Risk and Ambiguity in Models of Business Cycles

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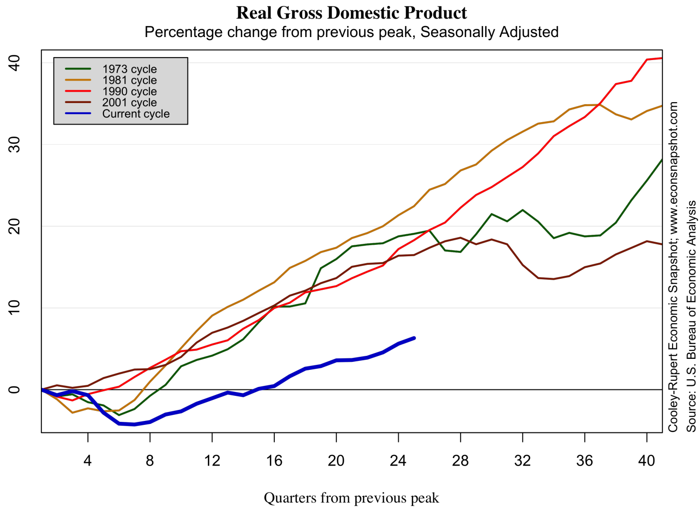
NYU STERN

The "Great Recession" and its aftermath



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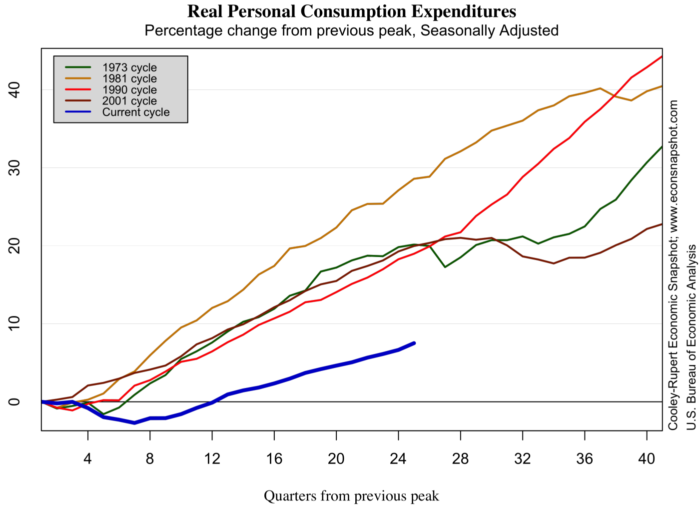

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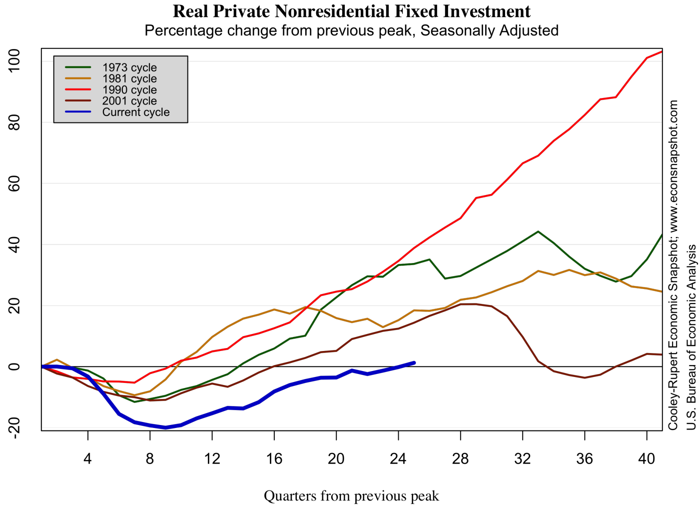

What happened?

- What we see
  - Magnitude: deeper recession than usual
  - Persistence: longer recovery — maybe slower, too
- Like Kydland-Prescott with productivity shocks?
  - Relative magnitudes look right
  - Comovements look right, too
  - But... measured productivity didn't fall very much

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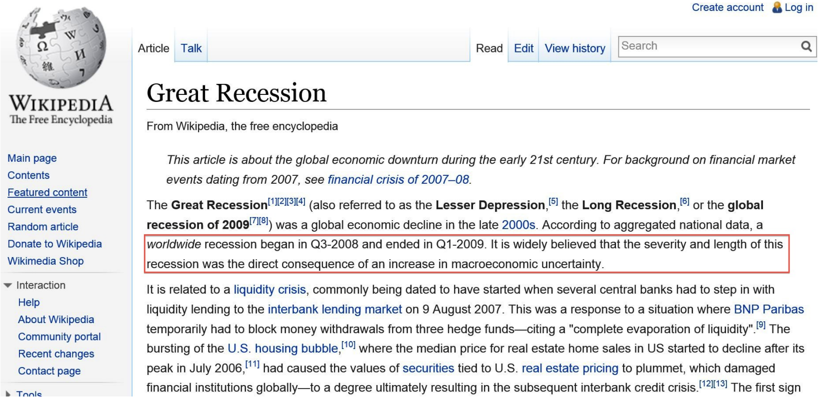
Was it uncertainty?



Great Recession

From Wikipedia, the free encyclopedia

This article is about the global economic downturn during the early 21st century. For background on financial market events dating from 2007, see financial crisis of 2007–08.

The **Great Recession**[1][2][3][4] (also referred to as the **Lesser Depression**,[5] the **Long Recession**,[6] or the **global recession of 2009**[7][8]) was a global economic decline in the late 2000s. According to aggregated national data, a *worldwide* recession began in Q3-2008 and ended in Q1-2009. It is widely believed that the severity and length of this recession was the direct consequence of an increase in macroeconomic uncertainty.

It is related to a liquidity crisis, commonly being dated to have started when several central banks had to step in with liquidity lending to the interbank lending market on 9 August 2007. This was a response to a situation where BNP Paribas temporarily had to block money withdrawals from three hedge funds—citing a "complete evaporation of liquidity".[9] The bursting of the U.S. housing bubble,[10] where the median price for real estate home sales in US started to decline after its peak in July 2006,[11] had caused the values of securities tied to U.S. real estate pricing to plummet, which damaged financial institutions globally—to a degree ultimately resulting in the subsequent interbank credit crisis.[12][13] The first sign

Was it uncertainty?

- Marco Buti, Director General of the European Commission

> *Economic theory suggests that* **uncertainty** *has a detrimental effect on economic activity by giving agents the incentive to postpone investment, consumption and employment decisions until uncertainty is resolved, and by pushing up the cost of capital through increased risk premia.*

What happened?

- Nick Bloom

> *The onset of the Great Recession was accompanied by a massive surge in* **uncertainty***. The size of this uncertainty shock was so large it potentially accounted for around one third of the 9% drop in GDP versus trend during 2008-2009.*

What we do

- Take a streamlined business cycle model
- Ask: How does **uncertainty** affect the **dynamics** of output, consumption, and investment?
  - Magnitude: Does uncertainty magnify fluctuations?
  - Persistence: Can it reduce the speed of recovery?

Modeling ingredients

- Streamlined **business cycle model**
    - Recursive preferences
    - Unit root in productivity
    - Fixed labor supply
- With fluctuations in **uncertainty**
    - *Risk* (stochastic volatility)
    - *Ambiguity* (unobservable long-term growth)

Preview of results

Fluctuations in uncertainty have **limited impact**

- Persistence
  - Separation property: internal **dynamics independent of risk and risk aversion**
  - Persistence must be in the shock
- Magnitude
  - Impact typically small, but magnified by **risk aversion**

Business cycle properties governed by IES

Risk and uncertainty

- **Recursive references**

$$\begin{aligned} U_t &= V[c_t, \mu_t(U_{t+1})] \\ &= [(1-\beta)c_t^{\rho} + \beta\mu_t(U_{t+1})^{\rho}]^{1/\rho} \\ \mu_t(U_{t+1}) &= [E_t(U_{t+1}^{\alpha})]^{1/\alpha} \end{aligned}$$

V, μ_t homogeneous of degree one, $RA = 1-\alpha$, $IES \equiv \sigma = 1/(1-\rho)$

- **Stochastic structure** of productivity a_t

$$\begin{aligned} \log g_t &= log(a_t/a_{t-1}) = \log g + e^{\top} x_t \;\; (\text{“productivity growth”}) \\ x_{t+1} &= Ax_t + v_t^{1/2} B w_{1t+1} \;\; (\text{“news”}) \\ v_{t+1} &= (1-\varphi_v)v + \varphi_v v_t + \tau w_{2t+1} \;\; (\text{“risk”}) \\ (w_{1t}, w_{2t}) &= \text{iid standard normals} \end{aligned}$$

Scaling

- Bellman equation

$$\begin{aligned} J(k_t, x_t, v_t, a_t) &= \max_{c_t} \; V\left\{c_t, \mu_t[J(k_{t+1}, x_{t+1}, v_{t+1}, a_{t+1})]\right\} \\ \text{s.t.} \qquad k_{t+1} &= f(k_t, a_t n) - c_t \end{aligned}$$

- Assume f $hd1$: $f(k, an) = k^{\omega}(an)^{1-\omega} + (1-\delta)k$
- **Rescaled** Bellman equation $[\tilde{k}_t = k_t/a_t,\ \tilde{c}_t = c_t/a_t]$

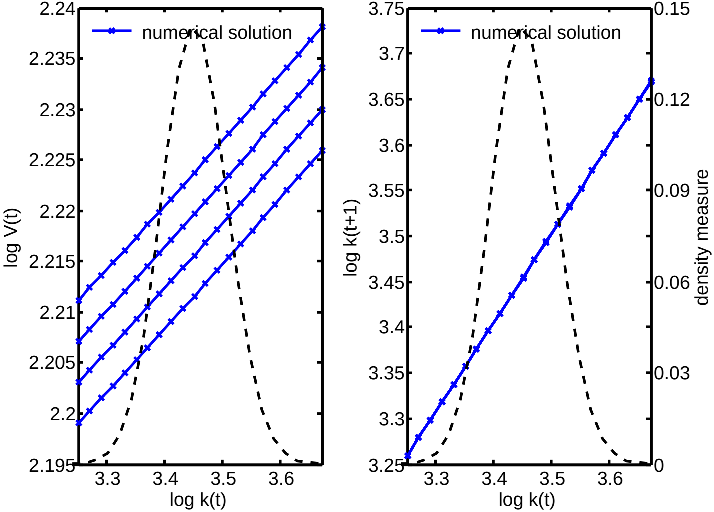
$$\begin{aligned} J(\tilde{k}_t, x_t, v_t) &= \max_{\tilde{c}_t} \; V\left\{\tilde{c}_t, \mu_t[g_{t+1} J(\tilde{k}_{t+1}, x_{t+1}, v_{t+1})]\right\} \\ \text{s.t.} \qquad g_{t+1}\tilde{k}_{t+1} &= f(\tilde{k}_t, n) - \tilde{c}_t \end{aligned}$$

- Numerical solution

Parameter values

Parameter	Value	Comment
Preferences		
ρ	-1	$\sigma = 1/2$
α	-9	risk aversion $= 1 - \alpha = 10$
β	—	chosen to hit $k/y = 10$ (quarterly)
Technology		
ω	$1/3$	Kydland and Prescott (1982, Table I), rounded off
δ	0.025	Kydland and Prescott (1982, Table I)
Productivity growth		
$\log g$	0.004	Tallarini (2000, Table 4)
e	1	normalization
A	0	no predictable component ("news")
B	1	normalization
$v^{1/2}$	0.015	Tallarini (2000, Table 4), rounded off
φ_v	0.95	arbitrary
τ	0.74×10^{-5}	makes v three standard deviations from zero

Model is essentially loglinear



Insights from loglinearization I

- Goal: loglinear decision rule for capital

$$\log \tilde{k}_{t+1} \quad = \quad h_k \log \tilde{k}_t + h_x^\top x_t + h_v v_t - \log g_{t+1}$$

- Dynamic programming version of Campbell (JME, 1994)
- Loglinearization around the **stochastic** steady-state

Insights from loglinearization II

- Loglinearize **capital's marginal product** and **law of motion**

$$\begin{aligned}\log f_{kt} &= \lambda_r \log \tilde{k}_t + \lambda_0 \\ \log \tilde{k}_{t+1} &= \lambda_k \log \tilde{k}_t - \lambda_c \log \tilde{c}_t + \lambda_1 - \log g_{t+1}\end{aligned}$$

  where $(\lambda_k, \lambda_c, \lambda_r)$ are steady-state objects.

- Guess **loglinear value function and derivative**

$$\begin{aligned}\log J_t &= p_k \log \tilde{k}_t + p_x^\top x_t + p_v v_t + p_0 \\ \log J_t^{\rho-1} J_{k,t} &= q_k \log \tilde{k}_t + q_x^\top x_t + q_v v_t + q_0\end{aligned}$$

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Separation property

Claim

Consider the loglinear approximation of capital's law of motion,

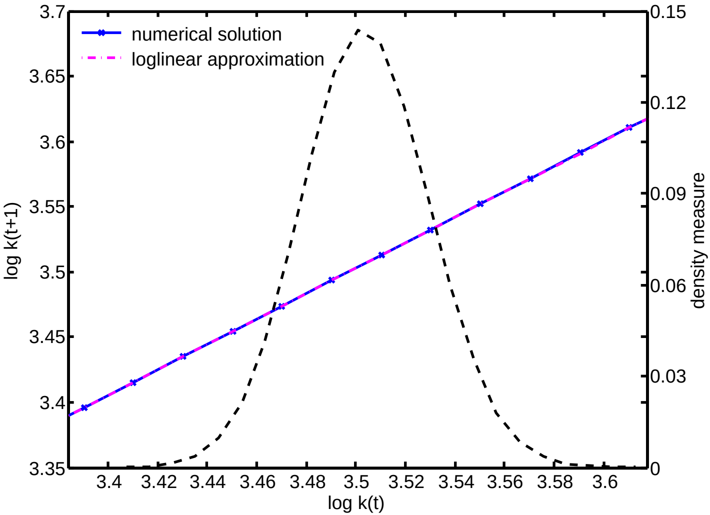
$$\log \tilde{k}_{t+1} = h_0 + h_k \log \tilde{k}_t + h_x^\top x_t + h_v v_t - \log g_{t+1}$$

If we hold constant the stochastic steady state:

1. h_k *is independent of* **properties of all shocks** *and* **risk aversion**
2. h_x *is independent of* **properties of uncertainty shocks** *and* **risk aversion**

$$\begin{aligned} h_k &= \lambda_k + \sigma\lambda_c(q_k - \lambda_r), \quad h_x^\top = \sigma\lambda_c q_x^\top \\ q_k &= q_k\left[\lambda_k + \sigma\lambda_c(q_k - \lambda_r)\right] + \lambda_r \\ q_x &= -(\sigma^{-1} + q_k)e^T A\left[(1 - \sigma q_k \lambda_c)I - A\right]^{-1} \end{aligned}$$

The claim is informative



Risk aversion magnifies uncertainty shocks

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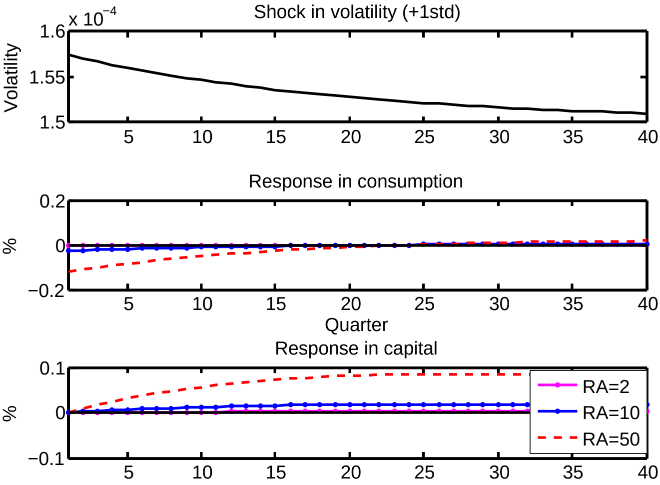

Business cycles governed by IES

	US Data	Benchmark			Cst. vol.
Risk Aversion		**2**	**10**	**50**	10
Standard deviations (%)					
Output growth	*1.04*	0.82	0.82	0.82	0.82
Consumption growth	*0.55*	0.75	0.75	0.76	0.75
Investment growth	*2.79*	1.03	1.04	1.06	1.02
Correlations with output growth					
Consumption growth	*0.52*	0.99	0.99	0.97	0.99
Investment growth	*0.65*	0.98	0.97	0.93	0.98

Intertemporal elasticity of substitution: 0.5

Business cycles governed by IES

	US Data	Benchmark	
IES		**0.5**	**1.5**
Standard deviations (%)			
Output growth	*1.04*	0.82	0.82
Consumption growth	*0.55*	0.75	0.39
Investment growth	*2.79*	1.04	1.92
Correlations with output growth			
Consumption growth	*0.52*	0.99	0.98
Investment growth	*0.65*	0.97	0.93

Risk aversion: 10

Risk and ambiguity

- Divide the state in two: $s_t = (s_{1t}, s_{2t})$
- **Ambiguity** (Klibanoff, Marinacci, & Mukerji; Ju & Miao)

$$\begin{aligned} \text{risk} &= p_{1t}(s_{1t+1}|s_{2t+1}, \mathcal{I}_t) \\ \text{ambiguity} &= p_{2t}(s_{2t+1}|\mathcal{I}_t) \end{aligned}$$

- Two-part certainty equivalent

$$\begin{aligned} \mu_{1t}(U_{t+1}) &= \left[E_{1t}(U_{t+1}^{\alpha})\right]^{1/\alpha} \\ \mu_{2t}[\mu_{1t}(U_{t+1})] &= \left\{E_{2t}[\mu_{1t}(U_{t+1})]^{\gamma})\right\}^{1/\gamma} \end{aligned}$$

α controls risk aversion, $\gamma < \alpha$ controls ambiguity aversion

A second certainty equivalent

- Rule of thumb: associate ambiguity with unobservables
- Consider three stochastic processes
  - x_t = **mean growth rate** (not observable)
  - $\log g_t$ = realized growth rate (observable)
  - v_t = "stochastic volatility"

$$\begin{aligned} \log g_t &= \log g + x_t + v_{t-1}^{1/2} w_{1,t} \\ x_{t+1} &= \varphi_x x_t + v_t^{1/2} w_{2,t+1} \\ v_{t+1} &= \varphi \bar{v} + (1 - \varphi_v) v_t + \tau w_{3,t+1} \end{aligned}$$

- Kill learning ($\varphi_x = 0$)
- Magnitudes small, separation property holds — as before

Calibration

Parameter	Value	Comment
Preferences		
ρ	-1	arbitrary
α	-9	arbitrary
γ	-29	arbitrary
β	—	chosen to hit $k/y = 10$ (quarterly)
Technology		
ω	$1/3$	Kydland and Prescott (1982, Table I), rounded off
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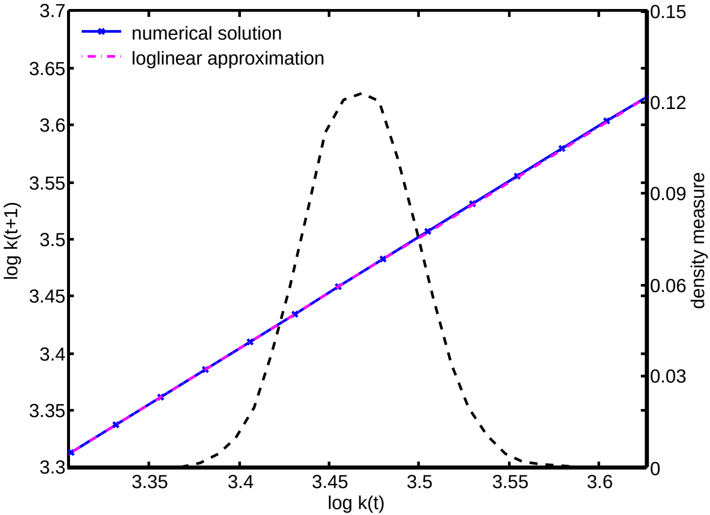
The model is still essentially loglinear



Learning?

- Absent stochastic volatility...

$$
\begin{aligned}
\log g_{t+1} &= \log g + x_{t+1} + \sigma_1 w_{1,t+1} \\
x_{t+1} &= \varphi x_t + \sigma_2 w_{2,t+1} \\
v_{t+1} &= (1-\varphi_v)\bar{v} + \varphi_v v_t + \tau w_{3,t+1}
\end{aligned}
$$

- Learning stabilizes: **No fluctuations in uncertainty**

$$
\begin{aligned}
\hat{x}_{t+1} &= \varphi \frac{\sigma_1^2}{A_t + \sigma_1^2} \hat{x}_t + \varphi \frac{A_t}{A_t + \sigma_1^2} \log\left(g_t/g\right) \\
A_{t+1} &= \sigma_2^2 + \frac{\varphi^2 A_t}{A_t + \sigma_1^1} \sigma_1^2
\end{aligned}
$$

Learning?

- Add stochastic volatility

$$
\begin{aligned}
\log g_{t+1} &= \log g + x_{t+1} + v_t^{1/2} w_{1,t+1} \\
x_{t+1} &= \varphi x_t + v_t^{1/2} w_{2,t+1} \\
v_{t+1} &= (1 - \varphi_v)\bar{v} + \varphi_v v_t + \tau w_{3,t+1}
\end{aligned}
$$

- **Fluctuating uncertainty**

Learning?

- Add stochastic volatility

$$\begin{aligned}\log g_{t+1} &= \log g + x_{t+1} + \sigma_1 w_{1,t+1} \\ x_{t+1} &= \varphi x_t + v_t^{1/2} w_{2,t+1} \\ v_{t+1} &= (1-\varphi_v)\bar{v} + \varphi_v v_t + \tau w_{3,t+1}\end{aligned}$$

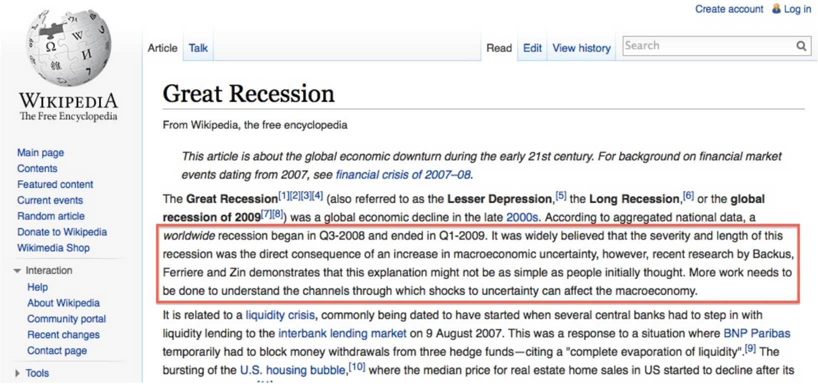
- Fluctuating uncertainty
- But will it break the **separation property**?

$$\log k_{t+1} = h_k \log k_t + m(x_t, \hat{x}_{t+1}, v_t, A_{t+1})$$

Summary

- Uncertainty fluctuations have intuitive appeal
- But they add little to standard business cycle model
    - Magnitude: impact is small with common parameter values
    - Persistence: they add nothing to internal dynamics, just the persistence of the shocks themselves

Open questions?



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It is related to a liquidity crisis, commonly being dated to have started when several central banks had to step in with liquidity lending to the interbank lending market on 9 August 2007. This was a response to a situation where BNP Paribas temporarily had to block money withdrawals from three hedge funds—citing a "complete evaporation of liquidity".[9] The bursting of the U.S. housing bubble,[10] where the median price for real estate home sales in US started to decline after its

Open questions

- What are we ambiguous about?
- What extensions hold the most promise?
    - Endogenous uncertainty
      Veldkamp; Fajgelbaum, Schaal, & Taschereau-Dumouchel
    - Idiosyncratic shocks
      Bachmann & Bayer; Bloom, Floetotto, Jaimovich, Saporta, & Terry
    - Financial frictions
      Cooley, Quadrini, & Marimon; Arellano, Bai, & Kehoe
- Other suggestions?

Related work (some of it)

- Recursive business cycles
  - Campanale, Castro, & Clementi; Tallarini
- Approximation methods
  - Anderson, Hansen, McGrattan, & Sargent; Campbell; Kaltenbrunner and Lochstoer; Malkhozov
- Risk and business cycles
  - Basu & Bundick; Caldara, Fernandez-Villaverde, Rubio-Ramirez, & Wen; Justiniano & Primiceri; Liu & Miao
- Ambiguity and business cycles
  - Ilut & Schneider; Jahan-Parvar & Miao; Ju & Miao;

Risk aversion magnifies uncertainty shocks

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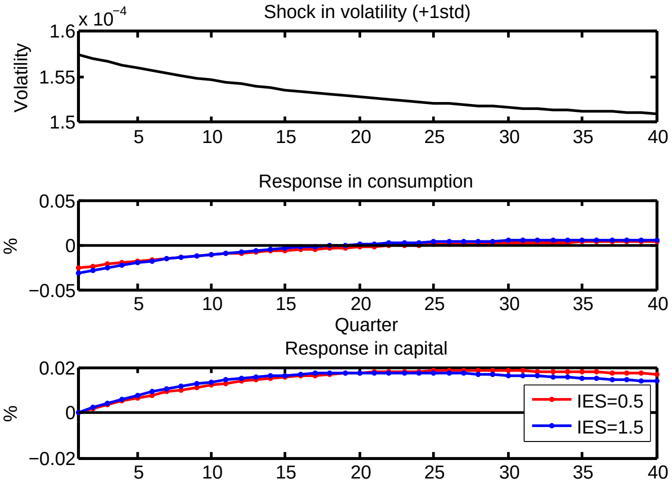
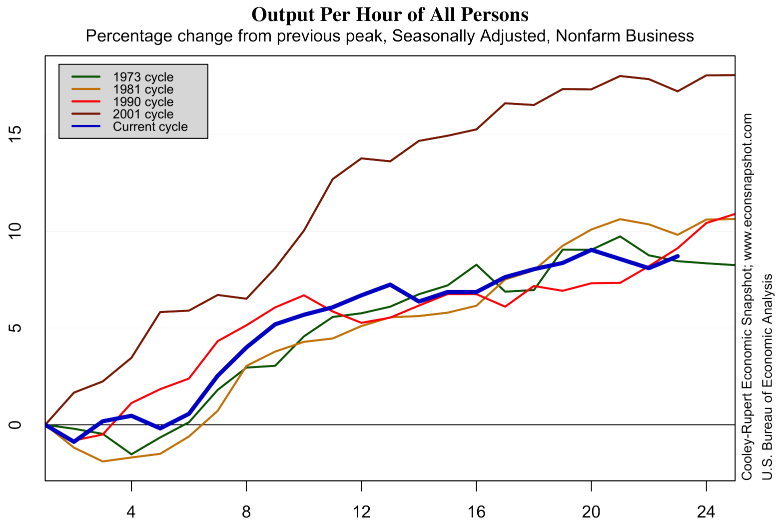


Productivity



Cooley-Rupert Economic Snapshot; www.econsnapshot.com
U.S. Bureau of Economic Analysis