].

An innovation is a "unit" that cannot be split; the agent either innovates, in which case effort is specific to the innovation size and quality, or she does not innovate, in which case the effort is considered to be zero. Although the agent might not choose to share knowledge and her innovation-effort is zero, she still works for the firm producing widgets, for which she chooses whatever effort she wishes. The production of widgets is not part of this paper.

We know from the US Census Bureau's records[2] that at any given time approximately 13% of all US firms (0.34% of the working force) are sole proprietors (1992 to 2003 data) and that market forces significantly affect the number of sole proprietors. During the high-tech boom

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[1] Put in another way, she uses the same effort $w_{firm} - e = w_{sole} - e$, where $w_{firm}$ the wages earned and $w_{sole}$ is the gross profit of the sole proprietor and $e$ is the effort expended. For the firm to keep her the following must be true: $w_{firm} - e \geq w_{sole} - e \Leftrightarrow w_{firm} - w_{sole} \geq 0$; thus, she must earn $w_{firm} - w_{sole} \geq \overline{w}$ where $\overline{w} > 0$.

[2] http://www.census.gov/csd/susb/susb03.htm

in Silicon Valley, many people left firms and started their own sole proprietorships, only to return to firms after the market crashed. Since many firms are not able to keep their innovating agents, it is useful to find what the agent's considerations are in making the decision to leave or stay. If the firm could keep the agent from selling her innovations in the market—which the firm must later purchase license to for use—the firm would become richer.

Thus the problem for the firm is to find the optimal level of incentives given that the agent has monetary and non-monetary considerations; the problem for the agent is to minimize the cost of effort given the environment. Based on behavioral and experimental economics research, we find that if the agent is in the company of uncooperative or incompetent team members, her innovation may become too costly and she may choose to mimic others and not innovate (27).

**The Properties of trust:** It has been suggested that "trust" is a discrete property of a person; trust is intimate and only applies to family and friends and trust toward strangers is calculated risk (40). This immediately raises several questions of which one is particularly interesting. It has been demonstrated that people trust strangers with "emotional" rather than a cognitive stance (3, 41-44). Furthermore, trust has been shown to be continuous (8) implying that if trust is "trust" with kin but "risk" with strangers then risk and trust are one and the same but of different intensity. Interestingly, recent research using the neurotransmitter oxytocin[3] shows that oxytocin enhances trust toward strangers but not toward a partner (kin) (6). This preliminary finding suggests that the human brain evaluates trust toward strangers differently from trust toward kin, suggesting that trust is at the maximum toward kin but toward strangers it can be increased.

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[3] Oxytocin is a hormone that is always present in the human brain in varying levels based on environmental stimuli; oxytocin is the biochemical marker of trust

**Teams:** Firms minimize their costs and maximize their outputs in a variety of ways. One way is creating formal teams. Formal teams are created by taking a single expert from each department associated with the design or production of a particular widget to form the *project team*. Project teams are not hierarchical. As there is only one agent per specialty, each agent has monopoly over his or her knowledge.

**Games in Experiments:** While self-serving *Homo economicus* in game theory defects in one-shot games, in life people cooperate even in one-shot blinded games (29, 45, 46, 46). This is shown in playing the public goods game (46), prisoners' dilemma (41), trust game (41) and the ultimatum and dictator games (3, 6, 24, 47). In each of these games, one or more prosocial behaviors, such as reciprocity, cooperation, and generosity play key roles. People obey cultural norms and participate rather than defect most of the time, particularly if punishment option is available, as in the ultimatum or public goods game (3, 43, 46, 48-55).

**Alternatives:** The moment a "unit" of knowledge is shared, the agent has no property rights to the innovation and receives only a one-time lump-sum pay that is shared by all team members. There is a risk associated with lack of trust; for example, the agent may share her un-contracted knowledge and the firm may forgo compensating for the effort. As released knowledge is not retractable, the firm may gain significant benefit without reciprocating. As innovation is not contracted, the agent finds out what reward she is receiving after she shared her knowledge. Another scenario might be that the agent shares her knowledge with her colleagues who turn on her and claim the knowledge as theirs. And finally, since the reward for the innovation goes to the team rather than to the innovator alone, which the team splits in some fashion among the members, those who did not innovate also receive share from the reward.

Research shows that reciprocity can become an incentive (56). The wealth of a country is dependent upon trust among its people (8, 57). Trust between members of the team is the probability of having reciprocity among them and is denoted by $\vartheta \in [0, 1]$. Since having no trust at all and complete trust are both uninteresting endpoints, the range of trust is restricted between (0, 1). The agent maximizes her utility with respect to the level of trust and reciprocity she believes exists in the team; this is denoted $p_{firm}$. The probability of the agent's chances of success outside the firm is denoted $p_{sole}$ and is bounded by (0, 1), as probability of 0 and 1 are both uninteresting corner solutions. This allows for the ratio to be taken: $\bar{p} = \frac{p_{firm}}{p_{sole}}$.

An important variable in the agent's cost of effort is the competence of the team members, which is denoted $\gamma \geq 1$. Competence implies that team members have similar levels of education, cultural experiences, and share mental models. In a team with highly competent members who have similar cultural backgrounds, the sum of two heads working together provides greater value than the sum of the same two heads working separately (58). Note that $\gamma \geq 1$, implying that the innovating agent's competence is 1; any team with the number of members $n > 1$ must have a competence factor of at least 1. Although agents in formal teams have similar levels of education, teams are typically culturally diverse and members may not share mental models; $\gamma$ is culture and education specific. The number of agents in the team is $n \geq 1$. The agent's cost of effort is captured by the following equation:

$$\boldsymbol{e_t} = \frac{\boldsymbol{n_t}\,\overline{\boldsymbol{p_t}}}{\boldsymbol{\gamma_t}\,\boldsymbol{\vartheta_t}} \tag{1}$$

The *t* subscript implies that innovation effort is time variant. If the agent chooses to not share her knowledge and becomes sole proprietor, she can sell her knowledge (patent and license it) and will have monopoly power until the patent rights expire. Being a sole proprietor comes with risks and costs: the costs of patenting and the risks and ambiguity associated with the market acceptance of this innovation. A sole proprietor agent has no protection. Administrative costs and costs of dealing with different levels of bureaucracy are denoted by $\tau$ and are treated as dead weight loss.

**Options:** Punishment is an effective form of participation enforcement and agents may punish by excluding non-reciprocating agents from future projects (59, 59-61). Agents who are not welcomed in project teams may lose their jobs. Since each project only lasts for one period and new projects potentially have the same agents in them, shirking affects reputation; shirking becomes negligible.

Imagine an agent *i* in this team. Agent *i* has some knowledge to share that could improve a process by reducing time, costs, or innovating a new process for a particular project. The agent has four choices: (1) Keep silent and not improve the project—the firm remains oblivious to additional value and stays at the same technology platform; (2) Offer her knowledge altruistically (without reward)—this is in firms of kin-relation; (3) Leave the firm; (4) Sell her innovation to the firm. Option (4) is a pursued ideal by all firms. In this paper the attention is on options (3) and (4).

**The Agent's Decision**

Trust and future reciprocity of reward sharing are of paramount concerns of agent in knowledge-sharing (30, 31, 56, 58, 62, 63). Trust and social history increase reciprocity; reciprocity is the strongest predictor of trust (43, 64). Norms of positive reciprocity often create trust among strangers in one-shot transactions (65).

Consider an agent choosing option (4) where gains from projects are rewarded to the team, which the members share in some fashion. This means that if agent *i* innovates, agent *j* of a two-member team receives some part of the reward without innovating. Agent $i$ will form expectation that agent $j$ will innovate at some future time, from which agent $i$ will receive reward without effort. This expectation compensates agent $i$ for sharing her innovation-reward now with agent $j$ because later she will receive rewards without participating.

Thus agent $i$'s cost of effort is directly affected by the expectation of future reciprocity by others. "Reciprocity … is the foundation of our uniqueness as creatures of social exchange, which we extended to include trade with nonkin and nontribal members" (66). "The higher the probability that you can be identified by your counterpart, the higher the probability that you will give to your counterpart an amount consistent with a social norm of reciprocity" (67). Because cooperation between team members is visible, project teams enforce reciprocity.

Proximate trust levels are assessable through formal and informal cultural norms (8, 68). Trusting in other agents' reciprocation is necessary for an agent to make the first move and share knowledge (69-71).

**Production Function with the Likelihood of Innovation**

There are two types of agents: investors (firms) and innovators. Innovators are in short supply relative to investors; each innovator is able to secure investor support[4]. As each unit of knowledge is unique and independent, we look at a one period change $t = 0,1$[5]. The innovator owns knowledge capital $h_t$. The firm's general widget pre-innovation production function is $y_0 = l_0^{1-\omega} k_0^{\omega}$ and $k_0$ is capital.

[4] Marimon and Quadrini (M-Q) formulated a production model that provides the base for the model developed here (72).
[5] We have Walrasian equilibrium market for innovators; Marshallian models cannot provide insight to demand and prices in the field of innovation. In other words, given that each innovation is unique, seeing the price of one innovation does not hint at the price of another innovation even of same magnitude and in the same industry; each innovation is unique and independent.

Technology changes as the firm adopts updated technologies. There is a likelihood that an agent will improve the technology but the actual innovation time is not known by the firm until the agent innovated. At that point the firm moves the production to this new technology level and the widget production will be $y_1 = l_1^{1-\alpha} k_1^{\alpha}$. Let variable $\beta$ represent the agent's likelihood of innovation, where β is dependent upon the agent's cost of effort for the innovation. The complete production function for the firm is then made up of two functions: widget production based on existing technology or widget production with new technology:

$$\bar{\boldsymbol{y}} = (\mathbf{1} - \boldsymbol{\beta})\binom{\mathbf{0}}{\mathbf{1}} \boldsymbol{l}_{\mathbf{0}}^{\mathbf{1}-\boldsymbol{\omega}} \boldsymbol{k}_{\mathbf{0}}^{\boldsymbol{\omega}} + \boldsymbol{\beta}\binom{\mathbf{0}}{\mathbf{1}} \boldsymbol{l}_{\mathbf{1}}^{\mathbf{1}-\boldsymbol{\alpha}} \boldsymbol{k}_{\mathbf{1}}^{\boldsymbol{\alpha}} \tag{2}$$

$\beta$ is either 0 or 1 based on the decision of the agent. If the agent innovates, $\beta$ is 1, which activates the second term but cancels the first as the firm moves to a new level of technology. $\bar{y}$ implies that either $y_0 or\ y_1$ may be the outcome of the agent's choice. New knowledge must increase the value of the production such that $y_1 \geq y_0$ for every type of agent-innovation[6]. Capital obsolescence increases with the degree of innovation (72)[7]. Capital depreciation rate also increases with the size of the innovation $\delta_t = \delta(\frac{z_{t+1}}{z_t})$[8]. I keep M-Q notation for simplicity and label the investment in knowledge $h_t$.

$$\bar{\boldsymbol{y}}_{\boldsymbol{t}} = (\mathbf{1} - \boldsymbol{\beta})\binom{\mathbf{0}}{\mathbf{1}} \boldsymbol{h}_{\boldsymbol{t}}^{\mathbf{1}-\boldsymbol{\omega}} \boldsymbol{k}_{\boldsymbol{t}}^{\boldsymbol{\omega}} + \boldsymbol{\beta}\binom{\mathbf{0}}{\mathbf{1}} \boldsymbol{h}_{\boldsymbol{t}+\mathbf{1}}^{\mathbf{1}-\boldsymbol{\alpha}} \boldsymbol{k}_{\boldsymbol{t}+\mathbf{1}}^{\boldsymbol{\alpha}} \tag{2a}$$

Investment in knowledge flows from $h_t \Rightarrow h_{t+1}$, given that $h_{t+1} > h_t$, this can be written as $h_{t+1} - h_t > 0$. The economy-wide knowledge is $H_t$ and is assumed to be known by the agent. The

[6] This is because innovation that is built on the previous levels of innovation is discounted in its value. Physical capital is technology specific. When the firm innovates, only part of the existing capital is usable for technology.
[7] This implies that technological obsolescence increases with the degree of capital investment, because if capital is assumed to be the singular driver of technology; with more capital available to invest, higher levels of technology will be produced regardless of other factors, such as the agents' willingness to innovate.
[8] This can be stated inversely as well: the depreciation rate of new technology is assumed to increase with the amount of capital invested, based on parallel example in the previous lines. Although M-Q's model assumes capital investment to be a one-way street toward innovation, in actuality it is not. If more capital leads to higher levels of innovation, as each level of new innovation depreciates the old, this forces the need for more capital.

agent's effort cost function is denoted by $e_t = \varphi(h_t, h_{t+1}; H_t)$.[9] There is an asymmetry between incumbent firms and newcomers with respect to capital investment. The capital of incumbent firms depreciates with the adoption of newer technologies. New firms, on the other hand, have no capital investment in older technologies. Recent research indicates that process innovation is more detrimental to firm success than product innovation but time and size matters; new and small firms should spend time product innovating and larger and older firms process innovating (73).

The cost of effort, starting up a business, and the costs of patenting are the only costs considered by the new firm. These costs are proportional to the change-level of knowledge from $h_t \Rightarrow h_{t+1}$. Physical capital fully depreciates after production and the innovator receives reward $r < R$ at the end of the period.[10]

Looking at capital as the only source of innovation assumes that there is a positive linear relationship between capital investment in innovation and amount of innovation—i.e., innovation is always available given the right amount of money. This makes innovation a supply and demand type good where innovation, as output, is always available so long as raw material, capital, is invested. This is intuitively incorrect; capital is independent from innovation. Innovation has capacity limiting factors outside of capital, such as human brain power. Everyone does not have the ability to innovate and those who have the ability might not want to innovate for any money—e.g. some inventors refused to work on the A-Bomb in spite of high monetary

[9] Strictly decreasing in $H_t$ and $h_t$, strictly increasing and convex in $h_{t+1}$, and satisfies $e_t = \varphi(h_t, h_{t+1}; H_t) > 0$.

[10] When an agent innovates and each member of the team receives a share of the innovation, the innovating agent receives less reward than the effort invested. The M-Q model assumes that given large enough *r* covering agent's cost of effort $e_t = \varphi(h_t, h_{t+1})$ such that $R - \varphi(h_t, h_{t+1}) \geq 0$, the agent *will* innovate. Were this the case, economics would have little to say about innovation other than recommend additional capital sources.

rewards; there are human considerations associated with innovation that capital availability alone cannot address.

By contrast, actions that have monetary costs associated with them may have desirable affects on the agent's utility in spite of the fact that financially choosing a costly option such as this does not appear to be a financially maximizing choice.[11] Thus the agent's cost of investment in innovating versus the amount of money she is able to recoup in rewards do not have to be equal financially so long as she is able to reap rewards from other factors, such as fame, pride, or increase in status in the firm, which can offset her "personal" costs to equal the utility gained.

**The Process Innovation Decision Model**

Formally the firm maximizes:

$$\max_{h_1,k_1,w_1}\left\{-\varphi(h_0,h_1)-k_1+\left[1-\delta\left(\frac{h_1}{h_0}\right)\right]k_0+(1-\beta)\binom{0}{1}h_0^{1-\omega}k_0^{\omega}+\beta\binom{0}{1}h_1^{1-\alpha}k_1^{\alpha}\right\} \quad (3.0)$$

s.t. the agent's participation in innovation:

$$r-\varphi(h_0,h_1)\geq D(h_0) \quad (3.1)$$

and the financial constraint (investor):

$$-R-k_1+\left[1-\delta\left(\frac{h_1}{h_0}\right)\right]k_0+(1-\beta)\binom{0}{1}h_0^{1-\omega}k_0^{\omega}+\beta\binom{0}{1}h_1^{1-\alpha}k_1^{\alpha}\geq 0 \quad (3.2)$$

Although the investor pays $R$ rewards, $R$ goes to the entire team and the innovating agent receives $r < R$. $R$ is used in the optimization since, the larger $R$ is, the larger $r$ the agent will receive. The model when the innovator starts a sole proprietorship is in equations 4.x below. Because the innovator will have monopoly power for the length of the patent or until an $h_2$ innovation takes place, an innovator who starts a new firm will get the whole surplus $S(h_1)$ for some time.

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[11] Recent research in behavioral and experimental economics shows that agents can receive "mental" rewards with high personal utility values. For example, a puzzle in experimental economics was recently resolved about why people punish at a cost to themselves, when neuro-imaging techniques on humans making economic decisions, showed that punishing activates the dopamine pathway and provides pleasure (25, 28).

$$\mathbf{S(h_1)} = \mathbf{max}_{h_1,k_1,w_1}\{-\varphi(h_0, h_1) - k_1 - \tau h_1 + h_1^{1-\alpha} k_1^{\alpha}\} \tag{4.0}$$

s.t. the agent's participation in sole proprietorship:

$$R - \varphi(h_0, h_1) \geq D(h_0 \tag{4.1}$$

and financial constraint of the investor:

$$-R - k_1 - \tau h_1 + h_1^{1-\alpha} k_1^{\alpha} \geq 0 \tag{4.2}$$

The sole proprietor takes the entire reward that the market pays for the innovation, which is greater than what the firm would pay to the agent for innovation. If the agent innovates within the firm, the costs associated with implementation are on the shoulders of the firm whereas if the agent is a sole proprietor, the costs are on her shoulders. The investor does not pay any part of the "reward" but funds the cost of $\tau$.

The first order conditions to (3.x) and (4.x) with respect to $h_1$ :

$$(1-\alpha)(\frac{k_1}{h_1})^{\alpha} = \varphi_{h_1}(h_0, h_1) + \delta(\frac{k_0}{h_0})[12] \tag{5.0}$$

$$(1-\alpha)(\frac{k_1}{h_1})^{\alpha} = \varphi_{h_1}(h_0, h_1) + \tau \tag{5.1}$$

The left hand side is the marginal productivity of knowledge and on the right are the marginal costs.[13]

**Agent's Utility**

The agent's cost of effort is derived from sharing the accumulation of her knowledge. The M-Q model used $H_t$ (world knowledge) as the accumulation of knowledge with which the agent is familiar—an innovation must be new to the world if it is new to the firm, since the firm

[12] The subscripts in the equations denote derivatives.
[13] The knowledge investment of the agent acting as sole proprietor is strictly decreasing in the entry cost $\tau$ and there exists a $\bar{\tau} > 0$ such that $h_1^{sole} = h_1^{firm}$ .

is using $H_t$ already. At time $t$, knowledge accumulation of the firm and the industry knowledge are equal: $H_t = h_t$. Consequently, the agent uses this knowledge level to measure her effort cost:

$$\boldsymbol{h_{t+1} = (1 - \emptyset)h_t + (H_t^{\theta} e_t^{1-\theta})^{v}} \tag{6.0}$$

where $\phi$ is depreciation rate, $e_t$ is the cost of effort in sharing knowledge, $\theta$ is a knowledge leakage parameter, and $v$ is a scale variable of returns on knowledge (72). Inverting this we get the agent's cost of effort function for staying with the firm:

$$\boldsymbol{e_t = \varphi(h_t, h_{t+1}; H_t) = \frac{[h_{t+1} - (1-\emptyset)h_t]^{\frac{1}{(1-\theta)v}}}{H_t^{\frac{\theta}{1-\theta}}}} \text{ [14]} \tag{6.1}$$

This model is used to calculate any particular element of the agent's effort function, which is $e = \frac{n\,\bar{p}}{\gamma\,\vartheta}$. Let $h_t$ represent the normalized value of the firm's output based on technology at time *t* and $h_{t+1}$ represents the normalized value of the firm's output if the agent had innovated and the new technology was implemented. Thus let $H_t$ represent the industry-wide value average using technology at time *t*, which is set to 1. The agent and the firm can calculate the probability of the agent's survival as a sole proprietor (leaving the firm) given the innovation-size that would take the firm to $h_{t+1}$ level.

$$\boldsymbol{p_{sole} = \frac{np_{firm}[h_{t+1} - (1-\emptyset)h_t]^{\frac{1}{(1-\theta)v}}}{\vartheta\gamma H_t^{\frac{\theta}{1-\theta}}}} \tag{6.2}$$

M-Q suggested interpretation for $\theta$ as knowledge spill-over, which may be set to zero, since the agent is silent about her knowledge. They also suggested interpretations for $v$, the corrosion value of innovation, and set it, for example, to 97%. Corrosion is technology specific.

[14] Homogeneous of degree $\rho = \dfrac{1 - \theta \cdot v}{(1-\theta) \cdot v}$.

Some technology, such as computers, is highly corrosive whereas technology for sewing machines is likely to be less sensitive. For the purpose of demonstrating with an example, assume this corrosion factor to be 97%, knowledge spill-over to be zero, and the general growth of the industry $\emptyset = 2\%, n = 3, \gamma = 3, \varphi = 0.9, and\ p_{firm} = 0.9$, and let $h_t = 1\ and\ h_{t+1} = 1.1$ (normalized), then the probability of the sole proprietor success is approximately 11%. Leaving all the same but reducing trust from 90% to 30%, we find that now there is a 33% chance for the agent to leave. Competence affects the agent decision to a lesser degree. Leaving everything the same but reducing competence from 3 to 2 increases the probability of the agent leaving from 11% to only 16%. Thus trust is more important for the agent's decision than other factors.

**Implications**

Trust matters. A firm may enhance its internal environment by formal and informal institutions that improve stability and reliance of team members on each other. The chance for punishment improves cooperation and reciprocity. Firms typically don't offer teams the opportunity to exclude members from future participation. It is left for future empirical study to see how punishment options may be implemented and if such would enhance trust among members in teams.

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