Liquidity and Safety over the Business Cycle

Andrea Ferrero
University of Oxford

Alexander Haas
University of Oxford

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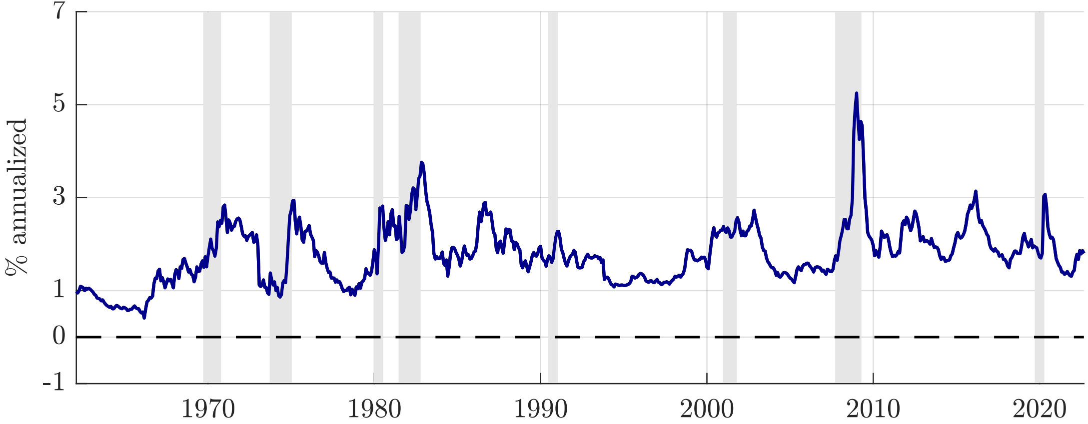
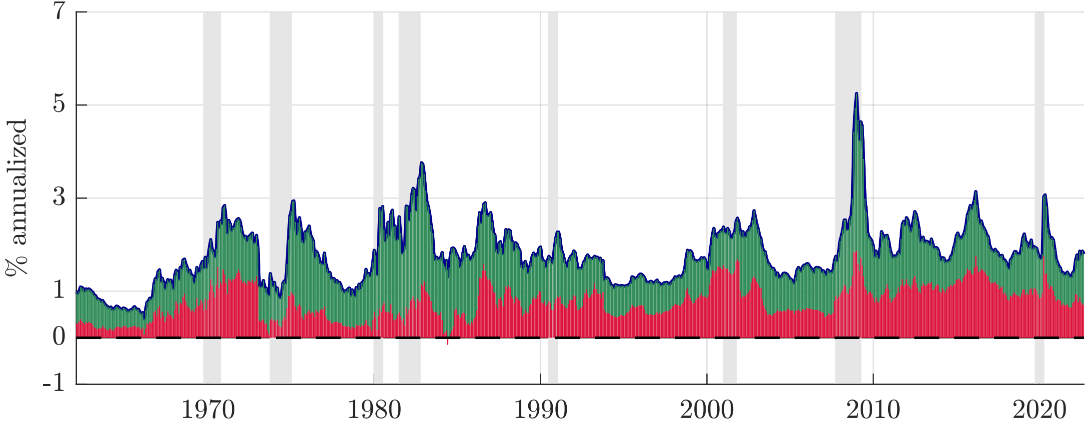
Motivation

- Broad consensus in macro-finance literature:
  - Financial conditions relevant over the business cycle
    [Kiyotaki & Moore 1997; Bernanke, Gertler & Gilchrist 1999]
  - In particular, both erosion of safety & dry-up of liquidity associated with early stages of 2007/08 Great Financial Crisis
    [Taylor & Williams 2009; Bernanke 2010, 2018; Gorton & Metrick 2010, 2012]
- **Liquidity and safety are broad (and interlinked) concepts**
  - Hard to separate but **distinction critical for policy design** in crises (credit easing in 07/08; March-2020) & **interlinked with fiscal multipliers**
  - Krishnamurthy & Vissing-Jorgensen (2012) suggest empirical decomposition
- This paper: **identify structural drivers of empirical liquidity & safety** in terms of shocks to supply of safe assets, asset resaleability & asset quality

Convenience yield



Convenience yield | Liquidity & Safety



This paper

- Endogenize both the liquidity & safety of private assets in a medium-scale NK model with heterogeneous firms and two financial frictions
  - **Liquidity:** resaleability constraint on private assets
  - **Safety:** shocks to asset quality & asymmetric information
- Estimate the model over the U.S. business cycle matching empirical liquidity and safety premia $\longrightarrow$ highlight **role of two types of financial shocks**
- **Crisis simulations & policy counterfactuals** for Fin Crisis & March-2020 $\longrightarrow$ policy implications (role of QE, fiscal multipliers), liquidity puzzle ...

Literature

- **Markets in the GFC** | Brunnermeier & Pedersen (2009); Taylor & Williams (2009); Ashcraft, Garleanu & Pederson (2010); Gorton & Metrick (2010, 2012) ...
- **Safe assets** | Krishnamurthy & Vissing-Jorgensen (2012); He, Krishnamurthy & Milbradt (2016, 2019); Caballero, Farhi & Gourinchas (2017); Caballero & Farhi (2018); Bayer, Born & Luetticke (2023) ...
- **Asset quality (& asymmetric information)** | Kurlat (2013); Bigio (2015); Dong & Wen (2023); Bierdel, Drenik, Herreño & Ottonello (2023) ...
- **Asset resaleability** | Kiyotaki & Moore [KM] (1997, 2019); Ajello (2016); Del Negro, Eggertsson, Ferrero & Kiyotaki [DEFK] (2017) ...
- **Business cycle fluctuations** | Justiniano, Primiceri & Tambalotti (2010); Christiano, Motto & Rostagno (2014); Becard & Gauthier (2021) ...
- **Liquidity puzzle** | Shi (2015); Guerron-Quintana & Jinnai (2019) ...

I. Motivation

II. Model

III. Estimation & Results

IV. Liquidity puzzle

V. Next steps

The model in a nutshell

- Households ▸ Households
  - Consume, supply labour & own firms and retailers
- Labour unions & investment goods firms ▸ Labour unions ▸ Investment goods firms
  - Differentiate homogeneous labour & set wages on a staggered basis
  - Transform final goods into investment goods
- **Heterogeneous firms (producers/ entrepreneurs)**
  - **Produce intermediate good**
  - **Invest in new capital formation & trade exisiting capital subject to**
    - **idiosyncratic investment efficiency** ϵ_t
    - **the current resaleability** ($\bar{\omega}_t$) **and quality of capital** ($\bar{\psi}_t$)
- Final goods firms & monetary and fiscal policy ▸ Final goods firms ▸ Government
  - Differentiate homogeneous intermediate good & set prices on a staggered basis
  - Interest rate policy, ZLB & government budget constraint

Heterogeneous firms: Production

Firms produce subject to a pre-determined capital stock, maximizing

$$R_{Kt}k_{it-1} \equiv P_{mt}a_t\left(u_{it}k_{it-1}\right)^{\alpha}\left(z_t\ell_{it}\right)^{1-\alpha} - W_t\ell_{it} - s(u_{it})k_{it-1}.$$

Given homogeneity of intermediate output, constant returns to scale, and the absence of idiosyncratic disturbances $\longrightarrow$ conventional aggregate relationships:

$$y_{mt} = a_t\left(u_tk_{t-1}\right)^{\alpha}\left(z_t\ell_t\right)^{1-\alpha} \qquad w_t = (1-\alpha)\frac{p_{mt}y_{mt}}{\ell_t}$$

$$s'(u_t) = \alpha\frac{p_{mt}y_{mt}}{u_tk_{t-1}} \qquad r_{Kt}k_{t-1} = \alpha p_{mt}y_{mt} - s(u_t)k_{t-1}$$

Heterogeneous firms: Investment

Firms invest in new capital formation & trade exisiting capital, maximizing

$$\mathbb{V}^P(k_{it-1}, b_{it-1}, \epsilon_t) \equiv \mathbb{V}_{it}^P = \mathbb{E}_t \left(\sum_{s=0}^{\infty} \mathcal{M}_{t+s} D_{it+s} \right)$$

subject to

$$D_{it} = R_{Kt} k_{it-1} - P_{It} i_{it} + P_{Kt}(k_{it}^{s,g} + k_{it}^{s,b} - k_{it}^{a}) + R_{t-1} B_{it-1} - B_{it}$$

$$k_{it} = (1-\gamma)\,\bar{\psi}_t k_{it-1} + \psi_t^* k_{it}^a - k_{it}^{s,g} + \epsilon_t i_{it}$$

$$k_{it}^{s,g} \leq \bar{\omega}_t \bar{\psi}_t (1-\gamma) k_{it-1} \quad \text{and} \quad k_{it}^{s,b} \leq \bar{\omega}_t (1-\bar{\psi}_t)(1-\gamma) k_{it-1}$$

$$\left\{ D_{it}, i_{it}, k_{it}, k_{it}^{s,g}, k_{it}^{s,b}, k_{it}^{a}, B_{it} \right\}_{t=0}^{\infty} \geq 0$$

In more detail | Three state variables

- Idiosyncratic investment efficiency $\epsilon_t \sim F(\epsilon_t)$
- Capital k_{it}: production factor & financial asset
  $\longrightarrow$ subject to two financial frictions:
  - **[ff 1]** limited resaleability (liquidity) of capital $\bar{\omega}_t$
  - **[ff 2]** limited quality (safety) of capital $\bar{\psi}_t$ & asymmetric information
- Government bonds B_{it}: financial asset
  $\longrightarrow$ supplied by the fiscal authority, perfectly liquid and safe

Heterogeneous firms: Investment

Firms invest in new capital formation & trade exisiting capital, maximizing

$$\mathbb{V}^P(k_{it-1}, b_{it-1}, \epsilon_t) \equiv \mathbb{V}^P_{it} = \mathbb{E}_t \left(\sum_{s=0}^{\infty} \mathcal{M}_{t+s} D_{it+s} \right)$$

subject to

$$D_{it} = R_{Kt} k_{it-1} - P_{It} i_{it} + P_{Kt}(k^{s,g}_{it} + k^{s,b}_{it} - k^{a}_{it}) + R_{t-1} B_{it-1} - B_{it}$$

$$k_{it} = (1-\gamma)\,\bar{\psi}_t k_{it-1} + \psi^*_t k^a_{it} - k^{s,g}_{it} + \epsilon_t i_{it}$$

$$k^{s,g}_{it} \leq \bar{\omega}_t \bar{\psi}_t (1-\gamma) k_{it-1} \quad \text{and} \quad k^{s,b}_{it} \leq \bar{\omega}_t (1-\bar{\psi}_t)(1-\gamma) k_{it-1}$$

$$\left\{ D_{it}, i_{it}, k_{it}, k^{s,g}_{it}, k^{s,b}_{it}, k^{a}_{it}, B_{it} \right\}_{t=0}^{\infty} \geq 0$$

Heterogeneous firms: Investment

- Law of motion of capital: $k_{it} = (1-\gamma)\,\bar{\psi}_t k_{it-1} + \epsilon_t i_{it} - k_{it}^{s,g} + \psi_t^* k_{it}^a$
- Resaleability constraints on good- and bad-quality capital:

$$k_{it}^{s,g} \leq \bar{\omega}_t \bar{\psi}_t (1-\gamma) k_{it-1} \quad \text{and} \quad k_{it}^{s,b} \leq \bar{\omega}_t (1-\bar{\psi}_t)(1-\gamma) k_{it-1}$$

- Non-negativity constraints: $\left\{ D_{it}, i_{it}, k_{it}, k_{it}^{s,g}, k_{it}^{s,b}, k_{it}^{a}, B_{it} \right\}_{t=0}^{\infty} \geq 0$

Idiosyncratic investment efficiency $\epsilon_t \sim F\left(\epsilon_t\right)$

[ff 1] Resaleability of capital $\bar{\omega}_t$ **[ff 2]** Quality of capital $\bar{\psi}_t$ (w/ asym inf: ψ_t^*)

In more detail | Decision rules & aggregation

Realization of $\epsilon_t \sim F(\epsilon_t)$: Firms self-select into **three distinct groups**

Accumulate liquidity (buy capital & bonds)	Invest but don't sell good-quality capital	Invest and sell good-quality capital

$\epsilon_t^* = (p_{It}/q_t)$ $\qquad$ $\epsilon_t^{**} = (p_{It}/p_{Kt})$

Aggregation? (i) IID shocks; (ii) firm-behavior linear in state variables; (iii) cut-off values only depend on aggregate realizations. ✓
[compare w/ BGG 1999, contrast w/ joint hh structure in Shi 2015 & DEFK 2017]

In more detail | Fin frictions & liquidity + safety premia

Fin frictions cause **spread (convenience yield)** betw govt bond & capital return

- **[ff 1]** Limited resaleability of capital $\bar{\omega}_t$
  $\longrightarrow$ widens wedge between q_t and q_{Bt}
- **[ff 2]** Limited quality (safety) of capital $\bar{\psi}_t$ & asymmetric information
  $\longrightarrow$ creates wedge between q_t and p_{Kt}

Nested models? With $\bar{\psi}_t = 1$ or no asymmetric information:
[ff 2] turned off, $q_t = p_{Kt}$ and $\epsilon_t^* = \epsilon_t^{**}$ [think KM 1997 or DEFK 2017]

Interior solutions? Endogenous adjustment to looser fin conditions via ϵ_t^*. No need to (i) compute a separate unconstrained (interior) model solution [vs DEFK 2017], (ii) model frictions as occ binding constraints (if $B_t < \bar{\bar{B}}_t$).

In more detail | Fin frictions & liquidity + safety premia

$$cy_t \equiv \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \left[1 + \int_{\epsilon^*_{t+1}}^{\epsilon_{t+1}} \left(\frac{\epsilon_{t+1}}{\epsilon^*_{t+1}} - 1 \right) dF(\epsilon) \right] \left(r^*_{Kt+1} - \frac{R_t}{\Pi_{t+1}} \right) \right\} = r^\omega_t + r^\psi_t$$

$$\text{where } r^\omega_t \equiv \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \left[\int_{\epsilon^*_{t+1}}^{\epsilon_{\max}} \left(\frac{\epsilon_{t+1}}{\epsilon^*_{t+1}} - 1 \right) dF(\epsilon) \right] \frac{(1-\bar{\omega}_{t+1})(1-\delta_{t+1})q_{t+1}}{q_t} \right\},$$

$$r^\psi_t \equiv \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \left[\int_{\epsilon^*_{t+1}}^{\epsilon_{\max}} \left(\frac{\epsilon_{t+1}}{\epsilon^*_{t+1}} - 1 \right) dF(\epsilon) - \int_{\epsilon^{**}_{t+1}}^{\epsilon_{\max}} \left(\frac{\epsilon_{t+1}}{\epsilon^{**}_{t+1}} - 1 \right) dF(\epsilon) \right] \frac{\bar{\omega}_{t+1}(1-\delta_{t+1})q_{t+1}}{q_t} \right\}$$
$$- \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \left[1 + \int_{\epsilon^*_{t+1}}^{\epsilon_{\max}} \left(\frac{\epsilon_{t+1}}{\epsilon^*_{t+1}} - 1 \right) dF(\epsilon) \right] \frac{\bar{\omega}_{t+1}(1-\bar{\psi}_{t+1})(1-\gamma)p_{Kt+1}}{q_t} \right\}$$

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The estimation in a nutshell

- **Model estimated using Bayesian methods** (parameter subset calibrated)
- Quarterly observations on 9 U.S. macro & financial variables from 1986–2019
  - 7 standard macro variables: GDP, consumption, investment, inflation, real wage, hours worked, fed funds rate (all quantities in real per capita terms)
  - 2 additional financial variables: **Liquidity and safety premia** [Extensions: Price of investment goods and public debt/GDP ratio]
- Model stationarized and with 10 exogenous shock processes
- Data transformations: First-differences of trending variables, all demeaned

Calibrated parameters

Parameter		Value	Parameter		Value
Households					
σ	Risk aversion	1.0000	β	Discount factor	0.9901
χ	Disutility weight on labor	0.8011	ξ	Curvature of labor disutility	1.0000
Labor unions			**Investment goods firms**		
θ_p	Elasticity of labor substitution	11.000	Υ	Trend in inv specific technology	1.0025
Producers					
α	Capital share	0.4000	γ	Depreciation rate	0.0216
ν	Inv efficiency: Pareto param	5.7661	$\varepsilon_{\min}$	Inv efficiency: Pareto bound	0.8266
a	Steady state cyclical productivity	1.0000	μ_{z^*}	Trend growth rate of economy	1.0038
$\bar{\omega}$	Steady state capital resaleability	0.7740	$\bar{\psi}$	Steady state capital quality	0.9966
Final goods firms			**Government**		
θ_w	Elasticity of goods substitution	6.0000	Π^*	Steady state inflation	1.0050
g/y	Steady state govt spending/GDP	0.2000	b/y	Steady state govt debt/GDP	1.6772

NOTE: All parameters are either calibrated to match standard targets in the literature or mean values of observables. In particular, $\bar{\omega}$ and $\bar{\psi}$ are calibrated to match the average safety and liquidity premia in the sample.

Estimated parameters I

Parameter		Prior			Posterior	
		Distr	Mean	SD	Mode	SD
(A) Economic parameters						
Households						
$\hbar$	Habit parameter	beta	0.5000	0.1500	0.6589	0.0544
Labor unions						
ι_w	Calvo wage stickiness	beta	0.7500	0.1500	0.4423	0.0643
γ_w	Wage indexing weight on π_{t-1}	beta	0.5000	0.1500	0.6298	0.1553
Investment goods firms						
f''	Curvature of inv adj costs	normal	5.0000	3.0000	1.0333	0.1506
Producers						
σ_s	Curvature of cap util costs	normal	1.0000	1.0000	5.1870	0.6348
Final goods firms						
ι_p	Calvo price stickiness	beta	0.7500	0.1500	0.7975	0.0235
γ_p	Price indexing weight on π_{t-1}	beta	0.5000	0.1500	0.1256	0.0531
Government						
ϕ_π	Policy weight on inflation	gamma	1.5000	0.2500	2.6894	0.2337
ϕ_y	Policy weight on output	gamma	0.2500	0.1000	0.1442	0.0557
ρ_m	Policy inertia parameter	beta	0.8000	0.1000	0.8383	0.0161

Estimated parameters II

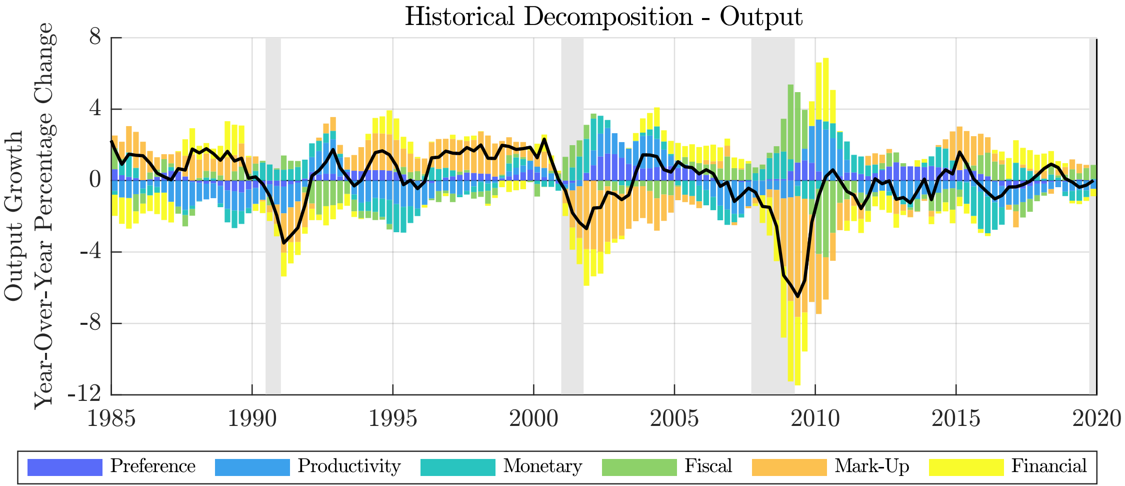
Parameter		Prior			Posterior	
		Distr	Mean	SD	Mode	SD
(B) Exogenous processes						
$\rho_{\chi w}$	AC wage mark-up shock	beta	0.5000	0.2000	0.9839	0.0117
$\sigma_{\chi w}$	SD wage mark-up innovation	invg2	0.0100	1.0000	0.0235	0.0035
ρ_a	AC cyclical productivity shock	beta	0.5000	0.2000	0.2089	0.1519
σ_a	SD cyclical productivity innovation	invg2	0.0100	1.0000	0.0020	0.0004
ρ_z	AC trend growth rate shock	beta	0.5000	0.2000	0.3781	0.1279
σ_z	SD trend growth rate innovation	invg2	0.0100	1.0000	0.0060	0.0009
ρ_ψ	AC capital quality shock	beta	0.5000	0.2000	0.8938	0.0316
σ_ψ	SD capital quality innovation	invg2	0.0100	1.0000	0.0023	0.0002
ρ_ω	AC capital resaleability shock	beta	0.5000	0.2000	0.7996	0.0426
σ_ω	SD capital resaleability innovation	invg2	0.0100	1.0000	0.0647	0.0052
$\rho_{\chi p}$	AC price mark-up shock	beta	0.5000	0.2000	0.8997	0.0379
$\sigma_{\chi p}$	SD price mark-up innovation	invg2	0.0100	1.0000	0.0188	0.0032
σ_m	SD monetary policy innovation	invg2	0.0100	1.0000	0.0013	0.0001
ρ_g	AC govt spending/GDP shock	beta	0.5000	0.2000	0.9674	0.0142
σ_g	SD govt spending/GDP innovation	invg2	0.0100	1.0000	0.0156	0.0009
ρ_b	AC govt debt/GDP shock	beta	0.5000	0.2000	0.7605	0.0283
σ_b	SD govt debt/GDP innovation	invg2	0.0100	1.0000	0.5050	0.0320
ρ_β	AC preference shock	beta	0.5000	0.2000	0.9496	0.0215
σ_β	SD preference innovation	invg2	0.0100	1.0000	0.0010	0.0004

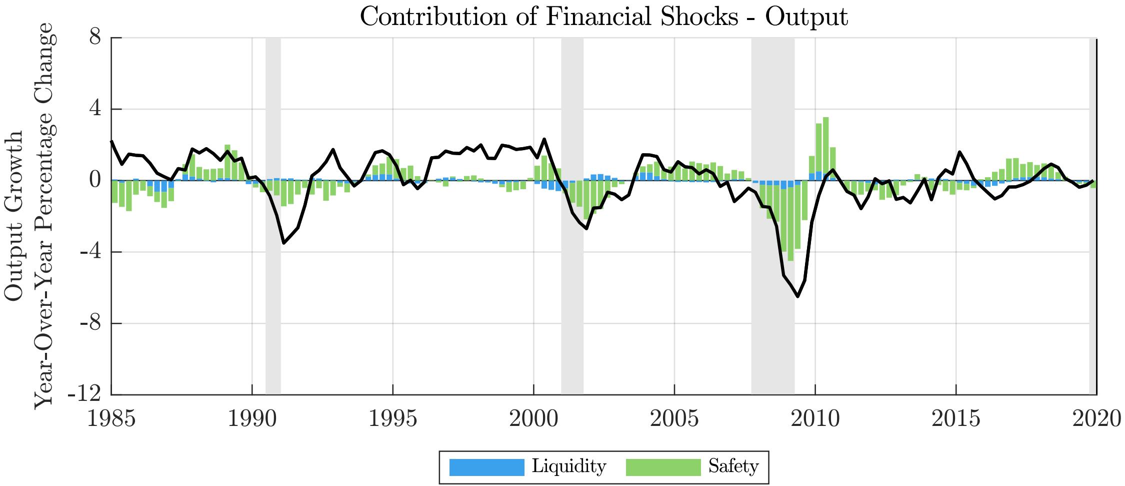
	$\varepsilon_{\chi wt}$	ε_{at}	ε_{zt}	$\varepsilon_{\psi t}$	$\varepsilon_{\omega t}$	$\varepsilon_{\chi pt}$	ε_{mt}	ε_{gt}	ε_{bt}	$\varepsilon_{\beta t}$
y_t	27.26	0.03	8.13	**13.53**	**0.48**	33.93	4.74	4.23	2.56	5.11
i_t	11.85	0.01	0.86	**24.08**	**0.57**	25.45	2.30	0.34	3.72	30.83
c_t	11.41	0.00	30.43	7.51	0.11	0.95	0.58	3.62	0.68	44.71
Π_t	5.43	0.73	2.00	35.66	1.04	15.77	21.46	1.29	6.43	10.19
R_t	2.16	0.05	1.29	59.11	1.39	4.62	13.37	1.07	10.41	6.53
cy_t	0.29	0.00	0.13	**51.55**	**7.30**	0.66	0.06	0.02	**39.00**	0.99
r_t^{ψ}	0.40	0.00	0.18	**34.93**	**7.40**	0.87	0.07	0.03	**54.71**	1.40
r_t^{ω}	0.02	0.00	0.01	**5.36**	**90.71**	0.04	0.00	0.00	**3.75**	0.10

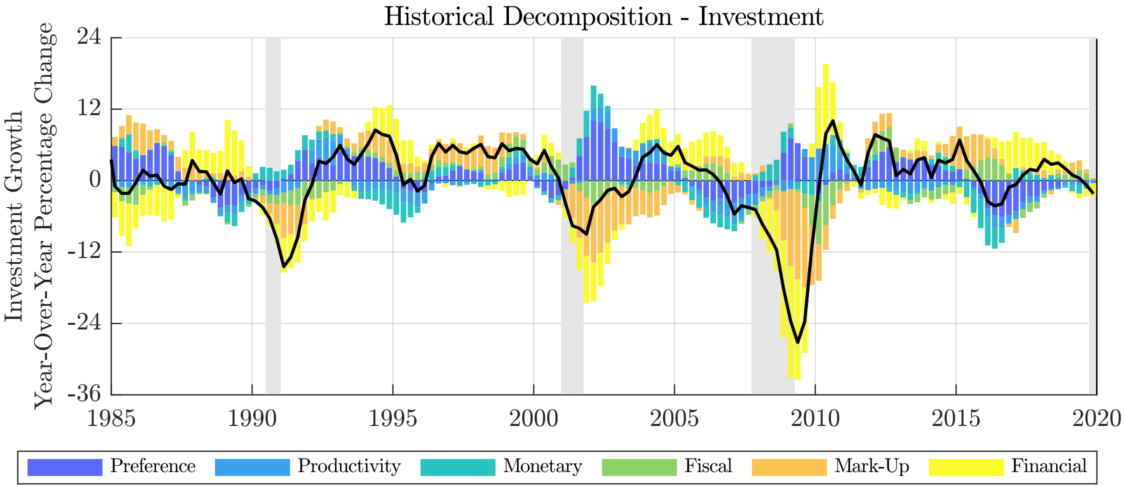
NOTE: This table displays the percent of the variance of the endogenous variables (rows) explained by the structural shocks in the model (columns) at business cycle frequency (HP-filtered variables with $\lambda = 1600$).

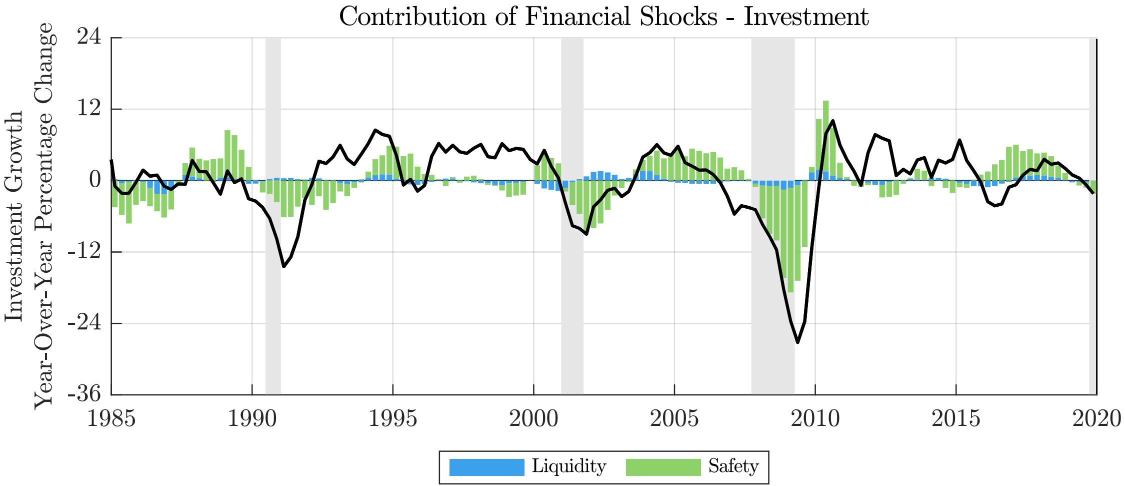
Preliminary results: Overview

- Unconditional variance decomposition of estimated model shows **important role for financial shocks** over the business cycle
- **Shocks to asset quality ($\epsilon_{\psi t}$) [safety] are key**, more so than shocks to asset resaleability ($\epsilon_{\omega t}$) [liquidity]
- **Shocks to supply of save assets (ϵ_{bt}) relevant for spreads**, but less important in explaining variation in real variables
- **Historical decomposition (next) confirms this** for key macro and financial variables over the sample from 1986 to 2019


Historical Decomposition - Output
Output Growth
Year-Over-Year Percentage Change
8
4
0
-4
-8
-12
1985
1990
1995
2000
2005
2010
2015
2020
Preference
Productivity
Monetary
Fiscal
Mark-Up
Financial


Contribution of Financial Shocks - Output
Output Growth
Year-Over-Year Percentage Change
8
4
0
-4
-8
-12
1985
1990
1995
2000
2005
2010
2015
2020
Liquidity
Safety


Historical Decomposition - Investment
Investment Growth
Year-Over-Year Percentage Change
24
12
0
-12
-24
-36
1985
1990
1995
2000
2005
2010
2015
2020
Preference
Productivity
Monetary
Fiscal
Mark-Up
Financial


Contribution of Financial Shocks - Investment
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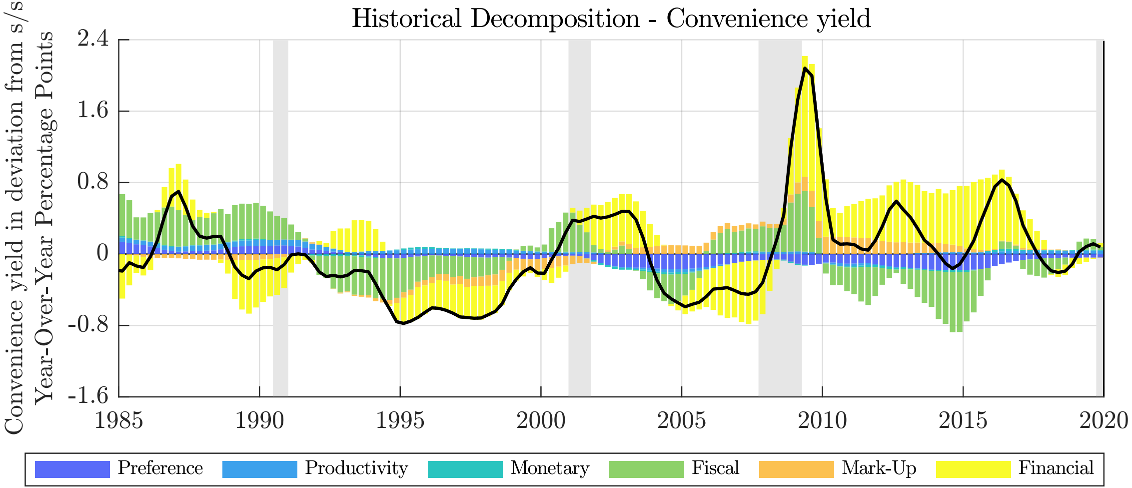
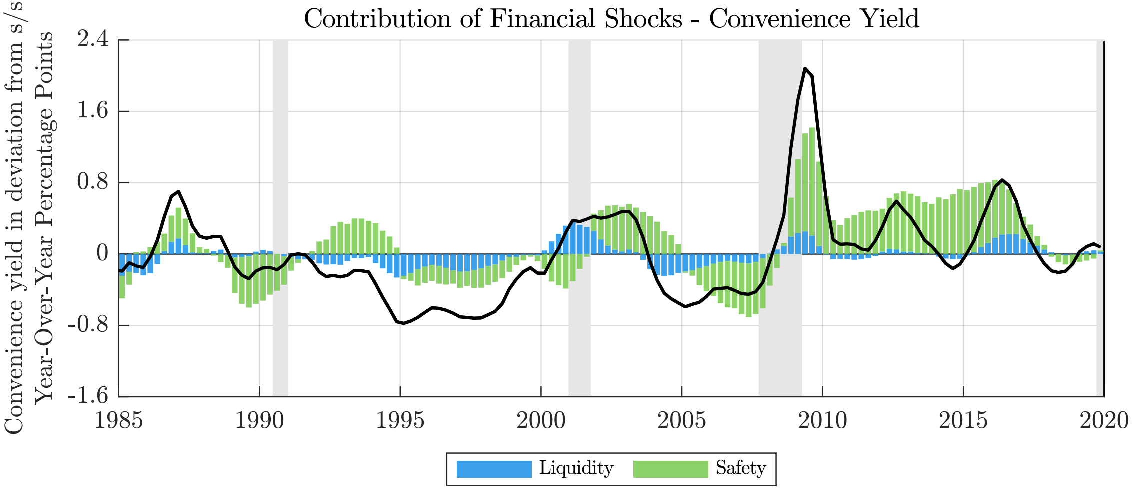

Historical Decomposition - Convenience yield
Convenience yield in deviation from s/s
Year-Over-Year Percentage Points
2.4
1.6
0.8
0
-0.8
-1.6
1985
1990
1995
2000
2005
2010
2015
2020
Preference
Productivity
Monetary
Fiscal
Mark-Up
Financial


Contribution of Financial Shocks - Convenience Yield
Convenience yield in deviation from s/s
Year-Over-Year Percentage Points
2.4
1.6
0.8
0
-0.8
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1985
1990
1995
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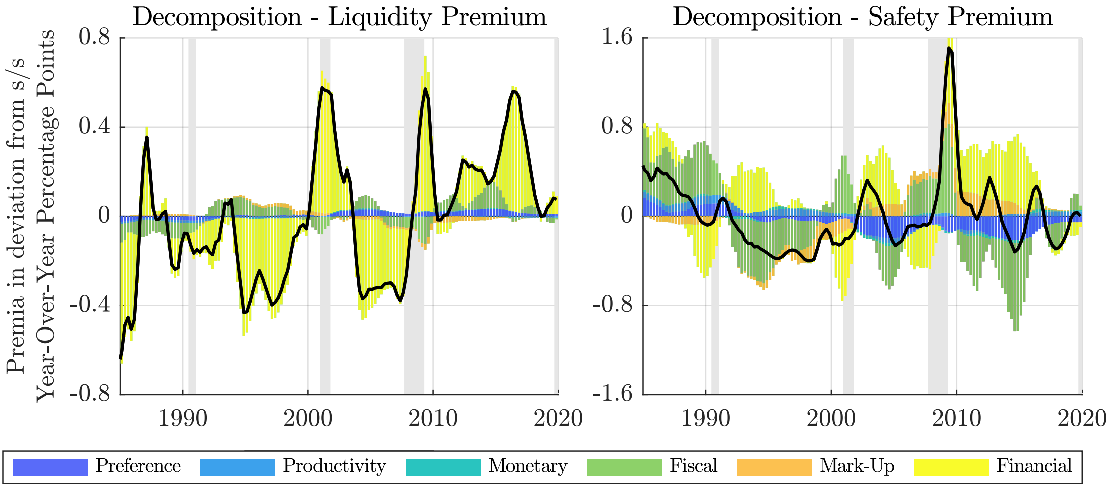
2005
2010
2015
2020
Liquidity
Safety


Decomposition - Liquidity Premium
Decomposition - Safety Premium
Premia in deviation from s/s
Year-Over-Year Percentage Points
0.8
0.4
0
-0.4
-0.8
1.6
0.8
0
-0.8
-1.6
1990
2000
2010
2020
Preference
Productivity
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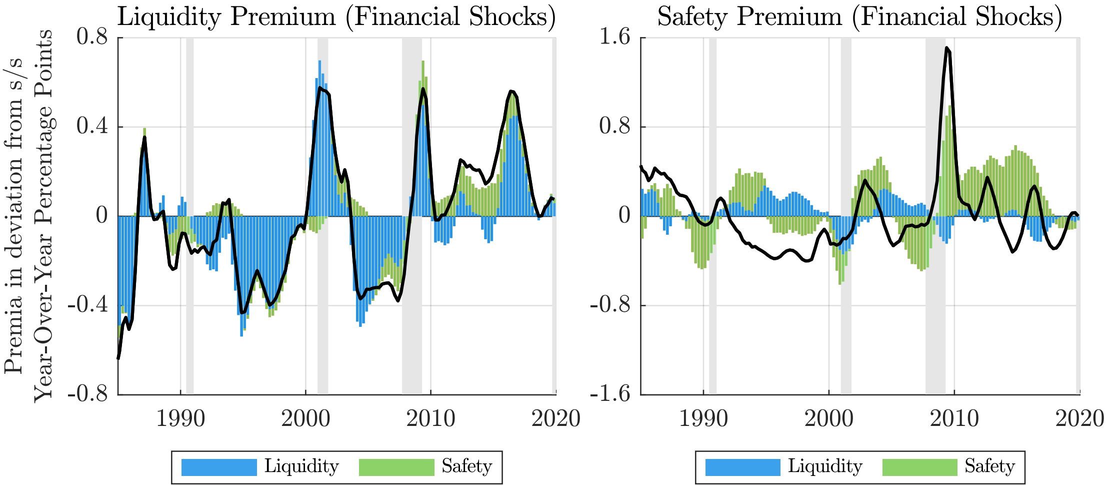
Liquidity Premium (Financial Shocks)
Safety Premium (Financial Shocks)
Premia in deviation from s/s
Year-Over-Year Percentage Points
0.8
0.4
0
-0.4
-0.8
1.6
0.8
0
-0.8
-1.6
1990
2000
2010
2020
Liquidity
Safety

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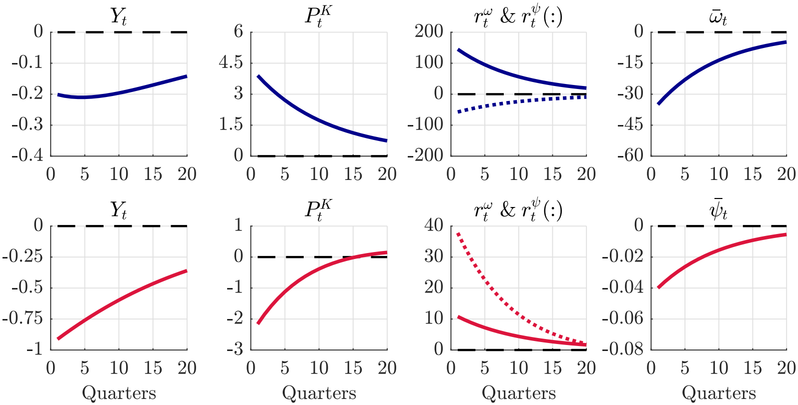
In more detail | A model without nominal rigidities



Note: Row 1 (blue) gives impulse responses for a shock to capital resaleability (liquidity), row 2 (red) displays impulse responses for a shock to capital quality (safety). Y_t is output, P_t^K is the price of capital, r_t^ω and r_t^ψ are liquidity and safety premia, respectively. $\bar{\omega}_t$, which is capital resaleability, and $\bar{\psi}_t$, which is the fraction of high-quality assets, display the respective exogenous disturbances. All impulse responses are given in % deviations from steady state.

The liquidity puzzle

Counterfactual asset price response: Models with a liquidity friction à la KM (2019) predict a stock market boom following an adverse financial shock.

- Shi (2015): Robust result; need a fall in the perceived quality of capital
- Ajello (2016): Nominal + real rigidities & shock to intermediation
- Guerron-Quintana and Jinnai (2019): Endogenous growth $\longrightarrow$ LR dividends $\downarrow$
- Kiyotaki and Moore (2019): Storage technology & CB liquidity injection

This paper: **Nominal rigidities & ZLB** (in the spirit of DEFK 2017)

In more detail | Intuition

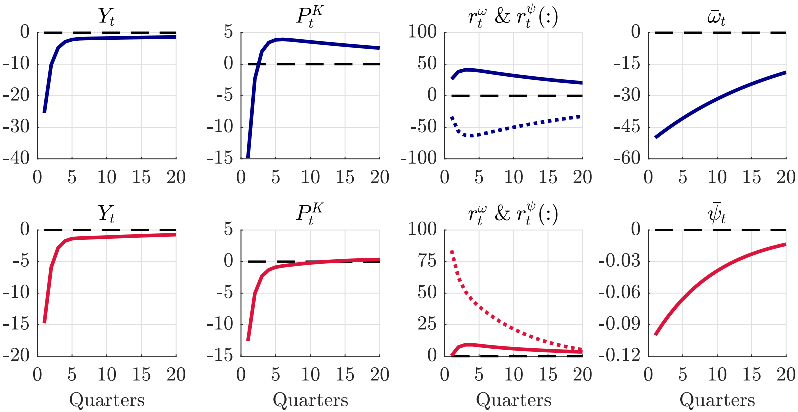
- At ZLB, $R_t = 1$ & $\mathbb{E}_t r_{t+1} \equiv (R_t / \mathbb{E}_t \Pi_{t+1}) \uparrow$. Via arbitrage, $\mathbb{E}_t r^*_{Kt+1} \uparrow$.

$$\mathbb{E}_t r^*_{Kt+1} \uparrow \equiv \frac{\mathbb{E}_t r_{Kt+1} + (1-\gamma)\, \mathbb{E}_t \bar{\psi}_{t+1} q_{t+1} \uparrow}{q_t \downarrow}$$

Note, however,

(i) $\mathbb{E}_t r^*_{Kt+1} - \mathbb{E}_t r_{t+1} \neq$ constant (but $\bar{\omega}_t \downarrow \rightarrow cy_t \uparrow$)
(ii) $\mathbb{E}_t r_{Kt+1} \neq$ constant (but slow-moving K_t and a_t pro-cyclical)
(iii) $q_t \neq p_{Kt}$ (but $p_{Kt} = \psi^*_t q_t$)

In more detail | A model with nominal rigidities & ZLB



Note: Row 1 (blue) gives impulse responses for a shock to capital resaleability (liquidity), row 2 (red) displays impulse responses for a shock to capital quality (safety). Y_t is output, P_t^K is the price of capital, r_t^ω and r_t^ψ are liquidity and safety premia, respectively. $\bar{\omega}_t$ - capital resaleability - and $\bar{\psi}_t$ - the fraction of high-quality assets - are the respective exogenous disturbances, **set to bring the model to the ZLB for 4 periods.** All impulse responses are given in % deviations from steady state. ▸ Calibration

I. Motivation

II. Model

III. Estimation & Results

IV. Liquidity puzzle

V. Next steps

This version

- Motivation [liquidity and safety over the business cycle]
- Model [medium-scale NK model w/ two financial frictions; insights]
- Estimation [data; historical decomposition; role of financial shocks]
- Liquidity puzzle [Nominal rigidities & ZLB]

Work in progress

- Estimation
  - data on public liquidity
- Crisis simulations & policy counterfactuals
  - impulse responses, forecast-errors, liquidity puzzle at ZLB
  - role of CB liquidity provision; March-2020 liquidity crunch; fiscal multipliers

Extra slides

Model: Households

- Consume, supply labor & own firms and retailers

The representative household maximizes

$$\mathbb{V}_t^H = \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \beta^s \left[\ln(c_{t+s} - \hbar c_{t+s-1}) - \frac{\chi}{1+\xi} \ell_{ht+s}^{1+\xi} \right] \right\}$$

subject to

$$P_t c_t + \int_{i \in [0,1]} V_{it} s_{it} \, di = W_{ht} \ell_{ht} + \int_{i \in [0,1]} (V_{it} + D_{it}) \, s_{it-1} \, di + \Omega_t - T_t,$$

◂ main part

Model: Labor unions

- Differentiate homogeneous labour & set wages on a staggered basis

$$\max_{\widetilde{W}_{lt}} \; \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \iota_w^s \mathcal{M}_{t+s} \left[(1-\tau_{wt+s}) \widetilde{W}_{lt} X_{t,t+s}^W - W_{ht+s} \right] \ell_{lt,t+s} \right\}$$

subject to

$$\ell_{lt,t+s} = \left(\frac{\widetilde{W}_{lt} X_{t,t+s}^W}{W_{t+s}} \right)^{-\theta_w} \ell_{t+s},$$

$$X_{t,t+s}^W = \begin{cases} \prod_{k=0}^{s-1} (\mu_{zt+k+1})^{\gamma_\mu} (\mu_z)^{1-\gamma_\mu} (\Pi_{t+k})^{\gamma_w} (\Pi_{t+k+1}^*)^{1-\gamma_w} & \text{if } s > 0 \\ 1 & \text{if } s = 0 \end{cases}$$

main part

Model: Investment goods firms

- Transform final goods into investment goods

The representative investment goods firm maximizes

$$\mathbb{V}_t^I = \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \mathcal{M}_{t+s} \left\{ P_{It+s} - \left[1 + f\left(\frac{i_{t+s}}{i_{t+s-1}} \right) \right] P_{t+s} \right\} i_{t+s} \right\}$$

where

$$f(x_t) \equiv \frac{1}{2} \left\{ \exp\left[\sqrt{f''} (x_t - x) \right] + \exp\left[-\sqrt{f''} (x_t - x) \right] - 2 \right\}$$

◂ main part

Model: Final goods firms

- Differentiate homogeneous goods & set prices on a staggered basis

$$\max_{\widetilde{P}_{jt}} \ \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \iota_p^s \mathcal{M}_{t+s} \left[(1 - \tau_{pt+s}) \widetilde{P}_{jt} X^P_{t,t+s} - P_{mt+s} \right] y_{jt,t+s} \right\}$$

subject to

$$y_{jt,t+s} = \left(\frac{\widetilde{P}_{jt} X^P_{t,t+s}}{P_{t+s}} \right)^{-\theta_p} y_{t+s},$$

$$X^P_{t,t+s} = \begin{cases} \prod_{k=0}^{s-1} (\Pi_{t+k})^{\gamma_p} (\Pi^*_{t+k+1})^{1-\gamma_p} & \text{if } s > 0 \\ 1 & \text{if } s = 0 \end{cases}$$

main part

Model: Monetary & fiscal policy

Interest rate policy, ZLB & government budget constraint

Monetary policy follows a standard Taylor Rule subject to the ZLB,

$$R_t = \max \left\{ R_{t-1}^{\rho_m} \left[R \left(\frac{\Pi_t}{\Pi_t^*} \right)^{\phi_\pi} \left(\frac{y_t / y_{t-1}}{\exp(\Gamma)} \right)^{\phi_y} \right]^{1-\rho_m} e^{\varepsilon_{mt}}, 1 \right\}$$

Govt spending & debt issuance are exogenous, the budget constraint is given by

$$B_{t+1} = R_t B_t + P_t g_t - T_t$$

◂ main part

Liquidity puzzle: Calibration of the simple model

main part

Parameter		Value	Parameter		Value
Households					
σ	Risk aversion	1.000	β	Discount factor	0.985
$\hbar$	Habit parameter	0.815	χ	Utility weight on labor	6.420
ξ	Inverse Frisch elasticity	0.500			
Producers					
α	Capital share	0.360	γ	Depreciation rate	0.022
ν	Inv efficiency: Pareto param	7.140	ϵ_{min}	Inv efficiency: Pareto bound	0.860
$\bar{\omega}$	SS capital resaleability (ff#1)	0.410	$\bar{\psi}$	SS capital quality (ff#2)	0.997
Retailers					
ζ	Elasticity of substitution	11.00	ι	Probability of fixed prices	0.750
Government					
ϕ_Π	Policy rule inflation response	1.500	ϕ_X	Policy rule output response	0.125
ρ	Policy rule inertia	0.000	G/Y	SS Govt expenditure/ GDP	0.200
B/Y	SS Govt debt/ GDP	0.560			