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

![Graphs showing equity/GDP, net equity payout, GDP growth, and net change in debt over time from 1960 to 2000. The graphs highlight periods of high volatility and show trends and fluctuations in these economic indicators.]
Excess return predictability: high prices, low future excess return

Predictability regression: $R = a + b \log(P/D) + \varepsilon$; $R^2 = 0.42$
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


2 **Business cycles, asset pricing & uncertainty shocks**

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
  \[
  U_t(C; s^t) = u(C_t(s^t)) + \beta \min_{p \in P_t(s^t)} E^p \left[ U_{t+1}(C; s^{t+1}) \right]
  \]
- Primitives:
  - felicity $u$, discount factor $\beta$
  - the one-step-ahead belief sets $P_t(s^t)$
- Larger set $P_t(s^t) \rightarrow$ 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 \( x_i \):
  \[
  x_{t+1,i} = \rho_i x_{t,i} + \sigma_i \varepsilon_{t+1,i} + \mu_{t,i} \\
  \mu_{t,i} \in [-a_{t,i}, a_{t,i}]
  \]
- 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

\[ \eta_{t,i} = (1 - \rho_{\eta,i}) \bar{\eta}_i + \rho_{\eta,i} \eta_{t-1,i} + \varepsilon_{t,\eta_i} \]

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 \( i.i. \mathcal{N} \left( 0, \sigma_{\mu}^2 \right) \)
  - 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

\[
\max E_0^* \sum_{t=1}^{\infty} M_t D_t
\]

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

- Key inputs:
  - expectations are under the HH’s worst-case conditional probabilities
  - 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 \(\rightarrow\) more \(D_t\), less \(B_t\))
  - + for 'uncertainty shocks' (ex. high \(E_t^* D_{t+1}\) \(\rightarrow\) more \(B_t\) and \(D_t\))
Price volatility & excess return predictability

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

- Excess return
  \[ x_{t+1}^e = \log(p_{t+1} + d_{t+1}) - \log p_t - \log(i_t) \approx \beta (\hat{p}_{t+1} - E_t^* \hat{p}_{t+1}) + (1 - \beta) (\hat{d}_{t+1} - E_t^* \hat{d}_{t+1}) \]

- 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 \( \Delta C \)
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:

\[ S_t = C(\xi_t) + TS_{t-1} + R\sigma(\xi_{t-1})\varepsilon_t \]

- time-variation in constant: from effect of volatility regime $\xi_t$

3. compute value function under worst case belief
4. verify that the guess $p^0$ indeed achieves the minimum
Estimation

- DSGE solution:

\[ S_t = C(\xi_t) + TS_{t-1} + R\sigma(\xi_{t-1})\varepsilon_t \]

- Linearity → 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

- **P/GDP ratio**
  - 1960: 1.3
  - 1970: 1.35
  - 1980: 1.4
  - 1990: 1.45
  - 2000: 1.5
  - 2010: 1.55

- **Regime sequence**
  - 1960: 1
  - 1970: 1.5
  - 1980: 2
  - 1990: 2.5
  - 2000: 1
  - 2010: 1

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Equity price/GDP: ambiguity over borrowing fixed cost
Spectral Decomposition: Low volatility regime

ΔC

Div/GDP

SP/GDP

b^f/GDP

μ^*
ψ^f
f^f
g
Am
Apsif
Aff
Ag
Spectral Decomposition: High volatility regime

\[ \Delta C \]

\[ \text{Div/GDP} \]

\[ \text{SP/GDP} \]

\[ b^f/GDP \]
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 \( \bar{\sigma} \)
   2. Worst-case mean:
      \[
      \bar{x}_i = -\frac{\bar{\eta}_i \bar{\sigma}_i}{1 - \rho_i}
      \]
   3. Worst-case endogenous variable \( \bar{Y} = f(\bar{x}) \) from deterministic FOCs
   4. Linearize around \( \bar{Y}, \bar{\sigma}, \bar{\eta}, \bar{x} \) and solve a ‘rational expectations’ model under worst-case belief \( p^0 \)
      \[
      \tilde{Y}_t = C(\xi_t) + T\tilde{Y}_{t-1} + R\sigma(\xi_{t-1}) \varepsilon_t
      \]
      time-variation in constant: from first order effect of volatility regime \( \xi_t \)


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

   \[ Y^* - \bar{Y} = T (Y^* - \bar{Y}) + R\bar{\eta}\sigma \]

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

   \[ \hat{Y}_t = C(\xi_t) + T\hat{Y}_{t-1} + R\sigma(\tilde{\xi}_{t-1})\epsilon_t + R(\bar{\eta}\sigma(\tilde{\xi}_{t-1}) + \bar{\sigma}\tilde{\eta}_{t-1}) \]