Uncertainty Shocks, Asset Supply and Pricing over the Business Cycle

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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

Log(equity value/GDP)

Investment growth, % p.a.

Log(net equity payout/GDP)

Net change in debt, % GDP
Excess return predictability: high prices, low future excess return

Predictability regression $R = a + b \log(P/D) + \epsilon$; $R^2 = 0.42$
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
   - **Uncertainty shocks & business cycles:** Ilut & Schneider (2012).

2. Asset pricing in production economies & uncertainty shocks
   - **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
Preferences: ambiguity aversion

- \( S = \text{state space} \)
  - 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
  \[
  U_t(C; s^t) = u(C_t(s^t)) + \beta \min_{p \in \mathcal{P}_t(s^t)} E^p [U_{t+1}(C; s^{t+1})]
  \]
- Primitives:
  - felicity \( u \), discount factor \( \beta \)
  - 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: $s^t = \text{history of innovations to exogenous shocks}$
- 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)

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

Entropy
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

\[ D_t = \text{Profits} - \text{Investment} - \text{corporate income tax} + Q^b_t B_t - B_{t-1} - 0.5\psi B^2_{t-1} + \tau B_{t-1}(1 - Q^b_{t-1}) - 0.5\phi (D_t / D_{t-1} - 1)^2 - F_t \]

1. Debt
   - \( Q^b_t \) = 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

\[
(1 + \tau_c) C_t = (1 - \tau_f) \left[ (1 - \alpha) Y_t + D_t \theta_{t-1} \right] + P_t (\theta_{t-1} - \theta_t) \\
+ B^h_{t-1} - Q^b_t B^h_t - \tau_f \left\{ B^h_{t-1} (1 - Q^b_{t-1}) + (P_t - P_{t-1}) \theta_{t-1} \right\}
\]

- 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

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

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

- Iterating forward

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

- For \( P/D \) volatility, want:
  1. Changes in expected growth rate of dividend share \( \hat{s}_t := \hat{d}_t - \hat{c}_t \)
  2. Under the worst-case conditional expectation
  3. But stable interest rates: small movements in \( E_t^* (\hat{c}_{t+\tau} - \hat{c}_t) \)

- Want ambiguity about dividends, not consumption!
Excess return predictability

- Excess stock return

  \[ x_{t+1}^e = \log(p_{t+1} + d_{t+1}) - \log p_t - \log(i_t) \]

  \[ \approx \beta [\hat{p}_{t+1} - \hat{d}_{t+1} - E_t^* (\hat{p}_{t+1} - \hat{d}_{t+1})] + (\hat{d}_{t+1} - E_t^* \hat{d}_{t+1}) \]

- Econometrician sees time varying expected excess returns
  - regression of excess returns on time t info gets \( E_t x_{t+1}^e \)
  - conditional premia reflect \( E_t - E_t^* \)
  - lower confidence = higher premia

- Movements in \( E_t x_{t+1}^e \): from stock returns, not interest rate
  - action from \( E_t^* \hat{d}_{t+1} \), not from \( E_t^* \hat{c}_{t+1} \)
Firm financing: response to shocks

- **Firm objective:** \( \max E_0^* \sum_{t=1}^{\infty} M_t D_t \)

\[
D_t = \text{Net Profits} + Q_t^b B_t - B_{t-1} \left[ 1 - \tau (1 - Q_{t-1}^b) \right] - 0.5\psi B_{t-1}^2 \\
- 0.5\phi \left( \frac{D_t}{D_{t-1}} - 1 \right)^2 - F_t
\]

- **FOC wrt \( B_t \):**

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

- 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 \(\zeta^{amb}_t\) and \(\zeta^{vol}_t\)
  - allow for negative correlation between shock \(Z_t\) & ambiguity
    (high uncertainty leads to lower MPK as in Ilut-Schneider 2012)

- **DSGE solution:**

\[
S_t = C \left( \zeta^{vol}_t, \zeta^{amb}_t \right) + TS_{t-1} + R\sigma \left( \zeta^{vol}_{t-1} \right) \varepsilon_t
\]

- linearity → 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

Log(Equity Value/GDP)

Log(Dividends/GDP)

Investment Growth

Debt/Equity Value

$10^{-3}$ Real Interest rate

Model: no obs. error

Data

Bianchi, Ilut, Schneider
Uncertainty Shocks, Asset Supply, Pricing
Smoothed regime probabilities of High Uncertainty regimes

Probability High Volatility

Probability High Ambiguity
Effects of Low ambiguity regime

![Graphs showing various economic indicators](image-url)
Effects of High volatility regime

- Log(Equity Value/GDP)
- Log(Dividends/GDP)
- Investment Growth
- Real Rate
- Debt/GDP
- Debt/Equity Value
Evolution on historical typical regime path

- **Log(Equity Value/GDP)**
  - 1960: 1.3
  - 1980: 1.4
  - 2000: 1.5

- **Log(Dividends/GDP)**
  - 1960: −2
  - 1980: 0
  - 2000: 2

- **Real Rate**
  - 1960: −2.8
  - 1980: −2.6
  - 2000: −2.4

- **Investment Growth**
  - 1960: 0.55
  - 1980: 0.6
  - 2000: 0.65

- **Debt/GDP**
  - 1960: 0.5
  - 1980: 1
  - 2000: 1.5

- **Regime sequence**
  - A(L) V(L)
  - A(H) V(L)
  - A(L) V(H)
  - A(H) V(H)
Conclusion

- When uncertainty about future fundamentals is low...
  - investors demand lower equity premia ⇒ 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
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 $\sigma_{i,\mu}^2$
  - 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 $\sigma_{t,i}^2 = \tilde{\sigma}_t,i^2 + \sigma_{i,\mu}^2$

- Agents
  - Consider nonstationary models given by different $\mu^*_{t,i}$s
  - Treat $\mu^*_{t,i}$ as ambiguous
  - Respond to uncertainty as if minimizing over $[-a_{t,i}, a_{t,i}]$
Parametrization

- Operating cost
  - heteroskedastic innovations
    \[
    \log f_{t+1} = \log \bar{f} + \rho_f \log f_t + \sigma_f(\zeta_{t}^{vol})\varepsilon_{t+1}^f
    \]
  - ambiguity depends on 2 state Markov chains
    \[
    a_{t,f} = \eta_f(\zeta_{t}^{amb})\sigma_f(\zeta_{t}^{vol})
    \]

- Production technology
  - allow for negative correlation between shock $Z_t$ & ambiguity
    \[
    Z_t \text{ depends on regime}
    \]
  \[
  \log Z_{t+1} = \bar{z} + \rho_z \log Z_t + \sigma_z(\zeta_{t}^{vol})\varepsilon_{t+1}^z + \nu_{t+1}
  \]
  \[
  \nu_{t+1} = -\chi \left( \eta_z(\zeta_{t+1}^{amb})\sigma_z(\zeta_{t+1}^{vol}) - E_t \left[ \eta_z(\zeta_{t+1}^{amb})\sigma_z(\zeta_{t+1}^{vol}) \right] \right)
  \]
  - ambiguity has continuous component $\hat{a}_t$
    \[
    a_{t,z} = \eta_z(\zeta_{t}^{amb})\sigma_z(\zeta_{t}^{vol}) + \hat{a}_{t,z}
    \]
    \[
    \hat{a}_{t+1,z} = \rho_a \hat{a}_{t,z} - \chi^{-1}\sigma_z(\zeta_{t}^{vol}) \varepsilon_{t+1}^z
    \]
Parameters

- Volatility regimes

  ‘High’: $\sigma_f = 1.11$; $\sigma_z = 0.017$
  ‘Low’: $\sigma_f = 0.61$; $\sigma_z = 0.0171$

- Ambiguity estimates:

  ‘High’: $\eta_f = 0.2$; $\eta_z = 0.87$
  ‘Low’: $\eta_f = 0.07$; $\eta_z = 0.82$
Parameters

- Volatility regimes
  - ‘High’: $\sigma_f = 1.11$; $\sigma_z = 0.017$
  - ‘Low’: $\sigma_f = 0.61$; $\sigma_z = 0.0171$

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  - ‘High’: $\eta_f = 0.2$; $\eta_z = 0.87$
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- Steady states:
  - $\bar{f} / GDP = 0.12\%$; $f^\text{worst} / GDP = 1.1\%$
  - $D / GDP = 9\%$; $D^\text{worst} / GDP = 3.5\%$
  - $E_t^* f_{t+1} / GDP = 0.12\% \times 1.07$

- Sample smoothed estimates
  - $\max f_t / GDP \approx 0.7\%$
  - $\max E_t^* f_{t+1} / GDP \approx 0.7\% \times 1.22$