Macroeconomic and Financial Interactions in Chile: An Estimated DSGE Approach

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Disclaimer

The views and conclusions presented are exclusively those of the authors and do not necessarily reflect the position of the Central Bank of Chile or its Board members.

Motivation

- The 2008 crisis, its international propagation, and the actual situation in Europe have highlighted the importance of incorporating financial transmission channels into central bank policy models
- The prevailing framework before 2008 (the New Keynesian model) proved to be incomplete:
  - Did not include relevant macro-financial interactions
  - Not well suited to analyze "unconventional" policies
- In emerging countries, need to evaluate tools to complement the usual implementation of inflation targeting in the context of significant global capital flows

State of policy models at the Central Bank of Chile

- In the Bank's Macroeconomic Analysis Division, financial aspects have been incorporated "on-demand" in the usual DSGE toolkit, but in an ad-hoc way and with limited evaluation of their empirical relevance
- In the Financial Policy Division, macro-financial interactions have also been incorporated, but typically with a reduced-form representation of the macro side (e.g. Alfaro and Sagner, 2011)
- Missing macro-financial "consensus" model that could be used for monetary policy analysis and in forecasting process

Aim of this project

Develop a DSGE model to be added to the Bank's toolkit, with the following characteristics:

1. Incorporates financial transmission channels and financial variables in a coherent (i.e. micro-founded and structural) way
2. Performs well from an empirical point of view, both in normal times and in times of financial stress
3. Can complement the forecast usually made with an existing large-scale DSGE model (e.g. risk scenarios)
4. Can be used to analyze both normal-times monetary policy and "complementary" policies (e.g. reserve requirements and other macro-prudential tools)

Timeline

2013: Empiricial evaluation

- Empirical relevance of considering financial variables to explain macro data, both in normal times and during crises
- Understand relationship between macroeconomic and financial variables in the context of a small open economy
- Analyze propagation of shocks through financial markets and frictions

2014: Policy analysis

- Evaluate how financial transmission mechanisms affect the role of conventional monetary policy
- Analyze "complementary" policies and their interaction with normal-times policy
- Optimal monetary policy

Current output

1. Extend in several dimensions a standard New Keynesian model of a small open economy to incorporate different aspects of the financial system and financial frictions
2. Estimate those different versions of the model to assess how financial features contribute to explain both macro data (GDP, investment, inflation, the exchange rate, etc.) and financial variables (spreads, credit, etc.)

Outline

1. Conceptual view of financial frictions
2. Summary of the baseline model
3. Model with financial frictions I: Bank side
4. Model with financial frictions II: Firm side
5. Estimation results: Model fit, parameter estimates, variance decompositions, etc.
6. Next Steps

Conceptual view of financial frictions

- Different interest rates:
  - R^D, deposit rate
  - R^{LB}, rate at which banks are willing to lend risk-free (not observable)
  - R^L, lending rate paid by firms
- Model without financial frictions:

  $R^D = R^{LB} = R^L$, no wedges
- Pre-crisis literature on financial frictions (*financial accelerator*; Bernanke, Gertler & Gilchrist, 1999):

  $R^D = R^{LB} > R^L$, spread depends on firm leverage
- Post-crisis literature for the U.S. economy:

  $R^D < R^{LB} = R^L$, spread depends on bank leverage
- We attempt to characterize both types of wedges:

  $R^D < R^{LB} < R^L$

The baseline model

Fairly standard New Keynesian model of a small open economy:[1]

- Consumption of home goods and imported goods
- Staggered price-setting à la Calvo with indexation both for domestic producers and importers (i.e. delayed pass-through)
- Sticky wages à la Calvo with indexation
- Labor-augmenting productivity growth
- Commodity sector (endowment, exogenous world price)
- Habits in consumption, investment adjustment costs
- Elastic country premium
- Taylor rule (smoothing, inflation and GDP growth)
- Exogenous government expenditure (Ricardian equivalence)

[1] Simplified version of the models of Medina & Soto (2007), Medina, Munro & Soto (2007). Similar to Adolfson, Laséen, Lindé & Villani (2007) model.

Banks à la Gertler & Karadi

- Gertler & Karadi (2011) framework, relatively popular in recent macro literature[2] for the analysis of "unconventional" monetary policies
- Banks intermediate deposits D_t and lend to firms ("entrepreneurs") for capital accumulation, loans are: $L_t = \alpha_L^K q_t K_t$
- Balance sheet is $L_t = D_t + N_t$, net worth N_t accumulates as:

$$N_{t+1} = r_{t+1}^L L_t - r_{t+1}^D D_t$$

- Bankers have finite lifetimes with survival rate ω and maximize expected terminal wealth:

$$V_t = E_t \sum_{s=0}^{\infty} (1-\omega)\omega^s \Xi_{t,t+s+1} N_{t+s+1} = \varrho_t^L L_t + \varrho_t^N N_t$$

[2] See, for instance, Gertler & Kiyotaki (2011), Gertler & Karadi (2013), Dedola, Karadi & Lombardo (2013), Kirchner & van Wijnbergen (2012), Rannenberg (2012), Villa (2013), Villa & Yang (2013), Areosa & Coelho (2013).

Banks à la Gertler & Karadi

- Moral hazard problem: Intermediaries can steal a fraction μ_t (exogenous, "bank risk") of assets and go bankrupt. Banks maximize terminal wealth subject to the incentive constraint: $V_t \geq \mu_t L_t$
- Solution to this problem implies that loans are tied to bank capital:
$$L_t = lev_t N_t, \qquad lev_t = \varrho_t^N / (\mu_t - \varrho_t^L)$$
where ϱ_t^L increases with flow of spreads $E_t[r_{t+s}^L - r_{t+s}^D]$, changes in bank leverage affect spreads, hence matter for equilibrium outcomes
- Evolution of aggregate net worth:
$$N_t = \omega(r_t^L L_{t-1} - r_t^D D_{t-1}) + \iota N$$

Banks à la Gertler & Karadi

- Parameters:
  - μ: steady state value of μ_t
  - ω: survival rate of existing banks
  - ι: capital injection for new banks
  - α_L^K: fraction loans/capital stock
- Calibration:
  - $\iota = 0.002$ (taking Gertler & Karadi, 2011).
  - $\alpha_L^K = 0.51$ (consistent with firm leverage in BGG model later on).
  - ω and ι chosen to match spread of 380 annual basis points (90 days bank lending rate vs. monetary policy rate), and average leverage ratio of 9 (bank credit/basic bank capital).

GK banks with BGG financial accelerator

- Entrepreneurs are heterogeneous: if they buy K_t units of capital in t, they have $\omega_{t+1}^e K_t$ units in $t+1$
- $\omega_t^e > 0$ has a distribution $F(\omega_t^e; \sigma_{\omega,t})$ with $E(\omega_t^e) = 1$, where $\sigma_{\omega,t}$ is an exogenous variable describing the dispersion of the distribution (representing "firm risk")
- Entrepreneurs' balance sheet: $q_t K_t = L_t + N_t^e$
- Asymmetric information: ω_t^e is only observed by entrepreneurs ex-post after buying capital, while third parties have to pay a monitoring cost to learn about ω_t^e

GK banks with BGG financial accelerator

- The optimal debt contract specifies an interest rate on the loan through a cut-off value $\bar{\omega}^e_{t+1}$ such that:
  - Entrepreneurs with low realizations of productivity default, the bank pays the monitoring cost and seizes the defaulting entrepreneurs' assets
  - Entrepreneurs with sufficiently high productivity ($\leq \bar{\omega}^e_{t+1}$) pay the established interest rate and keep the difference

- The banks require that the return on the loan (r^L_{t+1}) is:

$$L_t r^L_{t+1} \leq g(\bar{\omega}^e_{t+1}; \sigma_{\omega,t+1})[r^K_{t+1} + (1-\delta)q_{t+1}]K_t$$

where $g(\bar{\omega}^e_{t+1}; \sigma_{\omega,t+1})$ represents the fraction of total income generated by the investment that the bank can obtain given the distribution of entrepreneurs

GK banks with BGG financial accelerator

- The optimal debt contract is calculated maximizing the expected return to entrepreneurs, subject to the banks' participation constraint
- In equilibrium, there is a difference between the expected return of capital and the expected return to banks, which is an increasing function of the entrepreneurs' leverage ("external finance premium")
- Evolution of entrepreneurial net worth:

$$N_t^e = \upsilon \left\{ [r_t^K + (1-\delta) q_t] K_{t-1} h(\bar{\omega}_t^e ; \sigma_{\omega,t}) \right\} + \iota^e N^e$$

GK banks with BGG financial accelerator

- Parameters:
  - σ_ω: steady state value of $\sigma_{\omega,t}$.
  - υ: survival rate of existing entrepreneurs
  - ι^e: capital injection for new entrepreneurs
  - μ^e: monitoring cost
- Calibration:
  - $\mu^e = 0.12$ and $\upsilon = 0.97$ (BGG, Christiano, Motto & Rostagno, 2013)
  - σ_ω and ι^e such that the steady state leverage ratio of entrepreneurs is 2.05 (from consolidated data of Chilean financial supervisory authority) and the steady state premium is 120 annual basis points (average of A vs. AAA and BBB vs. AAA spreads)

Bayesian estimation

- Macro data: Growth rates of real GDP, private consumption, investment, real wages, government consumption, copper production, inflation, monetary policy rate, real exchange rate, Libor, EMBI Chile, foreign inflation, commercial partners' GDP, real copper price
- Financial data:
  - Growth rate of real bank credit
  - Spread 90 days bank lending rate vs. monetary policy rate
- Alternative combinations of shocks: u_t (investment shock), μ_t, $\sigma_{\omega,t}$

▸ Shocks ▸ Data

Model comparison

Marginal Model Likelihoods.

Model	Shocks	Data	Log MgL Estim. Data	Log MgL Macro Data
Baseline	u_t	Macro	-952.1	-952.1
GK	u_t	+ Spread, Lending	-1330.6	-1022.3
GK	μ_t	+ Spread, Lending	-1302.9	-1043.9
GK	u_t, μ_t	+ Spread, Lending	-1160.2	-1004.5
GK-BGG	u_t	+ Spread, Lending	-1330.6	-1025.7
GK-BGG	μ_t, $\sigma_{\omega,t}$	+ Spread, Lending	-1158.2	-1009.3
GK-BGG	u_t, μ_t, $\sigma_{\omega,t}$	+ Spread, Lending	-1147.6	-998.2
GK-BGG	u_t, μ_t	+ Spread, Lending	-1156.1	-996.0
GK-BGG	u_t, $\sigma_{\omega,t}$	+ Spread, Lending	-1146.3	-997.8

Note: These are Laplace approximations computed at the posterior mode.

Parameter estimates

Some Estimated Parameters.

Model	Shocks	Data	γ	ρ_u	σ_u	ρ_{σ_ω}	σ_{σ_ω}
Baseline	u_t	Macro	1.98	0.74	0.03		
GK	u_t, μ_t	+ Spr., Lend.	0.29	0.99	0.01		
GK-BGG	μ_t, $\sigma_{\omega,t}$	+ Spr., Lend.	0.55			0.29	1.24
GK-BGG	u_t, μ_t, $\sigma_{\omega,t}$	+ Spr., Lend.	10.05	0.17	0.31	0.80	0.07

Note: These are posterior mode estimates.

IRFs

Selected second moments

Standard Deviations: Data vs. Different Models.

Variable	Data	Baseline u_t Macro	GK u_t, μ_t + Spr., Lend.	GK-BGG μ_t, $\sigma_{\omega,t}$ + Spr., Lend.	GK-BGG u_t, μ_t, $\sigma_{\omega,t}$ + Spr., Lend.
ΔGDP	1.02	0.91	1.59	1.35	0.82
ΔC	1.10	0.92	1.07	1.01	1.05
ΔI	3.75	3.91	9.17	9.70	3.26
Infl.	0.74	0.58	0.63	0.64	0.63
MP Rate	0.46	0.48	0.66	0.61	0.62
RER	5.41	9.13	12.20	10.11	9.99
TB/GDP	5.32	3.64	3.80	3.72	3.65
ΔW	0.62	0.55	0.58	0.57	0.59
Spread	0.26		2.00	2.57	0.44
ΔL	1.41		3.85	2.48	1.45

Note: These are unconditional moments computed at the posterior mode.

Selected second moments

First-Order Autocorrelations: Data vs. Different Models.

Variable	Data	Baseline u_t Macro	GK u_t, μ_t + Spr., Lend.	GK-BGG μ_t, $\sigma_{\omega,t}$ + Spr., Lend.	GK-BGG u_t, μ_t, $\sigma_{\omega,t}$ + Spr., Lend.
ΔGDP	0.25	0.31	0.24	0.29	0.19
ΔC	0.63	0.59	0.62	0.66	0.63
ΔI	0.40	0.65	0.24	0.37	0.21
Infl.	0.63	0.66	0.70	0.70	0.73
MP Rate	0.88	0.92	0.93	0.94	0.94
RER	0.73	0.91	0.94	0.93	0.92
TB/GDP	0.73	0.91	0.90	0.91	0.91
ΔW	0.40	0.43	0.45	0.44	0.45
Spread	0.68		0.41	0.54	0.78
ΔL	0.56		-0.25	0.00	0.29

Note: These are unconditional moments computed at the posterior mode.

Variance decomposition

Variance Decomposition: Baseline vs. GK-BGG Model.

Variable	Shock								
	Pref.	Inv.	TFP (x2)	MP Rate	Fore. Rate	P. Co.	μ_t	$\sigma_{\omega,t}$	Sum
				A. Baseline					
ΔGDP	4	28	28	6	3	3			73
ΔC	58	2	5	1	5	21			92
ΔI	1	60	8	3	11	10			92
Infl.	3	19	46	11	6	8			93
MP Rate	3	24	14	11	12	25			89
RER	0	7	3	3	17	46			75
TB/GDP	1	6	1	1	17	49			75
ΔW	0	7	67	3	5	11			93
				B. GK-BGG, u_t, μ_t, $\sigma_{\omega,t}$					
ΔGDP	10	29	28	3	1	1	0	0	71
ΔC	43	2	7	1	11	25	0	0	89
ΔI	0	86	2	1	3	4	0	1	98
Infl.	6	3	55	6	12	10	0	0	92
MP Rate	8	5	20	9	21	23	0	0	87
RER	1	3	4	2	18	49	0	0	76
TB/GDP	2	2	1	0	13	60	0	0	78
ΔW	1	1	78	1	5	8	0	0	95
Spread	2	36	2	5	3	5	4	41	98
ΔL	1	73	15	4	2	2	0	1	98

Note: These are unconditional variance decompositions at the posterior mode.

Summary of estimation results

- GK-BGG is preferred to GK in terms of empirical fit; however, in both cases, the incorporation of financial variables reduces the capacity of the baseline NK-SOE model to explain Chilean macro data
- The models in their current form seem to have particular difficulties in explaining bank loans in the data
- Financial frictions affect the role of investment-specific shocks and adjustment costs (cf. Carlstrom & Fuerst, 1997; Justiniano, Primiceri & Tambalotti, 2011)

Next steps

- Modifications of current framework:
  - Additional observables for the entrepreneurs' problem: measures of firm spread, firm leverage
  - Add working capital loans to GK, GK-BGG
  - Foreign deposits on bank balance sheets
  - Model with BGG only
- Alternative models:
  - Strategic default by firms (Dubey, Geanakoplos & Shubik, 2005; Goodhart, Sunirand & Tsomocos, 2006)
  - Small and large firms as a way to understand capital inflows and outflows (Caballero, 2002)

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Appendix

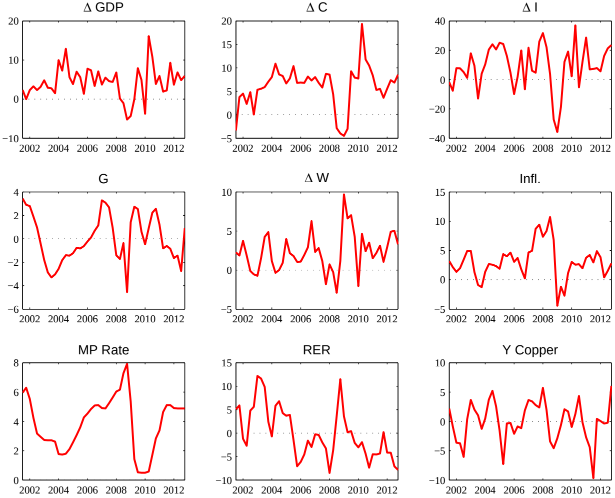
List of shocks

- Preferences: $E_t \sum_{s=0}^{\infty} \beta^s v_{t+s}[\log(C_{t+s} - \varsigma C_{t+s-1}) - \kappa h_{t+s}^{1+\phi}/(1+\phi)]$
- Investment-specific: $K_t = (1-\delta)K_{t-1} + [1 - \Gamma(I_t/I_{t-1})]u_t I_t$
- Productivity (permanent and transitory): $Y_t = z_t K_{t-1}^{\alpha}(A_t h_t)^{1-\alpha}$
- Monetary policy rate (i.i.d.)
- Commodity production
- Government expenditure
- External shocks:
  - Foreign interest rate
  - Country premium
  - Foreign inflation
  - Commercial partners' GDP
  - Commodity price
- Financial shocks:
  - "Bank risk" (μ_t)
  - "Firm risk" ($\sigma_{\omega,t}$)

Return

Data

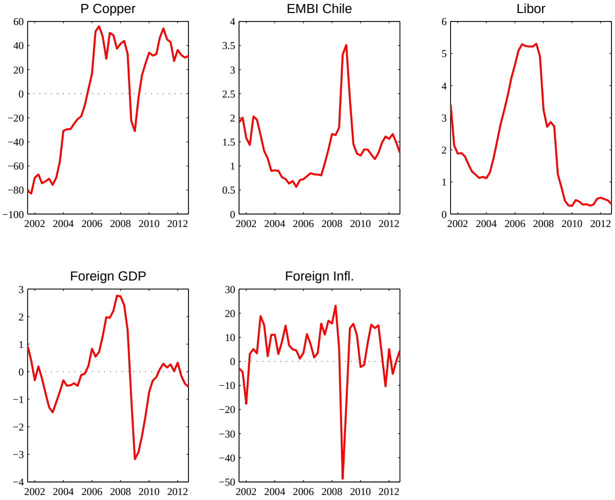
Domestic Macroeconomic Variables.



Note: Annualized quarterly rates for ΔGDP, ΔC, ΔI, ΔW, Infl., MP Rate;
Δ from mean/trend for RER, G, Y Copper.

Return

Foreign Exogenous Variables.

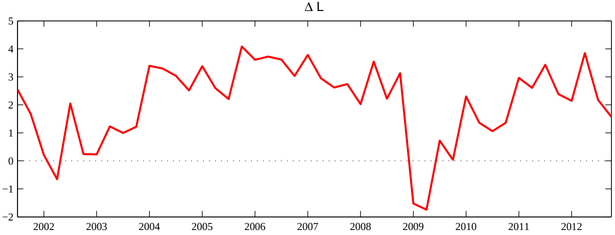


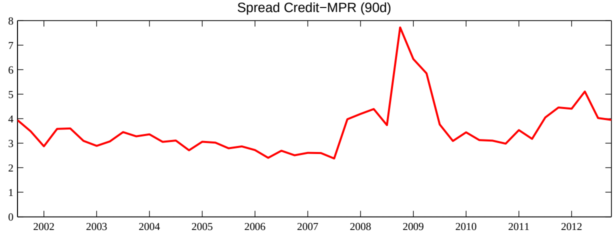
Note: Δ from mean/trend for *P* Copper, Foreign *GDP*; annualized quarterly rates for EMBI Chile, Libor, Foreign Infl.

Return

Data

Domestic Financial Variables.

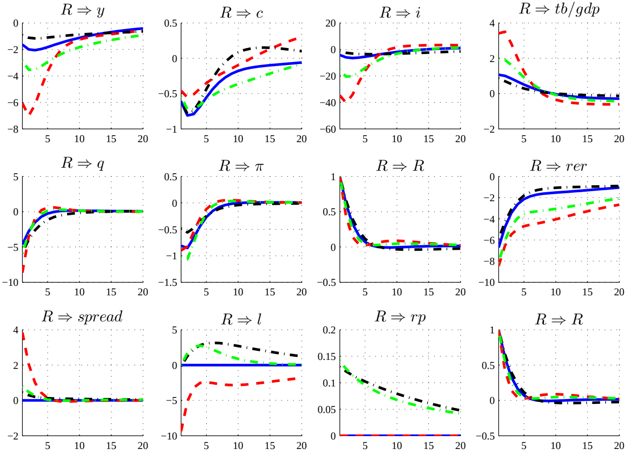




Note: Annualized quarterly rates.

Return

Impulse Responses to a Monetary Policy Rate Shock.

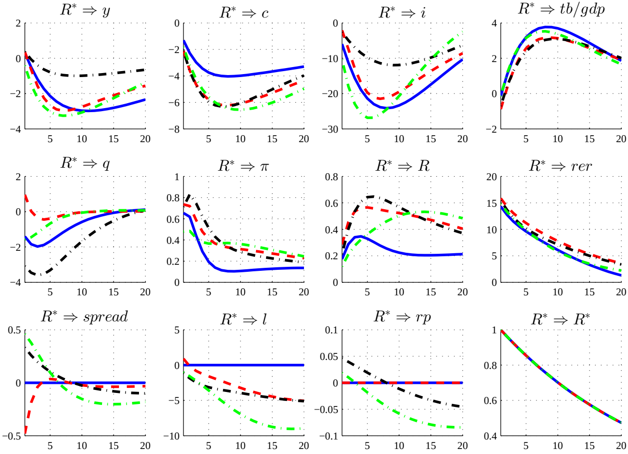


Note: blue-solid, baseline; dashed-red, GK; dash-dotted green, GK-BGG with μ_t and $\sigma_{\omega,t}$; dash-dotted black, GK-BGG with u_t, μ_t and $\sigma_{\omega,t}$.

◂ Return

IRFs

Impulse Responses to a Foreign Interest Rate Shock.

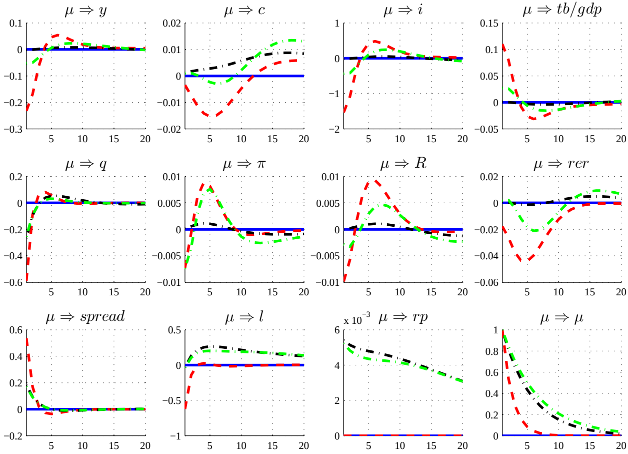


Note: blue-solid, baseline; dashed-red, GK; dash-dotted green, GK-BGG with μ_t and $\sigma_{\omega,t}$; dash-dotted black, GK-BGG with u_t, μ_t and $\sigma_{\omega,t}$.

Return

IRFs

Impulse Responses to a Shock to μ_t.

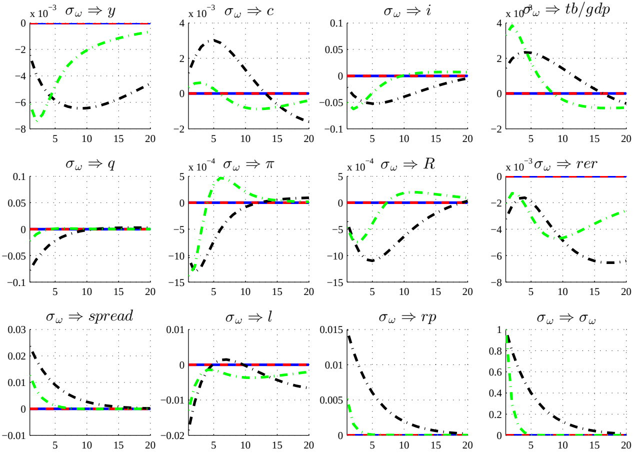


Note: blue-solid, baseline; dashed-red, GK; dash-dotted green, GK-BGG with μ_t and $\sigma_{\omega,t}$; dash-dotted black, GK-BGG with u_t, μ_t and $\sigma_{\omega,t}$.

Return

IRFs

Impulse Responses to a Shock to $\sigma_{\omega,t}$.

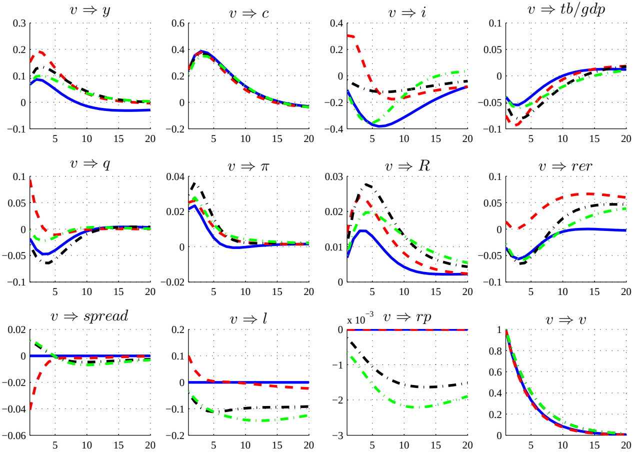


Note: blue-solid, baseline; dashed-red, GK; dash-dotted green, GK-BGG with μ_t and $\sigma_{\omega,t}$; dash-dotted black, GK-BGG with u_t, μ_t and $\sigma_{\omega,t}$.

Return

IRFs

Impulse Responses to a Preference Shock.

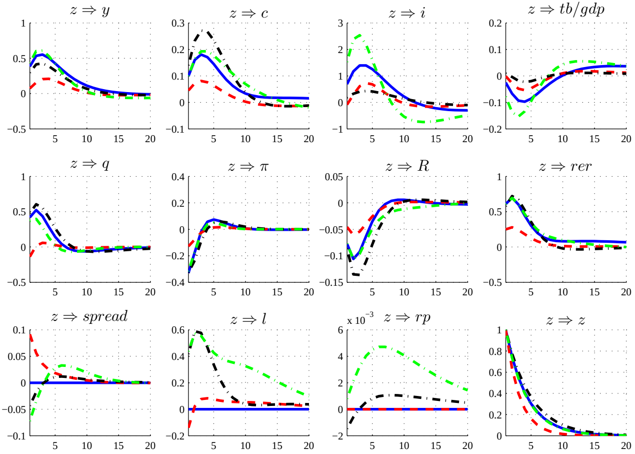


Note: blue-solid, baseline; dashed-red, GK; dash-dotted green, GK-BGG with μ_t and $\sigma_{\omega,t}$; dash-dotted black, GK-BGG with u_t, μ_t and $\sigma_{\omega,t}$.

Return

IRFs

Impulse Responses to a Temporary TFP Shock.

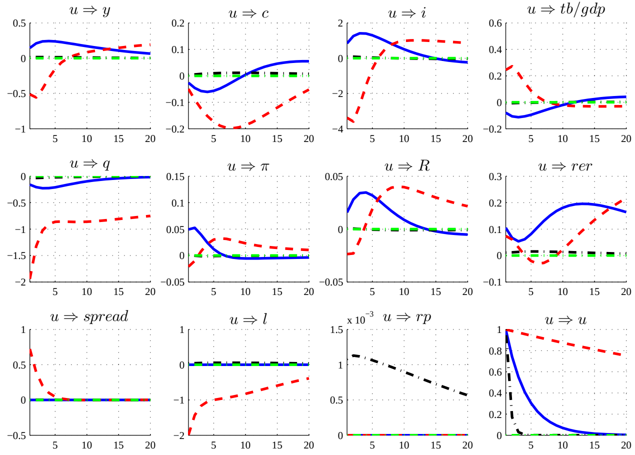


Note: blue-solid, baseline; dashed-red, GK; dash-dotted green, GK-BGG with μ_t and $\sigma_{\omega,t}$; dash-dotted black, GK-BGG with u_t, μ_t and $\sigma_{\omega,t}$.

Return

IRFs

Impulse Responses to a Marginal Efficiency of Investment Shock.

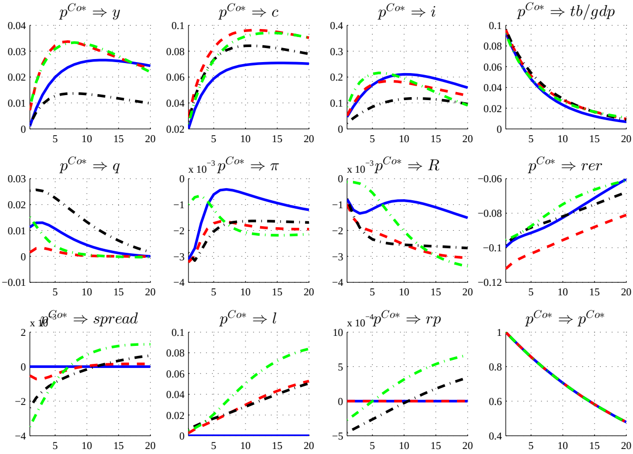


Note: blue-solid, baseline; dashed-red, GK; dash-dotted green, GK-BGG with μ_t and $\sigma_{\omega,t}$; dash-dotted black, GK-BGG with u_t, μ_t and $\sigma_{\omega,t}$.

Return

IRFs

Impulse Responses to a Commodity Price Shock.



Note: blue-solid, baseline; dashed-red, GK; dash-dotted green, GK-BGG with μ_t and $\sigma_{\omega,t}$; dash-dotted black, GK-BGG with u_t, μ_t and $\sigma_{\omega,t}$.

◂ Return