Financial Risks and Research Contracts in a model of Endogenous Growth

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Introduction

- Research needs "an idea" + financing to carry it out
- Some researchers obtain financing directly from banks (or close relatives and friends)
- Others collaborate with Venture Capitalists
- Venture Capital: $34 billion in 2007 (Forbes, Jan., 2008), from 86 public offerings and 304 acquisitions
- Top financiers include, Kleiner Perkins Caufield & Byers, Sequoia Capital, Sherpalo, Stanford University, Sun Microsystems, etc.

Introduction

- This paper: the relationship between different types of business-startup Financing and Growth.
- Entrepreneurs with ideas must finance physical-capital investments by either

  (i) borrowing funds directly from a financial institution (Regime I), or
  (ii) collaborating with a venture capitalist (Regime C)

- Successful innovation brings long-term profits

  Regime C: Shared between the entrepreneur and the venture capitalist; Contracting problems arise
  Regime I: All retained by the entrepreneur, but faces financial risks/imperfections – higher cost of financing physical capital

Two innovation regimes:

Regime I: Independent financing

- Paying a higher cost of financing to avoid financial risks

Regime C: research collaboration

- Entrepreneurs: invest labour
- Venture Capitalists: finance investments of physical capital
- Nash bargaining determines shares over expected value creation

Issues: how financial market imperfections, the contract environment (legal system), and research risk affect the incentives for R&D investment, and long-run growth

- Variety expansion model of innovation-based endogenous growth

Empirical support

- Reduced financial-market imperfections $\Longrightarrow$ higher innovation rate

  King and Levine (QJE, 1993; JME, 1993): positive correlation between financial development and rates of innovation & capital accumulation.

- Improvements in legal environment $\Longrightarrow$ higher innovation rate

  Samila and Sorenson (2009): venture capital has a greater impact on innovation and startups in regions where non-competition covenants are *not* strictly enforced.

- Venture capital

  Kortum and Lerner (Rand, 2000), Samila and Sorenson (REStat, 2010): venture capital is associated with higher rates of patenting.

  Zucker et al. (AER, 1998): venture capital may have a negative effect on startups after controlling for the ability of scientists.

Households

- Household's intertemporal utility function:

$$U = \int_0^{\infty} e^{-\rho t} \ln \left(\int_0^n x(i)^{\theta} di \right)^{\frac{1}{\theta}} dt$$

- Euler equation for expenditure: $\frac{\dot{E}(t)}{E(t)} = r(t) - \rho$.
  Set expenditure as the model numeraire, $r = \rho$.

- Instantaneous demand for a given product i: $x(i) = p(i)^{-\sigma} P_Y^{\sigma-1}$

Manufacturing

A mass n of symmetric firms compete according to monopolistic competition.

All firms face a constant probability of failure, $\varepsilon \in [0,1]$

- Unit cost of production:

$$C_x = w_L^{\alpha} w_K^{1-\alpha}$$

- Operating profit:

$$\pi = \left(p - w_L^{\alpha} w_K^{1-\alpha}\right) x = \frac{1}{\sigma n} \tag{6}$$

- Factor demands:

$$L_X = \alpha \omega^{\alpha-1} X, \qquad K_X = (1-\alpha)\omega^{\alpha} X \tag{7}$$

where $X \equiv nx$ and $\omega \equiv w_L / w_K$.

Innovation

The innovation sector is perfectly competitive.

- A research project develops a single product design according to

$$1 = bnl^{\beta}k^{1-\beta}, \tag{8}$$

where $b > 0$ and n is a proxy for the current stock of knowledge capital.

- The value of a successful new design is

$$v(t) = \int_t^{\infty} e^{-(\tau-t)(\rho+\varepsilon)}\pi(\tau)d\tau. \tag{9}$$

- The expected value of new research project is ψv, where $\psi \in [0,1]$ is the probability that a new design can be brought to market.

Innovation

Two different innovation regimes

- Regime I: Independent research projects – full ownership over created value but a higher cost of financing physical-capital investment
- Regime C: Research collaborations with venture capitalists – lower cost of financing physical-capital investment but only a partial share of ownership over created value

Financial market imperfections

Financial market imperfections arise from monitoring costs incurred by lenders attempting to prevent debt evasion. Galor and Zeira (RES,1993)

- Lenders (banks) obtain funds at the risk-free rate ρ and monitor loans with effort z, yielding a lending rate γ satisfying $\gamma w_K k = \rho w_K k + z$
- For an investment of physical capital of $w_K k$ in innovation, financial institutions set a monitoring effort that satisfies $(1+\gamma)w_K k = \mu z$.
- Thus, borrowers will not default (by paying a cost of μz as above), where $\mu > 1$ describes the strictness of regulation over debt default.
- Lending rate then becomes:

$$\gamma(\mu) = \frac{1+\mu\rho}{\mu-1} > \rho, \tag{10}$$

where $\gamma'(\mu) < 0$, and $\gamma(\mu) > \rho$.

Independent research projects

- Independent research projects maximize profit:

$$\max_{l_I, k_I} \quad \psi v b n l_I^{\beta} k_I^{1-\beta} - l_I w_L - (1+\gamma) k_I w_K \tag{11}$$

- First order conditions:

$$w_L l_I = \beta \psi v, \qquad (1+\gamma) w_K k_I = (1-\beta) \psi v$$

- Free-entry condition:

$$v_I \leq \frac{(1+\gamma)^{1-\alpha} w_L^{\alpha} w_K^{1-\alpha}}{\psi n}. \tag{12}$$

This condition binds if there are active independent research projects, $\dot{n} > 0$.

Research contracts

Research teams collaborate with venture capitalists:

- Research team invests labour
- Venture capitalist invests physical capital

Ex post Nash bargaining – $\max_{\delta} G \equiv [\delta\psi v - o_L v]^{1/2} [(1-\delta)\psi v - o_K v]^{1/2}$

$o_L v$ and $o_K v$ are outside options

$o_L, o_K \in [0, \psi]$: inverse of market thickness. A higher o_L implies lower competition among researchers, yielding higher outside options for them.

Alternatively, the legal regime, proximity to top-notch universities, and other elements such as the social status accorded to innovators.

- Contract environment:

$$\delta(o_L, o_K) = \frac{\psi + o_L - o_K}{2\psi}. \tag{14}$$

Regime C

- The venture capitalist maximizes residual profit:

$$(1-\delta)\psi v b n l_C^{\beta} k_C^{1-\beta} - (1+\rho) w_K k_C,$$

and its optimal capital investment is

$$(1+\rho) w_K k_C = (1-\delta)(1-\beta)\psi v. \tag{15}$$

- The research team invests labour to maximize residual profit:

$$\delta \psi v b n l_C^{\beta} k_C^{1-\beta} - w_L l_C,$$

and its optimal labour investment is

$$w_L l_C = \delta \beta \psi v. \tag{16}$$

Regime C

- Free-entry condition:

$$v_C \leq \frac{\zeta(1+\rho)^{1-\beta} w_L^{\beta} w_K^{1-\beta}}{\psi n}, \tag{17}$$

where

$$\zeta \equiv \frac{1}{\delta^{\beta}(1-\delta)^{1-\beta}}.$$

measures the inefficiencies generated in capital and labor investment by the holdup problem associated with bargaining.

Closing the model

Free-entry conditions –

- The value of a new product design equals the cost of product development, regardless of the innovation regime.
- No-arbitrage conditions:

$$\rho + \varepsilon = \frac{\pi}{v_i} + \frac{\dot{v}_i}{v_i} \qquad i = I, C \tag{19}$$

- Factor market clearing conditions:

$$L = L_X + L_i, \qquad K = K_X + K_i, \qquad i = I, C \tag{20}$$

  for either innovation regime.

Regime I

- Define the relative factor price as $\omega \equiv w_L/w_K$
- Constant factor allocation requires $\dot{\omega} = 0$.
- Innovation rate and relative factor price combinations that clear the factor markets:

$$g_L = \frac{\omega^{1-\beta}\psi(1+\gamma)^{\beta-1}L - \alpha(\sigma-1)(\rho+\varepsilon)}{\alpha(\sigma-1)+\beta} \tag{24}$$

$$g_K = \frac{\omega^{-\beta}\psi(1+\gamma)^{\beta-1}K - (1-\alpha)(\sigma-1)(\rho+\varepsilon)}{(1-\alpha)(\sigma-1)+(1-\beta)(1+\gamma)^{-1}} \tag{25}$$

Regime I

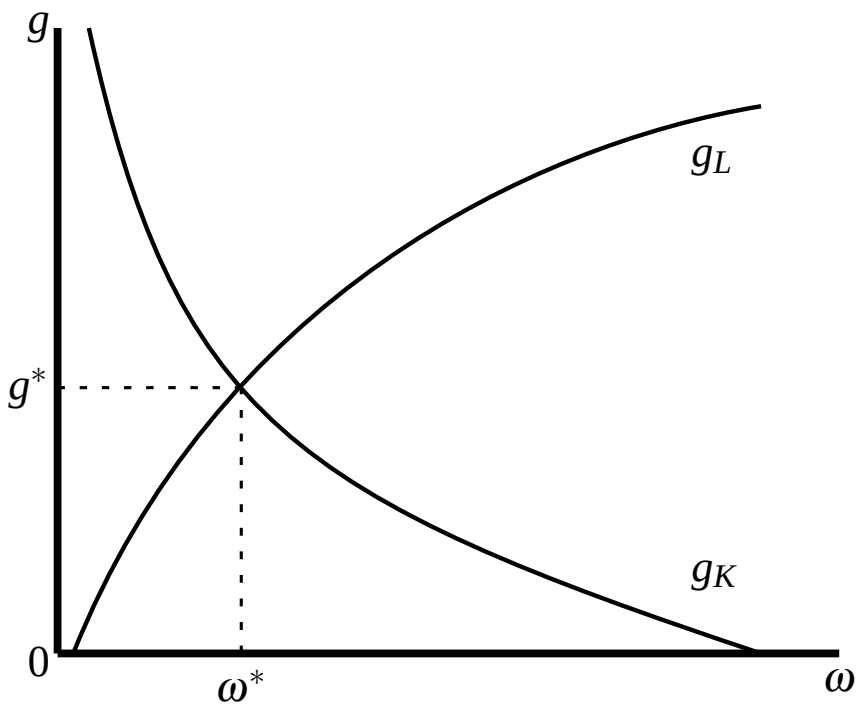


Figure 1: Long-run equilibrium

Changes in financial regulations

Proposition 1 *(Financial regulations and growth): An increase in μ raises the innovation rate g^* through a decrease in the leading rate γ.*

An improvement in financial regulations:

$$\mu \uparrow \Longrightarrow \gamma \downarrow \Longrightarrow v_I \downarrow \Longrightarrow g_I \uparrow$$

- King and Levine (QJE, 1993; JME, 1993) find a positive correlation between financial development and rates of innovation and capital accumulation.

Regime C

- Define the relative factor price as $\omega \equiv w_L/w_K$
- Constant factor allocation requires $\dot{\omega} = 0$.
- Innovation rate and relative factor price combinations that clear the factor markets:

$$g_L = \frac{\omega^{1-\beta}(1+\rho)^{\beta-1}\zeta^{-1}L - \alpha(\sigma-1)\rho}{\alpha(\sigma-1)+\beta}, \tag{29}$$

$$g_K = \frac{\omega^{-\beta}(1+\rho)^{\beta-1}\zeta^{-1}K - (1-\alpha)(\sigma-1)\rho}{(1-\alpha)(\sigma-1)+(1-\beta)(1+\rho)^{-1}}. \tag{30}$$

Changes in the contract environment

The contract environment is described by $\delta(o_L, o_K) = \frac{\psi + o_L - o_K}{2\psi}$.

Proposition 2 *(Outside option and growth): The relationship between o_L and g^* has an inverted-U shape with a maximum at $\beta = \delta$.*

An increase in the outside option of the research team o_L:

$$o_L \uparrow \Longrightarrow \delta \uparrow \Longrightarrow \begin{cases} \text{if } \delta < \beta, \text{ then } \zeta \downarrow \Longrightarrow v_C \downarrow \Longrightarrow g_C \uparrow \\ \text{if } \delta > \beta, \text{ then } \zeta \uparrow \Longrightarrow v_C \uparrow \Longrightarrow g_C \downarrow \end{cases}$$

- Samila and Sorenson (2009) find that venture capital has a greater impact on innovation and startups in regions where non-competition covenants are *not* strictly enforced.

Changes in the contract environment

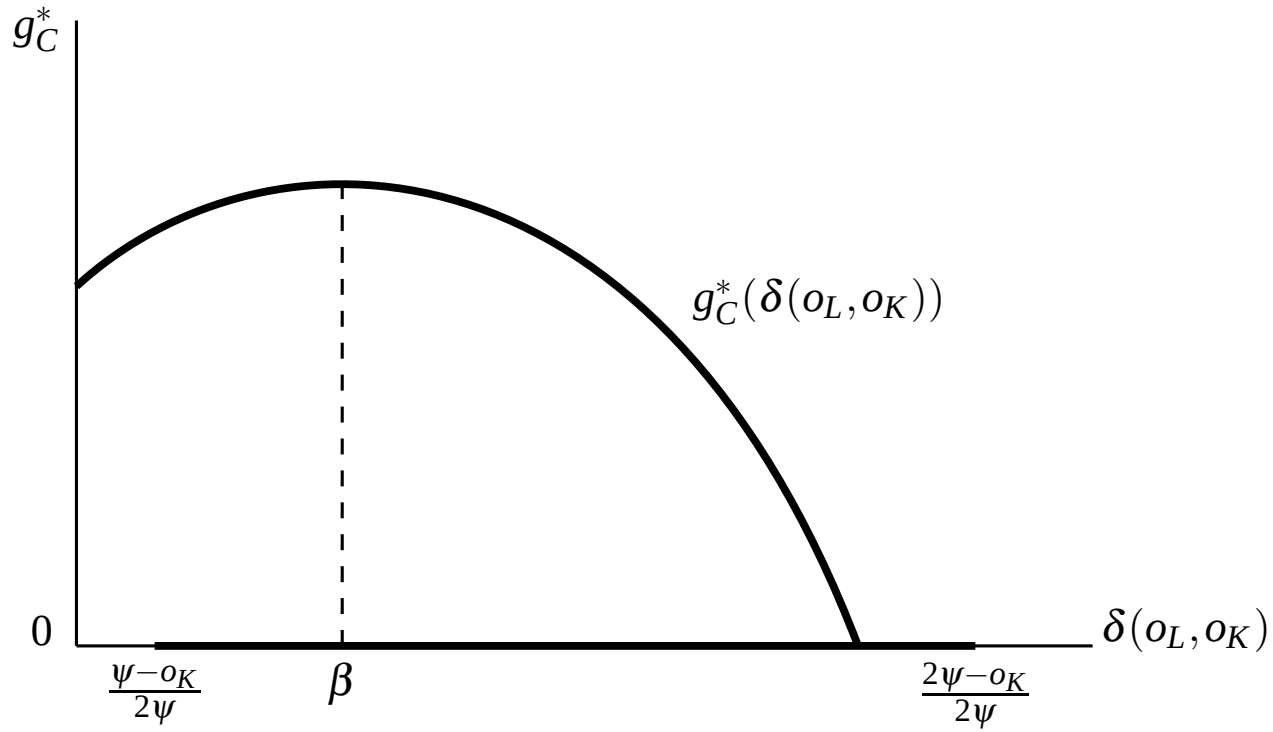


Figure 2: Improvements in the Contract Environment

Optimal innovation regimes

- Which innovation regime is optimal for entrepreneurs?

  Entrepreneurs prefer the regime with the greatest return. We use Tobin's q to compare returns:

$$q_i = \frac{\pi}{(\rho + \varepsilon + g)v_i}, \quad i = I, C. \tag{31}$$

  Entrepreneurs are indifferent between innovation regimes for $q_I = q_C$:

$$\mu_q = \frac{1}{1 - \zeta^{-\frac{1}{1-\beta}}}, \tag{32}$$

  Convex in μ, δ space with a minimum at $\beta = \delta$.

- For $\mu > \mu_q$ entrepreneurs prefer Regime I
- For $\mu < \mu_q$ entrepreneurs prefer Regime C

Optimal innovation regimes

- Which innovation regime is optimal for government?

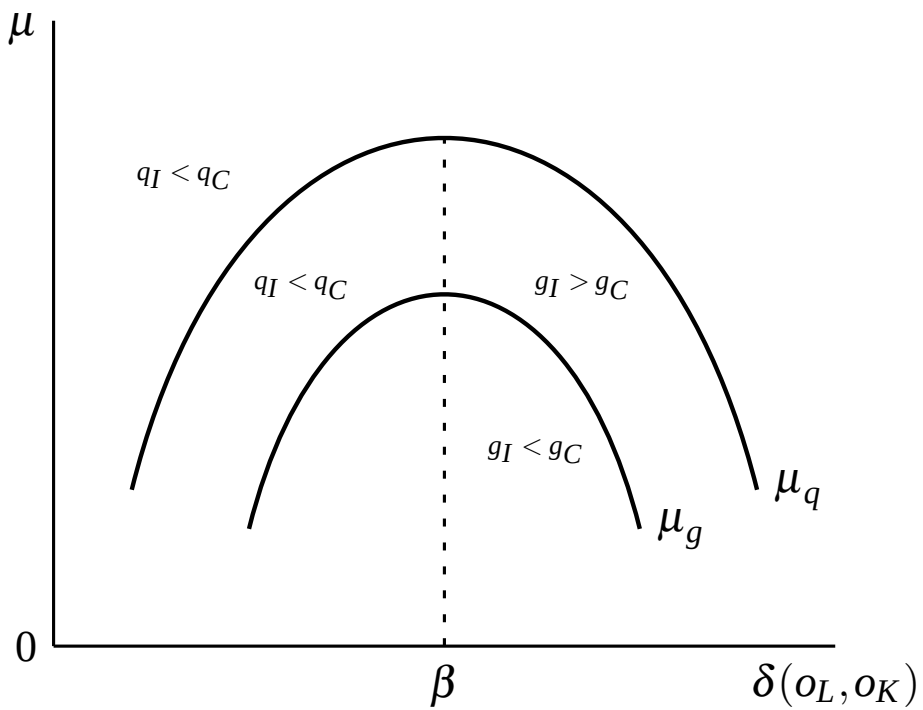
  Government prefers the regime with the higher growth rate, g_I or g_C, but is indifferent for $g_I = g_C$:

$$\mu_g = \frac{1}{1 - \frac{\omega_C}{\omega_I} \zeta^{-\frac{1}{1-\beta}}}. \tag{33}$$

  Convex in μ, δ space with a minimum at $\beta = \delta$.

- For $\mu > \mu_g$ government prefers Regime I
- For $\mu < \mu_g$ government prefers Regime C

Optimal innovation regimes



Ranking Growth Rates

The μ_q locus can be used to rank growth rates at different lending rates.

Proposition 3 *(Growth comparison):*

(i) Regime I has the higher growth rate for $\mu > \mu_q$*;*

(ii) Regime C has the higher growth rate for $\mu < \mu_q$*.*

- Kortum and Lerner (Rand, 2000) and Samila and Sorenson (2010) conclude that venture capital is associated with higher rates of patenting.
- Zucker et al. (AER, 1998) find that venture capital may have a negative effect on startups after controlling for the ability of scientists.

Alignment of R&D Incentives

Between the μ_g and μ_q curves, although Regime I provides a greater long-run rate of innovation, Regime C has the higher Tobin's q.

Proposition 4 *(Regime conflicts):*

(i) Entrepreneurs choose the regime with the lower growth rate for $\mu_g < \mu < \mu_q$*;*

(ii) For other values of μ*, they choose the regime with the higher growth rate.*

Research Risks

The probability of research success is denoted by ψ.

Proposition 5 *(Research risk and growth): An increase in the research risk* $(1-\psi)$ *lowers both* g_I^* *and* g_C^*.

Research Risks

Lemma 4 *(Research risk, optimal growth, and research incentives):*
The effects of an increase in research risk $(1-\psi)$ *on* μ_q *and* μ_g *depend on the sign of* $(\beta-\delta)(o_K-o_L)$.

The direct effects of a change in research risk are the same for both regimes, and shifts in μ_q and μ_g depend on the sign of the indirect effect through ζ:

$$\psi \downarrow \Longrightarrow \begin{cases} \text{if } (\beta-\delta)(o_K-o_L) > 0, \text{ then } \mu_q \uparrow \text{ and } \mu_g \uparrow \\ \text{if } (\beta-\delta)(o_K-o_L) < 0, \text{ then } \mu_q \downarrow \text{ and } \mu_g \downarrow \end{cases}$$

Research Risks

Proposition 6 *(Regime conflicts and the research risk): An increase in ψ expands the range of financial regulations and contract environments for which investors choose the suboptimal regime.*

A change in research risk always shifts the μ_q locus by more than the μ_g locus:

$$\left|\frac{d\mu_q}{d\psi}\right| - \left|\frac{d\mu_g}{d\psi}\right| > 0.$$

- The optimal regime is more likely to be chosen as R&D becomes riskier.

Changes in research risk

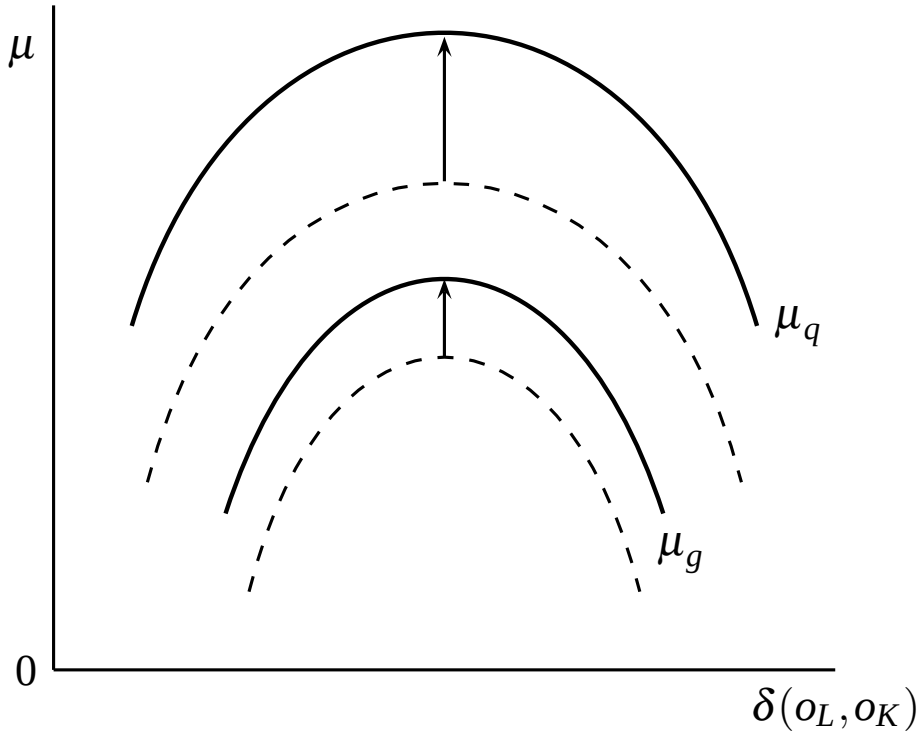


Figure: Effects of an increase in ψ

Further work in progress:

– Stock-market risks
– Mixed innovation regimes where both types of research coexist

Comments welcome!

Thank you!