Overconfidence and Speculative Bubbles

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Presented By: Michelle Zemel
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Motivation

Episodes of Price Bubbles - coexistence of high prices, high trading volume, and high price volatility
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- Overconfidence generates heterogeneity
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- Heterogeneous beliefs generate trade: the asset buyer acquires an option to sell the asset to other agents in the future when those agents have more optimistic beliefs
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- Introduce speculative component in prices
Main Results

- Overconfidence (heterogeneity) causes a significant bubble component in prices.
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- In equilibrium, bubbles are accompanied by large trading volume and high price volatility
- Sensitivity Analysis: Trading costs reduce trading volume greatly, but have a limited effect on the size of the bubble and on the price volatility
Economy

- Infinite horizon problem
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- Single risky asset traded continuously
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- Asset in finite positive supply, no short sales (or short selling cost and constraint)
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- Single risky asset traded continuously
- Asset in finite positive supply, no short sales (or short selling cost and constraint)
- Two groups of risk neutral agents, A and B
Risky Asset

- Asset pays dividends
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- Dividend driven by a fundamental variable
Risky Asset

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- Dividend driven by a fundamental variable
- Dividend process has noise, so fundamental variable is not observable
Fundamental Processes

The cumulative dividend process $D_t$ satisfies

$$dD_t = f_t dt + \sigma_D dZ^D_t,$$  \hspace{1cm} (1)

where $Z^D$ is a standard Brownian motion and $\sigma_D$ is a constant volatility parameter.

The fundamental variable $f$ is not observable. However, it satisfies

$$df_t = -\lambda (f_t - \bar{f}) dt + \sigma_f dZ'_f,$$ \hspace{1cm} (2)

where $\lambda \geq 0$ is the mean reversion parameter, $\bar{f}$ is the long-run mean of $f$, $\sigma_f > 0$ is a constant volatility parameter, and $Z'_f$ is a standard Brownian motion.
Signals

Agents observe two signals, $S^A$ and $S^B$. True processes for signals:

\[ ds_t^A = f_t dt + \sigma_s dZ_t^A, \]

\[ ds_t^B = f_t dt + \sigma_s dZ_t^B, \]

where $Z^A$ and $Z^B$ are standard Brownian motions, and $\sigma_s > 0$ is the common volatility of the signals.

We assume that all four processes $Z^D$, $Z^f$, $Z^A$, and $Z^B$ are mutually independent.
Overconfidence in Beliefs

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- $\Phi$ is the correlation each group attributes to the innovations in its signal and the innovations in the fundamental process
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agents in group $A$ believe that the process for $s^A$ is

$$ds^A_t = f_t dt + \sigma_s \Phi dZ^f_t + \sigma_s \sqrt{1 - \Phi^2} dZ^A_t.$$

Similarly, agents in group $B$ believe that the process for $s^B$ is

$$ds^B_t = f_t dt + \sigma_s \Phi dZ^f_t + \sigma_s \sqrt{1 - \Phi^2} dZ^B_t.$$
Formation of Beliefs

- Agents observe dividend process, signal A, and signal B
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- All variables are Gaussian $\Rightarrow$ standard filtering problem
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- The stationary variance of the beliefs process is the same for both groups:
Formation of Beliefs

- Agents observe dividend process, signal A, and signal B
- All variables are Gaussian \(\Rightarrow\) standard filtering problem
- The conditional beliefs are Gaussian with mean \(\hat{f}_c\) and variance \(\gamma^c\)
- The stationary variance of the beliefs process is the same for both groups:

\[
\gamma = \frac{\sqrt{\left(\lambda + (\phi \sigma_f / \sigma_s)\right)^2 + (1 - \phi^2)(\left(2\sigma_f^2/\sigma_s^2\right) + \left(\sigma_f^2/\sigma_D^2\right))} - \left[\lambda + (\phi \sigma_f / \sigma_s)\right]}{\left(1/\sigma_D^2\right) + \left(2/\sigma_s^2\right)}.
\]

**Lemma 1.** The stationary variance \(\gamma\) decreases with \(\phi\).
Evolution of Beliefs

- Conditional mean of the beliefs of each of the two groups differs:
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\[
\begin{align*}
    d\hat{f}^A &= -\lambda (\hat{f}^A - \bar{f})dt + \frac{\phi \sigma_f \gamma}{\sigma_s^2} (d\Delta^A - \hat{f}^A dt) \\
    &\quad + \frac{\gamma}{\sigma_s^2} (d\Delta^B - \hat{f}^A dt) + \frac{\gamma}{\sigma_D^2} (dD - \hat{f}^A dt), \\
    \\
    \text{and} \\
    d\hat{f}^B &= -\lambda (\hat{f}^B - \bar{f})dt + \frac{\gamma}{\sigma_s^2} (d\Delta^A - \hat{f}^B dt) \\
    &\quad + \frac{\phi \sigma_f \gamma}{\sigma_s^2} (d\Delta^B - \hat{f}^B dt) + \frac{\gamma}{\sigma_D^2} (dD - \hat{f}^B dt),
\end{align*}
\]
Difference of Beliefs

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- \( g^A \) and \( g^B \) represent the difference in beliefs (from the perspective of groups A and B respectively).
- \( g^A = \hat{f}^B - \hat{f}^A \) and \( g^B = \hat{f}^A - \hat{f}^B \)
Difference of Beliefs

\[ dg^A = -\rho g^A dt + \sigma_g dW^A, \]

and \( W^A \) is a standard Wiener process for agents in group \( A \), with innovations that are orthogonal to the innovations of \( f^A \).

and

\[ dg^B = -\rho g^B dt + \sigma_g dW^B, \]

where \( W^B \) is a standard Wiener process, and it is independent of innovations to \( f^B \).

with

\[
\rho = \sqrt{\left(\lambda + \phi \frac{\sigma_f}{\sigma_s} \right)^2 + (1 - \phi^2) \sigma_f^2 \left( \frac{1}{\sigma_s^2} + \frac{1}{\sigma_D^2} \right)},
\]

\[
\sigma_g = \sqrt{2} \phi \sigma_f,
\]
Motives of Trade

Fluctuations in differences of beliefs across agents will induce trade. An asset holder will want to sell when the other group is optimistic, as he will be profiting from their overvaluation. Investors that are optimistic about the prospect of future dividends will bid up the price of the asset and eventually hold the total (finite) supply of the asset. The assumption of no short sales is critical.
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- Asset will be sold at the optimistic agents reservation price
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Equilibrium Asset Price

Assume transaction cost \( c \geq 0 \) paid by seller. The amount that an agent is willing to pay reflects the agent's fundamental valuation and the fact that he may be able to sell his holdings for a profit at a later date at the demand price of agents in the other group. Essentially, he will hold an option to sell the asset, when he chooses, to the other party.

Let \( o \) denote the group that currently owns the asset, and let \( \bar{o} \) be the other group. Let \( E^o_t \) denote the expectation of members of group \( o \), conditional on time \( t \) information.
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- Let $o$ denote the group that currently owns the asset, and let $\bar{o}$ be the other group
- Let $E_t^o$ denote the expectation of members of group $o$, conditional on time $t$ information
Equilibrium Asset Price

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\[ p_t^0 = \sup_{\tau \geq 0} E_t^0 \left[ \int_t^{t+\tau} e^{-r(s-t)} dD_s + e^{-r\tau} (\hat{p}_{t+\tau}^0 - c) \right], \]

where \( \tau \) is a stopping time, and \( \hat{p}_{t+\tau}^0 \) is the reservation value of the buyer at the time of transaction \( t + \tau \).
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\[ \hat{p}_i^o = p^o(f^o_i, g^o_i) = \frac{\hat{f}}{r} + \frac{\hat{f}^o - \hat{f}}{r + \lambda} + q(g^o_i), \]

- Plug into original expression for price
Equilibrium Asset Price

Conjecture form of equilibrium price:

\[ p^e_t = p^e(f^e_t, g^e_t) = \frac{\tilde{f}}{r} + \frac{\tilde{f}^e - \tilde{f}}{r + \lambda} + q(g^e_t), \]

- Plug into original expression for price

\[ p^e_t = p^e(f^e_t, g^e_t) = \frac{\tilde{f}}{r} + \frac{\tilde{f}^e - \tilde{f}}{r + \lambda} + \sup_{\tau \geq 0} E^e_t \left[ \frac{g^e_{t+\tau}}{r + \lambda} + q(g^e_{t+\tau}) - c \right] e^{-r \tau}. \]
Equilibrium Asset Price

Conjecture form of equilibrium price:

\[ p_t^* = p^*(f_t^*, g_t^*) = \frac{\hat{f}_t^*}{r + \lambda} + q(g_t^*), \]

- Plug into original expression for price

\[ p_t^* = p^*(f_t^*, g_t^*) = \frac{\hat{f}_t^*}{r + \lambda} + \sup_{\tau \geq 0} \mathbb{E}_t^o \left( \frac{g_{t+\tau}^*}{r + \lambda} + q(g_{t+\tau}^*) - c \right) e^{-\tau r}. \]

- Resale Option Value must satisfy

\[ q(g_t^*) = \sup_{\tau \geq 0} \mathbb{E}_t^o \left( \frac{g_{t+\tau}^*}{r + \lambda} + q(g_{t+\tau}^*) - c \right) e^{-\tau r}. \]
Finding the equilibrium price is equivalent to constructing an option value function $q$ that satisfies

$$q(g_i^o) = \sup_{r \geq 0} E_t^o \left( \frac{g_i^{o+r}}{r + \lambda} + q(g_i^{o+r}) - c \right) e^{-rt}.$$
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- Similar to a Bellman equation, need to find a fixed point
Finding the equilibrium price is equivalent to constructing an option value function $q$ that satisfies

$$q(g_i^e) = \sup_{r \geq 0} E^0_t \left[ \frac{g_{i+r}^e}{r + \lambda} + q(g_{i+r}^e) - c \right] e^{-rr}.$$ 

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- Option Payoff has two components:
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$$q(g^o_i) = \sup_{r \geq 0} E_t^o \left[ \frac{g^o_{t+r}}{r + \lambda} + q(g^o_{t+r}) - c \right] e^{-rr}.$$ 

- Similar to a Bellman equation, need to find a fixed point
- Option Payoff has two components:
  - Buyer’s optimism about current price (difference in valuation)
  - Value of the new option sold to new buyer (to buy back the asset + option in the future)
Properties of the Option Value - Optimal Stopping Time

- There exists a unique $k^*(c)$ for each $c$ such that it is optimal to immediately exercise the option (sell the asset) when $g_t^o \geq k^*$.
Option Value

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- Continuation Region: $(-\infty, k^*)$
- Stopping Region: $(k^*, \infty)$
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- If $c > 0$, $k^* > c(r + \lambda)$
Duration between Trades

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- $c = 0 \Rightarrow$ expected duration between trades is 0, infinite trading volume
- Possible to calibrate a model to obtain any average daily trading volume by increasing $c$
Option Value

Value of Option

- For each $c$, there exists a unique $\beta_1 > 0$ such that

$$q(x) = \begin{cases} 
\beta_1 h(x) & \text{for } x < k^* \\
\frac{x}{r+\lambda} + \beta_1 h(-x) - c & \text{for } x \geq k^*.
\end{cases}$$

**Lemma 2.** For each $x \in \mathbb{R}$, $h(x) > 0$, $h'(x) > 0$, $h''(x) > 0$, $h'''(x) > 0$, $\lim_{x \to -\infty} h(x) = 0$, and $\lim_{x \to -\infty} h'(x) = 0.$
Option Value

Properties of H function:
Option Value

Properties of $H$ function:

\[
\begin{cases}
    U\left(\frac{r}{2\rho}, \frac{1}{2}, \frac{\rho}{\sigma_g^2}x^2\right) & \text{if } x \leq 0 \\
    \frac{2\pi}{\Gamma\left(\frac{1}{2} + (r/2\rho)\right)\Gamma\left(\frac{1}{2}\right)} M\left(\frac{r}{2\rho}, \frac{1}{2}, \frac{\rho}{\sigma_g^2}x^2\right) - U\left(\frac{r}{2\rho}, \frac{1}{2}, \frac{\rho}{\sigma_g^2}x^2\right) & \text{if } x > 0,
\end{cases}
\]

where $\Gamma(\cdot)$ is the gamma function, and $M: \mathbb{R}^3 \to \mathbb{R}$ and $U: \mathbb{R}^3 \to \mathbb{R}$ are two Kummer functions described in the Appendix. The function $h(x)$ is positive and increasing in $(-\infty, 0)$. In addition, $h$ solves equation (16) with

\[
h(0) = \frac{\pi}{\Gamma\left(\frac{1}{2} + (r/2\rho)\right)\Gamma\left(\frac{1}{2}\right)}.
\]
The Bubble

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\[
b = q(-k^*) = \frac{1}{r + \lambda h'(k^*) + h'(-k^*)}.
\]
A Closer Look at The Bubble

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- Trading frequency approaches infinity, small positive profits at each trade.
A Closer Look at The Bubble

- When $c = 0$, a trade occurs each time $g^o = 0$, there is no difference in beliefs
- The first component of the option payout is zero
- However, there is still a bubble in the price
- Limit as $c \to 0$, $k^* \to 0$
- Trading frequency approaches infinity, small positive profits at each trade
- This leads to positive bubble
Extra Volatility Component

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\[
\eta(x) = \frac{\sqrt{2}\phi \sigma_f}{r + \lambda(\frac{h'(x)}{h'(k^*) + h'(-k^*)}} \quad \forall x < k^*. 
\]
Effect of $\Phi$

Fig. 1.—Effect of overconfidence level: $a$, trading barrier; $b$, duration between trades; $c$, bubble; $d$, extra volatility component. Here, $r = 5$ percent, $\lambda = 0$, $\theta = 0.1$, $i_t = 2.0$, $i_d = 0$, and $c = 10^{-5}$. The values of the bubble and the extra volatility component are computed at the trading point. The trading barrier, the bubble, and the extra volatility component are measured as multiples of $\sigma/(r + \lambda)$, the fundamental volatility of the asset.
Effect of Information in Signals

Fig. 2.—Effect of information in signals: a, trading barrier; b, duration between trades; c, bubble; d, extra volatility component. Here, $r = 5$ percent, $\lambda = 0$, $\theta = 0.1$, $\phi = 0.7$, $i_p = 0$, and $\epsilon = 10^{-6}$. The values of the bubble and the extra volatility component are computed at the trading point. The trading barrier, the bubble, and the extra volatility component are measured as multiples of $\sigma / (r + \lambda)$, the fundamental volatility of the asset.
Fig. 3.—Effect of trading costs: a, trading barrier; b, duration between trades; c, bubble; d, extra volatility component. Here, $r = 5\%$, $\phi = 0.7$, $\lambda = 0$, $\theta = 0.1$, $i_s = 2.0$, and $i_p = 0$. The values of the bubble and the extra volatility component are computed at the trading point. The trading barrier, the bubble, the extra volatility component, and trading cost are measured as multiples of $\sigma_f / (r + \lambda)$, the fundamental volatility of the asset.
Conclusion

- Overconfidence $\Rightarrow$ Difference in Beliefs $\Rightarrow$ Speculative Component in Prices
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- Overconfidence ⇒ Difference in Beliefs ⇒ Speculative Component in Prices
- Prices have an option component because there is a possibility of profiting in the future from a divergence of beliefs
Overconfidence $\Rightarrow$ Difference in Beliefs $\Rightarrow$ Speculative Component in Prices

- Prices have an option component because there is a possibility of profiting in the future from a divergence of beliefs.
- Model can generate high prices, high trading volume, and increased price volatility.
Main Shortcoming - No learning
Discussion

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- This idea that the two groups trade back and forth, only on the hope that the other party will overestimate the value is not plausible
- Realized dividends reveal information about the fundamental variable, agents should be adjusting $\phi$
- In reality, the bubble will only last as long as it takes to learn $\phi$
- More realistic that some of the agents would learn the true process and try to exploit the other’s mispricing
Discussion

- Additional Restrictive Assumptions:

  - No short sales (what about the existence of derivative markets?)
  - Risk Neutral agents
  - Dumas, Kurshev, and Uppal (2007) - relaxes both of these assumptions, and introduces a group of rational arbitrageurs trying to capitalize on the mispricing of the irrational overconfident agents

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- This model would predict bubbles in these markets for new unfamiliar assets with no consensus valuation
- Of course, bubbles would disappear when learning became possible