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

  ⇒ 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 mkt 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 $t = 3$:
  \[ q = \Theta k^\alpha \]

- $\Theta$: 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 $\Theta$ 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 $\theta \sim \mathcal{N} (0, \pi_{\theta}^{-1})$

- Entrepreneurs observe
  
  $x_i = \theta + \xi_i$, $\xi_i \sim \mathcal{N} (0, \pi_x^{-1})$
  
  $y = \theta + \varepsilon$, $\varepsilon \sim \mathcal{N} (0, \pi_y^{-1})$

- “Representative” investor observes
  
  $w = \theta + \eta$, with $\eta \sim \mathcal{N} (0, \pi_{\omega}^{-1})$

- 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: $\mathcal{M} \equiv (p_i, s_i, k_i)_{i \in [0,N]}$
Similar to Kyle (1985)

Each entrepreneur $i$ submits supply correspondence

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

Representative investor submits demand correspondences $(S_i^d(\cdot | \mathcal{I}))_{i \in [0,N]}$, 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
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

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

Investor’s lifetime utility:

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

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Equilibrium
Equilibrium

- PBE satisfying following restrictions/refinements:
  - $p_i$ depends only on mkt information (standard)
  - representative investor’s posterior about $\theta$ is normal with mean $\hat{\theta} \equiv \mathbb{E}[\theta | I]$ normally distributed (known variances)
  - Each entrepreneur “informationally small”
    - investor’s posterior about aggregate TFP $\theta$ 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 is **perfectly elastic** at
  \[ p = \beta \hat{\Theta} k^\alpha \]

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

$$ K(\hat{\Theta}) = (\alpha \beta \hat{\Theta})^{\frac{1}{1-\alpha}}, \quad P(\hat{\Theta}) = \alpha^{\frac{\alpha}{1-\alpha}} (\beta \hat{\Theta})^{\frac{1}{1-\alpha}}, \quad S(\hat{\Theta}) = \alpha $$
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 $\Theta$ 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
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 $\theta|\mathcal{I}$,

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

First direction of feedback mechanism:

- higher $\hat{\theta} \Rightarrow$ higher IPO price $\Rightarrow$ higher startup activity, $N$
Equilibrium: Market valuation

- **Using Normality**
  \[ n_i = 1 \iff (1 - b)x_i + by \geq c \]

- **Aggregate level of startup activity:**
  \[ N = \Pr\((1 - b)x_i + by \geq c | \theta, y) = \Phi\left(\sqrt{\pi} \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** \( \theta \) **or correlated error,** \( \varepsilon \), **in entrepreneurs’ beliefs**

- **Hence,**
  \[ \hat{\Theta} = \mathbb{E}[\Theta | I'] = \mathbb{E}[\Theta | \omega, N] = \mathbb{E}[\Theta | \omega, z] \]

- **Second direction of feedback mechanism:**
  - higher startup activity \( N \Rightarrow \) higher \( \hat{\Theta} \Rightarrow \) higher IPO prices
Equilibrium: Fixed Point

Using

$$\hat{\theta} = \mathbb{E}[\theta | \omega, z] = \frac{\pi_{\omega}}{\pi} \omega + \frac{\pi_{z}}{\pi} z,$$

$$\mathbb{E}_i[\hat{\theta}] = \frac{\pi_{\omega} + \pi_{z}(1 - b)}{\pi} \mathbb{E}_i[\theta] + \frac{\pi_{z}}{\pi} b y$$

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 $\Gamma$ 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 \( \eta \), \( E_i[\hat{\theta}] \) is linear transformation of \( E_i[\theta] \)
- In this case,
  \[
  n_i = 1 \quad \Leftrightarrow \quad E_i[\theta] \geq \hat{C}
  \]
- 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:
  \[ n_i = 1 \iff \mathbb{E}_i[\theta] + \alpha \mathbb{E}_i[\hat{\theta} - \theta] \geq C \]

- 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

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

- 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
Proposition 4

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

- Higher $\alpha$: 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
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Welfare Analysis
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
\[
n_i = 1 \iff (1 - b)x_i + by \geq c,
\]
planner's problem:
\[
\max_{(b,c) \in \mathbb{R}^2, K \in \mathcal{C}} \mathbb{E} \left[ N(z) \left( \beta^2 \Theta K(\omega, z)^\alpha - \beta K(\omega, z) - 1 \right) \right]
\]
\[
s.t. \quad z = \theta + b\varepsilon, \quad N(z) = \Phi \left( \frac{\sqrt{\pi \lambda}}{1 - b} (z - c) \right)
\]
where \( \mathcal{C} \equiv \{ K : \mathbb{R}^2 \to \mathbb{R} \} \)
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
Proposition 5
Efficiency in startup decisions

\[ n_i = 1 \iff (1 - b^\diamond)x_i + b^\diamond y \geq c^\diamond \]

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
Proportional tax $T(\Pi, p)$ on entrepreneurs’ profits contingent on IPO price

Planner can infer $(\Theta, \hat{\Theta})$ from $P$ and $\Pi$
  - 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: $(1 + \tau)ps$
  - $\tau$ 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 $\Theta_i$

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
THANKS!
**Equilibrium: formal definition**

**Definition 1**

Eq. consists of startup strategies $n_i(x_i, y)$, supply correspondences $S^s_i(\cdot)$, demand correspondences $S^d_i(\cdot)$, 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, $\mu$ jointly satisfying:

(i) for all $(x_i, y)$,

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

(ii) for all $J_i$, all $(\tilde{p}_j)_{j \in [0, N]}, (\tilde{k}_j)_{j \in [0, N] \backslash i}$, $S^s_i(\cdot)$ maximizes $\Pi_i = (1 - s_i) \Theta k^\alpha_i$; given entrepreneurs’ posterior beliefs about $\Theta$, constraint $k_i = s_i p_i$, and others’ limit orders;

(iii) for all $I$, $(S^d_i(\cdot))_{i \in [0, N]}$ maximizes $V = \int [\beta \Theta f(k_i) - p_i] s_i \, di$ 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.