Fiscal Stimulus and Distortionary Taxation

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Outline

1. An NK model with distort. taxes and gov. capital.
   - Estimation and Historical Shocks
   - Explaining the financial crisis
2. Results
   - Benchmark
   - Sensitivity analysis
3. The power of monetary policy?
4. Conclusion
5. Appendix: Model and Estimation Details
   - Log-linearized equations
   - Estimation and Historical Shocks
   - Impulse-Response-Functions at Posterior Mean

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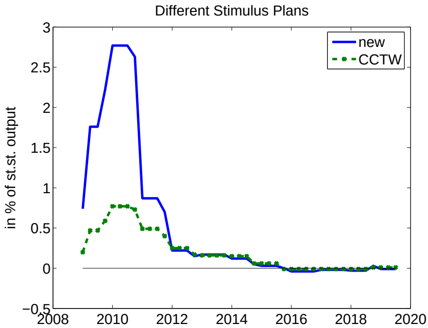
The Approach

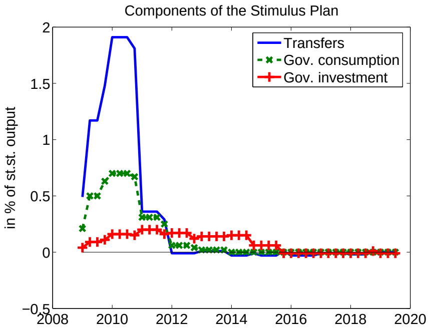
- Question: what is the fiscal multiplier for the ARRA?
- ARRA has gov. purchases, gov. investment, transfers.
- "Uhlig (2010) + Cogan-Cwik-Taylor-Wieland (CCTW), 2009." Extend.
- Start from Smets-Wouters, AER 2007.
- Add:
  1. Distortionary taxation.
  2. "Rule-of-thumb" (RoT) households: consume earnings each period.
  3. Baseline: transfers all to "RoT" households.
  4. Fiscal feedback rules for taxation.
  5. Government capital.
  6. ZLB. Benchmark 8 quarters. Consider 0, 4, 8, 12, endog.
- Fiscal multiplier at horizon s: compare NPV's.
- Estimate, provide Bayesian posteriors.
- Calculate sensitivity to key ingredients.

CCTW Stimulus: CCWT vs DU

DU (“new”) vs CCTW: Aggregate



DU in Detail



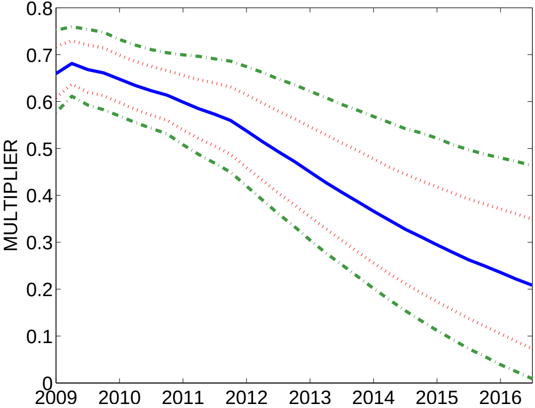
Sources: CCTW (2010), Congressional Budget Office (2009).

The Fiscal Multiplier

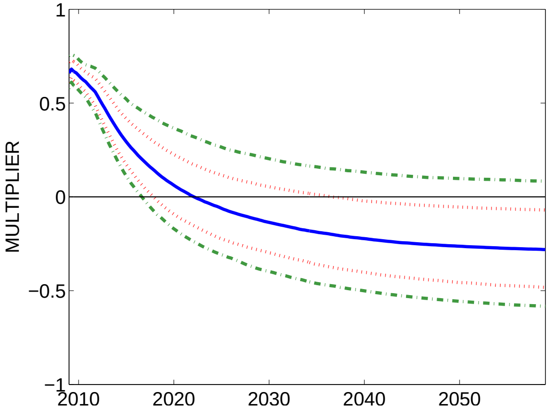
$$\varphi_t = \sum_{s=1}^{t} \left(\mu^s \prod_{j=1}^{s} R_j^{-1} \right) \hat{y}_s \Big/ \sum_{s=1}^{t} \left(\mu^s \prod_{j=1}^{s} R_j^{-1} \right) \hat{g}_s$$

- φ_t: horizon-t multiplier.
- $R_{j,ARRA}$: government bond return, from $j-1$ to j under ARRA.
- $\hat{y}_s$: output change at date s due to ARRA, in % of GDP.
- $\hat{g}_s$: ARRA spending at date s, in % of GDP.
- μ: balanced-growth factor.
- **Net present value** (NPV) fiscal multiplier.

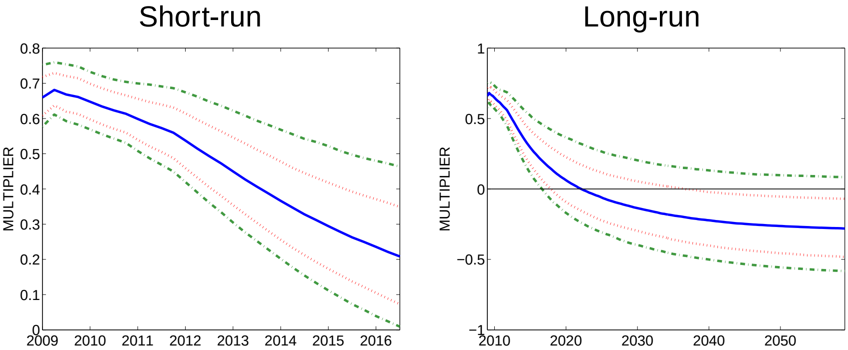
Fiscal multipliers. ZLB-target 8 qrts. Short-run ...



Fiscal multipliers. ZLB-target 8 qrts. ... and long run



Fiscal multipliers. ZLB-target 8 qrts.



Smets-Wouters (2007): overview

- Elaborate New Keynesian model.
- Continuum of households. They supply household-specific labor in monopolistic competition. They set Calvo-sticky wages.
- Continuum of intermediate good firms. They supply intermediate goods in monopolistic competition. They set Calvo-sticky prices.
- Final goods use intermediate goods. Perfect competition.
- Habit formation, adjustment costs to investment, variable capital utilization.
- Monetary authority: Taylor-type rule.

Modifications

- Distortionary labor taxation, consumption taxes, capital income taxes. Steady state levels: Trabandt-Uhlig (2009).
- ZLB: hold FFR at zero for k quarters.
- “Credit-constrained” or “rule-of-thumb” consumers (25%).
- Government capital.
- Estimate. Provide Bayesian posteriors for fiscal multipliers.
- Stimulus: path per ARRA
  - 17%: Government investment. Government capital.
  - 24%: Government consumption.
  - 59%: Transfers to credit-constrained consumers.

Tax rule

- Remaining deficit, prior to new debt and labor taxes ...

$$\begin{aligned} d_t &= \text{gov.spend.+subs.}_t + \text{old debt repaym.}_t \\ &\quad - \text{consump.tax rev.,cap.tax rev.}_t - \bar{\tau}^l \,\text{lab.income}_t \end{aligned}$$

- ... needs to be financed:

$$\tau_t^l \,\text{lab.income}_t + \text{new debt}_t = d_t$$

- Balanced growth debt, taxes, deficit: $\bar{d}_t$.
- Tax rule:

$$(\tau_t^l - \bar{\tau}^l)\,\text{lab.income}_t = \psi_\tau (d_t - \bar{d}_t)$$

Financial friction: bond premium shock.

$$
\begin{aligned}
1 &= \beta E_t \left[\frac{u_{c,t+1}}{u_{c,t}} \frac{R_t^{gov}}{\pi_{t+1}} \right] = \beta E_t \left[\frac{u_{c,t+1}}{u_{c,t}} (1 + \omega_t^{gov}) \frac{R_t^{FFR}}{\pi_{t+1}} \right] \\
&= \beta E_t \left[\frac{u_{c,t+1}}{u_{c,t}} \left((1 - \omega_t^k)[(1 - \tau^k) r_{t+1}^k + \delta \tau^k] + (1 - \delta) \frac{Q_{t+1}}{Q_t} \right) \right]
\end{aligned}
$$

1. Gov. bond shock ω_t^{gov}: wedge between FFR and gov't bonds.
2. Priv. bond shock ω_t^k: wedge between gov't bonds and priv. capital.

Stand-in for financial friction. With perfect foresight:

$$
\frac{R_t^{FFR}}{\pi_{t+1}} = \frac{1}{(1 + \omega_t^{gov})} \left((1 - \omega_t^k)[r_{t+1}^k - \tau^k (r_{t+1}^k - \delta)] + (1 - \delta) \right).
$$

Government capital in production

- Technology for intermediate goods production:

$$Y_t(i) = \tilde{\epsilon}_t^a \left(\frac{K_{t-1}^g}{\int_0^1 Y_t(j)dj + \Phi\mu^t} \right)^{\frac{\zeta}{1-\zeta}} K_t^s(i)^\alpha [\mu^t n_t(i)]^{1-\alpha} - \mu^t \Phi,$$

where Φ are fixed costs, K_t^s are capital services.

- ϵ_t^a is TFP, $\log \epsilon_t^a \sim$ AR(1).
- Government capital services K_{t-1}^g subject to congestion.
- Aggregate production function:

$$Y_t = \epsilon_t^a {K_{t-1}^g}^\zeta {K_t^s}^{\alpha(1-\zeta)} [\mu^t n_t]^{(1-\alpha)(1-\zeta)} - \mu^t \Phi, \quad \epsilon_t^a \equiv (\tilde{\epsilon}_t^a)^{1-\zeta}.$$

Along the balanced growth path: $\bar{\epsilon}^a \equiv 1$.

- Current profits:

$$P_t(i) Y_t(i) - W_t n_t(i) - R_t^k K_t^s(i)$$

Government capital accumulation

$$k_t^g = (1-\delta)\frac{k_{t-1}^g}{\mu} + q_t^g \left(1 - S_g\left(\frac{x_t^g}{x_{t-1}^g}\,\mu\right)\right) x_t^g$$

where

- $S_g(\mu) = S_g'(\mu) = 0, S_g''(\cdot) > 0$: adjustment costs.
- $q_t^{x,g}$: shock to the relative price of government investment.
- Constant capacity utilization.

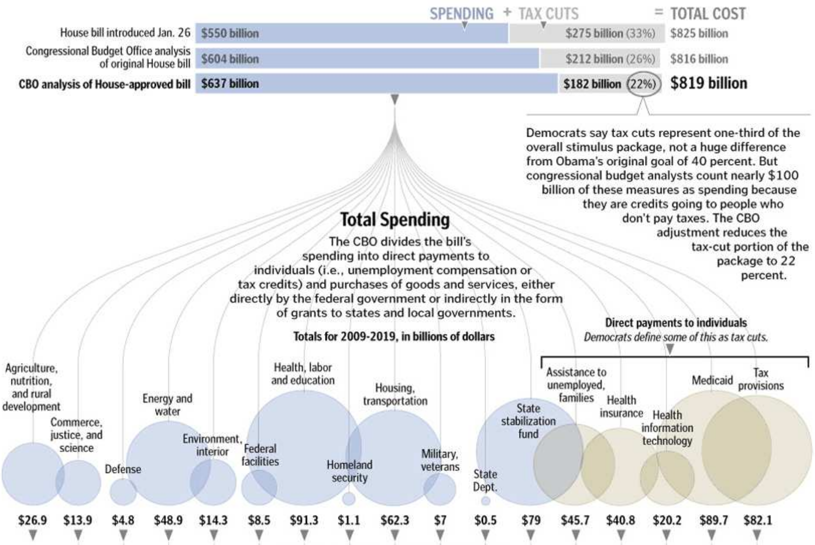
ZLB

- Benchmark implementation: “Switching off”: $\hat{R}_t = (1 - \mathbf{1}_{ZLB,t})\hat{R}_t^{TR} + \mathbf{1}_{ZLB,t}\hat{R}_{t-1}^{TR}$.
- Endogenous ZLB: FFR equals max of original SW Taylor rule and approximately zero (0.25% at annual rates):

$$\begin{aligned}
\hat{R}_t &= \max\{-(1-\bar{R}) + \frac{0.25}{400}, \hat{R}_t^{TR}\}, \\
\hat{R}_t^{TR} &= \psi_1(1-\rho_R)\hat{\pi}_t + \psi_2(1-\rho_r)(\hat{y}_t - \hat{y}_t^f) \\
&\quad + \psi_3\Delta(\hat{y}_t - \hat{y}_t^f) + \rho_R\hat{R}_{t-1}^{TR} + ms_t.
\end{aligned}$$

The Stimulus

Source: Washington Post 02/01/2009, accessed 10/31/2009



Categorizing the stimulus – Government Consumption

Item	Amount (bn USD)	Share
Dept. of Defense	4.53	0.59
Employment and Training	4.31	0.56
Legislative Branch	0.03	0
National Coordinator for Health Information Technology	1.98	0.26
National Institute of Health	9.74	1.26
Other Agriculture, Food, FDA	3.94	0.51
Other Commerce, Justice, Science	5.36	0.69
Other Dpt. of Education	2.12	0.28
Other Dpt. of Health and Human Services	9.81	1.27
Other Financial Services and gen. Govt	1.31	0.17
Other Interior and Environment	4.76	0.62
Special education	12.2	1.58
State and local law enforcement	2.77	0.36
State Fiscal Relief	90.04	11.68
State fiscal stabilization fund	53.6	6.95
State, foreign operations, and related programs	0.6	0.08
Other	2.55	0.33
Consumption	209.64	27.2

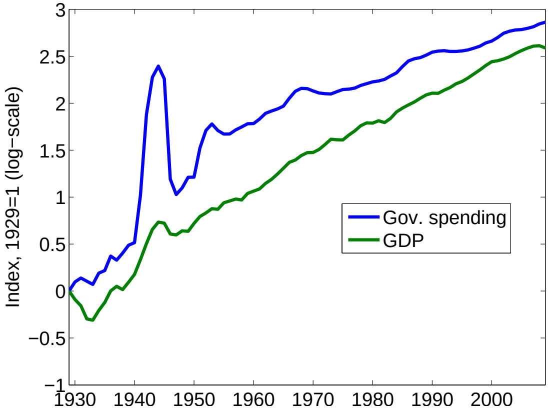
Categorizing the stimulus – Government Investment

Item	Amount (bn USD)	Share
Broadband Technology opportunities program	4.7	0.61
Clean Water and Drinking Water State Revolving Fund	5.79	0.75
Corps of Engineers	4.6	0.6
Distance Learning, Telemedicine, and Broadband Program	1.93	0.25
Energy Efficiency and Renewable Energy	16.7	2.17
Federal Buildings Fund	5.4	0.7
Health Information Technology	17.56	2.28
Highway construction	27.5	3.57
Innovative Technology Loan Guarantee	6	0.78
NSF	2.99	0.39
Other Energy	22.38	2.9
Other transportation	20.56	2.67
Investment	136.09	17.66

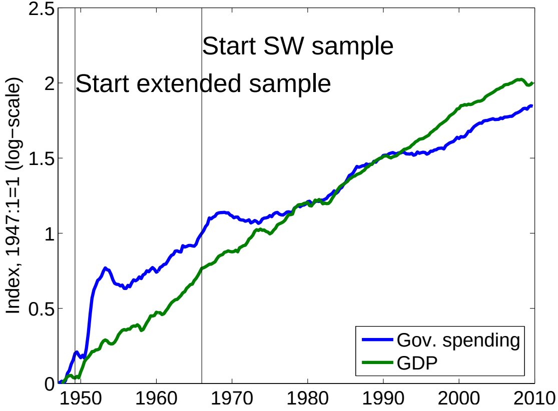
Categorizing the stimulus – Transfers

Item	Amount (bn USD)	Share
Assistance for the unemployed	0.88	0.11
Economic Recovery Programs, TANF, Child support	18.04	2.34
Health Insurance Assistance	25.07	3.25
Health Insurance Assistance	-0.39	-0.05
Low Income Housing Program	0.14	0.02
Military Construction and Veteran Affairs	4.25	0.55
Other housing assistance	9	1.17
Other Tax Provisions	4.81	0.62
Public housing capital fund	4	0.52
Refundable Tax Credits	68.96	8.95
Student financial assistance	16.56	2.15
Supplemental Nutrition Assistance Program	19.99	2.59
Tax Provisions	214.56	27.84
Unemployment Compensation	39.23	5.09
Transfers and Tax cuts	425.09	55.15

Which sample? Barro, Ramey.



Postwar GDP and government spending



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Estimation and Calculation.

Shocks: AR(1).

1. Technology.
2. Bond shock: wedge between FFR and gov't bonds.
3. Bond shock: wedge between gov't bond returns and returns on capital.
4. Gov. spending plus net export. Co-varies with technology.
5. Investment specific (rel. price).
6. Gov. investment specific. Used with gov. investment time series only.
7. Monetary policy.
8. Labor tax rates.
9. Mark-up: prices: ARMA(1,1).
10. Mark-up: wages: ARMA(1,1).

Observations – Time Series

1. Output: Chained 2005 real GDP, growth rates.
2. Consumption: Private consumption expenditure, growth rates.
3. Investment: private fixed investment, growth rates.
4. Government investment: growth rates.
5. Hours worked: Civilian employment index $\times$ average nonfarm business weekly hours worked index. Demeaned log.
6. Inflation: GDP deflator, quarterly growth rates.
7. Wages: Nonfarm Business, hourly compensation index. Growth rates.
8. FFR: Converted to quarterly rates.
9. Corporate-Treasury bond yield spread: Moody's Baa index – 10 yr Treasury bond at quarterly rates, demeaned.
10. Dallas Fed gross federal debt series at par value. Demeaned log.

Observations: Comments

- Time series: Updated SW dataset, 1948:2-2009:4. Quarterly. 4 Period pre-sample.
- Sources: NIPA, FRED 2, BLS.
- Nominal series for wages, consumption, government and private investment deflated with general GDP deflator.
- Differences to Smets-Wouters dataset: Use civilian non-institutionalized population throughout, although not seasonally adjusted before 1976. Base year for real GDP: 2005 instead of 1996.
- All series but real wages have a correlation of 100% across the two datasets. For the change in real wages, the correlation is 0.9.
- No data for the Corporate-Treasury bond yield spread before 1953:1. Set to zero.
- No data on FFR before 1954:3. Use secondary market rate for 3-month TBill before.
- Dallas Fed federal debt data.

Calibrated parameters

- Tax rates, and debt-GDP ratio from NIPA (Trabandt-Uhlig, 2009).
- Government spending components from NIPA.
- Kimball curvature parameters set to roughly match empirical frequency of price adjustment (Eichenbaum-Fisher, 2007).
- Depreciation per Cooley-Prescott (1994) based on $\frac{\bar{x}}{\bar{k}} = 0.0076$.

	SW 66:1–04:4	Extension 48:2–08:4
Depreciation δ	0.025	0.0145
Wage mark-up λ_w	0.5	0.5
Kimball curvature goods mkt. $\hat{\eta}_p$	10	10
Kimball curvature labor mkt. $\hat{\eta}_w$	10	10
Capital tax τ^k	n/a	0.36
Consumption tax τ^c	n/a	0.05
Labor tax τ^n	n/a	0.28
Share credit constrained ϕ	n/a	0.25
Gov. spending, net exports-GDP $\frac{\bar{g}}{\bar{y}}$	0.18	0.153
Gov. investment-GDP $\frac{\bar{x}^g}{\bar{y}}$	n/a	0.04
Debt-GDP $\frac{\bar{b}}{\bar{y}}$	n/a	$4\times$ 0.63

Estimates – Extended Model

	Prior	Prior mean (s.d.)	SW Model 66:1-08:4	New investment 66:1-08:4	Debt & Gov. Capital 49:2-08:4
Adj. cost $S''(\mu)$	norm	4.000 (1.500)	5.93 (1.1)	5.38 (1.03)	4.57 (0.82)
Risk aversion σ	norm	1.500 (0.375)	1.42 (0.11)	1.31 (0.1)	1.18 (0.07)
Habit h	beta	0.700 (0.100)	0.7 (0.04)	0.8 (0.03)	0.85 (0.02)
Calvo wage ζ_w	beta	0.500 (0.100)	0.77 (0.05)	0.77 (0.05)	0.84 (0.03)
Inv. labor sup. ela. ν	norm	2.000 (0.750)	1.96 (0.54)	2.14 (0.47)	2.33 (0.56)
Calvo prices ζ_p	beta	0.500 (0.100)	0.69 (0.05)	0.73 (0.06)	0.81 (0.04)
Wage indexation ι_w	beta	0.500 (0.150)	0.62 (0.1)	0.61 (0.12)	0.44 (0.09)
Price indexation ι_p	beta	0.500 (0.150)	0.26 (0.08)	0.29 (0.1)	0.3 (0.09)
Capacity util.	beta	0.500 (0.150)	0.59 (0.1)	0.54 (0.1)	0.45 (0.08)
$1+\frac{\text{Fix. cost}}{Y} = 1+\lambda_p$	norm	1.250 (0.125)	1.64 (0.08)	1.63 (0.08)	1.93 (0.06)
Taylor rule infl. ψ_1	norm	1.500 (0.250)	2 (0.17)	2.1 (0.17)	1.64 (0.19)
same, smoothing ρ_R	beta	0.750 (0.100)	0.82 (0.02)	0.83 (0.02)	0.92 (0.01)
same, LR gap ψ_2	norm	0.125 (0.050)	0.09 (0.02)	0.12 (0.03)	0.13 (0.03)
same, SR gap ψ_3	norm	0.125 (0.050)	0.24 (0.03)	0.26 (0.03)	0.2 (0.02)
Mean inflation (data)	gamm	0.625 (0.100)	0.76 (0.09)	0.73 (0.12)	0.56 (0.08)
100 $\times$ time pref.	gamm	0.250 (0.100)	0.16 (0.05)	0.14 (0.04)	0.11 (0.04)
Mean hours (data)	norm	0.000 (2.000)	1.07 (0.95)	1.07 (1.16)	-0.25 (0.67)
Trend $(\mu - 1) * 100$	norm	0.400 (0.100)	0.43 (0.02)	0.44 (0.01)	0.48 (0.01)
Capital share α	norm	0.300 (0.050)	0.19 (0.02)	0.21 (0.01)	0.24 (0.01)
Gov. adj. cost $S_g''(\mu)$	norm	0.000 (0.500)	n/a	n/a	6.85 (1.03)
Budget bal speed $\frac{\psi_\tau - 0.025}{0.175}$	beta	0.30 (0.20)	n/a	n/a	0.07 (0.05)
Implied ψ_τ	n/a	0.078 (0.035)	n/a	n/a	0.0373 (0.01)
Mean gov. debt	norm	0.000 (0.500)	n/a	n/a	0 (0.49)
Mean bond spread	gamm	0.500 (0.100)	n/a	n/a	0.45 (0.05)

Implied government share in production: $\zeta = 2.30\%$.

Estimates – Shock processes

	Prior	Prior mean (s.d.)	SW Model 66:1-08:4	New investment 66:1-08:4	Debt & Gov. Capital 49:2-08:4
s.d. tech.	invg	0.100 (2.000)	0.46 (0.03)	0.46 (0.03)	0.46 (0.02)
AR(1) tech.	beta	0.500 (0.200)	0.95 (0.01)	0.94 (0.01)	0.94 (0.01)
s.d. bond	invg	0.100 (2.000)	0.24 (0.03)	0.17 (0.02)	0.97 (0.05)
AR(1) bond ρ_q	beta	0.500 (0.200)	0.27 (0.1)	0.26 (0.07)	0.68 (0.03)
s.d. gov't	invg	0.100 (2.000)	0.54 (0.03)	0.3 (0.01)	0.35 (0.02)
AR(1) gov't	beta	0.500 (0.200)	0.98 (0.01)	0.99 (0.01)	0.98 (0.01)
Cov(gov't, tech.)	norm	0.500 (0.250)	0.53 (0.09)	0.36 (0.05)	0.3 (0.05)
s.d. inv. price	invg	0.100 (2.000)	0.43 (0.04)	1.17 (0.11)	1.26 (0.11)
AR(1) inv. price	beta	0.500 (0.200)	0.73 (0.06)	0.43 (0.07)	0.55 (0.06)
s.d. mon. pol.	invg	0.100 (2.000)	0.24 (0.02)	0.24 (0.01)	0.23 (0.01)
AR(1) mon. pol.	beta	0.500 (0.200)	0.16 (0.07)	0.14 (0.05)	0.22 (0.06)
s.d. goods m-up	invg	0.100 (2.000)	0.14 (0.01)	0.14 (0.01)	0.31 (0.02)
AR(1) goods m-up	beta	0.500 (0.200)	0.89 (0.04)	0.89 (0.05)	0.91 (0.05)
MA(1) goods m-up	beta	0.500 (0.200)	0.73 (0.08)	0.77 (0.07)	0.96 (0.02)
s.d. wage m-up	invg	0.100 (2.000)	0.26 (0.02)	0.26 (0.02)	0.23 (0.02)
AR(1) wage m-up	beta	0.500 (0.200)	0.97 (0.01)	0.97 (0.01)	0.96 (0.02)
MA(1) wage m-up	beta	0.500 (0.200)	0.91 (0.03)	0.91 (0.03)	0.91 (0.04)
s.d. Tax shock	invg	0.100 (2.000)	n/a	n/a	1.42 (0.07)
AR(1) tax shock	beta	0.500 (0.200)	n/a	n/a	0.97 (0.01)
s.d. gov. inv. price	invg	0.100 (2.000)	n/a	n/a	0.79 (0.09)
AR(1) gov. inv. price	beta	0.500 (0.200)	n/a	n/a	0.97 (0.01)
s.d. bond spread	invg	0.100 (2.000)	n/a	n/a	0.08 (0)
AR(1) bond spread	beta	0.500 (0.200)	n/a	n/a	0.91 (0.02)

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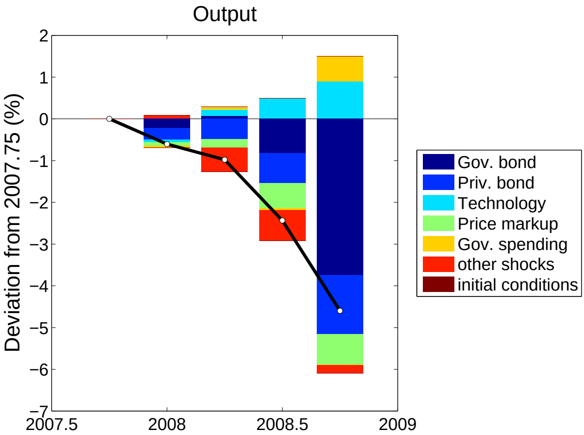
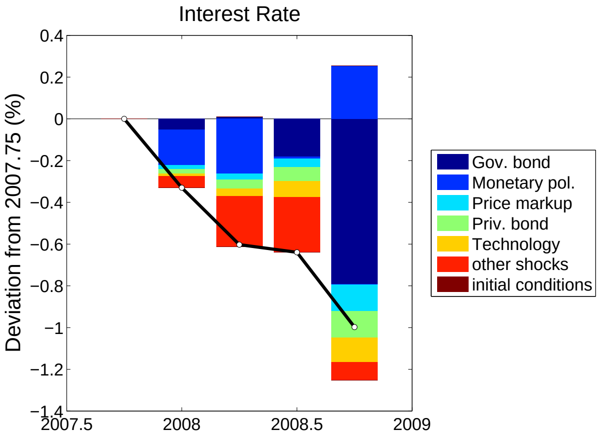
Historical Shock Decomposition: Output



Note: At posterior mean. 2007:4 is the NBER recession date.

Historical Shock Decomposition: Interest rates



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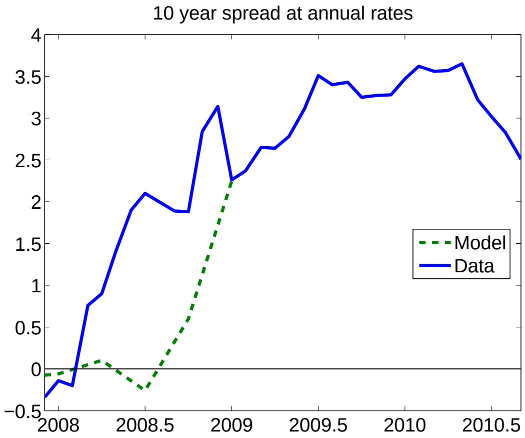
Decomposing the recession vs variance decomposition

	2008:4 vs. 2007:4 Historical decomposition		Total Sample Variance decomposition
Shock	%	%	
Gov. bond	-3.75	81.52	6.50
Priv. bond	-1.42	30.81	1.63
Technology	0.90	-19.53	19.21
Price markup	-0.73	15.86	8.59
Gov. spending	0.60	-12.98	4.14
Priv. inv.	-0.30	6.53	16.78
Labor tax	-0.27	5.91	9.20
Monetary pol.	0.20	-4.44	20.88
Wage Markup	0.15	-3.18	8.16
Gov. inv.	0.03	-0.73	4.92
Initial Values	-0.01	0.22	n/a
Sum	-4.60	100.00	100.01

Implied interest rate spread: Gov. bonds vs. FFR



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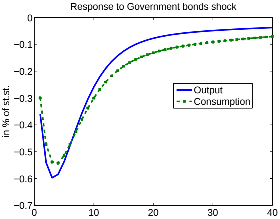
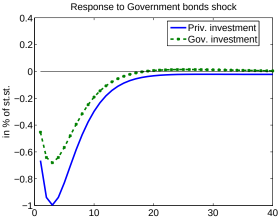
Government Bond Shock

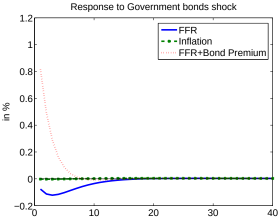
Output & Consumption



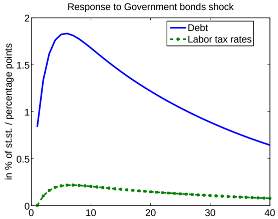
Investment



FFR & Inflation



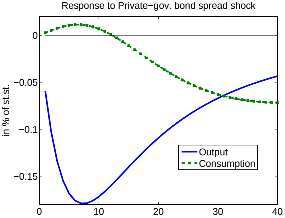
Debt & Labor tax



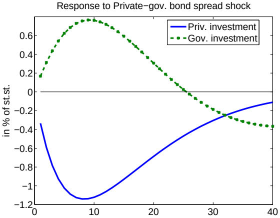
Note: Response to a one standard deviation shock.

Private-Government Bond Spread Shock

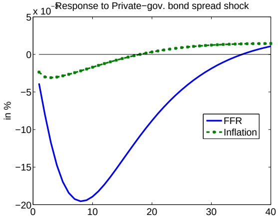
Output & Consumption



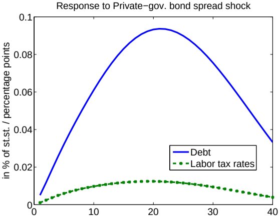
Investment



FFR & Inflation



Debt & Labor tax



Note: Response to a one standard deviation shock.

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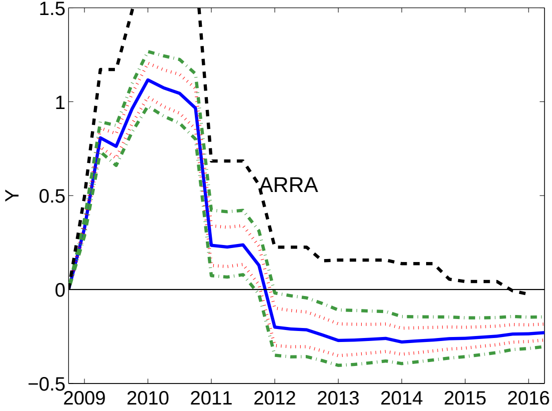
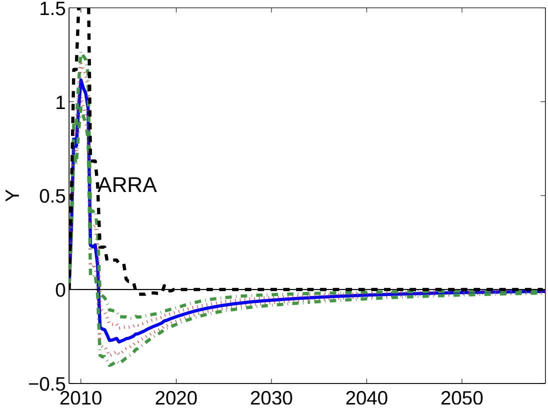
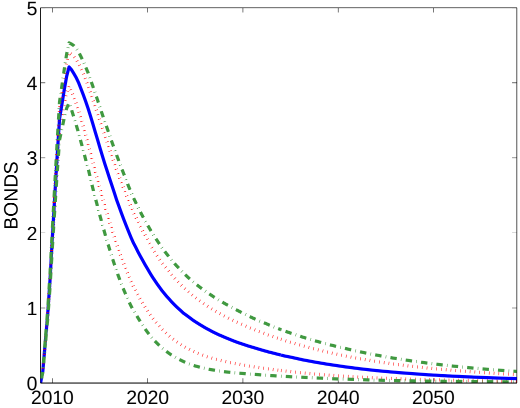
ARRA impact on output: short-run ...



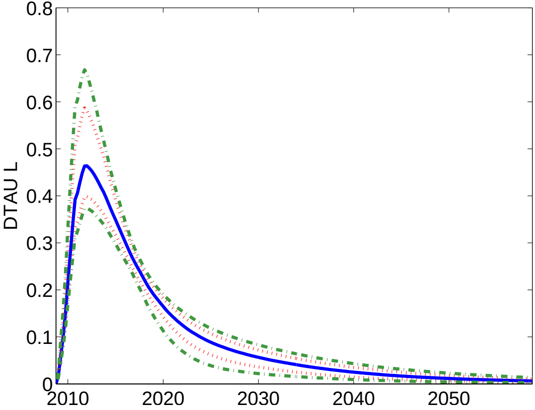
ARRA impact on output: ... and long-run



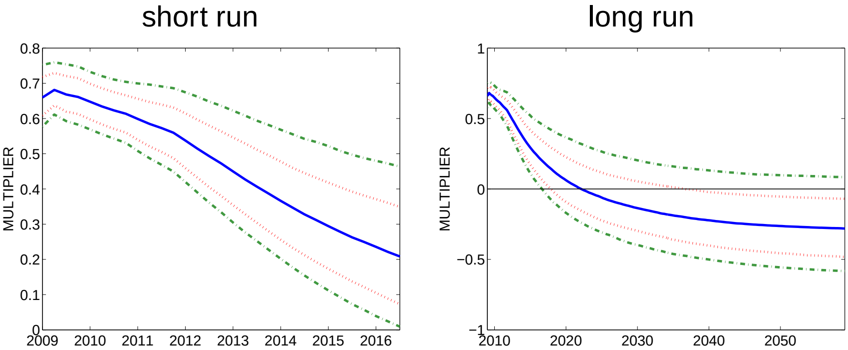
Debt: long-run



Labor tax rates: long run



Fiscal Multiplier: short and long run



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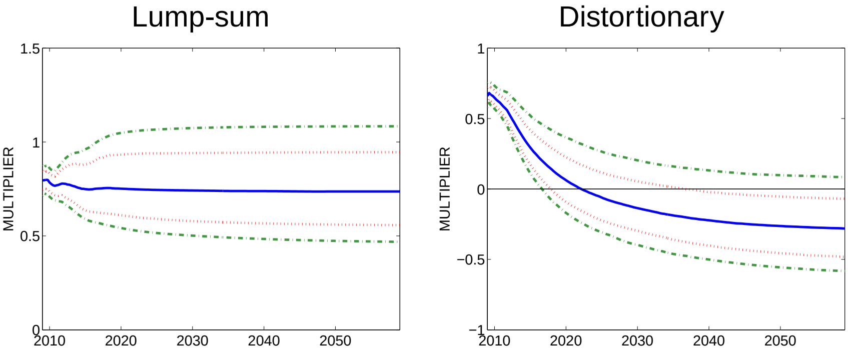
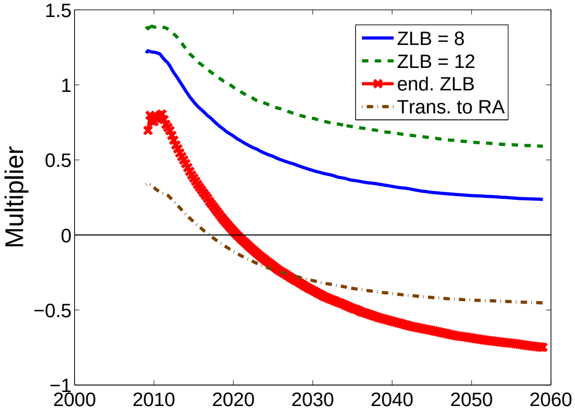
Lump sum vs distortionary taxation.



Multiplier: Sensitivity Analysis



(Note: DU stimulus, posterior medians)

One-year fiscal multipliers: sensitivity

Scenario	5%	16.5%	median	83.5%	95%
Benchmark	0.57	0.60	0.65	0.70	0.73
lump-sum taxes	0.71	0.74	0.78	0.83	0.86
ZLB: 0 Quart.	0.30	0.32	0.37	0.42	0.44
ZLB: 12 Quart.	0.71	0.74	0.80	0.88	0.94
ZLB: Endogenous	0.58	0.67	0.83	0.98	1.09
RoT=15%	0.50	0.53	0.58	0.62	0.66
RoT=40%	0.68	0.72	0.77	0.83	0.88
Share transf. to RoT=12.5%	0.36	0.37	0.41	0.44	0.47
Share transf. to RoT=50%	0.64	0.68	0.74	0.81	0.85
Share transf. to RoT=100%	1.01	1.09	1.19	1.30	1.37
Cap. share=35%	0.56	0.61	0.66	0.72	0.75
price/wage-stick.=10% est.	0.18	0.20	0.25	0.31	0.33
price/wage-stick.=40% est.	0.43	0.45	0.51	0.60	0.64
price/wage-stick.=115% est.	0.62	0.64	0.67	0.71	0.73

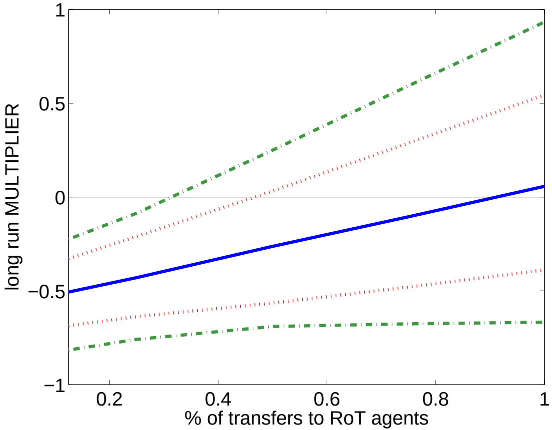
Long run fiscal multipliers as $t \to \infty$: sensitivity

Scenario	5%	16.5%	median	83.5%	95%
Benchmark	-0.64	-0.52	-0.31	-0.09	0.06
lump-sum taxes	0.46	0.56	0.74	0.94	1.09
ZLB: 0 Quart.	-0.94	-0.82	-0.65	-0.49	-0.37
ZLB: 12 Quart.	-0.41	-0.27	-0.01	0.28	0.54
ZLB: Endogenous	-1.78	-1.53	-1.18	-0.75	-0.49
RoT=15%	-0.81	-0.68	-0.47	-0.26	-0.08
RoT=40%	-0.40	-0.31	-0.11	0.16	0.37
Share transf. to RoT=12.5%	-0.81	-0.69	-0.51	-0.33	-0.22
Share transf. to RoT=50%	-0.69	-0.56	-0.26	0.03	0.25
Share transf. to RoT=100%	-0.67	-0.39	0.06	0.54	0.93
cap. share=35%	-0.98	-0.77	-0.54	-0.26	-0.13
price/wage-stick.=10% est.	-0.90	-0.80	-0.66	-0.57	-0.52
price/wage-stick.=40% est.	-0.74	-0.64	-0.49	-0.39	-0.34
price/wage-stick.=115% est.	-0.60	-0.47	-0.23	-0.06	0.08

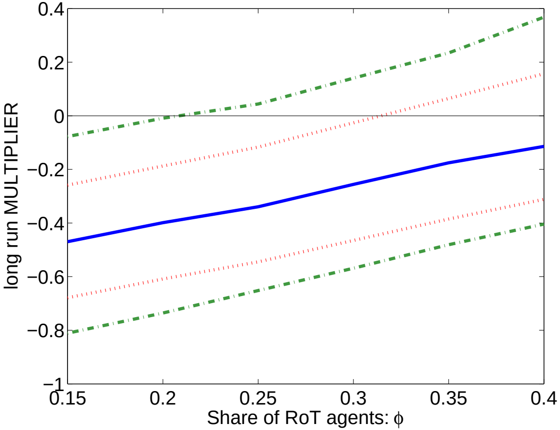
Sensitivity to RoTs and Transfers

	one year mult.			long-run mult.		
Transf. = RoT fract. =	10%	25%	40%	10%	25%	40%
	0.45	0.65	0.91	-0.58	-0.30	0.10
RoT share of popul. =	10%	25%	40%	10%	25%	40%
	0.54	0.65	0.79	-0.52	-0.30	-0.00
RoT share of transf. =	0%	25%	100%	0%	25%	100%
	0.48	0.65	1.16	-0.42	-0.30	0.08

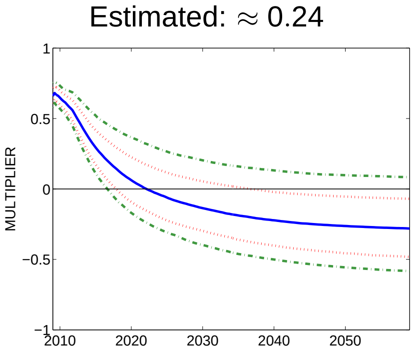
Sensitivity to RoT share of transfers

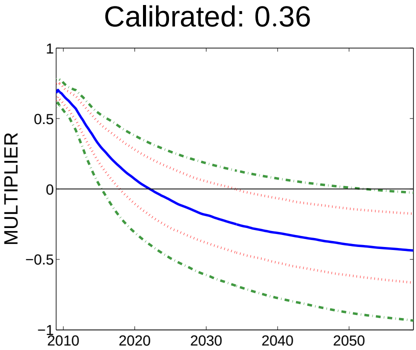


Sensitivity to RoT share of population

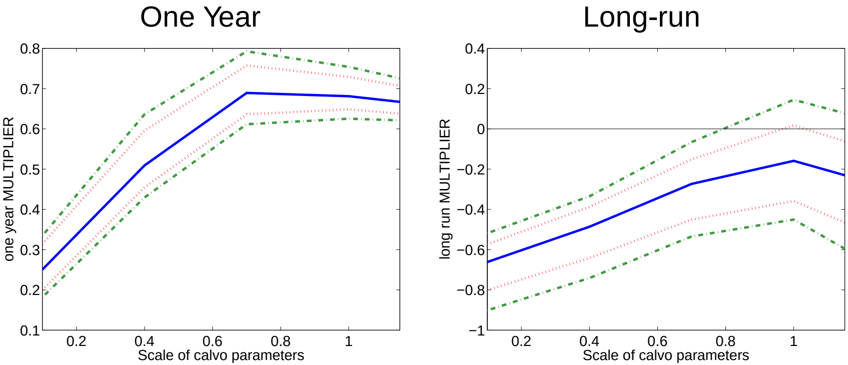


Sensitivity to capital share: 0.24 vs 0.36.

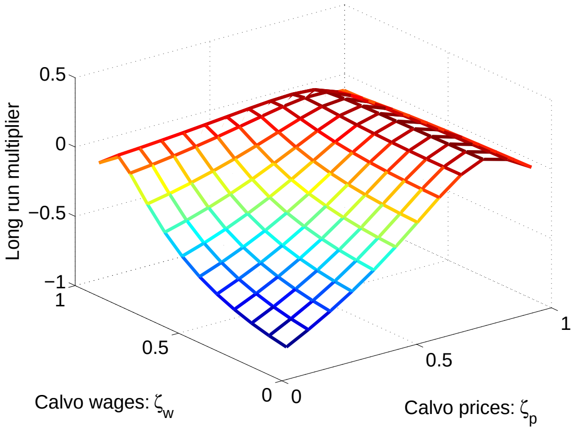




Sensitivity to price stickiness: scaling Calvo



Sensitivity of long-run fiscal multiplier.



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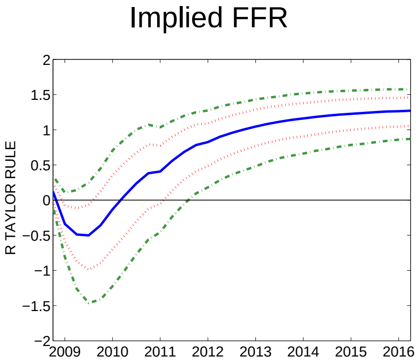
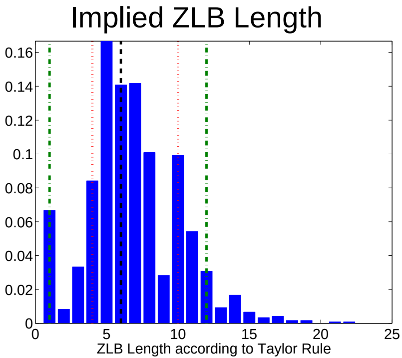
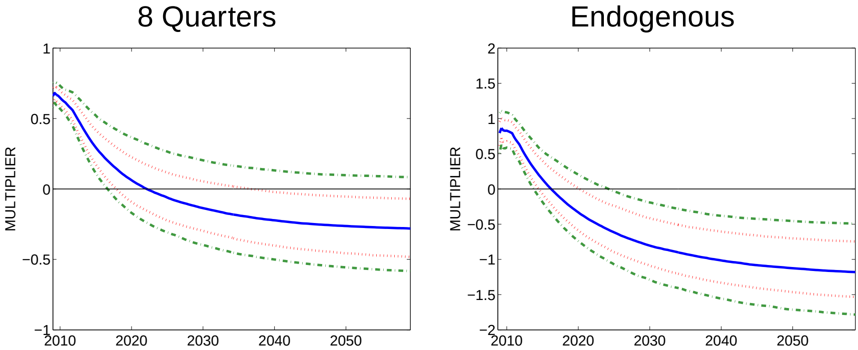
The shadow Taylor rule

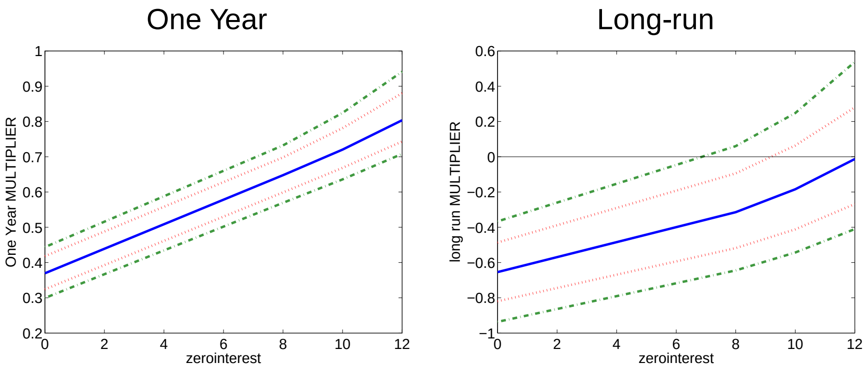




Sensitivity to ZLB: 8 quart. vs endog.



Sensitivity to length of ZLB



Changing ZLB length from 0 to k. No ARRA

	Output change (in %)			Inflation change (in %)	
ZLB imposed for ...	1 yr	5 yr's	NPV	1 yr	5 yr's
$k = 4$ quarters	0.083	0.008	0.998	0.000	-0.000
$k = 8$ quarters	0.456	0.054	6.392	0.004	-0.002
$k = 12$ quarters	0.756	0.117	12.882	0.011	-0.003
$k = 16$ quarters	0.902	0.181	18.294	0.017	-0.004

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Conclusions

1. We have quantified the size, uncertainty and sensitivity of fiscal multipliers in response to the American Recovery and Reinvestment Act (ARRA) of 2009.
2. Smets-Wouters meets CCWT meets Uhlig, extended.
3. Long run: debt repayment, higher taxes, lower output.
4. Benchmark:
   - modestly positive short-run multipliers, post. mean: 0.65.
   - modestly negative long-run multipliers, post mean: -0.31.
5. Particularly sensitive to
   - fraction of transfers to RoTs.
   - Length of ZLB.
6. Monetary policy is very powerful! Long ZLB increases output substantially, nearly no impact on inflation. Can that be true?

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Detrending

$$k_t = \frac{K_t}{\mu^t}, g_t = \frac{G_t}{\bar{y}\mu^t}, w_t = \frac{W_t}{P_t \mu^t}, r_t^k = \frac{R_t^k}{P_t}, \xi_t = \Xi_t \mu^{\sigma t}.$$

Final goods producers

- Objective:

$$\max_{Y_t, Y_t(i)} P_t Y_t - \int_0^1 P_t(i) Y_t(i) di \quad \text{s.t.} \quad \int_0^1 G\left(\frac{Y_t(i)}{Y_t}; \epsilon_t^p\right) di = 1,$$

  where $G(\cdot)$ is the Kimball aggregator. Generalizes CES demand by allowing the elasticity of demand to increase with relative prices.

$$G' > 0, \quad G'' < 0, \quad G(1; \lambda_{p,t}) = 1.$$

- $\log \lambda_{t,p}$ is an exogenous ARMA(1,1) mark-up shock (it changes the elasticity of demand and therefore the mark-up).

Intermediate goods producers

- Technology:

$$Y_t(i) = \tilde{\epsilon}_t^a \left(\frac{K_{t-1}^g}{\int_0^1 Y_t(j)dj + \Phi\mu^t} \right)^{\frac{\zeta}{1-\zeta}} K_t^s(i)^{\alpha}[\mu^t n_t(i)]^{1-\alpha} - \mu^t \Phi,$$

where Φ are fixed costs, K_t^s are capital services.

- ϵ_t^a is TFP, $\log \epsilon_t^a \sim$ AR(1).
- Government capital services K_{t-1}^g subject to congestion.
- Aggregate production function:

$$Y_t = \epsilon_t^a K_{t-1}^{g}{}^{\zeta} K_t^{s}{}^{\alpha(1-\zeta)}[\mu^t n_t]^{(1-\alpha)(1-\zeta)} - \mu^t \Phi, \quad \epsilon_t^a \equiv (\tilde{\epsilon}_t^a)^{1-\zeta}.$$

Along the balanced growth path: $\bar{\epsilon}^a \equiv 1$.

- Current profits:

$$P_t(i)Y_t(i) - W_t n_t(i) - R_t^k K_t^s(i)$$

Marginal costs

- The static FOC:

$$[n_t(i)] \quad MC_t(i)(1-\alpha)\frac{Y_t(i)+\mu^t\Phi}{n_t(i)} = W_t,$$

$$[K_t^s(i)] \quad MC_t(i)\alpha\frac{Y_t(i)+\mu^t\Phi}{K_t^s(i)} = R_t^k.$$

$$\Rightarrow K_t^s(i) = \frac{\alpha}{1-\alpha}\frac{W_t}{R_t^k}n_t(i)$$

- Marginal costs:

$$MC_t = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}\frac{W_t^{1-\alpha}(R_t^k)^{\alpha}\mu^{-(1-\alpha)t}}{\left(\frac{K_{t-1}^g}{Y_t+\mu^t\Phi}\right)^{\frac{\zeta}{1-\zeta}}\tilde{\epsilon}_t^a}$$

Price setting

- Dynamic problem:

$$\max_{P_t^*(i)} \sum_{s=0}^{\infty} \zeta_p^s \frac{\beta^s \Xi_{t+s} P_t}{\Xi_t P_{t+s}} \left[P_t^*(i) \left(\prod_{l=1}^{s} \pi_{t+l-1}^{\iota_p} \bar{\pi}^{1-\iota_p} \right) - MC_{t+s} \right] Y_{t+s}(i)$$

$$\text{s.t. } Y_{t+s}(i) = Y_{t+s}(G')^{-1} \left(\frac{P_t(i) X_{t,s}}{P_{t+s}} \int_0^1 G' \left(\frac{Y_t(j)}{Y_t} \right) \frac{Y_t(j)}{Y_t} dj \right),$$

  where:
  - Ξ_t : marginal utility of income of the non-credit constrained household at time t.
  - $\pi_t \equiv \frac{P_t}{P_{t-1}}$: inflation.
  - $1 - \zeta_p$: probability of potential price adjustment.
  - $$X_{t,s} = \begin{cases} 1 & s = 0, \\ \prod_{l=1}^{s} \pi_{t+l-1}^{\iota_p} \bar{\pi}^{1-\iota_p} & s = 1, \dots, \infty. \end{cases}$$

- Steady state: $1 = \bar{p}^*(i) = (1 + \lambda_p)\overline{mc}$

Aggregate profits and fixed costs

- Marginal costs (real, detrended):

$$mc_t = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)} \frac{w_t^{1-\alpha}(r_t^k)^{\alpha}}{\left(\frac{k_{t-1}^g/\mu}{y_t+\Phi}\right)^{\frac{\zeta}{1-\zeta}} \epsilon_t^{a\,\frac{1}{1-\zeta}}}.$$

- Aggregate real and detrended profits along the symmetric balanced growth path:

$$\begin{aligned}\Pi_t^p &= y_t - w_t n_t - r_t^k k_t = y_t - (1-\alpha)mc_t(y_t+\Phi) - \alpha mc_t(y_t+\Phi) \\ &= y_t[1-mc_t] - mc_t\Phi\end{aligned}$$

- In steady state, impose zero profits:

$$0 = \bar{\Pi}^p = \frac{\bar{y}}{1+\lambda_p}\left(\lambda_p - \frac{\Phi}{\bar{y}}\right) \quad \Rightarrow \frac{\Phi}{\bar{y}} = \lambda_p,$$

using $1 = \bar{p}^*(i) = (1+\lambda_p)\overline{mc}$.

Households

- $j \in [0, 1]$.
- Fraction $1 - \phi$ of labor force: infinite-horizon. Wage setters / Calvo sticky wages.
- Fraction ϕ is credit constrained (or "rule-of-thumb"). They do not save or borrow. Wage setting: assumed the same as for infinite-horizon households.

Households $j \in [0,1]$: Preferences.

$$U = \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \left[\frac{1}{1-\sigma} \left(C_{t+s}(j) - hC_{t+s-1} \right)^{1-\sigma} \right] \exp \left[\frac{\sigma - 1}{1+\nu} n_{t+s}(j)^{1+\nu} \right],$$

Households (not credit constrained): Budgets.

- Wedge between federal funds rate and gov't bonds: $q_t^b \neq 1$.
- Wedge between gov't bonds and private bonds: $\tilde{q}_t^k \neq 1$.

$$
\begin{aligned}
&(1+\tau^c)C_{t+s}(j) + X_{t+s}(j) + \frac{B^n_{t+s}(j)}{q^b_{t+s}R_{t+s}P_{t+s}} + A_t(j) \\
&\quad \leq S_{t+s} + \frac{B^n_{t+s-1}(j)}{P_{t+s}} + (1-\tau^n_{t+s})\frac{W_{t+s}[n_{t+s}(j) + \lambda_{w,t+s}n_{t+s}]}{P_{t+s}} + \\
&\quad \tilde{q}^k_{t+s-1}\left[(1-\tau^k)\left(\frac{R^k_{t+s}u_{t+s}}{P_{t+s}} - a(u_{t+s})\right) + \delta\tau^k\right]K^p_{t+s-1}(j) + \frac{\Pi^p_{t+s}\mu^t}{P_{t+s}},
\end{aligned}
$$

- where Π_t^p are goods market profits. Detrended:

$$
\begin{aligned}
&(1+\tau^c)c_{t+s}(j) + x_{t+s}(j) + \frac{b_{t+s}(j)}{q^b_{t+s}R_{t+s}} + a_t(j) \\
&\quad \leq s_{t+s} + b_{t+s-1}(j) + (1-\tau^n_{t+s})w_{t+s}(j)[n_{t+s}(j) + \lambda_{w,t+s}n_{t+s}] \\
&\quad\quad + \tilde{q}^k_{t+s-1}\left[(1-\tau^k)[r^k_{t+s}u_{t+s} - a(u_{t+s})] + \delta\tau^k\right]k^p_{t+s-1}(j) + \Pi^p_{t+s},
\end{aligned}
$$

Households: labor supply, wage setting

- Unions, Wage packers.
- Think of households as monopolistic suppliers of differentiated labor.
- Objective:

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\zeta_w)^s \frac{\beta^s \Xi_{t+s}}{\Xi_t} \left[(1-\tau^n_{t+s}) \frac{W_{t+s}(l)}{P_{t+s}} + \frac{U_{n,t+s}}{\Xi_{t+s}} \right] n_{t+s}(l),$$

- Constraints: Labor demand derived using Kimball aggregator

$$\frac{n_{t+s}(l)}{n_t} = (G')^{-1} \left[\frac{W_{t+s}(l)}{W_{t+s}} \int_0^1 G'\left(\frac{n_t(j)}{n(t)}\right) \frac{n_t(j)}{n_t} dj \right]$$

and

$$W_{t+s}(l) = \tilde{W}_t(l) \prod_{v=1}^{s} \mu(\pi_{t+v-1})^{\iota_w} (\pi_*)^{\iota_w}.$$

Households: labor supply, wage setting

- First order condition ($\bar{\beta} \equiv \beta\mu^{-\sigma}$), Dixit-Stiglitz case:

$$0 = \mathbb{E}_t \sum_{s=0}^{\infty} \frac{(\zeta_w \bar{\beta}\mu)^s \xi_{t+s}}{\xi_t \lambda_{w,t+s}} n_{t+s}(l) \Bigg[(1+\lambda_{w,t+s})(1+\tau^c) n_{t+s}^{\nu} [c_{t+s}^{RA} - (h/\mu) c_{t+s-1}^{RA}] - (1-\tau_{t+s}^n) \frac{\prod_{j=1}^{s} \pi_{t+j-1}^{\iota_w} \bar{\pi}^{1-\iota_w}}{\prod_{j=1}^{s} \pi_{t+j}} w_t^*(l) \Bigg]$$

- Steady state desired wage:

$$\bar{w}^* = (1+\bar{\lambda}_w) \frac{1-\tau^n}{1+\tau^c} \bar{n}^{\nu} \bar{c} [1 - h/\mu]$$

Households: capital accumulation

- $$k_t^p = (1-\delta)k_{t-1}^p(j) + q_t^x \left[1 - S\left(\frac{x_t(j)}{x_{t-1}(j)}\mu\right)\right] x_t(j),$$

  where
  - $S(\mu) = S'(\mu) = 0, S'' > 0$: adjustment cost.
  - q_t^x: shock to the relative price of investment.
- No arbitrage:

  $$\begin{aligned} 1 &= \bar{\beta}[(1-\tau^k)\bar{r}^k + \delta\tau^k + (1-\delta)] \\ \bar{r}^k &= \frac{\bar{\beta}^{-1} - (1-\delta) - \tau^k}{1-\tau^k} \end{aligned}$$

  where $\bar{\beta} \equiv \beta\mu^{-\sigma}$.

Households (not credit constrained): FOC

Denote Lagrange multipliers by $\beta^t(\Xi_t, \Xi_t^k)$, define $\xi_t \equiv \Xi_t \mu^{t\sigma}, Q_t \equiv \frac{\Xi_t^k}{\Xi_t}$.

$$[c_t] \quad \xi_t(1+\tau^c) = \exp\left(\frac{\sigma-1}{1+\nu} n^{1+\nu}\right) [c_t - (h/\mu)c_{t-1}]^{-\sigma}$$

$$[n_t] \quad \xi_t(1-\tau_t^n)w_t = \exp\left(\frac{\sigma-1}{1+\nu} n^{1+\nu}\right) n_t^\nu [c_t - (h/\mu)c_{t-1}]^{1-\sigma}$$

$$[b_t] \quad \xi_t = (\beta\mu^{-\sigma}) q_t^b R_t \mathbb{E}_t\left(\frac{\xi_{t+1}}{P_{t+1}/P_t}\right)$$

$$[k_t^p] \quad Q_t = (\beta\mu^{-\sigma})\mathbb{E}_t\left(\frac{\xi_{t+1}}{\xi_t}\left[\tilde{q}_t^k\left((1-\tau^k)[r_{t+1}^k u_{t+1} - a(u_{t+1}) + \delta\tau^k\right) + (1-\delta)Q_{t+1}\right]\right)$$

$$[x_t] \quad 1 = Q_t q_t^x \left(1 - S\left(\frac{x_t\mu}{x_{t-1}}\right) - S'\left(\frac{x_t\mu}{x_{t-1}}\right)\left(\frac{x_t\mu}{x_{t-1}}\right)\right)$$
$$+ (\beta\mu^{-\sigma})\mathbb{E}_t\left(\frac{\xi_{t+1}}{\xi_t} Q_{t+1} q_{t+1}^x S'\left(\frac{x_{t+1}\mu}{x_t}\right)\left(\frac{x_{t+1}\mu}{x_t}\right)^2\right)$$

$$[u_t] \quad r_{t+1}^k = a'(u_{t+1}).$$

Normalize $\bar{u} \equiv 1, a'(\bar{u}) \equiv \bar{r}^k$.

Households (not credit constrained): Bond shocks

- q_t^b shock is different from a discount factor shock. Both are “consumption Euler equation errors”, but a discount factor shock does not affect the investment Euler equation as the opportunity cost of investment is not directly affected by a DF shock.
- Households appropriate only a stochastic fraction of total return on capital. Realized return on capital differs from government bonds by government bond-FFR wedge and capital-government bond wedge.

$$\frac{\bar{r}^k(1-\tau^k)\mathbb{E}_t(\hat{r}^k_{t+1}) + (1-\delta)\mathbb{E}_t(\hat{Q}_{t+1})}{\bar{r}^k(1-\tau^k) + \delta\tau^k + 1 - \delta} - \hat{Q}_t$$

$$= \left(\hat{R}_t - \mathbb{E}_t[\pi_t]\right) + \hat{q}_t^b + \hat{q}_t^k.$$

- Note: the shock $\tilde{q}_t^k$ in the budget constraint has been rescaled here. $\hat{q}_t^k$ is the deviation of the rescaled shock from its steady state value.

Credit constrained Households

- Detrended budget constraint:

$$(1 + \tau^c)c_{t+s}^{RoT}(j) \; \leq \; s_{t+s}^{RoT} + (1 - \tau_{t+s}^n)w_{t+s}(j)n_{t+s}^{RoT}(j) + \Pi_{t+s}^p,$$

- Profits matter:

$$\hat{c}_t^{RoT} = \frac{1}{1+\tau^c}\left(\frac{\bar{s}^{RoT}}{\bar{c}^{RoT}}\hat{s}_t + \frac{\bar{w}\bar{n}}{\bar{c}^{RoT}}[(1-\tau^n)(\hat{w}_t + \hat{n}_t) - d\tau_t^n] + \frac{\bar{y}}{\bar{c}^{RoT}}\frac{d\Pi_t^p}{\bar{y}}\right),$$

$$\frac{d\Pi_t^p}{\bar{y}} = \frac{1}{1+\lambda_p}\hat{y}_t - \widehat{mc}_t.$$

- In steady state:

$$\bar{s}^{RoT} = \bar{s}, \qquad \bar{c}^{RoT} = \frac{\bar{s}^{RoT} + (1-\tau^n)\bar{w}\bar{n}}{1+\tau^c}$$

Pricing capital

$$\hat{Q}_t = \mathbb{E}_t(\hat{\xi}_{t+1} - \hat{\xi}_t) + \frac{[\bar{r}^k(1-\tau^k) + \tau^k\delta]\hat{q}_t^k}{\bar{r}^k(1-\tau^k) + \delta\tau^k + 1 - \delta} + \frac{\bar{r}^k(1-\tau^k)\mathbb{E}_t(\hat{r}_{t+1}^k) + (1-\delta)\mathbb{E}_t(\hat{Q}_{t+1})}{\bar{r}^k(1-\tau^k) + \delta\tau^k + 1 - \delta}.$$

- The government bond premium shock enters via the opportunity cost:

$$\mathbb{E}_t(\hat{\xi}_{t+1} - \hat{\xi}_t) = -\left(\hat{q}_t^b + \hat{R}_t - \mathbb{E}_t[\pi_t]\right).$$

Monetary authority

- Interest rate rule (in normal times) is described by:

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{\rho_R} \left[\left(\frac{\pi_t}{\bar{\pi}}\right)^{\psi_1} \left(\frac{Y_t}{Y_t^f}\right)^{\psi_2} \right]^{1-\rho_R} \left(\frac{Y_t / Y_{t-1}}{Y_t^f / Y_{t-1}^f}\right)^{\psi_3} \epsilon_t^r.$$

  Y_t^f is the output level in the economy without nominal frictions and without mark-up shocks.
- Money is supplied to satisfy money demanded at the desired interest rate.

Fiscal authority: Financing

- Adjusts marginal labor tax rates in proportion to the current deficit prior to debt issues and tax rates changes to achieve long-run budget balance:

$$(\tau_t^n - \bar{\tau}^n) w_t n_t + \epsilon_t^\tau = \psi_\tau (d_t - \bar{d}),$$

$$d_t \equiv \bar{y} g_t + x_t^g + s_t + \frac{b_{t-1}}{\pi_t} - \tau^c c_t - \bar{\tau}^n w_t n_t - \tau^k k_t^s r_t^k + \tau^k \delta \mu k_{t-1}^p.$$

- Government debt determined from budget constraint:

$$G_t + X_t^g + S_t + \frac{B_{t-1}}{P_t} \leq \frac{B_t}{q_t^b R_t P_t} + \tau^c C_t + \tau_t^n n_t \frac{W_t}{P_t} + \tau^k \left[u_t \frac{R_t^k}{P_t} - a(u_t) - \delta \right] K_{t-1}^p$$

Fiscal authority: Spending

- Faces exogenous process for government consumption $g_t = g_t^a + e_t^g$ and government investment $e_t^{x,g}$, where

$$\log g_t^a = (1 - \rho_g) \log \bar{g} + \rho_g \log g_{t-1}^a + \sigma_{ga} u_t^a + u_t^g$$

  and $e_t^{x,g}, e_t^g$ are other exogenous shocks.
- Taking the steady state tax rules as given, the government chooses investment and capital to maximize the net present discounted value of aggregate output:

$$\max_{\{K_{t+s}^g, X_{t+s}^g\}} \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \frac{\Xi_{t+s}}{\Xi_t} [Y_{t+s} - X_{t+s}^g],$$

  given K_{t-1}^g and subject to the aggregate production function and the capital accumulation equation.

Government Capital

$$k_t^g = (1-\delta)\frac{k_{t-1}^g}{\mu} + q_t^g \left(1 - S_g\left(\frac{[\epsilon_t^{x,g} + x_t^g]\mu}{[\epsilon_{t-1}^{x,g} + x_{t-1}^g]}\right)\right)[x_t^g + \epsilon_t^{x,g}]$$

where

- $S_g(\mu) = S_g'(\mu) = 0, S_g''(\cdot) > 0$: adjustment costs.
- $q_t^{x,g}$: shock to the relative price of government investment.
- $\epsilon_t^{x,g}$ exogenous government investment, zero at steady state.
- Constant capacity utilization.

Optimal government investment

- Real return on government capital:

$$r_t^g = \zeta \frac{Y_t + \phi \mu^t}{K_t^g} = \zeta \frac{y_t + \phi}{y_t} \mu \frac{y_t}{k_t^g}.$$

- Neglect costs of increases in tax rates.
- Euler equation:

$$1 = Q_t^g q_t^x \left(1 - S\left(\frac{[\epsilon_t^x + x_t]\mu}{[\epsilon_{t-1}^x + x_{t-1}]}\right) - S'\left(\frac{[\epsilon_t^x + x_t]\mu}{[\epsilon_{t-1}^x + x_{t-1}]}\right)\left(\frac{[\epsilon_t^x + x_t]\mu}{[\epsilon_{t-1}^x + x_{t-1}]}\right)\right)$$
$$+(\beta\mu^{-\sigma})\mathbb{E}_t \left(Q_{t+1}^g \frac{\xi_{t+1}}{\xi_t} q_{t+1}^x S'\left(\frac{[\epsilon_{t+1}^x + x_{t+1}]\mu}{[\epsilon_t^x + x_t]}\right)\left(\frac{[\epsilon_{t+1}^x + x_{t+1}]\mu}{[\epsilon_t^x + x_t]}\right)^2\right)$$

- Government discount rate affected by bond premium shocks:

$$\mathbb{E}_t(\hat{\xi}_{t+1} - \hat{\xi}_t) = -\hat{q}_t^b - \hat{R}_t + \mathbb{E}_t[\pi_t].$$

  Government discounts with the discount rate of the non-credit constrained agent.

Steady state equations

- Steady state return on capital services:

$$1 = \bar{\beta}[(1-\tau^k)\bar{r}^k + \delta\tau^k + (1-\delta)] \qquad \bar{r}^k = a'(\bar{u}),$$

  where $\bar{\beta} \equiv \beta\mu^{-\sigma}$.

- Wage from marginal cost equation, using $\overline{mc} = \frac{1}{1+\lambda_w}, \bar{\epsilon}^a = 1$:

$$\bar{w}^{1-\alpha} = \frac{\alpha^\alpha(1-\alpha)^{1-\alpha}}{1+\lambda_w} \frac{\left(\frac{\bar{y}}{\bar{y}+\Phi}\frac{\bar{k}^g}{\bar{y}}\right)^{\frac{\zeta}{1-\zeta}}}{\bar{r^k}^\alpha} = \frac{\alpha^\alpha(1-\alpha)^{1-\alpha}}{(1+\lambda_w)^{\frac{1}{1-\zeta}}} \frac{\left(\frac{\bar{k}^g}{\bar{y}}\right)^{\frac{\zeta}{1-\zeta}}}{\bar{r^k}^\alpha}$$

- Capital-output ratio:

$$\frac{\bar{k}}{\bar{y}} = \left(\frac{\bar{y}+\Phi}{\bar{y}}\right)^{\frac{1}{1-\zeta}} \left(\frac{\bar{k}^g}{\mu\bar{y}}\right)^{\frac{-\zeta}{1-\zeta}} \left(\frac{\bar{k}}{\bar{n}}\right)^{1-\alpha}$$

- Capital-labor ratio

$$\frac{\bar{k}}{\bar{n}} = \frac{\alpha}{1-\alpha}\frac{\bar{w}}{\bar{r}^k}$$

Resource constraint

- $$C_t + X_t + X_t^g + G_t + a(u_t)K_{t-1}^p = Y_t,$$
- Detrended:
$$c_t + x_t + x_t^g + \bar{y}g_t + a(u_t)\frac{k_{t-1}^p}{\mu} = y_t.$$
- Steady state (with unit capacity utilization):
$$\bar{y} = \bar{k^g}^{\zeta}\bar{k}^{\alpha(1-\zeta)}\bar{n}^{(1-\alpha)(1-\zeta)} - \Phi$$

  and
$$\frac{\bar{c}}{\bar{y}} + \frac{\bar{x}}{\bar{y}} + \frac{\bar{x}^g}{\bar{y}} + \bar{g} = 1$$

Calibrating share of government capital

- Observation for government investment: $\frac{\bar{x}}{\bar{y}} \approx 4.0\%$.
- Equalize returns and cost. Assume no indirect cost due to taxation.

$$\frac{\bar{x}}{\bar{y}} = [1 - (1-\delta)/\mu]\frac{\bar{k}^g}{\bar{y}} = \zeta \frac{\mu}{\bar{r}^g}\frac{\bar{y} + \Phi}{\bar{y}}$$

- Given $\bar{r}^g = \bar{\beta}^{-1}$, solve for the government capital share:

$$\zeta = \frac{\bar{y}}{\bar{y} + \Phi}\frac{\bar{r}^g}{\mu - (1-\delta)}\frac{\bar{x}^g}{\bar{y}} \approx 0.022$$

- Baxter-King (1993) assume $\frac{\bar{x}^g}{\bar{y}} = \zeta = 0.05$. Aggregate increasing returns.

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Extensions of Smets-Wouters (2007): Investment & Consumption

- Shadow price of investment:

$$\hat{Q}_t = -\hat{q}_t^b - (\hat{R}_t - \mathbb{E}_t[\pi_{t+1}]) + \frac{1}{\bar{r}^k(1-\tau^k) + \delta\tau^k + 1 - \delta} \times$$
$$\times [(\bar{r}^k(1-\tau^k) + \delta\tau^k)\hat{q}_t^r + \bar{r}^k(1-\tau^k)\mathbb{E}_t(\hat{r}_{t+1}^k) + (1-\delta)\mathbb{E}_t(\hat{Q}_{t+1})],$$

- Consumption growth:

$$\hat{c}_t = \frac{1}{1+h/\mu}\mathbb{E}_t[\hat{c}_{t+1}] + \frac{h/\mu}{1+h/\mu}\hat{c}_{t-1} - \frac{1-h/\mu}{\sigma[1+h/\mu]}(\hat{q}_t^b + \hat{R}_t - \mathbb{E}_t[\hat{\pi}_{t+1}])$$
$$- \frac{[\sigma-1][\bar{w}\bar{n}/\bar{c}]}{\sigma[1+h/\mu]} \frac{1}{1+\lambda_w} \frac{1-\tau^n}{1+\tau^c}(\mathbb{E}_t[\hat{n}_{t+1}] - n_t).$$

- Shocks rescaled for estimation – enter with unit coefficient.

Extensions: Consumption of the two agents

Euler equation for infinite-horizon agents:

$$\hat{c}_t^{RA} = \frac{1}{1+h/\mu}\mathbb{E}_t[\hat{c}_{t+1}] + \frac{h/\mu}{1+h/\mu}\hat{c}_{t-1} - \frac{1-h/\mu}{\sigma[1+h/\mu]}(\hat{q}_t^b + \hat{R}_t - \mathbb{E}_t[\hat{\pi}_{t+1}])$$
$$- \frac{[\sigma-1][\bar{w}\bar{n}/\bar{c}^{RA}]}{\sigma[1+h/\mu]}\frac{1}{1+\lambda_w}\frac{1-\tau^n}{1+\tau^c}(\mathbb{E}_t[\hat{n}_{t+1}] - n_t),$$

Consumption of the credit-constrained agents per budget constraint:

$$\hat{c}_t^{RoT} = \frac{1}{1+\tau^c}\left(\frac{\bar{s}^{RoT}}{\bar{c}^{RoT}}\hat{s}_t + \frac{\bar{w}\bar{n}}{\bar{c}^{RoT}}[(1-\tau^n)(\hat{w}_t + \hat{n}_t) - d\tau_t^n] + \frac{\bar{y}}{\bar{c}^{RoT}}\frac{d\Pi_t^p}{\bar{y}}\right),$$

using $\hat{n}_t = \hat{n}_t^{RoT} = \hat{n}_t^{RA}$ and $\bar{n} = \bar{n}^{RoT} = \bar{n}^{RA}$.

Extension: Aggregating consumption

Aggregate consumption:

$$\hat{c}_t = \frac{\bar{c}^{RA}}{\bar{c}}(1-\phi)\hat{c}_t^{RA} + \frac{\bar{c}^{RoT}}{\bar{c}}\phi\hat{c}_t^{RoT},$$

where

$$\bar{c}^{RoT} = \frac{\bar{w}\bar{n}(1-\tau^n)+\bar{s}}{1+\tau^c},$$

$$\bar{c}^{RA} = \frac{\bar{c}-\phi\bar{c}^{RoT}}{1-\phi}.$$

Extensions of Smets-Wouters (2007): Wages

- Evolution of wages (Dixit-Stiglitz case: $A_w = 1$, see below):

$$(1+\bar{\beta}\mu)\hat{w}_t - \hat{w}_{t-1} - \bar{\beta}\mu\mathbb{E}_t[\hat{w}_{t+1}]$$
$$= \frac{(1-\zeta_w\bar{\beta}\mu)(1-\zeta_w)}{\zeta_w} A_w \left[\frac{1}{1-h/\mu}[\hat{c}_t - (h/\mu)\hat{c}_{t-1}] + \nu\hat{n}_t - \hat{w}_t + \frac{d\tau_t^n}{1-\tau_n}] \right]$$
$$- (1+\bar{\beta}\mu\iota_w)\hat{\pi}_t + \iota_w\hat{\pi}_{t-1} + \bar{\mu}\mathbb{E}_t[\pi_{t+1}] + \hat{\lambda}_{w,t},$$

- Markup shock rescaled.
- In the flexible economy:

$$\hat{w}_t = \frac{1}{1-h/\mu}[\hat{c}_t - (h/\mu)\hat{c}_{t-1}] + \nu\hat{n}_t + \frac{d\tau_t^n}{1-\tau_l}.$$

Government capital

- Define $\hat{\epsilon}_t^{x,g} \equiv \frac{\epsilon_t^{x,g}}{\bar{x}^g}$.

$$\hat{k}^g = \left(1 - \frac{\bar{x}^g}{\bar{k}^g}\right)\hat{k}^g_{t-1} + \frac{\bar{x}^g}{\bar{k}^g}\hat{q}_t^{x,g} + \frac{\bar{x}^g}{\bar{k}^g}[\hat{x}_t^g + \hat{\epsilon}_t^{xg}]$$

- Return:

$$\hat{r}^g = \frac{\bar{y}}{\bar{y} + \Phi}\hat{y}_t - \hat{k}_t^g$$

Shadow price of government capital

$$\hat{Q}_t^g = -(\hat{R}_t + \hat{q}_t^b - \mathbb{E}_t[\pi_{t+1}]) + \frac{1}{\bar{r}^g + 1 - \delta}[\bar{r}^g \mathbb{E}_t(\hat{r}_{t+1}^g) + (1 - \delta)\mathbb{E}_t(\hat{Q}_{t+1}^g)],$$

Government investment

- Government investment: exogenous component $\hat{\epsilon}_t^{x,g} \equiv \frac{\epsilon_t^{x,g}}{\bar{x}^g}$. Otherwise optimal.
- Government-specific investment price shock $\hat{q}_t^{x,g}$.

$$\hat{x}_t^g = \frac{1}{1+\bar{\beta}\mu}\Big[\hat{x}_{t-1} + \hat{\epsilon}_{t-1}^{xg} + \bar{\beta}\mu\mathbb{E}_t([\hat{x}_{t+1}^g + \hat{\epsilon}_{t+1}^{xg}]) + \frac{1}{\mu^2 S_g''(\mu)}[\hat{Q}_t^g + \hat{q}_t^{x,g}]\Big] - \hat{\epsilon}_t^{xg}$$

- Consider additional constraint: for k quarters, the endogenous component of investment does not cause crowding out. Realized investment is given by:

$$\max\left\{\hat{x}_s^g, \delta\frac{\hat{k}_{s-1}^g}{\mu}\right\}, \qquad s \leq k.$$

Extensions of Smets-Wouters (2007): Tax rate and gov't deficit

Financing the current deficit:

$$\tau^n \frac{\bar{w}\bar{n}}{\bar{c}}\frac{\bar{c}}{\bar{y}}\left[\frac{d\tau_t^n}{\tau_n}\right] + \epsilon_t^\tau$$
$$= \frac{\psi_\tau}{\mu}\left[\mu[\hat{g}_t^a + \hat{g}^s] + \mu\frac{\bar{s}}{\bar{y}}\hat{s}_t + \frac{\bar{b}}{\bar{y}}\frac{\hat{b}_{t-1} - \hat{\pi}_t}{\bar{\pi}} - \mu\tau^n\frac{\bar{w}\bar{n}}{\bar{c}}\frac{\bar{c}}{\bar{y}}\left(\hat{w}_t + \hat{n}_t\right)\right.$$
$$\left. - \mu\tau_c\frac{\bar{c}}{\bar{y}}\hat{c}_t - \tau^k[\bar{r}^k r_t^k + (r_t^k - \delta)\hat{k}_{t-1}^p]\frac{\bar{k}}{\bar{y}}\right].$$

Budget:

$$\hat{g}_t + \frac{\bar{s}}{\bar{y}}\hat{s}_t + \frac{1}{\mu\bar{\pi}}\frac{\bar{b}}{\bar{y}}[\hat{b}_{t-1} - \hat{\pi}_t] = \frac{1}{\bar{R}}\frac{\bar{b}}{\bar{y}}[\hat{b}_t - \hat{R}_t - \hat{q}_t^b] + \tau_c\frac{\bar{c}}{\bar{y}}\hat{c}_t$$
$$+ \tau^n\frac{\bar{w}\bar{n}}{\bar{c}}\frac{\bar{c}}{\bar{y}}\left[\frac{d\tau_t^l}{\tau_l} + \hat{w}_t + \hat{n}_t\right] + \tau^k[\bar{r}^k r_t^k + (r_t^k - \delta)\hat{k}_{t-1}^p]\frac{\bar{k}}{\mu\bar{y}}.$$

Extension of SW: Introducing a ZLB

- Original SW Taylor rule:

$$\begin{aligned}
\hat{R}_t^{TR} &= \psi_1(1-\rho_R)\hat{\pi}_t + \psi_2(1-\rho_r)(\hat{y}_t - \hat{y}_t^f) \\
&\quad + \psi_3 \Delta(\hat{y}_t - \hat{y}_t^f) + \rho_R \hat{R}_{t-1}^{TR} + ms_t \\
&= 2.04(1-0.81)\hat{\pi}_t + 0.09(1-0.81)(\hat{y}_t - \hat{y}_t^f) \\
&\quad + 0.22\Delta(\hat{y}_t - \hat{y}_t^f) + 0.81\hat{R}_{t-1}^{TR} + ms_t \\
\hat{R}_t &= \max\{-(1-\bar{R}) + \frac{0.25}{400}, \hat{R}_t^{TR}\},
\end{aligned}$$

- implying a binding ZLB at an annual rate of 0.25%.
- Alternative ZLB implementation: “Switching off”: $\hat{R}_t = (1 - \mathbf{1}_{ZLB,t})\hat{R}_t^{TR} + \mathbf{1}_{ZLB,t}\hat{R}_{t-1}^{TR}$.
- Alternative 1. Original Taylor rule: $\hat{R}_t^{TR} = 1.5\hat{\pi}_t + 0.5(\hat{y}_t - \hat{y}_t^f) + ms_t$.
- Alternative 2. Clarida et al. (JEL, 1999): $\hat{R}_t^{TR} = ((1-0.79)(2.15\hat{\pi}_{t+1} + 0.93(\hat{y}_t - \hat{y}_t^f)) + 0.79\hat{R}_{t-1}^{TR} + ms_t$.

Extension of SW: Production and Expenditure

The production technology for final goods:

$$\hat{y}_t = \frac{\bar{y} + \Phi}{\bar{y}}[\alpha(1 - \zeta)\hat{k}_{t-1} + (1 - \alpha)(1 - \zeta)\hat{n}_t + \zeta\hat{k}_t^g + \hat{\epsilon}_t^a],$$

Spending identity with costs of capacity utilization:

$$\hat{y}_t = \hat{g}_t + \frac{\bar{c}}{\bar{y}}\hat{c}_t + \frac{\bar{x}}{\bar{y}}\hat{x}_t + \frac{\bar{x}^g}{\bar{y}}\hat{x}_t^g + \frac{\bar{r}^k\bar{k}}{\bar{y}}\hat{u}_t.$$

Extension of SW: Cost equation

- Economy with frictions:

$$\widehat{mc}_t = (1-\alpha)\hat{w}_t + \alpha\hat{r}_t^k - \frac{1}{1-\zeta}\left(\zeta\hat{k}_t^g - \zeta\frac{\bar{y}}{\bar{y}+\phi}\hat{y}_t + \hat{\epsilon}_t^a\right),$$

  which now includes a congestion effect.
- Frictionless economy: $\widehat{mc}_t = 0$.

Unchanged SW equations: Pricing

- Pricing equation

$$(1+\bar{\beta}\mu\iota_p)\hat{\pi}_t = \iota_p\hat{\pi}_{t-1}+\bar{\beta}\mu\mathbb{E}_t[\hat{\pi}_{t+1}]+A_p\frac{[1-\zeta_p\bar{\beta}\mu][1-\zeta_p]}{\zeta_p}\widehat{mc}_t+\hat{\lambda}_{p,t}.$$

$1-\zeta_p$ is the probability of (potential) price adjustment and, using the markup λ_p:

$$A_p = \frac{1+\frac{G'''}{G''}}{2+\frac{G'''}{G''}} = \frac{1}{1+\lambda_p\epsilon_p}, \qquad \epsilon = \frac{d\frac{G''}{xG'}}{dx}.$$

- Dixit-Stiglitz case:

$$G(x) = x^{\frac{1}{1+\lambda_p}} = x^{\frac{\varepsilon_p - 1}{\varepsilon_p}} \quad \Rightarrow \quad \epsilon_p = 0, A_p = 1.$$

- Higher $\lambda_p\epsilon_p$, lower estimated ζ_p. Used by SW to achieve higher frequency of price adjustment (Eichenbaum-Fisher, 2007).

Unchanged SW equations: Capital services and Capital Stock

Cost minimization yields:

$$\hat{k}_t = \hat{w}_t - \hat{r}_t^k + \hat{n}_t .$$

From the FOC with respect to capacity utilization:

$$\bar{r}^k \hat{r}_t^k = a''(1)\hat{u}_t \qquad \Rightarrow \hat{u}_t \equiv \frac{1-\psi_u}{\psi_u}\hat{r}_t^k .$$

The law of motion for capital implies:

$$\hat{k}_t^p = \left[1 - \frac{\bar{x}}{\bar{k}^p}\right]\hat{k}_{t-1}^p + \frac{\bar{x}}{\bar{k}^p}\hat{q}_t^x + \frac{\bar{x}}{\bar{k}^p}\hat{x}_t .$$

Unchanged SW equations: Investment

The FOC for investment implies:

$$\hat{x}_t = \frac{1}{1+\bar{\beta}\mu}\left[\hat{x}_{t-1} + \bar{\beta}\mu\mathbb{E}_t(\hat{x}_{t+1}) + \frac{1}{\mu^2 S''(\mu)}[\hat{Q}_t^k + \hat{q}_t^x]\right].$$

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Estimation and Calculation.

Shocks: AR(1).

1. Technology.
2. Bond shock: wedge between FFR and gov't bonds.
3. Bond shock: wedge between gov't bond returns and returns on capital.
4. Gov. spending plus net export. Co-varies with technology.
5. Investment specific (rel. price).
6. Gov. investment specific. Used with gov. investment time series only.
7. Monetary policy.
8. Labor tax rates.
9. Mark-up: prices: ARMA(1,1).
10. Mark-up: wages: ARMA(1,1).

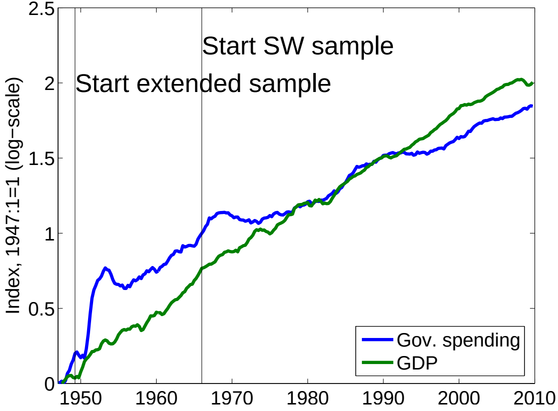
Observations – Overview

- Time series: Updated SW dataset, 1948:2-2009:4. Quarterly. 4 Period pre-sample.
- Sources: NIPA, FRED 2, BLS.
- Nominal series for wages, consumption, government and private investment deflated with general GDP deflator.
- Differences to Smets-Wouters dataset: Use civilian non-institutionalized population throughout, although not seasonally adjusted before 1976. Base year for real GDP: 2005 instead of 1996.
- All series but real wages have a correlation of 100% across the two datasets. For the change in real wages, the correlation is 0.9.
- No data for the Corporate-Treasury bond yield spread before 1953:1. Set to zero.
- No data on FFR before 1954:3. Use secondary market rate for 3-month TBill before.
- Dallas Fed federal debt data.

Observations – Time Series

1. Output: Chained 2005 real GDP, growth rates.
2. Consumption: Private consumption expenditure, growth rates.
3. Investment: private fixed investment, growth rates.
4. Hours worked: Civilian employment index $\times$ average nonfarm business weekly hours worked index. Demeaned log.
5. Inflation: GDP deflator, quarterly growth rates.
6. Wages: Nonfarm Business, hourly compensation index. Growth rates.
7. FFR: Converted to quarterly rates.
8. Corporate-Treasury bond yield spread: Moody's Baa index – 10 yr Treasury bond at quarterly rates, demeaned.
9. Dallas Fed gross federal debt series at par value. Demeaned log.
10. For model with gov. capital only: Government investment: growth rates.

Postwar GDP and government spending



Estimation and Simulation

- Dynare. If applicable, same priors as Smets-Wouters.
  - Pre-sample: 4 quarters.
  - Use Monte-Carlo algorithm to find starting values close to global optimum.
  - Given starting values close to optimum, use Newton-Raphson based algorithm.
- Sample from posterior using Metropolis-Hastings.
  - Dynare only allows locally stable draws: restriction on prior.
  - 1 MH chain, 10000 draws. Discard first 2000 draws.
  - Scale variance at posterior mode to obtain acceptance rate of $\approx \frac{1}{3}$.
- Simulate the economy for each draw.

Calibrated parameters

- Tax rates, and debt-GDP ratio from NIPA (Trabandt-Uhlig, 2009).
- Government spending components from NIPA.
- Kimball curvature parameters set to roughly match empirical frequency of price adjustment (Eichenbaum-Fisher, 2007).
- Depreciation per Cooley-Prescott (1994) based on $\frac{\bar{x}}{\bar{k}} = 0.0076$.

	SW	With gov. capital	
	66:1–04:4	48:2–08:4	66:1–08:4
Depreciation δ	0.025	0.0145	0.0145
Wage mark-up λ_w	0.5	0.5	0.5
Kimball curvature goods mkt. $\hat{\eta}_p$	10	10	10
Kimball curvature labor mkt. $\hat{\eta}_w$	10	10	10
Capital tax τ^k	n/a	0.36	0.36
Consumption tax τ^c	n/a	0.05	0.05
Labor tax τ^n	n/a	0.28	0.28
Share credit constrained ϕ	n/a	0.25	0.25
Gov. spending, net exports-GDP $\frac{\bar{g}}{\bar{y}}$	0.18	0.153	0.146
Gov. investment-GDP $\frac{\bar{x}^g}{\bar{y}}$	n/a	0.04	0.034
Debt-GDP $\frac{\bar{b}}{\bar{y}}$	n/a	$4\times$ 0.63	$4\times$ 0.63

Effects of different Calibration and Data

- Estimate original SW model with updated dataset and different time series definitions and calibration.
- Most posterior means differ only by sampling error.
- Systematic changes in the estimates of the SW model:
  - Three standard deviation higher external habit h.
  - One standard deviation lower intertemporal elasticity of substitution σ^{-1}.
  - Higher capital share α: the original model estimates a capital share of only 0.19 (standard deviation: 0.02). The modifications imply that α is centered around 0.21 (0.01).

Estimation results

- Higher private capital share α (0.24) and higher overall capital share ($\zeta + (1 - \zeta)\alpha \approx 0.26$).
- Prices stickiness varies.
- Higher fixed cost=higher steady state markup.
  - Higher fixed cost and probability of price adjustment related via Kimball curvature parameter.
  - Very different priors over fixed cost in literature (Levin et al., 2006; Smets and Wouters, 2003).
  - Estimation results (1.8-1.9) similar to Nekarda and Ramey (2010).
- Lower elasticity of labor supply without government capital.
- Higher intertemporal elasticity of substitution.
- Changes in Taylor rule.

Estimates – Extended Model

	Prior	Prior mean (s.d.)	SW Model 66:1-08:4	New investment 66:1-08:4	Debt & Gov. Capital 49:2-08:4
Adj. cost $S''(\mu)$	norm	4.000 (1.500)	5.93 (1.1)	5.38 (1.03)	4.57 (0.82)
Risk aversion σ	norm	1.500 (0.375)	1.42 (0.11)	1.31 (0.1)	1.18 (0.07)
Habit h	beta	0.700 (0.100)	0.7 (0.04)	0.8 (0.03)	0.85 (0.02)
Calvo wage ζ_w	beta	0.500 (0.100)	0.77 (0.05)	0.77 (0.05)	0.84 (0.03)
Inv. labor sup. ela. ν	norm	2.000 (0.750)	1.96 (0.54)	2.14 (0.47)	2.33 (0.56)
Calvo prices ζ_p	beta	0.500 (0.100)	0.69 (0.05)	0.73 (0.06)	0.81 (0.04)
Wage indexation ι_w	beta	0.500 (0.150)	0.62 (0.1)	0.61 (0.12)	0.44 (0.09)
Price indexation ι_p	beta	0.500 (0.150)	0.26 (0.08)	0.29 (0.1)	0.3 (0.09)
Capacity util.	beta	0.500 (0.150)	0.59 (0.1)	0.54 (0.1)	0.45 (0.08)
$1+\frac{\text{Fix. cost}}{Y} = 1+\lambda_p$	norm	1.250 (0.125)	1.64 (0.08)	1.63 (0.08)	1.93 (0.06)
Taylor rule infl. ψ_1	norm	1.500 (0.250)	2 (0.17)	2.1 (0.17)	1.64 (0.19)
same, smoothing ρ_R	beta	0.750 (0.100)	0.82 (0.02)	0.83 (0.02)	0.92 (0.01)
same, LR gap ψ_2	norm	0.125 (0.050)	0.09 (0.02)	0.12 (0.03)	0.13 (0.03)
same, SR gap ψ_3	norm	0.125 (0.050)	0.24 (0.03)	0.26 (0.03)	0.2 (0.02)
Mean inflation (data)	gamm	0.625 (0.100)	0.76 (0.09)	0.73 (0.12)	0.56 (0.08)
100 $\times$ time pref.	gamm	0.250 (0.100)	0.16 (0.05)	0.14 (0.04)	0.11 (0.04)
Mean hours (data)	norm	0.000 (2.000)	1.07 (0.95)	1.07 (1.16)	-0.25 (0.67)
Trend $(\mu - 1) * 100$	norm	0.400 (0.100)	0.43 (0.02)	0.44 (0.01)	0.48 (0.01)
Capital share α	norm	0.300 (0.050)	0.19 (0.02)	0.21 (0.01)	0.24 (0.01)
Gov. adj. cost $S_g''(\mu)$	norm	0.000 (0.500)	n/a	n/a	6.85 (1.03)
Budget bal speed $\frac{\psi_\tau - 0.025}{0.175}$	beta	0.30 (0.20)	n/a	n/a	0.07 (0.05)
Implied ψ_τ	n/a	0.078 (0.035)	n/a	n/a	0.0373 (0.01)
Mean gov. debt	norm	0.000 (0.500)	n/a	n/a	0 (0.49)
Mean bond spread	gamm	0.500 (0.100)	n/a	n/a	0.45 (0.05)

Implied government share in production: $\zeta = 2.30\%$.

Estimates – Shock processes

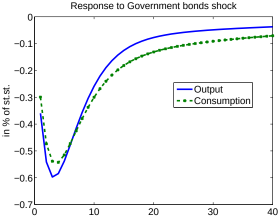
	Prior	Prior mean (s.d.)	SW Model 66:1-08:4	New investment 66:1-08:4	Debt & Gov. Capital 49:2-08:4
s.d. tech.	invg	0.100 (2.000)	0.46 (0.03)	0.46 (0.03)	0.46 (0.02)
AR(1) tech.	beta	0.500 (0.200)	0.95 (0.01)	0.94 (0.01)	0.94 (0.01)
s.d. bond	invg	0.100 (2.000)	0.24 (0.03)	0.17 (0.02)	0.97 (0.05)
AR(1) bond ρ_q	beta	0.500 (0.200)	0.27 (0.1)	0.26 (0.07)	0.68 (0.03)
s.d. gov't	invg	0.100 (2.000)	0.54 (0.03)	0.3 (0.01)	0.35 (0.02)
AR(1) gov't	beta	0.500 (0.200)	0.98 (0.01)	0.99 (0.01)	0.98 (0.01)
Cov(gov't, tech.)	norm	0.500 (0.250)	0.53 (0.09)	0.36 (0.05)	0.3 (0.05)
s.d. inv. price	invg	0.100 (2.000)	0.43 (0.04)	1.17 (0.11)	1.26 (0.11)
AR(1) inv. price	beta	0.500 (0.200)	0.73 (0.06)	0.43 (0.07)	0.55 (0.06)
s.d. mon. pol.	invg	0.100 (2.000)	0.24 (0.02)	0.24 (0.01)	0.23 (0.01)
AR(1) mon. pol.	beta	0.500 (0.200)	0.16 (0.07)	0.14 (0.05)	0.22 (0.06)
s.d. goods m-up	invg	0.100 (2.000)	0.14 (0.01)	0.14 (0.01)	0.31 (0.02)
AR(1) goods m-up	beta	0.500 (0.200)	0.89 (0.04)	0.89 (0.05)	0.91 (0.05)
MA(1) goods m-up	beta	0.500 (0.200)	0.73 (0.08)	0.77 (0.07)	0.96 (0.02)
s.d. wage m-up	invg	0.100 (2.000)	0.26 (0.02)	0.26 (0.02)	0.23 (0.02)
AR(1) wage m-up	beta	0.500 (0.200)	0.97 (0.01)	0.97 (0.01)	0.96 (0.02)
MA(1) wage m-up	beta	0.500 (0.200)	0.91 (0.03)	0.91 (0.03)	0.91 (0.04)
s.d. Tax shock	invg	0.100 (2.000)	n/a	n/a	1.42 (0.07)
AR(1) tax shock	beta	0.500 (0.200)	n/a	n/a	0.97 (0.01)
s.d. gov. inv. price	invg	0.100 (2.000)	n/a	n/a	0.79 (0.09)
AR(1) gov. inv. price	beta	0.500 (0.200)	n/a	n/a	0.97 (0.01)
s.d. bond spread	invg	0.100 (2.000)	n/a	n/a	0.08 (0)
AR(1) bond spread	beta	0.500 (0.200)	n/a	n/a	0.91 (0.02)

Outline

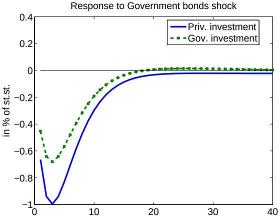
1. An NK model with distort. taxes and gov. capital.
   - Estimation and Historical Shocks
   - Explaining the financial crisis
2. Results
   - Benchmark
   - Sensitivity analysis
3. The power of monetary policy?
4. Conclusion
5. Appendix: Model and Estimation Details
   - Log-linearized equations
   - Estimation and Historical Shocks
   - Impulse-Response-Functions at Posterior Mean

Government Bond Shock

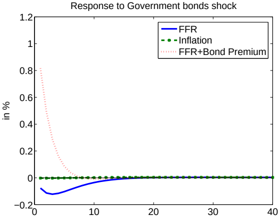
Output & Consumption



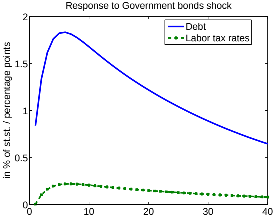
Investment



FFR & Inflation



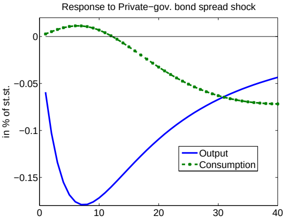
Debt & Labor tax



Note: Response to a one standard deviation shock.

Private-Government Bond Spread Shock

Output & Consumption



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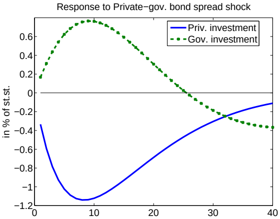

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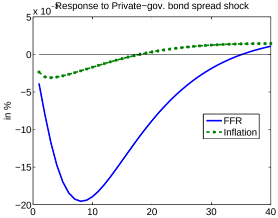

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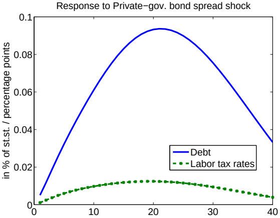
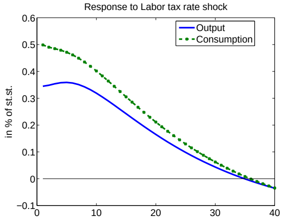


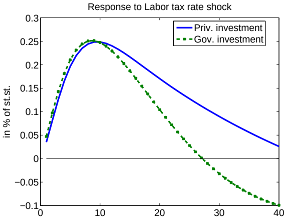
Note: Response to a one standard deviation shock.

Labor Tax Rate Shock

Output & Consumption



Investment



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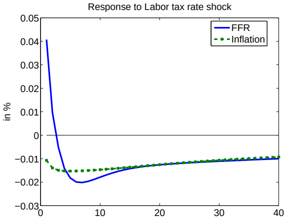
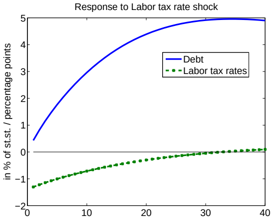


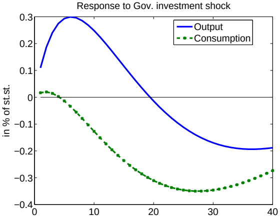
Debt & Labor tax



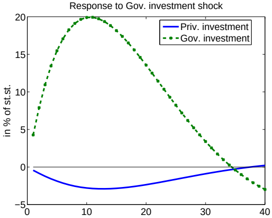
Note: Response to a one standard deviation shock.

Government Investment Shock

Output & Consumption



Investment



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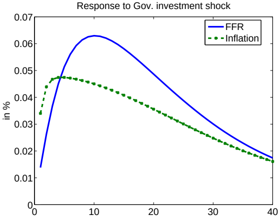
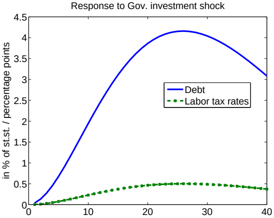


Debt & Labor tax

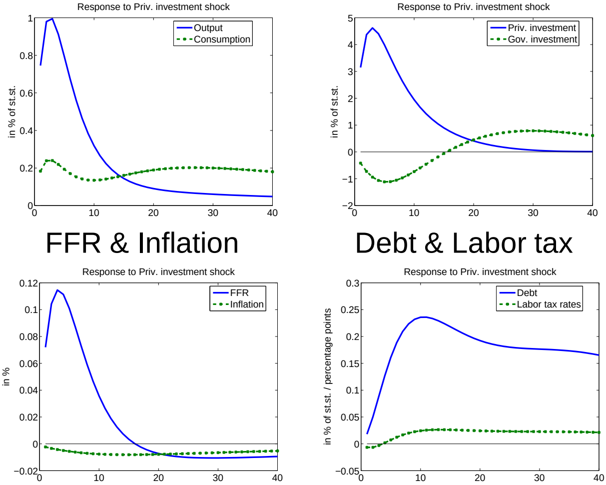


Note: Response to a one standard deviation shock.

Private Investment Shock

Output & Consumption

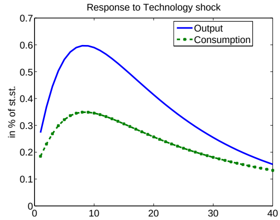
Investment



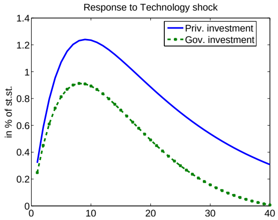
Note: Response to a one standard deviation shock.

Technology Shocks

Output & Consumption



Investment



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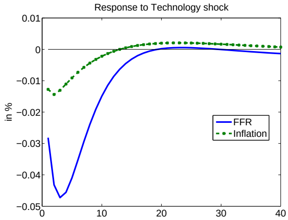
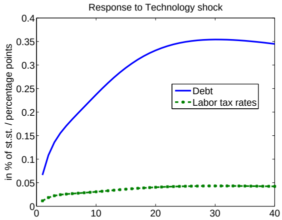


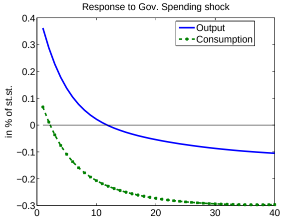
Debt & Labor tax



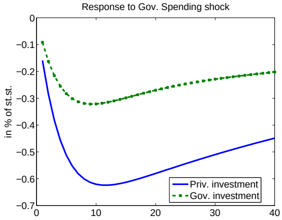
Note: Response to a one standard deviation shock. Innovations to technology also affect government spending.

Government Spending Shock

Output & Consumption



Investment



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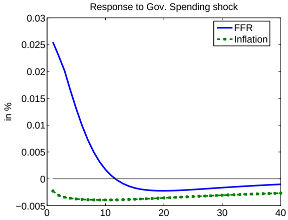
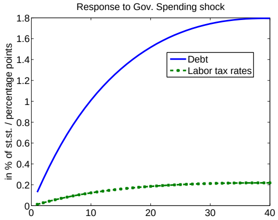


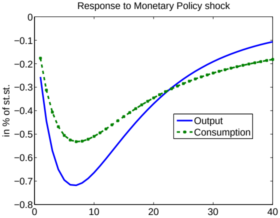
Debt & Labor tax



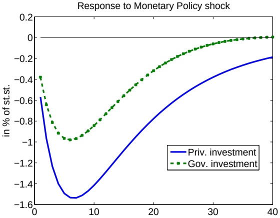
Note: Response to a one standard deviation shock.

Monetary Policy Shocks

Output & Consumption



Investment



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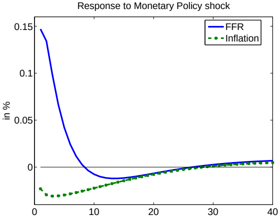
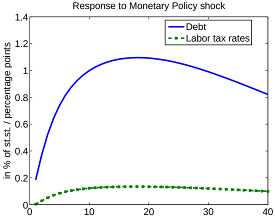


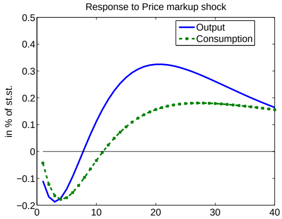
Debt & Labor tax



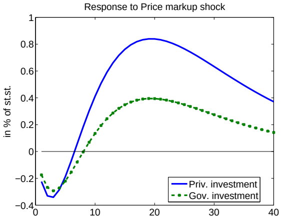
Note: Response to a one standard deviation shock.

Price Markup Shocks

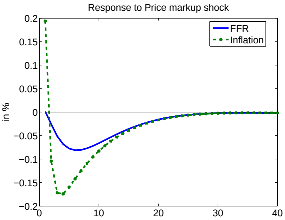
Output & Consumption



Investment



FFR & Inflation

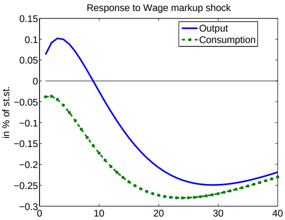


Debt & Labor tax

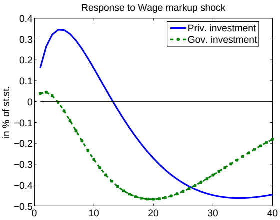
Note: Response to a one standard deviation shock. Markup shocks do not affect the flexible price economy.

Wage Markup Shocks

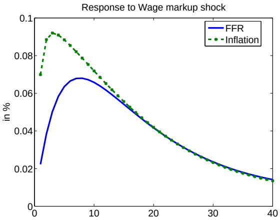
Output & Consumption



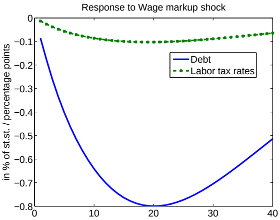
Investment



FFR & Inflation

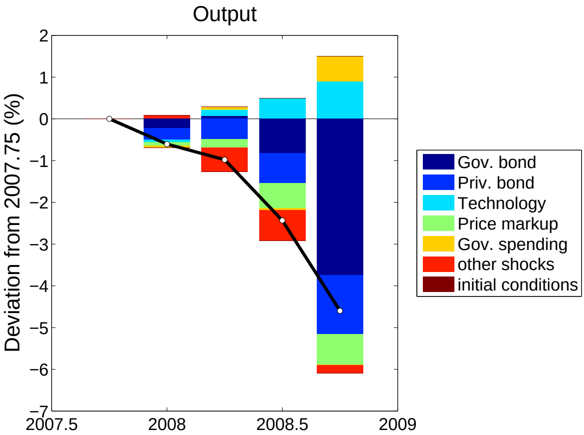


Debt & Labor tax



Note: Response to a one standard deviation shock. Markup shocks do not affect the flexible price economy.

Historical Shock Decomposition: Output



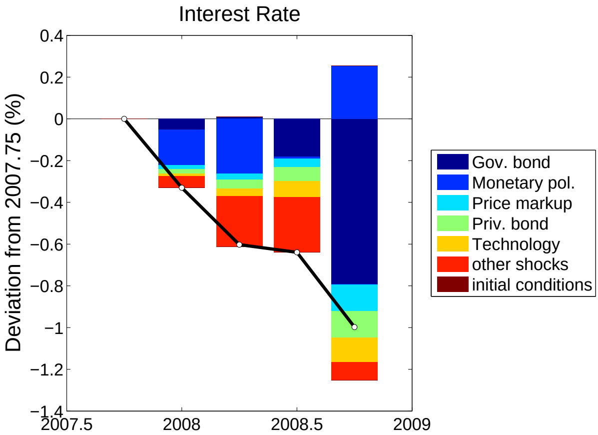
Note: At posterior mean. 2007:4 is the NBER recession date.

Shock Contributions to Output

	2008:4 vs. 2007:4		Theoretical Error Variance		
Shock	%	relative	10%	Median	90%
Gov. bond	-3.75	81.52	3.57	4.89	7.20
Priv. bond	-1.42	30.81	0.74	1.61	3.38
Technology	0.90	-19.53	13.23	21.42	31.55
Price markup	-0.73	15.86	2.38	5.74	11.64
Gov. spending	0.60	-12.98	2.88	4.29	6.02
Priv. inv.	-0.30	6.53	8.96	14.06	22.60
Labor tax	-0.27	5.91	3.64	6.11	10.54
Monetary pol.	0.20	-4.44	14.53	22.17	30.61
Wage Markup	0.15	-3.18	1.80	6.15	17.37
Gov. inv.	0.03	-0.73	4.42	6.98	10.66
Initial Values	-0.01	0.22		n/a	
Sum	-4.60	100.00		100.00	

Note: At posterior mean.

Historical Shock Decomposition: Interest rates



Note: At posterior mean. 2007:4 is the NBER recession date.

Shock Contributions to Interest Rates

	2008:4 vs. 2007:4		Theoretical Error Variance		
Shock	%	relative	10%	Median	90%
Gov. bond	-0.79	79.47	8.06	12.61	17.42
Monetary pol.	0.25	-25.52	8.62	12.08	16.37
Price markup	-0.13	12.94	4.70	9.62	19.89
Priv. bond	-0.12	12.50	0.51	0.98	1.81
Technology	-0.12	11.98	1.74	2.53	3.40
Labor tax	-0.05	4.64	0.99	2.10	5.18
Priv. inv.	-0.04	3.84	9.22	14.65	24.71
Wage Markup	-0.02	2.34	8.14	17.58	32.56
Gov. spending	0.02	-2.17	0.33	0.53	0.80
Gov. inv.	0.00	-0.03	13.17	20.55	30.73
Initial Values	0.00	-0.01		n/a	
Sum	-4.60	100.00		100.00	

Note: At posterior mean.