Understanding the Great Recession

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The Great Recession and its Aftermath

- Great Recession: extraordinary contractions in output, investment and consumption.
  - CET (2014), Hall (2014): cumulative loss of real GDP relative to its projected trend in 2007 is over 65% of 2007 real GDP.

- Per capita employment, LFPR dropped substantially, little sign of improving.
  - Unemployment rate declined from its peak.
  - But, decline primarily reflects drop in LFPR
  - While vacancies have risen to pre-recession levels, this rise hasn’t translated into higher employment.

- Despite all this economic weakness, decline in inflation relatively modest.
Questions

• What were the key forces driving U.S. economy during the Great Recession?

• Mismatch in the labor market?

• Why was the drop in inflation so moderate?
To answer our questions we need a model

- Model must provide empirically plausible account of key macroeconomic aggregates
  - employment, vacancies, LFPR, job finding rate, unemployment rate, real wages
  - output, consumption, investment, ..

- 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 were the key drivers, even for variables like labor force participation.

- Consumption wedge
  - motivated by literature stressing reduction in consumption as trigger for ZLB
  - perturbation to agents’ intertemporal Euler equation governing accumulation of risk-free asset.

- Financial wedge
  - motivated by sharp increase in credit spreads observed in post-2008 period.
  - perturbation to households’ first order condition for optimal capital accumulation.
Questions and Answers

• 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.

• Rise in government consumption associated with ARRA had peak multiplier effect in excess of 2.

• But overall effect was small because of size and timing of spending.
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, risk-free interest rate.

• These forces drove up firms’ marginal costs.
  – Exerted countervailing pressures on deflationary forces operative during post-2008 period
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.
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, $\rho l_{t-1}$ 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:

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

\[ f_t = \frac{x_t l_{t-1}}{L_t - \rho l_{t-1}}. \]
2.2. Household Maximization

Members of the household derive utility from a market consumption good and a good produced at home. The home good is produced using labor of individuals who are not in the labor force and unemployed individuals:

\[
C_H^t = (1 - \ell_t) (L_t)^{1-\ell} \ell_t^{1-\gamma} C_t^{1-\ell} \ell_t^{1-\gamma} C_H^{L_t - L_t - 1} \ell_t^{1-\gamma} C_H^{L_t} \ell_t^{1-\gamma} C_H^{L_t - 1}
\]

The term \( F(L_t; L_t - 1; \ell_t) = 0 \) captures the idea that it is costly to change the number of people who specialize in home production, \( F(L_t; L_t - 1; \ell_t) = 0 \):

Because workers experience no disutility from working, they supply their labor inelastically. An employed worker brings home the wages that it earns. Unemployed workers receive government-provided unemployment compensation which they give to the household. Unemployment benefits are financed by lump-sum taxes paid by the household. Workers maximize their expected income. By the law of large numbers, this strategy maximizes the total income of the household. Workers maximize expected income in exchange for perfect consumption insurance from the household. All workers have the same concave preferences over consumption. So the optimal insurance arrangement involves allocating the same level of the market good and the home good to all members of the household.

The representative household maximizes the objective function:

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

\[
\tilde{C}_t = \left(1 - \omega\right) (C_t)^{\chi} + \omega \left(C_H^t\right)^{\chi} \frac{1}{\chi}
\]

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

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E_0 \sum_{t=0}^{\infty} \beta^t U(\tilde{C}_t)
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\[
\tilde{C}_t = \left[(1 - \omega)(C_t)^{\chi} + \omega(C_t^H)^{\chi}\right]^{\frac{1}{\chi}}
\]

\[
C_t^H = (1 - L_t)^{1-\alpha_c} (L_t - l_t)^{\alpha_c}
\]

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Labor Market

\[
\max_{\{c_t,l_t,c_t^H,b_{t+1},k_{t+1},i_t,t_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t u(\tilde{c}_t)
\]

\[
P_t c_t + P_{I,t} I_t + B_{t+1} \leq R_{K,t} K_t + (L_t - l_t) P_t D_t + l_t W_t + R_{t-1} B_t - T_t
\]

\[
K_{t+1} = (1 - \delta_K) K_t + [1 - S (I_t/I_{t-1})] I_t
\]

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

Three types of worker-firm meetings:
i) E to E, ii) U to E, iii) N to E
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 $\gamma$ to firm of rejecting worker offer and preparing a counteroffer.

  – Rejection risks total break down in negotiations with probability $\delta$.

  – 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:

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

- $\vartheta_t$ 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:

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

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

- Value of unemployment to a worker:

\[ U_t = D + E_{t+1} \left[ s f_{t+1} V_{t+1} + s (1 - f_{t+1}) U_{t+1} \right] + (1 - s) N_{t+1} \]

where \( D \) denotes unemployment benefits.

- Value of non-participation

\[ N_t = E_{t+1} \left[ e_{t+1} (f_{t+1} V_{t+1} + (1 - f_{t+1}) U_{t+1}) \right] + (1 - e_{t+1}) N_{t+1} \]

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

- Our labor market structure.
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.
Estimated Replacement Ratio

- Replacement ratio: unemployment payments relative to wage.
  - In model, estimated to be 0.19 (i.e., 19%).

- Direct data measure:
  - \( \frac{\text{gov't payments for unemp. insurance per unemployed compensation per employed worker}}{} \)
  - Mean of ratio in our sample period, 14%.

- Standard DMP model requires replacement ratio \( > 90\% \) to reproduce volatility of labor market data (Hagedorn-Manovskii).

- People out of labor force account for virtually all of home production.
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

- 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 he starts trend in 1990, obtains similar results.
The U.S. Great Recession

Figure 6: The Great Recession in the U.S.

Notes: Gray areas indicate NBER recession dates.

Data

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The U.S. Great Recession

Log Real GDP

Inflation (%, y−o−y)

Federal Funds Rate (%)

Unemployment Rate (%)

Employment/Population (%)

Labor Force/Population (%)

Log Real Investment

Log Real Consumption

Log Real Wage

Log Vacancies

Job Finding Rate (%)

G−Z Corporate Spread (%)

Log TFP


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Data
2008Q2
Linear Trend from 2001Q1 to 2008Q2
The U.S. Great Recession

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Data

2008Q2

Linear Trend from 2001Q1 to 2008Q2

Forecast 2008Q3 and beyond
The U.S. Great Recession: Data Targets

- **GDP (%):** Data shows a significant decline from 2009 to 2015, indicating a major economic contraction.
- **Inflation (p.p., y-o-y):** Inflation was relatively stable with minor fluctuations from 2009 to 2015.
- **Federal Funds Rate (ann. p.p.):** The Federal Funds Rate increased from 2009 to 2011, then remained relatively stable until 2015.
- **Unemployment Rate (p.p.):** Unemployment rate increased sharply from 2009 to 2013, showing a significant rise in unemployment.
- **Employment (p.p.):** Employment data also shows a decrease from 2009 to 2015.
- **Labor Force (p.p.):** The labor force remained relatively stable with minor changes from 2009 to 2015.
- **Investment (%):** Investment data shows a decline from 2009 to 2015.
- **Consumption (%):** Consumption data shows a decline from 2009 to 2015.
- **Real Wage (%):** Real wage data shows a decline from 2009 to 2015.
- **Vacancies (%):** Vacancies data shows a decline from 2009 to 2015.
- **Job Finding Rate (p.p.):** Job finding rate data shows an increase from 2009 to 2015.
- **TFP Level (%):** TFP Level data shows a decline from 2009 to 2015.
- **Gov. Cons. & Invest. (%, exog.):** Government consumption and investment data shows a decline from 2009 to 2015.
Two Financial Market Shocks

Consumption wedge, $\Delta^b_t$: Shock to demand for safe assets (‘Flight to safety’, see e.g. Fisher 2014):

$$1 = (1 + \Delta^b_t)E_t m_{t+1} R_t / \pi_{t+1}$$
Two Financial Market Shocks

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2. Financial wedge, $\Delta^k_t$: Reduced form of ‘risk shock’,

   
   \[ 1 = (1 - \Delta^k_t) E_t m_{t+1} R^k_{t+1} / \pi_{t+1} \]
**Two Financial Market Shocks**

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2. **Financial wedge, $\Delta^k_t$:** Reduced form of ‘risk shock’, Christiano-Davis (2006), Christiano-Motto-Rostagno (2014):

\[
1 = (1 - \Delta^k_t) E_t m_{t+1} R^k_{t+1} / \pi_{t+1}
\]

- Financial wedge also applies to working capital loans:
  - Interest charge on working capital: $R_t (1 + \Delta^k_t)$
  - Assume 1/2 of labor inputs financed with loans.
  - Higher financial wedge directly increases cost to firms.
Measurement of Shocks

1. Financial wedge, $1 - \Delta^k_t$, measured using GZ spread data.

2. Government shock measured using $G$ data.

3. Neutral technology shock based on TFP data.

4. We don’t have data on the consumption wedge, $\Delta^b_t$.
   - In 2008Q3, agents expect $\Delta^b_t$ to jump from 0 to 0.33% until 2013Q2.
   - In 2012Q3 agents revise expectation and expect $\Delta^b_t$ to remain up until 2014Q3 (stand-in for fiscal cliff, sequester).

- Stochastic simulation starting 2008q3 (nonlinear model, no perfect foresight).
Exogenous Processes

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

Gov. Consumption & Investment (%)

Neutral Technology Level (%)

Consumption Wedge (annualized p.p.)

Notes: Data are the differences between raw data and forecasts, see Figure 4.
Initial path from 2008Q3
Revised path from 2012Q3
Assessing model’s implication for TFP
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

Figure 7: The U.S. Great Recession: Data vs. Model
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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 shock* - accounts for the biggest effect on real quantities.
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- Flight to quality shock - drives economy into lower bound, pushes down inflation.
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  - *TFP shock* - 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.
    \[ \Rightarrow Both \ raise \ countervailing \ pressure \ on \ inflation. \]
Decomposition for Inflation
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.
  – This claim is based on assumption that unemployment is at steady state.

• In our model, no shift occurs in the matching technology.
  – if anything, our model predicts an even bigger ‘shift’ than occurred.
The Beveridge Curve: Data vs. Model

Figure 15: Beveridge Curve: Data vs. Model

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Unemployment Rate (p.p. dev. from 2008Q2 data or model steady state)

Vacancies (log dev. from data trend or model steady state)

-10
-90
-80
-70
-60
-50
-40
-30
-20
-10

2008Q3
2009Q1
2010Q3
2011Q4
2013Q2
2009Q4

Data
Model
Model Predicts Fish Hook, Why?

- Simplest DMP style model

\[ U_{t+1} - U_t = (1 - \rho)(1 - U_t) - f_t U_t \]
Model Predicts Fish Hook, Why?

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

solving for \( f_t \):

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

Naturally implies a '…sh hook' pattern.
Model Predicts Fish Hook, Why?

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solving for \( f_t \):

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

solving for \( V_t \):

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

- Naturally implies a 'fish hook' pattern.
(\(\rho = 0.97, \alpha = 0.6, \sigma = 0.84\), monthly)
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:
  - firms face moderate degrees of price rigidities,
  - no sticky wages.

- 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.
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.
Background

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- 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.
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  - That is, we avoid microfounding the shocks.
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, the 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.
Outline

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  – 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).

Estimate model using pre-2008 data.
Use estimated model to analyze post-2008 data.
Outline

• Mostly, a standard ‘medium-sized’ DSGE model

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• Estimate model using pre-2008 data.

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The Effect of Neutral Technology

Figure 8: The U.S. Great Recession: Effects of Neutral Technology

GDP (%)

Inflation (p.p., y–o–y)

Federal Funds Rate (ann. p.p.)

Unemployment Rate (p.p.)

Employment (p.p.)

Labor Force (p.p.)

Investment (%)

Consumption (%)

Real Wage (%)

Vacancies (%)

Job Finding Rate (p.p.)

G–Z Corp. Bond Spread (ann. p.p.)

Gov. Cons. & Invest. (% exog.)

Fin. Wedge (quart. p.p., exog.)

Cons. Wedge (quart. p.p., exog.)
The Effect of Consumption Wedge

Figure 11: The U.S. Great Recession: Effects of Consumption Wedge
The Effect of Forward Guidance

Figure 13: The U.S. Great Recession: Effects of Forward Guidance
The Effect of 2012Q3 Consumption Wedge

- GDP (%)
- Inflation (p.p., y-o-y)
- Federal Funds Rate (ann. p.p.)
- Unemployment Rate (p.p.)
- Employment (p.p.)
- Labor Force (p.p.)
- Investment (%)
- Consumption (%)
- Real Wage (%)
- Vacancies (%)
- Job Finding Rate (p.p.)
- G-Z Corp. Bond Spread (ann. p.p.)
- TFP Level (%)
- Gov. Cons. & Invest. (%)
- Fin. Wedge (quart. p.p., exog.)
- Cons. Wedge (quart. p.p., exog.)
The Government Consumption Multiplier

Figure 16: Fiscal Multiplier in a 3 Year Zero Lower Bound Episode

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

Figure 12: The U.S. Great Recession: Effects of Government Consumption and Investment
Government Consumption Played only a Small Role

- Estimated multiplier around 2 during early period (American Recovery and Reinvestment Act of 2009)
- Rise in government consumption too small to have a substantial effect.
- Recent decline in government consumption is large, but has small multiplier effect.
- Consistent with ZLB analysis of Christiano-Eichenbaum-Rebelo (JPE2012).
- Government movements expected to last beyond ZLB have very small multiplier effects.
- Government beyond ZLB has negative impact on ZLB, because of depressive wealth effects on consumption.
Government Consumption Played only a Small Role

- Estimated multiplier around 2 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 effect on consumption.
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Other Labor Market Variables: Vacancies.

- Empirical measure of vacancies (JOLTS):
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Vacancies in our model:
- vacancies costless, but firm must post them to hire.
- if firm wants to hire $h$ workers it must post $v = h$ 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':

$$Q = \frac{agg\ hires}{agg\ vacancies} = \frac{agg\ job\ searchers}{agg\ vacancies} \cdot \sigma$$
Other Labor Market Variables: Vacancies.

- Empirical measure of vacancies (JOLTS):
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    \]
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- $Q$ determined in the ‘normal way’:
  \[ Q = \frac{\text{agg hires}}{\text{agg vacancies}} = \text{constant} \times \left( \frac{\text{agg job searchers}}{\text{agg vacancies}} \right)^\sigma \]
Other Labor Market Variables: Job Finding Rate.

- Job finding rate:

\[ f = \frac{\text{agg hires}}{\text{agg job searchers}} \]
Monetary Policy in the Great Recession

- From 2008Q3 to 2011Q2:

\[
\ln(Z_t) = \ln(R_t) + 1.7z + 0.25\sigma R_{\varepsilon t} + 0.015 z + 0.231 \ln(Y_t/Y_t) + 0.25 \Delta y/0.4Y_t.
\]

- The actual policy rate, \( R_t \):

\[
\ln(R_t) = \max \left( \ln(1) + \rho_R \ln(Z_{t-1}) + (1 - \rho_R) \ln(Z_t), \nu \right).
\]
Monetary Policy in the Great Recession

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

\[
\ln(Z_t) = \ln(R) + r_\pi \ln(\pi_t^A / \pi^A) + 0.25r_y \ln(\mathcal{Y}_t / \mathcal{Y}^*)
\]

\[
+ 0.231 r_{\Delta y} \ln(\mathcal{Y}_t / (\mathcal{Y}_{t-4} \mu^A)) + \sigma_R \varepsilon_{R,t}.
\]

- The actual policy rate, \( R_t \):

\[
\ln(R_t) = \max \{ \ln(1), \rho_R \ln(Z_{t-1}) + (1 - \rho_R) \ln(Z_t) \}
\]
Monetary Policy in the Great Recession

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

\[
\ln(Z_t) = \ln(R) + r_{\pi} \ln \left( \frac{\pi_t^A}{\pi^A} \right) + 0.25 r_y \ln \left( \frac{\mathcal{Y}_t}{\mathcal{Y}_t^*} \right) + 0.231 r_{\Delta y} \ln \left( \frac{\mathcal{Y}_t}{(\mathcal{Y}_{t-4})^A} \right) + \sigma_R \varepsilon_{R_t}.
\]

- The actual policy rate, \( R_t \):

\[
\ln(R_t) = \max \{ \ln(1), \rho_R \ln(Z_{t-1}) + (1 - \rho_R) \ln(Z_t) \}
\]

- 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%.
Stochastic Simulation of the Model

- Feed the four shocks to the model and simulate the post 2008Q2 data.
Stochastic Simulation of the Model

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

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- 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.
Fish Hooks in Other Recessions

U.S. Beveridge Curve

Unemployment Rate, U, (%) vs. Vacancy Rate, V, (%)
Fish Hooks in Other Recessions

U.S. Beveridge Curve

Unemployment Rate, U, (%) vs. Vacancy Rate, V, (%)

1957.5
Fish Hooks in Other Recessions

U.S. Beveridge Curve

Unemployment Rate, U, (%)
Vacancy Rate, V, (%)

2019.25

1960.25

Unemployment Rate, U, (%)
Fish Hooks in Other Recessions

U.S. Beveridge Curve

Unemployment Rate, U, (%)
Vacancy Rate, V, (%)
Fish Hooks in Other Recessions

U.S. Beveridge Curve

Unemployment Rate, U, (%)
Vacancy Rate, V, (%)

1973.75
Fish Hooks in Other Recessions

U.S. Beveridge Curve

Unemployment Rate, U, (%) vs. Vacancy Rate, V, (%)

1980

Unemployment Rate, U, (%) vs. Vacancy Rate, V, (%) graph for the years 1980, showing the Beveridge curve.
Fish Hooks in Other Recessions

U.S. Beveridge Curve

Unemployment Rate, U, (%) vs. Vacancy Rate, V, (%)
Fish Hooks in Other Recessions

U.S. Beveridge Curve

Unemployment Rate, U, (%)
Vacancy Rate, V, (%)
Fish Hooks in Other Recessions

U.S. Beveridge Curve

Unemployment Rate, U, (%)  
Vacancy Rate, V, (%)
End of Period Labor Market Flows

Unemployed and just-separated workers at end of $t$: separated workers at end of $t$z | employed in $t$z | unemployed in $t$z | labor force in $t$z | $L_{t1} = (1 - \rho)l_{t1} + L_{t1}l_{t1}$.

Some thrown exogenously into non-employment: stay and search for jobs $z | s(L_{t1}\rho l_{t1}) | go into non-employment $z | (1 - s)(L_{t1}\rho l_{t1})$. 
End of Period Labor Market Flows

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

\[
(1 - \rho) \cdot l_{t-1} + L_{t-1} - l_{t-1}
\]
End of Period Labor Market Flows

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

\[
(1 - \rho) \ l_{t-1} + L_{t-1} - l_{t-1}
\]
End of Period Labor Market Flows

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

\[
(1 - \rho) \underbrace{l_{t-1}}_{\text{employed in } t-1} + \underbrace{L_{t-1} - l_{t-1}}_{\text{labor force in } t-1}
\]

\[
= (1 - \rho) l_{t-1} + L_{t-1} - l_{t-1}
\]

\[
= L_{t-1} - \rho l_{t-1}.
\]
End of Period Labor Market Flows

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

$$\left\{ \begin{array}{l}
\text{separated workers at end of } t-1 \\
\text{employed in } t-1 \\
\text{unemployed in } t-1 \\
\text{labor force in } t-1
\end{array} \right\}$$

$$= (1 - \rho) l_{t-1} + L_{t-1} - l_{t-1}$$

$$= L_{t-1} - \rho l_{t-1}.$$  

• Some thrown exogenously into non-employment:

$$\left\{ \begin{array}{l}
\text{stay and search for jobs} \\
\text{go into non-employment}
\end{array} \right\}$$

$$s (L_{t-1} - \rho l_{t-1}), \quad (1 - s) (L_{t-1} - \rho l_{t-1})$$
Beginning of Period Job Search

- Labor force at start of time $t$:

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

- $L_t$ is the labor force at the start of period $t$.
- $s(L_{t-1} - \rho l_{t-1})$ represents period $t-1$ unemployed and separated who stay in labor force.
- $\rho l_{t-1}$ represents people that were employed in the previous period and remain attached.
- $r_t$ represents people sent to labor force from non-employment.
Beginning of Period Job Search

- Labor force at start of time $t$ :

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

  - period $t-1$ unemployed and separated who stay in labor force
  - people that were employed in previous period and remain attached
  - people sent to labor force from non-employment

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

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

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

\[
l_t = (\rho + x_t) l_{t-1} = \rho l_{t-1} + f_t \left( L_t - \rho l_{t-1} \right),
\]

where

\[
f_t = \frac{x_t l_{t-1}}{L_t - \rho l_{t-1}}.
\]
Job Finding

- Total meetings between workers and firms at start of \( t \): 
  
  \[
  l_t = (\rho + x_t) l_{t-1} = \rho l_{t-1} + f_t \left( L_t - \rho l_{t-1} \right),
  \]

  where 
  \[
  f_t = \frac{x_t l_{t-1}}{L_t - \rho l_{t-1}}.
  \]

- Workers and firms that meet, begin to bargain.
  - In equilibrium, meetings turn into matches.
Other Labor Market Variables: Vacancies.

- Empirical measure of vacancies (JOLTS):
  - position posted by an establishment, which it would fill if it met a suitable candidate.

\[ Q = \frac{\text{agg hires}}{\text{agg vacancies}} = \text{constant} \]
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 \( v = h \) vacancies (it takes \( Q \) as given).
- vacancies posted at the level of the establishment (firm has many establishments).

\( Q \) determined in the 'normal way':
\[
Q = \frac{\text{agg hires}}{\text{agg vacancies}} = \frac{\text{constant}}{\sigma} \text{agg job searchers agg vacancies}.
\]
Other Labor Market Variables: Vacancies.

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- $Q$ determined in the ‘normal way’:
  $$Q = \frac{\text{agg hires}}{\text{agg vacancies}}$$
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.
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    v = \frac{h}{Q}
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  - 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’:**
  \[
  Q = \frac{\text{agg hires}}{\text{agg vacancies}} = \text{constant} \times \left( \frac{\text{agg job searchers}}{\text{agg vacancies}} \right)^\sigma
  \]
Value functions for Workers and Firms

- Worker value functions:
  \[
  V_t = w_t + E_t m_{t+1} \left[ \rho V_{t+1} 
    + (1 - \rho) s \left( f_{t+1} \tilde{V}_{t+1} + (1 - f_{t+1}) U_{t+1} \right) 
    + (1 - \rho) (1 - s) N_{t+1} \right].
  \]
Value functions for Workers and Firms

- Worker value functions:

  \[ V_t = w_t + E_t m_{t+1} \left[ \rho V_{t+1} \right. \]
  \[ + (1 - \rho) s \left( f_{t+1} \tilde{V}_{t+1} + (1 - f_{t+1}) U_{t+1} \right) \]
  \[ + (1 - \rho) (1 - s) N_{t+1} \].

  \[ U_t = D + E_t m_{t+1} \left[ s f_{t+1} V_{t+1} \right. \]
  \[ + s (1 - f_{t+1}) U_{t+1} + (1 - s) N_{t+1} \]
Value functions for Workers and Firms

- Worker value functions:

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

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

\[
N_t = E_t m_{t+1} [e_{t+1} (f_{t+1} V_{t+1} + (1 - f_{t+1}) U_{t+1}) \\
+ (1 - e_{t+1}) N_{t+1}]
\]
Value functions for Workers and Firms

- Worker value functions:

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

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

\[ e_t = \frac{r_t}{1 - L_{t-1}} \]
Value functions for Workers and Firms

- Worker value functions:

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

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

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

\[ e_t = \frac{r_t}{1 - L_{t-1}} \]

- Firm value function:

\[ J_t = \delta_t - w_t + \beta E_t m_{t+1} J_{t+1} \]
Rest of Model is Standard, Medium-Sized DSGE

- Competitive final goods production: $Y_t = \left[ \int_{0}^{1} Y_{j,t}^{\lambda_f} \right]^{\lambda_f}$.
Rest of Model is Standard, Medium-Sized DSGE

- Competitive final goods production: \( Y_t = \left[ \int_0^1 \frac{1}{\lambda_f} Y_{j,t}^\lambda_f \, dj \right]^{\lambda_f} \).

- \( j^{th} \) input produced by monopolistic ‘retailers’:
Rest of Model is Standard, Medium-Sized DSGE

- Competitive final goods production: \( Y_t = \left[ \int_0^1 Y_{j,t}^{\lambda_f} \, dj \right]^{\lambda_f} \).

- \( j^{th} \) input produced by monopolistic ‘retailers’:
  - Production: \( Y_{j,t} = k_{j,t}^{\alpha} (z_t h_{j,t})^{1-\alpha} - \phi \).
Rest of Model is Standard, Medium-Sized DSGE

- Competitive final goods production: \( Y_t = \left[ \int_0^1 \frac{1}{Y_{j,t}} \, dj \right]^{\lambda_f} \).

- \( j^{th} \) 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
Rest of Model is Standard, Medium-Sized DSGE

- Competitive final goods production: $Y_t = \left[ \int_0^1 \frac{1}{\lambda_f} Y_{j,t}^\lambda_f dj \right]^\lambda_f$.

- $j^{th}$ input produced by monopolistic ‘retailers’:
  - Production: $Y_{j,t} = k_{j,t}^\alpha \left( z_t h_{j,t} \right)^{1-\alpha} - \phi$.
  - Homogeneous good, $h_{j,t}$, purchased in competitive markets for real price, $\vartheta_t$. 

Homogeneous input good $h_t$ produced by the …rms in our labor market model, ‘wholesalers’. Taylor rule.
Competitive final goods production: \( Y_t = \left[ \int_0^1 Y_{j,t}^{\lambda_f} \, dj \right]^{\lambda_f} \).

\( j^{th} \) input produced by monopolistic ‘retailers’:

- Production: \( Y_{j,t} = k_{j,t}^\alpha \left( z_{t} h_{j,t} \right)^{1-\alpha} - \phi. \)
- Homogeneous good, \( h_{j,t} \), purchased in competitive markets for real price, \( \vartheta_t \).
- Retailers prices subject to Calvo sticky price frictions (no price indexation).
Rest of Model is Standard, Medium-Sized DSGE

- Competitive final goods production: $Y_t = \left[ \frac{1}{\lambda_f} \int_0^1 Y_{j,t}^\lambda_f \, dj \right]^{\lambda_f}$.

- $j^{th}$ 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, $\vartheta_t$.
  - 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’.
Rest of Model is Standard, Medium-Sized DSGE

- Competitive final goods production: \( Y_t = \left[ \int_0^1 Y_{j,t} d\lambda_f \right]^{\lambda_f} \).

- \( j^{th} \) input produced by monopolistic ‘retailers’:
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- Taylor rule.