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

Jorge Fornero  Markus Kirchner

Macroeconomics Division
Mid-Term Forecasting Analysis Unit
Central Bank of Chile

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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**

(![](graph1.png))

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

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

(![](graph2.png))

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 about 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

\[ p_{cur_t} = a_t + b_t, \quad t = 0, 1, 2, \ldots \]

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

- \( K_t \) denotes the Kalman gain with \( \Sigma_t = E(b_t - \hat{b}_t)^2 \)

- Rearranging and assuming KF at steady state
  \[ \hat{b}_t = \rho \hat{b}_{t-1} + \frac{K}{\rho}(pcur_t - \rho \hat{b}_{t-1}) \]

- Learning on the persistent component are revised at a constant rate

- Estimation by ML yields \( \rho = 0.979 \) and \( \sigma_u = 0.0375 \) (\( \rho < 1 \)):
  1. Fix \( K = 0.15 \) allow agents to take 5 years to fully learn (Erceg and Levin, 2003; Céspedes and Soto, 2007)
  2. Obtain \( \kappa = \sigma_u / \sigma_\alpha = 0.17 \) from equations that yield \( K \) and \( \Sigma \)
  3. Rewrite the model as

\[
  pcu_{r_t} = \begin{cases} 
    b_t + (\sigma_u / \kappa) \xi_t, & \xi_t \sim NID(0, 1) \\
    b_t = \rho b_{t-1} + \sigma_u \zeta_t, & \zeta_t \sim NID(0, 1)
  \end{cases}
\]
Copper price decomposition

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Model for Analysis and Simulation (MAS) with mining


- 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 $\chi$ 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:

\[ K_{S,t} : \frac{Q_{S,t}}{P_{C,t}} = E_t \left\{ \Lambda_{t,t+1} \left[ \frac{Q_{S,t+1}}{P_{C,t+1}} (1 - \delta_S) + \frac{P_{S,t+1}A_S F_S^S (T_{t+1}, K_{S,t})}{P_{C,t+1}} \right] \right\} \]

\[ X_{S,t} : \varphi_0 \frac{P_{I_{S,t}}}{P_{C,t}} + \varphi_1 E_t \left\{ \Lambda_{t,t+1} \frac{P_{I_{S,t+1}}}{P_{C,t+1}} \right\} + \cdots \]

\[ + \varphi_{n-1} E_t \left\{ \Lambda_{t,t+n-1} \frac{P_{I_{S,t+n-1}}}{P_{C,t+n-1}} \right\} \]

\[ = E_t \left\{ \Lambda_{t,t+n-1} \frac{Q_{S,t+n-1}}{P_{C,t+n-1}} \left[ 1 - \Phi_S \left( \frac{X_{S,t}}{X_{S,t-1}} \right) \right] \right\} \]

\[ - \Phi'_S \left( \frac{X_{S,t}}{X_{S,t-1}} \right) \left( \frac{X_{S,t}}{X_{S,t-1}} \right)^2 \]

\[ + \Lambda_{t,t+n} \frac{Q_{S,t+n}}{P_{C,t+n}} \Phi'_S \left( \frac{X_{S,t+1}}{X_{S,t}} \right) \left( \frac{X_{S,t+1}}{X_{S,t}} \right)^2 \]

- 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 $\Delta$ in the international investment position:

$$ CAY_t = \frac{\varepsilon_t B_t^*}{P_{Y,t} Y_t} \frac{1}{(1 + i_t^*) \Theta_t} - \frac{\varepsilon_t B_{t-1}^*}{P_{Y,t} Y_t} \frac{1}{(1 + i_{t-1}^*) \Theta_{t-1}} $$

\[ \text{Change in the portfolio investment position} \]

\[ -(1 - \chi) \frac{Q_{S,t} (K_{S,t} - K_{S,t-1})}{P_{Y,t} Y_t} \]

\[ \text{Change in the position of the FDI} \]
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:

\[
Y_t = Hx_t + v_t, \quad v_t \sim NID(0, \Sigma_v)
\]
\[
x_t = C\hat{a}_t + D\hat{b}_t + Fx_{t-1} + G\epsilon_t, \quad \epsilon_t \sim NID(0, \Sigma_\epsilon)
\]

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

- **Total GDP**
- **Non-S GDP**
- **GDP sector S**
- **Total investment**
- **Non-S investment**
- **Inv. sector S**
- **Non-S Tobin’s q**
- **Tobin’s q sector S**
- **Current account / GDP**

Quarters after shock

Endogenous commodity production

Exogenous commodity production

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CAY historical decomposition

C. Current account balance (% of GDP)

- Persistent copper price shock
- Transitory copper price shock
- Foreign interest rate shocks
- Other shocks and init. values
- Smoothed variable

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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 $A_{S,t} = I_{S,t}^{\eta_l} F_{S,t}^{\eta_F}$ 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:

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

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

$$I_{H,t}(S) = \gamma_{IS} \left( \frac{P_{H,t}}{P_{I_{S,t}}} \right)^{-\eta_{IS}} I_{S,t}$$

$$I_{F,t}(S) = (1 - \gamma_{IS}) \left( \frac{P_{F,t}}{P_{I_{S,t}}} \right)^{-\eta_{IS}} I_{S,t}$$
Government balance

- A fraction $\chi$ of the cash flow from sector $S$ is taken by the government, and there are taxes $\tau_S$ 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 $\tau_t$ 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:

\[
\frac{P_{G,t}G_t}{P_{Y,t}Y_t} = \left[ \left( 1 - \frac{1}{(1+i^*_t)\Theta_t} \right) \frac{\varepsilon_t B_{G,t-1}^*}{P_{Y,t}Y_t} + \frac{\tau_t P_{Y,t}Y_t}{P_{Y,t}Y_t} + \chi \frac{CF_{S,t}}{P_{Y,t}Y_t} \right]
\]

- 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 \( \bar{P}_{S,t}^* \).