Learning About Commodity Cycles and Saving-Investment Dynamics in a Commodity-Exporting Economy

Jorge Fornero Markus Kirchner

Central Bank of Chile, Macroeconomic Analysis Division*

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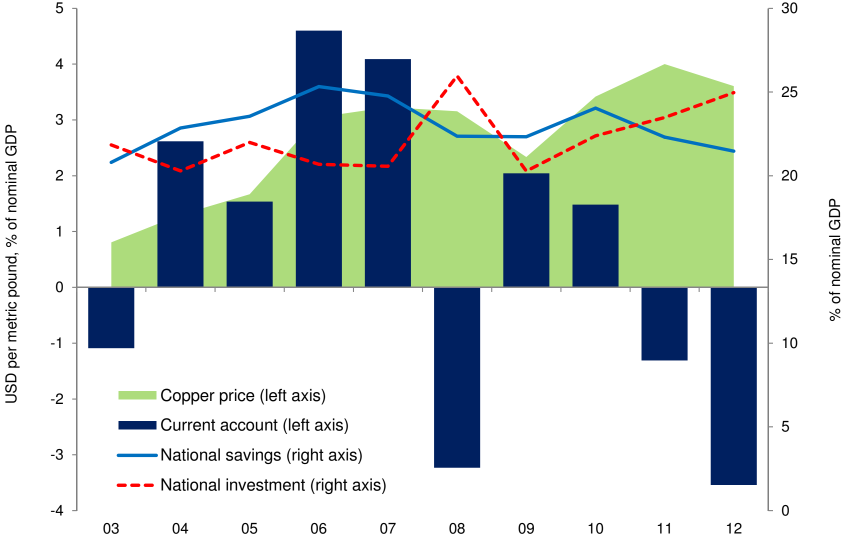
*The views and conclusions presented are exclusively those of the authors and do not necessarily reflect the position of the Central Bank of Chile or its Board members.

Motivation: Recent CA dynamics in commodity-exporting countries

- Commodity prices have surged over the past decade, and most commodity exporters have experienced record terms of trade.
- Despite very favorable terms of trade, many commodity exporters have accumulated sizable current account (CA) deficits.
- Some have even experienced a CA reversal over time:
  - In Chile, the CA balance moved from a surplus of 4.6% of GDP in 2006 to a deficit of -3.4% in 2012-13.
  - A similar process occurred e.g. in Brazil, Canada and Peru.
- CA deficits have become an important policy concern:
  - Might reflect macroeconomic imbalances such as excessive domestic absorption and over-borrowing.
  - Pose risk of a painful adjustment under sudden stops of capital flows.

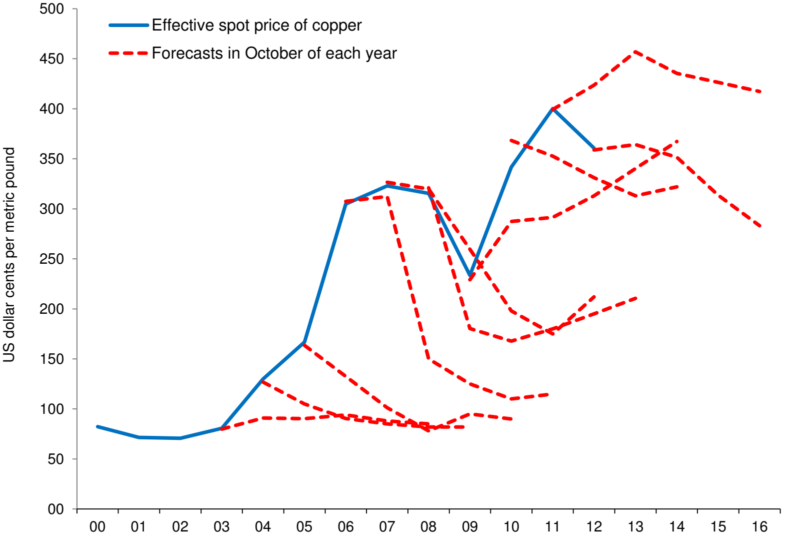
Copper price boom and external savings balance in Chile



Other stylized facts:

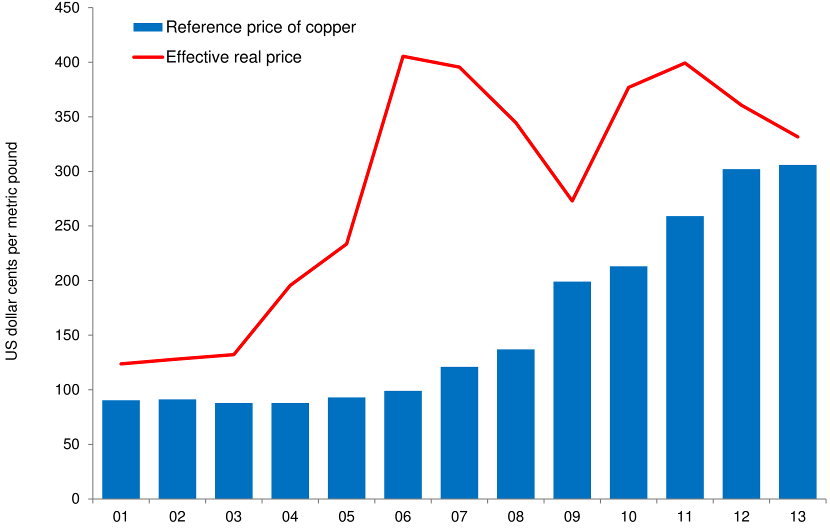
- Successive upward revisions of long-run copper price forecasts from 2006-07 onwards:
  - By professional forecasters.
  - By the panel of experts that counsels on the parameters of Chile's fiscal rule (including a long-run reference price of copper).
- Rise in national investment after 2007 was mainly driven by mining:
  - Investment in mining grew from 2.5% of GDP in 1976-2007 to almost 5% in 2008-12. Other investment also increased but less.
  - FDI in mining explained more than half of total FDI in 2008-12, and roughly tripled compared to historical volumes.

Evolution of professional copper price forecasts

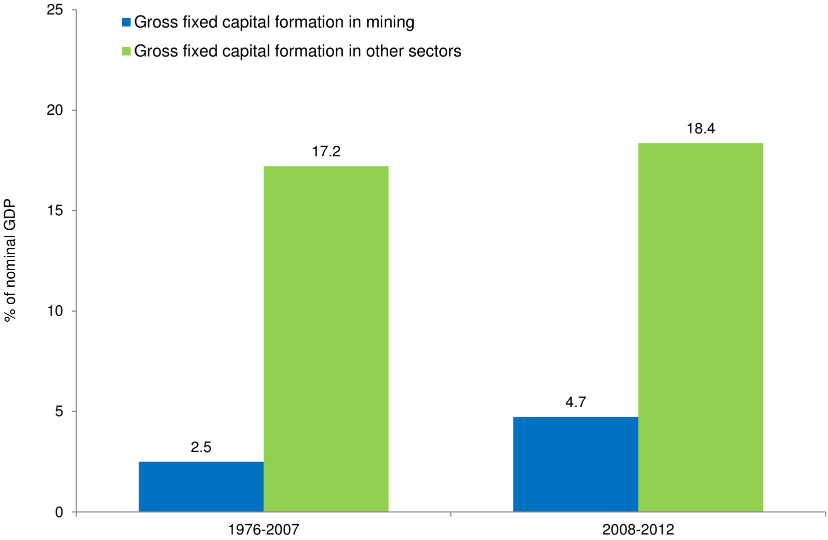


Note: Forecasts by CRU Group.

Evolution of the government's reference price of copper



Investment in mining vs other sectors



Objective of this paper

- Possible mechanism: Agents gradually adjusted their perceptions on the duration of the commodity cycle, which affected savings and investment especially in the commodity sector.
- Goal: Analyze the role of this mechanism for CA dynamics in a commodity-exporting economy.
- What do we do?
  - Incorporate two novel elements in an NK-SOE model:
    - Endogenous commodity production with capital and time to build.
    - Imperfect information and learning by agents on the persistence of commodity price shocks.
  - Estimate the model with Chilean data from 2001 to 2012, following a Bayesian approach.
  - Use the model to analyze the role of learning:
    - To drive the response of macro variables to commodity price shocks.
    - To understand the observed gradual CA adjustment in Chile.

Imperfect information: A simple unobserved components model for the copper price with persistent and transitory shocks

- Assume that the international price (real terms, log deviations from long-run mean) satisfies:

$$p^*_{S,t} = a_t + b_t, \quad t = 0, 1, 2, \ldots$$

- The unobservable shock a_t captures transitory "noise":

$$a_t \sim NID(0, \sigma_a^2).$$

- While b_t is an unobserved state variable that measures persistent, "fundamental" cycles:

$$b_t = \rho b_{t-1} + u_t, \quad \rho \in [0, 1), \quad u_t \sim NID(0, \sigma_u^2).$$

- Data: Price of refined copper (London Metals Exchange, deflated by trade-adjusted external price index); 1960Q1-2012Q4.

Learning behavior by agents and estimation of parameters

- Following Erceg and Levin (2003), agents use the Kalman filter (KF) to obtain the optimal linear inference of the state:

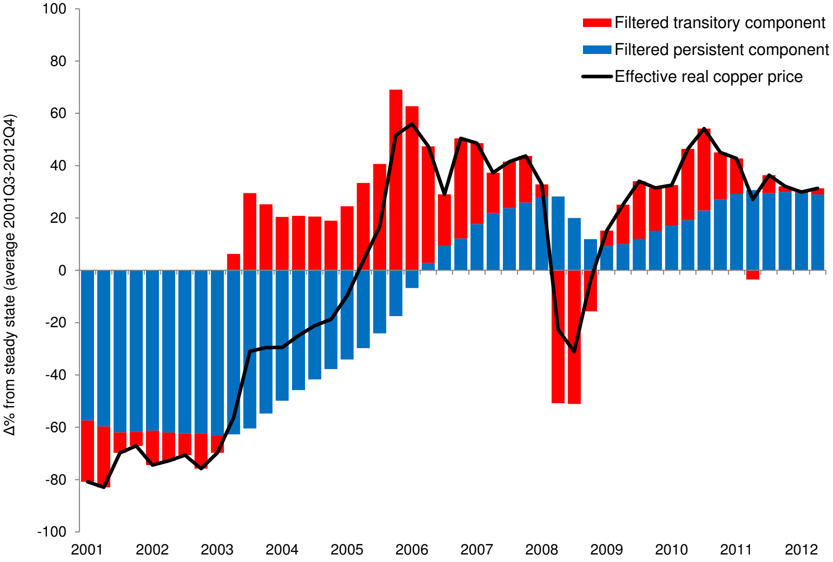
$$\hat{b}_t = E[b_t | p^*_{S,t}, \ldots, p^*_{S,0}] = \rho \hat{b}_{t-1} + K\rho^{-1}(p^*_{S,t} - \rho \hat{b}_{t-1}).$$

- K_t is the Kalman gain with $\Sigma_t = var[b_t | p^*_{S,t}, \ldots, p^*_{S,0}]$. For $t \to \infty$, steady state with $\Sigma_t = \Sigma$ and $K_t = K$.
- Agents learn at a constant rate, adjusting inference $\hat{b}_t$ and forecasts $\hat{p}^*_{S,t+h} = \rho \hat{b}^h_t$ according to past prediction errors.
- Parameters σ_a and σ_u not separately identified. Estimation ($\rho < 1$):
  1. Fix $K = 0.15$ (Erceg and Levin, 2003; Céspedes and Soto, 2007).
  2. Obtain $\kappa = \sigma_u / \sigma_a = 0.17$ from KF equations that yield K and Σ.
  3. Rewrite the model as

$$\begin{aligned} p^*_{S,t} &= b_t + (\sigma_u/\kappa)\xi_t, \qquad \xi_t \sim NID(0,1), \\ b_t &= \rho b_{t-1} + \sigma_u \zeta_t, \qquad \zeta_t \sim NID(0,1). \end{aligned}$$

  4. Obtain estimates by ML: $\rho = 0.979$, $\sigma_u = 0.0375$, $\sigma_a = 0.2032$.

Copper price decomposition from the KF



An NK model of a commodity-exporting small open economy

- Based on Medina and Soto (2007) model used for policy analysis at the Central Bank of Chile.[1]
- Basic structure similar to Smets and Wouters (2003, 2007), Christiano *et al.* (2005, CEE), Adolfson *et al.* (2007) models.
- Key extensions:
  1. Endogenous commodity production using capital specific to the commodity sector and a fixed factor (land).
  2. The government owns a share χ of total assets, the rest is FDI. Tax on profits of foreign investors.

[1] Main elements of the model: Consumption of home goods, imported goods, oil and food; 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; Habits in consumption; Investment adjustment costs; Non-Ricardian households; Taylor rule (smoothing, inflation and GDP growth); Elastic country premium; Commodity sector (endowment, exogenous international price); Structural balance fiscal rule for government spending (consumption, complete home bias).

Capital accumulation in the commodity sector (sector S)

- Production $Y_{S,t} = F(K_{S,t-1}, \dots)$. Slow accumulation of capital:
  - Convex costs of initiating investment projects (CEE, 2005; Uribe and Yue, 2006).
  - Time to build (Kydland and Prescott, 1982; Uribe and Yue, 2006). It takes $n \geq 1$ periods for investment projects to turn productive:

$$K_{S,t} = (1-\delta_S)K_{S,t-1} + [1 - \Phi_S(X_{S,t-n+1}/X_{S,t-n})]X_{S,t-n+1},$$

    where $X_{S,t-n+1}$ are investment projects started $t-n+1$ periods ago.
- Effective investment expenses are $I_{S,t} = \sum_{j=0}^{n-1} \varphi_j X_{S,t-j}$, where φ_j is fraction of projects initiated in $t-j$ and financed in t.
- $I_{S,t}$ is a CES bundle of domestic goods (e.g. construction) and imported goods (e.g. machinery). Generates spillover effects on non-commodity production and the trade balance.

- FOC, general case:

$$K_{S,t} \quad : \quad \frac{Q_{S,t}}{P_{C,t}} = E_t \left\{ \Lambda_{t,t+1} \left[\begin{array}{c} \frac{Q_{S,t+1}}{P_{C,t+1}}(1-\delta_S) \\ + \frac{P_{S,t+1} A_S F^S_{K_S}(T_{t+1}, K_{S,t})}{P_{C,t+1}} \end{array} \right] \right\}$$

$$\begin{aligned} X_{S,t} \quad : \quad & \varphi_0 \frac{P_{I_S,t}}{P_{C,t}} + \varphi_1 E_t \left\{ \Lambda_{t,t+1} \frac{P_{I_S,t+1}}{P_{C,t+1}} \right\} + \varphi_2 E_t \left\{ \Lambda_{t,t+2} \frac{P_{I_S,t+2}}{P_{C,t+2}} \right\} \\ & + \cdots + \varphi_{n-1} E_t \left\{ \Lambda_{t,t+n-1} \frac{P_{I_S,t+n-1}}{P_{C,t+n-1}} \right\} \\ & = E_t \left\{ \begin{array}{c} \Lambda_{t,t+n-1} \frac{Q_{S,t+n-1}}{P_{C,t+n-1}} \left[\begin{array}{c} 1 - \Phi_S\left(\frac{X_{S,t}}{X_{S,t-1}}\right) \\ -\Phi'_S\left(\frac{X_{S,t}}{X_{S,t-1}}\right) \frac{X_{S,t}}{X_{S,t-1}} \end{array} \right] \\ + \Lambda_{t,t+n} \frac{Q_{S,t+n}}{P_{C,t+n}} \Phi'_S\left(\frac{X_{S,t+1}}{X_{S,t}}\right) \left(\frac{X_{S,t+1}}{X_{S,t}}\right)^2 \end{array} \right\} \end{aligned}$$

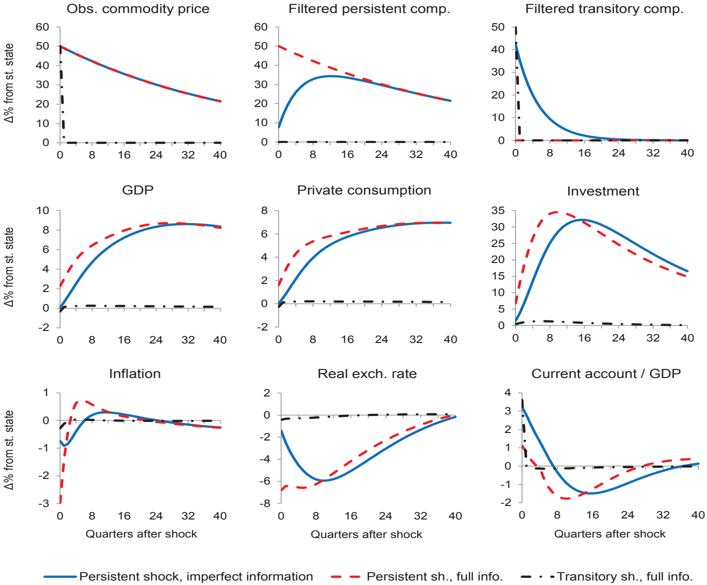
- Higher forecasted commodity price ($P_{S,t+1}$) stimulates investment.
- Due to TTB, future capital prices ($Q_{S,t+n-1}$, $Q_{S,t+n}$) matter: Only (perceived) persistent commodity price increases affect investment.

Government, foreign investors and CA balance

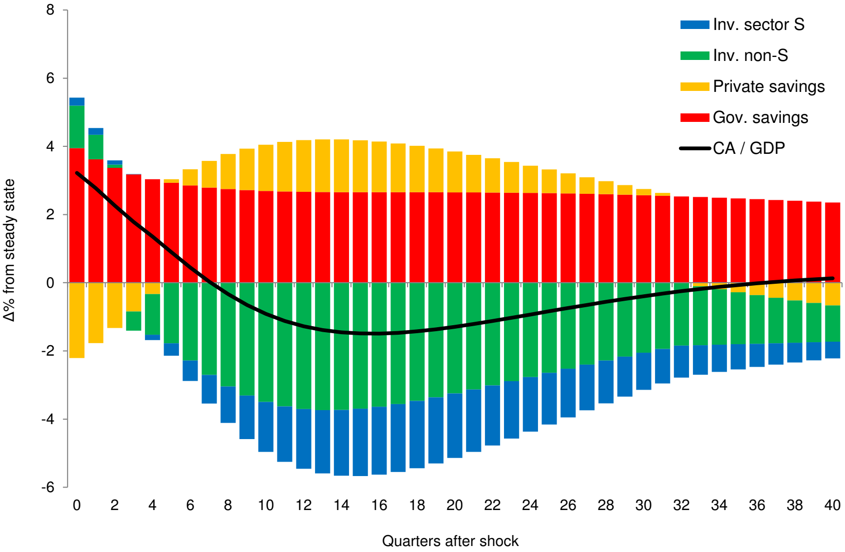
- A fraction χ of the cash flow from sector S goes to the government, plus taxes on profits of foreign investors.
- Government spending follows a structural balance rule linking it, *inter alia*, to a long-run reference price $\bar{P}^*_{S,t}$, i.e. the forecast of $P^*_{S,t}$ averaged over a 10 years horizon.
- Hence, (perceived) transitory price increases are mostly saved while a higher long-run price allows more spending.
- The CA balance then equals the change in the international investment position of the economy:

$$CAY_t = \underbrace{\frac{\varepsilon_t B^*_t}{P_{Y,t} Y_t} \frac{1}{(1+i^*_t)\Theta_t} - \frac{\varepsilon_t B^*_{t-1}}{P_{Y,t} Y_t} \frac{1}{(1+i^*_{t-1})\Theta_{t-1}}}_{\text{Change in portfolio investment position}}$$
$$\underbrace{-(1-\chi)\frac{Q_{S,t}(K_{S,t} - K_{S,t-1})}{P_{Y,t} Y_t}}_{\text{Change in FDI position}}.$$

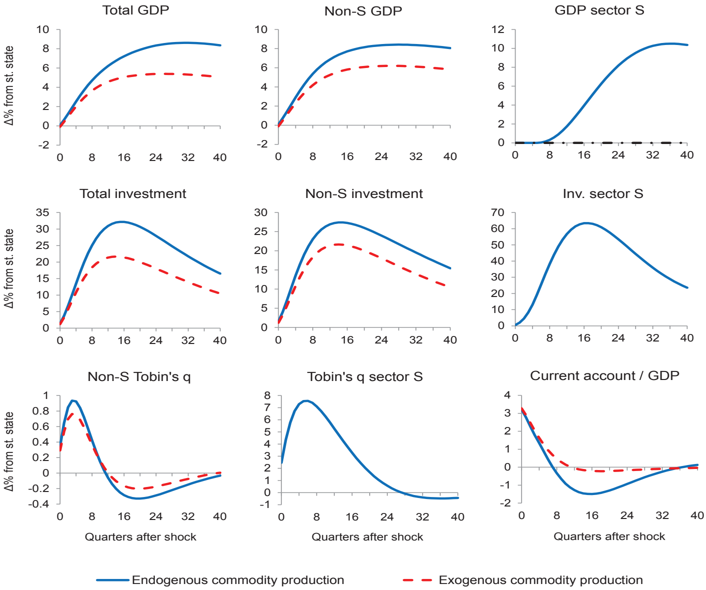
Results: IRFs to persistent and transitory commodity price shocks



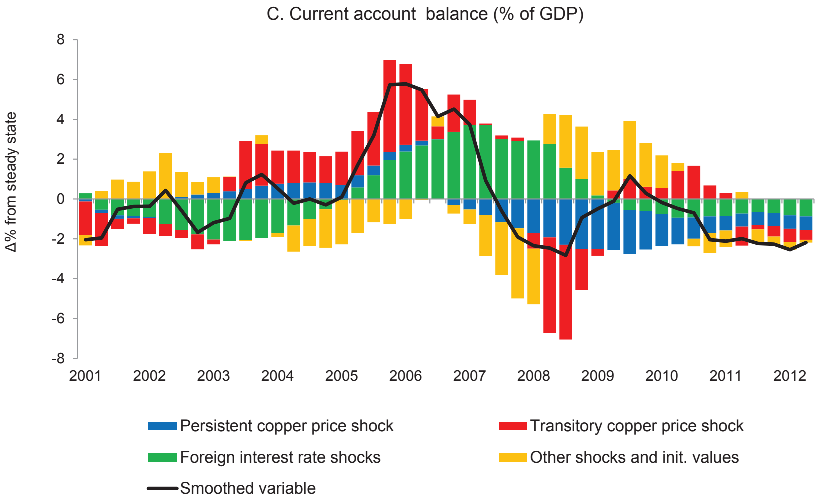
Components of the CA (persistent shock, imperfect information)



Closing the commodity investment channel



Historical decomposition of Chile's CA balance



Conclusions

- The interaction of commodity-specific investment and learning by agents is crucial to explain the gradual CA deterioration:
  - Higher savings in the short run, as agents fear that the commodity boom might be temporary.
  - Lower savings and higher investment afterwards, as agents learn about the actual persistence of the shock.
- Policy implications:
  - A gradual CA deterioration is not necessarily a sign of emerging imbalances: Product of investment in the commodity sector?
  - CA deficits due to FDI seem less worrisome than others, e.g. due to large portfolio inflows.
  - Anyhow, limited scope for monetary policy to affect investment and FDI in the commodity sector (not shown, see paper).

Appendix

Production and firms' problem in sector S

- Technology is Cobb-Douglas with decreasing returns to capital:

$$Y_{S,t} = A_{S,t} T_t^{\eta_S} K_{S,t-1}^{1-\eta_S},$$

where $A_{S,t}$ captures technological shocks specific to sector S (e.g. variations in mineral content of land), while T_t is growth trend.

- Define gross profits as:

$$\Pi_{S,t} = P_{S,t} Y_{S,t} - P_{C,t} T_t \kappa_S,$$

where $\kappa_S \geq 0$ are fixed costs.

- The nominal flow of investment is $P_{I_S,t} I_{S,t}$, and the firm is assumed to maximize its real cash flow $CF_{S,t} = \Pi_{S,t} - P_{I_S,t} I_{S,t}$:

$$\max E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \frac{CF_{S,t+i}}{P_{C,t+i}}.$$

- A fraction χ of the cash flow from sector S goes to the government, plus taxes τ_S on profits of foreign investors. Government balance:

$$\frac{\varepsilon_t B^*_{G,t}}{(1+i^*_t)\Theta_t} + P_{G,t} G_t = \varepsilon_t B^*_{G,t-1} + \tau_t P_{Y,t} Y_t + \chi CF_{S,t} + \tau_S (1-\chi)(\Pi_{S,t} - \delta_S Q_{S,t} K_{S,t-1}),$$

  where τ_t are lump-sum taxes on HHs (a fraction of nominal GDP).

- Government spending follows the structural balance rule:

$$\frac{P_{G,t} G_t}{P_{Y,t} Y_t} = \left[\begin{array}{c} \left(1 - \frac{1}{(1+i^*_{t-1})\Theta_{t-1}}\right) \frac{\varepsilon_t B^*_{G,t-1}}{P_{Y,t} Y_t} + \frac{\tau_t P_{Y,t} \bar{Y}_t}{P_{Y,t} Y_t} + \chi \frac{CF_{S,t}}{P_{Y,t} Y_t} \\ + \tau_S (1-\chi) \frac{\Pi_{S,t} - \delta_S Q_{S,t} K_{S,t-1}}{P_{Y,t} Y_t} - \frac{VC_t}{P_{Y,t} Y_t} - \frac{target}{P_Y Y} \end{array} \right].$$

- The term $VC_t = [\chi + \tau_S(1-\chi)] Y_{S,t} \varepsilon_t (P^*_{S,t} - \bar{P}^*_{S,t})$ is a cyclical adjustment that depends on the difference of $P^*_{S,t}$ and the long-run reference price $\bar{P}^*_{S,t}$.

Estimation of the model and computation of IRFs

- Estimation strategy:
  - Given exogeneity of the copper price for Chile, observe $\hat{b}_t$.
  - The state space representation to compute the likelihood is standard:

$$
\begin{aligned}
Y_t &= Hx_t + v_t, & v_t &\sim NID(0, \Sigma_v), \\
x_t &= D\hat{a}_t + E\hat{b}_t + Fx_{t-1} + G\epsilon_t, & \epsilon_t &\sim NID(0, \Sigma_\epsilon).
\end{aligned}
$$

  - With priors for a subset of parameters (leaving others calibrated), we estimate the model with Bayesian techniques.

- Computation of IRFs to commodity price shocks:
  1. Assume a persistent or transitory shock to the actual price $p^*_{S,t}$, and calculate the inferred persistent component $\hat{b}_t$ using the KF recursion.
  2. With $\hat{b}_t$ and $p^*_{S,t}$, compute $\hat{a}_t = p^*_{S,t} - \hat{b}_t$.
  3. Given $\hat{b}_t$ and $\hat{a}_t$, simulate the response of the economy.