The Tail that Wags the Economy: Belief-driven Business Cycles and Persistent Stagnation

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Introduction

The “Great Recession” spawned two major lines of business cycle research

- Belief shocks: News, sentiments, disaster risk, uncertainty...

- Secular stagnation: Long-lived adverse effects from large shocks
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- Most belief-driven theories have no internal propagation
- Effects only as persistent as exogenous persistence of belief shocks
- Cannot explain why some cycles are more persistent than others.
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Can belief changes explain persistent responses to transitory shocks?
Yes, when agents are learning about distributions (as opposed to hidden states)
This paper

A new approach to beliefs in business cycles

Agents estimate the distribution of aggregate shocks using real time data

- Empirical discipline on belief formation
- Delivers large, persistent responses to transitory shocks
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Results:

• Tail events have a large, permanent effect on beliefs
• Leverage amplifies belief revisions from left-tail shocks
• A calibrated model predicts a permanent 13% drop in US GDP
Contribution to the Literature

  - We add: new mechanism, acting through belief revisions

Belief-driven business cycles
  - Belief shocks: Gourio (2012), Angeletos and La’O (2013), Bloom (2009)...
    - We add: endogenous belief revisions, persistence
  - Learning models: Johannes et. al. (2012), Cogley and Sargent (2005)...
    - We add: production, flexible non-parametric distributions
  - Endogenous uncertainty: Fajgelbaum et.al. (2014), Straub and Ulbricht (2013)...
    - We add: empirical discipline, larger effects
Model

Preferences: Representative household

\[ U_t = \left[ (1 - \beta) \left( C_t - \zeta \frac{L_t^{1+\gamma}}{1 + \gamma} \right)^{1-\psi} + \beta \mathbb{E}_t \left( U_{t+1}^{1-\eta} \right)^{\frac{1-\psi}{1-\eta}} \right]^{\frac{1}{1-\psi}} \]

- \( M_{t+1} \equiv \left( \frac{dU_t}{dC_t} \right)^{-1} \frac{dU_t}{dC_{t+1}} \): Stochastic discount factor
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Technology: A continuum of firms, indexed by \( i \)

- Production: \( y_{it} = Ak_{it}^{\alpha} l_{it}^{1-\alpha} \)
- Aggregate capital quality shocks: \( k_{it} = \phi_t \hat{k}_{it} \quad \phi_t \sim G(\cdot) \quad iid \)
- Idiosyncratic shocks, \( \Pi_{it} = v_{it} [y_{it} + (1 - \delta)k_{it}] \)
- \( v_{it} \sim F(\cdot) \), common knowledge, \( iid \int v_{it} di = 1 \)
Model

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Beliefs:

- $$\mathbb{E}_t (\cdot) \equiv \mathbb{E} [\cdot | \mathcal{I}_t]$$: More on $$\mathcal{I}_t$$ later
Model

Labor markets

- Hired in advance, i.e. before observing aggregate/idiosyncratic shocks
- Non-contingent wages $\implies$ workers subject to default risk
- Economy-wide wage rate (in period $t$ consumption) $\mathcal{W}_t \equiv \left( \frac{dU_t}{dC_t} \right)^{-1} \frac{dU_t}{dL_{t+1}}$
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Credit markets

- Competitive lenders offer price schedules $q(\cdot)$ for 1-period bonds
- Total proceeds: $\chi q b_{it+1}$ where $\chi > 1$ reflects tax advantage of debt
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Default

- Firm assets sold to a identical new firm at a discount of $1 - \theta$
- Proceeds distributed pro-rata among bondholders and workers
The firm’s problem

\[ V(\Pi_{it}, B_{it}, S_t) = \max \left[ 0, \max_{d_{it}, \hat{k}_{it+1}, b_{it+1}, w_{it+1}, l_{it+1}} \left( d_{it} + \mathbb{E}_t M_{t+1} V(\Pi_{it+1}, B_{it+1}, S_{t+1}) \right) \right] \]

- **Dividends:** 
  \[ d_{it} \leq \Pi_{it} - B_{it} - \hat{k}_{it+1} + \chi q_{it} b_{it+1} \]

- **Discounted wages:** 
  \[ W_t \leq w_{it+1} q(\hat{k}_{it+1}, l_{it+1}, B_{it+1}, S_t) \]

- **Future obligations:** 
  \[ B_{it+1} = b_{it+1} + w_{it+1} l_{it+1} \]

- **Resources:** 
  \[ \Pi_{it+1} = v_{it+1} \left[ A(\phi_{t+1} \hat{k}_{it+1})^\alpha l_{it+1}^{1-\alpha} + (1 - \delta) \phi_{t+1} \hat{k}_{it+1} \right] \]

- **Bond price:** 
  \[ q(\hat{k}_{it+1}, l_{it+1}, B_{it+1}, S_t) = \mathbb{E}_t M_{t+1} \left[ r_{it+1} + (1 - r_{it+1}) \frac{\theta \tilde{V}_{it+1}}{B_{it+1}} \right] \]

- Dividends \( d_{it} \) can be negative, i.e. no financing constraints
- Default policy \( r_{it+1} \in \{0, 1\} \) and value \( \tilde{V}_{it+1} \equiv V(\Pi_{it}, 0, S_t) \)
- Aggregate state: \( S_t \) (includes information)
Information and learning

- Distribution $G$ of aggregate shocks unknown to agents
  - $\mathcal{I}_t$: (Finite) History of aggregate variables $\rightarrow \{\phi_{t-s}\}_{s=0}^T$

- Agents construct an estimate $\hat{G}_t$ from observed data
  - Use a standard Gaussian kernel density estimator
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- Equilibrium concept: anticipated utility
  - Agents myopic with respect to belief changes, but otherwise rational
The mechanism

$$\max_{\hat{k}_{t+1}, l_{t+1}, lev_{t+1}} \quad - \quad \hat{k}_{t+1} - \chi W_t l_{t+1}$$

$$+ \quad \mathbb{E}_t [M_{t+1} \Pi_{t+1}] \quad + \quad (\chi - 1) q_t \cdot lev_{t+1} \cdot \hat{k}_{t+1} \quad - \quad (1 - \theta) \mathbb{E}_t [M_{t+1} (1 - r_{t+1}) \Pi_{t+1}]$$

Output + Undep capital + Tax advantage of debt - Cost of default

A negative shock → More pessimistic beliefs
- $\mathbb{E}_t [M_{t+1} \Pi_{t+1}]$ declines (also present without debt)
- Tax advantage goes down (because $q_t$ declines)
- Default costs rise
⇒ Lower incentives to invest and hire
The mechanism

\[
\max_{\hat{k}_{t+1}, l_{t+1}, lev_{t+1}} - \hat{k}_{t+1} - \chi W_t l_{t+1}
\]

\[
+ \mathbb{E}_t [M_{t+1} \Pi_{t+1}] + (\chi - 1) q_t \cdot lev_{t+1} \cdot \hat{k}_{t+1} - (1 - \theta) \mathbb{E}_t [M_{t+1} (1 - r_{t+1}) \Pi_{t+1}]
\]

Output + Undep capital  
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Calibration

Strategy: Match aggregate and cross-sectional moments of the US economy

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>$\beta$</td>
<td>0.91</td>
<td>Discount factor</td>
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<td>$\eta$</td>
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<td>Risk aversion</td>
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<td>$\psi$</td>
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<td>$1$/Intertemporal elasticity of substitution</td>
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<td>$\gamma$</td>
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<td>$\delta$</td>
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<td>$A$</td>
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<td>TFP</td>
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<tr>
<td>$\chi$</td>
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<td>Tax advantage of debt</td>
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<td>$\theta$</td>
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<td>Recovery rate</td>
</tr>
<tr>
<td>$\hat{\sigma}$</td>
<td>0.33</td>
<td>Idiosyncratic volatility</td>
</tr>
<tr>
<td>$lev^{Target}$</td>
<td>0.70</td>
<td>Leverage ratio</td>
</tr>
</tbody>
</table>
Measuring capital quality shocks

\[ \phi_t = \frac{K_t}{\hat{K}_t} = \frac{\text{value of capital}}{\text{yesterday’s capital + investment}} \]

**Observables**

\[ NFA_{t}^{RC} = \text{Replacement cost of non-financial assets (Flow of Funds)} \]
\[ NFA_{t}^{HC} = \text{Historical cost of non-financial assets (Flow of Funds)} \]
\[ PINDX_{t}^{k} = \text{Investment price index (BEA)} \]

**Model objects**

\[ P_t^k K_t = NFA_{t}^{RC} \]
\[ P_{t-1}^k \hat{K}_t = (1 - \delta) NFA_{t-1}^{RC} + P_{t-1}^k X_{t-1} \]
\[ = (1 - \delta) NFA_{t-1}^{RC} + NFA_{t}^{HC} - (1 - \delta) NFA_{t-1}^{HC} \]

\[ \Rightarrow \phi_t = \left( \frac{P_t^k K_t}{P_{t-1}^k \hat{K}_t} \right) \left( \frac{PINDX_{t-1}^k}{PINDX_t^k} \right) \]
Capital quality shocks

- Between 1950-2007, $\phi_t$ in a relatively tight range around 1
- Large negative shocks in 2008-09 $\rightarrow$ significant rise in tail risk
Effect of a transitory shock

Experiment:

- Start with beliefs estimated on 1950-2007 data, add '08 and '09 shocks
- Simulate aggregate variables, holding beliefs fixed
- (For now, leverage is also held fixed - relaxed later).
Effect of a transitory shock

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Baseline results:

- Compare to de-trended data
  
  *GDP close to the data, overshoot on capital and undershoot on labor*
Effect of a transitory shock

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- Start with beliefs estimated on 1950-2007 data, add '08 and '09 shocks
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Baseline results:
- Compare to de-trended data
  \textit{GDP close to the data, overshoot on capital and undershoot on labor}

Decomposition:
- Role of shock size: Contrast 2008-09 shocks (5\(\sigma\)) to 2001 shock (1\(\sigma\)).
  \textit{Small shocks have transitory effects}
- Role of learning: Use distribution implied by full sample throughout
  \textit{Without learning, initial impact similar, but less persistence}
- Role of leverage: Assume no debt \((\chi = 1, \text{Lev} = 0)\)
  \textit{Debt accounts for a third of the long-run effects}
- Role of higher moments: Assume \(\mathbb{E}(\phi_t) = 1\) throughout
  \textit{Higher moments account for more than half of total effect}
- Role of risk-aversion: Assume \(\psi = \eta = 0\), i.e. preferences are quasi-linear
  \textit{Risk aversion doubles effects, both in the short run and long run}
• A permanent drop in output of 13%
Results: Model vs Data

- Data: Deviations from log-linear, pre-crisis trend
Persistent vs Permanent?

What would temper our long-run effects?
Persistent vs Permanent?

What would temper our long-run effects?

**Answer:** if long-run beliefs differ significantly from current, e.g. because of

- New data, e.g. a long period without crises or with very good shocks
- Agents discount (or forget) past data
- Agents perceive regime changes (the distribution changes over time)
Results: Role of shock size

- Small shocks → small belief revisions → negligible long-run effects
Results: Role of learning

- No learning → effects are transitory
Results: Role of debt

- Debt accounts for one-third of long-run effects
Results: Role of higher moments

- Higher moments account for half of the long-run effects
Results: Role of risk aversion

- Risk aversion amplifies effects of belief revisions
Conclusion

- A simple, tractable framework of investment and hiring under learning

- Debt and large belief changes combine to generate significant - and *persistent* - declines in economic activity

- A potential explanation for the recent prolonged stagnation?
The quasi-linear case

- $\psi = \eta = 0 \implies M_{t+1} = \beta$

- Isolates the effect of belief revisions on returns

- Results presented for endogenous leverage
Optimality conditions

\[(1 - \theta) \mathbb{E}_t [M_{t+1} \nu f (\nu)] = \left(\frac{\chi - 1}{\chi}\right) \mathbb{E}_t [M_{t+1} (1 - F (\nu))]\]

\[1 = \mathbb{E}_t \left[ R^k_{t+1} J^k (\nu) \right] - \chi \mathcal{W}_t \frac{l_{t+1}}{\hat{k}_{t+1}}\]

\[\chi \mathcal{W}_t = \mathbb{E}_t \left[ M_{t+1} (1 - \alpha) A_{\phi_{t+1}}^\alpha \left( \frac{\hat{k}_{t+1}}{l_{t+1}} \right)^\alpha J'(\nu) \right]\]

where

\[R^k_{t+1} = \frac{A_{\phi_{t+1}}^\alpha \hat{k}_{t+1}^{1-\alpha} l_{t+1}^{1-\alpha} + (1 - \delta) \phi_{t+1} \hat{k}_{t+1}}{\hat{k}_{t+1}}\]

\[J^k (\nu) = 1 + \nu (\chi - 1) (1 - F (\nu)) + (\theta \chi - 1) h (\nu)\]

\[J' (\nu) = 1 + h (\nu) (\theta \chi - 1) - \nu^2 f (\nu) \chi (\theta - 1)\]

Now,

\[\chi = 1 \Rightarrow \nu = 0 \Rightarrow J^k = J' = 1\]
Simulation with belief revisions post-2009

- Capital quality shock
- GDP
- Capital
- Labor
With belief revisions post-2009

**Capital quality shock**

**GDP**

[Graph showing Capital quality shock with blue line and data points representing GDP with red dots and blue line.]

**Capital**

**Labor**

[Graphs showing the impact of capital quality shock on capital and labor with blue lines and red data points.]

[Graphs showing the GDP with blue line and red data points for the years 2010 to 2040.]