Macroeconomic and Financial Interactions in Chile: An Estimated DSGE Approach

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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 or its Board members.

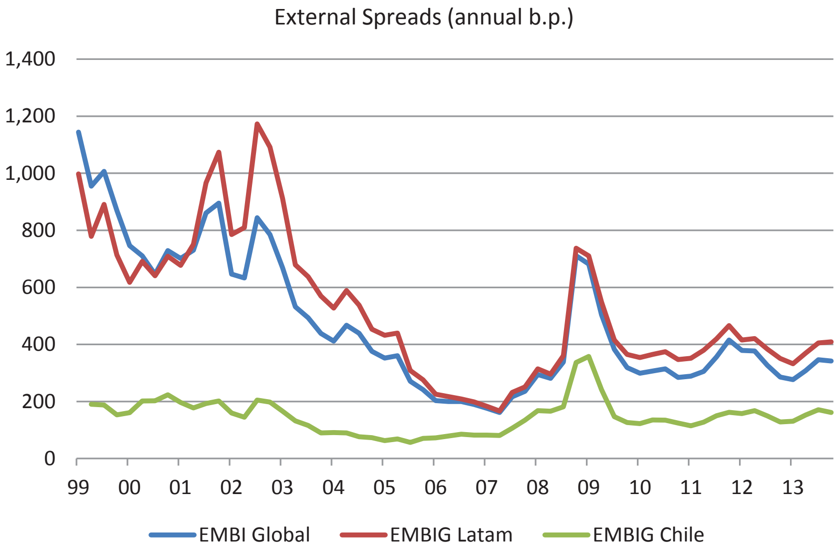
Background and objective

- The 2008 crisis and its aftermath have highlighted the need for central banks to evaluate policies to complement the usual implementation of inflation targeting frameworks.
- The prevailing tool for monetary policy analysis before 2008 (the New Keynesian model) is incomplete for that purpose:
  - Does not include relevant macroeconomic and financial interactions.
  - Not well suited to analyze policies targeting the financial sector.
- Against this background, we develop a DSGE model for Chile to (i) assess the empirical relevance of different financial transmission channels and (ii) evaluate if monetary policy can achieve better macroeconomic outcomes by smoothing the credit cycle.

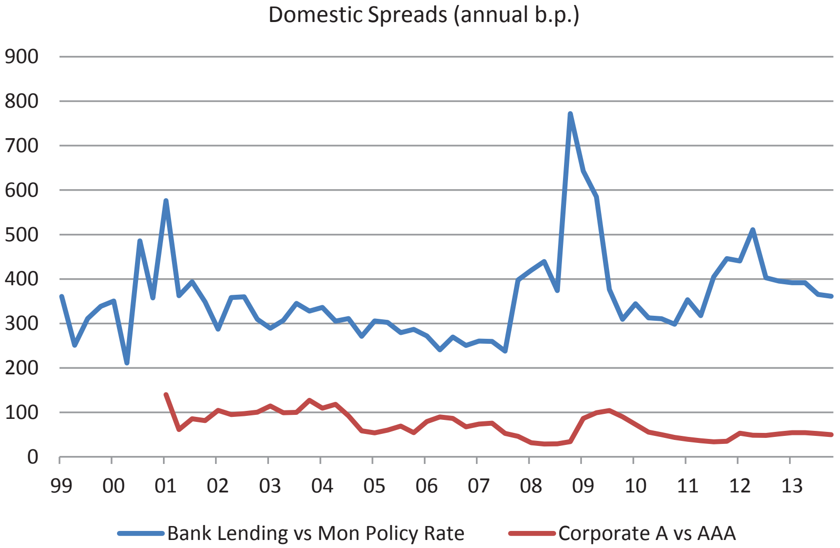
Literature on financial frictions in emerging countries

- The literature on fluctuations in emerging countries has focused on financial frictions between domestic and foreign agents:
  - Endogenous country premia (e.g. Neumeyer and Perri, 2005; Uribe and Yue, 2008; Garca-Cicco, Pancrazi, and Uribe, 2010; Mendoza, 2010).
  - Sovereign defaults (e.g. Arellano, 2008; Yue, 2010; Mendoza and Yue, 2012).
  - Dollarization and currency mismatches (e.g. Céspedes, Chang, and Velasco 2004; Devereux, Lane, and Xu, 2006; Gertler, Gilchrist, and Natalucci, 2007).
- However, in the new century, the picture has significantly changed for many emerging countries:
  - Fiscal situation seems under control (some governments are even net foreign lenders).
  - Dollarization has been reduced dramatically.
  - Country premia have not displayed the high levels they used to show years ago.

Evolution of emerging country spreads



Domestic financial spreads in Chile



Focus of the paper

- Hence, *external* financial frictions seem less important today, while *domestic* financial frictions seem more relevant.
- We therefore incorporate two types of domestic financial frictions into a standard small open economy DSGE model:
  - Between depositors and banks, as in Gertler and Karadi (2011, GK).
  - Between banks and firms, as in Bernanke *et al.* (1999, BGG).
- We estimate the model with Chilean data from 2001-12 following a Bayesian approach to answer several questions:
  - Do financial frictions improve the goodness-of-fit of the model in terms of non-financial variables?
  - Which frictions are useful to describe dynamics of financial variables?
  - How do the frictions affect the propagation of different shocks?
  - Which shocks account for most of the fluctuations?
- Finally, we asses if monetary policy can achieve better outcomes by smoothing the credit cycle ("leaning against the wind").

Summary of the baseline model

- The model without financial frictions is a fairly standard New Keynesian model of a small open economy:[1]
  - Consumption of domestic goods and imported goods (all tradable).
  - Domestic goods produced with capital and labor.
  - Staggered price-setting à la Calvo-Yun with indexation both for domestic producers and importers (i.e. delayed pass-through).
  - Sticky wages as in Schmitt-Grohé and Uribe (2006) with indexation.
  - Labor-augmenting productivity growth.
  - Habits in consumption and investment adjustment costs.
  - Variable capacity utilization.
  - Working capital loans.
  - Elastic country premium.
  - Taylor rule (smoothing, inflation and GDP growth).
  - Exogenous government expenditure (Ricardian equivalence).
  - Commodity sector (endowment, exogenous world price).

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[1] Simplified version of Medina and Soto (2007) model used for policy analysis and forecasting at the Central Bank of Chile. Simplified structure more similar to Adolfson, Laséen, Lindé, and Villani (2007) model.

Conceptual view of financial frictions

- We incorporate two kinds of financial frictions in the model:
  - Banks intermediate credit from households to entrepreneurs (to finance capital accumulation) and firms (for working capital) subject to a moral hazard problem, following GK.
  - Capital accumulation by entrepreneurs is risky and subject to a costly-state-verification problem, as in BGG.
- This allows us to match additional interest rate spreads:
  - Different interest rates (real rates in steady state):
    - r^*, international rate; r^D, domestic deposit rate.
    - r^L, rate at which banks are willing to lend risk-free (not observable).
    - r^{Le}, interest rate paid on loans (linked to return on capital).
  - Frictionless models: $r^* = r^D = r^L = r^{Le}$.
  - External financial frictions: $r^* < r^D = r^L = r^{Le}$.
  - Domestic frictions between banks and firms: $r^* = r^D = r^L < r^{Le}$.
  - Domestic frictions between depositors and banks: $r^* = r^D < r^L = r^{Le}$.
  - Our model: $r^* \approx r^D < r^L < r^{Le}$.

Frictions between depositors and banks á la GK

- Banks intermediate deposits D_t and lend to entrepreneurs and firms: $L_t^{WC} + L_t^K = D_t + N_t$. Net worth evolution:

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

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

$$V_t = E_t \sum_{s=0}^{\infty} (1-\omega)\omega^s \beta^{s+1} \Xi_{t,t+s+1} N_{t+s+1}.$$

- Moral hazard problem: Banks can steal a fraction μ_t (exogenous) of assets and go bankrupt. Incentive constraint: $V_t \geq \mu_t(L_t^{WC} + L_t^K)$.
- Solution implies that loans are tied to bank capital:

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

where marginal gain of assets $\varrho_t^{L,K} = \varrho_t^{L,WC} \equiv \varrho_t^L$ increases with flow of spreads $E_t[r_{t+s}^{L,K} - r_{t+s}]$ and $E_t[r_{t+s}^{L,WC} - r_{t+s}]$.

Frictions between banks and borrowers á la BGG I

- 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 $\omega_{t+1}^e K_t$ units 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 shocks", Christiano *et al.*, 2014).
- Asymmetric information and costly-state-verification problem: 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.
- The optimal debt contract specifies an interest rate on the loan through a cut-off value $\bar{\omega}_{t+1}^e$ 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 $(\leq \bar{\omega}_{t+1}^e)$ pay the established interest rate and keep the difference.

Frictions between banks and borrowers á la BGG II

- Banks require that the return on the loan ($r^{L,K}_{t+1}$) is:

$$L^K_t r^{L,K}_{t+1} \leq g(\bar{\omega}^e_{t+1}; \sigma_{\omega,t})[r^K_{t+1} u_{t+1} - \phi(u_{t+1}) + (1-\delta) q_{t+1}] K_t. \quad (1)$$

  where $g(\bar{\omega}^e_{t+1}; \sigma_{\omega,t})$ represents the fraction of the total income generated by the investment that the bank can obtain given the distribution of entrepreneurs.
- The optimal debt contract is calculated by maximizing over lev^e_t and $\bar{\omega}^e_t$ the expected return to entrepreneurs, subject to the banks' participation constraint (1).
- Solution implies a difference between the expected return of capital and the expected return to banks, which is an increasing function of entrepreneurs' leverage ("external finance premium").

Calibration and estimation strategy

- Several parameters are calibrated to match targeted steady state values. Calibrated parameters related to financial frictions:
  - Set capital injection for new banks $\iota = 0.002$ (GK), survival rate $\upsilon = 0.97$ (BGG), monitoring cost $\mu^e = 0.12$ (Christiano *et al.*, 2014).
  - Choose $\bar{\mu}$ (steady state fraction of divertable assets), ω (fraction of surviving banks), ι^e (capital injection for new entrepreneurs) and σ_ω (steady state dispersion of entrepreneurs) to match targets:
    - Average spread between 90-days loans rate and m.p.r. of 380 a.b.p.
    - Steady state external finance premium of 120 a.b.p. (average of A vs. AAA and BBB vs. AAA spreads).
    - Bank leverage ratio of 9 (banking system balance sheet data).
    - Entrepreneurs' leverage ratio of 2.05 (firms' balance sheet data).
- The remaining parameters are estimated using a Bayesian approach, using both macro and financial data. Shocks Data
- We compare estimation results for four different models: (i) Base, (ii) GK only, (iii) BGG only, (iv) GK+BGG.

Comparison of estimated models

- Do financial frictions improve the goodness-of-fit of the model?

Log Marginal Data Densities.

	Data Set	
Model	Macro	Macro + Loans + Spread
Base	-957.5	
GK	-1006.3	-1144.0
BGG	-993.0	-1134.2
GK+BGG	-1020.9	-1201.8

Note: These are Laplace approximations at the posterior mode.
Red marks highest densities for each data set.

Moments model vs. data I

- In which dimension do frictions improve fit for non-financial variables?

Standard Deviations of Macro Variables.

Variable	Data	Base	GK	BGG	GK+BGG
ΔGDP	1.02	0.99	1.00	0.90	0.96
ΔC	1.10	0.95	1.07	1.10	1.14
ΔI	3.75	4.37	6.06	3.18	5.55
TB/GDP	5.32	3.65	4.30	3.59	3.72
ΔW	0.62	0.60	0.78	0.63	0.84
R	0.46	0.51	1.30	0.68	1.16
π	0.74	0.62	1.13	0.68	0.99
rer	5.41	10.55	20.28	12.40	15.49

Note: These are unconditional moments at the posterior mode.
Red marks std. dev. closest to the data.

Moments model vs. data II

- In which dimension do frictions improve fit for non-financial variables?

First-Order Autocorrelations of Macro Variables.

Variable	Data	Base	GK	BGG	GK+BGG
ΔGDP	0.25	0.43	0.57	0.31	0.50
ΔC	0.63	0.60	0.70	0.66	0.71
ΔI	0.40	0.70	0.88	0.38	0.79
TB/GDP	0.73	0.92	0.94	0.92	0.92
ΔW	0.40	0.48	0.32	0.51	0.50
R	0.88	0.92	0.97	0.94	0.97
π	0.63	0.66	0.85	0.73	0.85
rer	0.73	0.93	0.98	0.95	0.96

Note: These are unconditional moments at the posterior mode.
Red marks autocorrelations closest to the data.

Moments model vs. data III

- Which frictions are useful to describe dynamics of financial variables?

Selected Second Moments of Financial Variables.

Variable	Data	GK	BGG	GK+BGG
A. Standard Deviation (%)				
ΔL	1.41	1.52	1.31	1.07
spr	0.26	1.04	0.49	0.92
B. Autocorrelation of Order 1				
ΔL	0.56	0.16	0.43	0.60
spr	0.68	0.20	0.89	0.21

Note: These are unconditional moments at the posterior mode.
Red marks moments closest to the data.

Variance decomposition

- Which shocks account for most of the fluctuations?

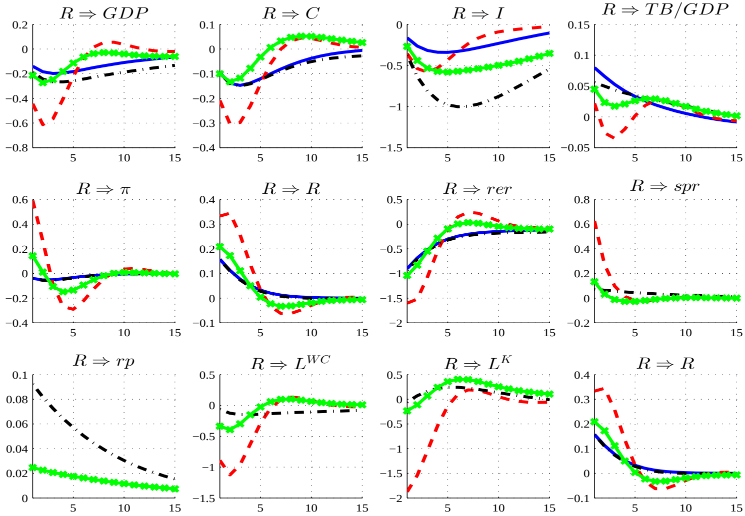
Variance Decomposition of Observed Variables.

	Pref.	MIE	Prod.	R^*	π^*	p^{Co*}	R	μ	σ_ω
				A. Base					
ΔGDP	7	28	24	4	6	6	7		
π	2	10	59	8	6	9	4		
				B. GK					
ΔGDP	38	8	11	5	5	9	3	1	
π	32	25	6	9	10	15	2	0	
ΔL	6	33	37	4	2	9	3	4	
spr	15	6	17	1	2	2	11	45	
				C. BGG					
ΔGDP	23	9	24	1	3	5	6		1
π	7	1	52	15	7	12	3		0
ΔL	1	69	18	3	2	3	2		1
spr	2	42	1	1	0	1	10		42
				D. GK+BGG					
ΔGDP	27	21	18	1	4	3	2	0	2
π	20	15	8	16	16	21	1	0	2
ΔL	3	21	29	8	10	19	1	5	4
spr	8	10	35	1	2	3	3	38	1

Note: These are contributions to unconditional variances in %.
Red marks largest contributions for each variable.

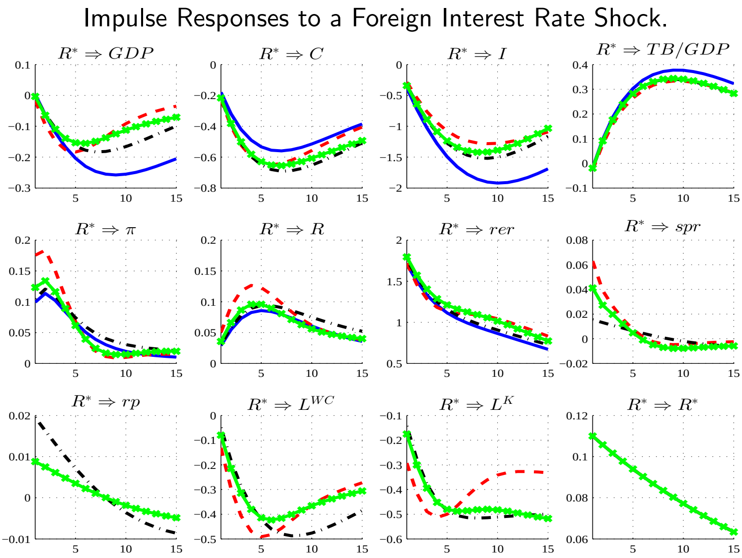
Impulse responses to domestic monetary policy shock

Impulse Responses to a Monetary Policy Rate Shock.



Note: blue-solid = baseline; dashed red = GK; dash-dotted black = BGG; crossed-solid green = GK-BGG.

Impulse responses to foreign interest rate shock



Note: blue-solid = baseline; dashed red = GK; dash-dotted black = BGG; crossed-solid green = GK-BGG.

Policy exercise

- Use the model with financial frictions that best fits the data (the BGG model) to evaluate if monetary policy can achieve better macroeconomic outcomes by reacting to financial variables (x_t):

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[\left(\frac{\pi_t}{\bar{\pi}}\right)^{\alpha_\pi} \left(\frac{y_t}{y_{t-1}}\right)^{\alpha_y} \left(\frac{x_t}{\bar{x}}\right)^{\alpha_x}\right]^{1-\rho_R} \exp(\varepsilon_t^R),$$

- Fix all other parameters at the posterior mode of the BGG model and choose the value of α_x to attain some alternative goals:
  - Minimize variance of either inflation or real GDP growth.
  - Maximize 2nd-order welfare (Schmitt-Grohé and Uribe, 2007) and compute consumption equivalent (λ) that makes households indifferent between the optimal rule (α_x^{opt}) and the benchmark ($\alpha_x = 0$):

$$\begin{aligned} & E\sum_{t=0}^{\infty} \beta^t v_t \left[\log\left(C(\alpha_x^{opt})_t - \varsigma C(\alpha_x^{opt})_{t-1}\right) - \kappa \frac{h(\alpha_x^{opt})_t^{1+\phi}}{1+\phi}\right] \\ = \quad & E\sum_{t=0}^{\infty} \beta^t v_t \left[\log\left[(1-\lambda)\left(C(0)_t - \varsigma C(0)_{t-1}\right)\right] - \kappa \frac{h(0)_t^{1+\phi}}{1+\phi}\right]. \end{aligned}$$

Leaning against the wind I

- Can policy rules that respond to financial variables reduce volatility?

Standard Deviations Under Different Policy Rules.

Variance to minimize	Response parameter	St. Dev. (%) π	ΔGDP	spr	ΔL
	A. Benchmark Rule				
	0	0.676	0.804	0.494	1.314
	B. Rule responds to ΔL_t				
π	0.071	0.674	0.797	0.500	1.305
ΔGDP	0.750	0.719	0.765	0.580	1.231
	C. Rule responds to spr_t				
π	-0.516	0.656	0.804	0.418	1.290
ΔGDP	-0.224	0.661	0.801	0.458	1.302

Note: Results correspond to the BGG model. Red marks lower st. dev. than under the benchmark rule.

Leaning against the wind II

- Can policy rules that respond to financial variables increase welfare?

Welfare Gains Under Different Policy Rules.

Response parameter	$100 * \lambda$	St. Dev. (%) π	ΔGDP	spr	ΔL
A. Benchmark Rule					
0	0	0.676	0.804	0.494	1.314
B. Rule responds to γL_t					
-0.370	-0.0039	0.698	0.848	0.471	1.355
C. Rule responds to spr_t					
-0.841	-0.0101	0.660	0.813	0.382	1.278

Note: Results correspond to the BGG model. Red marks largest gains in terms of consumption equivalents.

Conclusions

- Two main lessons from estimation exercise:
  - Domestic financial frictions help to improve the goodness-of-fit of a standard SOE model in several dimensions. Frictions between banks and borrowers (BGG setup) seem more useful than frictions between depositors and banks (GK or GK+BGG).
  - The presence of financial frictions alters significantly the propagation of structural shocks, particularly of foreign shocks.
- From a policy perspective, "leaning against the wind" strategies and smoothing the credit cycle may help to reduce the variance of inflation and output, but with relatively limited welfare gains.
- Future work should focus on occasionally binding constraints, sudden stops and domestic vis-a-vis foreign frictions.

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:
  - μ_t
  - $\sigma_{\omega,t}$

Return

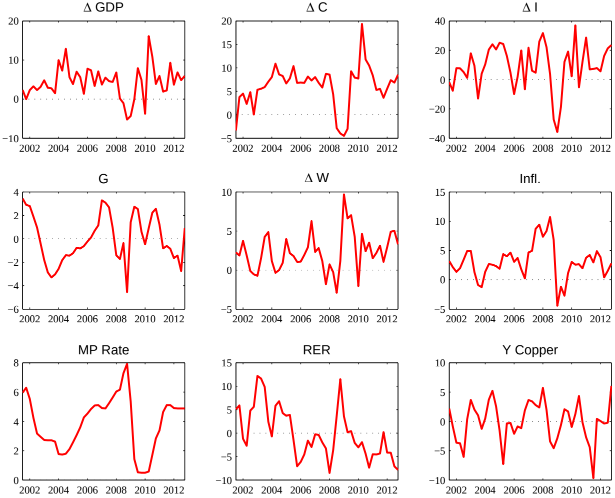
List of observed variables

- Macro data:
  - Growth rates of real GDP, private consumption, investment.
  - Real wage growth.
  - Government consumption.
  - Copper production.
  - Inflation (CPI).
  - Monetary policy rate.
  - Real effective exchange rate.
  - Short-term Libor.
  - EMBI Chile.
  - Foreign inflation (trade-weighted).
  - Commercial partners' GDP (trade-weighted).
  - Real copper price.
- Financial data:
  - Growth rate of real bank credit.
  - Spread 90 days bank lending rate vs. m.p.r., $spr_t = \frac{(R_t^{L,WC} L_t^{WC} + R_t^{L,e} L_t^K)}{L_t} \frac{1}{R_t}$.
  - Spread A vs. AAA, $rp_t \equiv \frac{E_t\{[r_{t+1}^K u_{t+1} - \phi(u_{t+1}) + (1-\delta) q_{t+1}]/q_t\}}{E_t\{r_{t+1}^{L,K}\}}$.

Return

Data

Domestic Macroeconomic Variables.

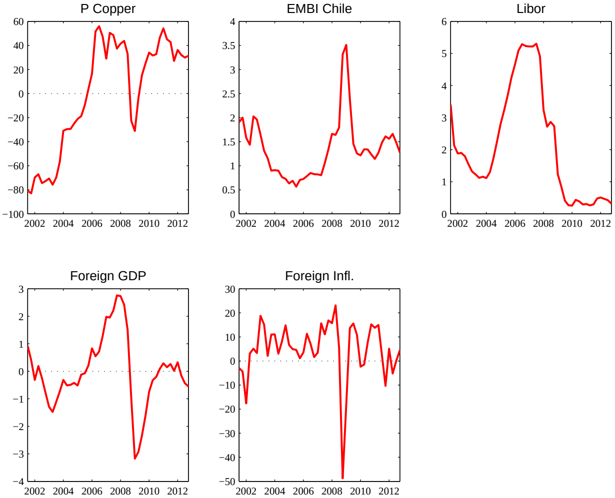


Note: Annualized quarterly rates for ΔGDP, ΔC, ΔI, ΔW, Infl., MP Rate;
Δ from mean/trend for RER, G, Y Copper.

Return

Data

Foreign Exogenous Variables.

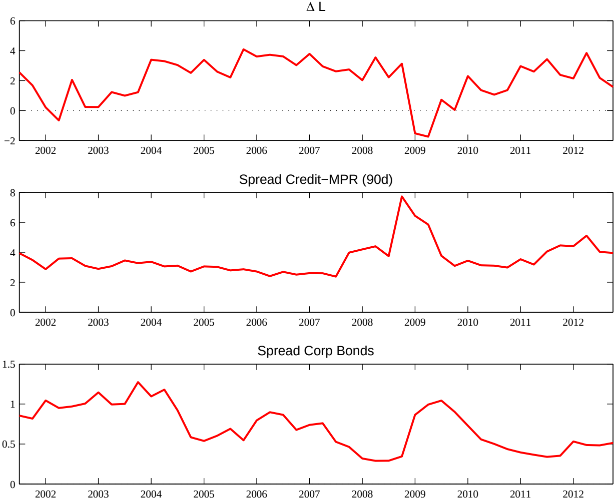


Note: Δ from mean/trend for *P* Copper, Foreign *GDP*; annualized quarterly rates for EMBI Chile, Libor, Foreign Infl.

Return

Data

Domestic Financial Variables.



Note: Annualized quarterly rates.

Return