Speculative Growth, Overreaction, and the Welfare Cost of Technology-Driven Bubbles

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[1] Any opinions expressed here do not necessarily reflect the views of the management of the Federal Reserve Bank of San Francisco or of the Board of Governors of the Federal Reserve System.

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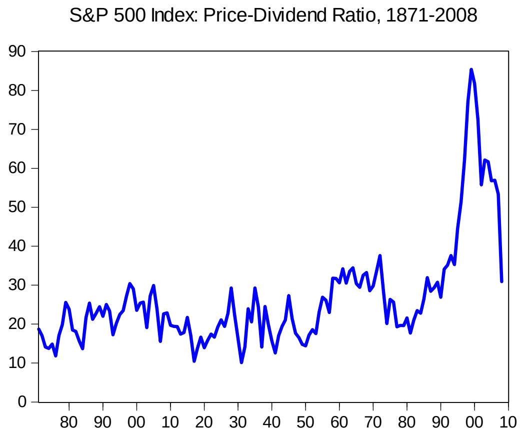
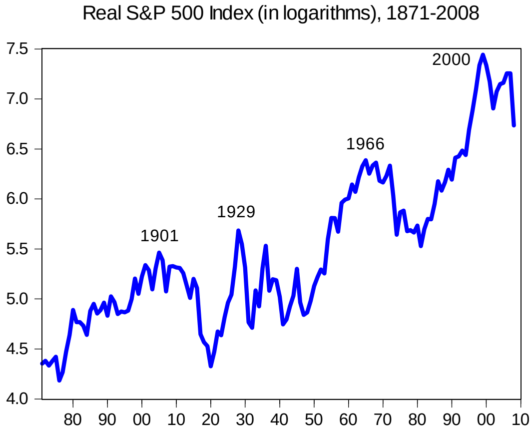
- Speculation can improve welfare if CRRA $\lesssim$ 1-1.5 and agents underinvest relative to socially-optimal level.
- When CRRA $>$ 1.5, the welfare cost of speculation (and business cycles) can be large.

U.S. Price-Dividend Ratio is Volatile and Highly Persistent



Four Major Run-ups in U.S. Stock Prices



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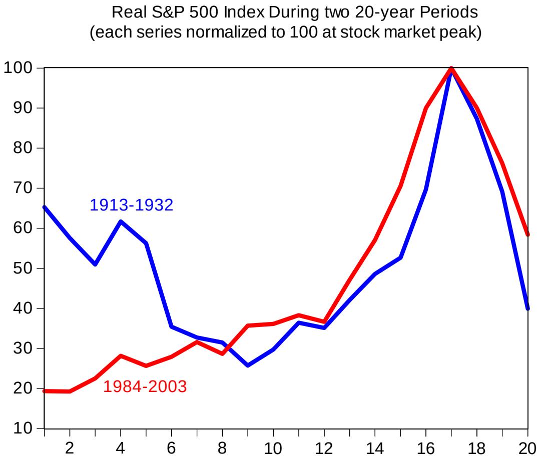
- Late 1990s: Widespread availability of the internet, innovations in computers and information technology, emergence of web-based business model.

Comparing Two Bubble Episodes



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."

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"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."

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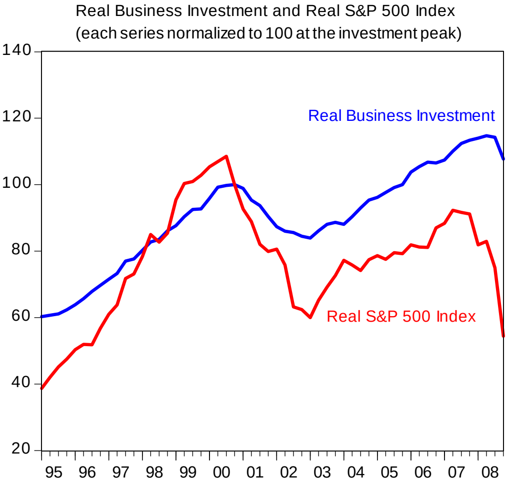
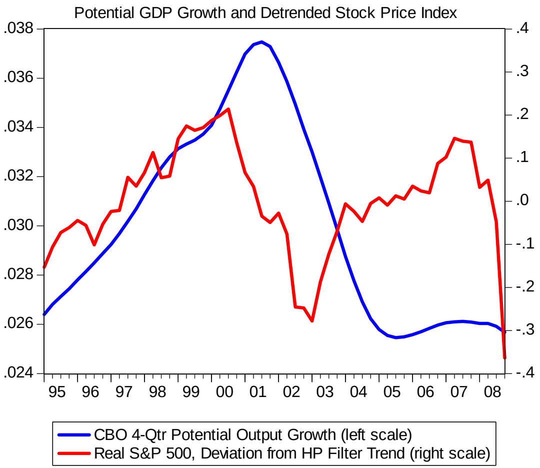
Federal Reserve Chairman Alan Greenspan, January 13, 2000.

Stock Bubbles Distort Business Investment



Stock Bubbles Influence Trend Growth

Rise and Fall of the “new economy.”



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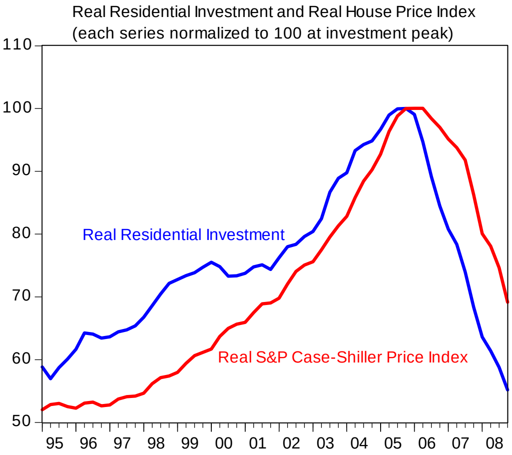
Housing Bubbles Distort Residential Investment



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- Behavioral RBC Model (Optimism and Overconfidence)
  - Jaimovich and Rebelo (2007)

RBC Model with Endogenous Growth & Adjustment Costs

Along the lines of Barlevy (AER, 2004).

The representative agent (or capitalist-entrepreneur) maximizes

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{c_t^{1-\alpha} - 1}{1-\alpha} \right], \qquad \alpha = \text{CRRA}, \quad \phi \equiv 1-\alpha$$

$$c_t + i_t = y_t$$

$$y_t = A \exp(z_t)\, k_t^{\theta} h_t^{1-\theta} \qquad h_t = K_t, \qquad \theta \in (0,1]$$

$$k_{t+1} = B\, k_t^{1-\lambda}\, i_t^{\lambda} \qquad \lambda \in (0,1]$$

$$z_{t+1} = \rho z_t + \varepsilon_{t+1} \qquad \varepsilon_{t+1} \sim N\left(0, \sigma_\varepsilon^2\right)$$

Adjustment Cost Formulation

Mapping to formulation of Jermann (JME, 1998) and Barlevy (AER, 2004).

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

$$\lambda = \frac{\psi_0 \psi_1 \left(\widetilde{i/k}\right)^{\psi_1}}{1 - \delta + \psi_0 \left(\widetilde{i/k}\right)^{\psi_1}} \qquad B = \frac{1 - \delta + \psi_0 \left(\widetilde{i/k}\right)^{\psi_1}}{\left(\widetilde{i/k}\right)^{\lambda}} \qquad \text{(Taylor Coefficients)}$$

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$$\underbrace{i_t / \lambda}_{p_t} = E_t \, \beta \left[\frac{c_{t+1}}{c_t} \right]^{-\alpha} \left[\underbrace{\theta y_{t+1} - i_{t+1}}_{d_{t+1}} + \underbrace{i_{t+1} / \lambda}_{p_{t+1}} \right] \qquad \text{(FOC)}$$

$$x_t \equiv \frac{i_t / \lambda}{c_t} = \frac{p_t}{c_t} \quad \Rightarrow \quad \frac{p_t}{d_t} = \frac{x_t}{\theta - (1 - \theta) \lambda x_t}, \qquad \text{(Stationary)}$$

Model Solution

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

$$\frac{x_t^{1-\lambda\phi}\exp[(1-\lambda)\phi\, z_t]}{(1+\lambda x_t)^{(1-\lambda)\phi}} \quad = \quad E_t \underbrace{\widetilde{\beta}\left[\frac{[\theta+x_{t+1}(1-\lambda+\lambda\theta)]\exp(\phi\, z_{t+1})}{(1+\lambda x_{t+1})^{\phi}}\right]}_{w_{t+1}} \qquad \text{(FOC)}$$

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

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Rational Law of Motion:

$$\begin{aligned} w_t &= \widetilde{w}\exp(m\, z_t), \\ z_t &= \rho z_{t-1} + \varepsilon_t, \\ \widetilde{w} &\equiv \exp[E(\log w_t)], \end{aligned}$$

Rational Forecast: $E_t w_{t+1} = \widetilde{w}\exp\left[m\rho\, z_t + \frac{1}{2}m^2\sigma_\varepsilon^2\right]$,

$m = m(\text{CRRA}) =$ rational technology response coefficient.

Rational Behavior vs. Self-Confirming Overeaction

Temporary technology innovations are perceived to be permanent.

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Speculative Forecast: $$\widehat{E}_t w_{s,t+1} = \widetilde{w}_s \exp\left[m_s\, z_t + \tfrac{1}{2} m_s^2 \sigma_u^2\right],$$

Actual Law of Motion (ALM):
$$\begin{aligned} w_{s,t} &= \widetilde{w}_s \exp\left[\mathrm{f}\left(m_s\right) z_t\right], \\ \text{where} \quad & \mathrm{f}'\left(m_s\right) \simeq 1. \end{aligned}$$

$m_s > m$ is calibrated to match std. dev. of $\dfrac{p_t}{d_t}$ in U.S. data.

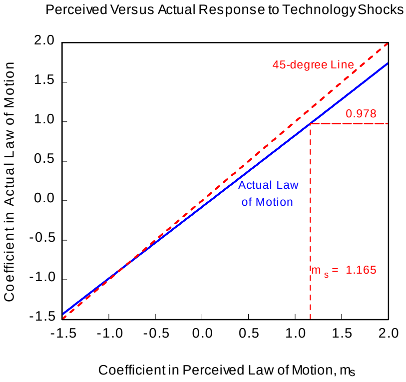
Calibrating the Speculation Model to Fit U.S. Data

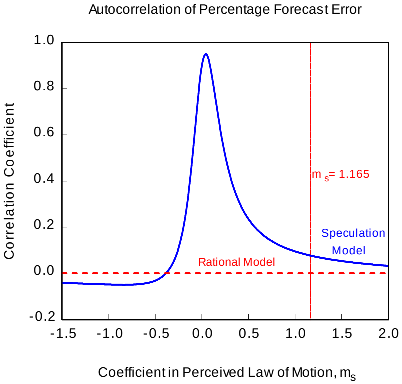
Rational model uses same parameter values.

Parameter	Value	Description/Empirical Target
θ	0.4	Capital share of income.
α	1.5	Degree of risk aversion.
A	0.333	Mean $k_t/y_t = 3$.
λ	0.070	Mean $i_t/y_t = 0.25$.
B	1.216	Mean consumption growth $= 1.98$ %.
σ_ε	0.059	Std. dev. consumption growth $= 3.99$ %.
ρ	0.9	Annual technology shock persistence.
σ_u	0.060	Perceived innovation variance.
β	0.967	Mean $p_t/d_t = 26.6$
m_s	1.165	Std. dev. $p_t/d_t = 13.8$
m	-0.427	Rational model value.

Overreaction Behavior Tends to be Self-Confirming

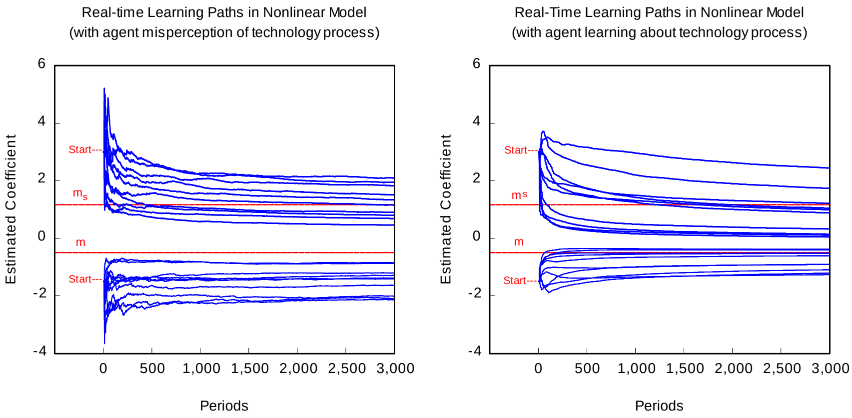
Observed forecast errors are close to white noise.





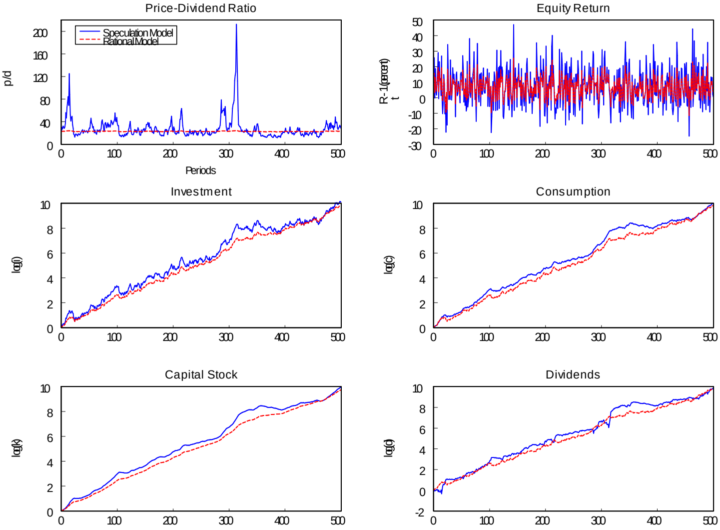
Real-Time Learning Paths

Estimated technology response coefficient is path-dependent.



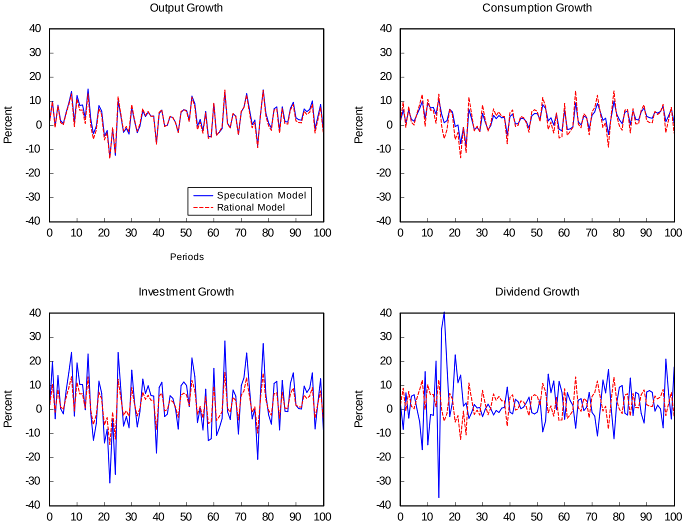
Model Simulations

Speculative bubbles coincide with economic booms and excess capital formation.



Business Cycle Behavior

Speculation magnifies investment volatility but reduces consumption volatility.



Volatility of Real Growth Rates: Model versus Data

Speculation model outpeforms rational model in matching data.

Variable	Dates	U.S. Economy	Rational Model	Speculation Model
$\Delta \log(y_t)$	1871-2008	5.28	5.93	5.94
$\Delta \log(c_t)$	1890-2008	3.99	5.82	3.98
$\Delta \log(i_t)$	1930-2008	16.2	6.24	12.2
$\Delta \log(d_t)$	1872-2008	12.2	5.42	7.80
$\Delta \log(p_t)$	1872-2008	17.9	6.24	12.2

Note: In percent, from 15,000 period simulation with $\theta = 0.4$, CRRA $= 1.5$.

Asset Pricing Moments: Model versus Data

Speculation model outpeforms rational model in matching data.

Statistic	U.S. Data	Rational Model	Speculation Model
Mean p_t/d_t	25.6	22.8	26.6
Std. Dev.	13.8	0.42	13.7
Skew.	2.20	0.04	4.12
Kurt.	8.21	2.94	42.1
Corr. Lag 1	0.93	0.90	0.84
Mean R_t	7.84 %	6.64 %	7.26 %
Std. Dev.	17.8 %	6.63%	12.6 %
Corr. Lag 1	0.04	-0.04	-0.06

Computed from 15,000 period simulation with $\theta = 0.4$, CRRA $= 1.5$.

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

Intuition for Welfare Results (continued)

- Speculation increases mean growth at low levels of actual risk aversion, but the reverse holds true for higher risk aversion.

Mean and Volatility of Consumption Growth (with $\theta = 0.4$)

α	Statistic	Deterministic Model	Rational Model	Speculation Model
0.5	Mean	1.62	1.61	2.00
	Std. Dev.	0	6.09	3.97
1.5	Mean	1.96	1.94	1.99
	Std. Dev.	0	5.82	3.98
2.5	Mean	2.06	2.12	1.98
	Std. Dev.	0	5.69	3.98

Note: In percent. Statistics are averages from a 15,000 period simulation.

Welfare Costs (in percent of per-period consumption)

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

Welfare Cost of Speculation

α	$\theta = 0.4$	$\theta = 0.6$	$\theta = 1.0$
0.5	−7.90	−3.93	6.20
1.0	−3.21	−2.56	4.72
1.5	0.74	−1.11	3.55
2.0	4.76	0.48	2.67
2.5	9.56	2.28	2.05

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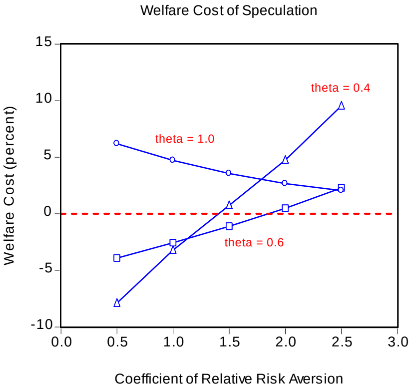
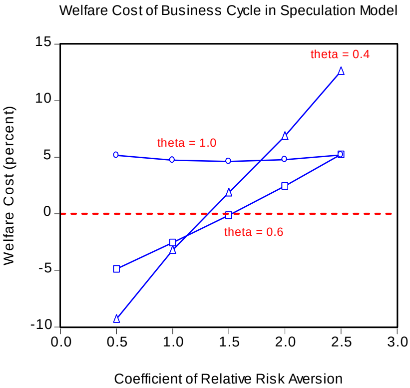
Welfare Cost of Business Cycles In Speculation Model

α	$\theta = 0.4$	$\theta = 0.6$	$\theta = 1.0$
0.5	−9.30	−4.87	5.16
1.0	−3.20	−2.55	4.74
1.5	1.87	−0.13	4.63
2.0	6.88	2.44	4.78
2.5	12.6	5.26	5.21

Welfare Costs

Costs increase rapidly with risk aversion when agents underinvest.





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

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Bernanke: "...I think implicitly your question is probably the very vexed question of bursting bubbles, and what to do about those...

[O]bviously the last decade has shown that bursting bubbles can be an extraordinarily dangerous and costly phenomenon for the economy and there is no doubt that as we emerge from the financial crisis, we will all be looking at that issue and what can be done about it..."

Fed Chairman Ben Bernanke, October 15, 2008