Wall Street and Silicon Valley: A Delicate Interaction

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Motivation

- "Technological revolutions and financial bubbles seem to go hand in hand"— The Economist, September 21, 2000
- Arrival of new, unfamiliar, investment opportunities
  - "Internet craze" late 1990s
  - "biotech revolution" early 1980s
  - "new financial instruments" mid 2000s

  $\Rightarrow$ high uncertainty, abnormal real and financial activity
  (Pastor and Veronesi, 2009)
- Financial markets look at real sector for clues and vice versa
  - co-movements in real investment and financial prices
- Do such co-movements reflect efficient response to available information?
- Or could they be product of excessive waves of optimism and pessimism?

This Paper

- Positive and normative implications of information spillovers between real and financial sector?
- Information spillovers from financial mkts to real economy
  - quite well studied
- Information spillovers from **real to financial sector**
  - largely under-explored
- Source of **non-fundamental volatility**
  - dampen response to fundamental shocks
  - amplify response to noise and higher-order-uncertainty
- Symptoms of (constrained) inefficiency
  - policy interventions
- Mechanism: collective signaling (from real to financial sector)
  - source of **endogenous complementarities**
  - micro-foundation for "beauty-contests" and "irrational-exuberance"

Plan

1. Model
2. Equilibrium
3. Positive Analysis
4. Welfare Analysis
5. Policy
6. Robustness and Extensions

Model

Model: Actors

- Two types of agents:
  - **entrepreneurs**
  - **financial investors**
- Two project phases:
  - **start-up**: entrepreneurs decide whether to start new project of unknown profitability
  - **IPO stage**: entrepreneurs expand project using IPO proceeds

Model: Technology

- Starting a project ($t = 1$)
  - 1 unit of perishable good
- Subsequent expansion ($t = 2$)
  - $k \in \mathbb{R}_+$: period-2 expansion
- Output at $t = 3$:

$$q = \Theta k^{\alpha}$$

- Θ: underlying fundamental

Model: Timing

- At $t = 1$, each entrepreneur endowed with 1 unit of perishable good
  - consume ($n_i = 0$)
  - invest to start project ($n_i = 1$)
- At $t = 2$, profile $(n_i)_{i \in [0,1]}$ of start-up activity publicly observed
- Entrepreneurs who did not initiate project at $t = 1$
  - no other source of income
  - no further action
- Entrepreneurs who initiated project
  - receive no income at $t = 2$
  - finance project expansion k_i by selling shares in IPO mkt
  - Budget constraint

$$k_i = p_i s_i,$$

- At $t = 3$, fundamental Θ publicly revealed
  - Entrepreneurs receive $(1 - s_i)\Theta k_i^{\alpha}$
  - Investors receive $s_i \Theta k_i^{\alpha}$

Model: Information

- $\theta \equiv \log \Theta$ with $\theta \sim \mathcal{N}\left(0, \pi_\theta^{-1}\right)$
- Entrepreneurs observe
  $x_i = \theta + \xi_i, \quad \xi_i \sim \mathcal{N}\left(0, \pi_x^{-1}\right)$
  $y = \theta + \varepsilon, \quad \varepsilon \sim \mathcal{N}\left(0, \pi_y^{-1}\right)$
- "Representative" investor observes
  $w = \theta + \eta$, with $\eta \sim \mathcal{N}\left(0, \pi_\omega^{-1}\right)$
- Investor's information at beginning of $t = 2$: $\mathcal{I} = \{\omega, (n_j)_{j \in [0,1]}\}$
- Entrepreneur i's information at beginning of $t = 2$:$\mathcal{J}_i = \{x_i, y, (n_j)_{j \in [0,1]}\}$
- Market-generated information:$\mathcal{M} \equiv (p_i, s_i, k_i)_{i \in [0,N]}$

Model: Financial Market Microstructure

- Similar to Kyle (1985)
- Each entrepreneur i submits supply correspondence

$$S_i^s((\tilde{p}_j)_{j\in[0,N]}, (\tilde{k}_j)_{j\in[0,N]\setminus i}|\mathcal{J}_i)$$

- Representative investor submits demand correspondences $\left(S_i^d(\cdot|\mathcal{I})\right)_{i\in[0,N]}$, one for each active IPO $i \in [0, N]$, with each

$$S_i^d((\tilde{p}_j)_{j\in[0,N]}, (\tilde{k}_j)_{j\in[0,N]}|\mathcal{I})$$

- Auctioneer selects triples $(p_i, s_i, k_i)_{i\in[0,N]}$ so that
  - each mkt clears
  - each expansion funded with IPO proceeds ($k_i = p_i \cdot s_i$)
- Two differences wrt Kyle (1985):
  - endogenous dividend (depends on k_i)
  - entrepreneurs do not have mkt power

Model: Payoffs

- Entrepreneurs' lifetime utility: $U_i = c_{i1} + \beta c_{i2} + \beta^2 c_{i3}$,
  - $c_{i1} = 1 - n_i$
  - $c_{i2} = 0$
  - $c_{i3} = 0$ if $n_i = 0$ and $c_{i3} = (1 - s_i)\Theta k_i^\alpha$ otherwise.
- At $t = 2$, representative investor can produce consumption good out of labor, l, at one-to-one rate
  - perfectly elastic supply of external funds
- Consumption levels of representative investor

$$c_2 = l - \int_{i \in [0,N]} p_i s_i di \qquad \text{and} \qquad c_3 = \int_{i \in [0,N]} s_i \Theta k_i^\alpha di,$$

- Investor's lifetime utility:

$$V = \int_{i \in [0,N]} \left[\beta \Theta k_i^\alpha - p_i \right] s_i di$$

Plan

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2. **Equilibrium**
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Equilibrium

Equilibrium

- PBE satisfying following restrictions/refinements:
  - p_i depends only on mkt information (standard)
  - representative investor's posterior about θ is normal with mean $\hat{\theta} \equiv \mathbb{E}[\theta|\mathcal{I}]$ normally distributed (known variances)
  - Each entrepreneur "informationally small"
    - investor's posterior about aggregate TFP θ invariant to (n_i, p_i, s_i, k_i)
    - ...function of cross-sectional distribution $(n_j, p_j, s_j, k_j)_{j \in [0,N]}$

Equilibrium: IPO Stage

- Representative investor's demand in IPO mkt i **perfectly elastic** at

$$p = \beta \hat{\Theta} k^{\alpha}$$

where

$$\hat{\Theta} \equiv \mathbb{E}[\Theta | \mathcal{I}'] \quad \textit{and} \quad \mathcal{I}' = \{\omega, (n_j)_{j \in [0,1]}\} \cup \{(p_j, s_j, k_j)_{j \in [0,N]}\}$$

Equilibrium: IPO Stage

- "Relaxed" problem in which entrepreneur i can condition his supply on $\hat{\Theta}$
- For every $\hat{\Theta}$, entrepreneur chooses (p, s, k) that maximize his utility s.t.
  - $k = p \cdot s$
  - $p = \beta \hat{\Theta} k^{\alpha}$
- To invest k, entrepreneur must sell

$$s = \frac{k}{\beta \hat{\Theta} k^{\alpha}}$$

- Entrepreneur's payoff

$$(1 - s)\Theta k^{\alpha} = \frac{\Theta}{\beta \hat{\Theta}} \left[\beta \hat{\Theta} k^{\alpha} - k \right]$$

thus maximized by

$$K(\hat{\Theta}) = (\alpha \beta \hat{\Theta})^{\frac{1}{1-\alpha}}, \qquad P(\hat{\Theta}) = \alpha^{\frac{\alpha}{1-\alpha}} (\beta \hat{\Theta})^{\frac{1}{1-\alpha}}, \qquad S(\hat{\Theta}) = \alpha$$

Equilibrium: IPO Stage

- Because $p = P(\hat{\Theta})$ is invertible, solution to relaxed problem can be implemented by submitting supply schedule

$$S_i^s((p_j)_{j\in[0,N]},(k_j)_{j\in[0,N]\setminus i}|\mathcal{J}_i) = K(P^{-1}(p_i))/p_i.$$

- Because each (p_i, s_i, k_i) depends only on $\hat{\Theta}$, representative investor does not update his beliefs about Θ after observing mkt outcomes:

$$\hat{\Theta} \equiv \mathbb{E}[\Theta|\mathcal{I}'] = \mathbb{E}[\Theta|\mathcal{I}].$$

- Remark: same conclusions if each entrepreneur submits **mkt order** instead of limit order

Equilibrium: Start-up Stage

- Each entrepreneur i finds it optimal to start project iff

$$\beta^2 \mathbb{E}_i[(1 - s_i)\Theta k_i^\alpha] \geq 1$$

- Using normality of $\hat{\theta} \equiv \mathbb{E}[\theta|\mathcal{I}']$ and of $\theta|\mathcal{I}$,

$$n_i = 1 \quad \Leftrightarrow \quad (1 - \alpha)\mathbb{E}_i[\theta] + \alpha\mathbb{E}_i[\hat{\theta}] \geq C$$

- **First direction of feedback mechanism**:
    - higher $\hat{\theta} \Rightarrow$ higher IPO price $\Rightarrow$ higher startup activity, N

Equilibrium: Market valuation

- Using Normality

$$n_i = 1 \quad \Leftrightarrow \quad (1-b)x_i + by \geq c$$

- Aggregate level of startup activity:

$$N = \Pr\left((1-b)x_i + by \geq c \,|\, \theta, y\right) = \Phi\left(\sqrt{\pi_x}\frac{(1-b)\theta + by - c}{1-b}\right)$$

- Observation of N conveys same information as "**endogenous**" signal

$$z \equiv (1-b)\theta + by = \theta + b\varepsilon$$

$$\pi_z = \pi_y / b^2$$

- Investors cannot tell apart whether high N driven by high θ or correlated error, ε, in entrepreneurs' beliefs
- Hence,

$$\hat{\Theta} = \mathbb{E}[\Theta|\mathcal{I}'] = \mathbb{E}[\Theta|\omega, N] = \mathbb{E}[\Theta|\omega, z]$$

- **Second direction of feedback mechanism**:
    - higher startup activity $N \Rightarrow$ higher $\hat{\Theta} \Rightarrow$ higher IPO prices

Equilibrium: Fixed Point

- Using
$$\hat{\theta} = \mathbb{E}[\theta|\omega, z] = \frac{\pi_\omega}{\pi}\omega + \frac{\pi_z}{\pi}z,$$
$$\mathbb{E}_i[\hat{\theta}] = \frac{\pi_\omega + \pi_z(1-b)}{\pi}\mathbb{E}_i[\theta] + \frac{\pi_z}{\pi}by$$
where
$$\mathbb{E}_i[\theta] = \delta_x x_i + \delta_y y$$
with
$$\delta_x \equiv \frac{\pi_x}{\pi_\theta + \pi_x + \pi_y} \quad \text{and} \quad \delta_y \equiv \frac{\pi_y}{\pi_\theta + \pi_x + \pi_y}$$
- Hence, each entrepreneur finds it optimal to start project iff
$$(1-b')x_i + b'y \geq c'$$
- There exist functions $\Gamma : \mathbb{R} \to \mathbb{R}$ and $\Lambda : \mathbb{R} \to \mathbb{R}$ s.t. if b^* is fixed point of Γ and $c^* = \Lambda(b^*)$, then there exists eq. in which each entrepreneur starts a project iff
$$(1-b^*)x_i + b^*y \geq c^*$$

Proposition 1

(i) There always exists eq. in which $b^* \in (0,1)$. (iii) Such eq. unique for all $\alpha \leq \bar{\alpha}$. (iv) For $\alpha > \bar{\alpha}$, multiple equilibria

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Positive Analysis

Role of information spillovers

- Suppose investors do not learn from N
- $\hat{\theta}$ is linear function of exogenous signal $\omega = \theta + \eta$
- Since entrepreneurs do not possess any information about η , $\mathbb{E}_i[\hat{\theta}]$ is linear transformation of $\mathbb{E}_i[\theta]$
- In this case,

$$n_i = 1 \quad \Leftrightarrow \quad \mathbb{E}_i[\theta] \geq \hat{C}$$

- Equivalently,

$$n_i = 1 \quad \Leftrightarrow \quad (1-\delta)x_i + \delta y \geq \hat{c}$$

  where

$$\delta_x \equiv \frac{\pi_x}{\pi_\theta + \pi_x + \pi_y} \quad \text{and} \quad \delta_y \equiv \frac{\pi_y}{\pi_\theta + \pi_x + \pi_y}$$

- With information spillovers: $b^* > \delta$

Proposition 2

Informational spillovers from real to financial sector amplify contribution of noise to aggregate volatility:

$$\frac{\partial N / \partial \varepsilon}{\partial N / \partial \theta} = b^* > \delta$$

Mispricing and speculation

- Entrepreneurs' startup rule:

$$n_i = 1 \quad \Leftrightarrow \quad \mathbb{E}_i[\theta] + \alpha \mathbb{E}_i[\hat{\theta} - \theta] \geq C$$

- **Mispricing:**

$$\hat{\theta} - \theta = \frac{\pi_\omega}{\pi}\eta + \frac{\pi_z}{\pi} b^* \varepsilon$$

- Higher $p \Rightarrow$ lower cost of capital $\Rightarrow$ higher return to startup activity
- Reminiscent of dot-com bubble: when entrepreneurs expect financial mkt to "overvalue" their businesses $\Rightarrow$ higher startup activity (Pastor and Veronesi, 2009)
- $\mathbb{E}_i[\eta] = 0$ whereas

$$\mathbb{E}_i[\varepsilon] = y - \mathbb{E}_i[\theta] = (1 - \delta_y)y - \delta_x x$$

- Because higher y contributes to both higher $\mathbb{E}_i[\theta]$ and higher $\mathbb{E}_i[\hat{\theta} - \theta]$, relative sensitivity of startup activity to sources with correlated noise higher than what warranted by informativeness of such sources
- Spillover from entrepreneurs' collective optimism to exuberance in financial mkt crowds out private information and amplifies non-fundamental volatility

Beauty contest interpretation

Proposition 3

In eq., each entrepreneur starts project iff

$$\mathbb{E}_i[(1-r)\theta + r\Phi^{-1}(N)] \geq c^{\#}$$

- binary-action coordination game among entrepreneurs
- Similar to "beauty-contest" literature but here strategic complementarity **endogenous**
  - each entrepreneur cares about other entrepreneurs' decisions because aggregate startup activity signals higher profitability and hence leads to higher IPO prices
  - complementarity originates in
    - **collective signaling** from Silicon Valley to Wall Street

Impact of α

Proposition 4

As long as eq. is unique ($\alpha < \bar{\alpha}$), higher α implies higher contribution of correlated noise to aggregate volatility.

- Higher α: higher sensitivity of IPO prices to mkt beliefs
- Sectors with high growth potential and high finance dependence most prone to "irrational exuberance", "manias" and "panics"
  - especially true in early stages, when significant uncertainty about eventual profitability

Plan

Welfare Analysis

Efficiency

- Are above properties symptom of inefficiency?

- Welfare:

$$\int_0^1 \left\{ n_i \left(\beta^2 \Theta k_i^\alpha - \beta k_i \right) + (1 - n_i) \right\} di = 1 + N \left(\beta^2 \Theta k^\alpha - \beta k - 1 \right)$$

  where $N = \int n_i di$ (concavity: $k_i = k$ all i)

- Restricting attention to linear rules

$$n_i = 1 \quad \Leftrightarrow \quad (1 - b)x_i + by \geq c,$$

  planner's problem:

$$\max_{(b,c)\in\mathbb{R}^2, \mathcal{K}\in\mathbf{C}} \mathbb{E}\left[N(z) \left(\beta^2 \Theta \mathcal{K}(\omega, z)^\alpha - \beta \mathcal{K}(\omega, z) - 1 \right) \right]$$

$$s.t. \quad z = \theta + b\varepsilon, \quad N(z) = \Phi\left(\frac{\sqrt{\pi_x}}{1-b}(z - c) \right)$$

  where $\mathbf{C} \equiv \{\mathcal{K} : \mathbb{R}^2 \rightarrow \mathbb{R}\}$

Efficiency

- Efficiency in period-2 expansions:

$$\mathcal{K}(\omega, z) = \arg\max_k \left\{ \beta \hat{\Theta} k^{\alpha} - k \right\},$$

where $\hat{\Theta} = \mathbb{E}[\Theta | \omega, z]$

- Same condition as under mkt equilibrium

- Equilibrium expansions thus efficient conditional on available information

$$\mathcal{K}(\omega, z) = K(\hat{\Theta}) = (\alpha\beta\hat{\Theta})^{\frac{1}{1-\alpha}}$$

  - ...yet available information need not be efficient

Efficiency

Proposition 5

Efficiency in startup decisions

$$n_i = 1 \quad \Leftrightarrow \quad (1 - b^\diamond)x_i + b^\diamond y \geq c^\diamond$$

requires lower sensitivity to correlated noise:

$$b^\diamond < b^*$$

- Eq. contribution of correlated noise to aggregate volatility inefficiently high
- Two reasons why $b^\diamond < b^*$:
    - speculative startup activity not warranted
    - information externality: reducing b increases precision of endogenous signal z and hence efficiency of period-2 expansions
- Both inefficiencies originate in information spillover
- Additional inefficiency in "levels": $c^\diamond \neq c^*$
    - akin to holdup problem
        - private return from starting project: $\beta^2(1-\alpha)\Theta K^\alpha$
        - social return: $\beta^2 \Theta K^\alpha - \beta K$

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Policy

Policy: Taxation of entrepreneurial profits

- **Proportional tax $T(\Pi, p)$ on entrepreneurs' profits contingent on IPO price**
- Planner can infer $(\Theta, \hat{\Theta})$ from P and Π
  - hence, de facto, T contingent $(\Theta, \hat{\Theta})$
- Net-of-taxes return to start-up activity:

$$(1 - T(\Theta, \hat{\Theta}))\Pi(\Theta, \hat{\Theta})$$

can be manipulated so as to implement efficient allocations

Policy: Tax on financial trades

- **Tax $\tau(p)$ on financial trades**
    - cost to investors of buying shares: $(1+\tau)ps$
    - τ increasing in p (macro-prudential)
- Because $p = P(\hat{\Theta})$, de facto, $\tau = T(\hat{\Theta})$
- Equilibrium prices:

$$p = \frac{\beta \hat{\Theta} f(k)}{1 + T(\hat{\Theta})}$$

- Such policies improve efficiency of entrepreneurs' entry decisions, but distorts stage-2 investment
    - cannot implement efficient allocations but can improve over laissez-faire eq.

Policy: Cap on shares sold

- **Cap on shares entrepreneurs can sell**
  - can increase sensitivity of start-up activity to fundamentals
  - forcing entrepreneurs to retain more "skin in the game" reduces speculative motive

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Robustness and Extensions

Robustness

1. "Irrational exuberance"
    1. correlated bias in beliefs
    2. correlated taste for startup activity
2. Imperfectly correlated fundamentals Θ_i
3. Imperfectly elastic demand schedules
    1. risk averse traders
4. Richer signals Wall Street receives from Silicon Valley - sales and orders
5. Richer entrepreneurs' signals
6. Endogenous collection of entrepreneurs' information

Extensions

- Waves of startup activity and IPOs
  - later entrepreneurs learn from earlier ones
- Short-termism driven by managerial compensation
  - alternative mechanism for real sector to care about asset prices

Conclusions

- Implications of information spillovers from real to financial sector
  - **amplification and non-fundamental volatility**
  - **bubbly co-movements in real investment and asset prices**
  - **inefficiency in startup activity**
- Corrective policies:
  - taxes on profits contingent on IPO prices
  - taxes on financial trades
  - IPO regulations – caps on shares sold

Conclusions

THANKS!

Equilibrium: formal definition

Definition 1

Eq. consists of startup strategies $n_i(x_i, y)$, supply correspondences $S_i^s(\cdot)$, demand correspondences $S_i^d(\cdot)$, IPO prices $(p_i)_{i\in[0,N]}$, investment expansions $(k_i)_{i\in[0,N]}$, shares issuances $(s_i)_{i\in[0,N]}$, and beliefs, μ jointly satisfying:
(i) for all (x_i, y),

$$n_i\left(x_i, y\right) \in \arg\max_k \mathbb{E}\left[\ 1 - n_i + n_i\beta^2\left((1-s_i)\Theta k_i^{\alpha}\right)\ \middle|\ x_i, y\ \right];$$

(ii) for all $\mathcal{J}_i$, all $(\tilde{p}_j)_{j\in[0,N]}, (\tilde{k}_j)_{j\in[0,N]\setminus i}$, $S_i^s(\cdot)$ maximizes $\Pi_i = (1-s_i)\Theta k_i^{\alpha}$; given entrepreneurs' posterior beliefs about Θ, constraint $k_i = s_i p_i$, and others' limit orders;
(iii) for all $\mathcal{I}$, $(S_i^d(\cdot))_{i\in[0,N]}$ maximizes $V = \int\left[\beta\Theta f(k_i) - p_i\right] s_i di$ given investor's posterior beliefs, constraint $k_i = s_i p_i$, and others' limit orders;
(iv) each active market $i \in [0, N]$ clears and $k_i = s_i p_i$;
(v) beliefs are consistent with Bayes' rule on path.

Go back