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Spin-offs of Entrepreneurial Firms : An O-Ring Approach

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Abstract:

The O-Ring theory provides a framework to analyse the emergence of firms organized as partnerships. The owner-managers of such entrepreneurial firms can benefit from ability matching within their production teams. However, they must also bear the project risk. Risk-aversion then induces a second-best solution. At the same time, integrated firms managed on behalf of risk-neutral residual-claimants face information and/or enforcement problems. Hence, they cannot organize ability-matched teams. It is shown that there exists an equilibrium such that groups of individuals sharing a superior ability level will found entrepreneurial firms. Low-quality individuals will be employed by managed firms which hire randomly.
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1 Motivation

While there exists a variety of definitions of entrepreneurship, Bull and Willard (1995) note two common features. According to the Knightian school of thought, the entrepreneur bears the risk associated with an uncertain business environment. At the same time, the Schumpeterian view emphasizes the function of the entrepreneur to implement "new combinations". Beginning with Cooper and Bruno (1977) and Cooper (1985), a number of authors have then already focussed on the "incubator" role of the place of employment prior to founding a new firm. In this respect, the recent emergence of the so-called "New Economy" - typically referring to firm foundations in the computer, information and communications, and bio-technology industries - appears to provide a prime example.

Hence, according to Bhidé's (2000, p. 54) survey of the 1989 *Inc. 500* companies, 71% of the respective start-ups are founded by individuals who "*replicated or modified an idea encountered during their previous employment*". Superior technological knowledge can therefore not explain the emergence of such new firms. Yet, Rajan and Zingales (2000, 2001a) emphasize that the nature of the "new combinations" has changed. In particular, the new technologies induce a fundamental shift of power from financial to human capital. The innovations originate from human capital rather than from inanimate assets. Thus, the allocation of the decision rights within the firm becomes the prime issue. Corporate venturing for new opportunities then results in a subdivision of the corporate physical assets.

Following the same basic argument, Baily and Lawrence (2001) conclude that the emergence of the "New Economy" reflects outsourcing decisions of human capital-intensive productions. Bhidé (2000, p. 94) observes that such spin-offs are typically led by former high-profile employees. Hence, 83% of the founders in his survey at least hold a four-year college degree. While financial innovations have made this development possible, the recent experience of financial volatility now adversely affects the "New Economy" firms [Baily and Lawrence (2001)]. Reintegration constitutes a means to overcome these problems. Moreover, according to Holmstrøm and Kaplan (2001), the process of disintegration generally terminates once the critical assets have been identified. Reintegration via mergers and acquisitions then follows again. Thus, even successful spin-offs are viewed as transitory phenomena.

Yet, there exist limits to vertical control associated with (re-)integration. Prat (2002) shows that flat hierarchies with ability-matched teams are dominant in production environments characterized by positive complementarities between specialized tasks. Moreover, flat hierarchies with "up-or-out"-promotion schemes for experienced managers provide "*incentives [...] to protect, rather than steal, the source of organizational rents*" [Rajan and Zingales (2001b, p. 805)]. The perspective to become owners themselves limits the exploitation risk and, therefore, enhances the incentives to specialize for young managers. Then, Bhidé (2000, p. 139-140, 367-368) again reports the particular importance of such team work in corporate ventures.

The two examples provided by Prat (2002) further demonstrate the pivotal role of adequate recruiting. In fact, "*unusual judgement or perceptiveness*" in employee selection characterizes the successful entrepreneur [Bhidé (2000, p. 108)]. Case studies show that - during the growth phase following the immediate start-up period - recruiting experienced managers from established firms constitutes a key success factor [Bhidé (2000, p. 282-288)]. At the same time, corporate policies in well-established firms to "*recruit individuals who will fit their culture and norms to promote cooperation and team work [...] limit their ability to employ the best individual for a given task [...]*" [Bhidé (2000, p. 324)]. Hence, entrepreneurial spin-offs constitute a persistent response to the established corporations' failure in organizing team-work in human capital-intensive industries.

Within the new spin-offs, stock ownership or stock option plans then serve as selection devices [Bhidé (2000, p. 87, 200)]. Rajan and Zingales (2001b, p. 832) add that ownership must be wide-spread throughout these new firms. Concentrated control rights would again increase the threat of expropriation for new team members. Thus, the incentives to specialize would be reduced. According to Audretsch and Thurik (2001), ownership-like management incentive schemes characterize "entrepreneurial" firms. Further, the change from "managed" to "entrepreneurial" firms constitutes the single most important characteristic associated with the emergence of the "New Economy". In fact, the past two decades have witnessed a significant increase in managerial stock ownership [Holderness et al. (1999)].

Following the Knightian view of entrepreneurship, Kihlstrom and Laffont (1979, 1983) already demonstrate the existence of a contract equilibrium. Less risk-averse individuals become risk-taking entrepreneurs who provide insurance for their more risk-averse employees. Yet, the recent experience of "New Economy" spin-offs sheds doubts on the self-selection of individuals as entrepreneurs, respectively employees according to their degree of risk-aversion. Thus, the increased necessity to compensate poor employee stock performance in cash has induced additional financial problems for the "New Economy" firms [Zingheim and Schuster (2000)]. Moreover, this development gives rise to motivation problems for the manager-owners who formerly received preferential treatment as high-potential employees [Weinberg (2001)]. Hence, partnership-like incentive schemes limit the scope of spin-offs. Individuals who - either as high-profile employees in established corporations, or as potential entrepreneurs - are equally risk-averse will demand a compensating risk-premium in order to join a firm in which incentives are provided via ownership.

The current study focuses on the trade-off between the benefits of ability-matching and the costs of partnership-like compensation schemes in entrepreneurial spin-offs. It applies the O-Ring production theory introduced by

Kremer (1993)[1]. On first sight, the O-Ring theory only constitutes a particular example of positive complementarities in organizing team-work. Yet, while previous work has focussed on the relationship between asset complementarity and the internal organization of firms, the current study analyzes entrepreneurial activity in terms of a labor market equilibrium. It is therefore more closely related to Gromb and Scharfstein (2002) and Landier (2001). However, both studies analyze informational equilibria. Failed firm founders are not stigmatized whereas project failure within a firm provides an informative signal concerning employee quality. In contrast, the O-Ring framework identifies individual abilities with probabilities of failing in task-performance. Thus, the benefits of ability-matching are directly linked to reductions in project-risk.

The remainder of the study is organized as follows. The next section introduces the basic analytical framework. Section 3 investigates the effects of firm organization and risk-aversion given exogenous alternative employment opportunities. It is shown that the first-best solution can be implemented by partnerships of risk-neutral individuals. However, partnerships of risk-averse individuals induce inefficient input choices. Section 4 then demonstrates the existence and characteristics of a competitive industry equilibrium with endogenous separation of entrepreneurial and managed firms. Matched groups of high-ability individuals found partnerships. Low-ability individuals will seek employment in managed firms which recruit randomly while offering certain income opportunities. The final section summarizes and discusses the results with particular reference to the perceived "volatility" of "New Economy" firms.

2 The basic O-Ring framework

The following theoretical framework modifies the basic O-Ring model introduced by Kremer (1993) only marginally. Thus, consider the expected revenue function

$$R = pF(k,n)\left[\prod_{i=1}^{n} q_i\right] n \tag{1}$$

where k refers to physical capital input and n denotes the number of tasks involved in a particular firm's production. For analytic convenience, the output price p is normalized to equal unity.

Further, $q_i \in [q_L, q_H]$, with $0 < q_L < q_H < 1$ and $i = 1, ..., n$, denotes the ability of the employee, respectively team member assigned to task i. Ability directly corresponds to the individual probability of perfect task

[1] The term "O-Ring theory" refers to the Challenger-accident which is blamed on the malfunctioning of a simple o-ring. By analogy, the weakest link in a production chain determines the team's productivity.

performance. More precisely, if the individual assigned to task i malperforms, the team as a whole cannot produce positive output. This occurs with probability $[1 - \prod_{i=1}^{n} q_i]$. Further, the probability q_i constitutes an individual characteristic of the particular team member assigned to task i.

Thus, (1) reflects a typical team production function. The output of the team depends on the performance of each team member. In fact, given the O-Ring framework, the productivity of the team is always governed by the lowest-quality employee hired. Only the fact that output is completely destroyed upon malperformance of a single team member may be considered as an extreme assumption. This approach therefore constitutes a particular variant of the positive complementarities in production discussed by Prat (2002)[2].

Intuitively, $F(k, n)$ then defines output per team member given that all members perform perfectly. It increases with physical capital employed and the number of tasks involved in production. Hence, increasing n implies a technological change towards the production of a more sophisticated variant of the industry's good, or service. For convenience, let $F(k, n) = [k]^{\alpha} [n]^{(1-\alpha)}$ in the following.

Spin-offs typically produce services which replace a formerly integrated production. Thus, new bio-technology firms often constitute R&D spin-offs founded and controlled by former employees of a pharmaceutical firm. Also, "New Economy" ICT firms customize standard accounting software, prepare Internet presentations, or optimize server-client networks for "Old Economy" firms. In principle these services can be - and, in less sophisticated variants, are still - produced in integrated firms as well.

The analysis therefore considers a particular labor market for professional specialists. In equilibrium, they are either employees of integrated firms, or partners in entrepreneurial spin-offs. For simplicity, abilities are distributed uniformly over the interval $[q_L, q_H]$. Thus, $N(q) = \bar{n} \geqq 0$ members of the pool of professionals share the ability q. The analysis abstracts from explicitly considering the labor-leisure trade-off. Given voluntary participation, all individuals supply one unit of labor inelastically.

Throughout the analysis draws on the following concept of a competitive industry equilibrium:

Definition: *If the competition of firms for professionals of different quality induces an allocation such that*

a) *the residual expected profit in all expected profit-maximizing firms equals zero,*

[2]Positive complementarities can be associated with super-modular revenue functions. However, the more general concept of super-modularity does not require that the revenue function is at least twice differentiable. Compare the discussion in Prat (2002).

b) *and all individuals of a given quality $q \in [q_L, q_H]$ obtain an identical expected utility level either as members of a partnership maximizing the expected utility of their partners, or being employed by an expected profit-maximizing firm,*

this allocation is said to constitute a competitive industry equilibrium.

Given that the two types of firms - partnerships and expected profit-maximizing firms - coexist, a separating competitive industry equilibrium must further satisfy that

c) *(i) no current member of a partnership prefers to be employed by an expected profit-maximizing firm, and (ii) no group of current employees of expected profit-maximizing firms prefers to found a new partnership.*

The next section serves to prepare the equilibrium analysis by investigating the optimal input decisions associated with firm type. Only for this purpose, let $V \geqq 0$ then denote an exogenous reservation income associated with alternative employment. Also, all firms are able to select individual workers to organize their production teams. Thus, abilities are publicly observable and the firms' recruitment decisions can be perfectly enforced. These assumptions allow to isolate the effects of firm organization and risk-aversion on the efficiency of input choices. They will be removed in section 4. The separating reservation income is then determined endogenously in labor market equilibrium.

3 Firm organization and risk-aversion

3.1 Expected profit-maximizing firms

In order to construct a benchmark case for further analysis, consider the standard expected profit-maximizing firm. Its residual claimant solves

$$Max_{(\{q_i\},n,k)} \qquad \pi(\{q_i\}, k, n) = R(\{q_i\}, n, k) - \sum_{i=1}^{n} w(q_i) - rk \tag{2}$$

where $w(q_i)$, with $i = 1, .., n$, denotes the wage income offered to the employee assigned to task i. The expression $\{q_i\}$ then refers to the ability-profile of the firm. Also, r is the rental rate of capital in a perfectly competitive capital market.

It can now be shown:

Proposition 1 *Suppose the reservation wage V is sufficiently low to allow for positive production. Also, there exist only expected profit-maximizing firms in the industry.*

(a) Then, with observable individual abilities, there exists a competitive industry equilibrium such that all firms employ a single ability-type only. Moreover, the corresponding identical ability level of the team members determines a unique optimal team size and capital input level for each firm. The optimal team size increases in the team members' identical ability level. The shares of revenue devoted to repaying capital and rewarding labor are given by the production elasticities α*, respectively* $(1-\alpha)$.

(b) The allocation implemented by the competitive industry equilibrium is efficient.

Proof. To begin with, note that, given (2), an expected profit-maximizing firm will not be induced to change its current ability profile, if

$$\frac{\partial \pi(\{q_i\}, k, n)}{\partial q_i} = 0 = \tag{3}$$

$$F(k,n)\left[\prod_{j\neq i} q_j\right] n - \frac{dw(q_i)}{dq_i}, \quad \forall i = 1,..,n$$

Now, assume that, in equilibrium, firms employ a single ability-type only. The expected profit of a firm hiring employees of ability q can then be obtained as

$$\pi(q) = F(k,n)q^n n - w(q)n - rk \tag{4}$$

If an interior optimum exists, it is characterized by the first-order conditions

$$\alpha k^{(\alpha-1)} n^{(1-\alpha)} q^n n = r \tag{5}$$

and

$$[2 - \alpha + \log(q)n]\, k^{\alpha} n^{(1-\alpha)} q^n = w(q) \tag{6}$$

Given that only expected profit-maximizing firms exist in equilibrium, condition b) of the definition of the competitive industry equilibrium requires the existence of a wage-schedule which unambiguously assigns a wage-payment $w(q)$ to all individuals of ability q. If production teams are homogeneous, the optimality of the recruiting decisions according to (3) implies that this schedule must satisfy

$$F(k,n)q^{(n-1)} n = \frac{dw(q)}{dq} \tag{7}$$

Then, if the firms' equilibrium choices of capital input and team size actually satisfy the first-order conditions (5) and (6), rearranging condition (5) reveals that

$$k^* = \left(\frac{\alpha q^{n^*}}{r}\right)^{\frac{1}{1-\alpha}} (n^*)^{\frac{2-\alpha}{1-\alpha}} \tag{8}$$

with superscripts "$*$" indicating optimal values. Inserting from (8) into (7) yields

$$\frac{dw^*(q)}{dq} = \left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}} (n^*)^{\frac{1}{1-\alpha}} q^{\left(\frac{n^*}{1-\alpha}-1\right)} n^*$$

$$\Longrightarrow \quad w^*(q) = (1-\alpha)\left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}} (n^*)^{\frac{1}{1-\alpha}} q^{\left(\frac{n^*}{1-\alpha}\right)} + c \tag{9}$$

The constant of integration c must equal zero. In the limit $q = q_L \to 0$, it reflects the wage offered when organizing teams consisting of professionals with zero quality. However, such teams would produce zero output with certainty. Thus, they cannot offer positive wage-income.

With $c = 0$, (9) then implies

$$n^* w^*(q) = (1-\alpha)(k^*)^{\alpha}(n^*)^{(1-\alpha)} q^{n^*} n^* = (1-\alpha)R^* \tag{10}$$

since $\alpha\left[\frac{2-\alpha}{1-\alpha}\right] + (1-\alpha) = \frac{1}{(1-\alpha)}$. This proves that the total wage-bill in each firm equals the share $(1-\alpha)$ of revenue. Moreover, according to (5), the rental payment for capital rk^* amounts to the share α of revenue in each of these firms. Thus, as required by condition a) of the definition of a competitive industry equilibrium, residual expected profits equal zero.

Further, inserting from (10) into (6) implies

$$\frac{1}{n^*} = -\log(q) \tag{11}$$

Thus, the optimal team size is increasing in the ability level of the team members. Interpreting this result, note that the function nq^n attains a unique maximum for $\frac{1}{n^*} = -\log(q)$.

Next, investigating the second-order conditions for the firm's optimization problem, reveals that

$$\frac{\partial^2 \pi^*(q)}{\partial k \partial k} = \alpha(\alpha-1)(k^*)^{(\alpha-2)}(n^*)^{(1-\alpha)} q^{n^*} n^* = \frac{-(1-\alpha)r}{k^*} < 0 \tag{12}$$

$$\frac{\partial^2 \pi^*(q)}{\partial k \partial n} = (1-\alpha)\alpha(k^*)^{(\alpha-1)}(n^*)^{(1-\alpha)} q^{n^*} = \frac{(1-\alpha)r}{n^*} > 0 \tag{13}$$

$$\frac{\partial^2 \pi^*(q)}{\partial n \partial n} = -(k^*)^{\alpha}(n^*)^{-\alpha} q^{n^*} = \frac{-rk^*}{(n^*)^2}\left(\frac{1+\alpha(1-\alpha)}{\alpha}\right) < 0 \tag{14}$$

upon utilizing (11) and (5). Thus,

$$\begin{vmatrix} \frac{\partial^2 \pi^*(q)}{\partial k \partial k} & \frac{\partial^2 \pi^*(q)}{\partial k \partial n} \\ \frac{\partial^2 \pi^*(q)}{\partial k \partial n} & \frac{\partial^2 \pi^*(q)}{\partial n \partial n} \end{vmatrix} = \frac{r^2(1-\alpha)}{(n^*)^2 \alpha} > 0 \tag{15}$$

Given the proposed characterization of the industry equilibrium, (n^*, k^*) thus constitute unique optimal choices for firms employing homogeneous teams consisting of type-q individuals.

Production will actually take place in firms characterized by team ability q such that

$$w^*(q) \geqq V \tag{16}$$

or some $q \in [q_L, q_H]$. By virtue of (9) $w^*(q)$ is monotonically increasing in q. Hence, positive production in this industry can be assured by assuming $w^*(q_H) > V \geqq w^*(q_L)$. Then, $q^* \in [q_L, q_H[$ - defined by $w^*(q^*) = V$ - characterizes the competitive labor market equilibrium. All professionals exhibiting abilities $q \geqq q^*$ will be employed in the industry, while individuals of quality $q < q^*$ will prefer the alternative employment.

So far, it has still be assumed that, in the competitive industry equilibrium, the firms select teams which are homogeneous with respect to the team members' abilities. However, note that the increasing wage-schedule derived in (9) now also implies that (3) actually characterizes an optimal choice of the $i - th$ team member's ability level.

Intuitively, since the LHS of (3) is monotonically increasing in $\left[\prod_{j \neq i} q_j\right]$, firms which have hired the highest-quality employees for the first $(n-1)$ tasks, will always bid most in order to fill the n-th position in the team. This implies that a firm which has decided to recruit the top-quality employee for one task will recruit only such top-qualities for all tasks.

Similarly, a firm which has decided to begin hiring by recruiting some medium-quality professional cannot successfully compete for higher-quality individuals when filling other positions. However, it will succeed in attracting other employees of the same quality when competing with firms which have started hiring lower-quality employees.

Thus, given the wage schedule $w^*(q)$ provided in (9), the firms' optimal recruitment decisions described by (3) imply that each firm will employ a single ability type only. Then, $(n^*(q), k^*(q))$ as characterized by (8) and (11) constitute the corresponding unique expected profit-maximizing choices in firms with teams consisting of individuals with identical ability q. Hence, the competitive industry equilibrium introduced in part a) of Proposition 1 exists.

For expositional reasons, the proof that this equilibrium implements an efficient allocation is relegated to the Appendix.[3]

[3] Recall that, by assumption, condition c) defining a separating competitive industry equilibrium does not apply to the case made in Proposition 1. While the proof of the proposition is then constructive, it has also been particularly organized to allow for the subsequent use of the first-order conditions for the expected profit-maximing firm's optimization problem. Thus, there may be other, and certainly more rigorous ways to prove Proposition 1.

Obviously, the efficiency-property of this competitive equilibrium motivates its further use as a benchmark case. When referring to this solution, the input choices $(k^*(q), n^*(q))$ will be denoted *first-best* in the following.

In addition to the characteristic features noted in Proposition 1, also recall that larger teams of superior ability produce more sophisticated variants of the industry's commodity or service. Hence, there exists a multitude of firms offering services of different sophistication in competitive industry equilibrium. According to (9), small differences in team abilities then yield rather large income differentials across firms. At the same time, there is no wage-differentiation within the firm.

3.2 Risk-neutral partnerships

Contrasting with the assumption of profit maximization utilized above, spin-offs typically constitute entrepreneurial firms. If not organized as formal partnerships, they distribute a large fraction of their economic profit among their employees via stock or stock option plans. Hence, it is appropriate to assume that such firms are self-managed by the members of the production team. Then, given that individuals are risk-neutral, they rather maximize surplus per team member. Thus, they solve

$$Max_{(\{q_i\},n,k)} \qquad \frac{R(\{q_i\},n,k) - rk}{n} \tag{17}$$

Note, however, that

$$\frac{d^2 \left[R(\{q_i\},n,k)/n\right]}{dq_i d\left[\prod_{j\neq i} q_j\right]} > 0 \tag{18}$$

as well. Hence, consider two professionals each founding such a partnership firm and one characterized by higher ability than the other. The superior ability founder will always be able to offer a more attractive partnership for other high-ability professionals. This remains to be true as the production teams grow by attracting even more partners. In labor market equilibrium entrepreneurial firms will therefore also consist of partners sharing an identical ability level.

Replacing $[\prod_{i=1}^{n} q_i]$ by q^n when solving (17), differentiating with respect to capital k restates (5). The first-order condition with respect to the number of tasks n further reveals

$$(1-\alpha)k^{\alpha}n^{-\alpha}q^n + k^{\alpha}n^{(1-\alpha)}q^n log(q) + \frac{rk}{n^2} = 0$$

$$\Longrightarrow \qquad [1 + nlog(q)] = 0 \tag{19}$$

upon substituting from (5). Again, the optimal choice of technology yields team size $n^*(q)$. Obviously, this also implies that the capital demanded by the firms is given by $k^*(q)$. The second-order sufficient conditions can be obtained as shown in (12) to (15) above.

Recall that the total wage bill in the profit maximizing case always equals the share $(1-\alpha)$ of expected revenue. With risk-neutral team members, the wage for employees in such firms is thus equal to the expected surplus net of capital rental payments. Obviously, this exactly coincides with the individual expected income generated in an entrepreneurial firm. Hence, given the results above, the ability level q^* also satisfies

$$(1-\alpha)\left[k^*(q^*)/n^*(q^*)\right]^{\alpha}\left[(q^*)^{n^*(q^*)}n^*(q^*)\right] = V \tag{20}$$

Thus, without further proof, it follows:

Proposition 2 *Again, assume that individual abilities are observable. However, suppose that there exist only firms organized as partnerships of risk-neutral individuals in the competitive industry equilibrium. Then, this equilibrium can be characterized as derived in Proposition 1 for the case when there exist only expected profit-maximizing firms.*

Given the particular O-Ring team production function (1), this equivalence result should be obvious. Rewarding factor inputs according to their marginal revenue implies that expected residual profits equal zero. With risk-neutral individuals, the institutional structure of the firm only determines the means to distribute income. It does not affect the realized income distribution.

Further, recalling that the distribution of abilities over the pool of professionals is uniform, there exist $\int_{q^*}^{1}\left[\frac{\bar{n}}{n^*(q)}\right]dq$ of such firms in industry equilibrium. Due to (11) and (19) firm size increases with team quality. Thus, the number of firms characterized by a particular team quality increases with decreasing team quality. It follows that small increases in the reservation income V induce the closing of a rather large number of firms in the industry[4].

3.3 Partnerships of risk-averse individuals

Let the members of the industry's pools of professionals now be risk-averse. Hence, they maximize their expected utility. Instantaneous preferences are

[4]Alternatively, suppose that the *pdf* of abilities is single-peaked. Given normally or log-normally distributed abilities - as often assumed - this result is even reinforced as long as the industry attracts professionals with above-average abilities. Moreover, in this case a small increase of V also induces a rather significant migration of professionals from the industry into alternative occupations.

characterized by a utility function $U(y)$, with $U'(y) > 0$ and $U''(y) < 0$ for incomes $y > 0$. Of course, assuming that there only exist managed firms which maximize expected profits, all results of section 3.1 can be retained. However, the manager-owners of entrepreneurial firms will maximize

$$EU = \left[\prod_{i=1}^{n} q_i\right] U(Y + F(k,n) - \frac{rk}{n}) + \left(1 - \left[\prod_{i=1}^{n} q_i\right]\right) U(Y - \frac{rk}{n}) \tag{21}$$

Introducing exogenous income $Y > 0$ in (21), the analysis will exclusively focus on interior solutions. Such solutions can be ensured by assuming that $U(y)$ satisfies the usual Inada-conditions.

If it is ever beneficial to found such firms, they will consist of teams of individuals characterized by identical abilities again. This follows from the fact that $\partial EU/\partial \left[\prod_{j \neq i} q_j\right] > 0$ for $F(k,n) > 0$. Thus, high-ability individuals will always find it more attractive to join partnerships already consisting of higher-quality team members in the first $(n-1)$ tasks. Replacing $[\prod_{i=1}^{n} q_i]$ by q^n in (21) then yields the first-order conditions

$$q^{\tilde{n}} U'(Y + F(\tilde{k},\tilde{n}) - \frac{r\tilde{k}}{\tilde{n}}) \left[\alpha \tilde{k}^{(\alpha-1)} \tilde{n}^{(1-\alpha)} - \frac{r}{\tilde{n}}\right] = (1 - q^{\tilde{n}}) U'(Y - \frac{r\tilde{k}}{\tilde{n}}) \frac{r}{\tilde{n}} \tag{22}$$

and

$$\begin{aligned} & -q^{\tilde{n}} log(q) \left[U(Y + F(\tilde{k},\tilde{n}) - \frac{r\tilde{k}}{\tilde{n}}) - U(Y - \frac{r\tilde{k}}{\tilde{n}})\right] \\ = \; & q^{\tilde{n}} U'(Y + F(\tilde{k},\tilde{n}) - \frac{r\tilde{k}}{\tilde{n}}) \left[(1-\alpha)\tilde{k}^{\alpha}\tilde{n}^{-\alpha} + \frac{r\tilde{k}}{\tilde{n}^2}\right] \\ & +(1 - q^{\tilde{n}}) U'(Y - \frac{r\tilde{k}}{\tilde{n}}) \frac{r\tilde{k}}{\tilde{n}^2} \end{aligned} \tag{23}$$

where $(\tilde{k},\tilde{n})$ denote the respective optimal choices in this case.
Substituting from (22) into (23) implies

$$-log(q) \frac{U(Y + F(\tilde{k},\tilde{n}) - \frac{r\tilde{k}}{\tilde{n}}) - U(Y - \frac{r\tilde{k}}{\tilde{n}})}{U'(Y + F(\tilde{k},\tilde{n}) - \frac{r\tilde{k}}{\tilde{n}})} = \tilde{k}^{\alpha}\tilde{n}^{-\alpha} \tag{24}$$

Concavity then implies that

$$-log(q)\tilde{n} < 1 \tag{25}$$

Thus, partnerships managed by risk-averse team members are *ceteris paribus* smaller than risk-neutral partnerships. Rearranging (22) it also follows

$$\begin{aligned}&\tilde{k}^{(\alpha-1)}\tilde{n}^{(1-\alpha)}\tilde{n}q^{\tilde{n}} \\ =\ & \frac{r}{\alpha}\left[q^{\tilde{n}}+(1-q^{\tilde{n}})\frac{U'(Y-\frac{r\tilde{k}}{\tilde{n}})}{U'(Y+F(\tilde{k},\tilde{n})-\frac{r\tilde{k}}{\tilde{n}})}\right]\end{aligned} \tag{26}$$

Substituting for r from (5) above,

$$\begin{aligned}&\tilde{k}^{(\alpha-1)}\tilde{n}^{(1-\alpha)}\tilde{n}q^{\tilde{n}} \\ =\ & (k^*)^{(\alpha-1)}(n^*)^{(1-\alpha)}n^*q^{n^*}\left[q^{\tilde{n}}+(1-q^{\tilde{n}})\frac{U'(Y-\frac{r\tilde{k}}{\tilde{n}})}{U'(Y+F(\tilde{k},\tilde{n})-\frac{r\tilde{k}}{\tilde{n}})}\right]\end{aligned} \tag{27}$$

Recall from Proposition 1 that, for a given team ability level q, nq^n is maximized by setting $n = n^*$. Thus, $n^*q^{n^*} > \tilde{n}q^{\tilde{n}}$, $\forall q \in [q_L, q_H]$. Risk-averse partners not only require an expected income sufficient to cover their share of capital costs. In addition, they must be compensated for risk associated with paying the capital rental costs even if production fails. Consequently, the cost of attracting partners is higher than in the risk-neutral case. This implies that the size of the production team falls short of maximizing the expected team output.

Also, due to decreasing marginal utilities, the last term in the RHS of (27) is greater than one. Thus, $n^* > \tilde{n}$ implies $(k^*/n^*) > (\tilde{k}/\tilde{n})$ and $k^* > \tilde{k}$. Let $\tilde{y}(q)$ then denote the certainty equivalent income of such risk-averse partners self-managing a firm of team quality q. Hence, $\tilde{y}(q) = U^{-1}(EU(q, \tilde{n}, \tilde{k}))$. Defining $\tilde{w}(q) = \tilde{y}(q) - Y$ as the respective certainty equivalent return to participating in the partnership, it is also immediately clear that

$$\begin{aligned}\tilde{w}(q) &< \tilde{k}^{\alpha}\tilde{n}^{(1-\alpha)}q^{\tilde{n}} - \frac{r\tilde{k}}{\tilde{n}} \\ &< (k^*)^{\alpha}(n^*)^{(1-\alpha)}q^{n^*} - \frac{rk^*}{n^*} = w^*(q)\end{aligned} \tag{28}$$

for all $q \in [q_L, q_H]$. The second inequality follows from the allocative distortions associated with maximizing expected utility.

Finally, note that

$$\frac{\partial EU(q,\tilde{n},\tilde{k})}{\partial q} = \tilde{n}q^{(\tilde{n}-1)}\left[U(Y+F(\tilde{k},\tilde{n})-\frac{r\tilde{k}}{\tilde{n}}) - U(Y-\frac{r\tilde{k}}{\tilde{n}})\right] > 0 \tag{29}$$

for all $q > 0$. Again, assume that there exists $q = \tilde{q} \in [q_L, q_H[$ such that $EU(\tilde{q}, \tilde{n}(\tilde{q}), \tilde{k}(\tilde{q})) = U(Y + V)$. Then, production will take place. However, only individuals of ability $q \geqq \tilde{q}$ will actually found entrepreneurial firms. The inequalities (28) then yield $\tilde{q} > q^*$.

Summarizing the analysis, it therefore follows:

Proposition 3 *Ceteris paribus, risk-aversion induces less firms founded as partnerships in competitive industry equilibrium. The firms actually founded produce less sophisticated services with inefficiently small teams. Moreover, capital input and capital per team member is inefficiently low.*

Else, the equilibrium with risk-averse partnerships shares the properties derived above already. Small variations in team quality again induce large expected income differentials between the partnerships. Also, a small increase in the relative attractiveness of alternative jobs induces a rather large reduction of the number of firms in the industry. Due to smaller firm sizes, the latter effect is even reinforced by introducing risk-aversion.

4 Endogenous separation of managed and entrepreneurial firms

Given that the industry technology constitutes public knowledge, the inefficiencies associated with risk-averse partnerships appear to preclude the emergence of competitive entrepreneurial firms. However, this conclusion requires that firm managements are always equally qualified to verify the different professionals' abilities. According to the O-Ring theory, successful production requires the coordination of - typically, complex and human capital-intensive- tasks and cooperation within the team. Given this production environment, the verification of the team members' abilities will plausibly be enhanced if the evaluation is carried out by the team members themselves.

Yet, even if verification is in principle possible, it is necessary to provide incentives to specialize on this task. In entrepreneurial firms the motivation to select appropriately is directly linked to the manager-owners' residual income claims. In contrast, wage-incentives for specialized human resource managers in large corporations cannot draw on direct measures of their recruitment success. Moreover, organizing the team not only requires selective recruiting. It will also be necessary to dismiss individuals who, upon being initially hired, turn out not to fit perfectly into the team. However, only large, well-diversified firms can be taken to satisfy the assumption of risk-neutrality. In such firms the possibility to implement a selective human resource policy is then additionally limited by their "corporate culture" and by law[5].

These arguments suggest that entrepreneurial firms possess a comparative advantage in organizing ability-matched teams. For analytic tractability, the following analysis then assumes that the ability to select team members constitutes an exclusive characteristic of partnerships. There also exist firms in which managements act on behalf of profit-maximizing ownerships.

[5] Compare Beck (1999) and Fabel et al. (1999), for instance.

Such firms recruit randomly. They can draw from the remaining pool of professionals who do not found partnerships.

Suppose that individuals seeking employment in managed firms are characterized by abilities $q \in [q_L, q^U]$, with $q^U \leqq q_H$. It is assumed that recruiting for each task in the firm represents an independent draw from the same pool of potential employees. Since abilities are distributed uniformly, random recruiting by managed firms then implies that the expected quality of an employee in each task i, $i = 1, ..., n$, is given by $E\{q_i \,|q_L < q_i < q^U\}$ $= \frac{1}{2}\left(q_L + q^U\right)$. Moreover, the respective expected profit maximization problem can be stated as

$$Max_{\{n,k\}} \quad F(k,n)n\prod_{i=1}^{n} E\{q_i \,|q_L < q_i < q^U\} - nV - rk \tag{30}$$

$$\rightarrow \quad Max_{\{n,k\}} \quad F(k,n)n\left[\frac{q_L + q^U}{2}\right]^n - nV - rk \tag{31}$$

where V now refers to the wage-income in managed firms. The first-order conditions can then be obtained as

$$r = \alpha(k^o)^{(\alpha-1)}(n^o)^{(1-\alpha)}n^o\left[\frac{q_L + q^U}{2}\right]^{n^o} \tag{32}$$

and

$$\begin{aligned} V \;=\; & log(\frac{q_L + q^U}{2})(k^o)^{\alpha}(n^o)^{(1-\alpha)}n^o\left[\frac{q_L + q^U}{2}\right]^{n^o} \\ & +(1-\alpha)(k^o)^{\alpha}(n^o)^{-\alpha}n^o\left[\frac{q_L + q^U}{2}\right]^{n^o} \\ & +(k^o)^{\alpha}(n^o)^{(1-\alpha)}\left[\frac{q_L + q^U}{2}\right]^{n^o} \end{aligned} \tag{33}$$

where the superscript "o" denotes the respective optimal values. According to (32), the capital rental payments account for the share α of expected revenue. Thus, competition among managed firms yields

$$V^o(q^U) = (1-\alpha)(k^o)^{\alpha}(n^o)^{(1-\alpha)}\left[\frac{q_L + q^U}{2}\right]^{n^o} \tag{34}$$

Substituting from (34) into (33) then implies

$$log(\frac{q_L + q^U}{2})n^o + 1 = 0 \tag{35}$$

Hence, firm size now maximizes the function $n[E\{q \mid q_L < q < q^U\}]^n$. In the case of managed firms which recruit randomly, the team size is determined by the "average" team member's ability. Using (32), (33) and (35), the second-order sufficient conditions are satisfied as well. The respective second-derivatives restate (12) to (15) with q being replaced by $\frac{q_L+q^U}{2}$.

Equations (32), (34), and (35) determine the input decisions and rewards of managed firms which recruit randomly from the pool of individuals with abilities $q \in [q_L, q^U]$. These choices are obviously efficient, given the expected team quality. If the industry's professionals can only choose between employment in managed firms and founding entrepreneurial firms, $V^o(q^U)$ again constitutes a reservation income for firm founders.

Investigating the possibility of a separating competitive industry equilibrium, it can then be shown:

Proposition 4 *Let individual preferences be characterized by risk-aversion. Also, the industry's professionals can only either find employment in managed firms which recruit randomly, or found entrepreneurial firms with ability-matched production teams. Then, if* $Y > rk^*(\frac{1}{2})$ *and the ability spread* $q_H - q_L$ *in the population is sufficiently large, there always exists a separating competitive industry equilibrium. In equilibrium, individuals characterized by* $q \leqq \tilde{q}$ *prefer to be employed by managed firms. At the same time, individuals with abilities* $q > \tilde{q}$ *will found entrepreneurial firms.*

Proof. Recall that $q \in [q_L, q_H]$, with $0 < q_L < q_H < 1$. Hence, the case $q = 0$ is excluded. Neither managed nor entrepreneurial firms will take up production, if a single member of the team destroys output with certainty. Also, for $q = 1$, the revenue function exhibits increasing returns to firm size. Thus, there does not exist an optimal firm size. Again, this holds irrespective of firm-type.

Then, suppose that the whole industry would consist of entrepreneurial firms. As shown in the previous section, the expected partnership utility satisfies $EU(q, \tilde{n}(q), \tilde{k}(q)) < U(Y + w^*(q))$, for all $q > 0$. Let $(n^o(q_L), k^o(q_L)$ refer to the input combination in managed firms, given that $q^U \rightarrow q_L$. Then, in managed firms $n^o(q_L) = n^*(q_L)$, $k^o(q_L) = k^*(q_L)$, and thus $V^o(q_L) = w^*(q_L) > 0$, for $q_L > 0$. Hence, a managed firm offering the wage-income $w^*(q_L)$ would be able to attract individuals with abilities $q = [q_L, q_L + \delta]$, with $\delta > 0$. Employing $n^*(q_L)$ of these individuals applying for jobs and investing $k^*(q_L)$, it would then earn positive profits.

Thus, the industry cannot consist of entrepreneurial firms only. Intuitively, random recruiting does not imply a loss of the benefits associated with ability-matching, if only a single ability-type is searching for a job in a managed firm. Offering a certain wage-income then constitutes a competitive advantage of managed firm employment.

Next, note that there exists a maximum wage-income $V^o(q_H) = w^*(\frac{q_H+q_L}{2})$ obtainable, if the whole industry consists only of managed firms. Also, $\lim_{(q_H-q_L)\rightarrow 1} w^*(\frac{q_H+q_L}{2})$ exists and is equal to $w^*(\frac{1}{2})$. This wage-income requires investments of $k^*(\frac{1}{2})$. Thus, assuming that the exogenous income satisfies $Y > rk^*(\frac{1}{2})$ implies that the maximum investment level of managed firms can be financed out of personal funds, given that the ability spread in the population is also at its maximum.

Then, for every feasible investment level $k^o(q)$ satisfying $Y > rk^o(q)$, $\{k^o(q), n^o(q)\} \neq \{\tilde{k}(q), \tilde{n}(q)\}$ obviously implies

$$EU(q, \tilde{k}(q), \tilde{n}(q)) > EU(q, k^o(q), n^o(q)) \tag{36}$$

for all $q > 0$. Focussing on the marginal entrepreneurial firm still to be founded, set $q = q^U$. Jensen's inequality implies

$$\begin{aligned} & EU(q^U, k^o(q^U), n^o(q^U)) - U(Y + V^o(q^U)) \\ > \;& (q^U)^{n^o(q^U)} U'(Y + F(k^o(q^U), n^o(q^U)) - \frac{rk^o(q^U)}{n^o(q^U)}) \times \\ & \times \left[\left(1 - \frac{q^U + q_L}{2}\right) F(k^o(q^U), n^o(q^U)) \right] \\ & + (1 - (q^U)^{n^o(q^U)})[U(Y - \frac{rk^o(q^U)}{n^o(q^U)}) - U(Y + V^o(q^U))] \end{aligned} \tag{37}$$

If the whole industry consists only of managed firms, $q^U = q_H$. Then, recall that all expressions on the RHS of (37) possess finite limits as $(q_H - q_L) \to 1$. It therefore follows

$$\begin{aligned} & \lim_{(q_H - q_L) \to 1} [EU(q_H, k^o(q_H), n^o(q_H)) - U(Y + V^o(q_H))] \\ > \;& U'(Y + F(k^*(\frac{1}{2}), n^*(\frac{1}{2})) - \frac{rk^*(\frac{1}{2})}{n^*(\frac{1}{2})}) \frac{1}{2} F(k^*(\frac{1}{2}), n^*(\frac{1}{2})) \end{aligned} \tag{38}$$

recalling that $(n^o(q^U), k^o(q^U)) = (n^*(\frac{q^U + q_L}{2}), k^*(\frac{q^U + q_L}{2}))$ and noting that $\lim_{(q_H - q_L) \to 1} (\frac{q_H + q_L}{2}) = \frac{1}{2}$.

Clearly, the RHS of this inequality is positive. Moreover, $Y > rk^*(\frac{1}{2})$ can now be verified to imply that the investment level associated with dominant partnerships is always individually feasible. Thus, it has been proved that there exits an ability level $q < q_H$ such that $EU(q, \tilde{n}(q), \tilde{k}(q)) > U(Y + V^o(q))$, if $Y > rk^*(\frac{1}{2})$ and the ability spread $(q_H - q_L)$ is sufficiently large. Given these two assumptions, the industry cannot consist of managed firms only.

Concluding, there must then also exist an ability level $\tilde{q} \in (q_L, q_H]$ such that $EU(\tilde{q}, \tilde{n}(\tilde{q}), \tilde{k}(\tilde{q})) = U(Y + V^o(\tilde{q}))$. This follows from (29). Also, (29) implies that $EU(q, \tilde{n}(q), \tilde{k}(q)) > U(Y + V^o(\tilde{q}))$, for $q > \tilde{q}$, and $EU(q, \tilde{n}(q), \tilde{k}(q)) < U(Y + V^o(\tilde{q}))$, for $q < \tilde{q}$. This proves the separating equilibrium property c) of $\tilde{q}$ as required by the definition provided in section 2 above. ■

INSERT FIGURE 1.

Figure 1 illustrates the properties of this separating equilibrium. The two conditions noted in the propositions are jointly sufficient for its existence. Also, they are not independent of each other, since $\partial k^o(q^U)/\partial q_L > 0$. Further, note that, in equilibrium, $k^o(\tilde{q})$ can actually be smaller than $k^*(\frac{1}{2})$. This is due to the fact that $\partial k^o(q^U)/\partial q^U > 0$. In particular, if the labor pool contains individuals characterized by rather low abilities, $k^*(\frac{1}{2})$ constitutes an upper bound on the capital required by managed firms. This follows from $\lim_{q_L \to 0} k^o(q^U) = \lim_{q_L \to 0} k^*(\frac{q^U + q_L}{2}) < k^*(\frac{1}{2})$, for all $q^U < 1$. The feasibility constraint $Y > rk^o(\tilde{q})$ which must hold in equilibrium may therefore be less restrictive than suggested by the proposition.

Moreover, consider the legal liability rules of real-world partnerships. Feasibility actually only implies that the total private wealth of the group of firm founders must be sufficient to cover the cost of capital associated with an integrated production. Thus, the restrictive nature of the feasibility constraint to some extent only reflects the theoretically interesting assumption that individuals share an identical degree of risk-aversion and level of private wealth.

The assumption of a sufficiently large ability spread within the industry's pool of professionals then further requires that differentiation by means of founding entrepreneurial firms must be beneficial. Obviously, the productive loss associated with ability pooling is relatively small, if there is only little variance of abilities across the population. Again judging the real-world implications, the ability spread within one profession should be related to the novelty of the production technology. If the industry is highly innovative, professional education can be guessed to be less standardized. Thus, it allows for more individual variance.

Finally, suppose the assumption that professionals can only find employment in the particular industry is relaxed. More attractive outside employment opportunities then reduce the size of the entrepreneurial segment in the industry. If an increasing number of low-ability professionals can find more profitable employment elsewhere, q_L increases. Hence, *ceteris paribus* $V^o(q^U)$ increases for all $q^U > q_L$. Thus, the migration of low-ability individuals into other industries decreases the relative attractiveness of entrepreneurial activity in the industry under consideration.

With respect to uniqueness and efficiency of the separating equilibrium, the following can further be shown:

Proposition 5 *Suppose the conditions noted in Proposition 4 are satisfied. Generally, the existence of multiple separating competitive industry equilibria cannot be excluded. Let the possible equilibrium separating ability levels be denoted* $\tilde{q}_k$*, with* $k = 1, ..., K$ *for* $K \geqq 1$*. Then, the unique efficient equilibrium is characterized by* $\tilde{q} = \max\{\tilde{q}_k\}$*.*

Proof. Given that the conditions noted in Proposition 4 are satisfied there exists at least one $\tilde{q} \in (q_L, q_H)$ such that $EU(\tilde{q}, \tilde{n}(\tilde{q}), \tilde{k}(\tilde{q})) =$

$U(Y+V^o(\tilde{q}))$ and $EU(q,\tilde{n}(q),\tilde{k}(q)) < U(Y+V^o(\tilde{q}))$, $\forall q \in [q_L,\tilde{q})$, while $EU(q,\tilde{n}(q),\tilde{k}(q)) > U(Y+V^o(\tilde{q}))$, $\forall q \in (\tilde{q},q_H]$. However,

$$\frac{\frac{\partial EU(q,\tilde{n}(q),\tilde{k}(q))}{\partial q}\Big|_{q=q^U}}{\frac{\partial U(Y+V^o(\tilde{q}))}{\partial q^U}} = \frac{U'(Y+F(\tilde{n}(q^U),\tilde{k}(q^U)) - r\frac{\tilde{k}(q^U)}{\tilde{n}(q^U)})}{U'(Y+V^o(q^U))} \times$$
$$\times\frac{(q^U)^{\left(\tilde{n}(q^U)-1\right)}\tilde{n}(q^U)(\tilde{n}(q^U))^{-\alpha}(\tilde{k}(q^U))^{\alpha}}{-\log(q^U)\frac{\partial V^o(q^U)}{\partial q^U}} \tag{39}$$

by virtue of (29) and (24). From $V^o(q^U)n^o(q^U) = R(\frac{q^U+q_l}{2}, n^o(q^U), k^o(q^U))$ $- rk^o(q^U)$ it follows that

$$\frac{\partial V^o(q^U)}{\partial q^U} = \frac{n^o(q^U)}{2}F(n^o(q^U),k^o(q^U))\left(\frac{q^U+q_L}{2}\right)^{\left(n^o(q^U)-1\right)} \tag{40}$$

Inserting from (40) into (39) then reveals that

$$\frac{\frac{\partial EU(q,\tilde{n}(q),\tilde{k}(q))}{\partial q}\Big|_{q=q^U}}{\frac{\partial U(Y+V^o(\tilde{q}))}{\partial q^U}} = \frac{U'(Y+F(\tilde{n}(q^U),\tilde{k}(q^U)) - r\frac{\tilde{k}(q^U)}{\tilde{n}(q^U)})}{U'(Y+V^o(q^U))} \times \tag{41}$$

$$\times\frac{(q^U)^{\left(\tilde{n}(q^U)-1\right)}F(\tilde{n}(q^U),\tilde{k}(q^U))\left(q^U+q_L\right)}{-\log(q^U)n^o(q^U)\left(\frac{q^U+q_L}{2}\right)^{n^o(q^U)}F(n^o(q^U),k^o(q^U))}$$

The separating competitive equilibrium is necessarily unique, if (41) is greater than one for all $q^U \in [q_L,q_H]$. However, (41) can generally be greater than, equal to, or smaller than one. Hence, such a single-crossing property cannot be established. In particular, the uniqueness of the separating competitive industry equilibrium can be seen to require specific assumptions concerning the properties of $U(\cdot)$.

Hence, suppose that there exist multiple intersections of the two functions each characterized by $\tilde{q}_k \in (q_L,q_H)$ such that $EU(\tilde{q}_k,\tilde{n}(\tilde{q}_k),\tilde{k}(\tilde{q}_k)) = U(Y+V^o(\tilde{q}_k))$, with $k=1,..,K$ and $K \geqq 1$. Utilizing the arguments provided in the proof of Proposition 4, K must be an odd number then. Let the potential equilibrium separating ability levels $\tilde{q}_k$ be ordered such that $\tilde{q}_1 < \tilde{q}_2 < \tilde{q}_3 < ... < \tilde{q}_K$. Again the arguments used in the proof of Proposition 4 then imply that $EU(q,\tilde{n}(q),\tilde{k}(q)) < U(Y+V^o(\tilde{q}_1))$, $\forall q \in [q_L,\tilde{q}_1)$ and $EU(q,\tilde{n}(q),\tilde{k}(q)) > U(Y+V^o(\tilde{q}_K))$, $\forall q \in (\tilde{q}_K,q_H]$.

Note that only the ability levels $\tilde{q}_\ell$, with $\ell = 1,3,5,..,K$, may therefore characterize a separating competitive industry equilibrium as defined above. This follows, since each of these ability $\tilde{q}_\ell$ levels satisfies $EU(\tilde{q}_\ell,\tilde{n}(\tilde{q}_\ell),\tilde{k}(\tilde{q}_\ell))$ $= U(Y+V^o(\tilde{q}_\ell))$ and $EU(q,\tilde{n}(q),\tilde{k}(q)) < U(Y+V^o(\tilde{q}_\ell))$, $\forall q \in [q_L,\tilde{q}_\ell)$, while $EU(q,\tilde{n}(q),\tilde{k}(q)) > U(Y+V^o(\tilde{q}_\ell))$, $\forall q \in (\tilde{q}_\ell,q_H]$.

The intersections characterized by $\tilde{q}_{\ell'}$, with $\ell' = \{2, 4, .., (K-1)\}$ also satisfy condition b) of the definition of a competitive industry equilibrium. Moreover, by construction, $EU(\tilde{q}_{\ell'}, \tilde{n}(\tilde{q}_{\ell'}), \tilde{k}(\tilde{q}_{\ell'})) = U(Y + V^o(\tilde{q}_{\ell'}))$. However, $EU(q, \tilde{n}(q), \tilde{k}(q)) > U(Y + V^o(\tilde{q}_{\ell}))$, for $q \in [\tilde{q}_{\ell'-1}, \tilde{q}_{\ell'})$, while $EU(\tilde{q}, \tilde{n}(q), \tilde{k}(q)) < U(Y + V^o(\tilde{q}_{\ell'}))$, for at least some $q \in (\tilde{q}_{\ell'}, \tilde{q}_{\ell'+1}]$. The first inequality implies that some groups of current employees of managed firms would rather found ability-matched partnerships. According to the second inequality, the members of some current partnerships would rather join managed firms. Thus, condition c) of the definition provided in section 2 is violated for $\tilde{q}_{\ell'}$, with $\ell' = \{2, 4, .., (K-1)\}$.

Finally, since $EU(q, \tilde{n}(q), \tilde{k}(q))$ is monotonically increasing in q and $U(Y + V^o(q^U))$ is monotonically increasing in q^U, its is obvious that $\tilde{q}_K$ characterizes the unique efficient separating competitive industry equilibrium. ■

INSERT FIGURE 2.

Figure 2 illustrates the case with three intersections of $EU(q, \tilde{n}(q), \tilde{k}(q))$ and $U(Y + V^o(q^U))$. The ability levels $\tilde{q}_1$ and $\tilde{q}_3$ obviously constitute possible separating competitive equilibria. Given that these allocations are established, condition c) of the equilibrium definition above is satisfied. In contrast, given that $q = q^U = \tilde{q}_2$, the current members of some partnerships characterized by ability levels greater than $\tilde{q}_2$ would prefer to become employed by a managed firm. Moreover, they can join such firms by simply entering the pool of potential employees.

Furthermore, the equilibrium characterized by $q = q^U = \tilde{q}_3$ pareto-dominates the equilibrium attained at $q = q^U = \tilde{q}_1$. Interestingly, the efficient equilibrium thus minimizes the entrepreneurial activity in the economy. This is due to the fact that, at the same time, it maximizes the amount of risk-shifting in the industry, while still offering sufficient incentives to found dominant partnerships.

Yet, it should be noted that moving the industry from the inefficient equilibrium at $q = q^U = \tilde{q}_1$ to the efficient equilibrium at $q = q^U = \tilde{q}_3$ requires coordinated actions of partnerships. In particular, all partnerships characterized by team abilities $q \in [\tilde{q}_1, \tilde{q}_3)$ would have to coordinate to simultaneously join managed firms. However, such behavior is not consistent with competition among partnerships.

5 Concluding comments

Obviously, the analysis does not exclusively apply to particular new industries. Rather, it models the trade-off between the comparative advantage of entrepreneurial groups in organizing team-production and the implied necessity to incur the project risk. Both issues constitute re-occurring themes in the literature on entrepreneurship. Thus, the recent experience of the emergence of a so-called "New Economy" only provides an example. The respective new technologies appear to be characterized by positive complementarities between the firm's human assets. Utilizing the O-Ring production theory, such complementarities can be directly linked to reductions in the project risk.

"New Economy" firms rather typically emerge as spin-offs led by former high-profile employees of integrated firms. The assumption of risk-aversion thus appears straightforward. In addition, one of two jointly sufficient conditions for the existence of a separating equilibrium then highlights a possibly existing financial constraint. The private wealth of an entrepreneur must suffice to cover the per-capita investment costs associated with integrated production, given that team quality equals the average ability in the total population of professional specialists.

Recent discussions often refer to a perceived "volatility" of "New Economy" firms. Section 3 has shown that a small change in the production technology or market environment which increases the attractiveness of employment in "Old Economy" managed firms implies a rather significant reduction in the number of entrepreneurial spin-offs. Moreover, while there always exists a unique efficient equilibrium, multiple equilibria cannot be ruled out. This introduces still another source of volatility with respect to the emergence of entrepreneurial firms. Following a shock, the industry may attain a different separating equilibrium. If the new equilibrium is characterized by a higher (lower) separating ability level, the average size of the entrepreneurial firm increases (decreases) and the number of such firms decreases (increases) rather drastically.

Finally, recall figure 1 which for convenience depicts a situation with only one such equilibrium. This equilibrium - and also every other equilibrium which may arise - appears inherently unstable. In equilibrium, the human resource managements of "Old Economy" firms can assess that the entrepreneurial partnerships consist of professionals characterized by superior ability. In fact, the size of an entrepreneurial firm constitutes a perfect signal of team-quality. Since teams in such firms are homogeneous, a possibly existing problem of asymmetric information concerning individual abilities is therefore completely resolved. Thus, as discussed by Holmstrøm and Kaplan (2001), entrepreneurial spin-offs may actually serve as a purely transitory "discovery process". Given the advantage of risk-sharing in managed firms, this process provides incentives for re-integration.

Yet, this argument actually requires more than merely a solution to the informational problem. As noted by Bhidé (2000, p. 324) the "corporate culture" of established firms may still prevent the installment of ability-matched teams of superior quality. Thus, the degree to which re-integration will occur is determined by the integrating firms' abilities to differentiate wages. In this respect, section 3 has emphasized that the O-Ring approach induces rather significant variations of wages across production teams. If large corporations are constrained in enforcing such income rules, they will prefer to participate in entrepreneurial firms by providing the necessary venture capital. Hence, the emergence of the so-called "New Economy" appears less driven by favorable conditions in financial markets [Baily and Lawrence (2001)]. Rather, it reflects an organizational strategy of "incubator" corporations whose internal reward schemes cannot implement sufficient wage-differentiation.

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Appendix

Proof of the efficiency of the competitive equilibrium derived in Proposition 1:

In order to prove part b) of Proposition 1, let $A = \{\left(\Phi, n^f, k^f, \{q_i^f\}\right)\}$ denote the set of all possible allocations with Φ firms such that firm f, $f = 1, ..., \Phi$, employs n^f individuals with the ability profile $\{q_i^f\} \equiv \{q_i^f \mid i = 1, ..., n^f\}$ and rents capital k^f at unit costs r. Clearly, the allocation $\left(\hat{\Phi}, \hat{n}^f, \hat{k}^f, \{\hat{q}_i^f\}\right)$ is efficient, if the total surplus in the industry net of capital costs associated with this allocation satisfies

$$\begin{aligned} \sum_{f=1}^{\hat{\Phi}} \left[R\left(\{\hat{q}_i\}, \hat{n}, \hat{k}\right) - r\hat{k}\right] &\geqq \sum_{f=1}^{\Phi} \left[R\left(\{q_i\}, n, k\right) - rk\right], \qquad (42) \\ \forall\{\left(\Phi, n^f, k^f, \{q_i^f\}\right)\} &\in A \end{aligned}$$

Now, consider an efficient allocation and select two firms $f \neq g$, with $f, g \in \left\{1, ..., \hat{\Phi}\right\}$, such that $\{\hat{q}_i^f\} \neq \{\hat{q}_i^g\}$. Then,

$$F(\hat{k}^f, \hat{n}^f) \left[\prod_{j \neq i}^{\hat{n}^f - 1} \hat{q}_j^f\right] \hat{n}^f = F(\hat{k}^g, \hat{n}^g) \left[\prod_{j \neq \ell}^{\hat{n}^g - 1} \hat{q}_j^g\right] \hat{n}^g \qquad (43)$$

constitutes a necessary condition for the maximization of the total (net) surplus , if in these two firms $\hat{q}_i^f = \hat{q}_\ell^g$, for at least one $i \in \left\{1, .., \hat{n}^f\right\}$ and $\ell \in \{1, .., \hat{n}^g\}$. Since the capital rental rate is the same for the two firms g and f, a second set of necessary conditions yields

$$\frac{1}{\hat{k}^f} F(\hat{k}^f, \hat{n}^f) \left[\prod_{j=1}^{\hat{n}^f} \hat{q}_j^f\right] \hat{n}^f = \frac{r}{\alpha} = \frac{1}{\hat{k}^g} F(\hat{k}^g, \hat{n}^g) \left[\prod_{j=1}^{\hat{n}^g} \hat{q}_j^g\right] \hat{n}^g \qquad (44)$$

Multiplying both sides of (43) by $\hat{q}_i^f = \hat{q}_\ell^g$ and insertion into (44) thus implies $\hat{k}^f = \hat{k}^g$. Since capital inputs must be identical in the two firms, efficiency further requires

$$\begin{aligned} &F(\hat{k}^f, \hat{n}^f) \left[\prod_{j=1}^{\hat{n}^f} \hat{q}_j^f\right] \hat{n}^f - F(\hat{k}^f, \hat{n}^g) \left[\prod_{j=1}^{\hat{n}^g} \hat{q}_j^g\right] \hat{n}^g = \\ &F(\hat{k}^g, \hat{n}^g) \left[\prod_{j=1}^{\hat{n}^g} \hat{q}_j^g\right] \hat{n}^g - F(\hat{k}^g, \hat{n}^f) \left[\prod_{j=1}^{\hat{n}^f} \hat{q}_j^f\right] \hat{n}^f \\ &\rightarrow \left(\hat{n}^f\right)^{(2-\alpha)} \left[\prod_{j=1}^{\hat{n}^f} \hat{q}_j^f\right] = \left(\hat{n}^g\right)^{(2-\alpha)} \left[\prod_{j=1}^{\hat{n}^g} \hat{q}_j^g\right] \qquad (45) \end{aligned}$$

Otherwise, exchanging teams between the two firms would yield higher total net surplus in the industry. At the same time, efficiency requires that exchanging two single team members between the two firms cannot yield a higher total industry surplus net of capital costs. Hence,

$$F(\hat{k}^f,\hat{n}^f)\left[\prod_{j=1}^{\hat{n}^f}\hat{q}_j^f\right]\hat{n}^f - F(\hat{k}^f,\hat{n}^f)\left[\prod_{j\neq i'}^{\hat{n}^f-1}\hat{q}_j^f\right]q_{\ell'}^g\hat{n}^f =$$

$$F(\hat{k}^g,\hat{n}^g)\left[\prod_{j=1}^{\hat{n}^g}\hat{q}_j^g\right]\hat{n}^g - F(\hat{k}^g,\hat{n}^f)\left[\prod_{j\neq \ell'}^{\hat{n}^f-1}\hat{q}_j^f\right]q_{i'}^f\hat{n}^f \qquad (46)$$

for tasks $i' \in \{\{1,...,\hat{n}^f\}\diagdown i\}$ and $\ell' \in \{\{1,...,\hat{n}^g\}\diagdown \ell\}$. Then, using (44) and (45), (46) implies $q_{i'}^f = q_{\ell'}^g$, for all tasks $i' \in \{\{1,...,\hat{n}^f\}\diagdown i\}$ and $\ell' \in \{\{1,...,\hat{n}^g\}\diagdown \ell\}$ as well. This contradicts that $\{\hat{q}_i^f\} \neq \{\hat{q}_i^g\}$ as assumed above.

Thus, given that the allocation is efficient, all firms which use a particular quality in one of their tasks must share an identical ability profile. Then, consider firms of a particular type t - assuming that there exist $t = 1,...,\hat{T}$ different types in the industry. Type-t firms operate with identical capital input $\hat{k}^t$ and total team sizes $\hat{n}^t$. Assume that their teams consist of J^t subgroups of individuals characterized by abilities q_j^t, with $j = 1,...,J^t$. As shown above, only type-t firms employ these abilities. Full employment of each ability class therefore implies

$$\hat{\Phi}^t\hat{n}_j^t = \bar{n}, \quad \forall j = 1,...,J^t \qquad (47)$$

where $\hat{\Phi}^t$ denotes the efficient number of type-t firms and $\hat{n}_j^t$ refers to the size of the group of q_j-individuals in each of these firms. Clearly, (47) implies $\hat{n}_j^t = \hat{n}^t = \bar{n}/\hat{\Phi}^t$, $\forall j = 1,...,J^t$.

However, holding $\hat{n}^t$ constant, re-sizing the subgroups by exchanging individuals of different abilities between firms of type-t, will increase total surplus net of capital costs unless

$$F(\hat{k}^t,\hat{n}^t)\hat{n}^t\prod_{j\neq\{i,\ell\}}^{J^t} q_j\left[\log(q_i)\hat{n}_i^t - \log(q_\ell)\hat{n}_\ell^t\right] = 0 \qquad (48)$$

for each pair of ability groups (i,ℓ), with $i,\ell \in \{1,...,J^t\}$ and $i \neq \ell$. Obviously, $\hat{n}_j^t = \hat{n}^t$, $\forall j = 1,...,J^t$, as obtained above, contradicts that (48) can be satisfied. Consequently, there can only exist firms which employ a single ability-type in the efficient allocation.

The proof is now easily concluded by noting that (5), obtained in the existence proof for the competitive industry equilibrium following Proposition 1 above, generally characterizes the efficient choice of capital input of type-q firms. Thus, $\hat{k}(q) = k^*(q,\hat{n}(q))$. Since residual expected profits equal zero in the competitive industry equilibrium and $(k^*(q), n^*(q))$ constitutes the unique profit maximum in type-q firms, it is then clear that the competitive industry equilibrium characterized in Proposition 1 a) implements an efficient allocation. Non-dominated allocations can only differ from this equilibrium allocation in distributing income over the individuals other than implied by (9). ■

Figure 1: A Separating Equilibrium

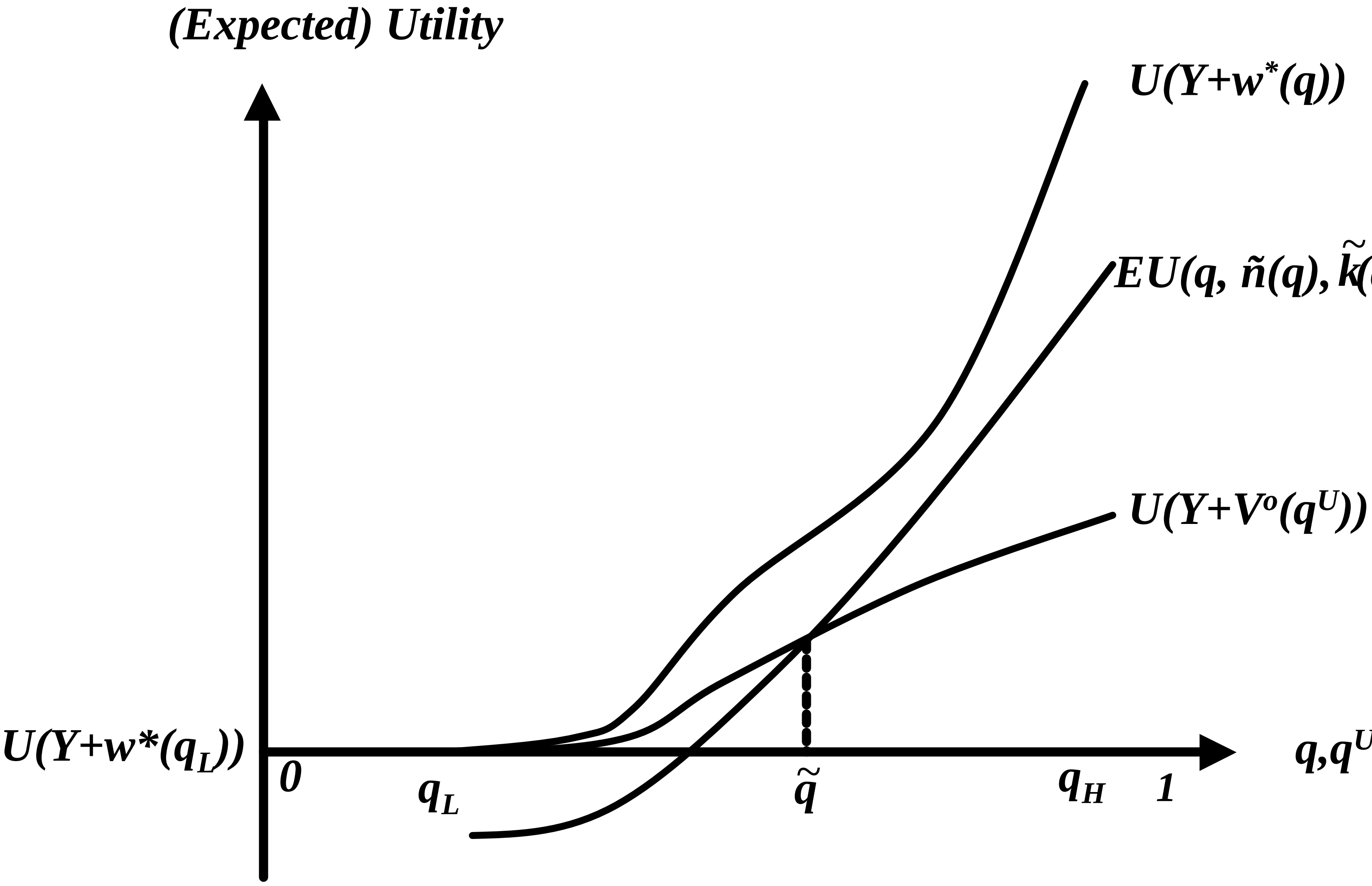

Figure 2: Multiple Separating Equilibria