

Understanding the Great Recession

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Disclaimer: The views expressed are those of the authors and not necessarily those of the Federal Reserve Board or any other person associated with the Federal Reserve System.

The Great Recession and its Aftermath

- Extraordinary contractions in GDP, investment and consumption.
- Employment and labor force participation dropped substantially, with little/no recovery.
- Vacancies recovered but unemployment still above pre-recession levels ('shift in Beveridge curve').
- Despite severe economic weakness, decline in inflation relatively modest.

Questions

- ① What were key forces driving U.S. economy during the Great Recession?
- ② Mismatch in the labor market?
- ③ Why was the drop in inflation so moderate?

Answering our Questions requires a Model

- Model must provide empirically plausible account of:
 - standard macro- and labor market data.
- Novel features of labor market
 - Endogenize labor force participation.
 - Derive wage inertia as an equilibrium outcome.
- Estimate model using pre-2008 data.
- Use estimated model to analyze post-2008 data.

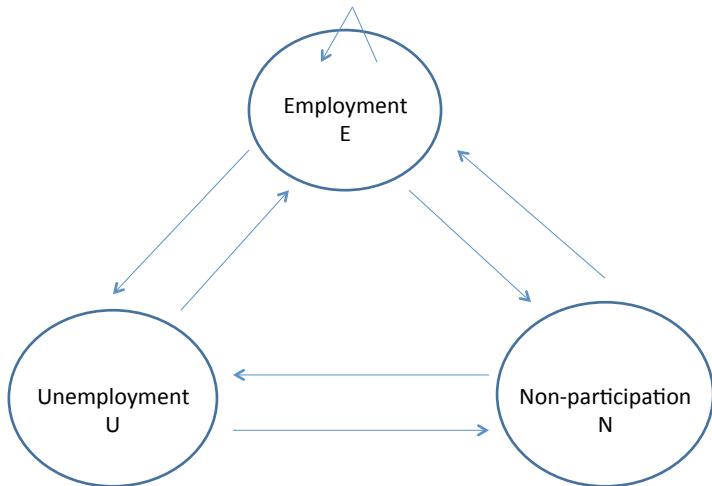
Questions and Answers

- What forces drove real quantities in the Great Recession?
 - Shocks to financial markets key drivers, even for variables like labor force participation.
 - *Financial wedge* and *consumption wedge*.
- Mismatch in the labor market?
 - Not a first order feature of the Great Recession.
 - We account for 'shift' in the Beveridge curve without resorting to structural shifts in the labor market.

Questions and Answers

- Why was the drop in inflation so moderate?
 - Prolonged slowdown in TFP growth during the Great Recession.
 - Rise in cost of firms' working capital as measured by spread between corporate-borrowing rate and risk-free interest rate.
 - Both forces exert countervailing pressure on inflation.

Labor Market

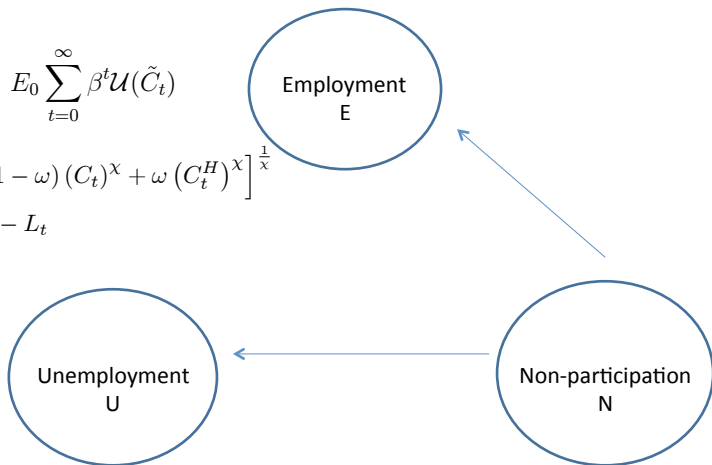


Labor Market

$$E_0 \sum_{t=0}^{\infty} \beta^t \mathcal{U}(\tilde{C}_t)$$

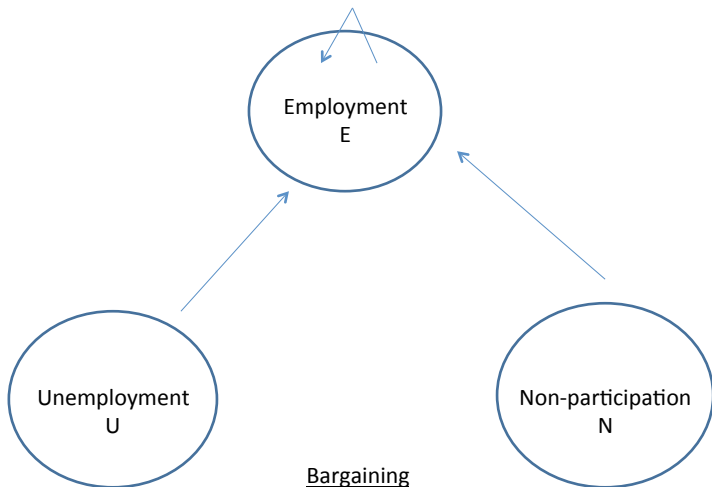
$$\tilde{C}_t = \left[(1 - \omega) (C_t)^x + \omega (C_t^H)^x \right]^{\frac{1}{x}}$$

$$C_t^H = 1 - L_t$$



- Household labor force decision
- Split between U and E determined by job-finding rate.

Labor Market



Bargaining

Three types of worker-firm meetings:

i) E to E , ii) U to E, iii) N to E

Alternating Offer Bargaining (AOB)

- Firms pay a fixed cost to meet a worker.
- Then, workers and firms bargain.
 - Disagreement leads to continued negotiations
- Hall-Milgrom (2008): if bargaining costs don't depend sensitively on state of economy, neither will wages.
- CET (2013): AOB outperforms Nash bargaining in empirical NK model (no Shimer puzzle)
 - after expansionary shock, rise in wages relatively small leading to substantial amplification.

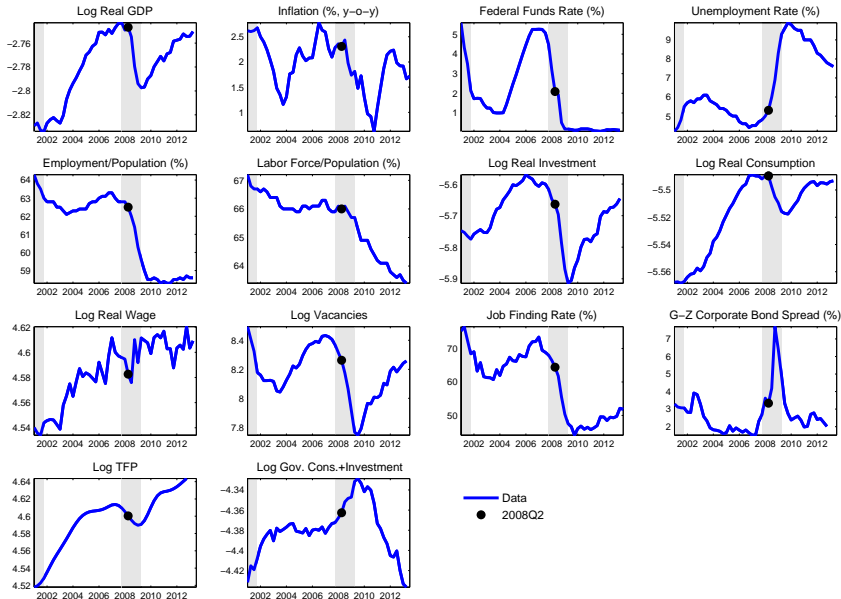
Estimated Medium-Sized DSGE Model

- Standard empirical NK model (e.g., CEE, ACEL, SW):
 - Calvo price setting frictions, but no indexation.
 - Habit persistence.
 - Variable capital utilization.
 - Working capital.
 - Adjustment costs: investment, labor force.
 - Taylor rule.
- Our labor market structure.
- Estimation strategy: Bayesian impulse response matching.
 - Shocks to monetary policy, neutral and investment-specific technology.
 - Our model performs well relative to this metric.

Accounting for the Great Recession

- Use model to assess which shocks account for gap between:
 - What actually happened.
 - What would have happened in absence of the shocks.

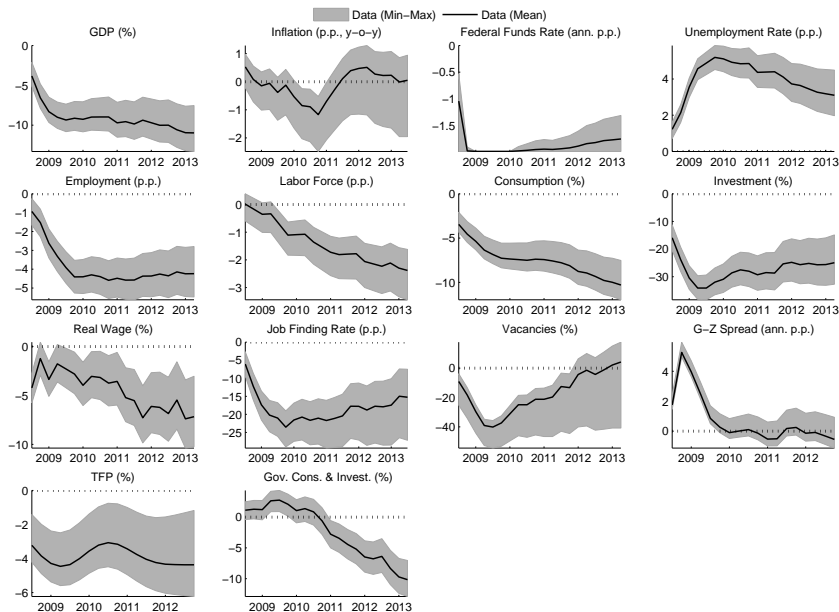
The U.S. Great Recession



Deriving Target Gaps

- We adopt a simple and transparent procedure to characterize what the data would have looked like absent the shocks that caused the Great Recession.
- For each variable, we fit a linear trend from date x to 2008Q2, where $x \in \{1985Q1; 2003Q1\}$.
- We extrapolate the resulting trend lines for each variable from 2008Q3 to 2013Q2.
- We calculate the *target gaps* as the differences between the projected values of each variable and its actual value.

U.S. Great Recession: Target Gap Ranges



Two Financial Market Shocks

- ① *Consumption wedge*, Δ_t^b : Shock to demand for safe assets ('Flight to safety', see e.g. Fisher 2014):

$$1 = (1 + \Delta_t^b) E_t m_{t+1} R_t / \pi_{t+1}$$

- ② *Financial wedge*, $\tilde{\Delta}_t^k$: Reduced form of 'risk shock', Christiano-Davis (2006), Christiano-Motto-Rostagno (2014):

$$1 = (1 - \tilde{\Delta}_t^k) E_t m_{t+1} R_{t+1}^k / \pi_{t+1}$$

- Financial wedge also applies to working capital loans:
 - Interest charge on working capital: $R_t (1 + \hat{\Delta}_t^k)$
 - Estimated share of labor inputs financed with loans: 0.56.
 - Higher financial wedge directly increases cost to firms.

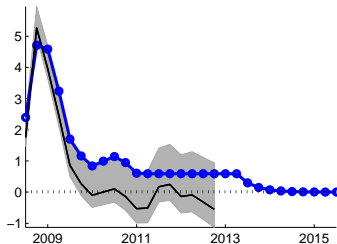
Measurement of Shocks

- ① Financial wedge, $\tilde{\Delta}_t^k$, measured using GZ spread data.
- ② Consumption wedge, Δ_t^b , measured using the Euler equation for the risk-free asset and $E_t \pi_{t+1}$ and R_t data.
- ③ Neutral technology shock based on *TFP* data.
- ④ Government shock measured using *G* data.

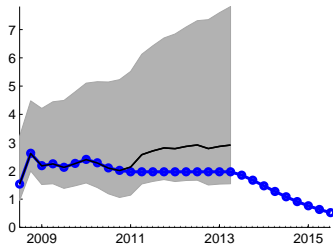
Exogenous Processes

■ Data (Min-Max Range) — Data (Mean) ● Model

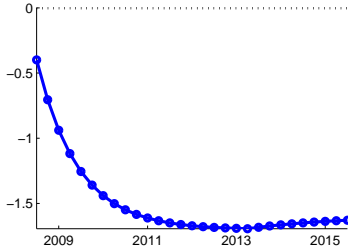
G-Z Corporate Bond Spread (annualized p.p.)



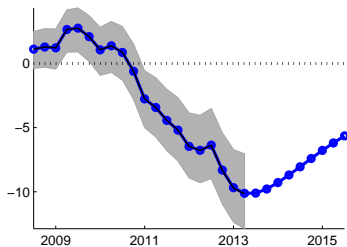
Consumption Wedge (annualized p.p.)



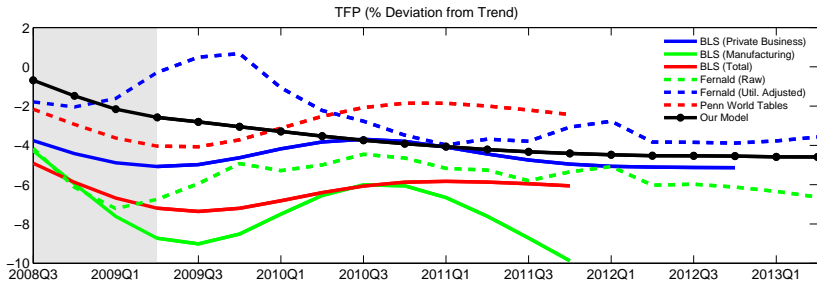
Neutral Technology Level (%)



Government Consumption & Investment (%)



Assessing model's implication for TFP



Stochastic Simulation of the Model

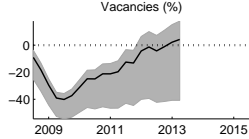
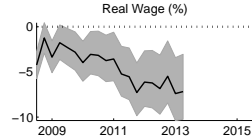
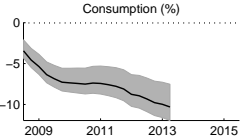
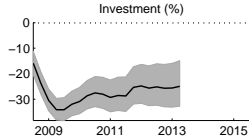
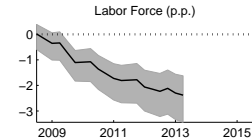
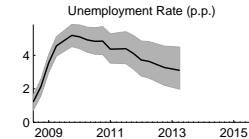
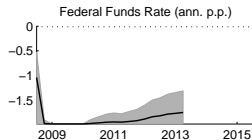
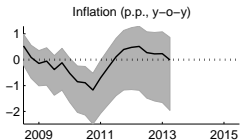
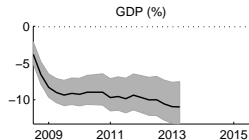
- Feed the four shocks to the model and simulate the post 2008Q2 data.
- Observed GZ , Δ^b , TFP and G data are treated as realizations of a stochastic process.
- At each date t , agents observe period t and earlier obs. only.
 - At t they must forecast future values of the shocks.
 - They compute forecasts using time series models for the shocks.
- Solve nonlinear model, imposing certainty equivalence.

Monetary Policy in the Great Recession

- From 2008Q3 to 2011Q2:
 - Taylor-type feedback rule subject to the ZLB.
- Policy from 2011Q3-2012Q4:
 - Date-based forward guidance
 - Keep funds rate at zero for next 8 quarters.
- Policy from 2013Q1:
 - keep funds rate at zero until either unemployment falls below 6.5% or inflation rises above 2.5%.

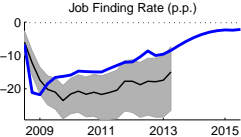
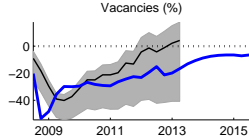
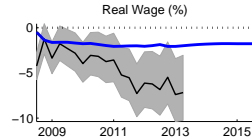
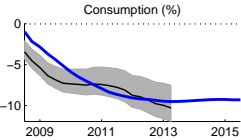
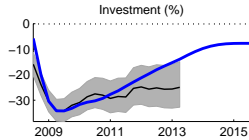
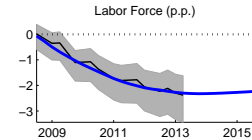
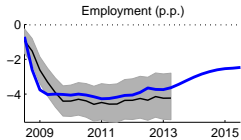
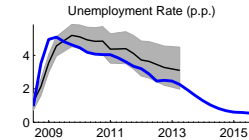
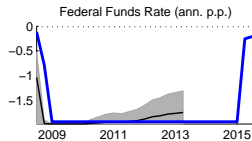
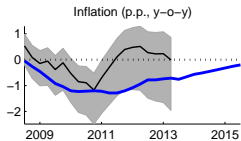
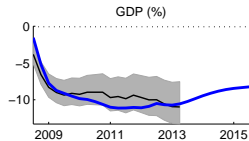
The U.S. Great Recession: Data vs. Model

■ Data (Min-Max Range) — Data (Mean) — Model



The U.S. Great Recession: Data vs. Model

■ Data (Min-Max Range) — Data (Mean) — Model



Decomposing What Happened into Shocks

- Our shocks roughly reproduce the actual data.
- We investigate the effect of a shock by shutting it off.
 - Resulting decomposition is not additive because of nonlinearity.
- Results:
 - *Financial wedge* - accounts for the biggest effects on real quantities.
 - *Consumption wedge* - less important than financial wedge.
 - *Government spending* - relatively small role.
 - *TFP* - plays an important role in preventing drop in inflation.

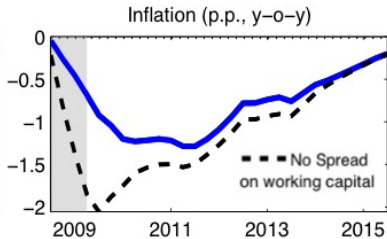
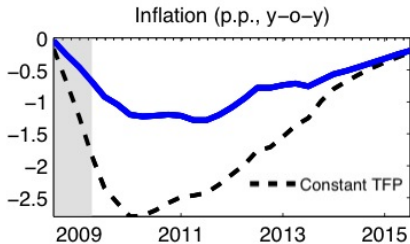
Phillips Curve

- Widespread skepticism that NK model can account for modest decline in inflation during the Great Recession.
- One response: Phillips curve got flat or always was very flat (e.g. Christiano, Eichenbaum and Rebelo, 2011).
- Alternative: standard Phillips curve misses sharp rise in costs
 - Unusually high cost of credit to finance working capital.
 - Fall in TFP.

⇒ *Both raise countervailing pressure on inflation.*

Decomposition for Inflation

— Baseline Model

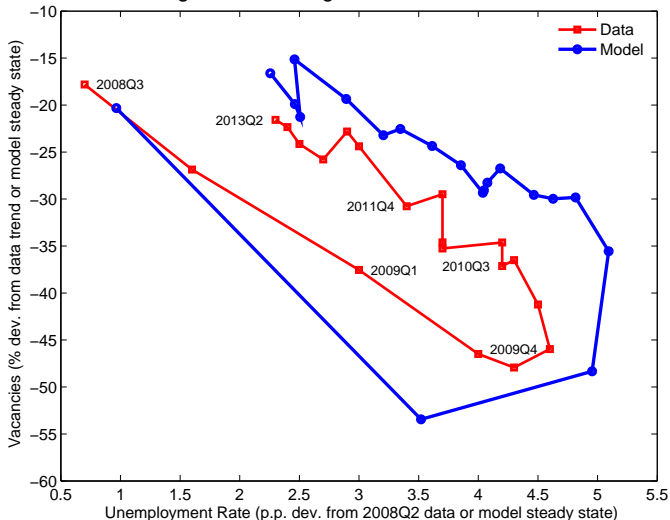


Beveridge Curve

- Much attention focused on 'sharp' rise in vacancies and relatively small fall in unemployment
 - Claim that fish hook shape is evidence of 'shift' in matching function.
 - Claim based on assumption that unemployment is at steady state.
- In our model, no shift occurs in the matching technology.
 - Still, our model accounts for the 'fish hook' shape of the Beveridge curve.

The Beveridge Curve: Data vs. Model

Figure 9: Beveridge Curve: Data vs. Model



Model Predicts Fish Hook, Why?

- Simplest DMP-style model

$$U_{t+1} - U_t = (1 - \rho)(1 - U_t) - f_t U_t$$

solving for f_t :

$$f_t = (1 - \rho) \frac{(1 - U_t)}{U_t} - \frac{U_{t+1} - U_t}{U_t} \underbrace{\quad}_{\text{matching function}} \sigma_t \left(\frac{V_t}{U_t} \right)^\alpha$$

solving for V_t :

$$V_t = \left[(1 - \rho) \frac{(1 - U_t)}{\sigma_t U_t^{1-\alpha}} - \frac{U_{t+1} - U_t}{\sigma_t U_t^{1-\alpha}} \right]^{1/\alpha}$$

standard approximation sets this to zero

- Naturally implies a 'fish hook' pattern.

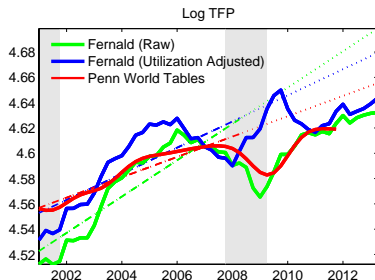
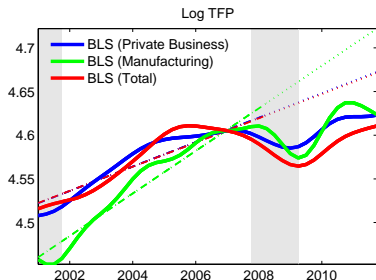
Conclusion

- Bulk of movements in economic activity during the Great Recession due to financial frictions interacting with the ZLB.
 - ZLB has caused negative shocks to aggregate demand to push the economy into a prolonged recession.
- Findings based on looking through lens of a NK model with unemployment and LFP.
- No (or little) evidence for ‘mismatch’ in labor market.
- Modest fall in inflation is not a puzzle once fall in TFP and risky working capital channel are taken into account.

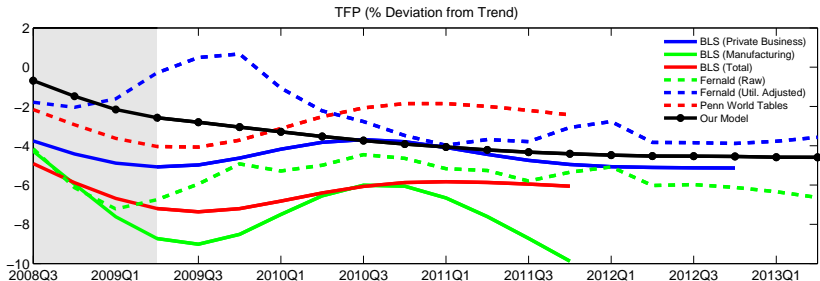
Counterfactual Simulations

- Results:
 - *No forward guidance* - economic activity would have dropped even more in the Great Recession.
 - *No zero lower bound* - economic activity would have contracted less (albeit modestly).
 - *No decline in labor force participation* - employment, consumption and output would have fallen substantially less in the Great Recession.

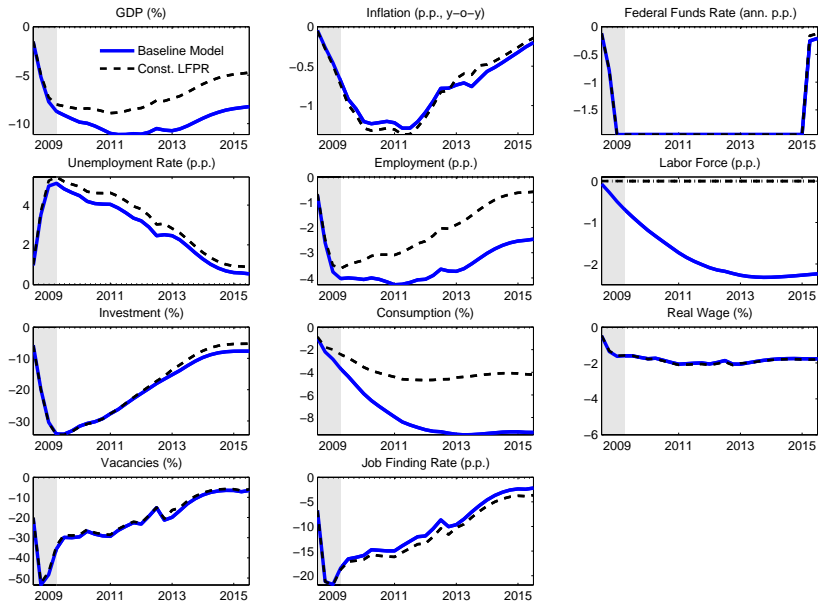
Assessing model's implication for TFP



Notes: Linear trend from 2001Q1–2008Q2 (dashed–dotted). Forecast 2008Q3 and beyond based on linear trend (dotted).



Effects of Labor Force Participation



Labor Market

$$\max_{\{C_t, L_t, C_t^H, B_{t+1}, K_{t+1}, I_t, l_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \mathcal{U}(\tilde{C}_t)$$

Employment
E

$$\begin{aligned} & P_t C_t + P_{I,t} I_t + B_{t+1} \\ \leq & R_{K,t} K_t + (L_t - l_t) P_t D_t + l_t W_t + R_{t-1} B_t - T_t \end{aligned}$$

$$K_{t+1} = (1 - \delta_K) K_t + I_t$$

Unemployment
U

Non-participation
N

- Household labor force decision
- Split between U and E determined by job-finding rate.

Estimation

- Bayesian impulse response matching.
- VAR based on pre-2008 data:
 - Macro variables and real wage, hours worked, unemployment, job finding rate, vacancies, labor force.
- Identify shocks to monetary policy, neutral and investment-specific technology.
- Parameter estimates minimize distances between model and VAR impulse responses.
 - Responses in our model resemble responses in data.

Labor Market

- Large number of identical households, with unit measure of members.
- Three types of activities:
 - $(1 - L_t)$ people in home production, not in labor force.
 - l_t people are in labor force and employed.
 - $(L_t - l_t)$ people unemployed, i.e. they're in labor force but don't have a job.

Labor Force Dynamics

- At end of each period, $1 - \rho$ percent of employed workers are separated from firm.
- Separated, unemployed worker have equal probability, $1 - s$, of exiting labor force.
- Job finding rate f_t : ratio of number of new hires divided by number of people searching for work
- e_t : rate at which workers transit from non-participation to being in labor force

Labor Force Dynamics

- At end of each period, $1 - \rho$ percent of employed workers are separated from firm.
 - So at end of period $t - 1$, $(1 - \rho)l_{t-1}$ workers separate from firms, ρl_{t-1} workers remain attached to their firm
- Let u_{t-1} denote unemployment rate at end of $t - 1$.
- Sum of separated and unemployed workers is given by:

$$\begin{aligned}(1 - \rho)l_{t-1} + u_{t-1}L_{t-1} &= (1 - \rho)l_{t-1} + \frac{L_{t-1} - l_{t-1}}{L_{t-1}}L_{t-1} \\ &= L_{t-1} - \rho l_{t-1}.\end{aligned}$$

Labor Force Dynamics

- Separated, unemployed worker have equal probability, $1 - s$, of exiting labor force.
- So $s(L_{t-1} - \rho l_{t-1})$ remain in labor force, search for work.
- Household chooses r_t , number of workers that it transfers from non-participation into labor force.

- Labor force in period t is:

$$L_t = s(L_{t-1} - \rho l_{t-1}) + \rho l_{t-1} + r_t.$$

– By its choice of r_t household in effect chooses L_t .

- e_t : rate at which workers transit from non-participation to being in labor force

$$e_t = \frac{r_t}{1 - L_{t-1}}$$

Labor Force Dynamics

- Law of motion for employment is:

$$l_t = (\rho + x_t) l_{t-1}.$$

where x_t is hiring rate.

- Job finding rate: ratio of number of new hires divided by number of people searching for work

$$f_t = \frac{x_t l_{t-1}}{L_t - \rho l_{t-1}}.$$

Modified version of Hall-Milgrom

- Firms pay a fixed cost to meet a worker.
- Then, workers and firms bargain.
 - Better off reaching agreement than parting ways.
 - Disagreement leads to continued negotiations.
- If bargaining costs don't depend sensitively on state of economy, neither will wages.
- After expansionary shock, rise in wages is relatively small.
 - See CET (2013), for intuition in a DSGE model with capital.

Modified version of Hall-Milgrom

- Bargaining protocol:
 - Day 1: firm makes opening offer. Worker can accept, reject and walk away or make counteroffer.
 - Day 2: worker makes counteroffer in case he rejected on first day. Firm can accept, reject and walk away or make counteroffer.
 - Day 3: firm makes counteroffer in case it rejected worker's counter offer...
 - Last day: worker makes take-it-or-leave-it offer.
- Opening offer is accepted.

Modified version of Hall-Milgrom

- Bargaining costs:
 - Direct cost of γ to firm of rejecting worker offer and preparing a counteroffer.
 - Rejection risks total break down in negotiations with probability δ .
 - Each day that negotiations continue means firm loses production for that day and worker loses wage.

Value Functions (abstract from growth)

- J_t is the value to a firm of an employed worker:

$$J_t = \vartheta_t - w_t + \rho E_t m_{t+1} J_{t+1}.$$

- ϑ_t and m_{t+1} are determined in general equilibrium.
- Free entry and zero profits dictate:

$$\kappa = J_t.$$

Value Functions

- Value of employment to a worker:

$$V_t = w_t + E_t m_{t+1} \left[\begin{array}{c} \rho V_{t+1} + (1 - \rho) s \left(\begin{array}{c} f_{t+1} V_{t+1} + \\ (1 - f_{t+1}) U_{t+1} \end{array} \right) \\ (1 - \rho)(1 - s) N_{t+1} \end{array} \right].$$

- $f_{t+1} V_{t+1}$ are job-to-job transitions, N_{t+1} is value of being out of labor force.

- Employment law of motion and job finding rate:

$$l_t = (\rho + x_t) l_{t-1} \text{ and } f_t = \frac{x_t l_{t-1}}{1 - \rho l_{t-1}}$$

- x_t denotes the hiring *rate*.

Value Functions

- Value of unemployment to a worker:

$$U_t = D + E_t m_{t+1} \left[\begin{array}{c} s f_{t+1} V_{t+1} + s(1 - f_{t+1}) U_{t+1} \\ + (1 - s) N_{t+1} \end{array} \right].$$

where D denotes unemployment benefits.

- Value of non-participation

$$N_t = E_t m_{t+1} [e_{t+1} (f_{t+1} V_{t+1} + (1 - f_{t+1}) U_{t+1}) + (1 - e_{t+1}) N_{t+1}]$$

where e_t is probability of being selected to join labor force.

Medium-Sized NK-DSGE Model (CEE, ACEL)

- Final homogeneous market good, Y_t , produced by competitive, 'retailer' firms, $Y_t = \left[\int_0^1 (Y_{j,t})^{\frac{1}{\lambda}} dj \right]^{\lambda}$
- $Y_{j,t}$ produced by monopolist *retailer*, using capital, intermediate goods, subject to neutral and investment specific technology shocks.
 - Retailer must borrow a share \varkappa cost of intermediate goods at time t interest rate
 - Calvo price setting frictions, but no indexation.
- Intermediate good produced using labor.

Medium-Sized DSGE Model

- Habit persistence in preferences
- Variable capital utilization.
- Adjustment costs.
 - Investment
 - Number of people in home sector.
- Taylor rule
 - Inflation relative to target, output relative to growth path, year-to-year-growth rate of output, lagged interest rate .

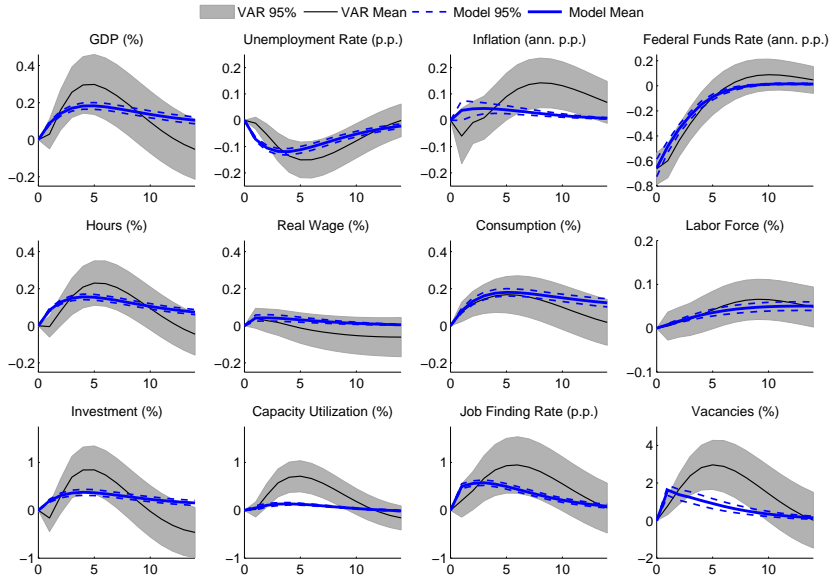
Identifying Assumptions at VAR stage

- Only variable that monetary policy shock affects *contemporaneously* is Federal Funds Rate.
- The only shocks that affect *labor productivity in long-run* are innovations to neutral technology and investment specific technology shocks.
- Only shock that affects *relative price of investment in long-run* is innovation to investment technology shock.

Estimated Parameters, Pre-2008 Data

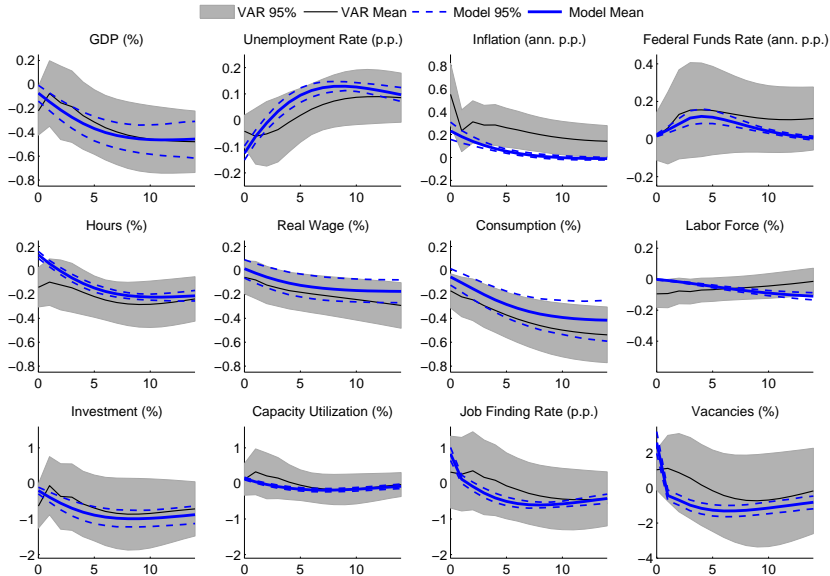
- Estimation by impulse response matching, Bayesian methods.
- Prices change on average every 4 quarters.
- δ : roughly 0.15% chance of a breakup after rejection.
- γ : cost to firm of preparing counteroffer roughly 0.6 day's production.
- Posterior mode of hiring cost: 0.5% of GDP
- Elasticity of substitution between home and market goods: 3.
 - set *a priori*, see Aguiar-Hurst-Karabarbounis (2012).

Responses to a Monetary Policy Shock



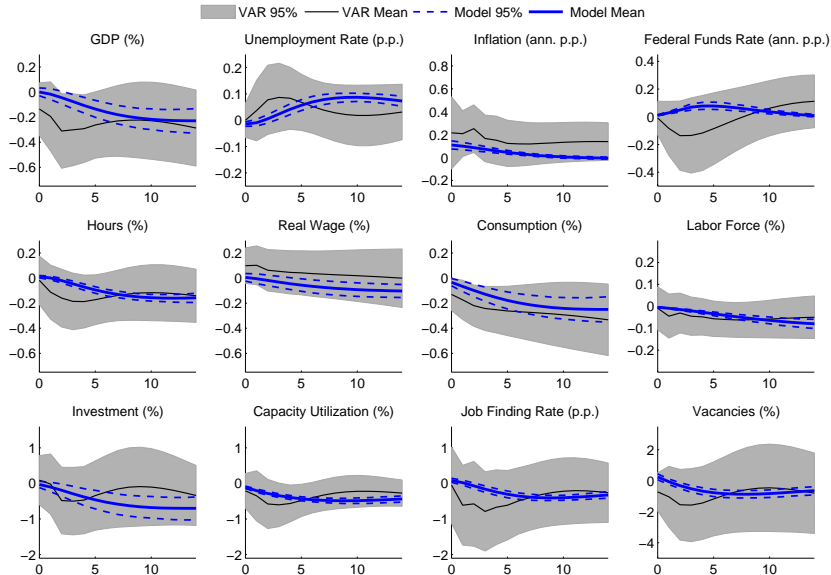
Notes: x-axis in quarters.

Responses to a Neutral Technology Shock



Notes: x-axis in quarters.

Responses to Invest.-Specific Tech. Shock.



Notes: x-axis in quarters.

Background

- GDP appears to have suffered a permanent fall since 2008.
- Trend decline in labor force participation accelerated after the 'end' of the recession in 2009.
- Unemployment rate persistently high
 - recent fall primarily reflects the fall in labor force participation.
- Employment rate fell sharply with little evidence of recovery.
- Vacancies have risen, but unemployment has fallen relatively little ('shift in Beveridge curve', 'mismatch').
- Investment and consumption persistently low.

What Sort of Model do we Need?

- The labor market is a big part of the puzzle.
 - need a model with endogenous labor force participation, unemployment, vacancies, etc.
- Need investment and capital.
- Incorporate price-setting frictions.
 - Hard to get a big recession out of ‘deleveraging’ and financial market frictions if market prices move efficiently.
 - We stress interaction of shocks with zero lower bound (ZLB).
 - Hard to get ZLB to matter in a model with flexible prices.
- Work with a modified New Keynesian DSGE model.
 - Forces are captured in the form of ‘wedges’.
 - That is, we avoid microfounding the shocks.

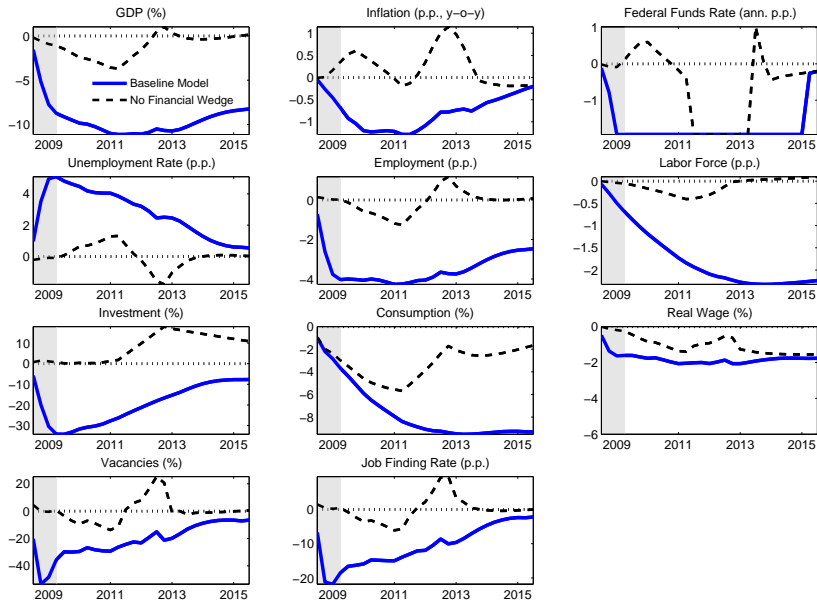
Outline

- Mostly, a standard 'medium-sized' DSGE model
- Must adapt the labor market side of the model:
 - adopt DMP-style matching and bargaining.
 - to account for observed labor market volatility,
 - environment must be characterized by wage inertia.
 - adopt alternating offer bargaining as described in Christiano-Eichenbaum-Trabandt 2013 (build on Hall-Milgrom).
 - no need to make wages exogenously 'sticky'.
- Estimate model using pre-2008 data.
- Use estimated model to analyze post-2008 data.

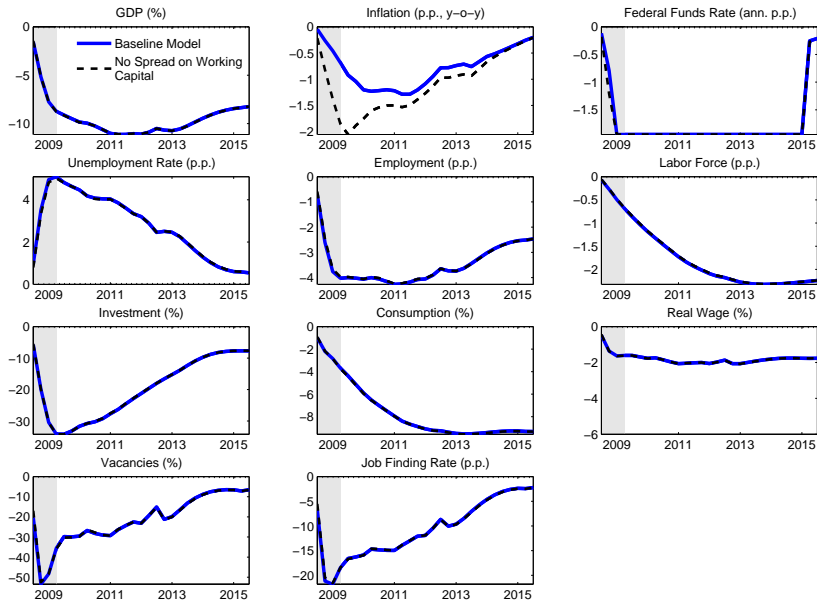
Effects of Financial Wedge Shock

- Accounts for the biggest effect on real quantities.
- Rise in financial wedge represents tax on intertemporal margin.
- With efficient markets: substitution from investment to consumption.
 - Accomplished by large drop in interest rate.
 - BUT: drop not feasible when ZLB is hit.
 - So, consumption not stimulated -> recession.
 - Drop in investment and consumption -> GDP must fall.
 - Households see terrible labor market -> keep people at home.
 - Labor force drops less than employment -> unemployment rises.
 - Recession leads to lower marginal costs -> inflation falls.

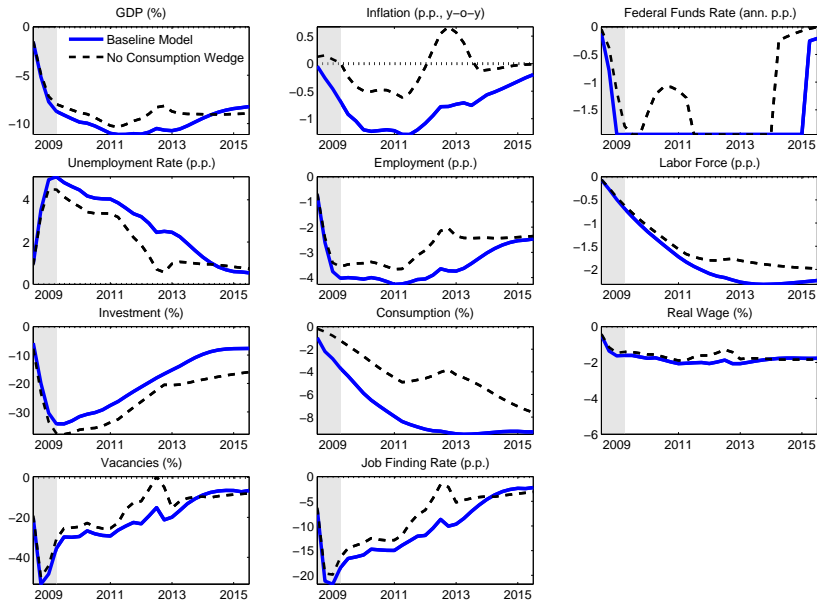
Effects of Financial Wedge



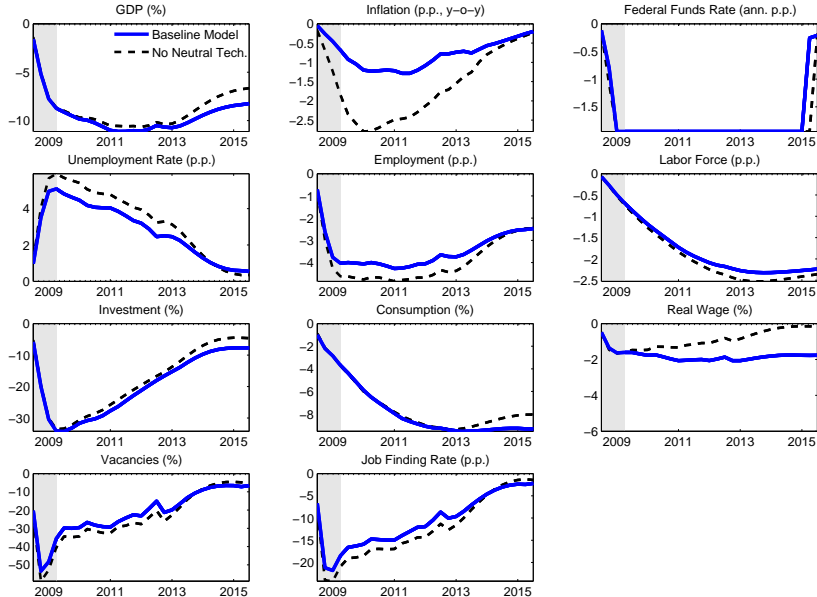
Effects of Spread on Working Capital



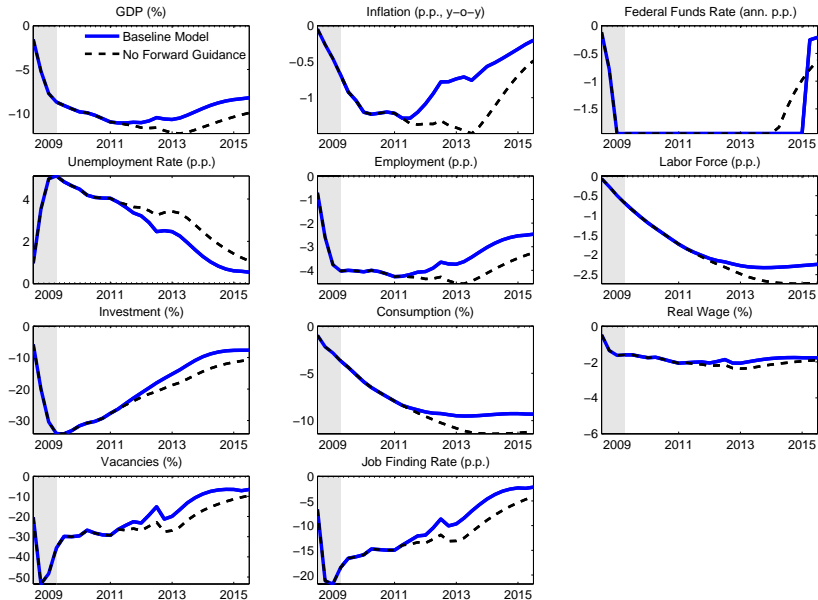
Effects of Consumption Wedge



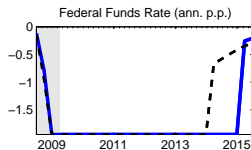
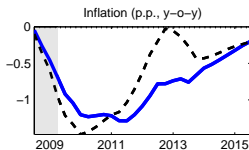
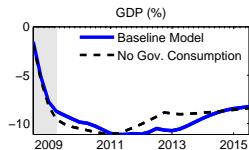
Effects of Neutral Technology



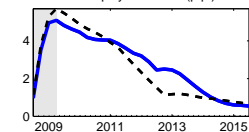
Effects of Forward Guidance



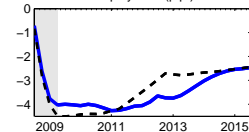
Effects of Government Consumption



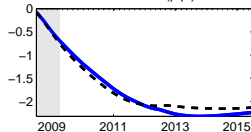
Unemployment Rate (p.p.)



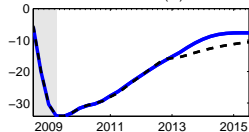
Employment (p.p.)



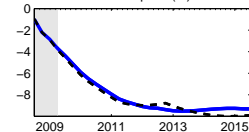
Labor Force (p.p.)



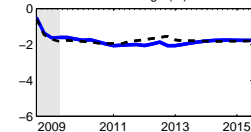
Investment (%)



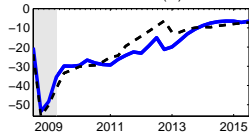
Consumption (%)



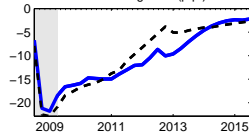
Real Wage (%)



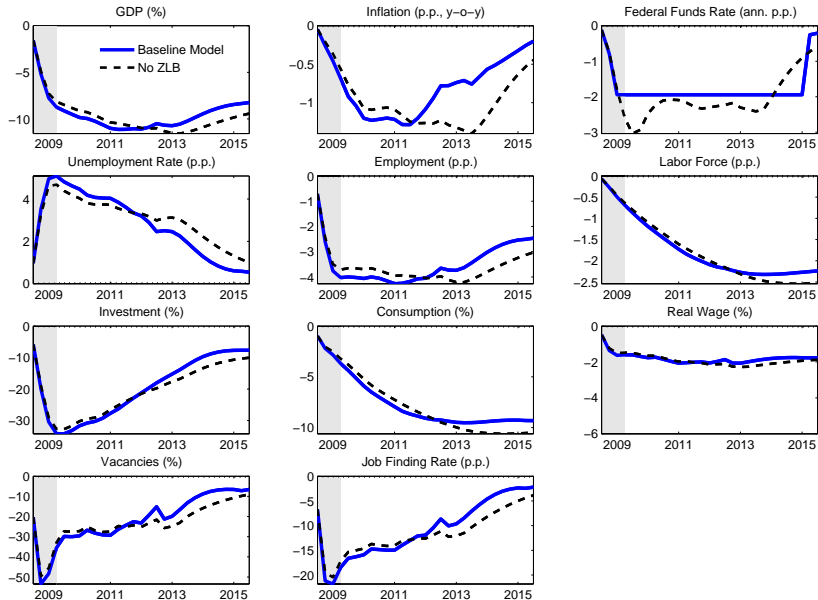
Vacancies (%)



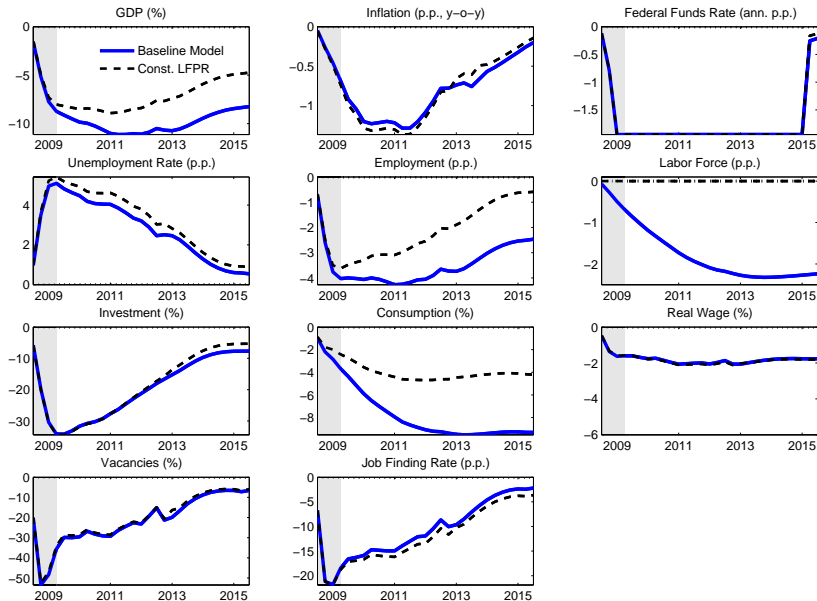
Job Finding Rate (p.p.)



Effects of the Zero Lower Bound



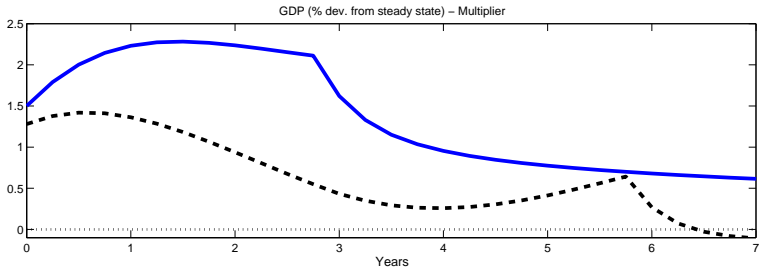
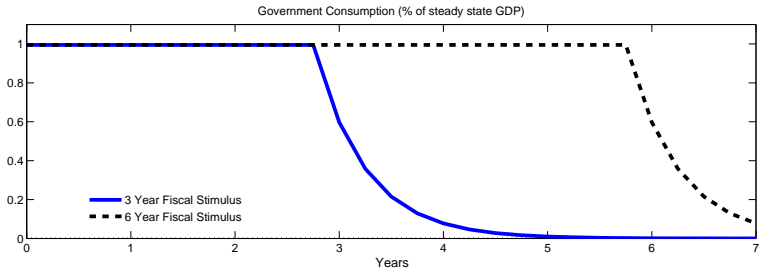
Effects of Labor Force Participation



Government Consumption Played only a Small Role

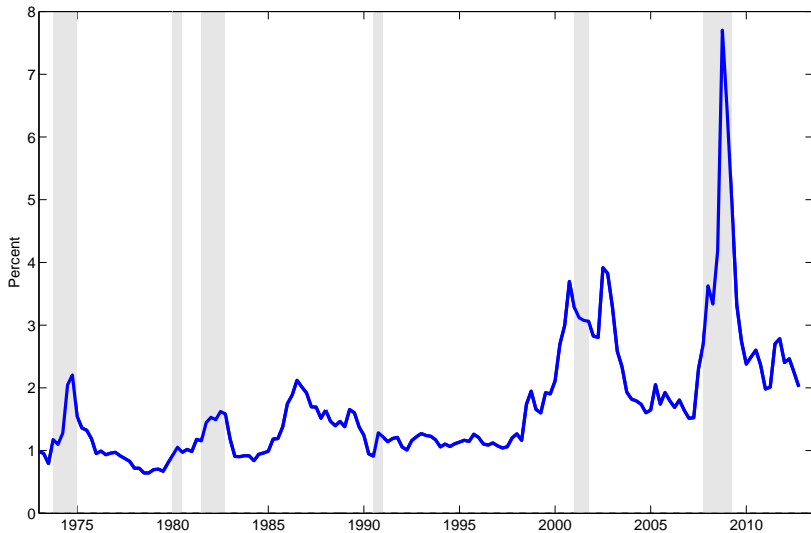
- Estimated multiplier around 1.6 during early period (American Recovery and Reinvestment Act of 2009)
 - But, rise in G then too small to have a substantial effect.
- Recent decline in G is large, but has small multiplier effect.
 - consistent with ZLB analysis of Christiano-Eichenbaum-Rebelo (JPE2012).
 - G movements expected to last beyond ZLB have very small multiplier effects.
 - G beyond ZLB has negative impact on ZLB, because of depressive wealth effects on consumption.

The Government Consumption Multiplier



Notes: Stimulus lasts for 3 or 6 years with $AR(1)=0.6$ thereafter. 3 years constant nominal interest rate. Perfect foresight.

Gilchrist-Zakrajšek Corporate Spread



Other Labor Market Variables: Vacancies.

- Empirical measure of vacancies (JOLTS):
 - position posted by an establishment, which it would fill if it met a suitable candidate.
 - compare vacancies in model with JOLTS.
- Vacancies in our model.
 - vacancies costless, but firm must post them to hire.
 - if firm wants to hire h workers it must post

$$v = \frac{h}{Q}$$

vacancies (it takes Q as given).

- vacancies posted at the level of the establishment (firm has many establishments).
 - if a vacancy produces a suitable candidate, he/she is hired.
- Q determined in the 'normal way':

$$Q = \frac{\text{agg hires}}{\text{agg vacancies}} = \text{constant} \times \left(\frac{\text{agg job searchers}}{\text{agg vacancies}} \right)^\sigma$$

Other Labor Market Variables: Job Finding Rate.

- Job finding rate:

$$f = \frac{\text{agg hires}}{\text{agg job searchers}}$$

The U.S. Great Recession

- To assess how economy would have evolved absent large shocks driving Great Recession:
 - With five exceptions, we fit linear trend from 2001Q1 to 2008Q2.
 - Extrapolate trend line for each variable.
 - Our model implies all nonstationary variables are difference stationary.
 - Our linear extrapolation procedure implicitly assumes that shocks in 2001-2008 were small relative to drift terms in time series.
- Same procedure as in Hall (2014) except the starts trend in 1990, obtains similar results

Monetary Policy in the Great Recession

- From 2008Q3 to 2011Q2:
 - Taylor-type rule

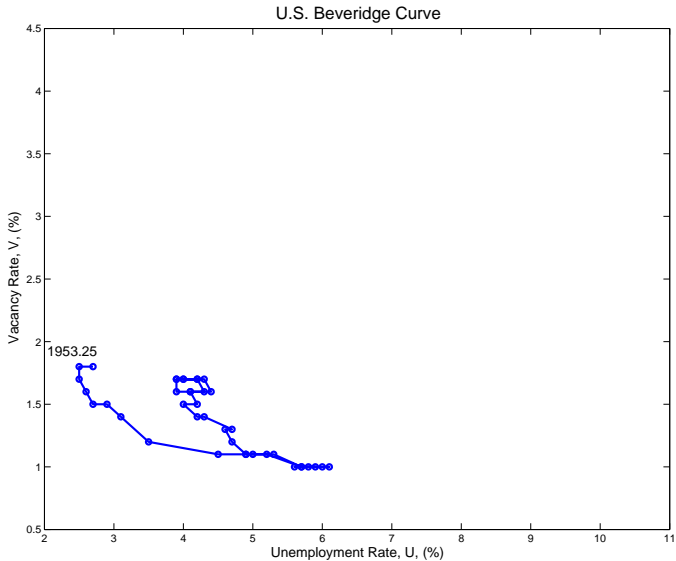
$$\ln(Z_t) = \ln(R) + 0.25 \overbrace{r_\pi}^{1.667} \ln\left(\pi_t^A / \pi^A\right) + 0.25 \overbrace{r_{\Delta y}}^{0.247} \ln\left(\mathcal{Y}_t / (\mathcal{Y}_{t-4} \mu_y^A)\right) + \sigma_R \varepsilon_{R,t}.$$

- The actual policy rate, R_t :

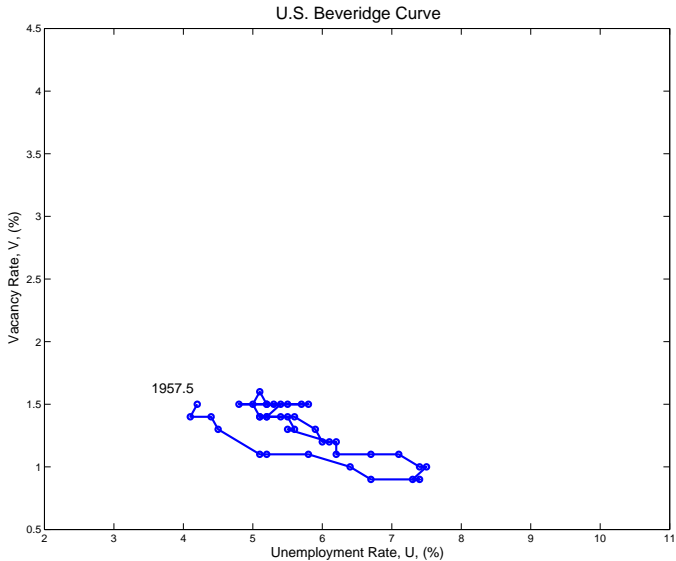
$$\ln(R_t) = \max \left\{ \ln(R/1.004825), \overbrace{\rho_R}^{0.751} \ln(Z_{t-1}) + (1 - \rho_R) \ln(Z_t) \right\}$$

- Policy from 2011Q3-2012Q4: date-based forward guidance (8 quarters)
- Policy from 2013Q1:
 - keep funds rate at zero until either unemployment falls below 6.5% or inflation rises above 2.5%.

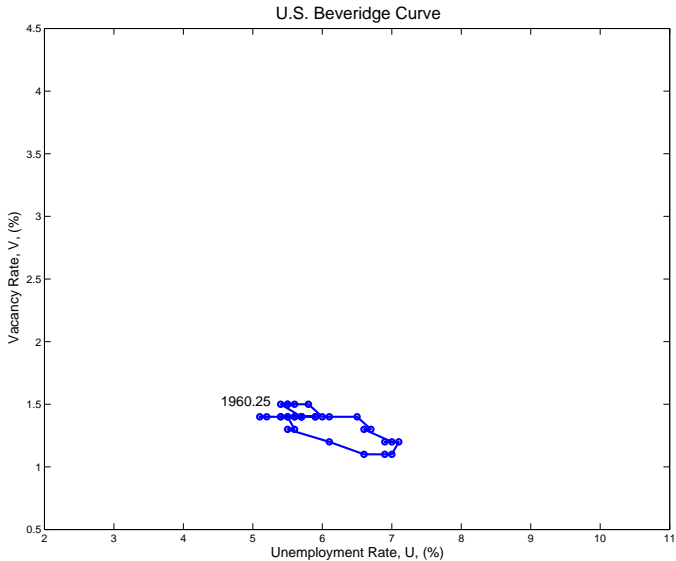
Fish Hooks in Other Recessions



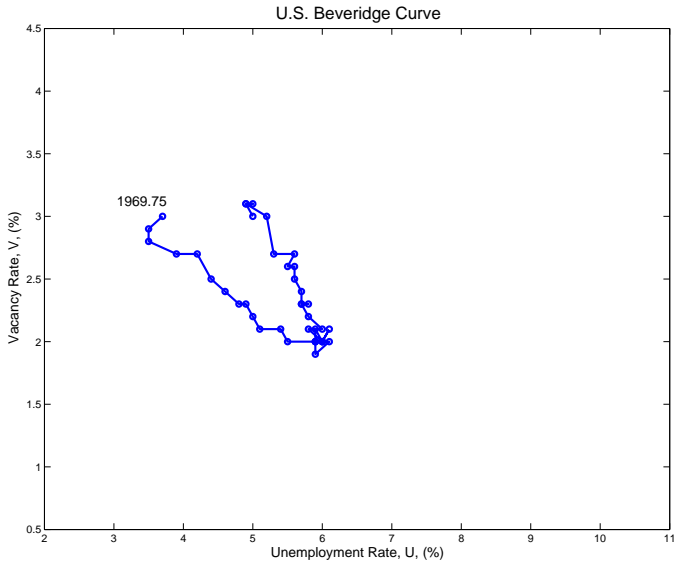
Fish Hooks in Other Recessions



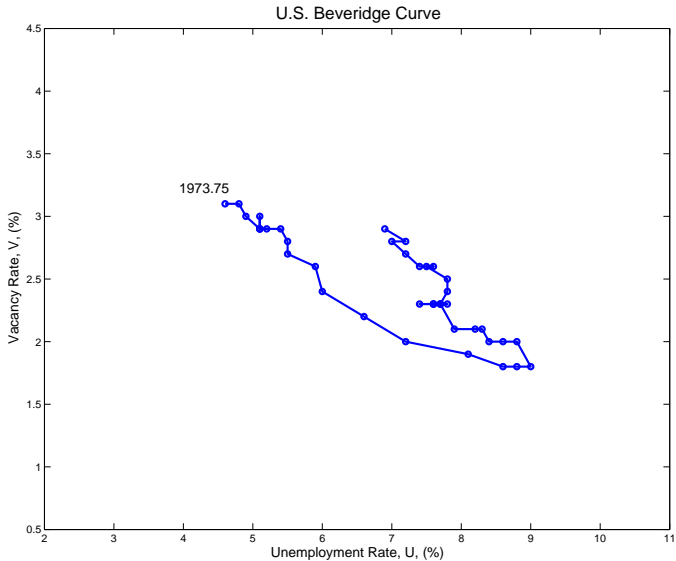
Fish Hooks in Other Recessions



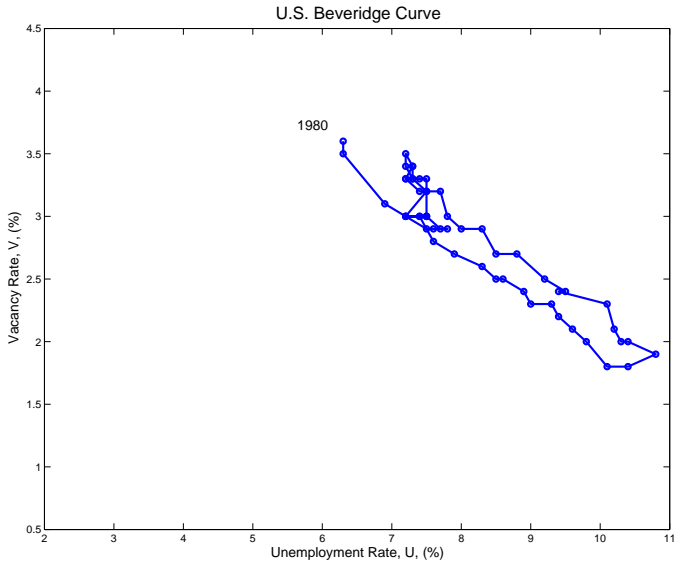
Fish Hooks in Other Recessions



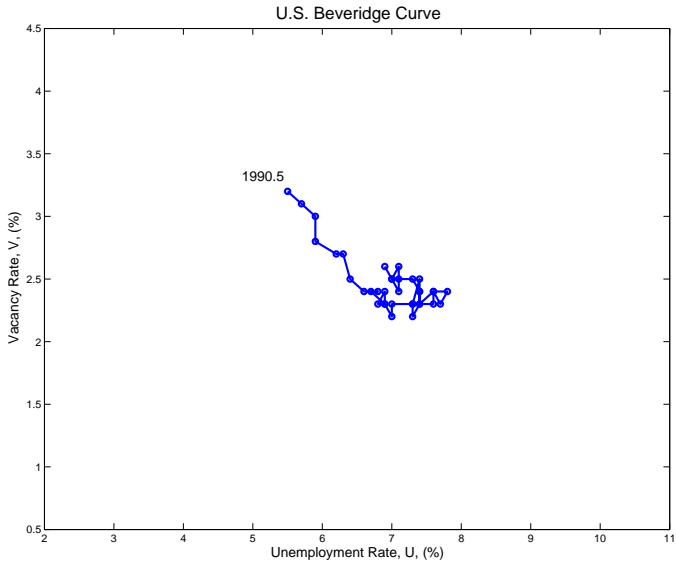
Fish Hooks in Other Recessions



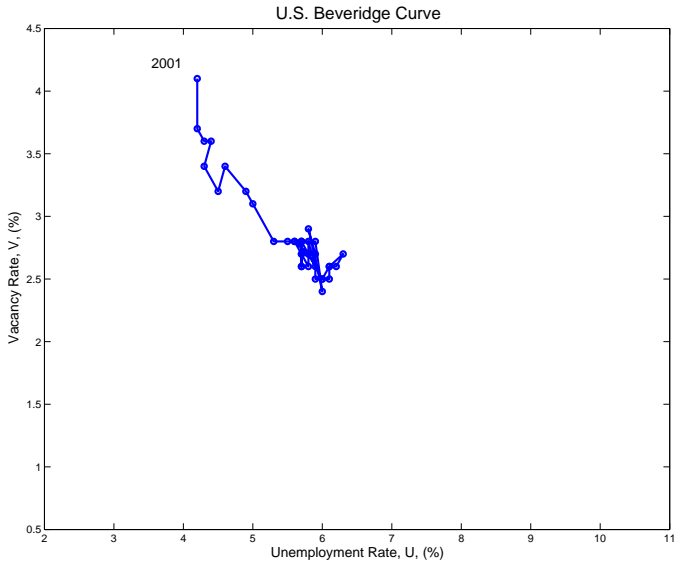
Fish Hooks in Other Recessions



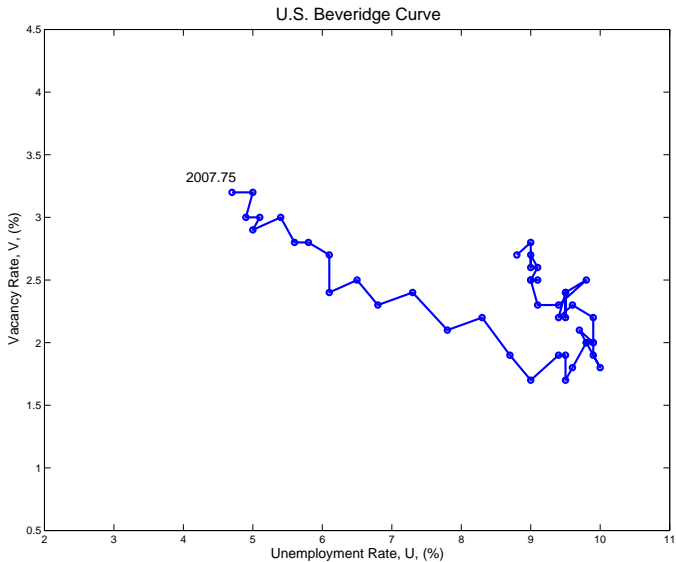
Fish Hooks in Other Recessions



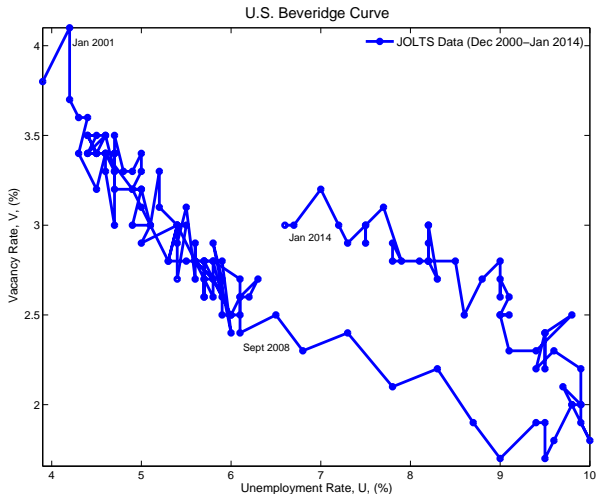
Fish Hooks in Other Recessions



Fish Hooks in Other Recessions

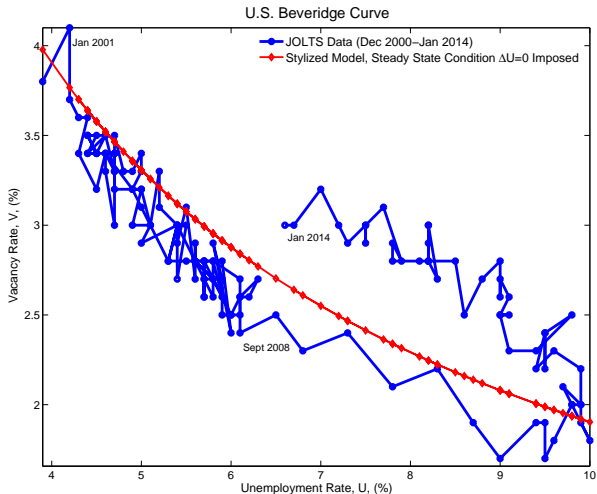


Magnitude of Fish Hook in DMP Model



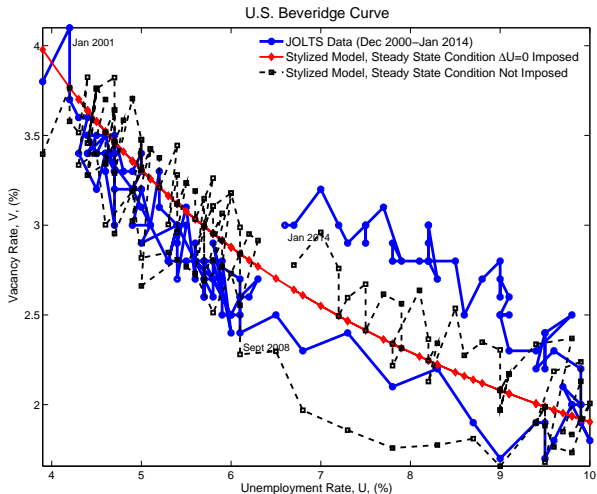
$$(\rho = 0.97, \alpha = 0.6, \sigma = 0.84, \text{ monthly})$$

Magnitude of Fish Hook in DMP Model



$$(\rho = 0.97, \alpha = 0.6, \sigma = 0.84, \text{ monthly})$$

Magnitude of Fish Hook in DMP Model



$$(\rho = 0.97, \alpha = 0.6, \sigma = 0.84, \text{ monthly})$$

End of Period Labor Market Flows

- Unemployed and just-separated workers at end of $t - 1$:

$$\begin{aligned} & \underbrace{\text{separated workers at end of } t-1}_{\text{employed in } t-1} \quad + \quad \underbrace{\text{unemployed in } t-1}_{\text{labor force in } t-1} \\ & (1 - \rho) \underbrace{l_{t-1}}_{\text{employed in } t-1} \quad + \quad \underbrace{L_{t-1}}_{\text{labor force in } t-1} - l_{t-1} \\ & = (1 - \rho) l_{t-1} + L_{t-1} - l_{t-1} \\ & = L_{t-1} - \rho l_{t-1}. \end{aligned}$$

- Some thrown exogenously into non-employment:

$$\underbrace{s (L_{t-1} - \rho l_{t-1})}_{\text{stay and search for jobs}} , \quad \underbrace{(1 - s) (L_{t-1} - \rho l_{t-1})}_{\text{go into non-employment}}$$

Beginning of Period Job Search

- Labor force at start of time t :

$$L_t = \begin{array}{l} \text{period } t-1 \text{ unemployed and separated who stay in labor force} \\ s(L_{t-1} - \rho l_{t-1}) \\ \text{people that were employed in previous period and remain attached} \\ + \rho l_{t-1} \\ \text{people sent to labor force from non-employment} \\ + r_t \end{array}$$

- Number of people searching for jobs at start of time t :

$$r_t + s(L_{t-1} - \rho l_{t-1}) = L_t - \rho l_{t-1}.$$

Job Finding

- Total meetings between workers and firms at start of t :

$$l_t = (\rho + x_t) l_{t-1} = \rho l_{t-1} + f_t \overbrace{(L_t - \rho l_{t-1})}^{r_t + s(L_{t-1} - \rho l_{t-1})},$$

where

$$f_t = \frac{\overbrace{x_t l_{t-1}}^{\text{aggregate hiring rate}}}{L_t - \rho l_{t-1}}.$$

- Workers and firms that meet, begin to bargain.
 - In equilibrium, meetings turn into matches.

Other Labor Market Variables: Vacancies.

- Empirical measure of vacancies (JOLTS):
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 - compare vacancies in model with JOLTS.
- Vacancies in our model.
 - vacancies costless, but firm must post them to hire.
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$$v = \frac{h}{Q}$$

vacancies (it takes Q as given).

- vacancies posted at the level of the establishment (firm has many establishments).
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- Q determined in the 'normal way':

$$Q = \frac{\text{agg hires}}{\text{agg vacancies}} = \text{constant} \times \left(\frac{\text{agg job searchers}}{\text{agg vacancies}} \right)^\sigma$$

Value functions for Workers and Firms

- Worker value functions:

$$\begin{aligned} V_t = & w_t + E_t m_{t+1} [\rho V_{t+1} \\ & + (1 - \rho) s (f_{t+1} \bar{V}_{t+1} + (1 - f_{t+1}) U_{t+1}) \\ & + (1 - \rho) (1 - s) N_{t+1}]. \end{aligned}$$

$$\begin{aligned} U_t = & D + E_t m_{t+1} [s f_{t+1} V_{t+1} \\ & + s (1 - f_{t+1}) U_{t+1} + (1 - s) N_{t+1}] \end{aligned}$$

$$\begin{aligned} N_t = & E_t m_{t+1} [e_{t+1} (f_{t+1} V_{t+1} + (1 - f_{t+1}) U_{t+1}) \\ & + (1 - e_{t+1}) N_{t+1}] \end{aligned}$$

$$e_t = \frac{r_t}{1 - L_{t-1}}$$

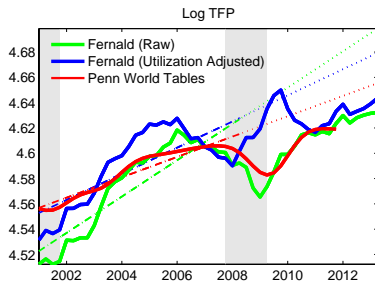
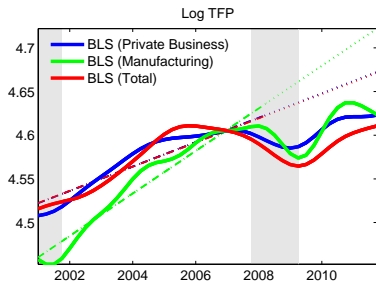
- Firm value function:

$$J_t = \vartheta_t - w_t + \beta E_t m_{t+1} J_{t+1}$$

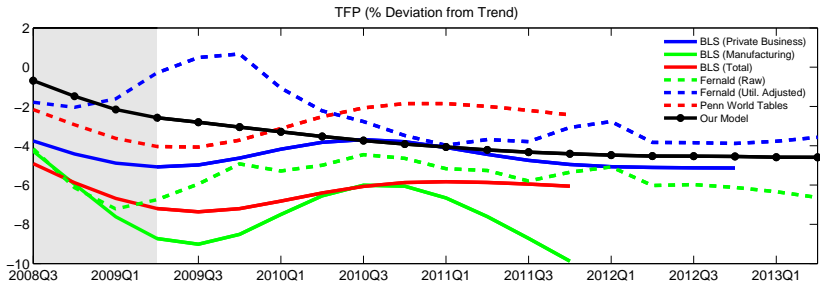
Rest of Model is Standard, Medium-Sized DSGE

- Competitive final goods production: $Y_t = \left[\int_0^1 Y_{j,t}^{\frac{1}{\lambda_f}} dj \right]^{\lambda_f}$.
- j^{th} input produced by monopolistic 'retailers':
 - Production: $Y_{j,t} = k_{j,t}^\alpha (z_t h_{j,t})^{1-\alpha} - \phi$.
 - Homogeneous good, $h_{j,t}$, purchased in competitive markets for real price, ϑ_t .
 - Retailers prices subject to Calvo sticky price frictions (no price indexation).
- Homogeneous input good h_t produced by the firms in our labor market model, 'wholesalers'.
- Taylor rule.

Very persistent decline in TFP



Notes: Linear trend from 2001Q1–2008Q2 (dashed–dotted). Forecast 2008Q3 and beyond based on linear trend (dotted).



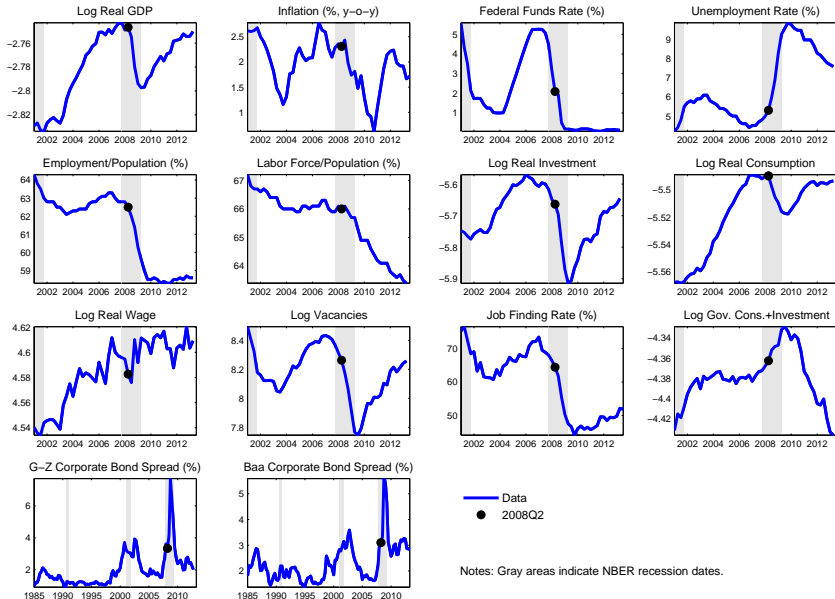
Components representation for technology shock

- We adopt unobserved components time series representation for growth rate of $\ln(z_t)$.
- Growth rate is sum of permanent, transitory component.
- When there's shock to $\ln(z_t)$, agents don't know whether it reflects permanent or temporary component.
 - Must solve signal extraction problem.
- Still, growth rate of technology is roughly a random walk.
 - Process as simple as a random walk can have components that are very different from a random walk.

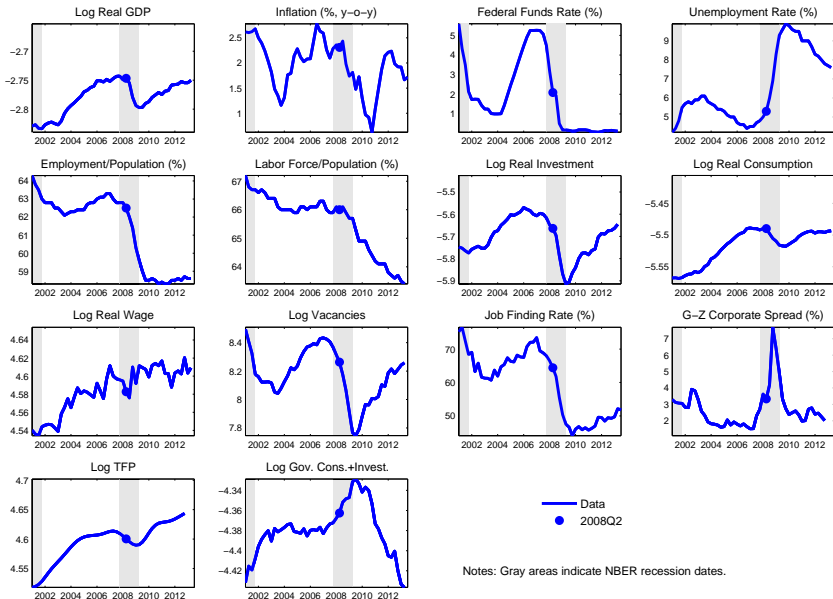
Components representaton for technology

- One-time shock to permanent component of $\ln(z_t)$ in 2008Q3.
- If agents knew in 2008Q3 that fall in TFP would be so persistent, model generates counterfactual surge in inflation.
 - We infer agents only gradually became aware of persistence in decline of TFP.
 - When estimating model we mpose prior that standard deviation of transitory shock is substantially larger than that of permanent shock.
- Notion that it took agents time to realize that drop in TFP was highly persistent is consistent with other evidence (e.g. Swanson and Williams).

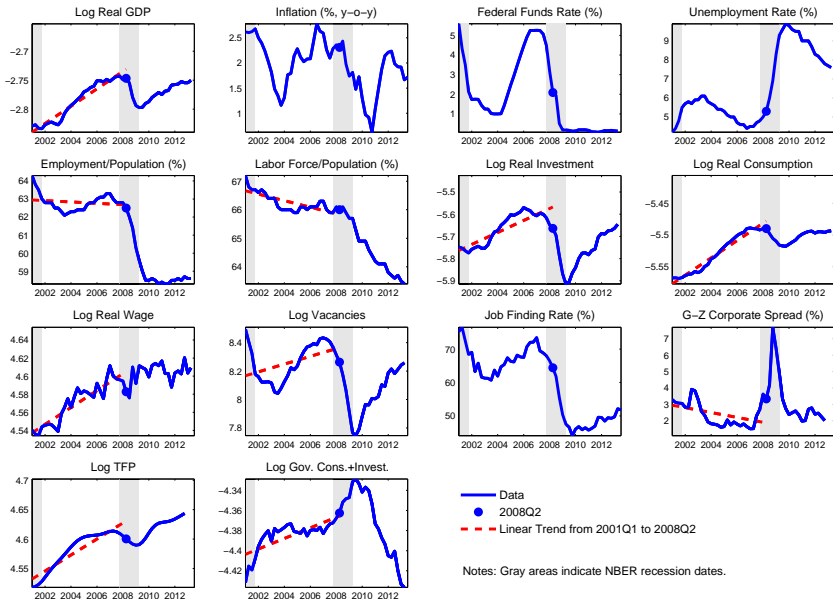
The U.S. Great Recession



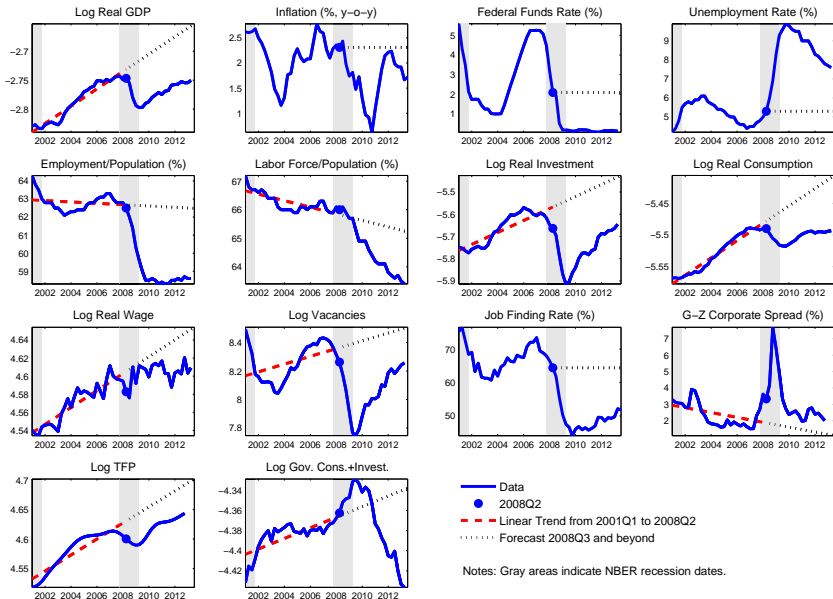
The U.S. Great Recession



The U.S. Great Recession



The U.S. Great Recession



The U.S. Great Recession: Data Targets

