Uncertainty Shocks, Asset Supply and Pricing over the Business Cycle

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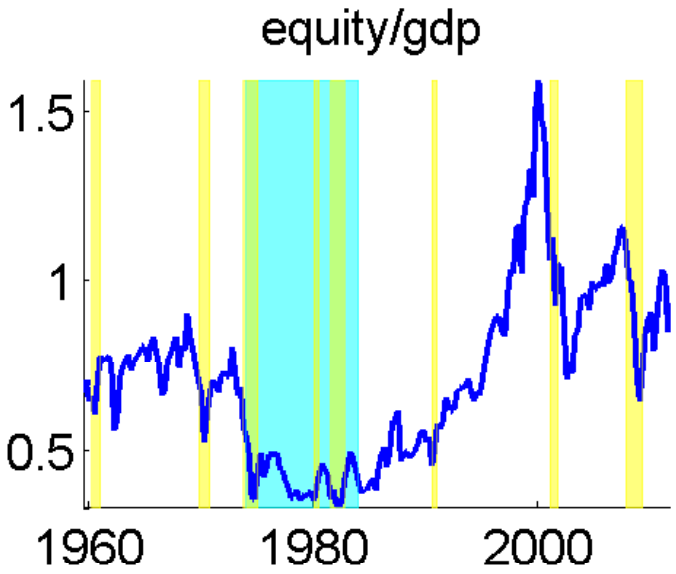
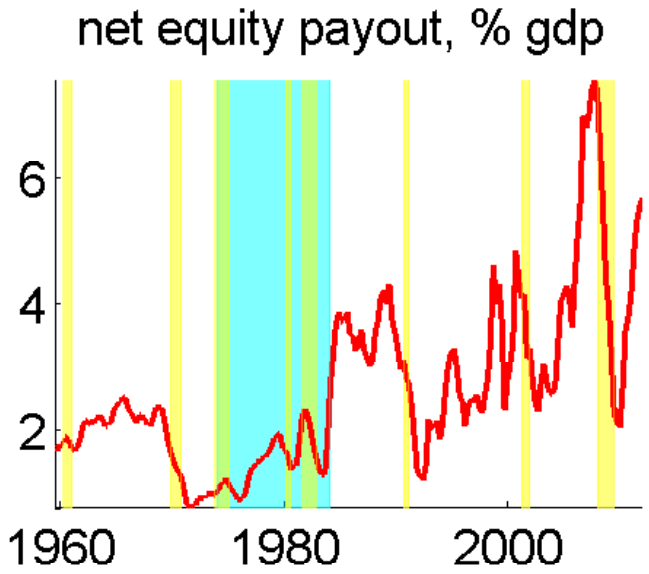
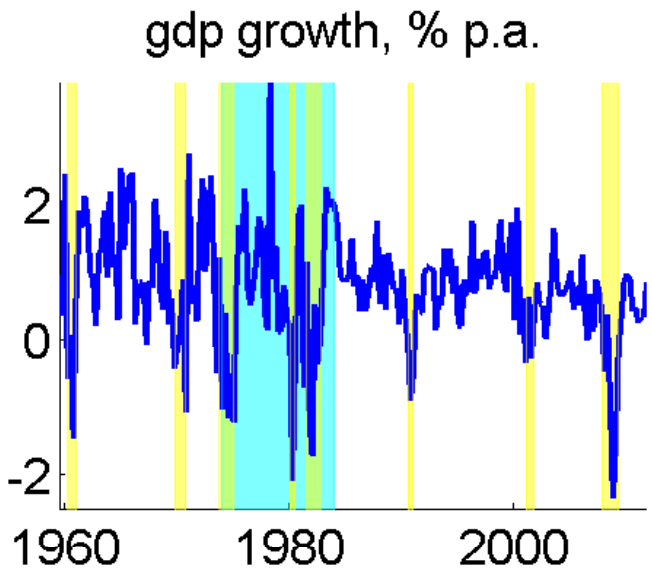
Motivation

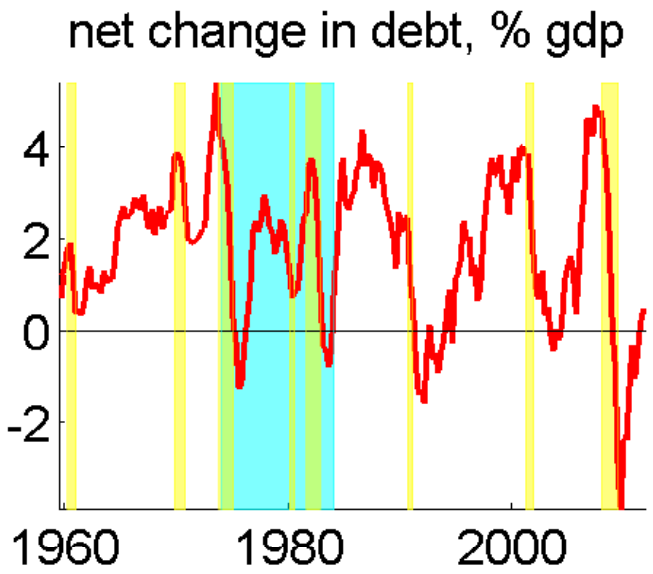
- When stock price is high...
  - future excess returns over bonds low
  - net payout to shareholders high
  - net corporate debt increases
- At business cycle frequencies
  - in recessions: stock price low, net payout low, net debt falls
- At lower frequencies
  - 1970s: stock price low, payout low, debt flat
  - more quantity volatility in 1970s

Nonfinancial business sector

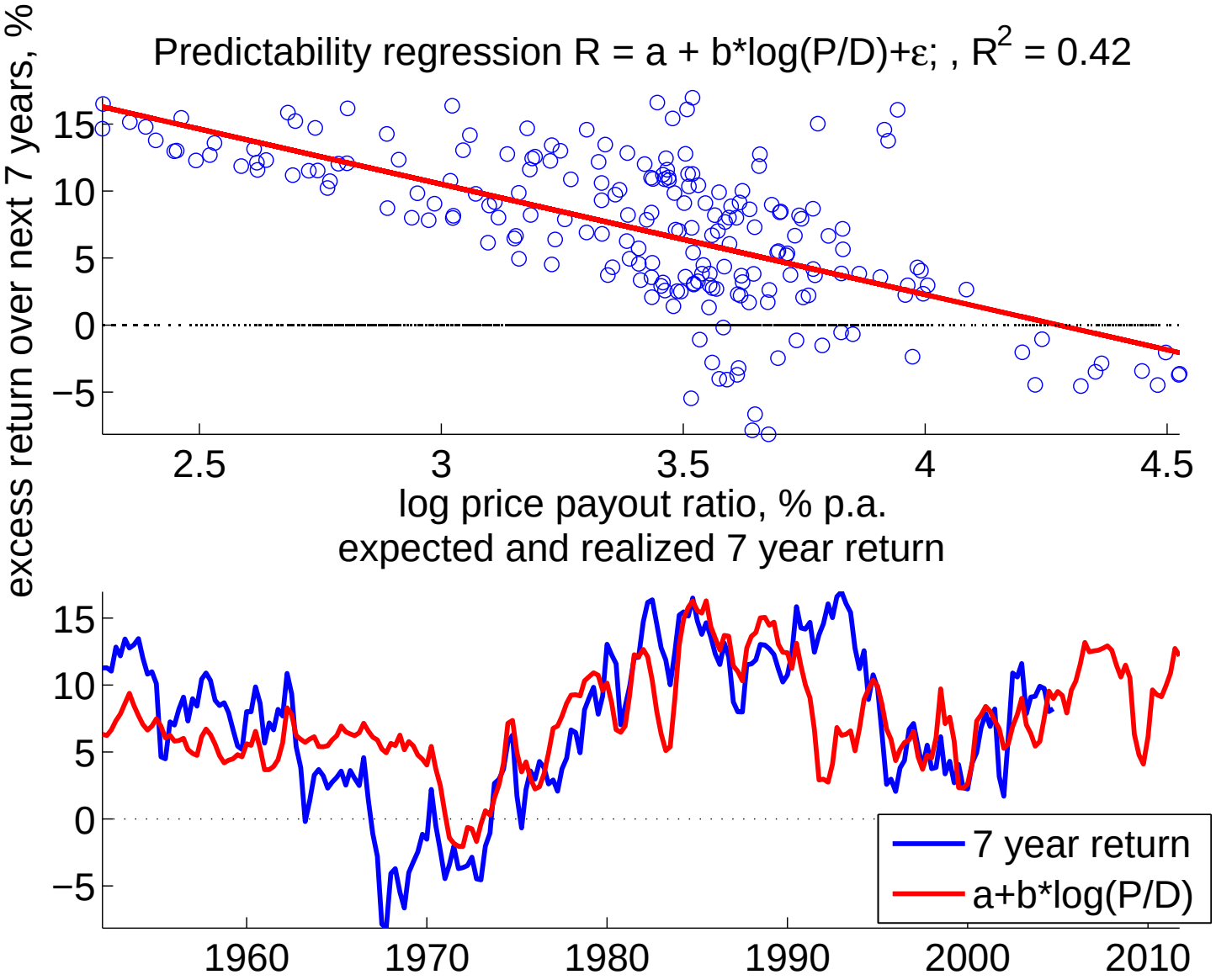








Excess return predictability: high prices, low future excess return



This paper

- Stylized facts: when uncertainty about financial conditions is low...
  - investors demand lower premia
  - firms facing credit market frictions choose more debt & payout
  - low frequency effect from volatility regimes
- DSGE model w/ endog. supply of equity & bonds
  - nonfinancial firms issue equity & debt
  - firms smooth dividends & face MC of borrowing increasing in debt
  - uncertainty = risk + ambiguity (Knightian uncertainty)
  - uncertainty shocks: regime switching volatility and confidence shocks
- Estimation
  - data from NIPA and Flow of Funds
  - Bayesian approach using 1st order approximation

Literature

1. **Multiple priors utility**: Gilboa & Schmeidler (1989), Epstein & Wang (1994), Epstein & Schneider (2003).
2. **Business cycles, asset pricing & uncertainty shocks**
   - **risk shocks**: Gourio (2010), Basu & Bundick (2011), Caldara, Fernandez-Villaverde, Rubio-Ramirez & Yao (2012), Christiano, Motto & Rostagno (2012), Malkhozov & Shamloo (2012)
   - **robustness:** Cagetti, Hansen, Sargent and Williams (2002), Bidder and Smith (2012), Pahar-Javan & Liu (2012)
3. **Business cycles & firm asset supply**: Covas & den Haan (2011), Gourio (2011), Jermann & Quadrini (2011), Adrian & Boyarchenko (2012), Croce, Kung, Nguyen & Schmid (2012)

Outline of the talk

- Preferences
  - time-varying confidence
- Model overview
  - firm financing
  - asset pricing
- Quantitative evaluation
  - solution
  - estimation and data
  - some results

Preferences: ambiguity aversion

- S = state space
  - one element $s \in S$ realized every period
  - histories $s^t \in S^t$
- Consumption streams $C = (C_t(s^t))$
- Recursive multiple-priors utility

$$U_t\left(C; s^t\right) = u\left(C_t\left(s^t\right)\right) + \beta \min_{p \in \mathcal{P}_t(s^t)} E^p\left[U_{t+1}\left(C; s^{t+1}\right)\right]$$

- Primitives:
  - felicity u, discount factor β
  - the one-step-ahead belief sets $\mathcal{P}_t(s^t)$
- Larger set $\mathcal{P}_t(s^t) \rightarrow$ less confidence about s_{t+1}

Ambiguity about mean innovations

- DSGE model: s^t = history of innovations to exogenous shocks
- Representation of one-step-ahead belief set $\mathcal{P}_t$ for shock x_i :

$$x_{t+1,i} = \rho_i x_{t,i} + \sigma_{t,i}\varepsilon_{t+1,i} + \mu_{t,i}$$
$$\mu_{t,i} \in [-a_{t,i}, a_{t,i}]$$

- Stochastic process $a_{t,i}$ regulates size of $\mathcal{P}_t(s^t)$
  - larger $a_{t,i}$ = larger set = less confidence about shock $x_{t+1,i}$
  - min operator selects worst case mean, e.g. $-a_{t,i}$
  - if ambiguity $a_{t,i}$ increases, agent acts "as if" bad news about $x_{t+1,i}$

Evolution of confidence

$$x_{t+1,i} = \rho_i x_{t,i} + \sigma_{t,i}\varepsilon_{t+1,i} + \mu_{t,i}$$
$$\mu_{t,i} \in [-a_{t,i}, a_{t,i}]$$

- Two sources for evolution of ambiguity $a_{t,i} = \eta_{t,i}\sigma_{t,i}$
  - follows if set $\mathcal{P}_t$ is relative entropy ball around $p^{\mu=0}$

1. Intangible information affecting confidence

$$\eta_{t,i} = (1 - \rho_{\eta,i})\overline{\eta}_i + \rho_{\eta,i}\eta_{t-1,i} + \varepsilon_{t,\eta_i}$$

2. Regime switching volatility $\sigma_{t,i}$
   - volatility lowers confidence; first order effects of changes in volatility

- True data generating process
  - deterministic sequence $\mu^*_{t,i}$ with moments converging to $i.i.\mathcal{N}\left(0, \sigma^2_\mu\right)$
  - neither agents nor econometrician can identify true sequence

Model overview

- RBC-style model with representative agent and firm
- Household maximizes recursive multiple priors utility
  - works for wages, holds bonds, stocks, pays taxes, receives endowment
- Firms maximize shareholder value (using HH's SDF)
  - margins for firm: investment, labor, net payout, capital structure
  - adjustment costs for net payout to shareholder
  - borrow at MC increasing in debt level
- Competitive markets: consumption good, equity, one period bonds
- Shocks
  - TFP growth, gov't spending
  - Financial conditions: MC of borrowing, fixed cost
- Ambiguity about all shocks
  - independent confidence shocks
  - also affected by common regime switching volatility

Firm financing decision

- Firm objective: max PV of net payout

$$\max E_0^* \sum_{t=1}^{\infty} M_0^t D_t$$

$$D_t = \text{Net Income} + \Delta B_t - \text{borrowing cost} - \text{dividend adj. cost}$$

- Key inputs:
  - expectations are under the HH's worst-case conditional porobabilities
  - incentive to smooth dividends
  - financing costs
- Property: firms issue more debt if expected dividend growth is larger
- BC + intertemporal FOC $\rightarrow$ comovement between D_t and B_t
  - $-$ for 'profit shocks' (ex. more income today $\longrightarrow$ more D_t, less B_t)
  - $+$ for 'uncertainty shocks' (ex. high $E_t^* D_{t+1}$ $\longrightarrow$ more B_t and D_t)

Price volatility & excess return predictability

- Loglinearized Euler equation

$$\hat{p}_t = (\widehat{c}_t - E_t^* \widehat{c}_{t+1}) + \beta E_t^* \hat{p}_{t+1} + (1-\beta) E_t^* \hat{d}_{t+1}$$

- Excess return

$$\begin{aligned} x_{t+1}^e &= \log(p_{t+1} + d_{t+1}) - \log p_t - \log(i_t) \\ &\approx \beta \left(\hat{p}_{t+1} - E_t^* \hat{p}_{t+1}\right) + (1-\beta) \left(\hat{d}_{t+1} - E_t^* \hat{d}_{t+1}\right) \end{aligned}$$

- What does econometrician measure?
  - observes data generated by true DGP; measures $E_t x_{t+1}^e$
  - conditional premia reflect $E_t - E_t^*$
  - lower confidence = higher premia
- Unconditionally: positive average equity premium because:
  1. stock return is higher under E than under E^*
  2. interest rate is lower: size depends on effect on ΔC

Solution

- Solution in two steps (Ilut and Schneider, 2012)

1. find recursive equilibrium
2. characterize variables under the econometrician's law of motion

- Characterizing equilibrium: a guess-and-verify approach

1. guess the worst case belief, say p^0
2. find recursive equilibrium under expected utility & belief p^0
   - compute loglinear approximation around "worst-case" steady state (sets risk to zero, but retains worst case mean)
   - DSGE solution can be expressed as a MS-VAR:

$$S_t = C\left(\xi_t\right) + TS_{t-1} + R\sigma\left(\xi_{t-1}\right)\varepsilon_t$$

   time-variation in constant: from effect of volatility regime ξ_t
3. compute value function under worst case belief
4. verify that the guess p^0 indeed achieves the minimum

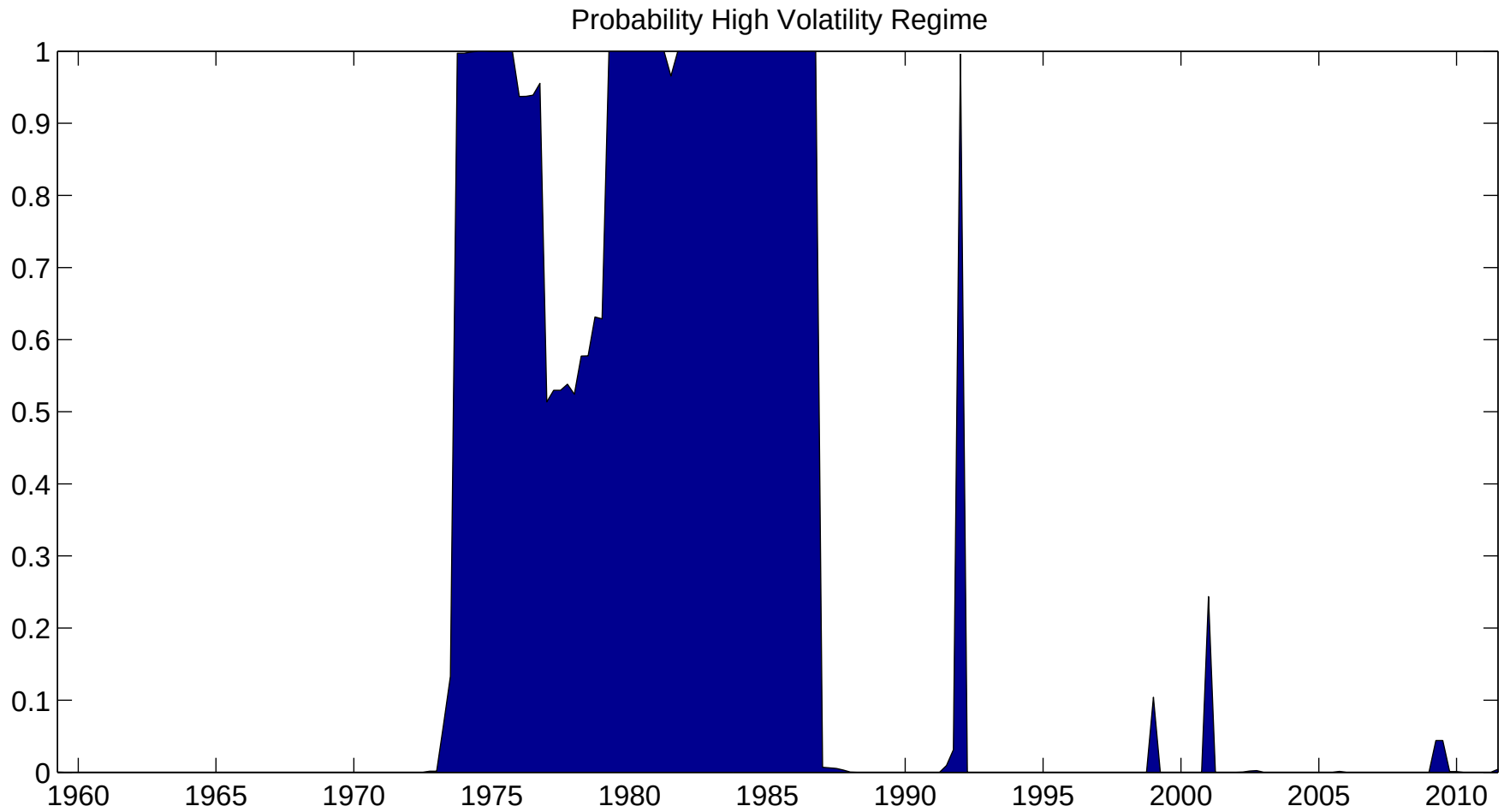
Estimation

- DSGE solution:

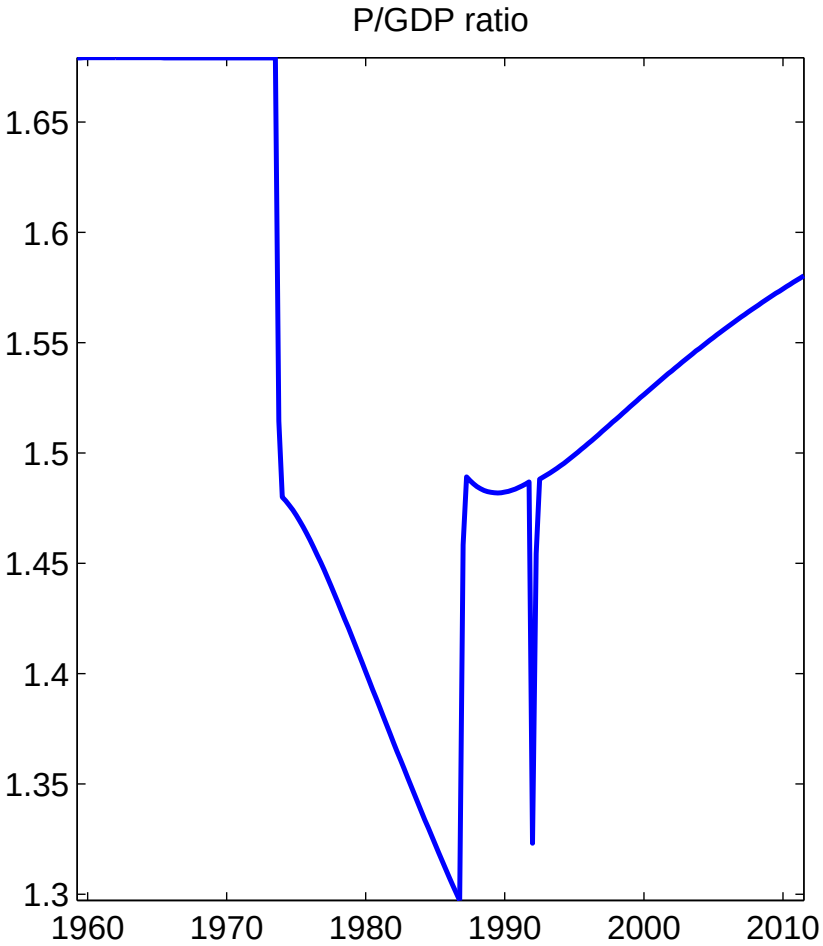
$$S_t = C\left(\xi_t\right) + TS_{t-1} + R\sigma\left(\xi_{t-1}\right)\varepsilon_t$$

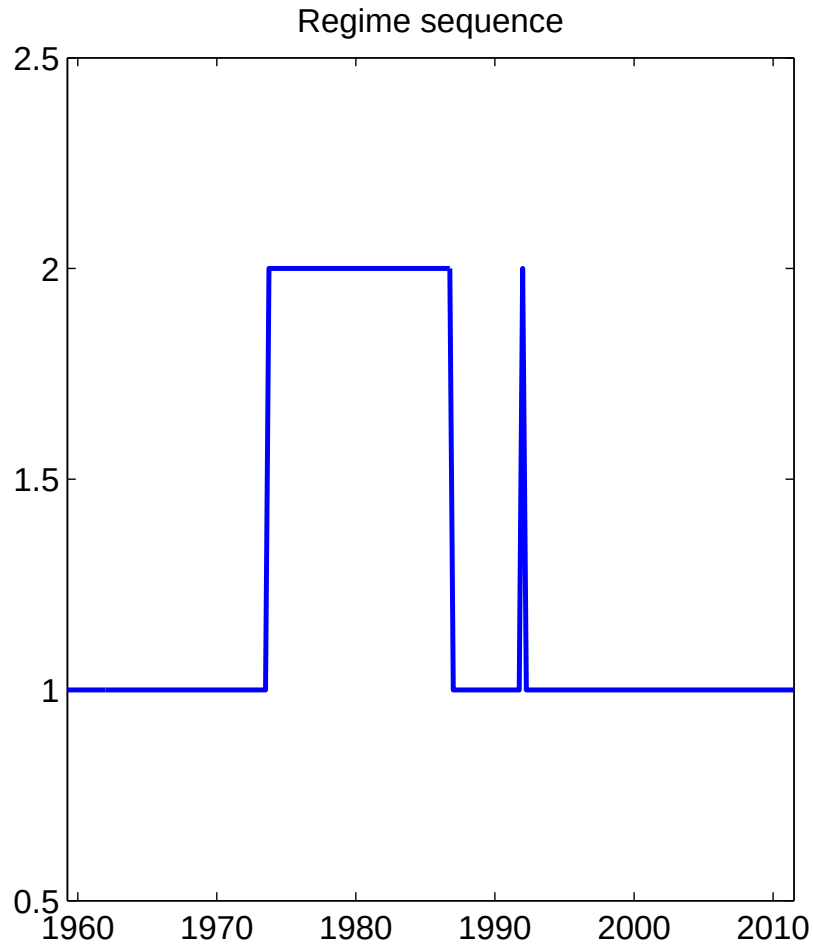
- Linearity $\rightarrow$ estimation using a slight modification of the Kalman filter
- Identification of ambiguity vs. volatility shocks:
  - stochastic volatility shows up as (likely) changes to the second moments
- Data: US 1959Q2-2011Q3
  - Macro aggregates: growth rates of Y, C and I
  - Asset prices: value of nonfin corporate equity / gdp, real interest rate, interest rate term spread
  - Asset supply: nonfinancial corporate net payout and net debt / gdp

Smoothed probability of the High Volatility regime

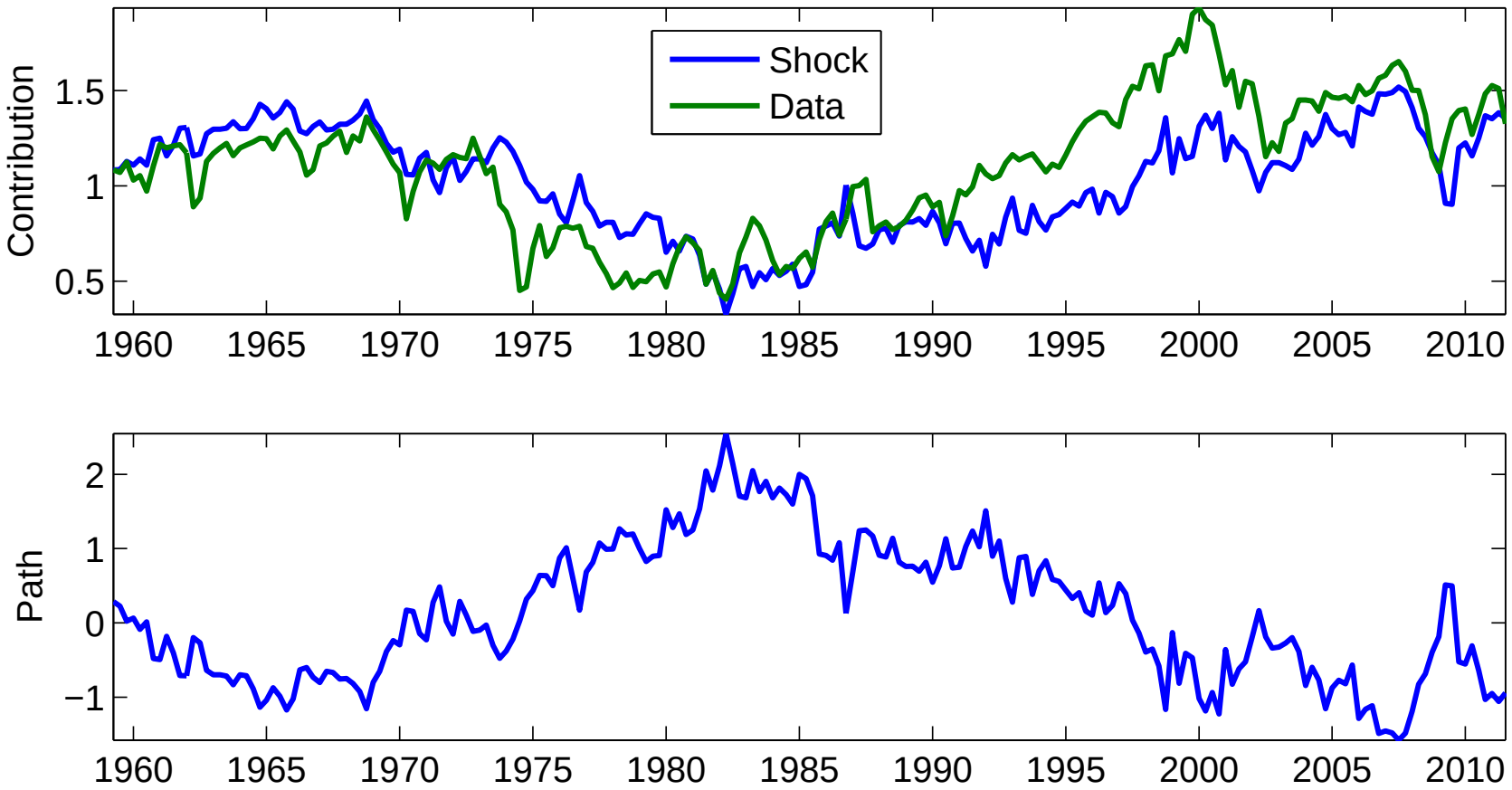


Equity price/GDP: effects of volatility regimes

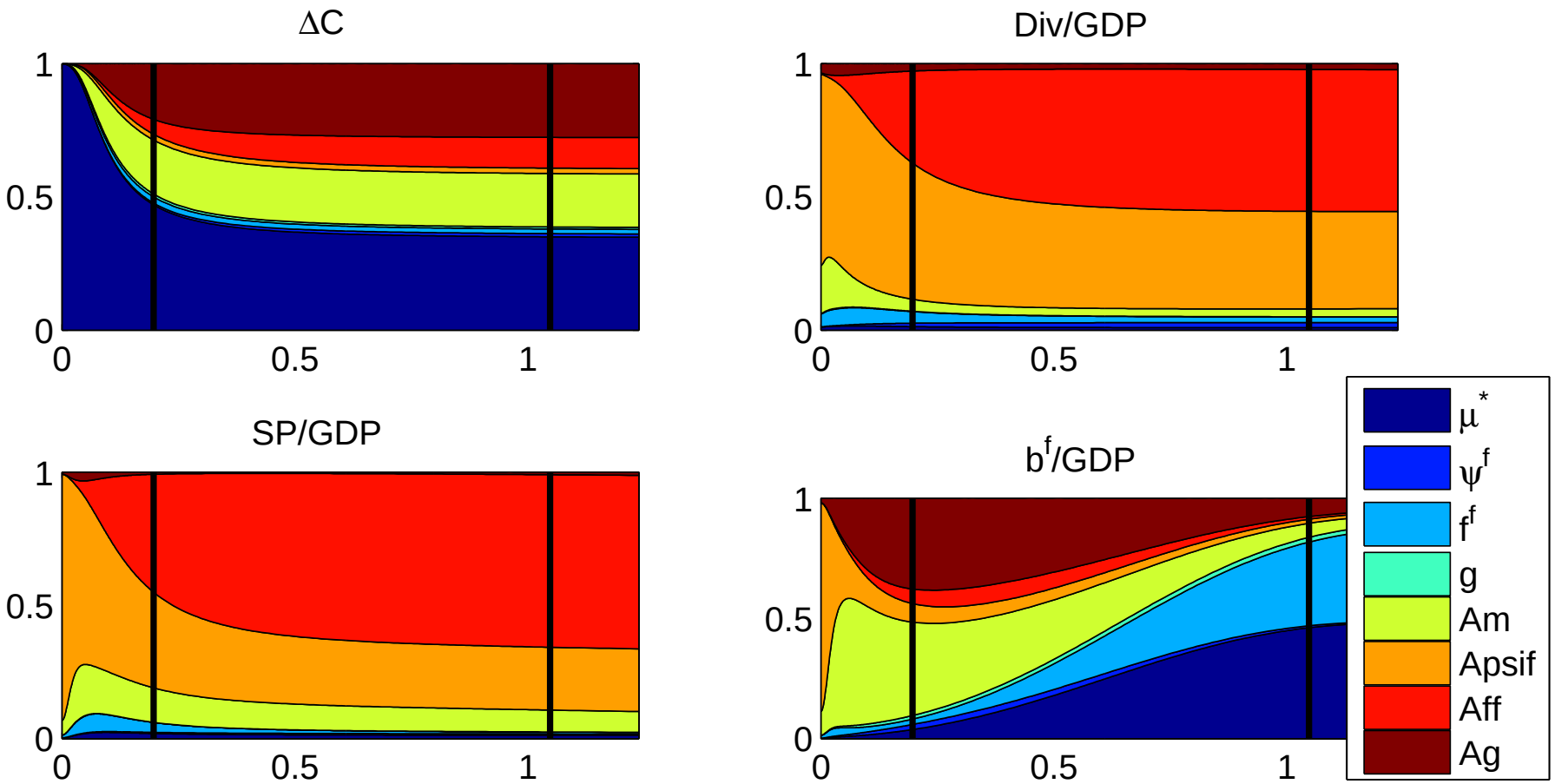




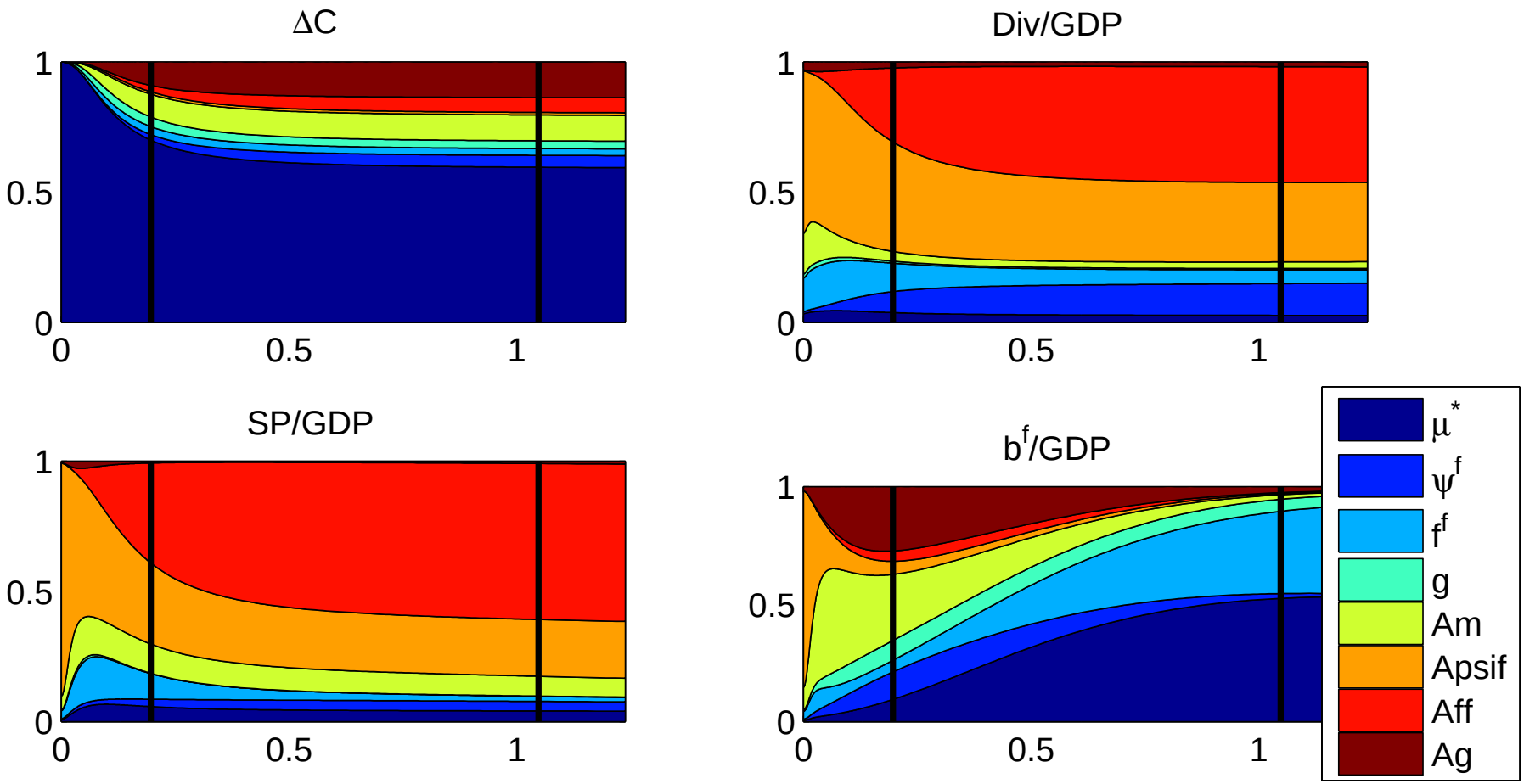
Equity price/GDP: ambiguity over borrowing fixed cost



Spectral Decomposition: Low volatility regime



Spectral Decomposition: High volatility regime



Conclusion

- DSGE model to study business cycles and asset prices
  - asset demand (equity, bonds)
    ambiguity averse agents
  - asset supply
    capital structure, credit market frictions
  - uncertainty shocks
    price volatility / predictability of excess returns
- Study dynamics using 1st order approximation
  - allows for tractable estimation
- Preliminary results:
  - uncertainty shocks: dynamics of asset supply and asset pricing

Solution

1. Find recursive equilibrium

1. Compute the ergodic volatility vector $\overline{\sigma}$
2. Worst-case mean:
$$\overline{x}_i = -\frac{\overline{\eta}_i \overline{\sigma}_i}{1-\rho_i}$$
3. Worst-case endogenous variable $\overline{Y} = f(\overline{x})$ from deterministic FOCs
4. Linearize around $\overline{Y}, \overline{\sigma}, \overline{\eta}, \overline{x}$ and solve a 'rational expectations' model under worst-case belief p^0

$$\widetilde{Y}_t = C(\xi_t) + T\widetilde{Y}_{t-1} + R\sigma(\xi_{t-1})\varepsilon_t$$

- time-variation in constant: from first order effect of volatility regime ξ_t

Solution

2. Equilibrium dynamics under econometrician's law of motion (p^*)

1. Zero-risk (ergodic) steady state Y^*
   - Expectations under belief p^0 but shocks set to their ergodic values under p^*
   - Y^* can be found from linearized solution

$$Y^* - \overline{Y} = T\left(Y^* - \overline{Y}\right) + R\overline{\eta\sigma}$$

2. Dynamics: define $\widehat{Y}_t = Y_t - Y^*$
   - beliefs formed under p^0 but realized innovations under p^*

$$\widehat{Y}_t = C\left(\xi_t\right) + T\widehat{Y}_{t-1} + R\sigma\left(\xi_{t-1}\right)\varepsilon_t + R\left(\overline{\eta\widetilde{\sigma}}\left(\xi_{t-1}\right) + \overline{\sigma}\widetilde{\eta}_{t-1}\right)$$