Macroeconomic and Financial Dynamics in Small Open Economies

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

Motivation

- Recent research on the role of financial frictions in DSGE models has focused on closed economy models for large countries.
- But not obvious that popular frictions from those models also "work" for small open economies (SOEs):
  - Which frictions can explain macro-financial data in a SOE context?
  - How do different frictions interact with typical SOE variables such as the exchange rate and the trade balance?
  - How are shocks of domestic and foreign origin propagated by frictions?
- Important empirical issue to be addressed before using DSGE models with financial frictions for regular analysis.

This paper

- Goal: To develop a model able to explain the dynamics of both macro variables (Y, C, I, inflation, policy rate, RER, TB, etc.) and financial variables (credit, spreads, etc.) in a SOE such as Chile.
- What we do:
  - Introduce two financial frictions into standard SOE-DSGE model:
    - Between depositors and banks (following GK, 2011).
    - Between banks and borrowers (following BGG, 1999).
  - Estimate versions of the model w/ and w/out frictions on Chilean macro-financial data following a Bayesian approach.
  - Evaluate the frictions based on the estimated models, comparing:
    - Frictionless baseline model with exogenous "wedges" to account for observed interest rate spreads.
    - Extended models with financial frictions: GK, BGG, GK+BGG; and BGG, GK+BGG with risk shocks (following CMR, 2014).

Main findings

- The analyzed financial frictions can be useful to explain observed macro-financial fluctuations in Chile.
- Of the two frictions, the one between banks and borrowers (i.e., BGG or GK+BGG) seems relatively more important.
  - Introducing GK frictions only tends to make the model less consistent with the data, due to worse fit of financial variables.
  - BGG frictions improve the overall fit through financial variables, although they tend to worsen the fit of macro variables.
  - Introducing GK+BGG frictions can improve the fit of financial variables without losing much fit of macro variables.
  - CMR risk shocks further improve fit of BGG and GK+BGG models.
- Foreign shocks play a relatively larger role with financial frictions.

Contributions to the literature

- Combining GK+BGG+CMR in SOE model, estimation.
  - See also Rannenberg (2013), Villa and Yang (2011), Villa (2013).
- Horse race with different types of financial frictions.
- Emphasis on domestic financial frictions.
  - See also Céspedes, Chang and Velasco (2004), Devereux, Lane and Xu (2006), Gertler, Gilchrist and Natalucci (2007), Fernández and Gulan (2012).

Rest of the presentation

- Model.
- Results.
  - Model comparison and goodness-of-fit analysis.
- Conclusions.

Baseline model

- SOE version of medium-scale New Keynesian model.
  - Consumption of H and F goods, all traded.
  - Calvo P and W stickiness w/ partial indexation.
  - Local currency pricing (i.e., delayed pass-through).
  - Habits in C, adjustment costs in I, variable K utilization.
  - Working capital constraint for firms.
  - Commodity sector (endowment, exogenous world price).
  - Elastic country premium (only HH access international markets).
  - Taylor rule (smoothing, inflation and Y growth).
  - Exogenous G expenditure (Ricardian equivalence holds).
- Exogenous driving forces:
  - Foreign: R^*, π^*, y^*, $p^{Co,*}$; Domestic: Preferences (v), TFPs (z, a), inv. (ϖ), gov. expenditures (g), commodity endowment (y^{Co}), country premium and UIP ($\zeta^i, i = 1, 2$); Monetary policy rate (ε_R).
  - Financial shocks (later).

Frictions between depositors and banks à la GK

- Banks intermediate deposits D_t and lend to firms and entrepreneurs: $L_t \equiv L_t^{WC} + L_t^K = D_t + N_t$. Wealth in $t+1$:

$$N_{t+1} = R_t^{L,WC} L_t^{WC} + R_{t+1}^{L,K} L_t^K - R_t D_t.$$

- Banks have finite lifetimes with survival rate ω and maximize expected terminal wealth (V_t).

- Moral hazard problem: bankers can steal fraction μ_t (exogenous and stochastic) of assets and go bankrupt. Incentive constraint $V_t \geq \mu_t L_t$.

Frictions between depositors and banks à la GK

- Banks' problem can be written as:

$$\max_{L_t^{WC}, L_t^K} V_t = \varrho_t^{L,WC} L_t^{WC} + \varrho_t^{L,K} L_t^K + \varrho_t^N N_t \quad \text{s.t.} \quad V_t \geq \mu_t (L_t^{WC} + L_t^K) \quad \forall t.$$

- Solution implies:
  - $\varrho_t^{L,K} = \varrho_t^{L,WC} \equiv \varrho_t^L$, which are increasing in expected flow of spreads $E_t[R_{t+1+s}^{L,K} - R_{t+s}]$ and $E_t[R_{t+s}^{L,WC} - R_{t+s}]$.
    - There is a relationship between $E_t[R_{t+1}^{L,K}]$ and $R_t^{L,WC}$.
  - Loans are tied to bank capital:

$$L_t^{WC} + L_t^K = lev_t N_t, \qquad lev_t \equiv \varrho_t^N / (\mu_t - \varrho_t^L).$$

    - Changes in bank leverage affect spreads (c.p., $lev_t \uparrow$, $\varrho_t^L \uparrow$, spreads $\uparrow$).
    - Role for banking shock μ_t.

Frictions between banks and borrowers à la BGG

- Entrepreneurs' balance sheet: $Q_t K_t = L_t^K + N_t^e$.
- Entrepreneurs have heterogeneous technology: if they buy K_t units of capital in t they obtain $\omega_{t+1}^e R_{t+1}^K K_t$ in $t+1$, where
  - ω_t^e has a distribution $F(\omega_t^e; \sigma_{\omega,t-1})$ with $E(\omega_t^e) = 1$ and $\sigma_{\omega,t}$ describes cross-sectional dispersion (risk shock; CMR, 2014).
  - R_{t+1}^K is the aggregate return on capital.
- Asymmetric information and costly-state-verification problem: banks observe ω_t^e ex-post against a monitoring cost.

Frictions between banks and borrowers à la BGG

- The optimal debt contract specifies an interest rate on the loan $R_t^{L,e}$ through a cut-off $\bar{\omega}_{t+1}^e$ such that:
  - Entrepreneurs with $\omega_{t+1} < \bar{\omega}_{t+1}^e$ default, the bank pays the monitoring cost and seizes the defaulting entrepreneurs' assets.
  - Entrepreneurs with $\omega_{t+1} \geq \bar{\omega}_{t+1}^e$ pay the established interest rate $(R_t^{L,e} L_t^K \leq \bar{\omega}_{t+1}^e R_{t+1}^K K_t)$ and keep the difference.
- The optimal debt contract is calculated by maximizing over lev_t^e, $\bar{\omega}_{t+1}^e$ and $R_t^{L,e}$ the expected return to entrepreneurs, subject to $L_t^K R_{t+1}^{L,K} \leq g(\bar{\omega}_{t+1}^e; \sigma_{\omega,t}) R_{t+1}^K K_t$, where $g(\bar{\omega}_{t+1}^e; \sigma_{\omega,t})$ is the income that the bank can obtain given the distribution of entrepreneurs.
- Solution implies external finance premium $efp_t = E_t\{R_{t+1}^K\}/E_t\{R_{t+1}^{L,K}\}$ that is an increasing function of entrepreneurs' leverage.

Financial shocks and observables

- In the full model there are two shocks:
  - Bank leverage: μ_t (fraction of assets that can be stolen).
  - Risk shock: $\sigma_{\omega,t}$ (variance of entrepreneurs' idiosyncratic productivity).
- CMR news shocks:

$$\log(\sigma_{\omega,t}/\bar{\sigma}_\omega) = \rho_{\sigma_\omega} \log(\sigma_{\omega,t-1}/\bar{\sigma}_\omega) + \varepsilon_t^{\sigma_\omega},$$

$$\varepsilon_t^{\sigma_\omega} = \tau_{0,t} + \tau_{1,t-1} + \cdots + \tau_{p,t-p}.$$

  - In period t agents observe $\tau_{j,t}$ for $j = 0, ..., p$, so $\tau_{0,t}$ is a surprise shock, while $\tau_{j,t}$ for $j > 0$ are the news shocks, with variances $E\{\tau_{0,t}^2\} = \sigma_{\sigma_\omega}^2$ and $E\{\tau_{j,t}^2\} = \sigma_{\sigma_\omega,n}^2$ for $j > 0$.
  - Furthermore, $\tau_{i,t}$ and $\tau_{j,t}$ are correlated with coefficients $\rho_{\sigma_\omega,n}^{|i-j|}$.
  - Overall, 4 parameters $(\rho_{\sigma_\omega}, \sigma_{\sigma_\omega}, \rho_{\sigma_\omega,n}, \sigma_{\sigma_\omega,n})$. We set $p = 4$.
- Observables: total credit L_t, stock market index N_t^e, bank spread $spr_t \equiv [R_t^{L,WC}(L_t^{WC}/L_t) + R_t^{L,e}(L_t^K/L_t)]/R_t$ and efp_t.

Alternative models with exogenous spreads

- Baseline:

$$R_t^{L,WC} = R_t^{L,e} = spr_t^{exo} R_t, \quad E_t\{R_{t+1}^K\} = efp_t^{exo} R_t^{L,e},$$

$$L_t^K = \alpha_L^K Q_t K_t, \quad N_t^e = Q_t K_t - L_t^K,$$

where spr_t^{exo} and efp_t^{exo} are exogenous AR(1) processes.

- GK:

$$spr_t = \frac{R_t^{L,WC}(L_t^{WC}/L_t) + E_t\{R_{t+1}^{L,K}\}(L_t^K/L_t)}{R_t},$$

$$E_t\{R_{t+1}^K\} = efp_t^{exo} E_t\{R_{t+1}^{L,K}\}, \quad L_t^K = \alpha_L^K Q_t K_t, \quad N_t^e = Q_t K_t - L_t^K,$$

where $R_t^{L,WC}$ and $E_t\{R_{t+1}^{L,K}\}$ are determined by the banks' problem.

- BGG:

$$R_{t+1}^{L,K} = R_t^{L,WC} = spr_t^{exo} R_t.$$

Parametrization strategy

- Several parameters are calibrated to match steady state values.
- Remaining parameters are estimated using a Bayesian approach.
  - Macro data (2001Q3-2012Q4):
    - Growth rates of real GDP, private and government consumption, investment; trade balance.
    - Real wage growth.
    - Mining GDP and real international copper price.
    - Inflation (CPI).
    - Monetary policy rate.
    - Real effective exchange rate.
    - Short-term Libor.
    - EMBI Chile.
    - Commercial partners' GDP and inflation (trade-weighted).
  - Financial data:
    - Growth rate of real bank credit.
    - Growth rate of stock market index IPSA (deflated).
    - Bank spread: 90 days bank lending rate vs. m.p.r.
    - External finance premium: A vs. AAA.

Bayesian model comparison

Log Marginal Data Densities.

Dataset	Base	GK	BGG	BGG+ CMR	GK+ BGG	GK+ BGG+ CMR
Estimation	-1498	-1537	-1451	-1431	-1507	-1467
Macro	-629	-631	-710	-704	-644	-651
Financial	-386	-475	-330	-325	-366	-353

Note: Throughout, blue/red marks best-/worst-fitting models. Macro data: ΔGDP, ΔC, ΔI, TB/GDP, R, π, ΔW, RER. Financial data: ΔL, ΔN^e, spr, efp. Estimation dataset: Macro+Financial+EMBI Chile+Exo.Obs. All marginal data densities were computed using a Laplace approximation at the posterior mode obtained with the estimation dataset.

Moments of macro variables

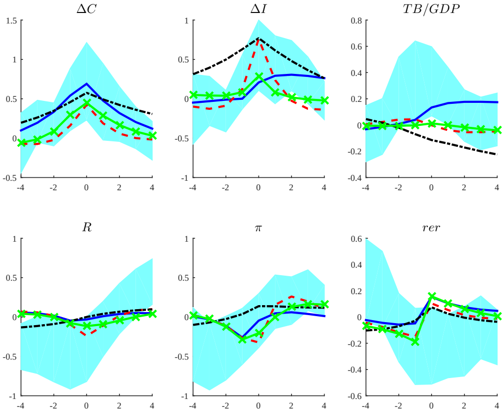
Selected Second Moments.

Variable	Data		Base	GK	BGG	BGG+ CMR	GK+ BGG	GK+ BGG+ CMR
A. Standard Deviation (%)								
ΔGDP	1.01	(0.13)	1.43	1.22	1.71	1.41	1.02	1.03
ΔC	1.09	(0.15)	1.19	1.00	1.27	1.30	1.01	1.05
ΔI	3.71	(0.45)	3.39	4.87	7.14	6.42	3.14	3.48
TB/GDP	5.26	(0.54)	4.70	4.07	6.89	6.89	4.01	4.20
R	0.46	(0.04)	0.72	0.61	3.03	3.07	0.59	0.71
π	0.73	(0.09)	0.78	0.70	2.86	2.75	0.66	0.77
rer	5.35	(0.49)	7.97	9.21	17.73	15.17	8.67	8.58
B. Autocorrelation Order 1								
ΔGDP	0.25	(0.22)	0.46	0.12	0.67	0.63	0.17	0.15
ΔC	0.63	(0.21)	0.69	0.50	0.86	0.85	0.64	0.66
ΔI	0.40	(0.22)	0.49	0.37	0.83	0.83	0.23	0.42
TB/GDP	0.73	(0.16)	0.95	0.93	0.97	0.97	0.94	0.94
R	0.88	(0.16)	0.95	0.90	1.00	1.00	0.93	0.96
π	0.63	(0.21)	0.70	0.57	0.98	0.98	0.72	0.77
rer	0.73	(0.16)	0.86	0.86	0.95	0.95	0.83	0.83

Note: GMM standard errors for data moments in parenthesis. Model moments computed at the posterior mode of each respective model.

Correlations w/ GDP of macro variables

Leads and Lags Correlation with GDP Growth.



Note: Each panel displays the correlation between a given variable x_{t+h} and ΔGDP_t, for $h = -4, -3, \ldots, 3, 4$. Gray areas: ± 2 standard error bands around the data moment (GMM); Blue solid lines: Baseline model; Dashed red: GK; Dash-dotted black: BGG+CMR; Crossed-solid green: GK+BGG+CMR.

Moments of financial variables

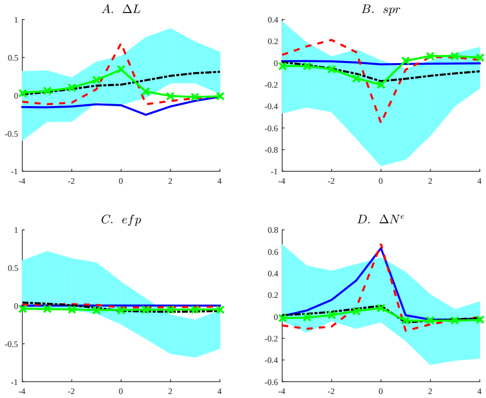
Selected Second Moments.

Variable	Data		Base	GK	BGG	BGG+ CMR	GK+ BGG	GK+ BGG+ CMR
			A. Standard Deviation (%)					
ΔL	1.39	(0.16)	0.64	2.26	1.84	1.77	1.40	1.59
ΔN^e	9.75	(0.91)	0.96	2.38	8.89	8.66	3.60	5.49
spr	0.26	(0.05)	0.23	1.39	0.32	0.36	0.35	0.43
efp	0.07	(0.01)	0.07	0.06	0.50	0.66	0.24	0.69
			B. Autocorrelation Order 1					
ΔL	0.56	(0.18)	0.49	-0.16	0.34	0.29	0.28	0.46
ΔN^e	0.20	(0.12)	0.09	-0.17	-0.04	-0.03	-0.03	-0.01
spr	0.68	(0.27)	0.74	0.12	0.86	0.90	0.52	0.55
efp	0.84	(0.13)	0.85	0.84	0.94	0.97	0.91	0.97

Note: GMM standard errors for data moments in parenthesis. Model moments computed at the posterior mode of each respective model.

Correlations w/ GDP of financial variables

Leads and Lags Correlation with GDP Growth.



Note: Each panel displays the correlation between a given variable x_{t+h} and ΔGDP_t, for $h = -4, -3, \ldots, 3, 4$. Gray areas: ± 2 standard error bands around the data moment (GMM); Blue solid lines: Baseline model; Dashed red: GK; Dash-dotted black: BGG+CMR; Crossed-solid green: GK+BGG+CMR.

Conclusions

- Main results:
  - The presence of financial frictions can help to improve the fit of a standard NK-SOE model for Chilean data.
    - To explain macro variables, Base, GK and GK+BGG models have similar performance.
    - Financial variables are better explained by BGG and GK+BGG models.
    - The interaction between both types of variables is better described by GK+BGG model.
  - Important role for risk shocks to explain investment and credit cycles.
  - Foreign shocks tend to play a relatively larger role in models with financial frictions (see paper).
- Other issues:
  - Domestic vs. foreign lending.
  - Sectoral distinctions (T, NT).
  - Correlation of risk shocks with external variables?
  - Occasionally binding financial frictions.

Extras

Calibrated parameters I

Calibrated Parameters.

Param.	Description	Value	Source
σ	Risk aversion	1	Medina and Soto (2007)
ϕ	Inverse Frish elasticity	5	Kirchner and Tranamil (2016)
α	Capital share in production	0.33	Medina and Soto (2007)
δ	Capital depreciation	0.06/4	Medina and Soto (2007)
ϵ_H	E.o.S. domestic aggregate	11	Medina and Soto (2007)
ϵ_F	E.o.S. imported aggregate	11	Medina and Soto (2007)
o_C	Share of F in Y^C	0.26	Input-ouput matrix (2008-2012)
o_I	Share of F in I	0.36	Input-ouput matrix (2008-2012)
o_G	Share of F in G	0	Normalization
χ	Government share in commodity sector	0.61	Average (1987-2012)
s^{tb}	Trade balance to GDP in SS	4%	Average (1987-2012)
s^g	Gov. exp. to GDP in SS	11%	Average (1987-2012)
s^{Co}	Commodity prod. to GDP in SS	10%	Average (1987-2012)
$\bar{\pi}$	Inflation in SS	3%	Inflation Target in Chile
p^H	Relative price of H in SS	1	Normalization
h	Hours in SS	0.3	Normalization
$\bar{a}$	Long-run growth	2.50%	4.5% GDP - 2% labor force grth. (avg. 01-12)
R	MPR in SS.	5.80%	Fuentes and Gredig (2008)
R^*	Foreign rate in SS	4.50%	Fuentes and Gredig (2008)

Calibrated parameters II

Calibrated Parameters.

		GK banks	
ξ	Country premium in SS	140bp	EMBI Chile (avg. 01-12)
lev	Leverage financial sector	9	Own calculation (see text)
spread	90 days lending-borrowing spread	380bp	Loan rate vs. MP rate (avg. 01-12)
ι	Injection for new bankers	0.002	Gertler and Karadi (2011)
		BGG entrepreneurs	
μ^e	Bankruptcy cost	0.12	Christiano *et al.* (2010)
υ	Survival rate of entrepreneurs	0.97	Bernanke *et al.* (1999)
efp	Entrepreneurs' external finance premium	120bp	Spread A vs. AAA, corp. bonds (avg. 01-12)
lev^e	Entrepreneurs' leverage	2.05	For the non-financial corp. sector (avg. 01-12)
		Exogenous processes	
$\rho_{y^{Co}}$	Auto corr. y^{Co}	0.4794	Own estimation
ρ_g	Auto corr. g	0.6973	Own estimation
ρ_{R^*}	Auto corr. R^*	0.9614	Own estimation
ρ_{y^*}	Auto corr. y^*	0.8665	Own estimation
ρ_{π^*}	Auto corr. π^*	0.3643	Own estimation
$\rho_{p^{Co*}}$	Auto corr. p^{Co*}	0.962	Own estimation
$\sigma_{y^{Co}}$	St. dev. shock to y^{Co}	0.0293	Own estimation
σ_g	St. dev. shock to g	0.0145	Own estimation
σ_{R^*}	St. dev. shock to R^*	0.0011	Own estimation
σ_{y^*}	St. dev. shock to y^*	0.0062	Own estimation
σ_{π^*}	St. dev. shock to π^*	0.0273	Own estimation
$\sigma_{p^{Co*}}$	St. dev. shock to p^{Co*}	0.1413	Own estimation

Estimated parameters

Estimated Parameters.

			Posterior Mode					
Para.	Description	Prior Mean	Base	GK	BGG	BGG+ CMR	GK+ BGG	GK+ BGG+ CMR
ς	Habits	0.7	0.82	0.70	0.90	0.90	0.77	0.78
η^C	E.o.S. Cons. H, F	1.4	2.39	2.41	2.01	2.11	2.57	2.59
η^I	E.o.S. Inv. H, F	1.4	1.11	1.59	1.36	1.40	1.55	1.55
η^*	Elast. exports	0.3	0.45	0.60	0.16	0.17	0.73	0.79
γ	Inv. Adj. Cost	4	10.08	0.31	4.52	4.61	10.56	11.62
θ_H	Calvo prob. H	0.75	0.41	0.72	0.97	0.96	0.48	0.47
ϑ_H	Index. H	0.5	0.45	0.12	0.44	0.41	0.50	0.50
θ_F	Calvo prob. F	0.75	0.70	0.87	0.64	0.66	0.88	0.88
ϑ_F	Index. F	0.5	0.23	0.32	0.19	0.16	0.44	0.50
ϕ_u	Utilization Cost	1	0.84	1.01	1.39	1.24	1.00	0.95
α_L^{WC}	Share work. cap.	0.7	0.71	0.77	1.49	1.06	0.07	0.10

Contributions to Unconditional Variances (%).

	v	ϖ	z	a	R^*	π^*	p^{Co*}	R	ζ^2	efp^{ex}	spr^{ex}	μ	σ_ω
							A. Base						
ΔGDP	40	13	9	7	2	4	1	3	10	0	0		
ΔC	76	4	0	4	5	1	7	1	1	0	0		
ΔI	6	89	0	3	0	0	1	0	0	0	0		
$\frac{TB}{GDP}$	1	14	1	2	11	5	59	0	5	0	0		
R	6	12	9	2	33	4	14	7	12	0	0		
π	3	6	34	2	24	4	8	1	17	0	0		
rer	1	3	2	1	24	11	29	2	26	0	0		
ΔL	6	83	1	4	2	0	1	1	2	0	0		
ΔN^e	43	6	10	5	8	1	1	9	12	0	2		
spr	0	0	0	0	0	0	0	0	0	0	100		
efp	0	0	0	0	0	0	0	0	0	100	0		

Note: Computed at posterior mode.

Variance decomposition II

Contributions to Unconditional Variances (%).

	v	ϖ	z	a	R^*	π^*	p^{Co*}	R	ζ^2	efp^{ex}	spr^{ex}	μ	σ_ω
							B. GK+BGG						
ΔGDP	16	9	17	8	3	6	0	8	16			0	0
ΔC	69	1	2	4	6	2	9	2	3			0	0
ΔI	0	91	1	2	2	0	1	3	0			1	0
$\frac{TB}{GDP}$	5	2	1	1	14	9	62	0	6			0	0
R	13	4	12	1	25	5	14	19	7			0	0
π	9	3	47	6	14	3	6	5	7			1	0
rer	1	1	2	0	23	12	23	4	33			0	0
ΔL	1	74	12	2	2	0	1	4	1			2	0
ΔN^e	1	37	1	3	0	0	0	43	0			11	4
spr	1	29	2	2	1	0	0	7	1			54	2
efp	2	43	0	0	2	1	2	11	1			2	34

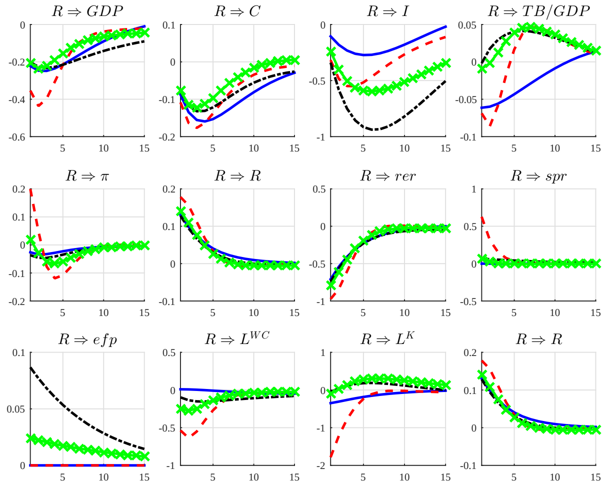
Note: Computed at posterior mode.

Contributions to Unconditional Variances (%).

	v	ϖ	z	a	R^*	π^*	p^{Co*}	R	ζ^2	efp^{ex}	spr^{ex}	μ	σ_ω
							C. GK+BGG+CMR						
ΔGDP	18	7	13	9	3	6	0	5	19			0	1
ΔC	72	1	1	4	6	2	7	1	2			0	3
ΔI	0	66	0	1	1	0	1	1	0			0	29
$\frac{TB}{GDP}$	6	2	1	1	14	8	57	0	5			0	5
R	16	4	7	1	22	4	13	9	7			0	16
π	13	4	29	7	14	3	6	3	8			1	12
rer	1	1	1	0	23	12	22	2	34			0	3
ΔL	1	55	8	2	1	0	0	2	1			2	26
ΔN^e	1	17	0	1	0	0	0	11	0			2	67
spr	1	21	1	2	1	0	0	3	1			33	37
efp	0	6	0	0	0	0	0	1	0			0	92

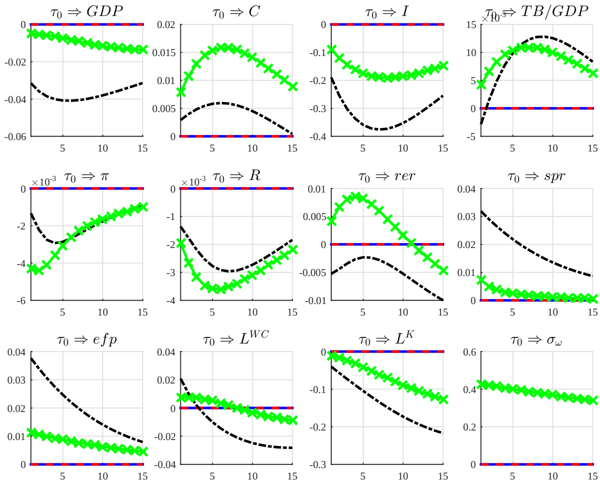
Note: Computed at posterior mode.

Impulse responses: Monetary policy shock



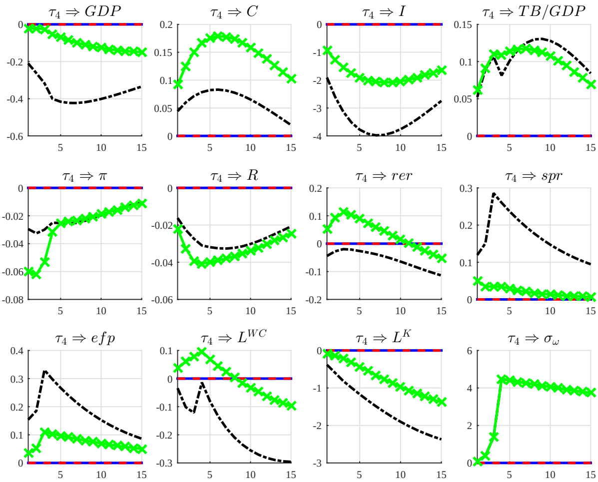
Note: Blue solid: Baseline model; Dashed red: GK; Dash-dotted black: BGG+CMR; Crossed-solid green: GK+BGG+CMR. All IRFs were computed at the posterior mode of the GK+BGG+CMR model.

Impulse responses: Risk shock (unanticipated)



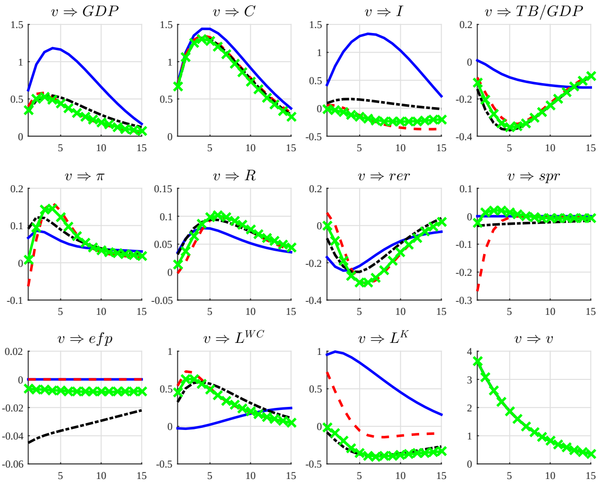
Note: Blue solid: Baseline model; Dashed red: GK; Dash-dotted black: BGG+CMR; Crossed-solid green: GK+BGG+CMR. All IRFs were computed at the posterior mode of the GK+BGG+CMR model.

Impulse responses: Risk shock (anticipated 4 periods)



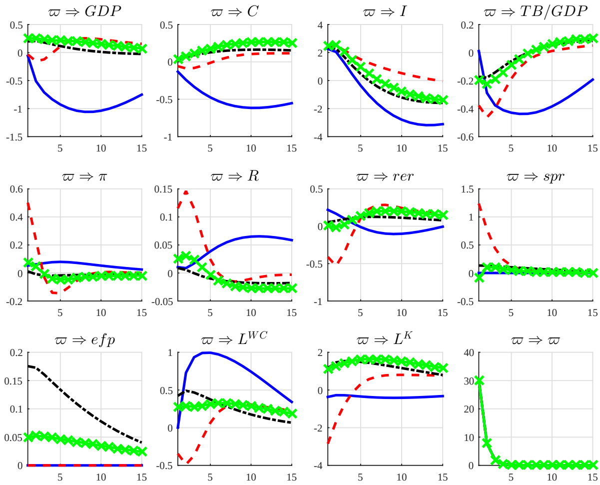
Note: Blue solid: Baseline model; Dashed red: GK; Dash-dotted black: BGG+CMR; Crossed-solid green: GK+BGG+CMR. All IRFs were computed at the posterior mode of the GK+BGG+CMR model.

Impulse responses: Preference shock



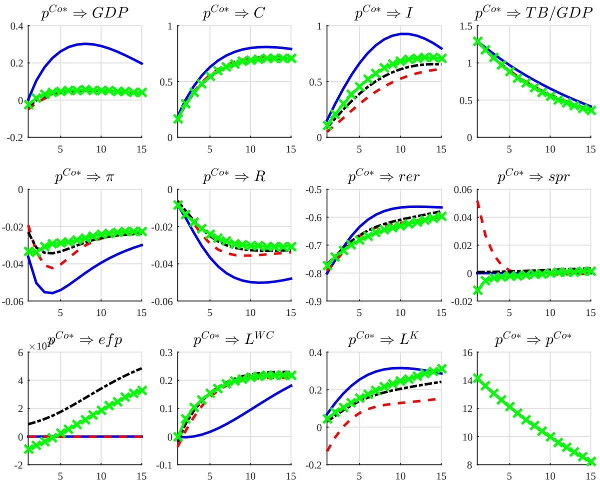
Note: Blue solid: Baseline model; Dashed red: GK; Dash-dotted black: BGG+CMR; Crossed-solid green: GK+BGG+CMR. All IRFs were computed at the posterior mode of the GK+BGG+CMR model.

Impulse responses: Investment-specific technology shock



Note: Blue solid: Baseline model; Dashed red: GK; Dash-dotted black: BGG+CMR; Crossed-solid green: GK+BGG+CMR. All IRFs were computed at the posterior mode of the GK+BGG+CMR model.

Impulse responses: Commodity price shock



Note: Blue solid: Baseline model; Dashed red: GK; Dash-dotted black: BGG+CMR; Crossed-solid green: GK+BGG+CMR. All IRFs were computed at the posterior mode of the GK+BGG+CMR model.