

# Uncertainty, Real Activity, and Risk Aversion during the Great Recession

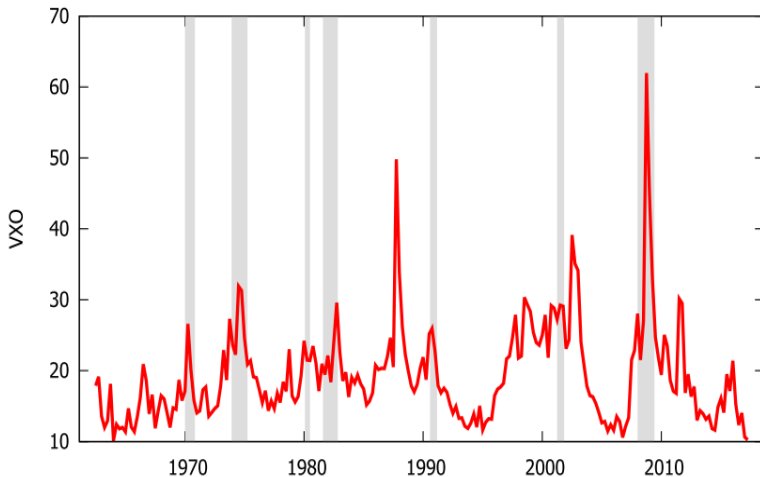
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Non-linearities: Policy Challenges and New Perspectives", Sept.  
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# Financial uncertainty and the business cycle



- Uncertainty during the Great Recession: Concern for policymakers

► Blanchard

# Financial uncertainty and the Great Recession

- ▶ "But while policymakers clearly think uncertainty has played a central role in driving the Great Recession and slow recovery, **the econometric evidence is really no more than suggestive.**" (Bloom, 2014)
- ▶ "An assumption of linearity may be adequate for estimating average relationships, but **few expect that an economy will respond linearly to every aberration.**" (Greenspan, 29 August 2003)

# Research questions

- ▶ **Q1: Real effects of uncertainty shocks:  
State-dependent? Great Recession vs. normal times?**
  - ▶ identification of new facts regarding the real effects of uncertainty shocks during the Great Recession
  - ▶ focus on financial uncertainty shocks, drivers of the business cycle (Ludvigson, Ma, and Ng 2019; Angelini, Bacchiocchi, Caggiano, and Fanelli 2019)
- ▶ **Q2: Structural interpretation of asymmetric effects of uncertainty shocks during the Great Recession?**
  - ▶ identification of structural drivers
  - ▶ calibration/estimation macro models for policy analysis

⇒ Need nonlinear models

# This paper

- ▶ **Estimate IVARs with post-WWII U.S. data**, GDP growth as conditioning indicator
  - ▶ Aim: State-dependent GIRFs to detect/quantify nonlinearities
- ▶ **Estimate nonlinear DSGE model à la Basu and Bundick (2017)** via Bayesian direct inference approach (Christiano et al., 2011)
  - ▶ Able to generate comovements to financial uncertainty shocks
  - ▶ Aim: Unveil whether/which structural instabilities in key parameters are needed to replicate the facts
- ▶ **Analyze Great Recession**
  - ▶ Output loss & implications for calibrating models for policy analysis, counterfactual on role of monetary policy

# Main findings

- ▶ **Responses of real activity indicators to uncertainty shocks: Stronger during Great Recession**
  - ▶ Larger than predicted by a linear VAR
- ▶ **Nonlinear effects of uncertainty shocks explained by counter-cyclical risk aversion**
  - ▶ Good fit of the DSGE model in both states (normal times/GR) thanks to parameter instability
  - ▶ High risk aversion crucial to replicate IVAR Great Recession responses
- ▶ **Great recession: Role of nonlinearities...**
  - ▶ DSGE model estimated conditional on nonlinear IVAR explains about 60% of the output loss in the 2008Q4-2014Q3 period; only 40% if a linear VAR is employed
- ▶ **Great recession: ... and policy counterfactual**
  - ▶ Fed's immediate and aggressive response helped to prevent a deeper recession

# Plan of the presentation

- ▶ Literature review
- ▶ IVAR model: Specification, estimation, evidence
- ▶ DSGE model: Review, estimation, evidence
- ▶ Great recession
- ▶ Conclusions

## Literature review

- ▶ **State-dependent effects of uncertainty shocks:** Caggiano, Castelnuovo, and Groshenny (2014), Caggiano, Castelnuovo, Nodari (2017), Caggiano, Castelnuovo, Figueres (2017); Alessandri and Mumtaz (2018); Chatterjee (2018a)
- ▶ **Interacted-VAR:** Mitnik (1990); Towbin and Weber (2013), Sáet al. (2014), Aastveit et al. (2017), Pellegrino (2017a,b), Caggiano, Castelnuovo, Pellegrino (2017)
- ▶ **Structural analysis of uncertainty-driven comovements:** Basu and Bundick (2017)
- ▶ **Bayesian IRF matching:** Christiano et al. (2011); Castelnuovo and Pellegrino (2018)
- ▶ **Estimation of III-order approx. DSGE frameworks:** Fernández-Villaverde et al. (2011, 2015), Rudebusch and Swanson (2012), Born and Pfeifer (2014), Andreasen, Fernández-Villaverde, Rubio-Ramírez (2017), Ruge-Murcia (2017); Chatterjee (2018b); Mumtaz and Theodoridis (2019)



Interacted VAR

## Interacted VAR

- ▶ IVAR à la Pellegrino (2017a,b), Caggiano, Castelnuovo, and Pellegrino (2017):

$$\mathbf{Y}_t = \alpha + \sum_{j=1}^L \mathbf{A}_j \mathbf{Y}_{t-j} + \left[ \sum_{j=1}^L \mathbf{c}_j \ln VXO_{t-j} \times \Delta \ln GDP_{t-j} \right] + \eta_t$$
$$E(\eta_t \eta_t') = \Omega$$

- ▶  $\mathbf{Y}_t = [\ln VXO_t, \ln GDP_t, \ln C_t, \ln I_t, \ln Hours_t, \ln P_t, R_t]'$
- ▶ Nonlinear effects of shocks to  $\ln VXO_t$  conditional on realizations of  $\Delta \ln GDP_{t-j}$
- ▶ Advantages of IVAR: Parsimonious framework, full sample estimation, resamples nonlinearity decision rules of III-order model while preserving stability [results robust to IVAR with higher order terms]
- ▶ [Shadow rate consistent with a negative policy rate in DSGE model (Wu and Zhang 2017; Mouabbi and Sahuc 2017)]

## Interacted-VAR (cont'd)

- ▶ Uncertainty can be (both) a cause and a consequence of business cycle fluctuations
- ▶ Uncertainty shocks identified using **narrative sign restrictions** as in Ludvigson et al. (LMN):
  - ▶  $\eta_t = \mathbf{B}e_t$ ,  $E(e_t e_t') = \mathbf{I}_n \Rightarrow \Omega = \mathbf{B}\mathbf{B}'$  ;  $\mathbf{B} = [\mathbf{b}_1, \dots, \mathbf{b}_n]$
  - ▶ Infinitely many solutions:
$$\mathcal{B} = \{ \mathbf{B} = \mathbf{P}\mathbf{Q} : \mathbf{Q} \in \mathcal{O}_n, \text{diag}(\mathbf{B}) \geq 0, \Omega = \mathbf{B}\mathbf{B}' \}$$
    - ▶  $\mathbf{Q}\mathbf{Q}' = \mathbf{I}_n$ ,  $\Omega = \mathbf{P}\mathbf{P}'$
  - ▶  $\rightarrow$  Impose restrict. to get the set of admissible solutions  $\bar{\mathcal{B}}$
- ▶ Constraints on  $e_t(\mathbf{B})$ :
  - ▶ *Event constraints*: identified unc shock >75th (1987Q4, 2008Q4) [LMN] or 50th (Bloom's dates + 2016Q1) percentile of the empirical density in selected dates (▶ [Dates](#))
  - ▶ *External variable constraints*: shocks must have negat. (posit.) correlation with stock market returns (gold price)

## Interacted-VAR (cont'd)

- ▶ GIRFs as in Koop et al. (1996), Kilian and Vigfusson (2011):

$$GIRF_{\mathbf{y}}(h, \delta, \boldsymbol{\omega}_{t-1}) = E[\mathbf{y}_{t+h} | \delta, \boldsymbol{\omega}_{t-1}] - E[\mathbf{y}_{t+h} | \boldsymbol{\omega}_{t-1}]$$

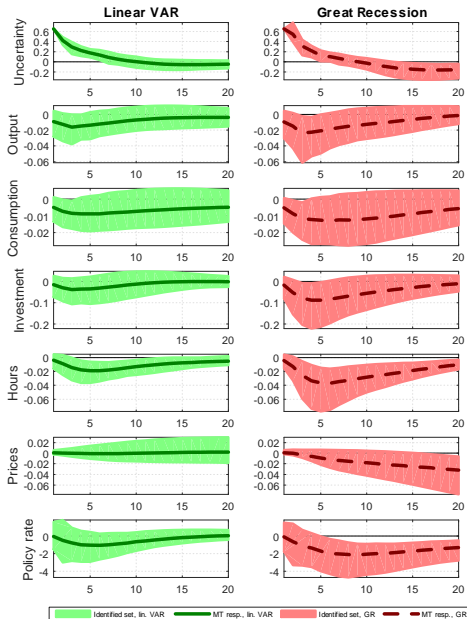
- ▶ Focus on two responses:

- ▶ **great recession**:  $GIRF_{\mathbf{y}}(h, \delta, \boldsymbol{\omega}_{2008Q3})$
- ▶ nested **linear VAR**:  $IRF_{\mathbf{y}}(h, \delta)$

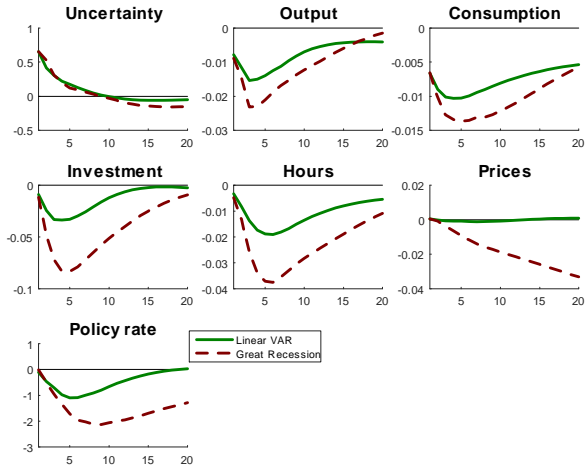
- ▶  $\delta = \delta_{2008Q4} = 4.4$  standard deviation uncertainty shock  
(▶ Distribution)

- ▶ Details: Sample: 1962Q3-2017Q4, VAR(4), OLS estimation
- ▶ Linearity rejected ( $pval < 0.01$ ) via LR tests

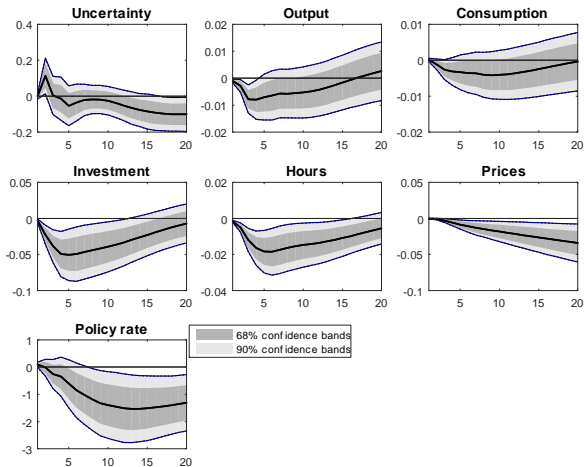
# IVAR results: State-conditional GIRFs



# IVAR results: Median Target GIRFs



# IVAR results: Difference of state-conditional GIRFs



► Model uncertainty

## IVAR results: main results

- ▶ Real effects of financial uncertainty shocks stronger during the Great Recession
- ▶ Results robust to: credit spread, higher-order terms, money, fiscal stance, LMN financial uncertainty, time-varying VCV  
(▶ checks)
- ▶ **DSGE model-related interpretation?**



DSGE framework

# DSGE model at a glance

- ▶ Medium-scale New Keynesian DSGE model à la Basu and Bundick (2017,2018)
  - ▶ sticky prices (Rotemberg), invest. adj. costs, var. cap. util.
- ▶ External habits in consumption added to generate hump-shaped responses
- ▶ EZ preferences:

$$V_t = \left[ (1 - \beta) \left( a_t \tilde{C}_t^\eta (1 - N_t)^{(1-\eta)} \right)^{\frac{1-\sigma}{\theta_V}} + \beta (E_t V_{t+1}^{1-\sigma})^{\frac{1}{\theta_V}} \right]^{\frac{\theta_V}{1-\sigma}}$$

$$\tilde{C}_t = C_t - H_t, \quad \text{with } H_t = bC_{t-1}$$

$$\theta_V \equiv (1 - \sigma) / (1 - \psi^{-1})^{-1}$$

- ▶ Demand-side uncertainty shock:

$$\begin{aligned} a_t &= (1 - \rho_a) a + \rho_a a_{t-1} + \sigma_a^a \varepsilon_t^a \\ \sigma_t^a &= (1 - \rho_{\sigma^a}) \sigma^a + \rho_{\sigma^a} \sigma_{t-1}^a + \sigma^{\sigma^a} \varepsilon_t^{\sigma^a} \end{aligned}$$

## DSGE model at a glance (cont'd)

- ▶ Comovements due to an uncertainty shock, economic intuition:  $unc \uparrow$ ,  $C \downarrow$ ,  $L^s \uparrow$ ,  $L^d =$ ,  $w \downarrow$ ,  $mc \downarrow$ ,  $p \approx$ ,  $markup \uparrow$ ,  $Y \downarrow$ ,  $L^d \downarrow$ ,  $H \downarrow$ ,  $I \downarrow$
- ▶ Model-implied VXO, match with our IVAR analysis:

$$VXO_t^M = 100 \cdot \sqrt{4 \cdot VAR_t(R_{t+1}^E)}$$

- ▶ DSGE IRFs can be captured directly by a VAR, direct inference sensible ▶ Monte Carlo

## DSGE model: State-dependent estimation

- ▶ Christiano et al.'s (2011) Bayesian Minimum Distance approach applied to a III-order approximated model, state-dependent estimation
- ▶ IVAR GIRFs as "data". Under some assumptions, able to write the (limited information) likelihood and characterize the (quasi-) posterior density
- ▶ Our application allows for state-dependent parameters, employs an observable variable to identify the states, and is not computationally cumbersome
- ▶ Basu and Bundick (2017) nonlinear model estimated on the basis of state-dependent GIRFs

## Christiano et al.'s (2011) Bayesian MD estimation

- ▶ IVAR GIRFs  $\widehat{\psi}^i$  as "data", distribution as a function of the true DSGE model parameters  $\zeta_0$ :

$$\widehat{\psi}^i \stackrel{a}{\sim} N(\psi(\zeta_0^i), \mathbf{V}^i(\zeta_0^i, n^i)), \text{ for } i = R, E$$

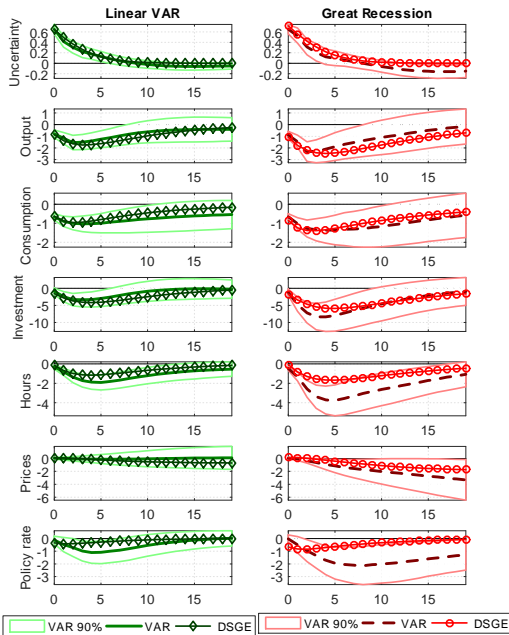
- ▶ Approx. likelihood (Kim 2002):

$$\begin{aligned} f(\widehat{\psi}^i | \zeta^i) &= \left( \frac{1}{2\pi} \right)^{\frac{N^i}{2}} \left| \mathbf{V}^i(\zeta_0^i, n^i) \right|^{-\frac{1}{2}} \\ &\quad \times \exp \left[ -\frac{1}{2} \left( \widehat{\psi}^i - \psi(\zeta^i) \right)' \mathbf{V}^i(\zeta_0^i, n^i)^{-1} \left( \widehat{\psi}^i - \psi(\zeta^i) \right) \right] \end{aligned}$$

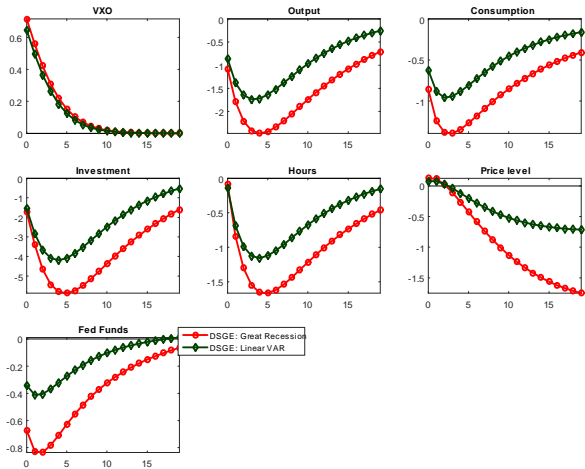
- ▶  $\psi(\zeta^i)$ : DSGE-based GIRFs (III order perturbation)
- ▶  $p(\zeta^i)$  common between regimes, posterior density (MCMC):

$$f(\zeta^i | \widehat{\psi}^i) = \frac{f(\widehat{\psi}^i | \zeta^i) p(\zeta^i)}{f(\widehat{\psi}^i)}$$

# DSGE fit: linear vs Great Recession



# DSGE's GIRFs



# DSGE model's estimated parameters

		Priors	Posteriors	
Parameter	Interpretation	D(mean,std)	Linear VAR	Great Recession
			All param. Mode,std	All param. Mode,std
$\rho_{\sigma^a}$	Unc.shock,pers.	B(0.77,0.10)	<b>0.64</b> , 0.03	<b>0.65</b> , 0.03
$\sigma$	Risk aversion	G(100,60)	<b>385.90</b> , 50.45	<b>533.04</b> , 59.16
$b$	Habits	B(0.75,0.15)	<b>0.64</b> , 0.06	<b>0.66</b> , 0.04
$\phi_K$	Inv. adj. costs	G(3.92,2)	<b>2.29</b> , 0.50	<b>3.21</b> , 0.60
$\phi_P$	Price adj. costs	G(240,40)	<b>236.78</b> , 32.26	<b>282.10</b> , 33.54
$\rho_{\pi}$	TR par., inflat.	IG(1.5,0.25)	<b>1.05</b> , 0.01	<b>1.05</b> , 0.01
$\rho_y$	TR par., out. gr.	G(0.2,0.15)	<b>0.20</b> , 0.04	<b>0.28</b> , 0.05



► calibrated parameters

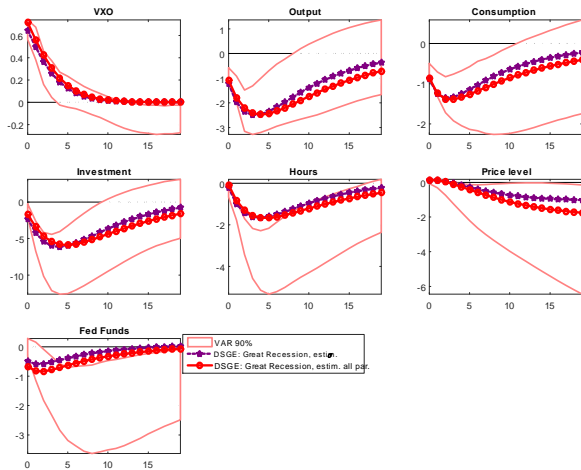


DSGE results: Drivers

# Role of state-dependent parameters

- ▶ Lots of instability in structural parameters, e.g. risk aversion, investment adj costs, price adj costs, CB response to output
- ▶ Relative role? Explorations conducted by swapping parameters one at a time point to risk aversion as crucial ( ▶ Counterfactual )
- ▶ Re-estimate our models by allowing for risk aversion only to be state-dependent; rest of the model calibrated with estimates conditional on linear VAR ( ▶ Distance criterion )

# A risk aversion-only story?



## DSGE model: Assessment

- ▶ Good performance of the model in replicating state-dependent IVARs
- ▶ Hours: Difficult to match, common across macro models.
  - ▶ Possibly, mismatch between theoretical concept and empirical counterpart due to heterogeneities on the labor market (Solon et al 1994); call for compositionally-adjusted measure of hours worked (Basu and Bundick 2017)
- ▶ Uncertainty persistence: unchanged

## DSGE model: Assessment (cont'd)

- ▶ **Crucial parameter: Higher risk aversion in Great Recession**, which implies (Swanson 2018 [▶ formula](#)):

$$RRA_{GR} = 145 > RRA_{lin} = 105$$

- ▶ Higher RRA in Great Recession in line with:
  - ▶ macro-finance (Cochrane 2017, Kim 2014)
  - ▶ experimental evidence (Cohn et al. 2015, Guiso et al. 2017)
  - ▶ surveys (Schildberg-Hörisch 2018)
- ▶ Nonlinearity implicit in the model not sufficient to match empirical facts ([▶ no endog. asymmetries](#))
- ▶ [Too high RRA?
  - ▶ Rudebusch and Swanson (2012): estimated RRA of 110
  - ▶ Barillas, Hansen and Sargent (2009): high RRA / true model vs. low RRA / doubts on model]

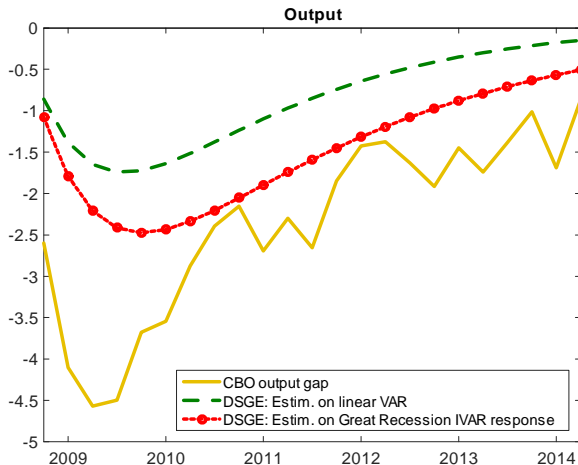
Output loss

## Role of nonlinearities for exercises with DSGE model

- ▶ **How much of the total output loss during the Great Recession is due to an uncertainty shock?**
- ▶ Uncertainty shock in 2008Q4: 4.4 standard deviation uncertainty shock (similar for linear/nonlinear VAR model)
- ▶ DSGE model's predictions conditional on estimates obtained with linear vs. nonlinear VAR?
- ▶ Actual data-reference: CBO output gap (2008Q3=0), sample: 2008Q4-2014Q2

# Great recession: Role of nonlinearities

Output response to the uncertainty shock in 2008Q4



- Total loss: -53%; DSGE/nonlinear (linear) VAR: -31% (-20%)



## Our findings offer empirical support to:

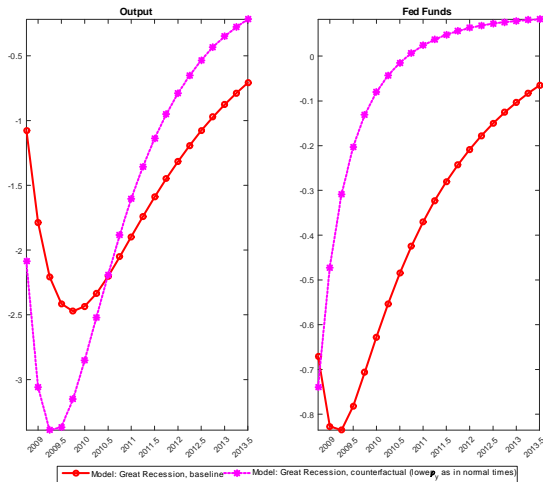
- ▶ *"[...] Although some nonlinearities are accounted for in our modeling exercises, we cannot be certain that our simulations provide reasonable approximations of the economy's behavior in times of large idiosyncratic shocks."*
  - ▶ Alan Greenspan, opening remarks at the "Monetary Policy and Uncertainty" symposium, Jackson Hole, August 29, 2003
- ▶ *"For negative economic shocks such as the financial crisis in 2008–2009, the evidence rather consistently documents an increase in risk aversion, using a variety of methods."*
  - ▶ Schildberg-Hörisch (2018, *Journal of Economic Perspectives*, "Are Risk Preferences Stable?")

Output loss: Policy counterfactual

# Role of monetary policy according to the DSGE

- ▶ **What was the role of monetary policy in the propagation of the 2008Q4 uncertainty shock?**
- ▶ Estimation:
  - ▶  $\rho_{\pi}^{GR} = \rho_{\pi}^{linear}$
  - ▶  $\rho_y^{GR} = 0.28 > \rho_y^{linear} = 0.20$
- ▶ Q: Did the Fed helped mitigate the depth of the Great Recession?
- ▶ Parallel with Great Depression: monetary policy was not accomodative enough (Friedman and Schwartz, 1963; Christiano, Motto, and Rostagno, 2003)
- ▶ Counterfactual ex.: replace  $\rho_y^{GR}$  with  $\rho_y^{linear}$ 
  - ▶ what would have happened?
- ▶ Actual data-reference: in 2008Q3 FFR = 1.94

# Great recession: Role of monetary policy



- The Fed immediate and aggressive response played a significant role in mitigating the depth of the Great Recession.

# Conclusions

- ▶ IVAR analysis, real effects of financial uncertainty shocks stronger during the Great Recession
- ▶ Predictions matched with a nonlinear DSGE model estimated in a state-dependent fashion. Crucial parameter: risk aversion (counter-cyclical). Informative to build theoretical models with endogenous mechanisms
- ▶ DSGE model estimated conditional on nonlinear VAR explains about 60% of the output loss during the Great Recession, just 40% if data modeled with a linear VAR
- ▶ Implications for model calibration and policy - should a central bank directly react to financial volatility?
- ▶ More aggressive monetary policy prevented a greater recession
- ▶ Future research on financial & labor market frictions.

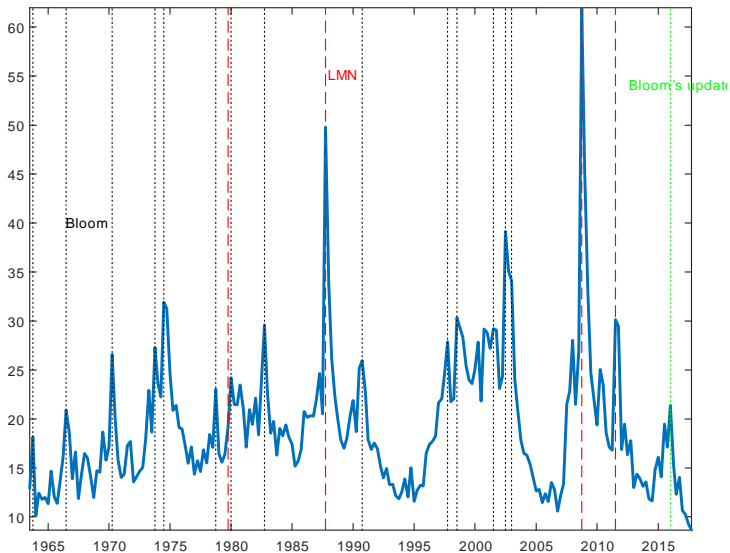
Thanks a lot!

# Uncertainty in the time of the Great Recession

*"If you think that another Depression might be around the corner, **better to be careful and save more. Better to wait and see how things turn out.** Buying a new house, a new car or a new laptop can surely be delayed a few months. The same goes for firms: **given the uncertainty, why build a new plant or introduce a new product now? Better to pause until the smoke clears.** This is perfectly understandable behavior on the part of consumers and firms—but **behaviour which has led to a collapse of demand, a collapse of output and the deep recession** we are now in."*

Olivier Blanchard, IMF's Chief Economist, The Economist, Jan. 29, 2009 [▶ back](#)

# Event constraints

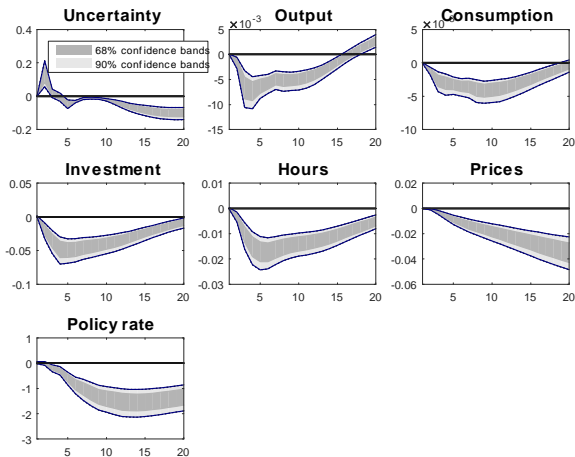




# Event constraints: cont'd ( [back](#) )

<i>Event constraints</i>			
<i>t</i>	Event	Constraint on $e_{FU,t}$	Source
1962Q4	Cuban missile crisis	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	Bloom
1963Q4	Assassination of JFK	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	Bloom
1966Q3	Vietnam buildup	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	Bloom
1970Q2	Cambodia and Kent state	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	Bloom
1973Q4	OPEC I, Arab-Israeli War	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	Bloom
1974Q3	Franklin National	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	Bloom
1978Q4	OPEC II	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	Bloom
1979Q4	Volcker experiment	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	LMN
1980Q1	Afghanistan, Iran hostages	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	Bloom
1982Q4	Monetary policy turning point	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	Bloom
1987Q4	Black Monday	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 75th)$	Bloom & LMN
1990Q4	Gulf War I	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	Bloom
1991Q4	Dissolution of the Soviet Union	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	Bloom
1997Q4	Asian crisis	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	Bloom
1998Q3	Russian, LTCM default	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	Bloom
2001Q3	9/11	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	Bloom
2002Q3	Worlcom, Enron	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	Bloom
2003Q1	Iraq invasion	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	Bloom
2008Q4	Great recession	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 75th)$	Bloom & LMN
2011Q3	Debt ceiling crisis	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	LMN
2016Q1	FFR liftoff, China, Japanese negative rate	$e_{FU,t} > \text{perc}(\mathbf{e}_{FU_t}(\mathbf{B}), 50th)$	Bloom (update)
<i>External variable constraints</i>			
External variable $S_t$		Constraint on $\rho(\mathbf{e}_{FU_t}, S_t)$	
Stock market return		$< \text{perc}(\rho(\mathbf{e}_{FU_t}(\mathbf{B}), S_t), 50th)$	LMN
Real price of gold (log difference)		$> \text{perc}(\rho(\mathbf{e}_{FU_t}(\mathbf{B}), S_t), 50th)$	LMN

# Difference of state-conditional GIRFs: Model uncertainty



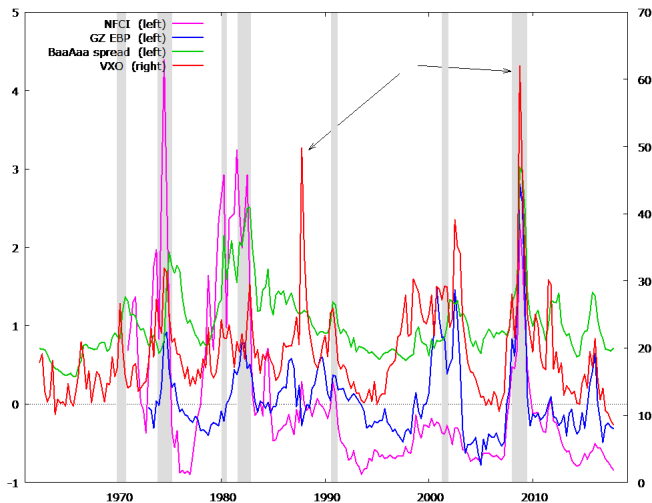
► back

## VAR checks: credit spread

- ▶ *"the shocks that produced the [great] recession were primarily associated with financial disruptions and heightened uncertainty"* (Stock and Watson, 2012)
- ▶ Narrative restrictions to disentangle the shocks:
  - ▶ uncertainty shocks: baseline NSR
  - ▶ financial (first moment) shocks:  
 $shock_{2008Q4} > median(shocks(\mathbf{B})_{2008Q4})$  &  
 $shock_{1987Q4} < median(shocks(\mathbf{B})_{1987Q4})$
- ▶ NSR allow us to not take a stance on the contemporaneous relationship between uncertainty and financial shocks
- ▶ We are interested in correctly identifying uncertainty shocks

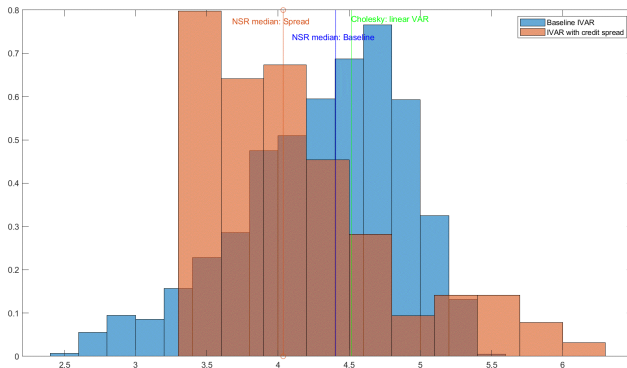
# VAR checks: credit spread (cont'd)

## ► Uncertainty vs financial stress:



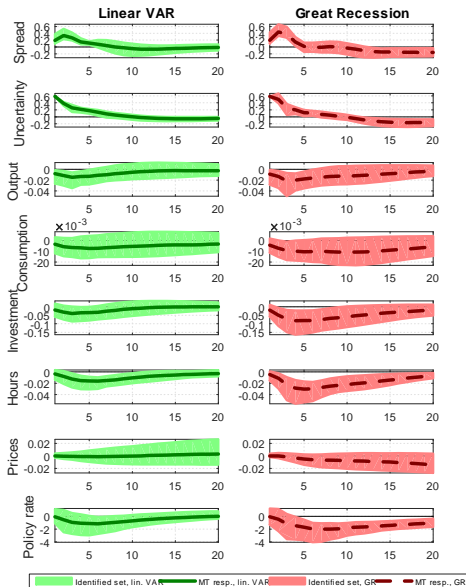
# VAR checks: credit spread (cont'd)

- Size of the uncertainty shock in 2008Q4:

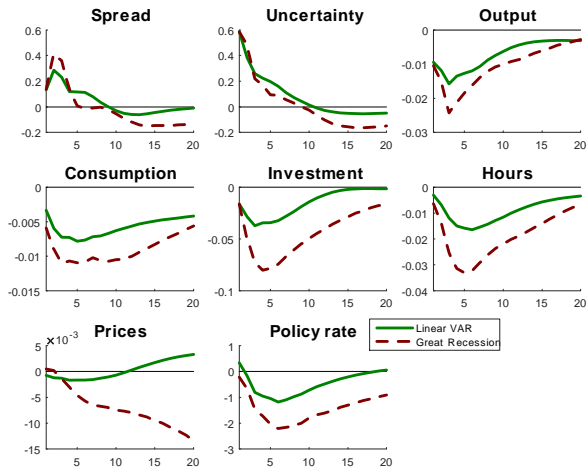


- Part of the uncertainty spike is acknowledged to be a consequence of other shocks ( [► back\\*](#) )

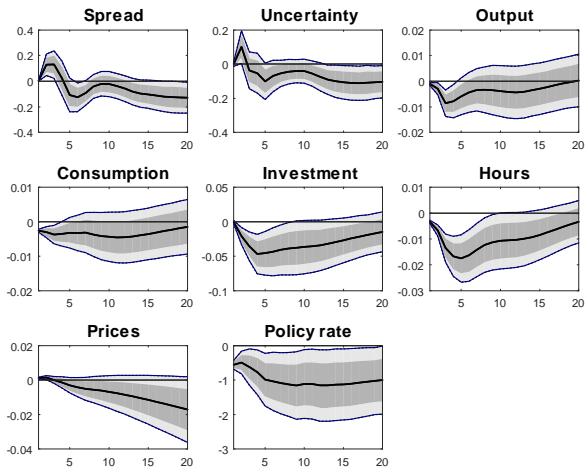
# VAR checks: credit spread (cont'd)



# VAR checks: credit spread (cont'd)



## VAR checks: credit spread (cont'd)





## Peak responses: Baseline vs. credit spread case

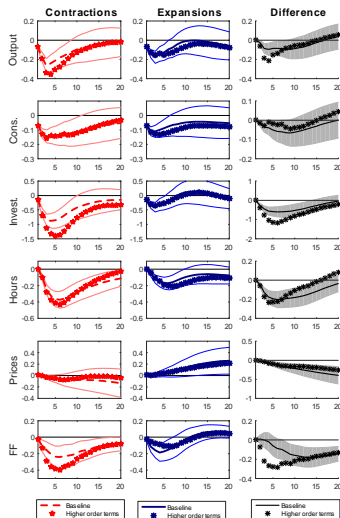
	Output	Consumption	Investment	Hours
Baseline IVAR and VAR				
Peak response: Linear	-1.54%	-1.03%	-3.34%	-1.90%
Peak response: Great Recession	-2.32%	-1.36%	-8.32%	-3.75%
Ratio GR/Linear	1.50	1.32	2.49	1.97
IVAR and VAR with financial spread				
Peak response: Linear	-1.58%	-0.78%	-3.70%	-1.63%
Peak response: Great Recession	-2.44%	-1.10%	-8.11%	-3.33%
Ratio GR/Linear	1.54	1.41	2.19	2.04



▶ back

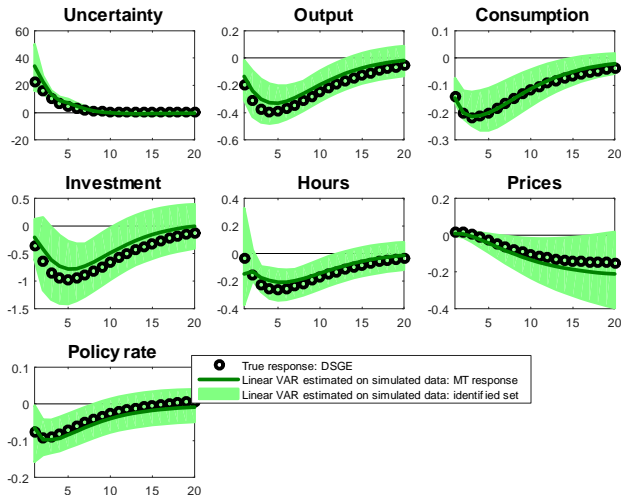
# IVAR with higher order terms [▶ back](#)

$$Y_t = \alpha + \sum_{j=1}^L A_j Y_{t-j} + \left[ \begin{array}{l} \sum_{j=1}^L c_j \ln VXO_{t-j} \times \Delta \ln GDP_{t-j} \\ + \sum_{j=1}^L c_j (\ln VXO_{t-j})^2 \times \Delta \ln GDP_{t-j} \\ + \sum_{j=1}^L c_j \ln VXO_{t-j} \times (\Delta \ln GDP_{t-j})^2 \end{array} \right] + u_t$$



# Monte Carlo exercise: Validation identification in population

- ▶ Sample of 2500 simulated observations from non-pruned, III order-approx. DSGE ([▶ back](#)):

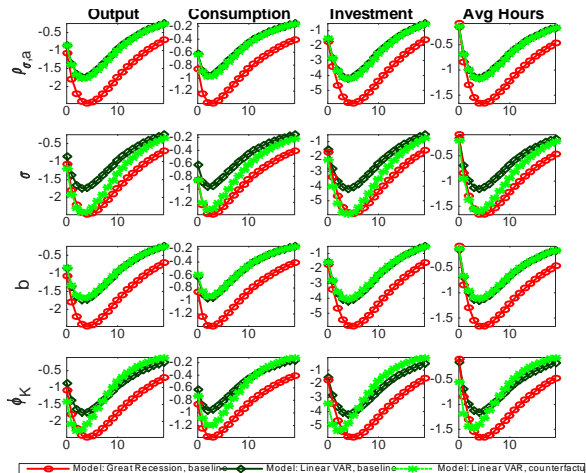


# DSGE calibrated parameters

Par.	Description	Value	Source
$\sigma_{\sigma^a}$	volatility of the uncertainty shock	0.004	BB (2018)
$\rho^a$	persistence of the preference shock	0.98	BB (2018)
$\sigma^a$	volatility of the preference shock	0.005	BB (2018)
$\rho^Z$	persistence of the technology shock	0.35	BB (2018)
$\sigma^Z$	volatility of the technology shock	0.019	BB (2018)
$\alpha$	capital's share in production	0.333	BB (2017,2018)
$\beta$	household discount factor	0.994	BB (2017,2018)
$\delta$	steady state depreciation rate	0.025	BB (2017,2018)
$\delta_1$	first-order utilization parameter	$1/\beta - 1 + \delta$	BB (2017,2018)
$\Pi$	steady state inflation rate	1.005	BB (2017,2018)
$\nu$	firm leverage parameter	0.9	BB (2017,2018)
$\delta_2$	second-order utilization parameter	0.0003	BB (2017,2018)
$\theta_\mu$	elasticity of subst. between intermediate goods	6.0	BB (2017,2028)
$\psi$	intertemporal elasticity of substitution	0.5	BB (2018)

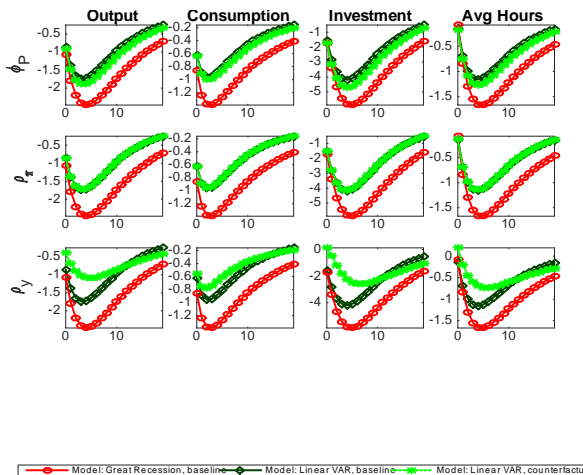
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# Counterfactual exercise: drivers response in great recession



# Counterfactual exercise: drivers response in great recession

## (2)



► back

Avg. distance criterion: drivers of state-dependent resp.

$$Avg.Crit = \sum_{i=contr,exp} \frac{1}{2} \left( \widehat{\boldsymbol{\psi}}^i - \boldsymbol{\psi} \left( \boldsymbol{\zeta}^i \right) \right)' \mathbf{V}_i^{-1} \left( \widehat{\boldsymbol{\psi}}^i - \boldsymbol{\psi} \left( \boldsymbol{\zeta}^i \right) \right)$$

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Average distance criterion:  
1 parameter-only estimations

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$\rho_{\sigma^a}$	115.34
$\sigma$	<b>108.06</b>
$b$	113.67
$\phi_K$	110.13
$\phi_P$	118.40
$\rho_{\pi}$	121.82
$\rho_y$	114.95

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▶ back

## RRA for the Basu and Bundick's model with ext. habits

$$RRA \underset{\bar{N} \text{ arbitrary}}{\equiv} R^c$$

$$RRA = \left( \frac{\eta}{\eta + (1 - \eta)(1 - b)} \right) \cdot \left( \frac{1}{\psi} \cdot \frac{\left( 1 + \frac{(1 - \eta)}{\eta} (1 - b) \right)}{(1 - b) \left( 1 + \frac{(1 - \eta)}{\eta} \right)} + \left( \sigma - \frac{1}{\psi} \right) \left( \frac{\eta}{(1 - b)} + 1 - \eta \right) \right)$$

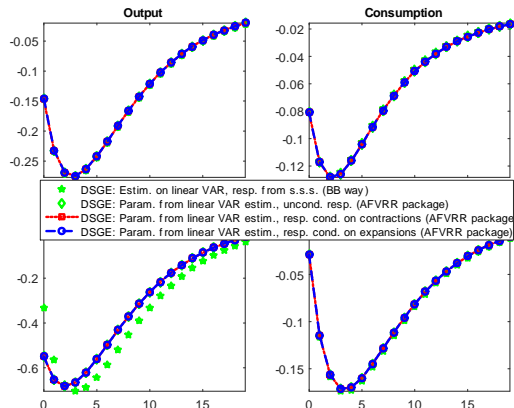
► if  $b = 0 \rightarrow RRA = \eta \cdot \sigma$

► [back](#)



# Any endog. asymmetry?: DSGE state-conditional GIRFs

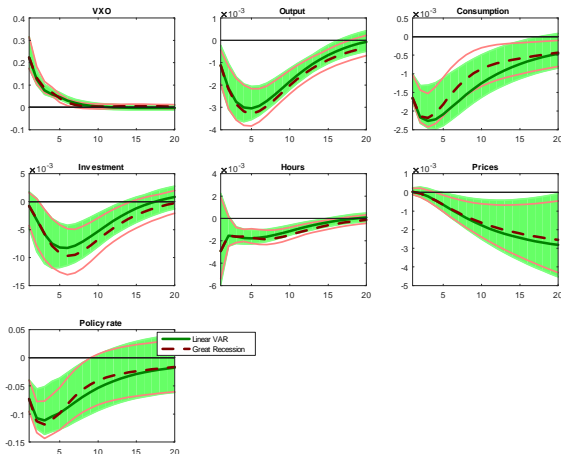
- Role of initial conditions in the *pruned* DSGE model for the propagation of the uncertainty shock (Andreasen, Fernández-Villaverde, and Rubio-Ramírez (2017)):



- Theoretically proved in Cacciatore and Ravenna (2018)

# Any endog. asymmetry?: (I)VAR estim. on simulated data

- ▶ Sample of 2500 simulated observations from *non-pruned*, III order-approx. DSGE:



- ▶ If non-pruned, IV order-approx. DSGE: approximation errors too big! ( ▶ back )