Entrepreneurship and the Division of Ownership in New Ventures

Dominique Demougin

Walther-Rathenau-Chair in Organization Theory
School of Business and Economics
Humboldt University of Berlin
Spandauer Str. 1, 10178 Berlin, Germany
demougin@wiwi.hu-berlin.de

Oliver Fabel

Chair for Managerial Economics, in particular Business Policy
Department of Economics
Faculty of Law, Economics, and Political Science
University of Konstanz, Box D144, 78457 Konstanz, Germany
oliver.fabel@uni-konstanz.de

The current study investigates a tripartite incentive contract between an innovator supplying an intellectual asset, a professional assigned to productive tasks, and a consulting firm specializing in matching ideas and professional skills. A rather simple pure tripartite partnership implements the consultant's expected profit maximum and maximizes the project's expected surplus. The liquidity-constrained professional is compensated by receiving a share of one half in the new venture. The consultant's and the innovator's shares reflect the relative value of search. However, the consultant's optimal search effort to find an appropriate production partner is inefficiently low.

The authors acknowledge financial support of the German Research Council's (DFG) Collaborative Research Center 649 "Economic Risk" and its Research Group 454 "Heterogeneous Labor". Significant parts of this work have been finished while Demougin was a visiting scholar at BETA, University of Nancy 2, and Fabel at the Department of Economics, Finance, and Legal Studies, University of Alabama. The authors have received helpful discussions by participants of workshops at the Copenhagen Business School, organized by U. Kaiser and N. Malchow-Moeller, the Center for European Economic Research (ZEW) in Mannheim, in particular G. Licht and I. Bertschek, and the Institute for Strategy and the Economics of the Firm at the University of Zürich, specifically U. Backes-Gellner and E. Franck. Two anonymous referees and the editor of this journal have also provided critical but encouraging comments. However, the usual disclaimer applies.

Journal of Economics & Management Strategy, Volume 16, Number 1, Spring 2007, 111–128

1. Introduction

The current study investigates optimal incentive contracts to set up a new innovative firm. Three parties are involved in the project: the innovator supplying the idea for a new scientific application, a professional assigned to productive tasks, and a consultant specializing in matching innovators and professionals. The innovator's idea and the professional's effort constitute productive complements while the consultant's matching effort only increases the expected value of the project.[1] The objective of this paper is to analyze the resulting tripartite mechanism design problem under moral hazard and adverse selection.

To fix ideas, consider the following example. A biologist has identified relevant antigenic proteins of a bacterium allowing the development of a new diagnostic test. To produce a marketable test, the researcher would require the cooperation of a partner with the appropriate experience in developing, producing, and marketing pharmaceuticals. Typically, a consultant then offers his services to match the scientist with an industrial partner. However, while the consultant searches for an adequate professional, he can only reserve the exclusive right to act as a middleman between the innovator and a candidate professional still to be introduced. The innovator retains the right to opt out until a formal memorandum of association is signed.

In this example, one would expect numerous incentive problems. Initially only the scientist will know the precision and the complexity of the new test compared to already existing diagnostic methods.[2] However, only the professional possesses both some scientific expertise himself and industrial experience. Hence, the quality of the match between the innovator's idea and the professional's productive skills constitutes private information of the latter. Involving a consultant can reduce the matching uncertainty for the innovator. Yet, it also introduces additional difficulties. Specifically, due to the sequential nature of the players' interactions the contract must be renegotiation-proof between the innovator and the consultant. Finally, neither the search effort of the consultant nor the productive effort of the professional are likely to be contractible.

The "consultant" in the description above resembles a university technology transfer center[3] or, more generally, a "business angel," respectively a venture capitalist involved in "early-stage" project

1. Following Biais and Perotti (2003), for example, the consultant nevertheless provides the actual entrepreneurial innovation.

2. Jensen et al. (2003), Chukumba and Jensen (2006), and Elfenbein (2006) provide more general discussions on the nature of an academic innovator's private information.

3. O'Shea and Allen (2006). Chukumba and Jensen (2006) analyze startups and licensing as substitute forms of technology transfer.

development.[4] Although our analysis is therefore closely related to the existing literature on venture-capital backed startups, the problem of matching ideas and skills in teams of innovators and professionals has so far not attracted much attention by economists. Typically, economic analyses focus on startups in the "first financing stage."[5] It has long been recognized that venture capitalists provide important consulting and management services.[6] Thus, the optimal contract must solve a double moral hazard problem since both the innovator's and the "inside" investor's efforts affect project success.

Specifying the type of moral hazard problem then allows to investigate the institutional structure of venture-capital backed firms. For example, Aghion and Bolton (1992), Dewatripont and Tirole (1994) and Hart and Moore (1994, 1998) analyze models in which the entrepreneur can generate non-transferable private benefits, "steal" part of the cash-flow, or threaten to leave the firm (which is worth less without her due to the inalienability of human capital). In this kind of environment, the optimal contract assigns to the venture capitalist the right to take control in the "poor" states of nature or respectively to liquidate the firm.

Other authors examine the time structure of contracts. For example, Admati and Pfleiderer (1994) and Cornelli and Yosha (2003) show that "staging" the financing precludes mispricing securities, and/or "window dressing." Building upon a similar framework, Bergemann and Hege (1997) find that increasing shareholdings of the venture capitalist reflects her learning about the project's quality. Nöldecke and Schmidt (1998) and Lülfesmann (2004) show that contingent ownership contracts set efficient incentives in such sequential investment problems—in particular, if the first step requires to supply non-marketable R&D-effort. Thus, according to Schmidt (2003), the sequential nature of the double moral hazard problem implies the predominant use of convertible securities in financing new ventures.[7]

While this literature exclusively analyzes bipartite incentive-problems between a credit-constrained innovator and a venture capitalist, there exists an understanding that startups pose the problem of aligning incentives in a multipartite environment. Moreover, this environment does not reflect the hierarchical structures common to

4. Sohl (2003a,b).

5. Gompers and Lerner (2001), Kaplan and Strömberg (2001), and Botazzi and Da Rin (2002) provide extensive literature surveys.

6. See e.g., Rind (1981), Tyebjee and Bruno (1984), Sahlman, (1990), Lerner (1995), and Hellmann and Puri (2002).

7. This finding is empirically confirmed by Kaplan and Strömberg (2000). At the same time, the study strongly supports the earlier analyses of the allocation of control rights.

most multi-agent problems discussed in the literature.[8] For example, Rajan and Zingales (1998) and Dessi (2005) already analyze multipartite contracting to found a new firm. However, the former analysis endogenizes the number of agents while assuming an exogenous ownership structure. Dessi (2005) focuses very specifically on the "first financing phase" again. During this phase, the venture capitalist obtains additional information through his involvement in the new firm's operations. Hence, his decision to convert debt into ownership provides a credible signal concerning project quality to outside investors.

Obviously, it is difficult to analyze the complex interplay of the different incentive-compatibility and collusion-proofness conditions in multipartite problems. Thus, analyses of tripartite relationships are rare in the otherwise well developed contracting literature. Brown and Wolfstetter (1989) and Tsoulouhas (1999) constitute noticeable exceptions which also demonstrate, however, that solution concepts require a set of appropriate simplifications. In this respect, we have chosen to let the consultant act as a principal in the tripartite relationship[9] that appears to fit best with numerous case studies on high-tech startups. According to Dessi (2005), "*the relative scarcity of venture capitalists' skills and expertise seems well-established*" such as to support this assumption.[10]

Given this assumption, the subsequent analysis addresses the set of problems involved in matching ideas and skills during a startup's "early stage." A risk-neutral innovator possesses private information concerning the value of her business idea. To realize the project she requires a professional. However, she has no expertise in recruitment herself and may therefore turn to a risk-neutral consultant. Professionals perform operative tasks and are assumed to be liquidity constrained.[11] This assumption reflects that high-tech firms—such as pharmaceutical, computer, and software companies—prefer to organize their new (joint) ventures as budgeted projects.[12] Neither the value of the innovator's idea nor the effort supplies of the consultant and the professional are verifiable. To align incentives between the three parties compensations can therefore only be conditioned on the resulting (net) revenue.

The next crucial assumption of our model states that the consultant's initial contract offer to the innovator must be renegotiation-proof.

8. See Mookherjee (2005) for a recent survey and a taxonomy of principal-agent problems.

9. Alternatively, one could introduce elements of cooperative game theory—such as the Shapley-value concept—in the otherwise noncooperative game. See Perez-Castrillo and Wettstein (2005).

10. On this issue also see Biais and Perotti (2003).

11. As is well known from Nöldecke and Schmidt (1998) and Lülfesmann (2004) the professional would otherwise offer an option-to-buyout contract.

12. Davila and Foster (2004, 2005).

The assumption implies that the terms of the incentive contract with the professional still to be found must be rationally anticipated and included in this initial offer. Although the model structure does not satisfy the standard requirements necessary to apply the revelation principle, renegotiation-proofness then allows to pursue a stepwise solution procedure similar to backward-induction.

As explained above, the professional, once found, can observe the innovator's type. Thus, solving a standard moral hazard problem, it is optimal to allocate a fixed share of one half in the new venture to the professional. There are no additional fixed payments. Because the professional's optimal contract is therefore independent of project-type, communication possesses no value. Nevertheless, contracting between the innovator and the consultant remains cumbersome. The contract must still simultaneously address the adverse selection problem with respect to innovator-types and the verification problem concerning the consultant's choice of search intensity.

Our model analysis shows that the consultant's expected profit optimum requires to set fixed payments equal to zero and only share the remaining half of the revenue with the innovator. Search effort is enforced upon the consultant by the credible threat that the innovator could opt out. However, because the professional earns a rent, the intensity of search is inefficiently low. Further, the sharing rule between the consultant and the innovator reflects the relative value of the project-specific search activity. Consequently, the innovator cannot gain by misrepresenting her type and will report truthfully to the consultant. Concluding, the optimal tripartite contract constitutes a pure revenue-sharing contract among all three parties. It can be implemented through a governance structure in which ownership shares determine the three parties revenue claims.

This paper is organized as follows. The subsequent section introduces the basic model, derives the value of the innovator's outside option, and explains the time-structure of the game. Section 3 derives the optimal tripartite contract. The final section provides a summary and draws conclusions.

2. The Model

2.1 The Production and Information Structure

Consider an environment with risk-neutral parties. An innovator has generated a business idea of type $\theta \geqq 0$ drawn from a distribution $G(\theta)$. In order to exploit this idea economically, she needs the assistance of an industry professional. Professionals can be of different ability not equally matched with the innovator's project type. The quality of the match–that is, the "goodness of fit" between the innovator's idea and the professional's skills—is denoted by x where $x \in [0, 1]$ is a random variable drawn from the distribution $F(x; s)$. The variable $s \geqq 0$ denotes search effort in recruiting a professional. We assume that $F(x, s)$ satisfies the regularity requirements $F_s(x, s) < 0$ and $F_{ss}(x, s) > 0$.[13] The innovator can delegate the search activity to a consultant. Production further requires the professional to supply effort $e \geq 0$.

Jointly, the innovative idea, quality of the match, and professional effort generate revenue

$$y = \mu\theta x e \tag{1}$$

where μ is an independently distributed, positive random variable with $E(\mu) = 1$. Revenue is understood to be net of all production costs except for the cost of compensating the professional. The professional's private costs of effort are given by the quadratic cost function $\frac{e^2}{2}$. The innovator is taken to incur prohibitively high costs of searching for a professional on her own while the consultant's search costs are $c(s)$, with $c'(s) > 0$, $c''(s) > 0$, and $c(0) = 0$.

The contractual relationships between the parties are subject to multiple constraints summarized in the following assumption.

Assumption 1: *All the relevant distributions are common knowledge. In addition,*

1. *if the innovator delegates search to a consultant, she observes the search effort;*
2. *upon contracting, but before supplying effort, the professional observes θ and x;*
3. *third parties called upon to enforce the contract can only observe y and verify whether explicit contractual terms are fulfilled;*
4. *the professional is financially constrained requiring payments to be non-negative.*

Assumptions 1.1–1.3 imply that contracting between the innovator and the consultant is subject to hidden action and hidden information preventing first-best. Due to 1.4, contracting with the professional is also second-best because it must solve a moral hazard and adverse selection problem subject to a liquidity-constraint.

A very specific feature of our model is that, due to his experience in industrial production, the professional, once matched, actually observes

13. Intuitively, intensified search generates a first-order stochastic dominant distribution where the search technology satisfies the Convexity of Distribution Function Condition (CDFC). For a general reference, see Rogerson (1985).

the productive potential of the project, i.e., the value of θx. In contrast, drawing on his experience in matching ideas and professionals, the consultant can reduce but not eliminate the uncertainty about the quality x of a particular match. Finally and purely for tractability, we limit compensation rules to be linear in revenue y.[14]

2.2 The Innovator's Outside Option

In this subsection we analyze the innovator's stand-alone project which results if she does not contract with a consultant and must find a professional by herself. The expected profit from this alternative constitutes her outside-option. Given that her search costs are assumed prohibitive, she draws x from the distribution $F(x, 0)$. In the ensuing match with a professional, we assume she has the entire bargaining power. Accordingly, standard principal-agent analysis can be used to derive the optimal contract.

The informational structure for the innovator's stand-alone project follows directly from assumption 1.2, i.e., the agency relationship is subject to a moral hazard and adverse selection problem. After the parties are matched, an innovator (i.e., the principal) of type θ offers a contract $\mathcal{C}^{IP} = \{a(\theta, r), b(\theta, r)\}$ to the professional (i.e., the agent) where ρ denotes the professional's report on x. Applying the revelation principle, the contract between a θ-innovator matched with a professional of type x yields a compensation $a(\theta, x) + b(\theta, x)y$ for the professional.

Thus, the value of the outside option for an innovator of type θ can be derived as

$$v(\theta) = \max_{(e(\theta,x),a(\theta,x),b(\theta,x))} \int_{x \geqq 0} [\theta x e(\theta, x) - a(\theta, x) - b(\theta, x)\theta x e(\theta, x)]\, dF(x, 0), \tag{I}$$

$$\text{subject to } (e(\theta, x), x) = \arg\max_{(\eta,\rho)} a(\rho, \theta) + b(\rho, \theta)\theta x \eta - \frac{\eta^2}{2}, \tag{IC}$$

$$a(\theta, x) + b(\theta, x)\theta x e(\theta, x) - \frac{(e(\theta, x))^2}{2} \geqq 0, \tag{PC}$$

$$a(\theta, x) + b(\theta, x)\mu\theta x e(\theta, x) \geqq 0, \quad \forall \mu. \tag{LL}$$

14. Observe that we are only limiting the compensation rules to be linear, not the contract itself. Holmström and Milgrom (1987) provide further support for the linearity assumption given that contracts are intended to extend further into the new firm's future business.

Note that in (I) the term in the square bracket already constitutes the expected value taken over μ. The same observation holds for the following two constraints. Equality (IC) is the typical incentive compatibility constraint for an agency relationship with moral hazard and adverse selection and inequality (PC) is the participation condition. The limited liability requirement (LL) must then be satisfied for all revenue realizations.

Proposition 1: *If the innovator pursues her stand-alone project, she offers a type-independent incentive contract $a^*(\theta, r) = 0$ and $b^*(\theta, r) = 1/2$. Given this optimal contract with the professional, the value of the outside option for an innovator of type θ is $v(\theta) = \frac{\theta^2}{4}E[x^2 \mid s = 0]$.*

Proof. We initially substitute the first-order constraint with respect to effort

$$b(\theta, x)\theta x = e(\theta, x) \tag{2}$$

for (IC). After deriving the solution of this simplified optimization problem, we verify that it satisfies truth-telling with respect to x as well.

Inserting from (2) into (PC) implies that the participation constraint cannot be binding. Also according to (2), bonus payments are nonnegative. Because a positive fixed payment $a(\theta, x)$ only reduces the innovator's expected profit, (LL) implies $a^*(\theta, x) = 0$. Using (2) to replace $e(\theta, x)$ in the innovator's objective function and optimizing pointwise yields $b^*(\theta, x) = b^* = \frac{1}{2}$. Thus, $e^*(\theta, x) = \frac{1}{2}\theta x$. By insertion, we have

$$v(\theta) = \int_{x \geqq 0} \left[\frac{1}{2}(\theta x)^2 - \frac{1}{4}(\theta x)^2\right] dF(x, 0) = \frac{\theta^2}{4}E[x^2 \mid s = 0]. \tag{3}$$

Finally, observe that truth-telling with respect to x is trivially satisfied since a^* and b^* are constant. □

The optimal stand-alone contract is extremely simple. The innovator and the professional equally share the project's revenue. Because this revenue has been defined net of all production costs other than the professional's compensation, the optimal contract can thus be implemented by founding a partnership of equals. As one would expect in a moral hazard and adverse selection environment, the professional earns a positive rent. Moreover, within the current environment communication possesses no value as discussed by Demougin (1989) and Melumad and Reichelstein (1989).

2.3 The Timing of the Tripartite Game

As discussed in the introduction, we assume that the consultant acts as a principal in the tripartite agency problem. The timing of the tripartite game is as follows. First, the innovator observes the value of her project θ. Second, the consultant makes a take-or-leave-it contract offer $\mathcal{C}^{CI} = \{r, s(r), \delta(r), \gamma(r), \mathcal{C}^{CP}\}$ to the innovator where r denotes the innovator's report about her project-type, $s(r)$ the consultant's promised search intensity, $\delta(r)$ a fixed payment to the innovator, and $\gamma(r)$ her revenue share. Clearly, the compensation offer to the innovator is conditional on not opting out to pursue her stand-alone project. Further, the offer includes the specification of a standard incentive contract $\mathcal{C}^{CP}$ with a professional still to be found. Thus, $\mathcal{C}^{CP} = \{\rho, \alpha(\rho), \beta(\rho)\}$ where ρ denotes the professional's report on θx while $\alpha(\rho)$ and $\beta(\rho)$ are the corresponding fixed payment and and revenue claim of the professional.

Third, the innovator decides whether to accept the consultant's offer $\mathcal{C}^{CI}$. If she does not accept the contract, the innovator pursues her stand alone-project. At stage four, the innovator makes her report r. Fifth, the consultant searches with intensity σ which is simultaneously observed by the innovator. Recall that, so far, the initial contract $\mathcal{C}^{CI}$ has only established the exclusive right for the consultant to act as a middleman between the innovator and a professional found through the consultant's search activity. Thus, sixth, the innovator now decides whether or not to accept the compensation package $\{\delta(r), \gamma(r)\}$ or opt out to pursue her stand-alone project.

Seventh, a professional is drawn from the distribution $F(x, s)$ and he observes θ and x. Eighth, based on the contract $\mathcal{C}^{CI}$, the consultant makes the take-or-leave-it offer $\mathcal{C}^{CP}$ to the professional. At this stage, we require that the professional's contract offer does not lead to a renegotiation of the initial contract $\mathcal{C}^{CI}$ between the consultant and the innovator. Said differently, $\mathcal{C}^{CI}$ is taken to constitute an equilibrium contract offer.[15] Ninth, the professional makes the report ρ about her information θx.[16] Finally, y is realized and payments are made according to the tripartite contract $\mathcal{C}^{CI}$.

15. In contrast, suppose $\mathcal{C}^{CP}$ were not part of the innovator's contract $\mathcal{C}^{CI}$. At stage eight, the consultant would then offer a contract to the professional that maximizes his own expected profit based on his share of the revenue, that is, $(1 - \gamma(r))$. However, this contract cannot sustain in equilibrium. Indeed, the innovator would have an incentive to renegotiate to increase her fixed payment and reduce her share γ. Obviously, the parties would anticipate this renegotiation.

16. The fact that the professional's report combines both the information on x and θ would also obtain for more generalized production functions of the type $y = \mu q(x, \theta)e$.

3. The Optimal Tripartite Contract

The existing literature does not allow to conclude that the revelation principle will generally apply in the tripartite game described above. In particular, if the innovator's report $r(\theta)$ were not type-revealing, the consultant's subjective belief concerning the conditional distribution of θx would differ from that of the innovator at stage eight. We can therefore not use standard backward induction to solve for the optimal tripartite contract. Yet, given the assumption that the initial contract $\mathcal{C}^{CI}$ is renegotiation-proof, we can still pursue a step-wise procedure.

Observe that, for $\mathcal{C}^{CI}$ to be renegotiation-proof between the innovator and the consultant, $\mathcal{C}^{CP}$ must maximize these two parties' expected joint surplus net of the professional's compensation costs. Given that beliefs may differ between the innovator and the consultant, it would generally be difficult to agree on a contract which maximizes expected joint profit.

However, due to the assumption that the professional observes the realizations of both θ and x, the contract is independent of the belief structure in our model. Hence, let $z = \theta x$ and $H(z)$ be any distribution of z over the common support $z \geq 0$. Consider the solution to the following problem:

$$\max_{[\alpha(z),\beta(z),e(z)]} \int_{z\geq 0} \{ze^{*}z) - \alpha(z) + \beta(z)ze(z)\}\, dH(z) \tag{II}$$

subject to

$$(e(z), z) = \arg\max_{(\eta,\rho)} \; \alpha(\rho) + \beta(\rho)z\eta - \frac{(\eta)^2}{2}, \tag{PIC}$$

$$\alpha(z) + \beta(z)ze(z) - \frac{(e(z))^2}{2} \geqq 0, \tag{PPC}$$

$$\alpha(z) + \beta(z)z\mu e(z) \geqq 0, \quad \forall \mu. \tag{PLL}$$

Again, the professional's incentive compatibility and participation constraints (PIC) and (PPC) are in terms of expectations taken over the revenue shock μ, while the liquidity constraint (PLL) must be satisfied for all realizations of revenue y.

Proposition 2: *Independent of the belief structure, the optimal renegotiation-proof contract $\mathcal{C}^{CP*}$ offered to the professional is characterized by $\alpha^{*}(\theta x) = 0$ and $\beta^{*}(\theta x) = 1/2$. The professional supplies effort $e^{*}(\theta x) = \frac{1}{2}\theta x$.*

The proof follows exactly along the same lines as that of Proposition 1 and is therefore omitted. Hence, it is also true that communication between the consultant and the professional possesses no information value.

Given Proposition 2, the expected compensation costs associated with the effort supply $e^*(\theta, x) = \frac{1}{2}\theta x$ can simply be inserted into the consultant's problem to find the optimal contract offer to the innovator $\mathcal{C}^{CI}$. Observe that the revelation principle then applies for the remaining problem, since the optimal contract with the professional $\mathcal{C}^{CP*} = \{\rho, 0, \frac{1}{2}\}$ is independent of the parties' beliefs. In particular, the innovator cannot influence the professional's contract (thus, the resulting effort supply) through variations in reporting.

Hence, the consultant acting as the principal solves

$$\max_{[\delta(\theta), \gamma(\theta), s(\theta)]} E_\theta E_x \left\{ \frac{(\theta x)^2}{4} [1 - 2\gamma(\theta)] - \delta(\theta) - c(s(\theta)) \mid s(\theta) \right\} \tag{III}$$

subject to

$$\theta = \arg \max_{r \geq 0} \delta(r) + \gamma(r) \frac{\theta^2}{2} E_x\{x^2 \mid s(r)\}, \tag{IIC}$$

$$\begin{cases} s(\theta) = \arg \max_{\sigma} [1 - 2\gamma(\theta)] \dfrac{\theta^2}{4} E_x\{x^2 \mid \sigma\} - \delta(\theta) - c(\sigma) \mid \sigma\}, & \text{(CCC)} \\ \qquad \text{subject to } \delta(\theta) + \gamma(\theta) \dfrac{\theta^2}{2} E_x\{x^2 \mid \sigma\} \geq v(\theta). & \text{(IPC)} \end{cases}$$

The objective function (III), the innovators' incentive-compatibility constraints (IIC), and the consultant's credibility constraint (CCC) all contain expected values taken over the revenue shock μ.

The latter constraint (CCC) states that, after the innovator has accepted the contract and made a report at stage four of the game, it must be optimal for the consultant to provide the promised search effort. Thus, anticipating the effort supply of a professional who must still be found, the consultant will determine his search activity to maximize his expected profit. Note, however, that in maximizing his expected profit the consultant is constrained by the innovator's participation condition (IPC). If the expected income of the innovator would fall short of $v(\theta)$, she would opt out and pursue her stand-alone project.

To solve the optimization problem (III), we begin by investigating the (CCC)-constraint. We initially assume that $[1 - 2\gamma(\theta)] \geq 0$. Subsequently, we verify that this requirement is indeed satisfied.

Introducing a slackness variable $\zeta(\theta)$, we can rewrite the (IPC)-condition as

$$\delta(\theta) + \gamma(\theta) \frac{\theta^2}{2} E_x\{x^2 \mid s(\theta)\} - v(\theta) - (\zeta(\theta))^2 = 0. \tag{4}$$

Note that, for every given $\gamma(\theta) > 0$, the expected income of the innovator is monotonically increasing in the consultant's search effort. Thus, we can substitute from (4) into the consultant's objective function at stage five when he decides upon his search intensity and rewrite (CCC) as

$$\max_{(\sigma,\zeta(\theta))} \frac{\theta^2}{4} E_x\{x^2 \mid \sigma\} - v(\theta) - (\zeta(\theta))^2 - c(\sigma). \tag{CCC$'$}$$

Restating the consultant's credibility constraint immediately yields two conclusions. First,

$$s^*(\theta) = \arg\max_{\sigma} \frac{\theta^2}{4} E_x\{x^2 \mid \sigma\} - c(\sigma). \tag{5}$$

Hence, search effort in the tripartite contract is second-best because of the rent paid to the professional. Second, $\zeta^*(\theta) = 0$ which implies that the innovator's participation constraint must be binding.

Intuitively, it is optimal for the consultant to maximize his expected profit by minimizing the expected costs of compensating the innovator. This compensation cost minimum is realized if the innovator's expected income just meets her participation constraint. Within the current framework, this solution can also serve to enforce the promised search effort upon the consultant. He can credibly commit to search with intensity $s^*(\theta)$ because the innovator would opt out if the consultant would choose a lower intensity.[17]

Using this result, notice that, at stage 4, the innovator's optimization with respect to reporting will satisfy

$$v(\theta) = \max_{r \geq 0} \delta(r) + \gamma(r)\frac{\theta^2}{2} E_x\{x^2 \mid s^*(\theta)\}, \tag{6}$$

because the rational consultant will anticipate the innovator's reporting behavior. By the envelope theorem it must therefore be true that

$$v'(\theta) = \frac{\theta^2}{2} E_x\{x^2 \mid 0\} = \gamma(\theta)\theta E_x\{x^2 \mid s^*(\theta)\}. \tag{7}$$

Given the value of $v(\theta)$ provided in Proposition 1 above, it follows that

$$\gamma^*(\theta) = \frac{1}{2} \frac{E_x\{x^2 \mid 0\}}{E_x\{x^2 \mid s^*(\theta)\}}. \tag{8}$$

Observe that $[1 - 2\gamma^*(\theta)] > 0$ for all θ such that $s^*(\theta) > 0$. Hence, our initial assumption can now be verified to be satisfied. Finally, to obtain

17. Hence, the solution to the consultant's constraint optimization problem (CCC) does not constitute an interior solution which would be characterized by the first-order condition $(1 - \gamma(\theta))\theta \int [xe(\theta, x) - (e(\theta, x))^2] f_s(x; s(\theta))\, dx = c'(s(\theta))$. Note that this interior solution implies that effort falls short of $s^*(\theta)$ for every $\gamma(\theta) > 0$.

the optimal fixed payment to the innovator we can substitute for $\gamma^*(\theta)$ into (IPC) which implies $\delta^*(\theta) = 0$.

This contract induces innovators to report correctly because their payments are actually independent of their reports. Observe that

$$\delta^*(r) + \gamma^*(r)\frac{\theta^2}{2}E_x\{x^2 \mid s^*(r)\} = 0 + \frac{\theta^2}{4}\frac{E_x\{x^2 \mid 0\}}{E_x\{x^2 \mid s^*(r)\}}E_x\{x^2 \mid s^*(r)\}$$
$$= \frac{\theta^2}{4}E_x\{x^2 \mid 0\} = v(\theta). \tag{9}$$

Thus, whatever value r an innovator chooses to report, the consultant responds by searching with intensity $s^*(r)$. Yet, in this case the innovator's share of revenue is given by $\gamma^*(r)$ and, with fixed payments $\delta^*(r)$ equal to zero, she again only obtains an expected equal to $v(\theta)$. Since the innovator therefore possesses no incentive to misrepresent her type, the incentive-compatibility constraint (IIC) is clearly satisfied as well.

Summing up the above analysis, yields the following:

Proposition 3: *The optimal triparitite contract is characterized as*

$$\mathcal{C}^{CI*} = \{s^*(\theta), \delta^*(\theta), \gamma^*(\theta), \mathcal{C}^{CP*}\}$$
$$= \left\{s^*(\theta), 0, \frac{1}{2}\frac{E_x\{x^2 \mid 0\}}{E_x\{x^2 \mid s^*(\theta)\}}, \mathcal{C}^{CP*}\right\}, \tag{10}$$

where the consultant's search intensity $s^*(\theta)$ is implicitly characterized by

$$c'(s^*(\theta)) = \frac{\theta^2}{4}\int x^2 f_s(x; s^*(\theta))\,dx. \tag{11}$$

The proposition warrants some remarks. First, the conclusion that $\delta^*(\theta) = 0$ is important. Suppose to the contrary that $\delta^*(\theta) > 0$ for some realization of θ. Then individuals without any innovative project [$\theta = 0$] could report r, obtain this positive fixed payment, and go bankrupt afterwards. Obviously, this solution is not viable because the consultant would attract an infinity of such zero-value projects.

Second, the model yields a rather strong and testable prediction concerning the innovator's share. According to (8),

$$\frac{\partial \gamma^*(\theta)}{\partial \theta} = -\frac{1}{2}\frac{E_x\{x^2 \mid 0\}}{[E_x\{x^2 \mid s^*(\theta)\}]^2}\frac{\partial E_x\{x^2 \mid s^*(\theta)\}}{\partial s(\theta)}\frac{\partial s^*(\theta)}{\partial \theta} \tag{12}$$

and, totally differentiating (11), yields

$$\frac{\partial s^*(\theta)}{\partial \theta} = -\frac{\dfrac{\theta}{2}\dfrac{\partial E_x\{x^2 \mid s^*(\theta)\}}{\partial s(\theta)}}{\dfrac{\theta^2}{4}\dfrac{\partial^2 E_x\{x^2 \mid s^*(\theta)\}}{(\partial s(\theta))^2} - c''(s^*(\theta))} > 0. \tag{13}$$

Thus, the innovator's share decreases with higher project value.[18] Economically, this result implies that industry-wide consulting activities increase with the proportion of high (above average) value projects. At the same time, the average innovator's share decreases.

Third, the optimal tripartite contract maximizing the consultant's expected profit also exhibits a very simple structure. Renegotiation-proofness requires that the professional recruited by the consultant receives a share of one-half of the revenue. Thus, the consultant and the innovator can only distribute half of the expected revenue among them. As discussed above, they cannot use fixed payments to do so. Consequently, the optimal tripartite contract can also be implemented by founding a partnership. Ownership shares of $\{(1-\gamma^*(\theta)), \gamma^*(\theta), \frac{1}{2}\}$ for the consultant, the innovator, and the professional in this partnership of three then optimally determine the distribution of project revenue. Clearly, given the moral hazard problem when contracting with a professional, renegotiation-proofness further implies that the contract $\mathcal{C}^{CI*}$ maximizes the project's expected surplus.

Finally, recall that the innovator retains her right to opt out until the consultant has completed his search and turns back to her with a candidate professional. Hence, taking only a slightly different perspective, this opting-out possibility of the innovator mirrors a contingent-ownership claim of the consultant when he sets out to search for a professional: only contingent on the innovator's acceptance of the professional introduced by the consultant, the consultant can realize his ownership claim. Yet, the consultant's search effort cannot be verified and, in our model, takes place before the joint venture is formally founded. Hence, in contrast to the literature on debt conversion as means to implement contingent ownership claims, the consultant's contingent claim is part of an implicit contract.

4. Summary and Conclusions

The current analysis investigates a tripartite incentive contract between an innovator supplying the idea for a new scientific application as

18. Nevertheless, the value of this share increases because $v'(\theta) > 0$.

a necessary asset, a professional assigned to productive tasks, and a consulting firm specializing in recruiting qualified personnel. Contracts can only be contingent on the venture's earnings gross of these parties' compensation costs. The optimal tripartite contract then implies pure (net) revenue-sharing. The liquidity-constrained professional receives a claim on half of the new venture's revenue.[19] The innovator shares her remaining half with the consultant.

The sharing rule between the consultant and the innovator reflects the relative value of the project-specific search activity. Thus, innovators can be taken to report their project value truthfully. Further, the innovator receives her reservation income which is equal to the expected value of their stand-alone project. This rule ensures that the promised search effort is enforced on the consultant by the innovator's threat to opt out. Moreover, although the value of an innovator's partnership share increases with project value, the share itself actually decreases. Correspondingly, the consultant's share which compensates for his consulting service increases with higher project value.

These sharing-rules of the optimal tripartite incentive contract can be implemented formally by founding a partnership of three. Yet, in contrast to Biais and Perotti (2003), the respective ownership-shares taken in the new firm do not reflect any transfer of financial resources. Note that in our model the professional becomes the majority owner. This view of optimal ownership structures in innovative ventures also contrasts with Casamatta (2003) and the related work on "stage financing." In these studies, the liquidity constraint of the innovator motivates the presence of a venture capitalist whose financial involvement then provides useful instruments to set appropriate incentives.

Within the current framework, the prospect to become a partner which mirrors the innovator's option to participate or, else, pursue her stand-alone project sets appropriate incentives for the consultant as a matching-specialist. Thus, the current analysis also adds to the existing literature on contingent-ownership contracts. In Nöldecke and Schmidt (1998) and Lülfesmann (2004) the sequential order of ownership-acquisition reflects the sequential nature of moral hazard problems. In contrast, the opting-out contract with pure revenue-sharing derived above provides efficient incentives to simultaneously solve the moral hazard problem of the consultant and the adverse selection problem with respect to innovator-types. Formally, the opting-out alternative of the innovator is likely to be reflected in a letter of intent signed with

19. However, this particular sharing rule reflects the quadratic cost assumption. Following Belleflamme and Bloch (2000) and Hauswald and Hege (2003) asymmetries in the productive capacities of the necessary assets would yield asymmetric ownership strutures.

the consultant. Only if the innovator accepts the producer introduced by the consultant, the respective memorandum of association will then also be signed.

In fact, the "biologist" example in the introduction constitutes the stylized account of a real case in which one of the authors was involved. The consultant being a venture capital subsidiary of a large pharmaceutical firm introduced only one suitable producer which turned out to be a subsidiary of the same pharmaceutical.[20] Likely, the scientist took this outcome to signal insufficient search by the consultant. Thus, ending a lengthy period of negotiating up-front investments—that is, fixed payments—which were supposed to reflect asset values, the scientist actually opted out. He is now pursuing his work on new diagnostics heading the research division of a super-national health organization.

References

Admati, A.R. and P. Pfleiderer, 1994, "Robust Financial Contracting and the Role of Venture Capitalists," *Journal of Finance*, 49, 371–402.

Aghion, P. and P. Bolton, 1992, "An Incomplete Contracts Approach to Financial Contracting," *Review of Economic Studies*, 59, 473–494.

Belleflamme, P. and F. Bloch, 2000, *Optimal Ownership Structures in Asymmetric Joint Ventures*, Department of Economics, Queen Mary & Westfield College, Working Paper No. 411, University of London.

Bergemann, D. and U. Hege, 1997, "Venture Capital Financing, Moral Hazard, and Learning," *Journal of Banking and Finance*, 22, 703–735.

Biais, B. and E. Perotti, 2003, *Entrepreneurs and New Ideas*, Working Paper No. 347, Toulouse, IDEI.

Botazzi, L. and M. Da Rin, 2002, "Venture Capital in Europe and the Financing of Innovative Companies," *Economic Policy*, 34, 231–269.

Brown, M. and E. Wolfstetter, 1989, "Tripartite Income-Employment Contracts and Coalition Incentive Compatibility," *RAND Journal of Economics*, 20, 291–307.

Casamatta, C., 2004, "Financing and Advising: Optimal Financial Contracts with Venture Capitalists," *Journal of Finance*, 58, 2059–2086.

Chukumba, C.O. and R.A. Jensen, 2006, "University Invention, Entrepreneurship, and Startups," Working Paper No. 11475 provided by National Bureau of Economic Research, Inc.

Cornelli, F. and O. Yosha, 2003, "Stage Financing and the Role of Convertible Debt," *Review of Economic Studies*, 70, 1–32.

Davila, T. and G. Foster, 2004, *Management Accounting Systems Adoption: Evidence and Performance Implications from Startup Companies*, Palo Alto, Research Paper No. 1874, Graduate School of Business, Stanford University.

—— and ——, 2005, *Startup Firms: Growth, Management Control Systems Adoption, and Performance*, Barcelona-Madrid, Working Paper No. 603, IESE Business School, University of Navarra.

20. Wright et al. (2004) point out that venture capitalists who offer their services as "early stage" consultants are often subsidiaries or departments of industrial firms.

Demougin, D.M., 1989, "A Renegotiation-Proof Mechanism for a Principal-Agent Model with Moral Hazard and Adverse Selection," *RAND Journal of Economics*, 20, 256–267.

Dessi, R., 2005, "Start-up Financing, Monitoring, and Collusion," *RAND Journal of Economics*, 36, 255–274.

Dewatripont, M. and J. Tirole, 1994, "A Theory of Debt and Equity: Diversity of Securities and Manager-Shareholder Congruence," *Quarterly Journal of Economics*, 109, 1027–1054.

Elfenbein, D.W., 2006, "Publications, Patents, and the Market for University Inventions," Working Paper, April 30.

Gompers, P.A. and J. Lerner, 2001, "The Venture Capital Revolution," *Journal of Economic Perspectives*, 15, 145–168.

Hart, O. and J. Moore, 1994, "A Theory of Debt Based on the Inalienability of Human Capital," *Quarterly Journal of Economics*, 109, 851–879.

—— and ——, 1998, "Default and Renegotiation: A Dynamic Model of Debt," *Quarterly Journal of Economics*, 113, 1–41.

Hauswald, R. and U. Hege, 2003, *Ownership and Control in Joint Ventures: Theory and Evidence*, Les Cahiers de Recherche No. 750, Groupe HEC, Paris.

Hellmann, T. and M. Puri, 2002, "Venture Capital and the Professionalization of Start-Up Firms: Empirical Evidence," *Review of Financial Studies*, 13, 959–984.

Holmström, B. and P.R. Milgrom, 1987, "Aggregation and Linearity in the Provision of Intertemporal Incentives," *Econometrica*, 55, 303–328.

Jensen, R.A., J.G. Thursby, and M.C. Thursby, 2003, "The Disclosure and Licensing of University Inventions," *International Journal of Industrial Organization*, 21, 1255–1270.

Kaplan, S.N. and P. Strömberg, 2000, *Financial Contracting Meets the Real World: An Empirical Analysis of Venture Capital Contracts*, Working Paper No. 513, University of Chicago, Graduate School of Business, The Center for Research in Security Prices.

—— and ——, 2001, "Venture Capitalist as Principals: Contracting, Screening and Monitoring," *American Economic Review*, 91, 426–430.

Lülfesmann, C., 2004, "Research Collaborations with Sequential Investments," *Economica*, 71, 241–259.

Lerner, J., 1995, "Venture Capitalists and the Oversight of Private Firms," *Journal of Finance*, 50, 301–318.

Melumad, N.D. and S. Reichelstein, 1989, "Value of Communication in Agencies," *Journal of Economic Theory*, 47, 334–368.

Mookherjee, D., 2005, *Decentralization, Hierarchies and Incentives: A Mechanism Design Perspective*, Working Paper No. WP2005-033, Boston University, Department of Economics.

Nöldecke, G. and K. Schmidt, 1998, "Sequential Investments and Options to Own," *RAND Journal of Economics*, 29, 633–653.

O'Shea, R.P. and T.J. Allen, 2006, "Determinants and Consequences of University Spinoff Activity: A Conceptual Framework," in F. Therin, ed., *Handbook of Research in Techno-Entrepreneurship*, Cheltenham Glos, UK: Edward Elgar.

Perez-Castrillo, D. and D. Wettstein, 2005, "Implementation of the Ordinal Shapley Value for a Three Agent Economy," *Economics Bulletin*, 3, 1–8.

Rajan, R.G. and L. Zingales, 1998, "Power in a Theory of the Firm," *Quarterly Journal of Political Economy*, 113, 387–432.

Rind, K.W., 1981, "The Role of Venture Capital in Corporate Development," *Strategic Management Journal*, 2, 169–180.

Rogerson, W.P., 1985, "The First-Order Approach to Principal-Agent Problems," *Econometrica*, 53, 1357–1368.

Sahlman, W., 1990, "The Structure and Governance of Venture-Capital Organizations," *Journal of Financial Economics*, 27, 473–521.

Schmidt, K., 2003, "Convertible Securities and Venture Capital Finance," *Journal of Finance*, 58, 1139–1166.

Sohl, J.E., 2003a, "The US Angel and Venture Capital Market: Recent Trends and Developments," *Journal of Private Equity*, 6, 7–17.

——, 2003b, "The Private Equity Market in the USA: Lessons from Volatility," *Venture Capital*, 5, 29–46.

Tsoulouhas, T., 1999, "Renegotiation-Proof Labour and Credit Contracts with Worker Mobility," *Economica*, 66, 433–454.

Tyebjee, T.T. and A.V. Bruno, 1984, "A Model of Venture Capitalist Investment Activity," *Management Science*, 9, 1051–1066.

Wright, M., A. Vohora, and A. Lockett, 2004, "The Formation of High-Tech Spinouts: The Role of Joint Ventures and Venture Capital Investors," *Journal of Technology Transfer*, 29, 287–310.