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

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Fifth BIS CCA Research Conference on “Challenges from changing international financial conditions”

Bogota, Colombia, 22-23 May 2014

*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.
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

Copper price (left axis)
Current account (left axis)
National savings (right axis)
National investment (right axis)

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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

Reference price of copper

Effective real price

US dollar cents per metric pound

01 02 03 04 05 06 07 08 09 10 11 12 13
Investment in mining vs other sectors

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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:

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

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 \(\Sigma_t = \text{var}[b_t|p_{S,t}^*, \ldots, p_{S,0}^*]\). 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 \(\hat{p}_{S,t+h}^* = \rho \hat{b}_t^h\) according to past prediction errors.

Parameters \(\sigma_a\) and \(\sigma_u\) not separately identified. Estimation (\(\rho < 1\)):

1. Fix \(K = 0.15\) (Erceg and Levin, 2003; Césedes and Soto, 2007).
2. Obtain \(\kappa = \sigma_u/\sigma_a = 0.17\) from KF equations that yield \(K\) and \(\Sigma\).
3. Rewrite the model as

\[
\begin{align*}
     p_{S,t}^* &= b_t + (\sigma_u/\kappa)\xi_t, \quad \xi_t \sim \text{NID}(0,1), \\
     b_t &= \rho b_{t-1} + \sigma_u \zeta_t, \quad \zeta_t \sim \text{NID}(0,1).
\end{align*}
\]

4. Obtain estimates by ML: \(\rho = 0.979, \sigma_u = 0.0375, \sigma_a = 0.2032\).
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.\(^1\)
- Key extensions:
  - 1. Endogenous commodity production using capital specific to the commodity sector and a fixed factor (land).
  - 2. The government owns a share \(\chi\) 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 $Y_{S,t} = F(K_{S,t-1}, \ldots)$. 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:
    \[ K_{S,t} = (1 - \delta_S)K_{S,t-1} + [1 - \Phi_S(\frac{X_{S,t-n+1}}{X_{S,t-n}})]X_{S,t-n+1}, \]
    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 $\varphi_j$ 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.
Cash flow maximizing capital-investment choice

- FOC, general case:

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

\[
X_{S,t} : \varphi_0 \frac{P_{I_S,t}}{P_{C,t}} + \varphi_1 E_t \left\{ \Lambda_{t,t+1} \frac{P_{I_S,t+1}}{P_{C,t+1}} \right\} + \varphi_2 E_t \left\{ \Lambda_{t,t+2} \frac{P_{I_S,t+2}}{P_{C,t+2}} \right\}
+ \cdots + \varphi_{n-1} E_t \left\{ \Lambda_{t,t+n-1} \frac{P_{I_S,t+n-1}}{P_{C,t+n-1}} \right\}
\]

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

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

- 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.
A fraction $\chi$ 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:

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

Change in portfolio investment position

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

Change in FDI position
Results: IRFs to persistent and transitory commodity price shocks

- Obs. commodity price
- Filtered persistent comp.
- Filtered transitory comp.
- GDP
- Private consumption
- Investment
- Inflation
- Real exch. rate
- Current account / GDP

Persistent shock, imperfect information: blue
Persistent sh., full info.: red
Transitory sh., full info.: black

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Components of the CA (persistent shock, imperfect information)

- Inv. sector S
- Inv. non-S
- Private savings
- Gov. savings
- CA / GDP

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Closing the commodity investment channel

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Endogenous commodity production

Exogenous commodity production
Historical decomposition of Chile’s CA balance

C. Current account balance (% of GDP)

Δ% from steady state


-8 -6 -4 -2 0 2 4 6 8

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 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:

\[ Y_{S,t} = A_{S,t} T^\eta_t K^{1-\eta}_S, \]

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 $\chi$ of the cash flow from sector $S$ goes to the government, plus taxes $\tau_S$ 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 $\tau_t$ are lump-sum taxes on HHs (a fraction of nominal GDP).

Government spending follows the structural balance rule:

$$\frac{P_{G,t} G_t}{P_{Y,t} Y_t} = \left[ \left( 1 - \frac{1}{(1 + i^*_{t-1}) \Theta_{t-1}} \right) \frac{\varepsilon_t B^*_{G,t-1}}{P_{Y,t} Y_t} + \frac{\tau_t P_Y, t \bar{Y}_t}{P_{Y,t} Y_t} + \chi \frac{CF_{S,t}}{P_{Y,t} Y_t} \right].$$

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:
    \[
    \begin{align*}
    Y_t & = Hx_t + \nu_t, & \nu_t & \sim NID(0, \Sigma_\nu), \\
    x_t & = D\hat{a}_t + E\hat{b}_t + Fx_{t-1} + G\epsilon_t, & \epsilon_t & \sim NID(0, \Sigma_\epsilon).
    \end{align*}
    \]
  - 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.