Uncertainty Shocks, Asset Supply and Pricing over the Business Cycle

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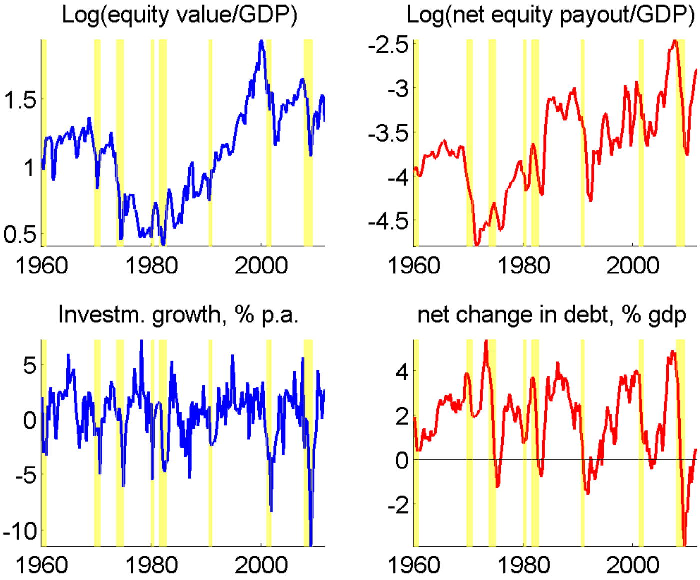
4th BU/Boston Fed conference on Macro-Finance Linkages, 2013

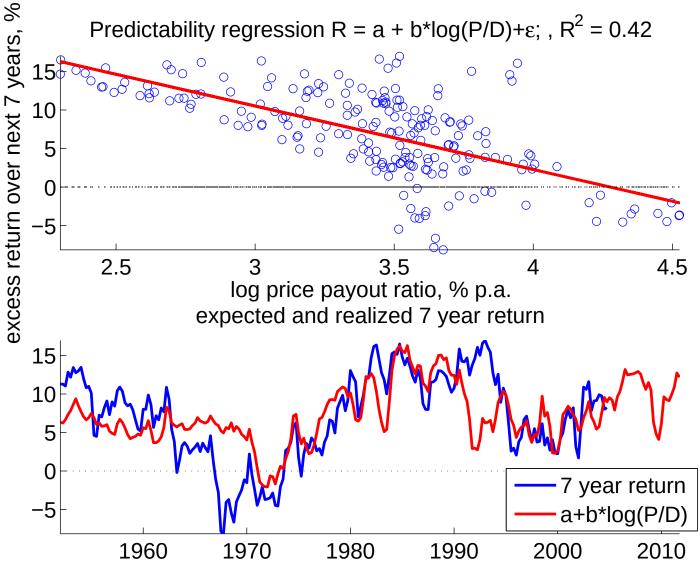
Motivation

- When stock prices are high...
  - net payout to shareholders high
  - net corporate debt increases
  - future excess stock returns (over bonds) low

Nonfinancial corporate sector



Excess return predictability: high prices, low future excess return



This paper

- When uncertainty about future fundamentals is low...
  - investors demand lower equity premia $\Rightarrow$ stock prices high
  - firms worry less about financing constraints
    pay out more & borrow to exploit tax advantage of debt
- Two types of changes in aggregate uncertainty
  - low frequency shift in volatility...
  - higher frequency shifts in investor's confidence...
    ...helps synchronize real & financial variables, including stock prices

What we do

- Business cycle model
  - firms choose payout and capital structure
  - fundamental shocks to technology
  - agents averse to ambiguity (Knightian uncertainty)
  - volatility & confidence regimes change perceived ambiguity
- Estimation
  - data from NIPA and Flow of Funds
  - Bayesian approach using 1st order approximation
  - infer relative importance of shocks, regimes

Literature

1. Multiple priors utility
    - **Preferences:** Gilboa & Schmeidler (1989), Epstein & Wang (1994), Epstein & Schneider (2003).
    - **Uncertainty shocks & business cycles:** Ilut & Schneider (2012).
2. Asset pricing in production economies & uncertainty shocks
    - **aggregate volatility:** Basu & Bundick (2011), Caldara, Fernandez-Villaverde, Rubio-Ramirez & Yao (2012), Gourio (2012, 2013), Malkhozov & Shamloo (2012)
    - **robustness:** Cagetti, Hansen, Sargent & Williams (2002), Bidder and Smith (2012), Pahar-Javan & Liu (2012)
    - **idiosyncratic volatility**: Arellano, Bai & Kehoe (2010), Gilchrist, Sim & Zakrajsek (2010), Christiano, Motto & Rostagno (2012)
3. Business cycles & firm asset supply
    - Covas & den Haan (2011), Glover, Gomes & Yaron (2011), Jermann & Quadrini (2011), Croce, Kung, Nguyen & Schmid (2012)

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}
- Why this functional form?
  - preference for knowing the odds (Ellsberg Paradox)
  - worst case belief endogenous – depends on C

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 :

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

  - min operator selects worst case mean, e.g. $-a_{t,i}$
  - if ambiguity $a_{t,i}$ increases, agent acts "as if" bad news about $x_{t+1,i}$
- Describe ambiguity by two processes: $a_{t,i} = \eta_{t,i}\sigma_{t,i}$

1. Intangible information affects confidence
2. Volatility lowers confidence (first order effect) Entropy

- 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

- Representative agent and firm, competitive markets
- Firms maximize shareholder value by producing

$$Y_t = Z_t K_t^{\alpha} N_t^{1-\alpha}$$

  - choose investment, net payout, capital structure
- Household maximizes recursive multiple priors utility
  - inelastically supplies labor, holds bonds, stocks, pays taxes
- Two types of shocks:
  - production technology Z_t
  - lump-sum operating cost F_t
- Ambiguity about both shocks

Firm financing

- Net payout to shareholders

$$\begin{aligned} D_t &= \text{Profits - Investment - corporate income tax} \\ &+ Q_t^b B_t - B_{t-1} - 0.5\psi B_{t-1}^2 + \tau B_{t-1}(1 - Q_{t-1}^b) \\ &- 0.5\phi \left(D_t / D_{t-1} - 1 \right)^2 - F_t \end{aligned}$$

1. Debt
   - Q_t^b = price of riskless one period bond
   - upward sloping marginal cost vs. tax advantage of debt
2. Payout: growth rate adjustment cost
3. F_t : operating cost

Households

- Household felicity

$$\log C_t$$

- Household budget constraint

$$\begin{aligned}(1+\tau_c)C_t &= (1-\tau_l)\left[(1-\alpha)Y_t + D_t\theta_{t-1}\right] + P_t(\theta_{t-1}-\theta_t)\\ &\quad + B^h_{t-1} - Q^b_t B^h_t - \tau_l\left\{B^h_{t-1}(1-Q^b_{t-1}) + (P_t - P_{t-1})\,\theta_{t-1}\right\}\end{aligned}$$

- Market clearing: goods, debt ($B^h_t = B_t$), equity ($\theta_t = 1$)

Solution

- Characterize equilibrium law of motion

1. worst case mean for shock $x_{t+1,i}$ either $a_{t,i}$ or $-a_{t,i}$
2. find equilibrium law of motion under expected utility & belief p^*
   - compute loglinear approximation around "worst-case" steady state (sets risk to zero, but retains worst case mean)
3. describe model dynamics under econometrician's law of motion
   - effects of uncertainty captured by difference from worst case

Price volatility

- Loglinearized Euler equation

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

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

- Iterating forward

$$\hat{p}_t - \hat{d}_t = E_t^* \sum_{\tau=1}^{\infty} \beta^{\tau-1} \left(\left(\hat{d}_{t+\tau} - \hat{c}_{t+\tau} \right) - \left(\hat{d}_t - \hat{c}_t \right) \right)$$

- For P/D volatility, want:
  1. Changes in expected growth rate of dividend share $\widehat{s}_t := \hat{d}_t - \hat{c}_t$
  2. Under the worst-case conditional expectation
  3. But stable interest rates: small movements in $E_t^* \left(\hat{c}_{t+\tau} - \hat{c}_t \right)$
- Want ambiguity about dividends, not consumption!

Excess return predictability

- Excess stock return

$$
\begin{aligned}
x^e_{t+1} &= \log(p_{t+1} + d_{t+1}) - \log p_t - \log(i_t) \\
&\approx \beta \left[\hat{p}_{t+1} - \hat{d}_{t+1} - E^*_t \left(\hat{p}_{t+1} - \hat{d}_{t+1}\right)\right] + \left(\hat{d}_{t+1} - E^*_t \hat{d}_{t+1}\right)
\end{aligned}
$$

- Econometrician sees time varying expected excess returns
  - regression of excess returns on time t info gets $E_t x^e_{t+1}$
  - conditional premia reflect $E_t - E^*_t$
  - lower confidence = higher premia
- Movements in $E_t x^e_{t+1}$: from stock returns, not interest rate
  - action from $E^*_t \hat{d}_{t+1}$, not from $E^*_t \widehat{c}_{t+1}$

Firm financing: response to shocks

- Firm objective: $\max E_0^* \sum_{t=1}^{\infty} M_0^t D_t$

$$
\begin{aligned}
D_t \; &= \text{Net Profits} + Q_t^b B_t - B_{t-1}\left[1-\tau(1-Q_{t-1}^b)\right] - 0.5\psi B_{t-1}^2 \\
&\quad - 0.5\phi\left(D_t / D_{t-1} - 1\right)^2 - F_t
\end{aligned}
$$

- FOC wrt B_t :

$$
Q_t^b \lambda_t = E_t^*\left(M_{t+1}\lambda_{t+1}\right)\left[1-\tau\left(1-Q_t^b\right)+\psi B_t\right]
$$

  - payout smoothing: increase debt if expected payout growth is larger
- Profit shock: negative comovement between D_t and B_t
  - ex. low income today: reduce payout, but increase debt
- Uncertainty shock: positive comovement between D_t and B_t
  - ex. higher confidence today: behave as if future payout higher
  - increase debt, but also increase payout

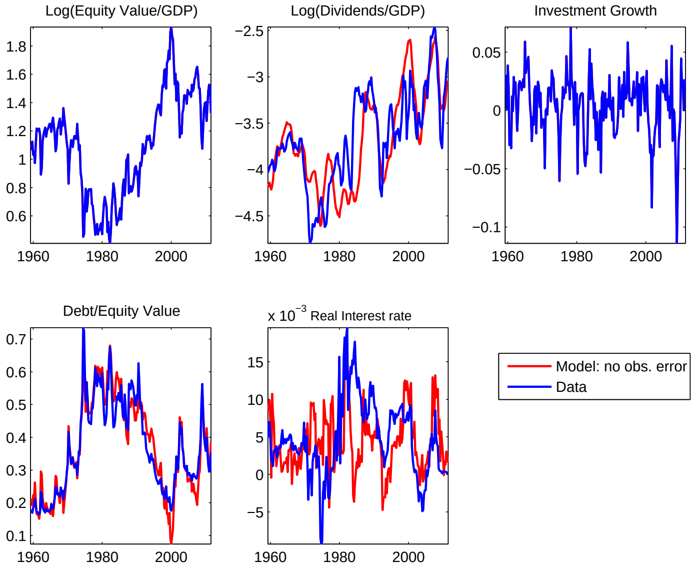
Estimation

- Shocks:
  - comovement of $(\eta_{t,Z}, \eta_{t,F})$ and $(\sigma_{t,Z}, \sigma_{t,F})$: regimes ξ_t^{amb} and ξ_t^{vol}
  - allow for negative correlation between shock Z_t & ambiguity (high uncertainty leads to lower MPK as in Ilut-Schneider 2012)
- DSGE solution:

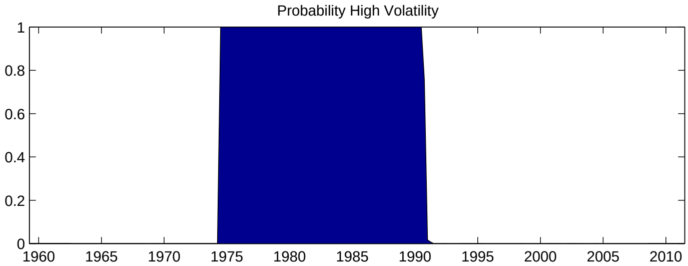
$$S_t = C\left(\xi_t^{vol}, \xi_t^{amb}\right) + TS_{t-1} + R\sigma\left(\xi_{t-1}^{vol}\right)\varepsilon_t$$

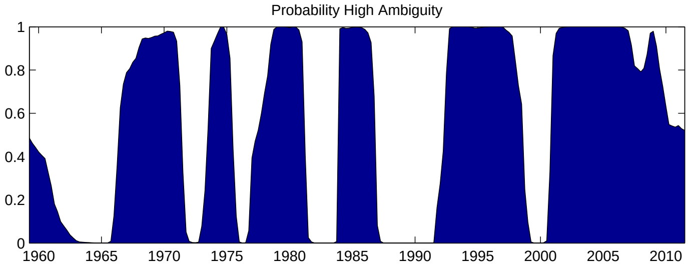
  - linearity $\rightarrow$ estimation using Kalman filter
  - identification: volatility regimes show up as changes to second moments
- Data: US 1959Q1-2011Q3
  - Macro aggregate: growth rate of Investment
  - Asset prices: value of nonfin corporate equity/gdp, real interest rate
  - Financial: nonfin corporate net payout/gdp and net debt/equity
  - Observation error on RIR, payout/gdp, debt/equity

Observables

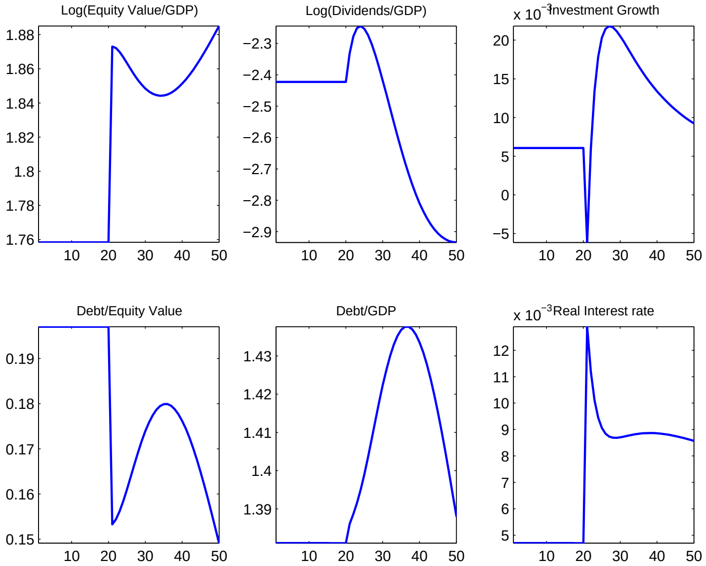


Smoothed regime probabilities of High Uncertainty regimes

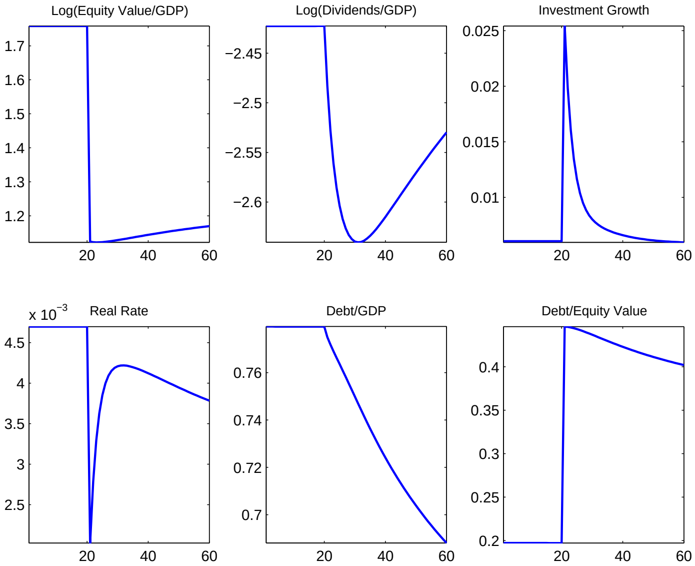




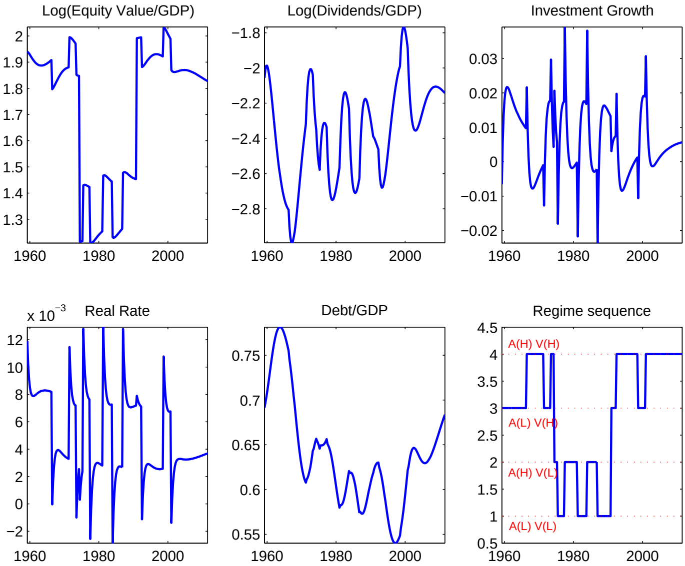
Effects of Low ambiguity regime



Effects of High volatility regime



Evolution on historical typical regime path



Conclusion

- When uncertainty about future fundamentals is low...
  - investors demand lower equity premia $\Rightarrow$ stock prices high
  - firms worry less about financing constraints
    pay out more & borrow to exploit tax advantage of debt
- Two types of uncertainty shocks
  - low frequency shift in volatilities (1970s slump)
    decouples real from financial quantities
  - business cycle frequency shifts in investor confidence
    synchronize real & financial variables

Evolution of confidence

- Describe ambiguity by two processes: $a_{t,i} = \eta_{t,i}\sigma_{t,i}$

1. Intangible information affects confidence
2. Volatility lowers confidence (first order effect)

- Linearity follows if $\mathcal{P}_t$ is relative entropy ball around $\mu_t = 0$:

$$\frac{\mu_{t,i}^2}{2\sigma_{t,i}^2} \leq \frac{1}{2}\eta_{t,i}^2$$

- Identification of $\eta_{t,i}$ vs. $\sigma_{t,i}$
  - same effect on decision rules, through $a_{t,i}$
  - but $\sigma_{t,i}$ is a change to the second moment of innovations
  - while $\eta_{t,i}$ does not change any moment of fundamentals

Back

Beliefs vs data

- True DGP for shock x_i

$$x_{t+1,i} = \rho_i x_{t,i} + \tilde{\sigma}_{t,i}\varepsilon_{t+1,i} + \mu^*_{t,i}$$

  - deterministic sequence $\{\mu^*_{t,i}\}$ unknown
    empirical moments same as iid normal process with mean zero & variance $\sigma^2_{i,\mu}$
  - cannot identify $\mu^*_{t,i}, \tilde{\sigma}_{t,i}$ without further assumptions
- Econometrician
  - resolve uncertainty probabilistically by assuming stationarity
  - represent uncertainty as risk

$$x_{t+1,i} = \rho_i x_{t,i} + \sigma_{t,i}\varepsilon_{t+1,i}$$

  where $\sigma^2_{t,i} = \tilde{\sigma}^2_{t,i} + \sigma^2_{i,\mu}$
- Agents
  - consider nonstationary models given by different $\mu^*_{t,i}$s
  - treat $\mu^*_{t,i}$ as ambiguous
  - respond to uncertainty as if minimizing over $[-a_{t,i}, a_{t,i}]$ Back

Parametrization

- Operating cost
  - heteroskedastic innovations

$$\log f_{t+1} = \log \bar{f} + \rho_f \log f_t + \sigma_f(\xi_t^{vol})\varepsilon_{t+1}^f$$

  - ambiguity depends on 2 state Markov chains

$$a_{t,f} = \eta_f(\xi_t^{amb})\sigma_f(\xi_t^{vol})$$

- Production technology
  - allow for negative correlation between shock Z_t & ambiguity

$\rightarrow$ Z_t depends on regime

$$\log Z_{t+1} = \bar{z} + \rho_z \log Z_t + \sigma_z(\xi_t^{vol})\varepsilon_{t+1}^z + v_{t+1}$$
$$v_{t+1} = -\chi\left(\eta_z(\xi_{t+1}^{amb})\sigma_z(\xi_{t+1}^{vol}) - E_t\left[\eta_z(\xi_{t+1}^{amb})\sigma_z(\xi_{t+1}^{vol})\right]\right)$$

$\rightarrow$ ambiguity has continuous component $\hat{a}_t$

$$a_{t,z} = \eta_z(\xi_t^{amb})\sigma_z(\xi_t^{vol}) + \hat{a}_{t,z}$$
$$\hat{a}_{t+1,z} = \rho_a \hat{a}_{t,z} - \chi^{-1}\sigma_z\left(\xi_t^{vol}\right)\varepsilon_{t+1}^z$$

Parameters

- Volatility regimes

$$\text{`High'}: \ \sigma_f = 1.11; \ \sigma_z = 0.017$$
$$\text{`Low'}: \ \sigma_f = 0.61; \ \sigma_z = 0.0171$$

- Ambiguity estimates:

$$\text{`High'}: \ \eta_f = 0.2; \ \eta_z = 0.87$$
$$\text{`Low'}: \ \eta_f = 0.07; \ \eta_z = 0.82$$

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- Steady states:

$$\bar{f} \,/\, GDP = 0.12\%; \ f^{worst} \,/\, GDP = 1.1\%$$
$$D \,/\, GDP = 9\%; \ D^{worst} \,/\, GDP = 3.5\%;$$
$$E_t^* f_{t+1} \,/\, GDP = 0.12\% * 1.07$$

- Sample smoothed estimates

$$\max f_t \,/\, GDP \approx 0.7\%$$
$$\max E_t^* f_{t+1} \,/\, GDP \approx 0.7\% * 1.22$$