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Experimentation and project selection: Screening and learning ☆

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ABSTRACT

Firms must strike a delicate balance between the *exploitation* of well-known business models and the *exploration* of risky, untested approaches. In this paper, we study financial contracting between an investor and a firm with private information about its returns from exploration and exploitation. The investor-optimal mechanism offers contracts with different tolerance for failures to screen returns from exploitation, and with different exposure to the project's revenues to screen returns from exploration. We derive necessary and sufficient conditions for private information about returns from exploration to have zero value to the firm. When these conditions fail, private information about exploration may even decrease the firm's payoff.

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1. Introduction

To be successful, most firms need to strike a delicate balance between *exploiting* well-known business models and *exploring* new approaches (cf. Roberts and Weitzman, 1981). Exploration is costly and inherently risky. Most untested approaches fail, but some of them turn out to be exceptionally profitable.

Firms engaged in innovation typically require external financing to develop their ventures. Their choices of which projects to pursue, and the economic rents obtained from them, depend on the financing contracts signed with outside investors.

As long recognized by economists, asymmetric information is a key determinant of financial contracts. Firms often have an informational advantage (or expertise) on the potential of their innovative projects (exploration) – for example, because

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they have a better understanding of market conditions or the details of their technology.[1] They are also typically better informed about the profitability of on-going business ventures and the best alternative use of their human and physical assets (exploitation). The decision between exploiting and exploring (i.e., project selection) may also be affected by internal agency problems[2] and indirect costs of failure, such as stigma,[3] that constrain the ability or willingness of firms to innovate.

In this paper, we study financial contracting in environments in which firms have private information about the payoff from *both* exploration and exploitation. Our analysis sheds light on three fundamental questions on the economics of innovation. First, what contractual solutions arise to mitigate adverse selection in the financing of innovation? Second, how does asymmetric information affect project selection and the frequency/duration of experimentation? Third, in light of the multiple sources of informational advantage held by firms, what determines the rents from engaging in innovation?

We employ a two-arm bandit problem to capture the firm's exploration/exploitation trade-off.[4] In each period, the firm (or entrepreneur) either plays a *safe arm* with a known distribution of payoffs (capturing exploitation) or a *risky arm* (capturing exploration) that may be either "good" or "bad." Revenues are always zero if the risky arm is bad. If the risky arm is good, large revenues come at geometrically-distributed random times. Playing the risky arm therefore requires the firm to forego the payoff from the safe arm.

We model the financing of innovation by embedding the two-arm bandit problem described above into a principal-agent framework. The entrepreneur (agent) needs financing from an investor (principal) to play the risky arm. Without the investor's assistance, the entrepreneur is only able to play the safe arm. Both the investor and the entrepreneur *learn* about the risky arm by observing its revenues.

There is asymmetric information regarding the primitives of the bandit problem that the agent plays. The agent has private information about the probability that the risky arm is good (the *expected returns* from exploration) and about the expected payoff from playing the safe arm (the *opportunity cost* of exploration). We follow a mechanism design approach to derive the revenue-sharing rules and the exploration/exploitation strategies that maximize investor profits and identify the contractual features that optimally screen the entrepreneur's (two-dimensional) private information.

We start by analyzing two natural benchmarks where the informational asymmetry between the investor and the entrepreneur is one-dimensional. In the first benchmark, the payoff from the safe project is common knowledge but the entrepreneur has private information about the quality of the risky project. We show that the investor can attain the first-best profits in this case by reimbursing the entrepreneur's foregone rents from exploitation and collecting all the profit from the project. This result, which echoes the classic contributions of Riordan and Sappington (1988) and Crémer and McLean (1988), underscores the appropriability of innovation in arm's length relationships.

Next, we consider the *expert investor* benchmark, where the probability that the risky project is good is common knowledge, but the entrepreneur is privately informed about her opportunity cost of exploration. In the solution to this problem, the investor offers a menu of *stopping plans* to the entrepreneur, guaranteeing the financing of exploration until a critical period regardless of the output realizations. After this critical period, financing is continued if and only if high revenues were produced in at least one period. The investor screens the entrepreneur's opportunity cost by offering stopping plans with different durations. Entrepreneurs with high opportunity costs choose shorter plans, while those with unprofitable alternatives choose longer plans.

Because the investor needs to leave informational rents to the entrepreneur, the solution of this one-dimensional benchmark features under-experimentation (i.e., too few entrepreneurs experiment) and early termination (i.e., the risky project is halted too early) relative to the first-best outcome where innovation is self-financed. Moreover, the investor can implement the optimal mechanism using lump-sum payments (such as a golden handshake).

These two benchmarks lay the ground to our characterization of the optimal mechanism under two-dimensional private information. Our main result gives a necessary and sufficient condition for the solution to the expert investor benchmark to be implementable, in which case expertise about the risky project quality does not affect payoffs. We show that, with two-dimensional asymmetric information, the investor can implement the optimal mechanism using *linear contracts*, which are particularly simple and commonly used in project financing. A linear contract specifies the entrepreneur's remuneration as the sum of a lump-sum payment (such as a golden handshake) and a variable payment that is linear in the revenue from the project (such as equity). The investor uses the duration of the contract and the exposure to the revenue from exploration to screen the two dimensions of private information. Entrepreneurs with better projects pick higher-powered contracts (that is, contracts with larger revenue shares but smaller lump-sum payments). Entrepreneurs with higher opportunity costs pick contracts with smaller durations. The interaction between both dimensions of private information manifests itself in the use of variable payments that depend on the project's revenue (e.g., equity). Although expertise about the risky project's quality generates no additional informational rents to the entrepreneur, it determines the contractual form employed at the optimum.

[1] Aboody and Lev (2000) show that R&D is a major source of insider private information. Gompers (1995) shows that venture capitalists concentrate in early-stage companies and high technology industries, where informational asymmetries are more prevalent. Gompers and Lerner (2004, chapter 7) describe how staged investment helps venture capitalists screen asymmetric information about project quality.

[2] There is empirical evidence that, when deciding between exploration and exploitation, firms often behave as if the returns from their on-going ventures were larger than they actually are; as induced, for example, by career concerns of managers – see Kerr et al. (2014).

[3] Landier (2006) argues that indirect costs such as the stigma from failure are important barriers to experimentation.

[4] Two-arm bandit problems were first introduced in the economics literature by Rothschild (1974).

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