Speculative Growth and Overreaction to Technology Shocks

Kevin J. Lansing
Federal Reserve Bank of San Francisco

June 5, 2009
Overview

“Excess volatility” of asset prices may affect capital accumulation, growth, and welfare.

- The price-dividend ratio in standard RBC models is nearly constant. But U.S. price-dividend ratio is highly volatile.
Overview

“Excess volatility” of asset prices may affect capital accumulation, growth, and welfare.

- The price-dividend ratio in standard RBC models is nearly constant. But U.S. price-dividend ratio is highly volatile.

- This paper: Introduce “excess volatility” (overreaction to technology shocks) in an RBC model with endogenous growth. In making forecasts, speculative agents behave like rational agents with very low risk aversion.
“Excess volatility” of asset prices may affect capital accumulation, growth, and welfare.

- The price-dividend ratio in standard RBC models is nearly constant. But U.S. price-dividend ratio is highly volatile.

- This paper: Introduce “excess volatility” (overreaction to technology shocks) in an RBC model with endogenous growth. In making forecasts, speculative agents behave like rational agents with very low risk aversion.

- Misspecified forecast rule alters dynamics in a way that tends to confirm the stronger technology response.
Overview
“Excess volatility” of asset prices may affect capital accumulation, growth, and welfare.

- The price-dividend ratio in standard RBC models is nearly constant. But U.S. price-dividend ratio is highly volatile.

- This paper: Introduce “excess volatility” (overreaction to technology shocks) in an RBC model with endogenous growth. In making forecasts, speculative agents behave like rational agents with very low risk aversion.

- Misspecified forecast rule alters dynamics in a way that tends to confirm the stronger technology response.

- Speculation generates asset price bubbles that coincide with improved technology, investment booms, and faster growth.
Overview

“Excess volatility” of asset prices may affect capital accumulation, growth, and welfare.

- The price-dividend ratio in standard RBC models is nearly constant. But U.S. price-dividend ratio is highly volatile.

- This paper: Introduce “excess volatility” (overreaction to technology shocks) in an RBC model with endogenous growth. In making forecasts, speculative agents behave like rational agents with very low risk aversion.

- Misspecified forecast rule alters dynamics in a way that tends to confirm the stronger technology response.

- Speculation generates asset price bubbles that coincide with improved technology, investment booms, and faster growth.

- Speculation can improve welfare if CRRA \( \leq 1 \) and agents underinvest relative to socially-optimal level.
Overview

“Excess volatility” of asset prices may affect capital accumulation, growth, and welfare.

- The price-dividend ratio in standard RBC models is nearly constant. But U.S. price-dividend ratio is highly volatile.

- This paper: Introduce “excess volatility” (overreaction to technology shocks) in an RBC model with endogenous growth. In making forecasts, speculative agents behave like rational agents with very low risk aversion.

- Misspecified forecast rule alters dynamics in a way that tends to confirm the stronger technology response.

- Speculation generates asset price bubbles that coincide with improved technology, investment booms, and faster growth.

- Speculation can improve welfare if CRRA ≤ 1 and agents underinvest relative to socially-optimal level.

- When CRRA > 1, the welfare cost of speculation can be large.
U.S. Price-Dividend Ratio is Volatile and Highly Persistent

S&P 500 Index: Price-Dividend Ratio
Four Major Run-ups in U.S. Stock Prices

Real S&P 500 Index (in logarithms)

- 1901
- 1929
- 1966
- 2000

- **Early 1900s**: High-speed rail travel, transatlantic radio, long-line electrical transmission.

- **Early 1900s**: High-speed rail travel, transatlantic radio, long-line electrical transmission.

- **1920s**: Mass-produced autos, travel by highways and roads, commercial radio broadcasts, widespread electrification of manufacturing.

- **Early 1900s**: High-speed rail travel, transatlantic radio, long-line electrical transmission.

- **1920s**: Mass-produced autos, travel by highways and roads, commercial radio broadcasts, widespread electrification of manufacturing.

- **1950s and 60s**: Widespread introduction of television, advent of the suburban lifestyle, space travel.
Overview

Historical Motivation

Related Literature

Model

Calibration

Results

Conclusion


- **Early 1900s**: High-speed rail travel, transatlantic radio, long-line electrical transmission.

- **1920s**: Mass-produced autos, travel by highways and roads, commercial radio broadcasts, widespread electrification of manufacturing.

- **1950s and 60s**: Widespread introduction of television, advent of the suburban lifestyle, space travel.

- **Late 1990s**: Widespread availability of the internet, innovations in computers and information technology, emergence of web-based business model.
Comparing Two Bubble Episodes

Real S&P 500 Index During Two 20-year Periods
(each series normalized to 100 at stock market peak)
“When we look back at the 1990s, from the perspective of say 2010...[w]e may conceivably conclude from that vantage point that, at the turn of the millennium, the American economy was experiencing a once-in-a-century acceleration of innovation, which propelled forward productivity, output, corporate profits, and stock prices at a pace not seen in generations, if ever.”
Technology and the late-1990s Stock Market Bubble

“When we look back at the 1990s, from the perspective of say 2010...[w]e may conceivably conclude from that vantage point that, at the turn of the millennium, the American economy was experiencing a once-in-a-century acceleration of innovation, which propelled forward productivity, output, corporate profits, and stock prices at a pace not seen in generations, if ever.”

“Alternatively, that 2010 retrospective might well conclude that a good deal of what we are currently experiencing was just one of the many euphoric speculative bubbles that have dotted human history. And, of course, we cannot rule out that we may look back and conclude that elements from both scenarios have been in play in recent years.”
"When we look back at the 1990s, from the perspective of say 2010...[w]e may conceivably conclude from that vantage point that, at the turn of the millennium, the American economy was experiencing a once-in-a-century acceleration of innovation, which propelled forward productivity, output, corporate profits, and stock prices at a pace not seen in generations, if ever."

"Alternatively, that 2010 retrospective might well conclude that a good deal of what we are currently experiencing was just one of the many euphoric speculative bubbles that have dotted human history. And, of course, we cannot rule out that we may look back and conclude that elements from both scenarios have been in play in recent years."

Business Investment and Stock Prices

Real Business Investment and Real S&P 500 Index
(each series normalized to 100 at the investment peak)
Rise and Fall of the "New Economy"

Potential GDP Growth and Detrended Stock Price Index

- **CBO 4-Qtr Potential Output Growth (left scale)**
- **Real S&P 500, Deviation from HP Filter Trend (right scale)**
“[T]he financial services sector has been dramatically transformed by technology...With these advances in technology, lenders have taken advantage of credit-scoring models and other techniques for efficiently extending credit to a broader spectrum of consumers.”
Technology and the mid-2000s Housing Market Bubble

“[T]he financial services sector has been dramatically transformed by technology...With these advances in technology, lenders have taken advantage of credit-scoring models and other techniques for efficiently extending credit to a broader spectrum of consumers.”

“...Where once more-marginal applicants would simply have been denied credit, lenders are now able to quite efficiently judge the risk posed by individual applicants and to price that risk appropriately. These improvements have led to rapid growth in subprime mortgage lending.”
Technology and the mid-2000s Housing Market Bubble

“[T]he financial services sector has been dramatically transformed by technology...With these advances in technology, lenders have taken advantage of credit-scoring models and other techniques for efficiently extending credit to a broader spectrum of consumers.”

“...Where once more-marginal applicants would simply have been denied credit, lenders are now able to quite efficiently judge the risk posed by individual applicants and to price that risk appropriately. These improvements have led to rapid growth in subprime mortgage lending.”

Federal Reserve Chairman Alan Greenspan, April 8, 2005.
Residential Investment and House Prices

Real Residential Investment and Real House Price Index
(each series normalized to 100 at investment peak)
Related Literature (partial list)

- Rational Bubbles and Endogenous Growth (OLG Models)
  - Caballero, Farhi, and Hammour (2006)
  - Olivier (2000)
  - Grossman and Yanagawa (1993)
  - King and Ferguson (1993)
Related Literature (partial list)

- **Rational Bubbles and Endogenous Growth (OLG Models)**
  - Caballero, Farhi, and Hammour (2006)
  - Olivier (2000)
  - Grossman and Yanagawa (1993)
  - King and Ferguson (1993)

- **Non-Fundamental Asset Price Movements and Investment**
  - Chirinko and Schaller (2001, 2007)
  - Gilchrist, Himmelberg, and Huberman (2005)
  - Panageas (2005)
  - Johnson (2007)
Related Literature (partial list)

- **Rational Bubbles and Endogenous Growth (OLG Models)**
  - Caballero, Farhi, and Hammour (2006)
  - Olivier (2000)
  - Grossman and Yanagawa (1993)
  - King and Ferguson (1993)

- **Non-Fundamental Asset Price Movements and Investment**
  - Chirinko and Schaller (2001, 2007)
  - Gilchrist, Himmelberg, and Huberman (2005)
  - Panageas (2005)
  - Johnson (2007)

- **Behavioral RBC Model (Optimism and Overconfidence)**
  - Jaimovich and Rebelo (2007)
The representative agent (or capitalist-entrepreneur) maximizes

\[
E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{c_t^{1-\alpha} - 1}{1 - \alpha} \right],
\]

\[
\alpha = \text{CRRA}
\]

\[
\phi \equiv 1 - \alpha
\]

\[
c_t + i_t = y_t
\]

\[
y_t = A \exp(z_t) k_t^\theta h_t^{1-\theta}
\]

\[
h_t = K_t, \quad \theta \in (0, 1]
\]

\[
k_{t+1} = B k_t^{1-\lambda} i_t^\lambda
\]

\[
\lambda \in (0, 1]
\]

\[
z_{t+1} = \rho z_t + \varepsilon_{t+1}
\]

\[
\varepsilon_{t+1} \sim N(0, \sigma^2_\varepsilon)
\]
Adjustment Cost Formulation
Mapping to formulation of Jermann (JME, 1998) and Barlevy (AER, 2004).

\[
\frac{k_{t+1}}{k_t} = 1 - \delta + \psi_0 \left( \frac{i_t}{k_t} \right)^{\psi_1} \approx B \left( \frac{i_t}{k_t} \right)^\lambda
\]

\[
\lambda = \frac{\psi_0 \psi_1 \left( \frac{i}{k} \right)^{\psi_1}}{1 - \delta + \psi_0 \left( \frac{i}{k} \right)^{\psi_1}} \quad B = \frac{1 - \delta + \psi_0 \left( \frac{i}{k} \right)^{\psi_1}}{\left( \frac{i}{k} \right)^\lambda} \quad \text{(Taylor Coefficients)}
\]
Adjustment Cost Formulation
Mapping to formulation of Jermann (JME, 1998) and Barlevy (AER, 2004).

\[
\frac{k_{t+1}}{k_t} = 1 - \delta + \psi_0 \left( \frac{i_t}{k_t} \right)^\psi_1 \simeq B \left( \frac{i_t}{k_t} \right)^\lambda
\]

\[
\lambda = \frac{\psi_0 \psi_1 (i/k)^\psi_1}{1 - \delta + \psi_0 (i/k)^\psi_1}
\]

\[
B = \frac{1 - \delta + \psi_0 (i/k)^\psi_1}{(i/k)^\lambda}
\]

(Taylor Coefficients)

\[
\frac{i_t}{\lambda} = E_t \beta \left[ \frac{c_{t+1}}{c_t} \right]^{-\alpha} \left[ \theta y_{t+1} - i_{t+1} + \frac{i_{t+1}}{\lambda} \right]
\]

(FOC)

\[
x_t \equiv \frac{i_t}{\lambda} = \frac{p_t}{c_t} \quad \Rightarrow \quad \frac{p_t}{d_t} = \frac{x_t}{\theta - (1 - \theta) \lambda x_t},
\]

(Stationary)
Model Solution

Investment-consumption ratio depends on technology shock (except for log utility).

\[
\frac{x_t^{1-\lambda \phi} \exp[(1-\lambda)\phi z_t]}{(1+\lambda x_t)^{(1-\lambda)\phi} = E_t \tilde{\beta} \left[ \frac{[\theta + x_{t+1}(1-\lambda+\lambda \theta)] \exp(\phi z_{t+1})}{(1+\lambda x_{t+1})^\phi} \right] \quad \text{(FOC)}
\]

\[
x_t \equiv \frac{i_t}{\lambda} = \frac{p_t}{c_t}, \quad \phi \equiv 1 - \text{CRRA}, \quad \tilde{\beta} \equiv \beta \left[ (A\lambda)^\lambda B \right]^{\phi}
\]
Model Solution

Investment-consumption ratio depends on technology shock (except for log utility).

\[
\frac{x_t^{1-\lambda \phi} \exp[(1-\lambda) \phi z_t]}{(1+\lambda x_t)^{(1-\lambda) \phi}} = E_t \tilde{\beta} \left[ \frac{[\theta + x_{t+1}(1-\lambda+\lambda \theta)] \exp(\phi z_{t+1})}{(1+\lambda x_{t+1})^{\phi}} \right]_{w_{t+1}}
\]  

(FOC)

\[
x_t \equiv \frac{i_t}{\lambda} = \frac{p_t}{c_t}, \quad \phi \equiv 1 - \text{CRRA}, \quad \tilde{\beta} \equiv \beta \left[ (A\lambda)^\lambda B \right]^\phi
\]

Solution: \( x_t = \tilde{x} \exp(\gamma z_t) \Rightarrow w_t = \tilde{w} \exp(m z_t) \)

Forecast: \( E_t w_{t+1} = \tilde{w} \exp \left[ m \rho z_t + \frac{1}{2} m^2 \sigma^2 \right], \quad m = m(\text{CRRA}) \)

Nonlinear Allocation Rule: \( c_t = \frac{y_t}{1+\lambda x_t}, \quad y_t = A \exp(z_t) k_t \)
Rational Forecast versus Speculative Forecast
Speculative agent knows law of motion of technology, but not optimal response.

Rational Forecast: \[ E_t w_{t+1} = \tilde{w} \exp \left[ m \rho z_t + \frac{1}{2} m^2 \sigma^2 \right] \]

Speculative Forecast: \[ \hat{E}_t w_{s,t+1} = \tilde{w}_s \exp \left[ m_s \rho z_t + \frac{1}{2} m^2_s \sigma^2 \right] \]
Rational Forecast versus Speculative Forecast
Speculative agent knows law of motion of technology, but not optimal response.

\[ E_t w_{t+1} = \hat{w} \exp \left[ m \rho z_t + \frac{1}{2} m^2 \sigma^2 \right] \]

Speculative Forecast:

\[ \hat{E}_t w_{s,t+1} = \hat{w}_s \exp \left[ m_s \rho z_t + \frac{1}{2} m_s^2 \sigma^2 \right] \]

Overreaction: \[ |m_s| > |m| \]

Approximation Point: \[ \log (\hat{w}_s) = E [\log (w_{s,t})] \]

\[ m_s \] is calibrated to match std. dev. of \[ \frac{p_t}{d_t} \] in U.S. data.
Calibrating the Speculation Model to Fit U.S. Data
Rational model uses same parameter values.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Empirical Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta$</td>
<td>0.4</td>
<td>Capital share of income.</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>1.5</td>
<td>Degree of risk aversion.</td>
</tr>
<tr>
<td>$A$</td>
<td>0.333</td>
<td>Mean $k_t / y_t = 3$.</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.069</td>
<td>Mean $i_t / y_t = 0.25$.</td>
</tr>
<tr>
<td>$B$</td>
<td>1.211</td>
<td>Mean consumption growth = 2.06 %.</td>
</tr>
<tr>
<td>$\sigma_\varepsilon$</td>
<td>0.047</td>
<td>Std. dev. consumption growth = 3.56 %.</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.95</td>
<td>Corr $\left( p_t / d_t, p_{t-1} / d_{t-1} \right) = 0.93$.</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.969</td>
<td>Mean $p_t / d_t = 26$.</td>
</tr>
<tr>
<td>$m_s$</td>
<td>1.008</td>
<td>Std. dev. $p_t / d_t = 13$.</td>
</tr>
<tr>
<td>$m$</td>
<td>$-0.562$</td>
<td>Rational model value (endogenous).</td>
</tr>
</tbody>
</table>
Overreaction Behavior Tends to be Self-Confirming

Perceived versus Actual Response to Technology Shocks

- Actual Law of Motion for CRRA = 1.5
- Actual Law of Motion for CRRA = 0.12
- 45 degree Line

Actual Coefficient from Law of Motion

Perceived Coefficient Used in Forecast Rule, $m_s$

$m_s = -0.562$

$m_s = 1.008$

0.793
Convergence to the Rational Equilibrium Can Be Very Slow

Real Time Learning Paths

Estimated Response Coefficient

Periods

Convergence to the Rational Equilibrium Can Be Very Slow
Speculative bubbles coincide with economic booms and excess capital formation.
Business Cycle Behavior
Speculation magnifies investment volatility but reduces consumption volatility.
## Unconditional Moments: Model versus Data

<table>
<thead>
<tr>
<th>Statistic</th>
<th>U.S. Data</th>
<th>Rational Model</th>
<th>Speculation Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean $p_t/d_t$</td>
<td>25.9</td>
<td>23.9</td>
<td>26.7</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>13.3</td>
<td>0.42</td>
<td>12.6</td>
</tr>
<tr>
<td>Skew.</td>
<td>2.45</td>
<td>0.12</td>
<td>2.76</td>
</tr>
<tr>
<td>Kurt.</td>
<td>9.82</td>
<td>3.00</td>
<td>17.5</td>
</tr>
<tr>
<td>Corr. Lag 1</td>
<td>0.93</td>
<td>0.95</td>
<td>0.93</td>
</tr>
<tr>
<td>Mean $err_t$</td>
<td>—</td>
<td>0.00 %</td>
<td>0.18 %</td>
</tr>
<tr>
<td>$\sqrt{\text{Mean } err_t^2}$</td>
<td>—</td>
<td>2.66 %</td>
<td>4.87 %</td>
</tr>
<tr>
<td>Corr ($err_t, err_{t-1}$)</td>
<td>—</td>
<td>−0.01</td>
<td>0.23</td>
</tr>
<tr>
<td>Corr ($err_t, err_{t-2}$)</td>
<td>—</td>
<td>−0.01</td>
<td>0.21</td>
</tr>
<tr>
<td>Corr ($err_t, err_{t-3}$)</td>
<td>—</td>
<td>−0.01</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Computed from 10,000 period simulation with $\theta = 0.4$, CRRA = 1.5.
Intuition for Welfare Results

- Fluctuations (due to speculation or business cycles) can affect the mean and volatility of consumption growth.
Intuition for Welfare Results

- Fluctuations (due to speculation or business cycles) can affect the mean and volatility of consumption growth.

- Decreased consumption growth implies less resources devoted to investment, and hence a higher initial consumption $E(c_0)$.
Intuition for Welfare Results

- Fluctuations (due to speculation or business cycles) can affect the mean and volatility of consumption growth.

- Decreased consumption growth implies less resources devoted to investment, and hence a higher initial consumption \( E(c_0) \).

- Higher initial consumption can mitigate the welfare costs of slower growth.
Fluctuations (due to speculation or business cycles) can affect the mean and volatility of consumption growth.

Decreased consumption growth implies less resources devoted to investment, and hence a higher initial consumption $E(c_0)$.

Higher initial consumption can mitigate the welfare costs of slower growth.

Higher initial consumption is less desirable when agents underinvest, i.e., when $\theta < 1$. 

As CRRA increases, consumption growth volatility becomes more costly. Which of these effects dominates depends on parameter values.
Intuition for Welfare Results

- Fluctuations (due to speculation or business cycles) can affect the mean and volatility of consumption growth.

- Decreased consumption growth implies less resources devoted to investment, and hence a higher initial consumption $E(c_0)$.

- Higher initial consumption can mitigate the welfare costs of slower growth.

- Higher initial consumption is less desirable when agents underinvest, i.e., when $\theta < 1$.

- As CRRA increases, consumption growth volatility becomes more costly.
Intuition for Welfare Results

- Fluctuations (due to speculation or business cycles) can affect the mean and volatility of consumption growth.

- Decreased consumption growth implies less resources devoted to investment, and hence a higher initial consumption $E(c_0)$.

- Higher initial consumption can mitigate the welfare costs of slower growth.

- Higher initial consumption is less desirable when agents underinvest, i.e., when $\theta < 1$.

- As CRRA increases, consumption growth volatility becomes more costly.

- Which of these effects dominates depends on parameter values.
Speculation increases mean growth at low levels of actual risk aversion, but the reverse holds true for higher risk aversion.

<table>
<thead>
<tr>
<th>$\alpha$</th>
<th>Statistic</th>
<th>Deterministic Model</th>
<th>Rational Model</th>
<th>Speculation Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>Mean</td>
<td>1.79</td>
<td>1.77</td>
<td>1.93</td>
</tr>
<tr>
<td></td>
<td>Std. Dev.</td>
<td>0</td>
<td>4.63</td>
<td>3.58</td>
</tr>
<tr>
<td>1.5</td>
<td>Mean</td>
<td>2.00</td>
<td>1.97</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>Std. Dev.</td>
<td>0</td>
<td>4.80</td>
<td>3.58</td>
</tr>
<tr>
<td>2.5</td>
<td>Mean</td>
<td>2.05</td>
<td>2.01</td>
<td>1.91</td>
</tr>
<tr>
<td></td>
<td>Std. Dev.</td>
<td>0</td>
<td>4.88</td>
<td>3.59</td>
</tr>
</tbody>
</table>

Note: In percent. Statistics are averages from a 10,000 period simulation.
Welfare Costs (in percent of per-period consumption)

1 percent of consumption = $100 billion in 2007 dollars.

<table>
<thead>
<tr>
<th>α</th>
<th>θ = 0.4</th>
<th>θ = 0.6</th>
<th>θ = 1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>-5.87</td>
<td>-3.22</td>
<td>3.35</td>
</tr>
<tr>
<td>1.0</td>
<td>-1.58</td>
<td>-1.38</td>
<td>2.52</td>
</tr>
<tr>
<td>1.5</td>
<td>2.99</td>
<td>0.58</td>
<td>1.98</td>
</tr>
<tr>
<td>2.0</td>
<td>9.09</td>
<td>2.92</td>
<td>1.72</td>
</tr>
<tr>
<td>2.5</td>
<td>19.8</td>
<td>6.13</td>
<td>1.78</td>
</tr>
</tbody>
</table>
Welfare Costs (in percent of per-period consumption)
1 percent of consumption = $100 billion in 2007 dollars.

<table>
<thead>
<tr>
<th>Welfare Cost of Speculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
</tr>
<tr>
<td>0.5</td>
</tr>
<tr>
<td>1.0</td>
</tr>
<tr>
<td>1.5</td>
</tr>
<tr>
<td>2.0</td>
</tr>
<tr>
<td>2.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Welfare Cost of Business Cycles In Speculation Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
</tr>
<tr>
<td>0.5</td>
</tr>
<tr>
<td>1.0</td>
</tr>
<tr>
<td>1.5</td>
</tr>
<tr>
<td>2.0</td>
</tr>
<tr>
<td>2.5</td>
</tr>
</tbody>
</table>
Welfare Costs
Costs increase rapidly with risk aversion when agents underinvest.
Periods of major technological innovation have typically been accompanied by speculative bubbles.
Conclusion

- Periods of major technological innovation have typically been accompanied by speculative bubbles.
- Many economists consider technology shocks to be a fundamental driving force for business cycles.
**Conclusion**

- Periods of major technological innovation have typically been accompanied by speculative bubbles.

- Many economists consider technology shocks to be a fundamental driving force for business cycles.

- **Behavioral RBC model**: speculative agents forecast like rational agents who have low risk aversion.
Conclusion

- Periods of major technological innovation have typically been accompanied by speculative bubbles.

- Many economists consider technology shocks to be a fundamental driving force for business cycles.

- Behavioral RBC model: speculative agents forecast like rational agents who have low risk aversion.

- Overreaction tends to be self-confirming; forecast errors are not persistent.
Conclusion

- Periods of major technological innovation have typically been accompanied by speculative bubbles.

- Many economists consider technology shocks to be a fundamental driving force for business cycles.

- **Behavioral RBC model**: speculative agents forecast like rational agents who have low risk aversion.

- Overreaction tends to be self-confirming; forecast errors are not persistent.

- Even from the narrow perspective of a theoretical model, it remains an open question whether speculative behavior is harmful to society.
Conclusion

- Periods of major technological innovation have typically been accompanied by speculative bubbles.

- Many economists consider technology shocks to be a fundamental driving force for business cycles.

- **Behavioral RBC model**: speculative agents forecast like rational agents who have low risk aversion.

- Overreaction tends to be self-confirming; forecast errors are not persistent.

- Even from the narrow perspective of a theoretical model, it remains an open question whether speculative behavior is harmful to society.

- For higher degrees of risk aversion, the welfare costs of speculation and business cycles can be large.