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

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Motivation (I)

- The Chilean CAY reversed from a superavit in 2006 (4.6% of GDP) to a deficit in 2012-3 (-3.4%) in a context of high ToT
- Same pattern emerges for Peru and Canada
- Are there any fundamental common drivers underlying these CA evolutions?
- Old question. The CA deficit reflects an excess of absorption that need to be financed with debt.
- If markets sentiments change abruptly, then a macro adjustment must follow

Motivation (II)

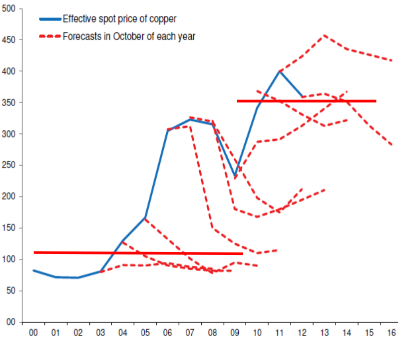
There are other stylized facts

- The long-run copper price after 2008 is revised upward. This eased the fiscal structural rule, allowing increases in G.
    - professional forecasters
    - external panel of experts that counsels on the parameters of the fiscal rule
- Mining investment played a greater role: from representing 2.5% of GDP on average (1976-2007) it grew to 4.7% on average 2008-12
- FDI in the mining sector explained 50% out of the total in 3 years in the period 2008-12

The copper price in the long run

Fig 6: Effective spot price of copper vs. forecasts by CRU Group

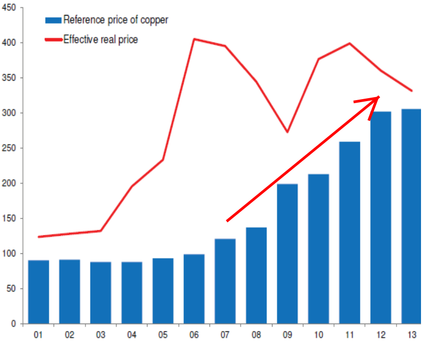
(USD cents per metric pound)



Source: Central Bank of Chile and CRU Group.

Fig 7: Government reference price of copper vs. effective price

(real USD cents per metric pound)

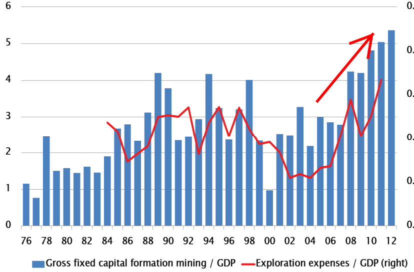


Source: Ministry of Finance and Central Bank of Chile.

Mining investment

Fig 3: Gross Investment in Mining & Exploration Expenses

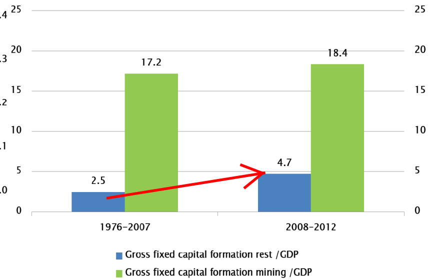
(% nominal GDP)



Source: Cochilco, CBCh and Metals Economics Group. Data for 2012 is preliminary.

Fig 4: Gross Investment in Mining & rest of the sectors

(% nominal GDP)



Source: BCCH. Data for 2012 is preliminary.

Hypothesis and objective

- H: The upward evolution of the copper price was persistent enough to move the perceived long run price up.
- This unlocked mining investment to expand copper production and that pushed the CA into a gradual deficit
- Goal: to examine the relevance of learning on the persistence of commodity price shocks for saving-investment dynamics in a DSGE model for a commodity-exporting SOE
- What we do?
- Modify the standard model with focus on CAY with learning (Medina, Soto and Munro, 2007) and with endogenous production of mining firms (instead of endowment, Medina and Soto, 2006)

Results

- The interaction of mining specific investment and learning by agents is crucial to explain the gradual CA adjustment
- Agents take time to learn on the true fundamental shock: they save more and invest less in the short run. But as agents infer more accurate the fundamental they spend leading to a gradual CA deficit
- Then, responses under learning lie in between responses of persistent and transitory shocks under RE
- Besides mining investment, by complementarity other demand components expand as well
- A historical decomposition of CAY reveals that the superavit is importantly explained by the transitory shock (as well as short after the Subprime Crisis), but since 2006 plays a greater role the fundamental copper price shock.

Stochastic process of the copper price

- Suppose the demean (real) copper price satisfies

$$pcur_t = a_t + b_t, \quad t = 0, 1, 2, \ldots$$

- where a_t captures a transitory "noise":

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

- b_t is an unobserved state variable that measures "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: real copper price (BML deflated by trade-adjusted external prices, IPE); 1960:1-2012:4.

Learning formation and estimation

- Optimal linear forecast of the state (Kalman Filter, KF):

$$\hat{b}_{t+1} = E[b_{t+1}|pcur_t, ...] = (\rho - K_t)\hat{b}_t + K_t pcur_t$$

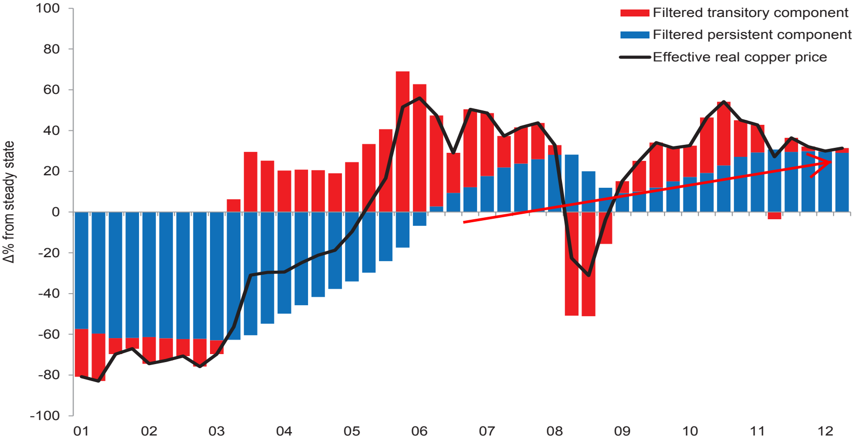
- K_t denotes the *Kalman gain* with $\Sigma_t = E(b_t - \hat{b}_t)^2$
- Rearranging and assuming KF at steady state

$$\hat{b}_t = \rho\hat{b}_{t-1} + \boxed{\frac{K}{\rho}}(pcur_t - \rho\hat{b}_{t-1})$$

- Learning on the persistent component are revised at a constant rate
- Estimation by ML yields $\rho = 0.979$ and $\sigma_u = 0.0375$ (ρ<1):
  1. Fix $K = 0.15$ allow agents to take 5 years to fully learn (Erceg and Levin, 2003; Céspedes and Soto, 2007)
  2. Obtain $\kappa = \sigma_u/\sigma_a = 0.17$ from equations that yield K and Σ
  3. Rewrite the model as

$$\begin{aligned} pcur_t &= b_t + \boxed{(\sigma_u/\kappa)}\xi_t, \qquad \xi_t \sim NID(0,1) \\ b_t &= \rho b_{t-1} + \sigma_u\zeta_t, \qquad \zeta_t \sim NID(0,1) \end{aligned}$$

Copper price decomposition



Model for Analysis and Simulation (MAS) with mining

- MAS follows Smets and Wouters (2003) and Christiano, Eichenbaum y Evans (2005).
- It shares many features, so we focus on key extensions:
- Allow for accumulation of capital specific to the sector S. The firm's technology is Cobb-Douglas with a fixed input (earth)
- The government owes a share χ out of total assets (FDI what remains). The government appropriates the earnings of its own share and levies a tax on foreign benefits
- The accumulation of capital in S is slow.
  1. Convex costs to start new investment projects (CEE, 2005)
  2. time to build (Kydland and Prescott, 1982; Uribe and Yue, 2006): it takes $n \geq 1$ periods to turn productive a project. Investment is the weighted sum of expenses done for projects in course.

Optimality, capital accumulation

- FOC, general case:

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

$$X_{S,t} \quad : \quad \varphi_0 \boxed{\frac{P_{I_S,t}}{P_{C,t}}} + \varphi_1 E_t \left\{ \Lambda_{t,t+1} \boxed{\frac{P_{I_S,t+1}}{P_{C,t+1}}} \right\} + \cdots$$

$$+ \varphi_{n-1} E_t \left\{ \Lambda_{t,t+n-1} \boxed{\frac{P_{I_S,t+n-1}}{P_{C,t+n-1}}} \right\}$$

$$= E_t \left\{ \begin{array}{c} \boxed{\Lambda_{t,t+n-1} \frac{Q_{S,t+n-1}}{P_{C,t+n-1}}} \left[\begin{array}{c} 1 - \Phi_S\left(\frac{X_{S,t}}{X_{S,t-1}}\right) \\ -\Phi'_S\left(\frac{X_{S,t}}{X_{S,t-1}}\right)\frac{X_{S,t}}{X_{S,t-1}} \end{array} \right] \\ + \boxed{\Lambda_{t,t+n} \frac{Q_{S,t+n}}{P_{C,t+n}}} \Phi'_S\left(\frac{X_{S,t+1}}{X_{S,t}}\right)\left(\frac{X_{S,t+1}}{X_{S,t}}\right)^2 \end{array} \right\}$$

- These equations determine the evolution of investment projects ($X_{S,t}$) and of the shadow price of capital ($Q_{S,t}$)

Government and CAY

- Government expenses are determined by the structural balance (long-run taxes)
- The CA balance equals the Δ in the international investment position:

$$CAY_t = \underbrace{\frac{\varepsilon_t B_t^*}{P_{Y,t} Y_t} \frac{1}{(1+i_t^*)\Theta_t} - \frac{\varepsilon_t B_{t-1}^*}{P_{Y,t} Y_t} \frac{1}{(1+i_{t-1}^*)\Theta_{t-1}}}_{\text{Change in the portfolio investment position}}$$

$$\underbrace{-(1-\chi)\frac{Q_{S,t}(K_{S,t} - K_{S,t-1})}{P_{Y,t} Y_t}}_{\text{Change in the position of the FDI}}$$

Strategy

Estimation:

1. Exogeneity of the copper price for Chile, observe $\hat{b}_t$
2. The state space representation to compute the likelihood is standard:

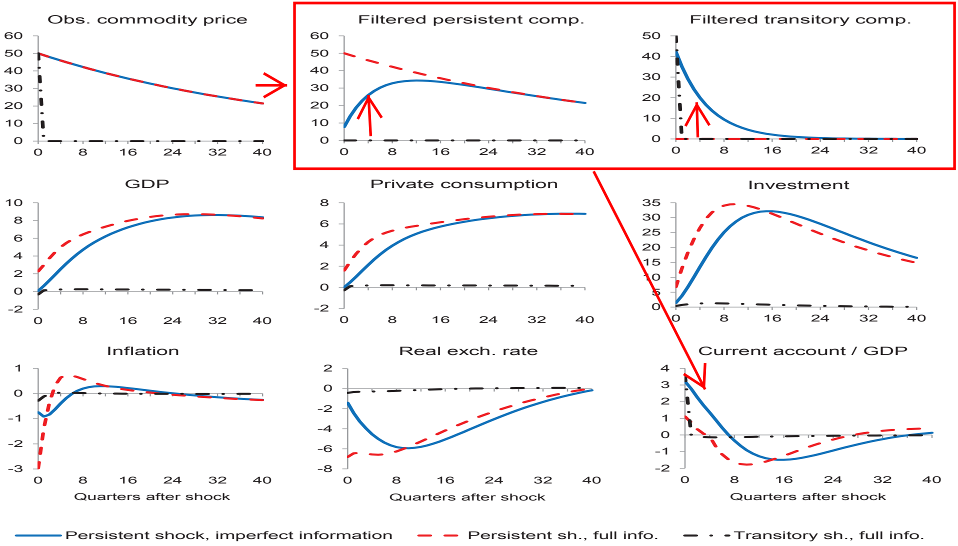
$$
\begin{aligned}
Y_t &= Hx_t + v_t, & v_t &\sim NID(0, \Sigma_v) \\
x_t &= \boxed{C\hat{a}_t} + \boxed{D\hat{b}_t} + Fx_{t-1} + G\epsilon_t, & \epsilon_t &\sim NID(0, \Sigma_\epsilon)
\end{aligned}
$$

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

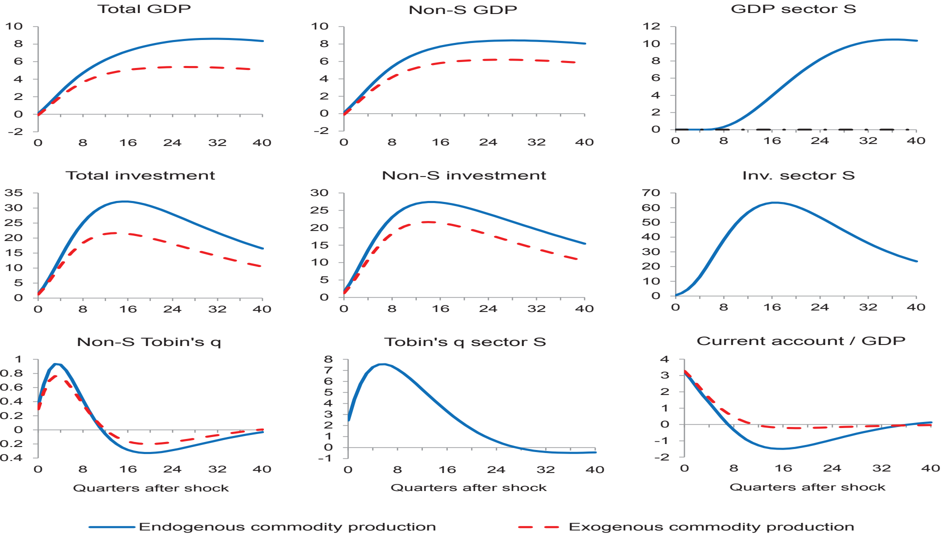
IRF:

1. Obtain the persistent component $\hat{b}_t$ with KF
2. With $\hat{b}_t$ and the price $pcur_t$, infer the noise $\hat{a}_t$
3. Given fundamental shocks jointly with $\hat{b}_t$ and $\hat{a}_t$, simulate the response of the economy

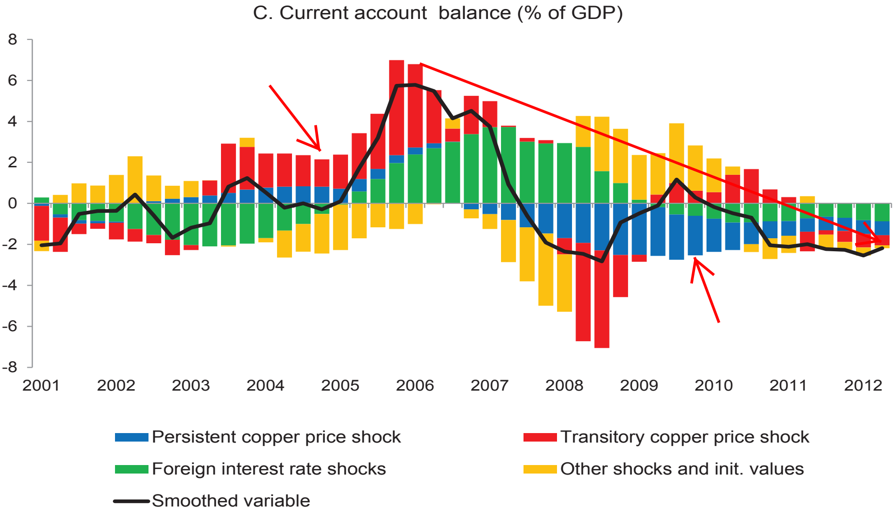
IRFs persistent and transit. copper price shock (+50%)



IRFs same shock but with copper endowment



CAY historical decomposition



Conclusions

- The copper price explains a significant share of the recent evolution of the CA
- More specifically, when the copper price rises permanently, the extension of the MAS model with mining jointly with learning explain first a CA superavit followed by a gradual deficit
- The CA deficit and the government expenses are the most endogenous variables of the model, but even so they reflect -through the model- efficient decisions that learn on the true persistence of a high copper price
- The CA deficit is consistent with the fundamentals of the model. There is some evidence for the expansionary MP conducted by CBs of central economies; but, this would not be the main driver at least for Chile.

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Production function and firm's problem

- Technology is Cobb-Douglas (with $\eta_S = \eta_{l_S} + \eta_{F_S} > 0$):

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

- where $A_{S,t} = l_{S,t}^{\eta_{l_S}} F_{S,t}^{\eta_{F_S}}$ is exogenous and captures technological shocks specific to mining sector
- Define gross benefits 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 that maximized the cash flow $CF_{S,t} = \Pi_{S,t} - P_{I_S,t} I_{S,t}$

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

Investment composition

- Investment real aggregator specific to the S sector combines home $I_{H,t}(S)$ and foreign $I_{F,t}(S)$ goods:

$$I_{S,t} = \left[\gamma_{I_S}^{\frac{1}{\eta_{I_S}}} I_{H,t}(S)^{1-\frac{1}{\eta_{I_S}}} + (1-\gamma_{I_S})^{\frac{1}{\eta_{I_S}}} I_{F,t}(S)^{1-\frac{1}{\eta_{I_S}}} \right]^{\frac{\eta_{I_S}}{\eta_{I_S}-1}}$$

- The FOC from expenses minimization (problem) result in usual demands

$$\begin{aligned} I_{H,t}(S) &= \gamma_{I_S} \left(\frac{P_{H,t}}{P_{I_S,t}} \right)^{-\eta_{I_S}} I_{S,t} \\ I_{F,t}(S) &= (1-\gamma_{I_S}) \left(\frac{P_{F,t}}{P_{I_S,t}} \right)^{-\eta_{I_S}} I_{S,t} \end{aligned}$$

Government balance

- A fraction χ of the cash flow from sector S is taken by the government, and there are taxes τ_S on benefits that belong to foreign shareholders
- The government budget constraint is

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

where τ_t are lump-sum taxes on households (as nominal GDP percentage)

Chilean fiscal Rule

- The public expenses follows the structural rule that assures a structural balance:

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

- 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 of the effective copper price $P^*_{S,t}$ minus the reference price $\bar{P}^*_{S,t}$