Start-up Financing, Entry and Innovation

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This paper

- A new model of the VC market that incorporates key frictions that start-ups face in accessing capital.
- Investigate two central questions
  1. Why have other countries been unable to replicate the success of the US VC market?
  2. Why does VC focus on such a narrow set of technologies? **Today!**
- These questions lend themselves to model-based analysis, but existing models
  - Do not consider the implications of staged-financing.

Today

- **New model** of the VC market, with a central role for staged financing.

- **Scope of VC.** Is VC able to fund the most transformative technologies?
    - VC might fail to fund the most transformative innovations, e.g. long-horizon projects (Lerner & Nanda, 2020; Narain, 2024).
    - Key finding. Absent frictions, US VC-backed start-ups in 'Computer Related' sectors drop from 61% to 47%, offset by closer-to-science sectors.

Related Literature

- Staged-financing
  - VC contracts: Gompers (1995), Bergemann & Hege (1998), Neher (1999), Kaplan & Strömberg (2003).
  - Financing risk: Nanda & Rhodes-Kropf (2013, 2017).
- Venture capital markets
  - Market structure: Inderest & Müller (2004), Michelacci & Suarez (2004), Jovanovic & Szentes (2013).
  - Macro: Opp (2019), Akcigit et al. (2022), Greenwood et al. (2022), Ando (2023).

The model environment

Model overview

- Start-ups need external funding to develop risky projects
    - Finding a willing VC takes time.
    - Heterogeneity, lemons problem, difficulty evaluating projects.
    - **Model:** Search and matching friction.

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- Agency conflicts in contract negotiations
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  - **Model:** Private information + benefits $\rightarrow$ inefficient continuation (Gompers '95).
- Coordination issues between investors across funding rounds
  - **Model:** Start-up must renew search after each funding round.

The investment decision

- Entrepreneur (E) and VC negotiate equity contract
  - Capital injection K and equity stake to VC, s.
- E begins the process of developing their innovation
  - At some point, the E receives a private signal about project viability.
  - With probability $1 - p$, the signal is *negative*.
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- Staged-financing $\implies$ financing risk.

Model Appendix

Do these frictions bias investment away from certain projects?

- More funding rounds $\implies$ increased financing risk.
- Firms with long-horizon projects raise more funding rounds
  - Milestone financing: Longer-horizon projects receive more funding at each round.
  - Nevertheless raise more rounds of funding (under mild conditions).

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- **In the data.** **Corr(time-to-exit, number of rounds)**$> \mathbf{0}$ at granular sector (VEIC) level.

Quantification

Do alternative exit routes offer a solution?

- Acquisitions substitute for financing
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- Option most valuable to start-ups with the most severe financing issues.

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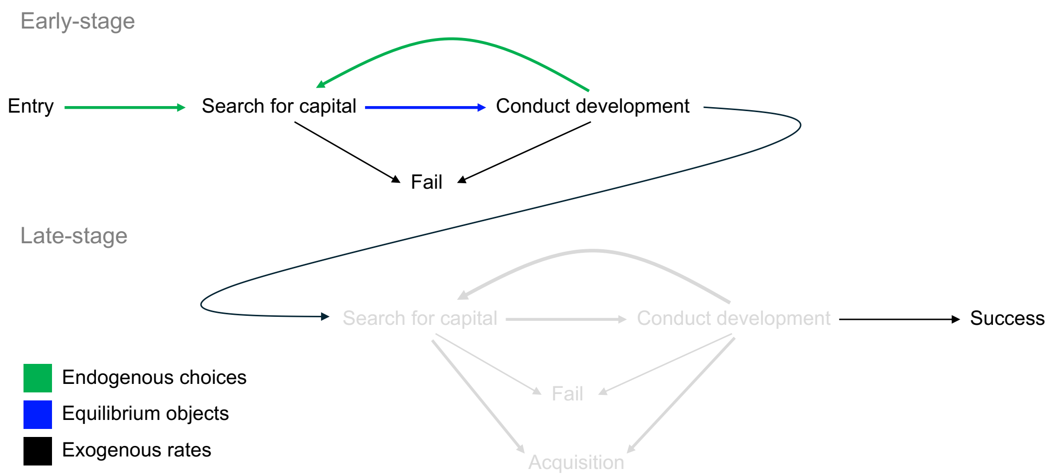
- Option most valuable to start-ups with the most severe financing issues.
- **Implication.** Long-horizon projects with limited alternative exit opportunities particularly affected.

Quantitative model: Start-up lifecycle



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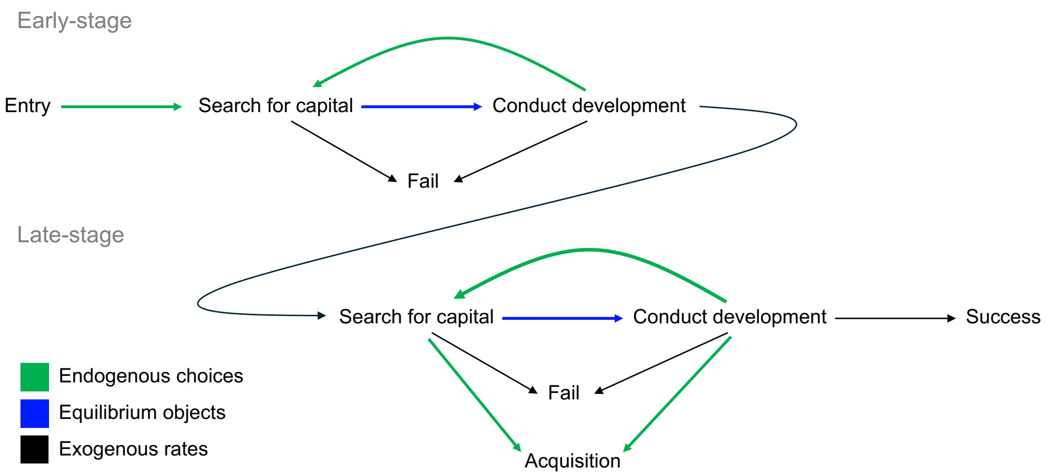

Overview

- Assessment of quantitative model
    - **Sample.** US VC-backed start-ups receiving first funding 2005-2015 (Thomson Reuters).
    - Ex-ante homogenous start-ups.
    - Strong fit to untargeted features of data. Details

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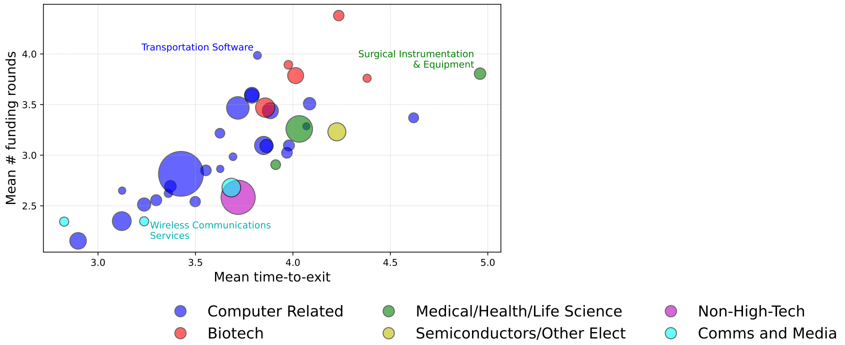
- **Focus for today.** Scope of VC
  - Counterfactual. In the absence of agency and matching/coordination frictions, how would the composition of VC funding across firm characteristics change?

Financing risk, development horizons and exit opportunities



Each point represents a Venture Economics Industry (VEIC), included as distinct observations if there are at least 20 exits during the sample period and at least one of each type (acquisition and success). Sectors that do not meet these criteria are grouped at the aggregate (six) sector level and reported together. The size of each point is proportional to the number of firms in the sector.

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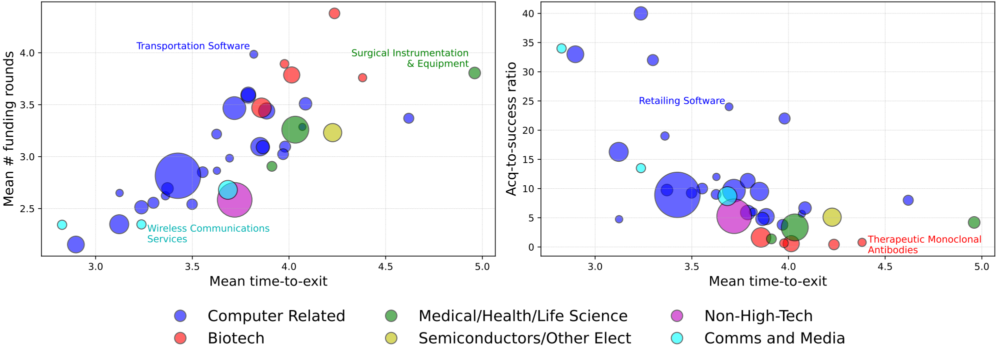

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- Long-horizon projects require more funding rounds.
- Long-horizon projects less likely to exit by acquisition.

Estimating sectoral misallocation of VC funding

1. Project ‘types’ by development horizon and acquisition opportunities
   - Long-horizon projects with limited acq. opportunities most affected by frictions. Details

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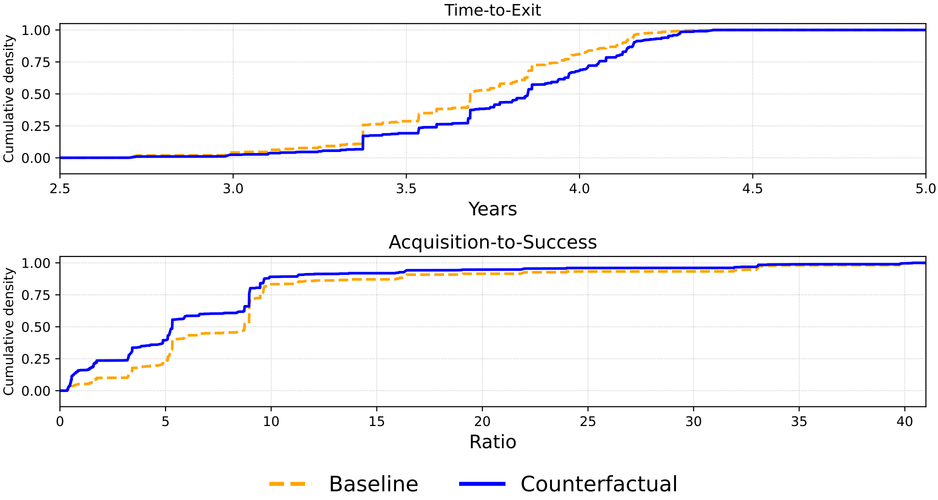
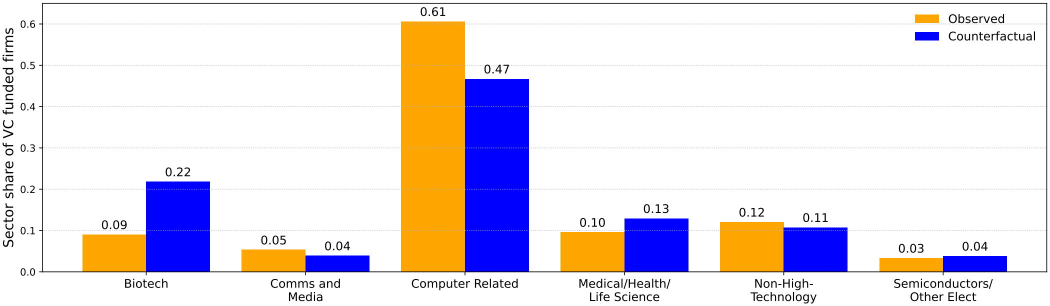
3. Recover counterfactual share of each type, absent frictions
   - **Reality.** Share of each type determined by *frictional NPV.*
   - **Counterfactual.** Share of each type determined by *frictionless NPV.*

Funding biased towards short-horizon projects with established exit pathways



Sectoral misallocation of VC funding



- **Over-represented.** Communications & Media, Computed Related, and Non-High-Technology
- **Under-represented.** Biotech, Medical/Health/Life Science, and Semiconductors/Other Elect.

Validation exercise

Wrapping up

- New model
  - Microfoundations for agency frictions drawing on Gompers (1995).
  - Theory to tie VC activity and start-up outcomes to frictions in VC markets via observable features of contracts.
  - Market efficiency and welfare.

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  - Model matches series of untargeted features of US VC data.
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- **Scope of VC.** Estimates of sectoral misallocation of VC funding.

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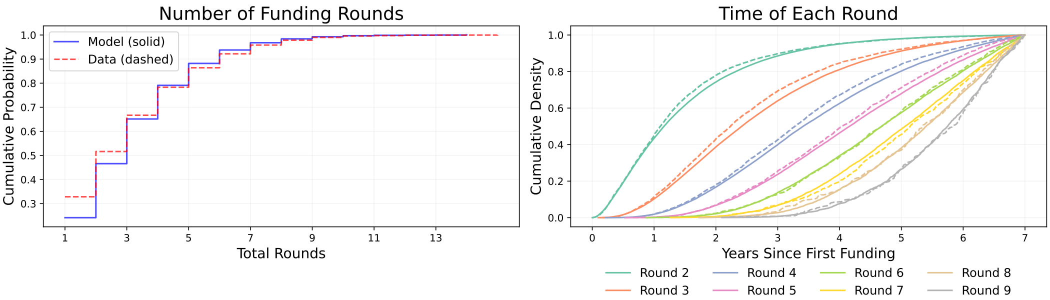
- Scope of VC. Estimates of sectoral misallocation of VC funding.
- UK case-study. Funding patterns consistent with funding gap for UK start-ups, compounded by more limited market for firms.

Quantification Appendix

Assessing model fit: funding patterns



The Figure reports the cumulative distribution of the number of funding rounds (left-hand side) and the time of each funding round (right-hand side) in the model (solid) and data (dashed). To aid visualisation, only the first nine funding rounds are included. In the model estimation, the mean number of funding rounds and the mean number of late-stage funding rounds are included as targeted moments; no information on the timing of funding rounds is included. The sample includes all US VC-backed start-ups that received their first early-stage funding round between 2005-2015 inclusive and data is censored at seven years following first funding. The model is estimated assuming ex-ante homogenous start-ups.

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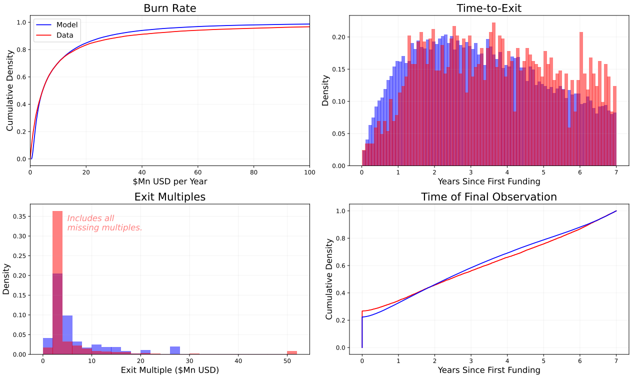
Assessing model fit: capital injections, time-to-exit, exit multiples



The Figure reports distributions of a number of statistics in the model (blue) and data (red). In the model estimation: (i) the median burn rate is targetted; (ii) no information about the time-to-exit is targeted; (iii) the share of *acquisition* multiples in excess of 10X is targeted; and (iv) no information about the time of the final observation is targeted. Data on exit multiples is poor and exits with missing values are assigned an exit multiple of 1.5X, following Kerr et al. (2014). The sample includes all US VC-backed start-ups that received their first early-stage funding round between 2005-2015 inclusive and data is censored at seven years following first funding. The model is estimated assuming ex-ante homogenous start-ups.

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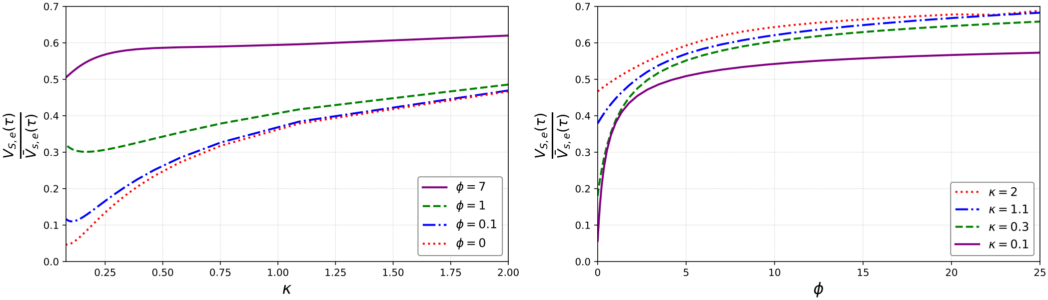
Entry distortions



Ratio of frictional to frictionless entry value across technologies

The Figure reports contours of the ratio between the frictional and frictionless project value in the (κ, ϕ) space. In the model, κ parameterises the project development horizon, with higher values for κ lowering the development horizon, and ϕ parameterises the arrival rate of acquisition offers to start-ups, with higher values for ϕ implying a greater availability of acquisition offers. Specifically, the left figure holds ϕ fixed at different values as κ is varied, and the right figure does the opposite. In all cases, π is adjusted so as to hold the frictionless project value constant, so that variation is driven solely by the frictional value.

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Joint distributions

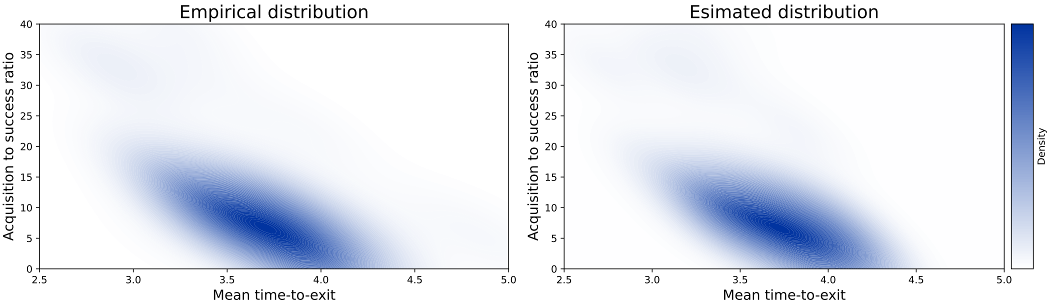

Figure 1: Empirical and model-implied distributions

The left-side figure depicts kernel density estimates for the true joint distribution of sectors in the (acquisition-to-success, time-to-exit)-space. The right-side figure shows the kernel density estimate for the distribution of technologies in the same space.

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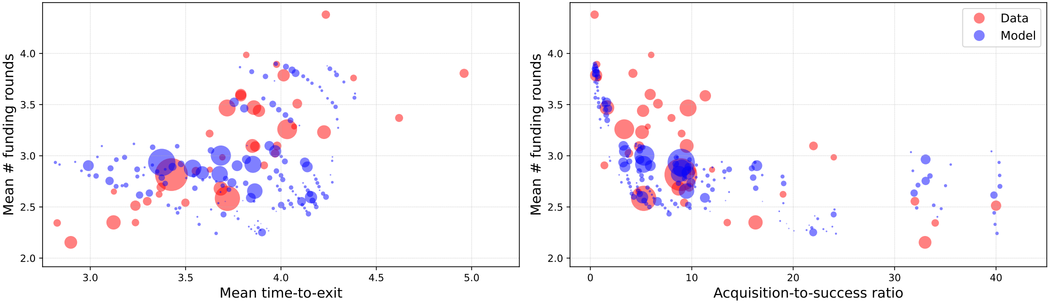
Validation exercise



- Model replicates
  - Positive association b/w the number of funding rounds and the average time-to-exit.
  - Negative relationship b/w the number of funding rounds and the acq-to-success ratio.

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Model Appendix

Baseline model overview

- Continuous time, infinite horizon. Focus on steady-state equilibrium.
- Venture capitalists
  - Measure M of VCs can fund at most one project at a time.
  - Risk neutral, discount rate ρ.
- Start-ups
  - Ex-ante homogenous.
  - Endogenous entry decision.
  - Zero wealth $\rightarrow$ external financing.
  - Risk neutral, discount rate ρ.
- Search equilibrium determines endogenous meeting rate between start-ups and VCs.
- Start-ups that exhaust capital must search anew.

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Start-up projects and VC contracts

- A start-up's **project**...
  - ... requires flow investment k to resolve project uncertainty...
  - ... which arrives at exogenous Poisson rate κ...
  - ... and is successful w/prob p (payoff $= \pi$), failure w/prob $1 - p$ (payoff$= 0$).

- A **contract** specifies
  - ... a share ς to the VC ...
  - ... and a Poisson "contract rate", ω, which determines the *rate at which funding runs out*...
  - ... after which the start-up gets value V_s.

- The value of the project gross of development costs, V_d, solves the HJB

$$\rho V_d = \kappa \left[p \pi - V_d\right] + \omega \left[V_s - V_d\right]$$

The VC contract

- Optimal contract requires knowing the value of the VC's capital commitment.
- Frictionless benchmark. Symmetric information + complete markets.
    - Suppose that the realisation of project uncertainty at date $T_\kappa \sim Exp(\kappa)$ is observed by the VC $\rightarrow$ contractible.
    - Then, optimal contract provides funding until date T_κ ...
    - ... so that $\omega = 0$ is optimal (upfront funding)...
    - ... and the expected capital cost associated with the contract

$$K_{\text{frictionless}} = \frac{k}{\rho + \kappa + \omega}\Big|_{\omega=0} = \frac{k}{\rho + \kappa}$$

- Equivalent to the cost of an entrepreneur investing their own funds.

Opportunistic behaviour raises cost of funds

- **Frictional setting.** Private information + benefits $\implies$ "inefficient continuation" (Gompers, 1995).
  - **Private information** : T_κ unobserved by VC $\implies$ non-contractible.
  - **Private benefits**: Entrepreneur (E) derives flow benefit x_e when receiving funding.
- Microfoundation $\rightarrow$ sufficient conditions on x_e s.t. E reports success, but not failure.[1]
- Expected capital cost for contract ω becomes

$$K(\omega) = \underbrace{\frac{k}{\rho+\kappa+\omega}}_{\text{Frictionless expected capital cost}} + \underbrace{\frac{\kappa(1-p)}{\kappa+\omega}}_{\text{Pr(negative result)}} \underbrace{\frac{k(\kappa+\omega)}{(\rho+\omega)(\rho+\kappa+\omega)}}_{\text{Expected capital cost from continuation}} = \left(1+\frac{\kappa(1-p)}{\rho+\omega}\right)\frac{k}{\rho+\kappa+\omega}$$

[1] "No news is never good news"", Janeway (2018).

The contract problem

- VC receives $\varsigma \times V_d(\omega)$ and commits capital with expected value $K(\omega)$.
- **Assumption.** VC has no bargaining power in contract negotiations $\implies$ PC binds: $\varsigma V_d = K(\omega)$.[2]
- Then, taking V_s as given, the contract rate, ω, solves

$$V^M = \sup_{\{\varsigma \in [0,1], \omega \in [0,\infty)\}} \left\{ (1-\varsigma) V_d(\omega) \right\}$$

$$\text{subject to} \quad \varsigma V_d(\omega) = K(\omega), \quad K(\omega) = \left(1 + \frac{\kappa\,(1-p)}{\rho+\omega}\right) \frac{k}{\rho+\kappa+\omega}$$

where V^M is the value retained by existing shareholders.

[2] This condition is not necessarily, but simplifies the exposition.

Search and entry

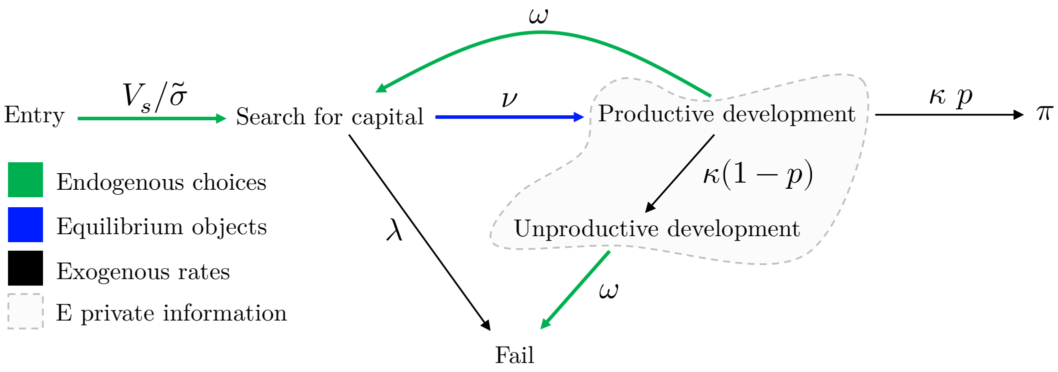
- Start-ups search for capital following
  - Entry.
  - Exhausting previous investment.
- Start-ups in search
  - Fail at exogenous rate λ.
  - Meet with VCs at endogenous rate ν.
- The value of a firm in search, V_s, solves the HJB

$$(\rho + \lambda) V_s = \nu \left[V^M - V_s \right]$$

- Optimal entry rule implies flow rate of start-up entry $V_s / \tilde{\sigma}$.[3]

[3] Details omitted. Intuitively, entry is increasing in the value of entry, V_s, and decreasing in $\tilde{\sigma}$, which parameterises the supply of entrepreneurial projects.

Start-up lifecycle



Equilibrium conditions

- The SS measures of firms
  - With funding and potentially viable projects (productive development), μ_d^p.
  - With funding but failed projects (unproductive development), μ_d^u.
- A measure μ_{vc} of VCs are not funding start-ups, $\mu_{vc} = M - \mu_d^p - \mu_d^u$.
- With μ_s start-ups in search and μ_{vc} unencumbered VCs, the flow of meetings is

$$m(\mu_s, \mu_{vc}) = \mu_s^\alpha \mu_{vc}^\beta, \quad \Longrightarrow \quad \nu = \mu_s^{\alpha-1} \mu_{vc}^\beta$$

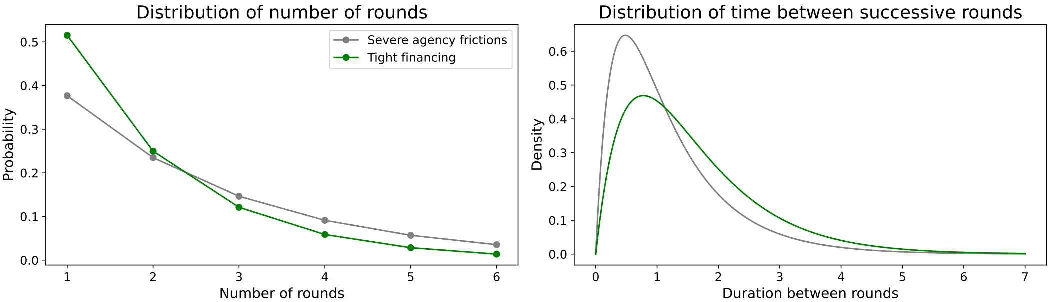
- In steady-state

$$\begin{aligned}
\text{Productive development:} \quad & \nu \mu_s = (\kappa + \omega) \mu_d^p \\
\text{Unproductive development:} \quad & \kappa(1-p)\mu_d^p = \omega \mu_d^u \\
\text{Search:} \quad & \omega \mu_d^p + \frac{V_s}{\sigma} = (\lambda + \nu)\mu_s
\end{aligned}$$

Model dynamics

- Agency friction $\rightarrow$ wedge, $\frac{\kappa(1-p)}{\rho+\omega}$, that raises the cost of funds.
- The wedge
    - Increases for larger capital commitments, $\omega \downarrow$, reflecting greater exposure to opportunistic behaviour.
    - Increases for more novel projects, $p \downarrow$ (c.f. Nanda & Rhodes-Kropf, 2017).
    - Decreases for long-term projects $\rightarrow$ milestone financing.
- Optimal contract rate, ω, balances
    - Reductions in cost of capital ($\implies \omega \uparrow \ \& \ K(\omega) \downarrow$).
    - Insurance against financing risk ($\implies \omega \downarrow \ \& \ K(\omega) \uparrow$).

A theory of funding patterns



- Number of rounds, $N_f \sim Geometric(q)$, for $N_f \in \{1, 2, 3, ...\}$ where $q = \frac{\kappa}{\kappa+\omega} + \frac{\omega}{\kappa+\omega} \cdot \frac{\lambda}{\lambda+\nu}$.
- Time between rounds, $T_{br} \sim Hypo(\kappa + \omega, \lambda + \nu)$.

Distortions induced by financing conditions

- What are the implications of tighter financing conditions?
    - Lower meeting rate, $\nu \downarrow$, or higher failure rate in search, $\lambda \uparrow$.
- Ambiguous effect on **start-up outcomes**
    - Direct effect may be offset by greater demand for insurance against financing risk.
- Unambiguous negative effect on the **entry rate**
    - Funding becomes more difficult to secure.
    - Insurance is costly.

Distortions across project types

- Endogenous success probability, $p_d = (1 - f_d) \times p$.
  - f_d is the probability of failure from financing risk.[4]
- Denote by $\bar{V}_s$ the frictionless entry value.

$$\textbf{Outcome distortion} = p_d/p = (1 - f_d), \qquad \textbf{Entry distortion} = V_s/\bar{V}_s$$

- **Key insight.** Consider two start-up types $i = a, b$ facing the same funding conditions, ν and λ. If $\mathbb{E}[N_f^a] > \mathbb{E}[N_f^b]$, then start-ups of type a face greater
  - Outcome distortions; and
  - Entry distortions.[5]

$\rightarrow$ To understand distortions across projects, sufficient to consider $\mathbb{E}[N_f]$.

[4] f_d and p_d are probabilities for viable firms with funding (as opposed to in search).
[5] This is an approximate result, true for $\rho \rightarrow 0$.

Distortions greatest for: low-quality, novel, and long-horizon projects

- **Low-quality projects**: low p, π, κ, or high k
  - Lower marginal benefit of insurance $\rightarrow$ smaller capital injections.
  - Frequent visits to the capital market: $\mathbb{E}[N_f] \uparrow$.
- **Novel projects**: low p for constant frictionless NPV
  - Heightened agency frictions $\rightarrow$ smaller capital injections.
  - Frequent visits to the capital market: $\mathbb{E}[N_f] \uparrow$.
- **Long-horizon projects**: low κ for constant frictionless NPV
  - Milestone financing $\rightarrow$ larger capital injections.
  - BUT typically still require more funding rounds: $\mathbb{E}[N_f] \uparrow$.