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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- Effects only as persistent as exogenous persistence of belief shocks
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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

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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

Secular stagnation: Summers (2014), Eggertsson and Mehrotra (2014), Gordon (2015)

- *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, $\Pi_{it} = v_{it} \left[y_{it} + (1-\delta) k_{it} \right]$
- $v_{it} \sim F(\cdot)$, common knowledge, iid $\int v_{it} di = 1$

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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 $\rightarrow$ 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

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

$$\begin{aligned}
\text{Dividends:} \quad & d_{it} \leq \Pi_{it} - B_{it} - \hat{k}_{it+1} + \chi q_{it} b_{it+1} \\
\text{Discounted wages:} \quad & \mathcal{W}_t \leq w_{it+1} q\left(\hat{k}_{it+1}, l_{it+1}, B_{it+1}, S_t\right) \\
\text{Future obligations:} \quad & B_{it+1} = b_{it+1} + w_{it+1} l_{it+1} \\
\text{Resources:} \quad & \Pi_{it+1} = v_{it+1} \left[A(\phi_{t+1} \hat{k}_{it+1})^{\alpha} l_{it+1}^{1-\alpha} + (1-\delta)\phi_{t+1} \hat{k}_{it+1} \right] \\
\text{Bond price:} \quad & q\left(\hat{k}_{it+1}, l_{it+1}, B_{it+1}, S_t\right) = \mathbb{E}_t M_{t+1} \left[r_{it+1} + (1 - r_{it+1}) \frac{\theta \tilde{V}_{it+1}}{B_{it+1}} \right]
\end{aligned}$$

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

The mechanism

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

$$+ \underbrace{\mathbb{E}_t \left[M_{t+1} \Pi_{t+1} \right]}_{\text{Output + Undep capital}} \quad + \quad \underbrace{(\chi - 1)\, q_t \cdot lev_{t+1} \cdot \hat{k}_{t+1}}_{\text{Tax advantage of debt}} \quad - \quad \underbrace{(1-\theta)\, \mathbb{E}_t \left[M_{t+1} (1 - r_{t+1}) \Pi_{t+1} \right]}_{\text{Cost of default}}$$

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A negative shock $\rightarrow$ More pessimistic beliefs

- $\mathbb{E}_t \left[M_{t+1} \Pi_{t+1} \right]$ declines (also present without debt)
- Tax advantage goes down (because q_t declines)
- Default costs rise

$\Rightarrow$ **Lower incentives to invest and hire**

Calibration

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

Parameter	Value	Description
β	0.91	Discount factor
η	10	Risk aversion
ψ	0.50	1/Intertemporal elasticity of substitution
γ	0.50	1/Frisch elasticity
ζ	1	Labor disutility
α	0.40	Capital share
δ	0.03	Depreciation rate
A	1	TFP
χ	1.06	Tax advantage of debt
θ	0.70	Recovery rate
$\hat{\sigma}$	0.33	Idiosyncratic volatility
lev^{Target}	0.70	Leverage ratio

Measuring capital quality shocks

$$\phi_t = \frac{K_t}{\hat{K}_t} = \frac{\text{value of capital}}{\text{yesterday's capital} + \text{investment}}$$

Observables

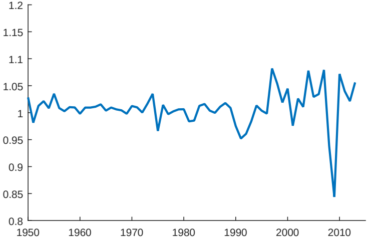
$$\begin{aligned} NFA_t^{RC} &= \text{Replacement cost of non-financial assets (Flow of Funds)} \\ NFA_t^{HC} &= \text{Historical cost of non-financial assets (Flow of Funds)} \\ PINDX_t^k &= \text{Investment price index (BEA)} \end{aligned}$$

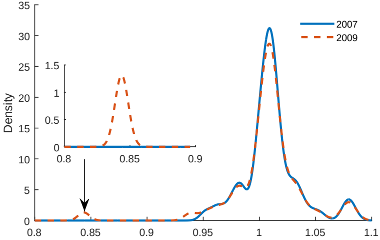
Model objects

$$\begin{aligned} P_t^k K_t &= NFA_t^{RC} \\ P_{t-1}^k \hat{K}_t &= (1-\delta) NFA_{t-1}^{RC} + P_{t-1}^k X_{t-1} \\ &= (1-\delta) NFA_{t-1}^{RC} + NFA_t^{HC} - (1-\delta)\, NFA_{t-1}^{HC} \\ \Rightarrow \qquad \phi_t &= \left(\frac{P_t^k K_t}{P_{t-1}^k \hat{K}_t} \right) \left(\frac{PINDX_{t-1}^k}{PINDX_t^k} \right) \end{aligned}$$

Capital quality shocks

- Between 1950-2007, ϕ_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*
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- Compare to de-trended data
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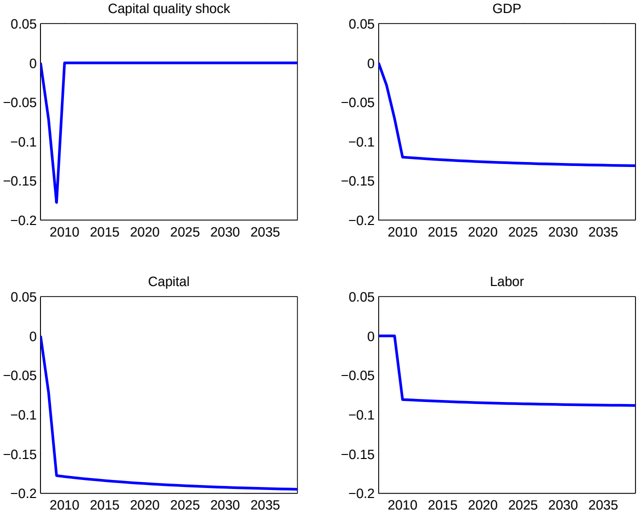
Decomposition:

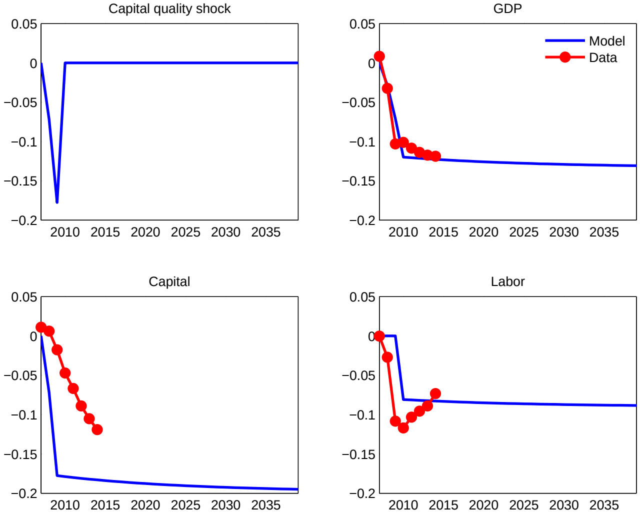
- Role of shock size: Contrast 2008-09 shocks (5σ) to 2001 shock (1σ).
  Small shocks have transitory effects
- Role of learning: Use distribution implied by full sample throughout
  Without learning, initial impact similar, but less persistence
- Role of leverage: Assume no debt ($\chi = 1$, $Lev =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

Results: Baseline



- 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 ?

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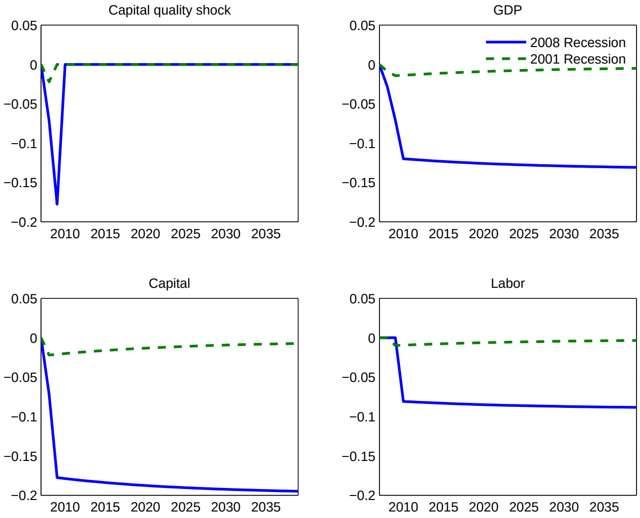
Answer: *if long-run beliefs differ significantly from current, e.g. because of*

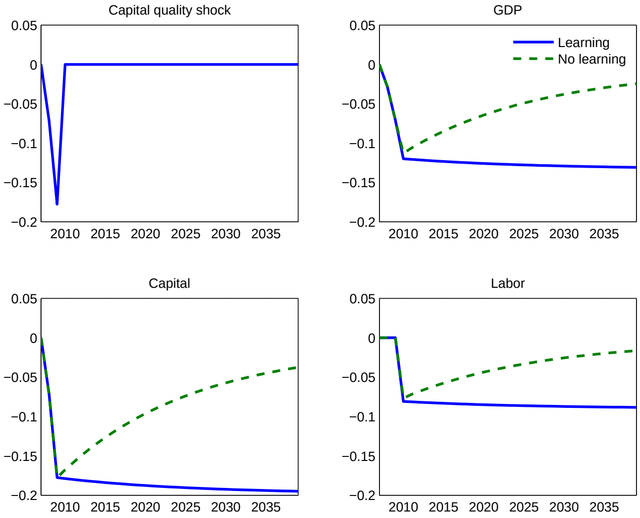
- *New data, e.g. a long period without crises or with very good shocks*
- *Agents discount (or forget) past data*
- *Agents perceive regime changes (the distribution g changes over time)*

Results: Role of shock size



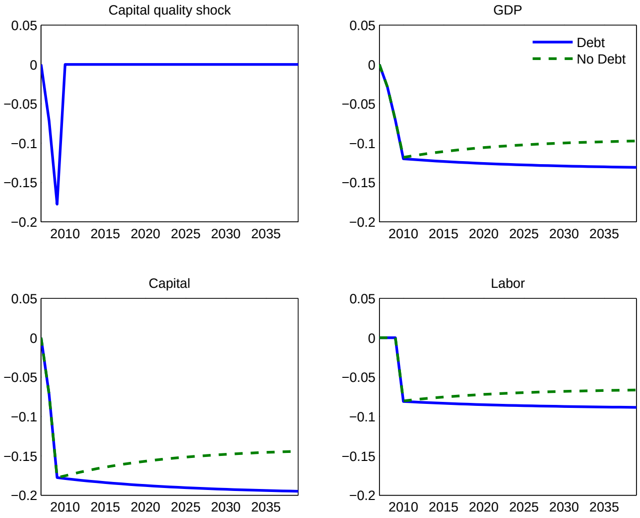
- Small shocks → small belief revisions → negligible long-run effects

Results: Role of learning



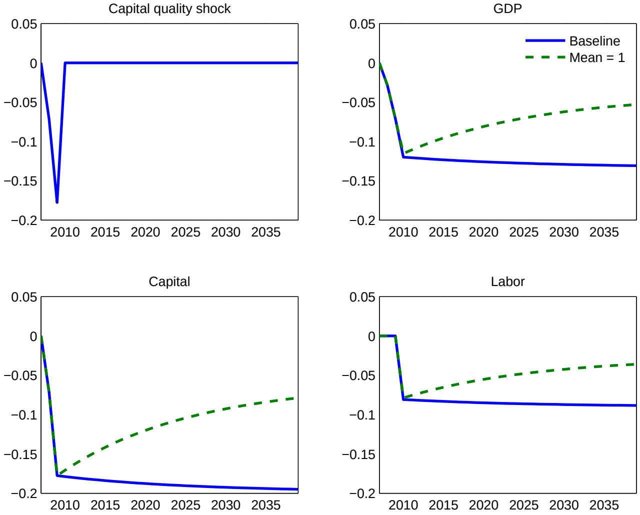
- No learning $\rightarrow$ effects are transitory

Results: Role of debt



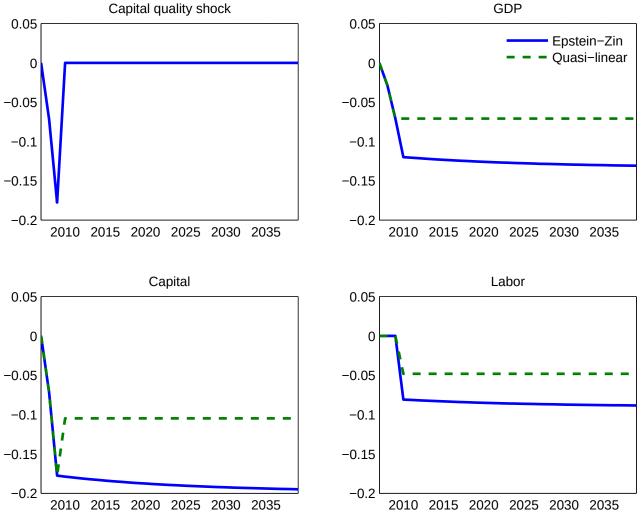
- Debt accounts for one-third of long-run effects

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

- $\psi = \eta = 0 \qquad \Rightarrow \qquad M_{t+1} = \beta$
- Isolates the effect of belief revisions on returns
- Results presented for endogenous leverage

Optimality conditions

$$
\begin{aligned}
(1-\theta)\,\mathbb{E}_t\left[M_{t+1}\underline{v}f\left(\underline{v}\right)\right] &= \left(\frac{\chi-1}{\chi}\right)\mathbb{E}_t\left[M_{t+1}\left(1-F\left(\underline{v}\right)\right)\right] \\
1 &= \mathbb{E}_t\left[M_{t+1}R^k_{t+1}J^k(\underline{v})\right] - \chi\mathcal{W}_t\frac{l_{t+1}}{\hat{k}_{t+1}} \\
\chi\mathcal{W}_t &= \mathbb{E}_t\left[M_{t+1}\left(1-\alpha\right)A\phi^{\alpha}_{t+1}\left(\frac{\hat{k}_{t+1}}{l_{t+1}}\right)^{\alpha}J^l(\underline{v})\right]
\end{aligned}
$$

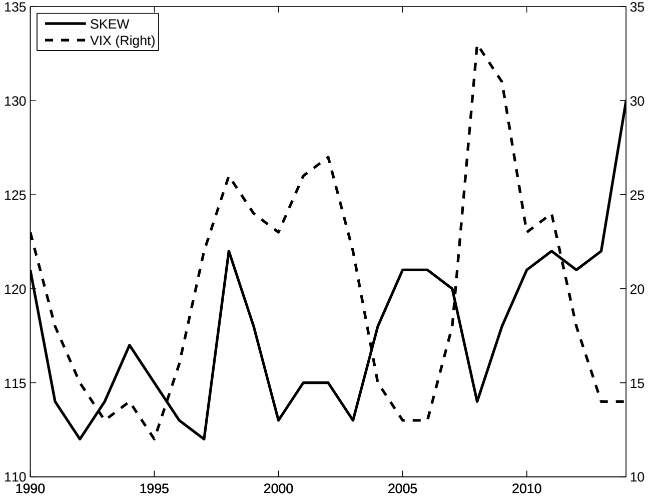
where

$$
\begin{aligned}
R^k_{t+1} &= \frac{A\phi^{\alpha}_{t+1}\hat{k}^{\alpha}_{t+1}l^{1-\alpha}_{t+1}+(1-\delta)\phi_{t+1}\hat{k}_{t+1}}{\hat{k}_{t+1}} \\
J^k(\underline{v}) &= 1+\underline{v}\left(\chi-1\right)\left(1-F\left(\underline{v}\right)\right)+\left(\theta\chi-1\right)h\left(\underline{v}\right) \\
J^l(\underline{v}) &= 1+h\left(\underline{v}\right)\left(\theta\chi-1\right)-\underline{v}^2f\left(\underline{v}\right)\chi\left(\theta-1\right)
\end{aligned}
$$

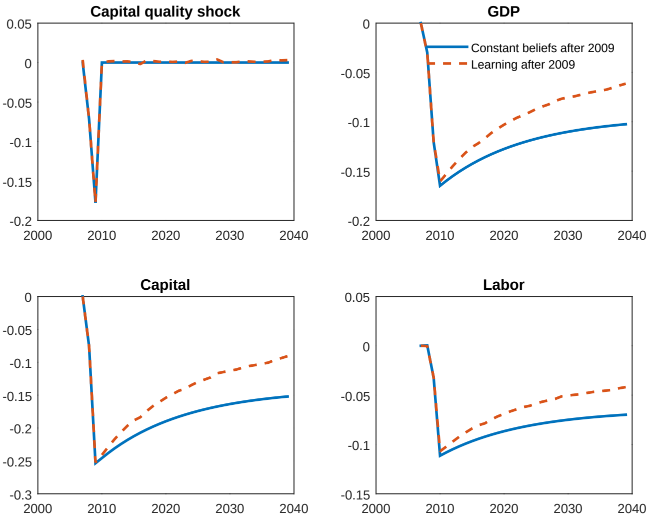
Now,

$$
\chi = 1 \quad\Rightarrow\quad \underline{v}=0 \quad\Rightarrow\quad J^k = J^l = 1
$$

Variance vs Tail Risk



Simulation with belief revisions post-2009



With belief revisions post-2009