A macro model with leverage and endogenous boom-bust cycles

Felix Geiger[1]
Lukas Scheffknecht[2]

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[1] felix.geiger@uni-hohenheim.de
[2] lukas.scheffknecht@uni-hohenheim.de

Agenda

Research motivation

[...] The basic New-Keynesian DSGE macro-model is unidimensional in that it abstracts entirely from the key financial risk, that is default risk. [...] It is unrealistic; it is essentially non-monetary and non-financial, with no role for financial intermediation; academically it divides macro, with no proper role for default risk, from finance, where the relationship between risk and return and the probability of default are central.

Charles Goodhart (2009)

Research motivation

Our key questions

- How can we integrate financial procyclicality in a stylized way into a standard macro model?
- Which implications can we derive for monetary policy and for macroprudential regulation?

Literature

Work on financial procyclicality

- Adrian/Shin (2008): Active balance sheet management and targeting of leverage ratios result in spirals of rising/falling asset prices and expanding/contracting balance sheets.
- Rajan (2005): Sticky return targets - e.g. due to sticky costs of outstanding debt - imply greater risk-taking in a low-yield environment.
- Borio/Zhu (2008): Monetary policy affects the perception and the pricing of risk by economic agents ('risk-taking-channel').
- Dell'Arrichia et al. (2005): Banks relax their lending standards in booms. Sharp reverses if a bust occurs.
- Empirical support is given by Altunbas et al. (2009), Gambacorta(2009), Jimenez/Saurina(2006), Ioannidou et al.(2008).

The limitations of the New Keynesian Model

- The New-Keynesian benchmark model as in Woodford (2003) or Galí (2008) provides no explicit role for financial markets.
- Extensions such as Curdia and Woodford (2009) incorporate financial frictions and financial shocks.
- Within the model, the financial system however still serves only as an amplification device for exogenous shocks.
- There is no role for endogenous and procyclical market developments independently affecting the real economy.
- Systemic risk builds up 'in the background'.

The first theorem of the financial instability hypothesis is that the economy has financing regimes under which it is stable, and financing regimes in which it is unstable. The second theorem of the financial instability hypothesis is that over periods of prolonged prosperity, the economy transits from financial relations that make for a stable system to financial relations that make for an unstable system.

Hyman Minsky (1992)

Modeling approaches

- Agent-based financial market model of Westerhoff (2008) with heterogeneous agents and bounded rationality generates pronounced boom-bust cycles.
- Lengnick/Wohltmann (2010) integrate this model into a macro setup with forward-looking expectations to depict the real-economy impact of asset price movements.
- Thurner/Farmer/Geanakopolos (2009) employ a financial market model with leveraged heterogenous agents. The model produces sharp busts and volatility clusters.
- Aim of our work: integration of the modeling approaches into a general macroeconomic model with procyclicality and the possibility of asset price reversals.

Financial market model

General setup

- Agent-based market model with three types of agents: momentum traders (M), fundamentalists (F) and noise traders (N)
- The asset price behaves according to a price-impact function

$$S_{t+1} = S_t + a(W_t^M D_t^M + W_t^F D_t^F + W_t^N D_t^N) \tag{1}$$

- D_t^i with $i = M, F, N$ denote the orders generated by each type of agents
- W_t^i denote their relative weights in the trader population

General setup

- Momentum traders and fundamentalists form their price expectations as follows:

$$E_t^M[S_{t+1} - S_t] = k^M[S_t - S_{t-1}] \tag{2}$$

$$E_t^F[S_{t+1} - S_t] = k^F[F_t - S_t] \tag{3}$$

- These trading rules yield the following demand functions:

$$D_t^M = b(S_t - S_{t-1}) + \epsilon_t^M \tag{4}$$

$$D_t^F = c(F_t - S_t) + \epsilon_t^F \tag{5}$$

$$D_t^N = d\epsilon_t^N \tag{6}$$

General setup

- The weights of these strategies vary over time.
- Agents are assumed to compare the attractiveness of their strategy continuously and to switch between them when indicated.
- Attractiveness is given by:

$$A_t^i = (S_t - S_{t-1})D_{t-2}^i + gA_{t-1}^i \tag{7}$$

- The fraction of agents using a certain strategy is described by

$$W_t^i = \frac{\exp\{eA_t^i\}}{\exp\{eA_t^F\} + \exp\{eA_t^M\} + \exp\{eA_t^N\}} \tag{8}$$

Introducing leverage

- We *constrain* the momentum trader to engage in leveraged asset purchases with an initial cash position C_0.
- Balance sheet expansion is financed by loans leading to a negative cash position ($L_t = \max[-C_t, 0]$).
- Our leverage ratio is given by

$$\lambda_t = \frac{S_t N_t}{S_t N_t + C_t} \tag{9}$$

$$N_t = N_{t-1} + D_t^M \qquad C_t = C_{t-1} - (N_t - N_{t-1}) S_t \tag{10}$$

- Valuation effects can effect leverage drastically.
- Leverage must not exceed an (exogenously / endogenously) determined threshold $\lambda_t^{\max}$ either determined by funding suppliers or by policy

$$\lambda_t^{\max} = \max\left[1, \frac{\lambda^{\max}}{1 + \varrho \sigma_t^{2,S}}\right]. \tag{11}$$

Setting up a coordination game

- D_t^M is determined sequentially.
- At the beginning of a period, the momentum traders has to check whether $\lambda_t^{\max}$ gets touched due to valuation effects.
- If yes, deleveraging takes place (*margin call*).
- If the valuation effect leads to a negative net worth with $W_t^M = N_t S_t + C_t$, we model a stylized default; the momentum trader will be removed and reintroduced in the next period
- If there is leeway to leverage up, asset demand is realized according to the trading rule D_t^M.

Macro model setup

- We use a hybrid New-Keynesian model. Real asset price enters the AD relation through a wealth effect.
- Notation: Log deviation from steady state values which are normalized to zero.

$$i_q = \rho i_{q-1} + (1-\rho)\left[\delta_\pi \pi_q + \delta_x x_q + \vartheta^\top \xi_q\right] + \epsilon_q^i \tag{12}$$

$$x_q = \alpha E_q[x_{q+1}] + (1-\alpha)x_{q-1} - \frac{1}{\sigma}(i_q - E_q[\pi_{q+1}]) + \eta(s_q - p_q) + \epsilon_q^x \tag{13}$$

$$\pi_q = \beta E_q[\pi_{q+1}] + (1-\beta)\pi_{q-1} + \kappa x_q + \epsilon_q^\pi \tag{14}$$

Integration

- The sub-models operate on different time scales: macro model is quarterly, financial model is daily
- Macro model agents have rational expectations concerning inflation and output; log asset price is purely exogenous.
- Quarterly asset price is given by

$$s_q = \frac{1}{64} \sum_{t=64(q-1)+1}^{64q} \log S_t \tag{15}$$

- In turn, the realized output gap affects the perceived fundamental value of the asset price in the financial market model

$$F_t = h \exp(x_q) \quad \text{for } t = 64(q-1)+1 : 64q \tag{16}$$

Benchmark Calibration

Macro Block

- Demand: $\alpha = 0.6, \sigma = 2, \eta = 0.3$
- Supply: $\beta = 0.6, \kappa = 0.35$
- Monetary Policy: $\rho = 0.75, \delta_\pi = 1.5, \delta_y = 0.5$

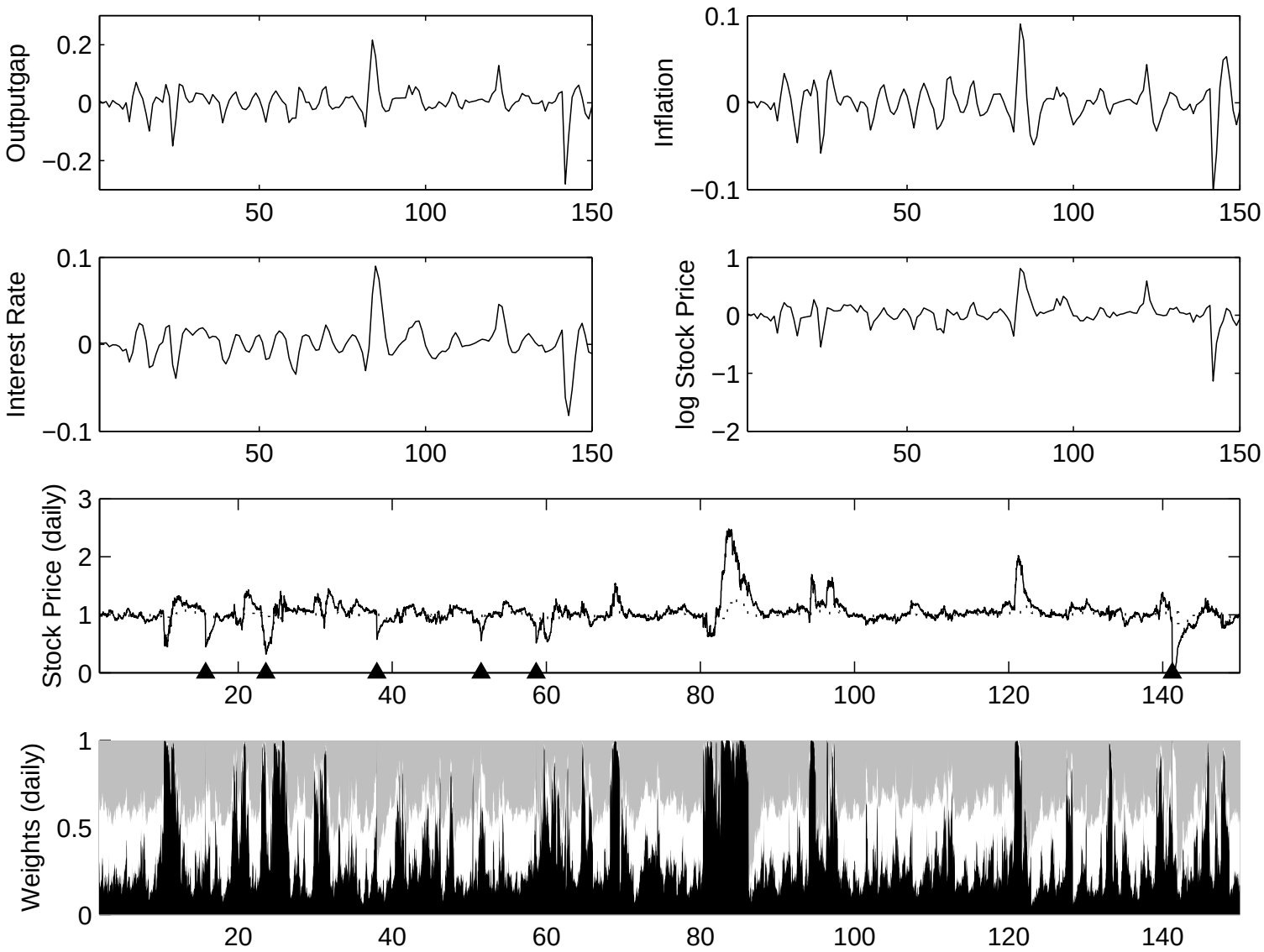
Financial Market Block

- $a = 1, b = 0.08, c = 0.04, d = 0.04, g = 0.975, h = 1, \sigma^M = 0.05, \sigma^F, \sigma^N = 0.01, \varrho = [0, 10]$
- In case of endogenous leverage, $\sigma_t^{2,S}$ is calculated for the last 30 trading days.

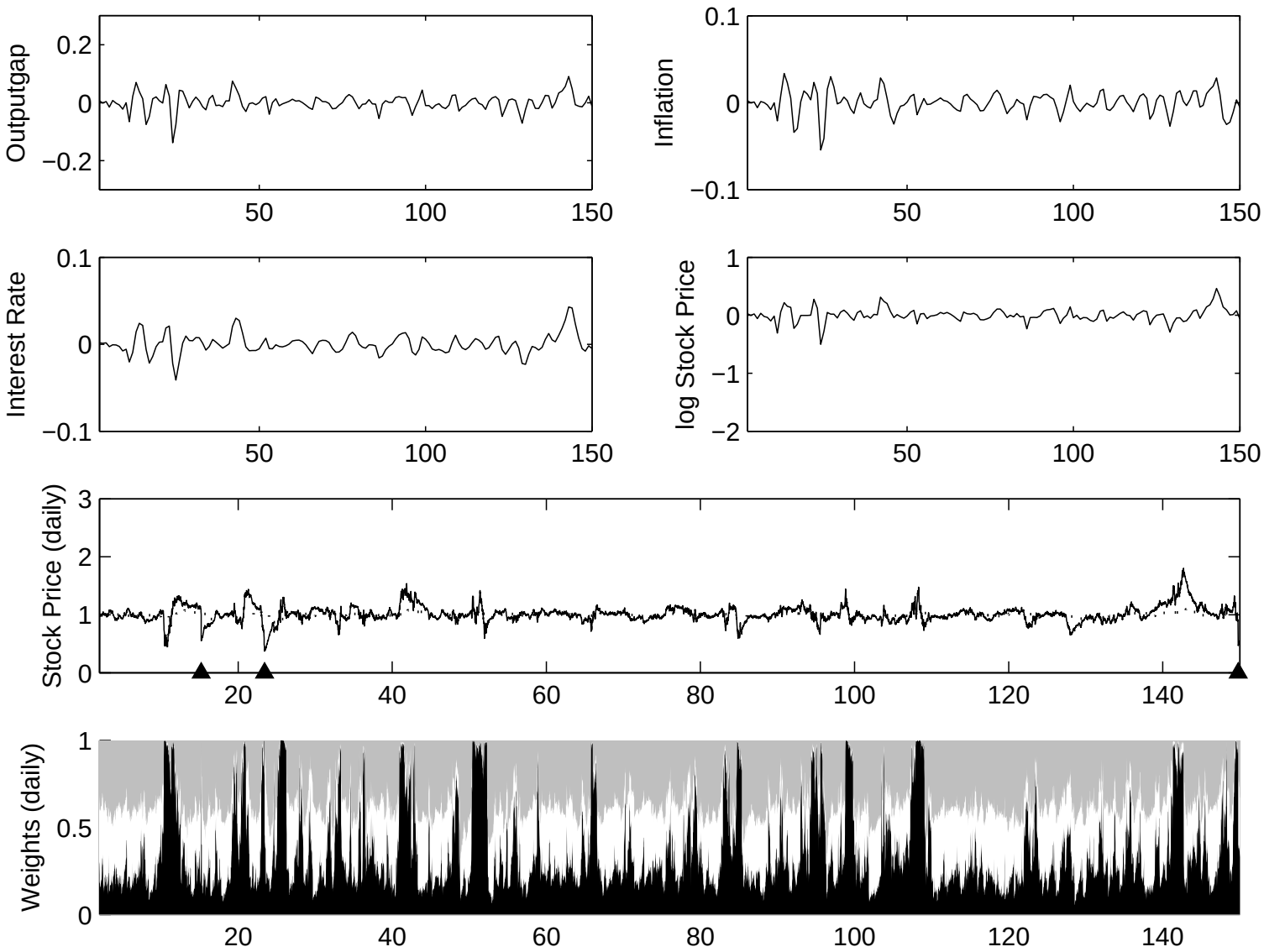
Simulation

1. Derive the structural matrices for the macro model and the RE solution.
2. Start financial market activity with output gap as input for F_t.
3. Calculate average asset price and use it as input for the macro block.
4. Continue with [2.].

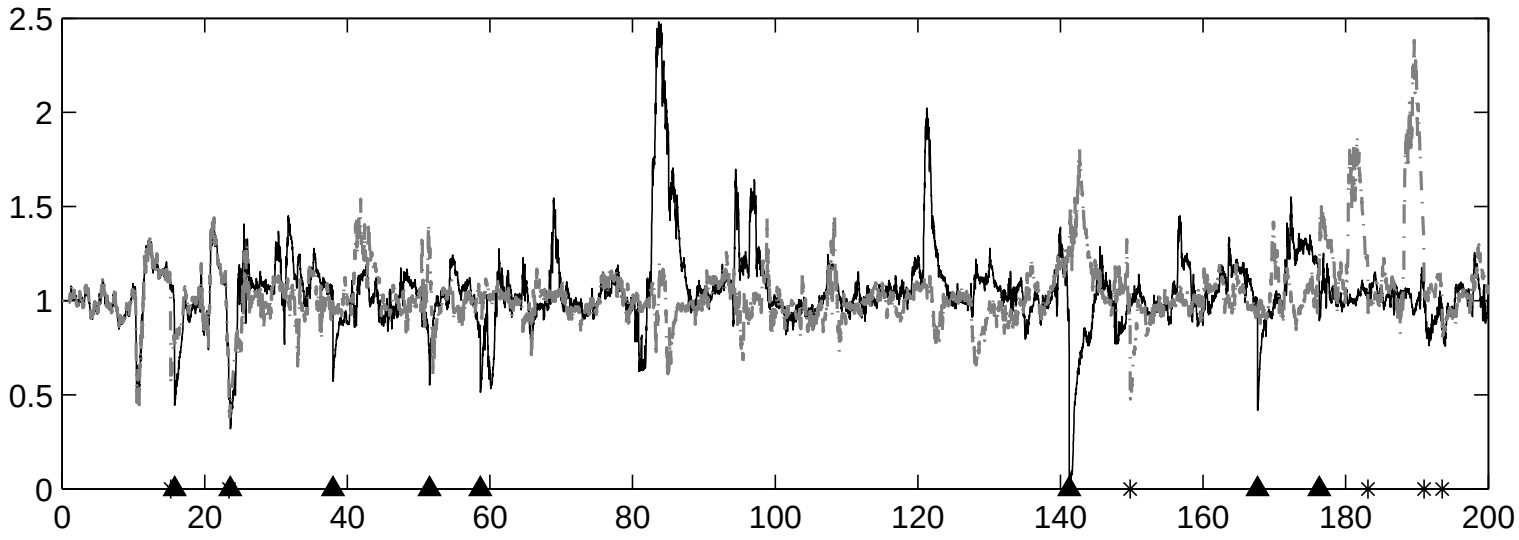
Benchmark (no macro shocks, $\lambda_t^{\max} = \lambda^{\max} = 10$)

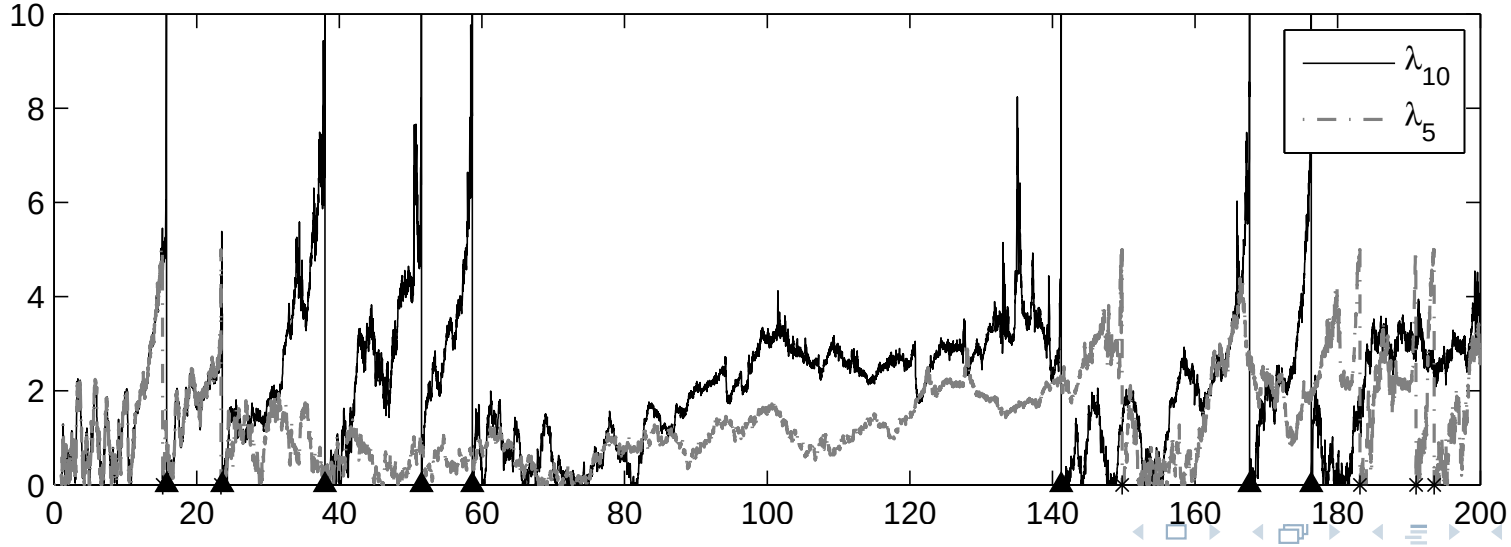


Benchmark (no macro shocks, $\lambda_t^{\max} = \lambda^{\max} = 5$)

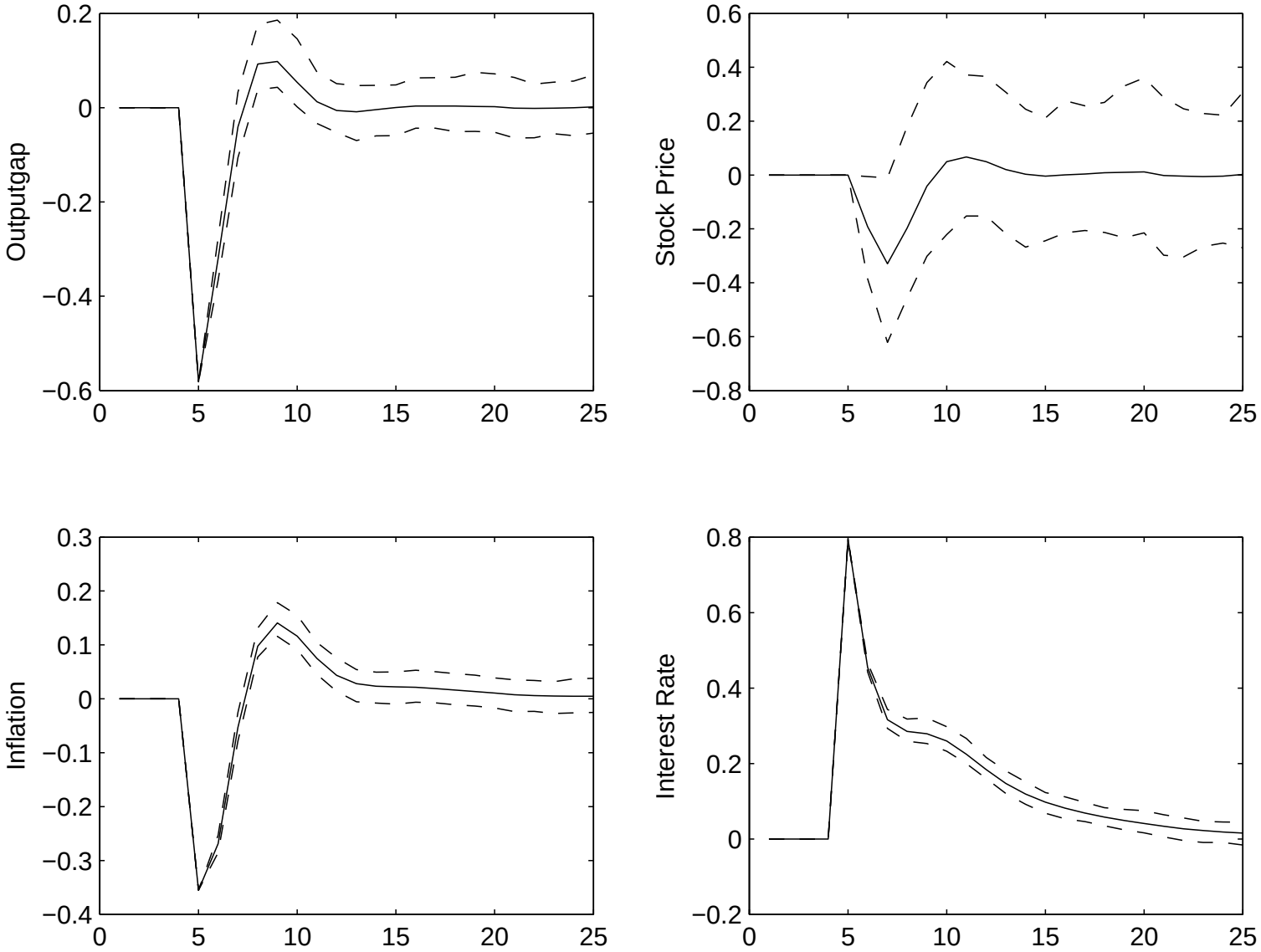


Benchmark (no macro shocks, $\lambda_t^{\max} = \lambda^{\max} = 5, 10$)

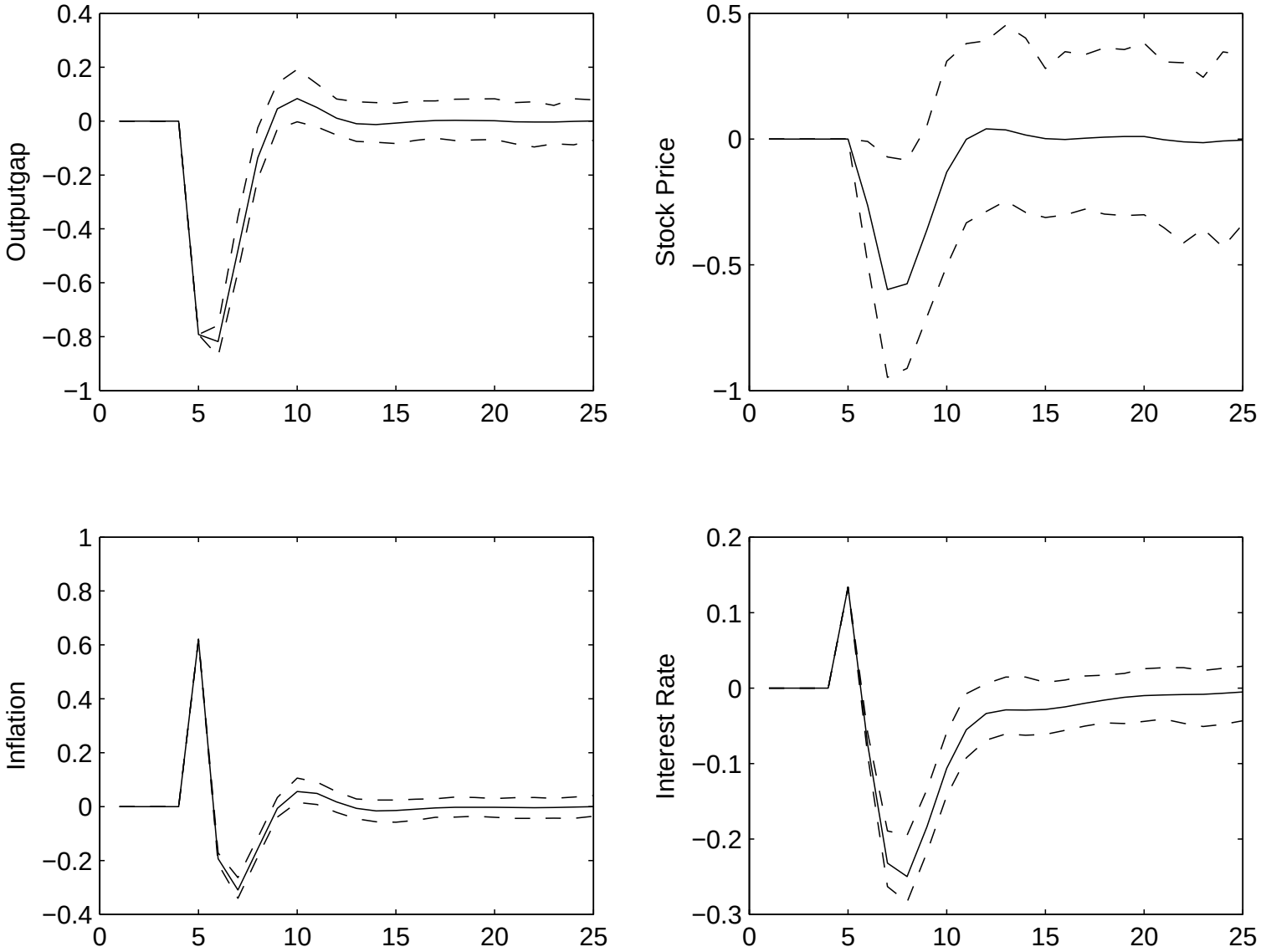




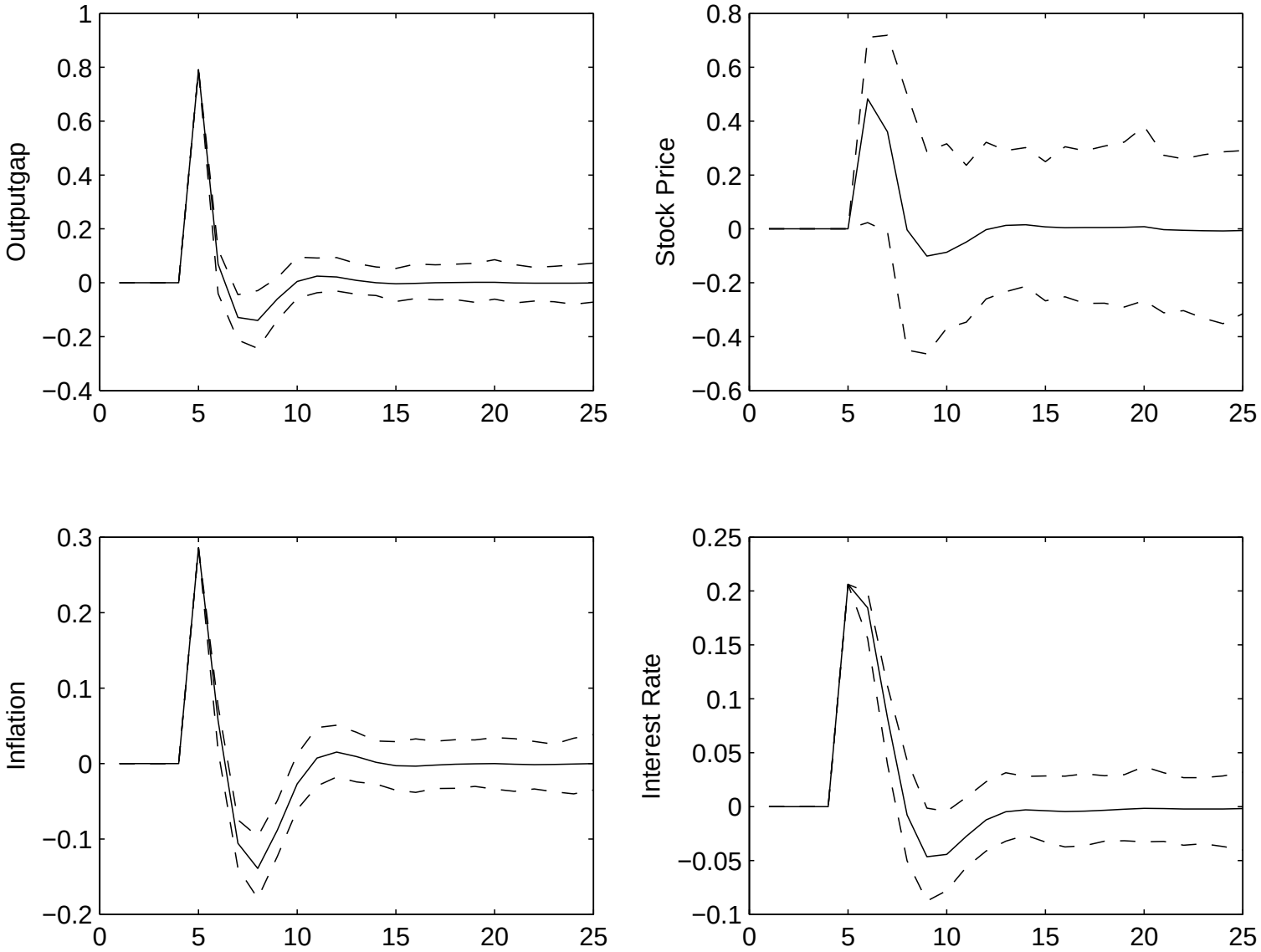
Benchmark (interest rate shock in $q = 5, \lambda_t^{\max} = \lambda^{\max} = 10$, mean responses)



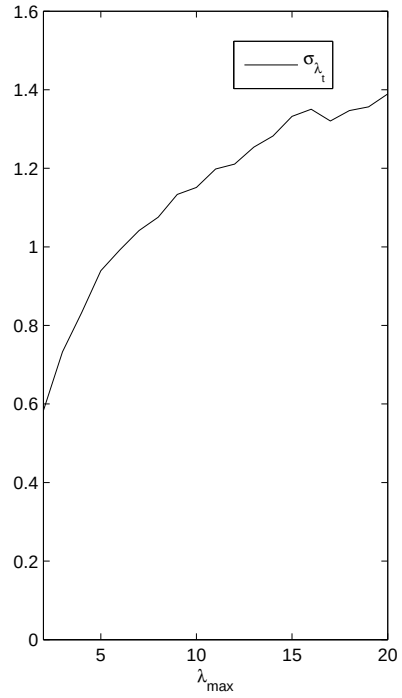
Benchmark (supply shock in $q = 5, \lambda_t^{\max} = \lambda^{\max} = 10$, mean responses)

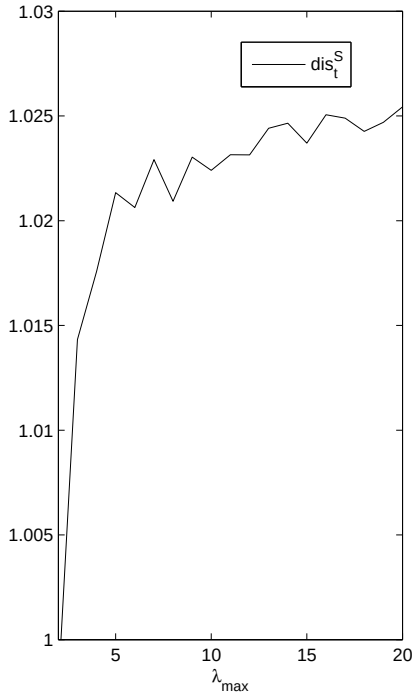


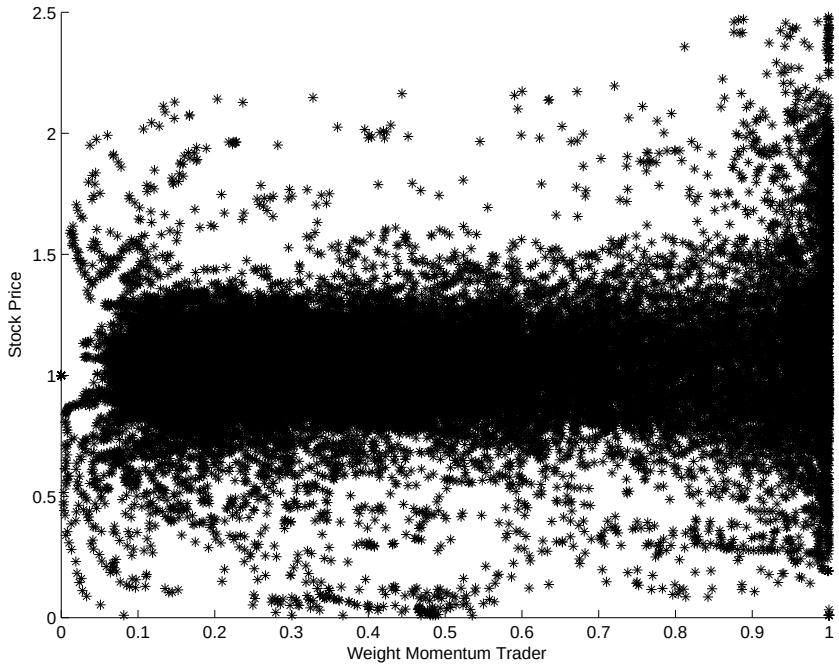
Benchmark (demand shock in $q = 5, \lambda_t^{\max} = \lambda^{\max} = 10$, mean responses)



Benchmark (stylized results)







Key statistics

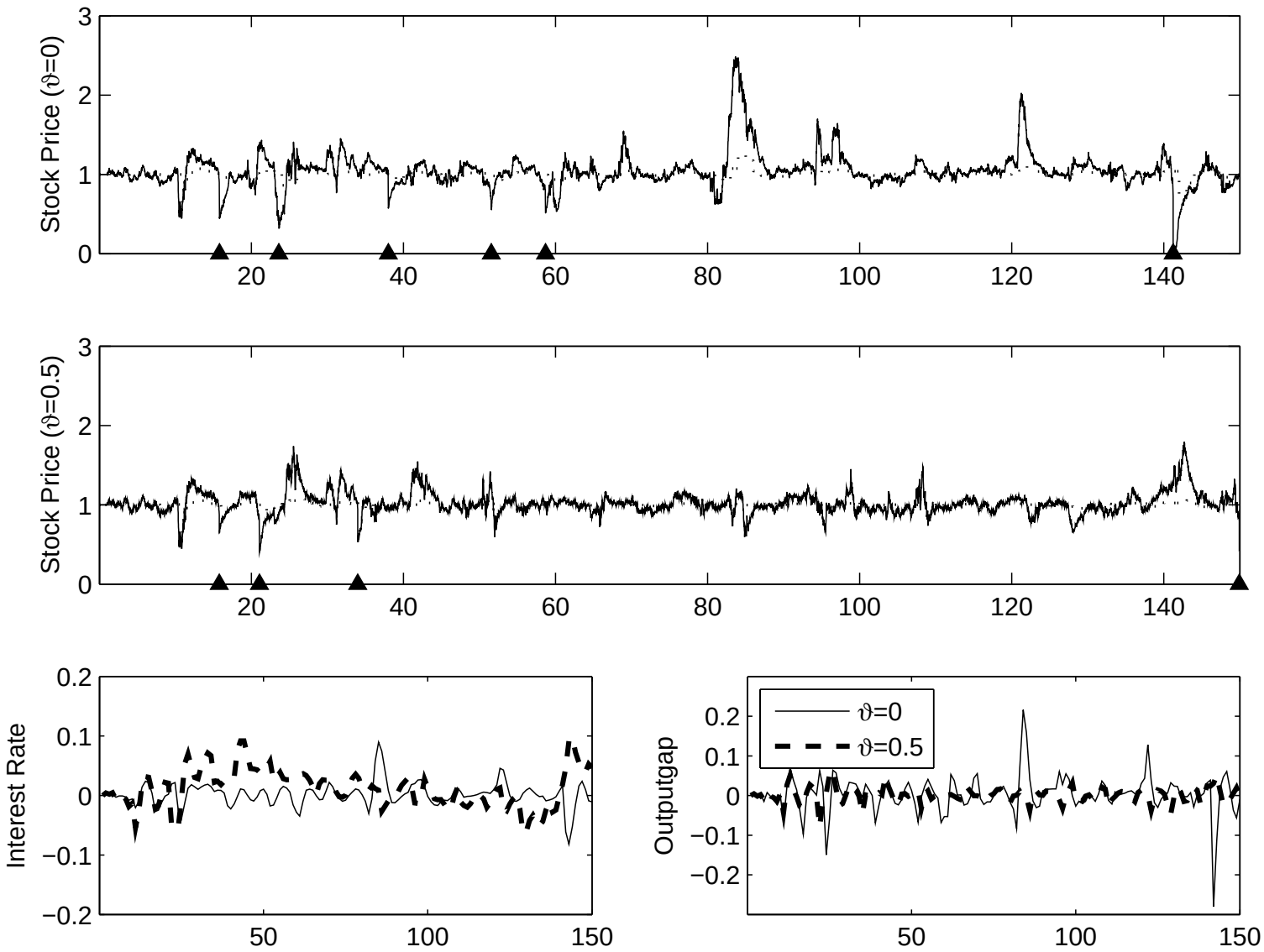
- Higher λ^{max} tends to increase volatility on financial market
- $dis_t^S = 1/(T)\sum_{t=1}^{T} |S_t - \bar{F}_t|$
- Extreme values of the asset price in case of the presence of a large weight of momentum traders

Policy Measures

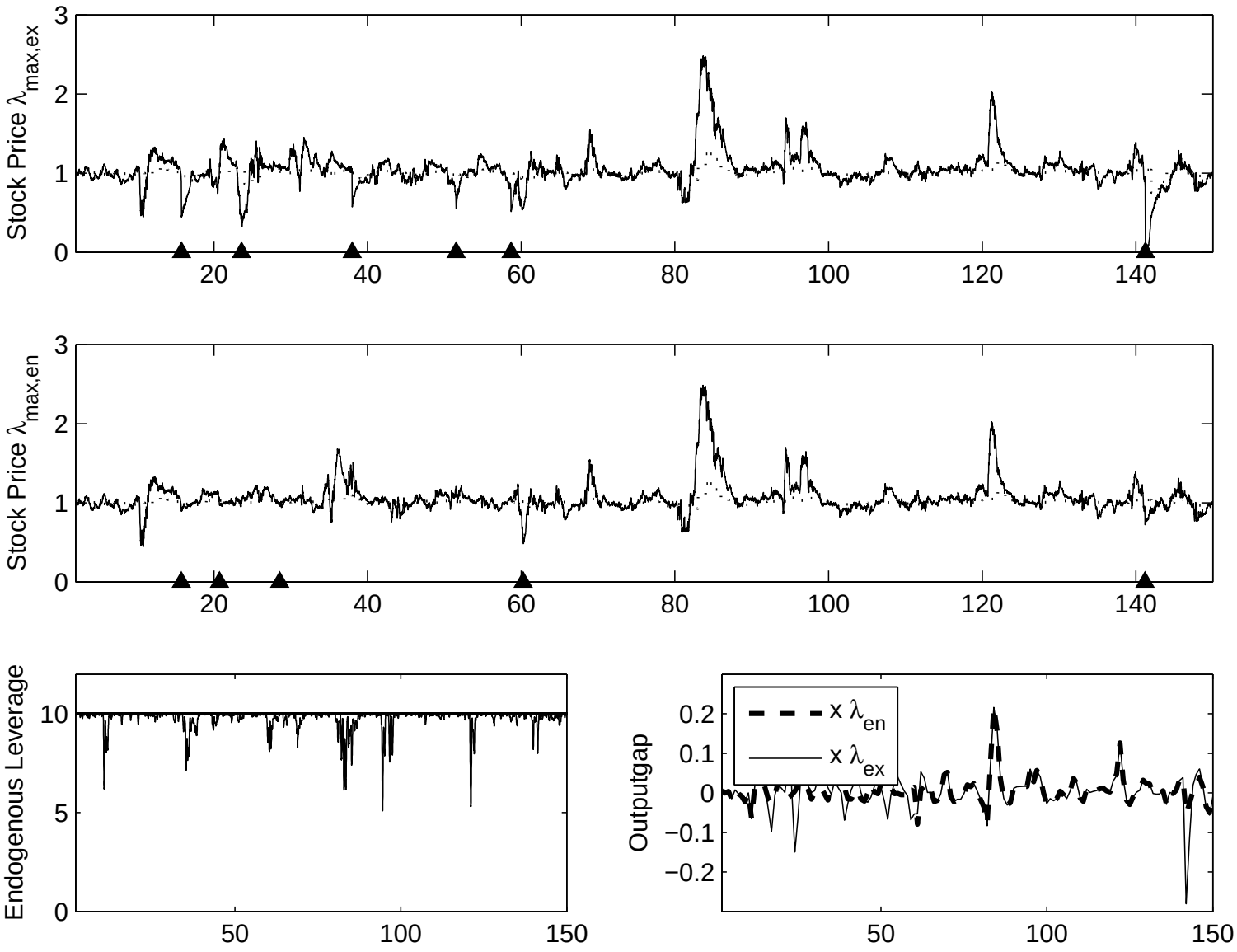
Policy

- Monetary Policy: reacting to asset price misalignments
  - $i_t \uparrow \rightarrow x_t \downarrow \rightarrow F_t \downarrow \rightarrow$ mispricing signal of fundamentalist increases $D_t^F \uparrow \rightarrow S_t$ approaches F_t.
- Macroprudential regulation: time-varying permitted maximal leverage $\lambda_t^{\max}$ over the course of the financial cycle
  - If the asset price S_t is fast-paced, volatility σ_t^S increases. An adequate adjustment of $\lambda_t^{\max}$ prevents the momentum trader to aggressively pursuit her trend-chasing strategy, to lever-up drastically and to bring the increasing weight of the momentum trader as well as momentum to a halt more early.

Asset Price Reaction (no macro shocks, $\lambda^{\max} = 10, \vartheta = 0.5, \xi_q = (s_q - p_q)$)



Endogenous Leverage (no macro shocks, $\lambda^{\max} = 10, \lambda_t^{\max} = \lambda^{\max}/(1+\varphi\sigma_t^S)$)



Conclusion

- Hybrid New-Keynesian model with endogenous boom-bust cycles, leverage and default.
- Waves of persistent bubbles and macroeconomic expansion.
- De-leveraging causes fire sales, default and output detoriation (dependent on the degree of leveraging and trading population in the run-up to the fire sale).
- Monetary Policy can smoothen output dynamics in case of a wealth effect.
- Time-varying macroprudential regulation can dampen the effects of fire sales.

To Do's:

- Sensitivity and robustness analysis for different parameter constellations
- Welfare analysis of policy measures (which measure outweighs?)
- Can we use leverage as indicator for future financial instability?