# Comparing Different Regulatory Measures to Control Stock Market Volatility: A General Equilibrium Analysis


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# Outline

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# Two Major Themes of the Paper

**Develop a model where financial markets influence real sector**

- Specifically, can sentiment-prone investors affect real economy?
  - investment,
  - output,
  - consumption
- Results: We show negative externalities due to sentiment-prone investors.

# Two Major Themes of the Paper

## Financial Regulation

- Which policy measure is most effective for regulating financial markets and reducing its negative externalities?
  1. Tobin Tax
  2. Short-sale constraint
  3. Borrowing / Leverage constraint
- Results:
  - Tobin tax and short-sale constraint are counter-effective.
  - Borrowing / Leverage constraint seems to be promising.

# Related Literature

- Our model is related to the literature on "investor sentiment" and "behavioral equilibrium theory."
  - Single non-Bayesian household: Barberis, Shleifer, and Vishny (1998) and Daniel, Hirshleifer, and Subrahmanyam (1998)
  - Non-optimizing households: Hong and Stein (1999)
  - Sentiment and production: Panageas (2005)
- Also, the literature on the remedies to the recent financial crisis is close to our work.
  - Collateral restrictions: Geanakoplos and Fostel (2008) and Geanakoplos (2009).
  - Credit constraints: Krishnamurthy (2003).
  - Monetary tools: Ashcraft, Gârleanu, and Pedersen (2010).

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# First Key Feature of Our Model: Investors with Heterogeneous Beliefs

- Hansen (2007): "While introducing heterogeneity among investors will complicate model solution, it has intriguing possibilities."
- Stiglitz (2010) criticizes representative-investor models; states importance of heterogeneous investors as key challenge.
- Sargent (2008) in his presidential address to the American Economic Association, discusses extensively the implications of the common beliefs assumption for policy.

# Second Key Feature of Our Model: Heterogeneous Beliefs with Endogenous Risk

- Model meets twin challenges set by Eichenbaum (2010).
- The twin challenges Eichenbaum (2010) posed are:
  1. to model heterogeneity in beliefs and persistent disagreement between investors, and
  2. financial market frictions with risk residing internally in the financial system rather than externally in the production system.
- The twin challenges are met here because in our model the heterogeneity of investor beliefs is a fluctuating, stochastic one so that it constitutes an **internal source** of risk:
  - sentiment is stochastic, and
  - volatility of sentiment is stochastic;

  thus, market alternates between periods of quiescence and agitation.

# Third Key Feature of Our Model: Market Incompleteness and Frictions

- Typically, general-equilibrium models assume complete financial markets, which simplifies the task of solving for equilibrium.
- However, once regulatory constraints are introduced, financial markets are not complete.
- We identify the equilibrium when markets are incomplete.

# Outline

# Model: Production I

- We assume that there exists a representative firm producing and paying out a single consumption good.
- At each period $t$ the firm uses the capital stock $K_t$ to generate production $Y_t = K_t \times Z_t$, where $Z_t$ denotes the stochastic technology.
- The capital of the firm depreciates at the periodic rate $\delta$, and after investment $I_t$ its law of motion can be described as

$$K_{t+1} = (1 - \delta)K_t + I_t$$

- We assume that the change in the capital level is subject to quadratic adjustment costs $\frac{\xi}{2}\left(\frac{I_t}{K_t} - \delta\right)^2 K_t$

# Model: Production II

- Investment $I_t$ is chosen to maximize value of firm $P_{k,t}$ for owner $k$:

$$P^S_{k,t}(K_t) = \max_{I_t,\ldots,I_{T-1}} \left\{ D_t + E_t \left[ \sum_{\tau=t+1}^{T} \frac{M_{k,\tau}}{M_{k,t}} D_\tau \right] \right\}$$

- We assume that the value of the firm is maximized with respect to the expectations of the rational investor.
  - Carceles-Poveda and Coen-Pirani (2007) show that with constant-returns-to-scale production, investors agree on investment decisions even in markets that are not complete.
  - Even though markets are not complete, the pricing kernels of the two investors are similar, and so the investment choices they make are also similar.

# Model: Households/Investors

- Additive external habit ("catching up with the Joneses"):

$$\max E_k \sum_{t=0}^{T} \beta_k^t \frac{(c_{k,t} - h_k \times C_t)^{1-\gamma_k}}{1-\gamma_k}, \quad \text{where}$$

- $h_k$ is the habit factor; scaling last period's aggregate consumption $C_t$
- $\gamma_k > 0$ controlling the investor's risk appetite
- $E_k$ is investor $k$'s cond. expectation (subjective probability measure)
- subject to budget equation

$$c_{k,t} + \underbrace{\theta^S_{k,t} S_{k,t}}_{\text{equity investment}} + \underbrace{\theta^B_{k,t} B_{k,t}}_{\text{risk-free investment}} = \theta^S_{k,t-1}(S_{k,t} + D_t) + \theta^B_{k,t-1}$$

# Model: Source of Uncertainty

Uncertainty in the economy is generated by a Hidden Markov Model.

**Hidden Part**

- Two unobservable fundamental states: 'Expansion' or 'Recession'.
- Transition between the unobservable states follows a Markov process.

**Observables**

- While the state of the economy is unobservable for the investors, they observe
  1. productivity realization $Z_t$: 'high' or 'low'
  2. a public signal: 'positive' or 'negative'

# Model: Beliefs

- We assume that
  - the realized technology level provides information about the current state of the economy,
  - while the signal is pure noise.
- Investors use the observations to form conditional state probabilities using a nonlinear analog of the Kalman filter.
- One investor ("rational") knows signal is pure noise.
- The other investor ("sentiment-prone") believes incorrectly that signal also provides useful information; assigning weight $w$.

# Regulatory Measures

1. Tobin tax $\kappa_t$ affects the individual budget constraint:

$$c_{k,t} + \theta^S_{k,t} S_{k,t} + \theta^B_{k,t} B_{k,t} + \kappa_t \, S_{k,t} \left| \theta^S_{k,t} - \theta^S_{k,t-1} \right| = \theta^S_{k,t-1} \left( S_{k,t} + D_t \right) + \theta^B_{k,t-1}$$

   Tax revenue is reimbursed to investors as a lump-sum transfer.

2. Short-sale constraint restricts the holdings of the risky asset to be above a predefined limit $\rho$:

$$\theta^S_{k,t} \geq \rho, \forall k, t.$$

3. Leverage constraint limits the amount of borrowing, or equivalently, investment in the risky asset, to be less than a specified level $\alpha$:

$$\frac{\theta^S_{k,t} \times S_{k,t}}{\theta^B_{k,t} \times B_{k,t} + \theta^S_{k,t} \times S_{k,t}} \leq \alpha, \ \forall k, t,$$

# Equilibrium

Equilibrium in this economy is defined as

- consumption policies, $c_{k,t}$, that maximize lifetime expected utility
- portfolio policies, $\theta_{k,t}^{\{B,S\}}$, that finance the optimal portfolio policy
- investment policy, $I_t$, that maximizes the value of the firm
- price processes for the financial assets, $\{B_t, S_t\}$, such that the following markets clear at each state and date:
  - markets for the stock and bond,
  - market for consumption, and investment.

# Outline

# Calibration of the Model

- For the quantitative analysis we calibrate our model to match several stylized facts of the U.S. macroeconomy and financial markets.
- For example, output and investment volatility as well as the levered equity risk premium and its volatility.
- We solve model for 30 years, assuming each period in model corresponds to one year, with the last 15 years used as burn-in period.
- All statistics are based on 10,000 simulated paths of economy.
- We assume the two investors have homogeneous preferences.

# Parameter Values

| Description | Variable | Value |
|---|---|---|
| **Hidden Markov Chain** | | |
| Autocorrelation hidden states | $A_{1,1},\ A_{2,2}$ | 0.95 |
| Precision of technology | $B_{1,1}+B_{1,2}, B_{2,3}+B_{2,4}$ | 0.95 |
| Probability of the initial state | $\pi_k$ | 0.5 |
| **Preferences and Beliefs** | | |
| Sentiment of irrational Agent | $w$ | 0.9 |
| Subject time preference | $\rho_k$ | 0.9606 |
| Risk aversion | $\gamma_k$ | 3 |
| Habit parameter | $h_k$ | 0.1 |
| **Production** | | |
| Depreciation | $\delta$ | 0.08 |
| Volatility of technology | $\sigma_T$ | 4.90% |
| Technology growth | $d_T$ | 0.60% |
| Adjustment costs | $\xi$ | 13 |

# Financial and Business Cycle Statistics: Model vs. U.S. Data

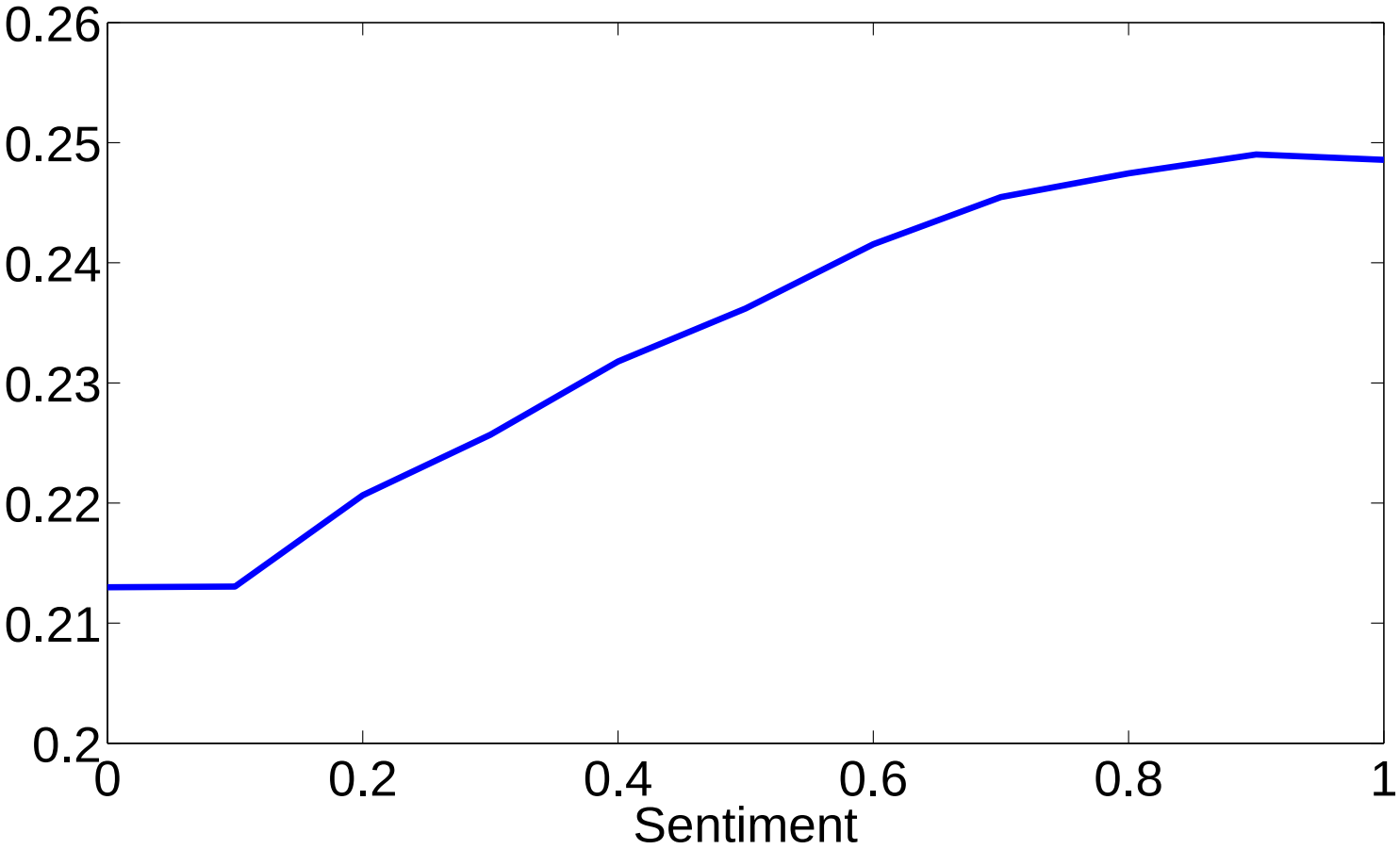
| Description | Variable | Model | Data |
|---|---|---|---|
| Macroeconomic variables | | | |
| Output volatility | $\sigma(Y)$ | 3.99% | 3.78% |
| Normalized investment volatility | $\sigma(I)$ | 2.67% | 2.39% |
| Normalized consumption volatility | $\sigma(C)$ | 0.93% | 0.40% |
| Correlation between investment & output | $Cor(I, Y)$ | 0.82 | 0.96 |
| Correlation between consumption & output | $Cor(C, Y)$ | 0.95 | 0.76 |
| | | | |
| Financial variables | | | |
| Risk-free rate | $r_f$ | 2.30% | 1.94% |
| Interest rate volatility | $\sigma(r_f)$ | 8.30% | 5.44% |
| Equity premium | $E[R^{ep}]$ | 3.30% | 6.17% |
| Equity premium volatility | $\sigma(R^{ep})$ | 21.70% | 19.40% |
| Sharpe ratio | $E[R^{ep}]/\sigma(R^{ep})$ | 15% | 32% |

# Outline

# Effect of Sentiment on Financial Variables

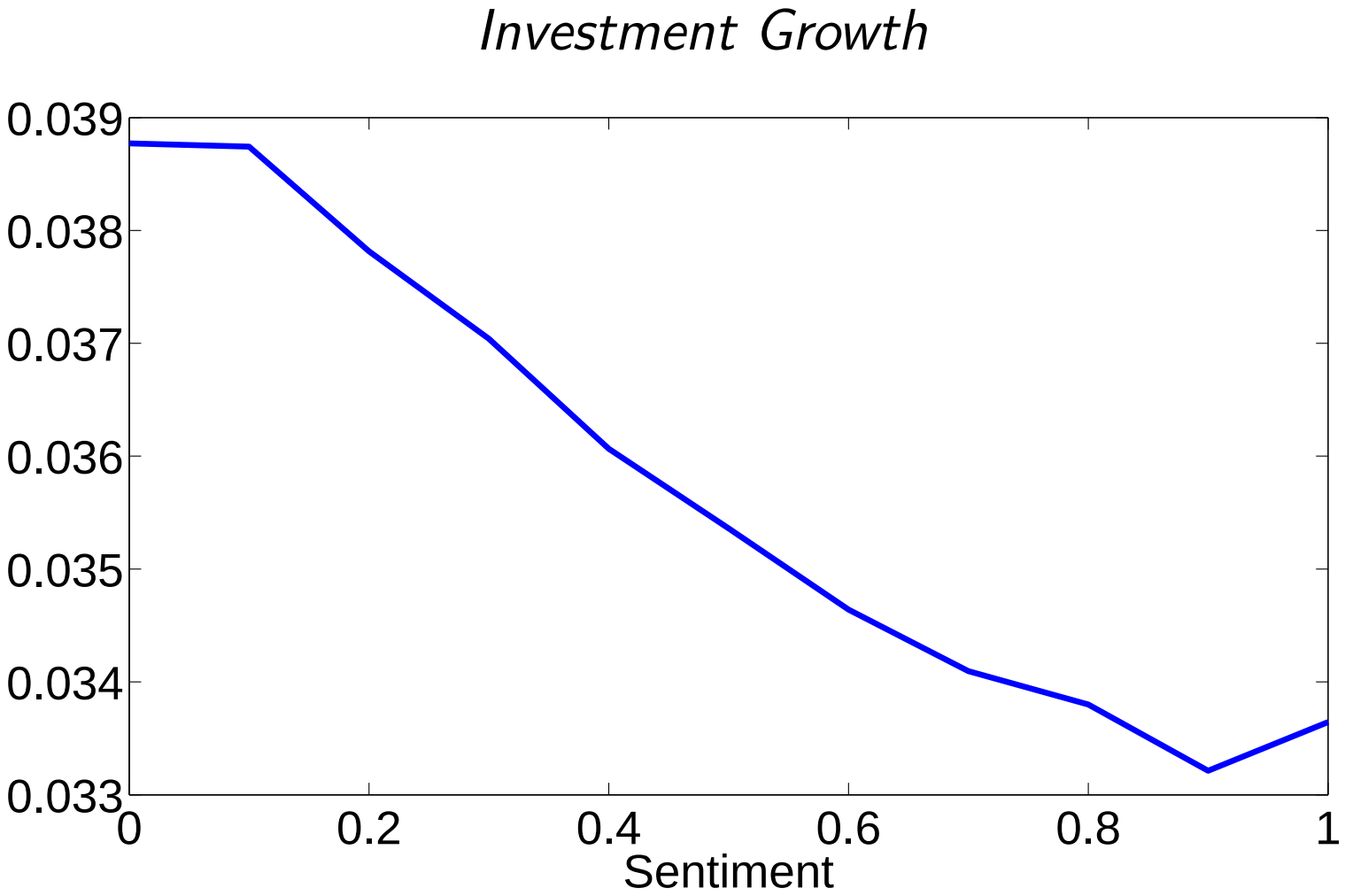
Sentiment is measured by weight put on uninformative signal by "sentiment-prone" investor.

*Volatility of Stock Returns*

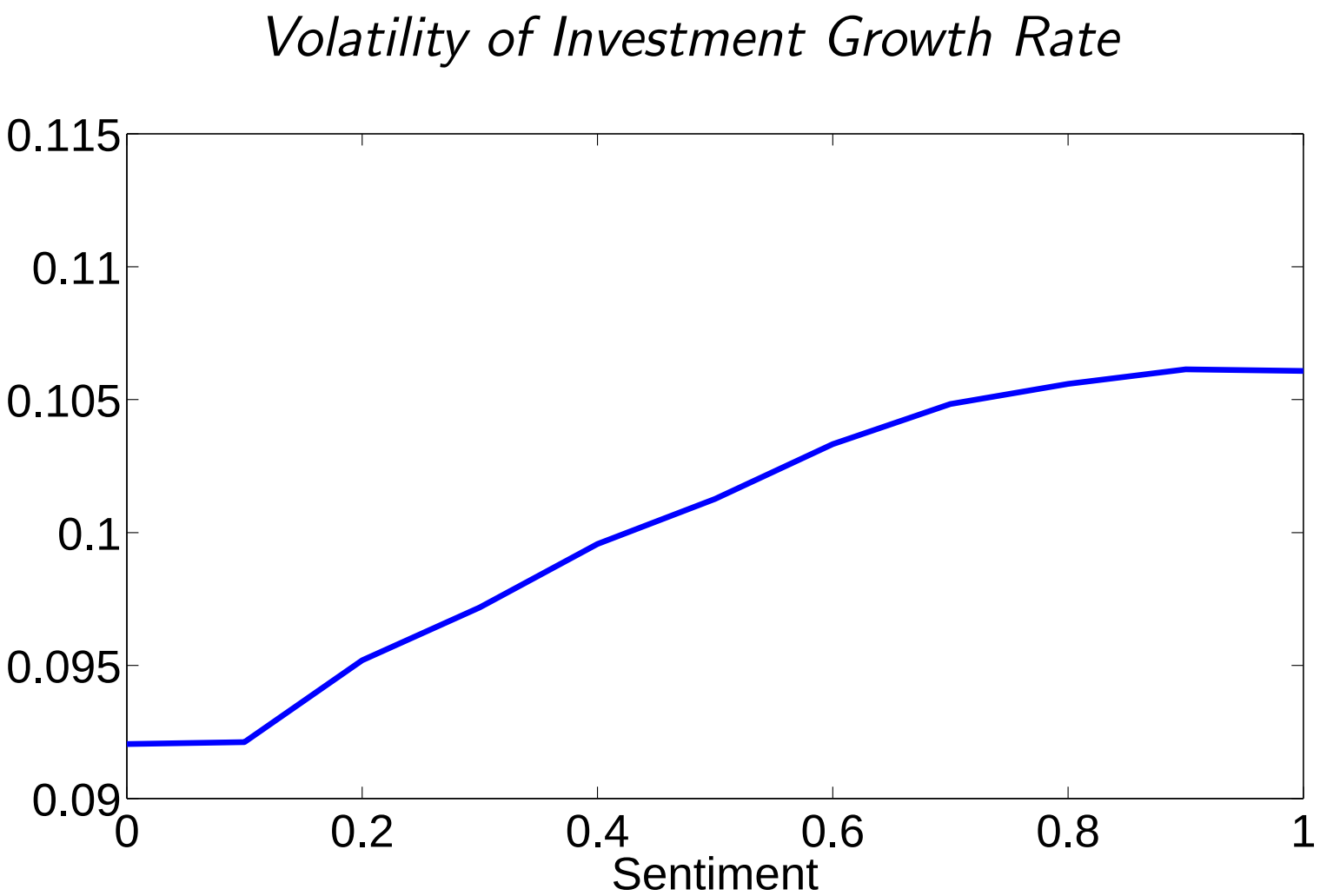



- Results for interest rate volatility are comparable.

# Effect of Sentiment on Investment Growth



# Effect of Sentiment on Investment Growth




- Results for output / consumption are comparable.

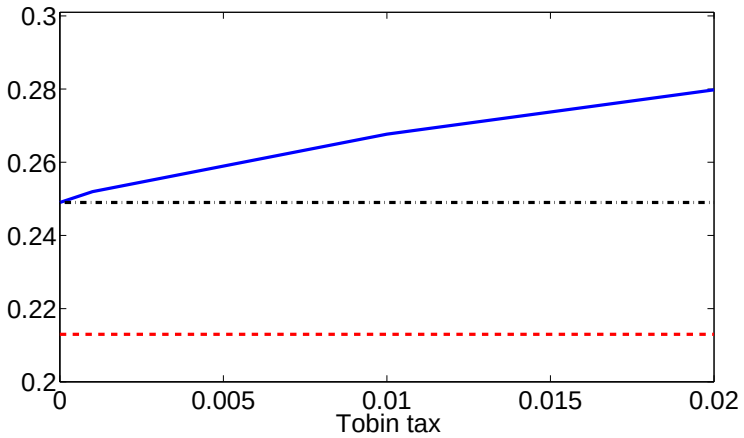
# Outline

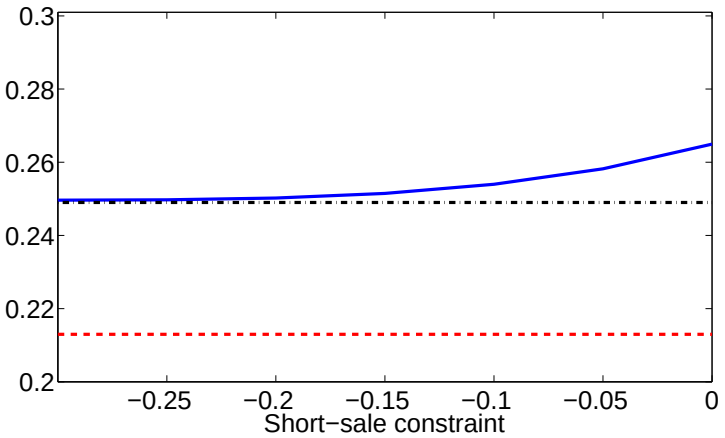
# Effect of Regulatory Measures

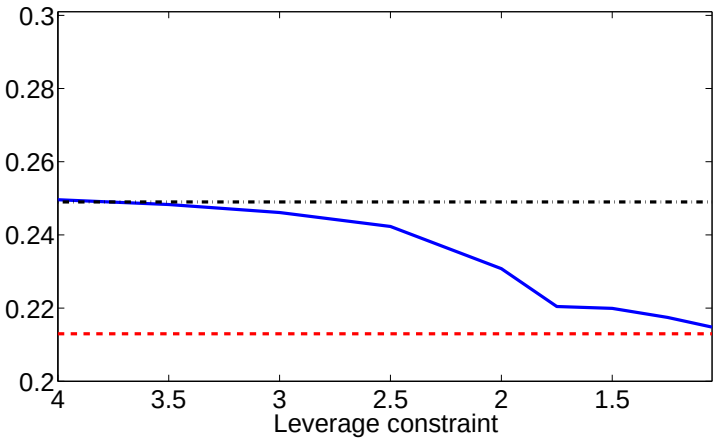
- We illustrate the effects of regulatory measures using figures.
- Each plot has **three lines**:
  - The **red line** depicts case when *both* investors learn rationally;
  - The **black line** depicts case of excessive volatility due to "sentiment-prone" trading but without regulations;
  - The **blue line** depicts case with a particular regulatory measure in the economy with excessive volatility.

# Volatility of Stock Returns

Red: Both rational; Black: One sentiment-prone, no regulation; Blue: With regulation

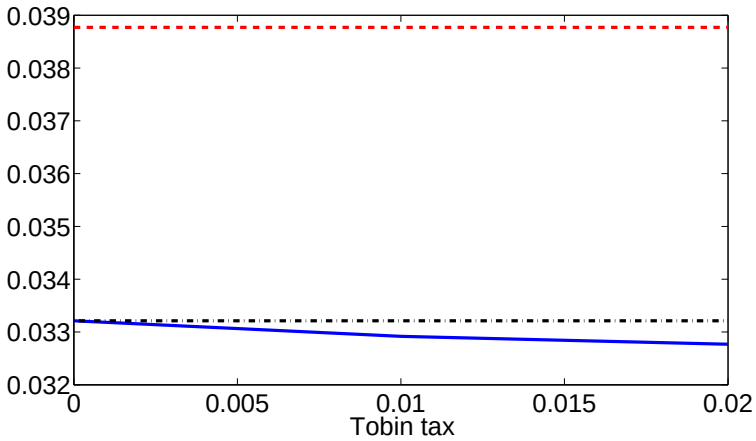


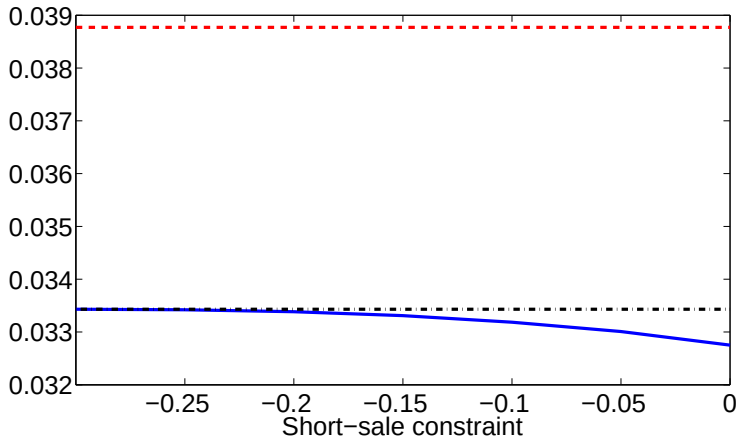



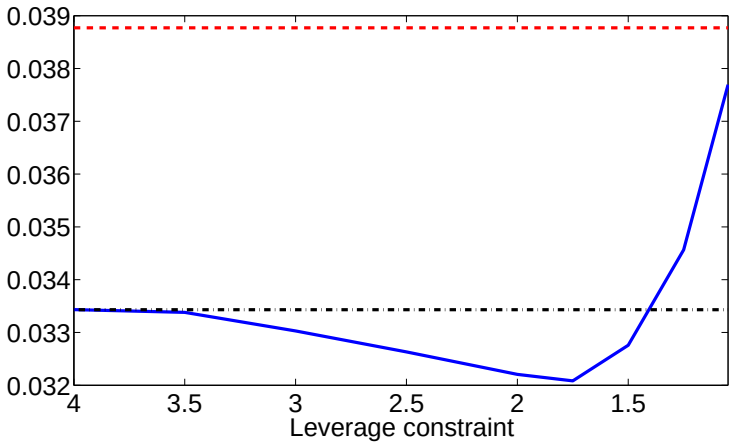



# Investment Growth

Red: Both rational; Black: One sentiment-prone, no regulation; Blue: With regulation

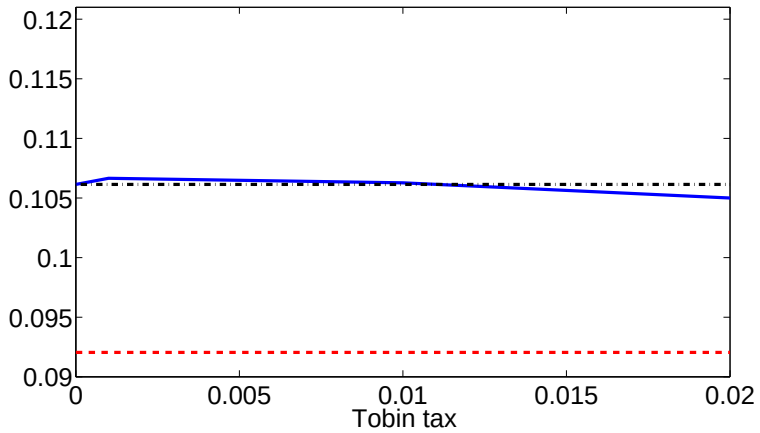


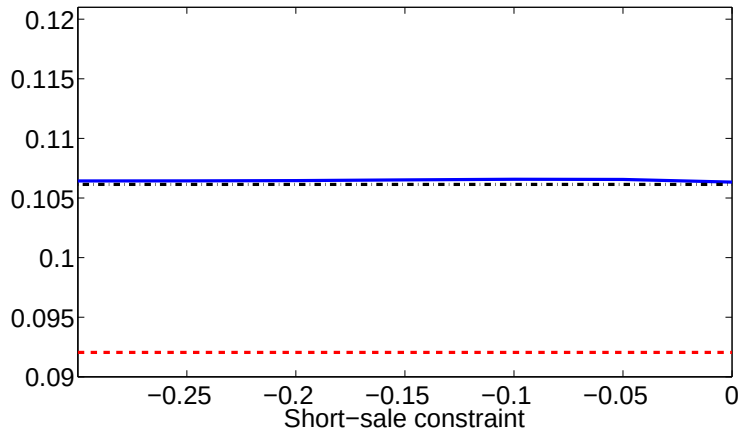



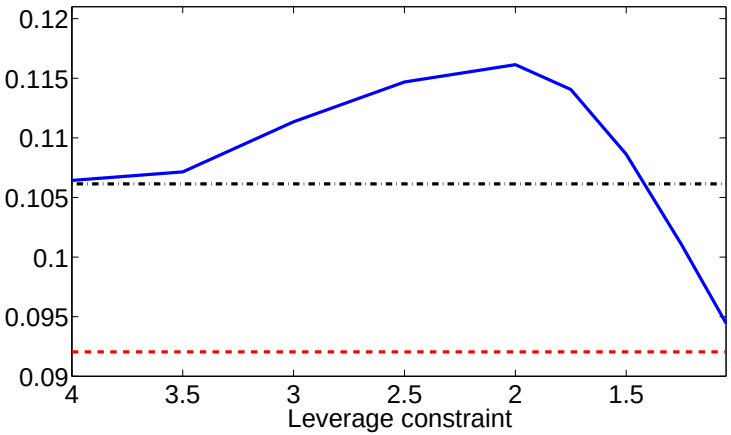



# Investment Growth Volatility

Red: Both rational; Black: One sentiment-prone, no regulation; Blue: With regulation



# Summary of Findings

**Code:**

- Blue indicates positive effect (good)
- Red indicates negative effect (bad)

| Quantity | **Tobin Tax** | **Short-sale Constraint** | **Leverage Constraint** |
|---|---|---|---|
| **Financial Markets** | | | |
| Financing costs | Lower | Lower | Lower |
| Volatility | Higher | Higher | Lower |
| **Production** | | | |
| Investment and output | Reduced | Reduced | Increased |
| Volatility | Increased | Increased | Mixed |
| **Consumption** | | | |
| Growth | Lower | Lower | Much higher |
| Volatility | Higher | Higher | Lower |

# Outline

# Conclusion

## Real Effects of Financial Markets

- Study the impact of sentiment-prone investors on the real sector.
- Results: We demonstrate negative externalities due to sentiment-prone investors.

## Financial Regulation

- We quantitatively assess the effectiveness of regulatory measures:
  - Tobin financial transaction tax: Mostly negative ...
  - Short-sale constraint: Mostly negative ...
  - Leverage constraint: Promising ...

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