Joint project: Incorporating financial stability considerations in policy analysis: a model for Latin American countries.

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Motivation

• Joint project by 4 central banks (Chile, Colombia, Mexico and Peru).
• Objective: provide a model that can capture main features of those economies and that could be useful for policy analysis, aimed for cross country comparison.
• Common characteristics:
  - Exposure to commodity price fluctuations (all 4 are commodity exporters).
  - Exposure to financial factors (all 4 depend heavily on capital flows and external financing conditions).
  - Less developed financial system, concentrated in the banking sector.
The model

From survey: key ingredients to capture empirical regularities of these economies:

• Small open economy with commodity sector.
• Nominal rigidities with incomplete pass-through.
• Banking sector financing with financial frictions.
• Other rigidities: investment adjustment costs, habit formation in consumption and variable capital utilization.
• Monetary policy using short term interest rate (Taylor Rule).
Modelling strategy

• Depart from baseline model of Christiano, Trabandt and Walentin (JEDC 2011, CTW).

• Main extensions:
  - Domestic financial intermediaries (banks)
  - Commodity sector.
  - Observable country risk premium.
Financial sector extension
Setup

• We borrow the financial sector from Alpanda et al (2014), but we simplify it

• There is a continuum of
  – Households, who deposit savings at banks
  – Entrepreneurs, who use loans and net worth to accumulate capital, and
  – Banks, who intermediate between savers and borrowers

• All agents maximize their objectives (utility and dividends)

• This structure yields two types of spreads:
  – Deposit spread,
    \[ R_{D,t} = R_t (1 + \gamma^D_t) \]
  – Lending spread,
    \[ R_{E,t} = R_{D,t} (1 + \gamma^E_t), \text{ or } R_{E,t} = R_t (1 + \gamma^D_t)(1 + \gamma^E_t) \]
Monitoring costs and balance sheets

- Households pay a cost to monitor their deposits at Banks

\[ c_{h,\tau} + \left( 1 + Y^D \right) \frac{L^D_{h,\tau}}{P_{\tau}} + \frac{B_{h,\tau}}{P_{\tau} R_{\tau}} + \frac{S_{B_{h,\tau}}}{P_{\tau} \Phi_{h,\tau}} \leq W_{h,\tau} H_{h,\tau} + R_{D,\tau-1} \frac{L^D_{h,\tau-1}}{P_{\tau}} + \frac{B_{h,\tau-1}}{P_{\tau}} + \frac{S_{B_{h,\tau-1}}}{P_{\tau}} + \Lambda_{h,\tau} \]

- Banks pay a cost to monitor their loans to entrepreneurs

\[ \frac{D^B_{j,\tau}}{P_{\tau}} + R_{D,\tau-1} \frac{L^D_{j,\tau-1}}{P_{\tau}} + \left( 1 + Y^E \right) \frac{L^E_{j,\tau}}{P_{\tau}} \leq R_{E,\tau-1} \frac{L^E_{j,\tau-1}}{P_{\tau}} + \frac{L^D_{j,\tau}}{P_{\tau}} - \frac{\Phi \left( \frac{D^B_{j,\tau}}{P_{\tau}} / \frac{D^B_{j,\tau-1}}{P_{\tau}} - \mu_{d} \right)^2}{2 \left( \frac{D^B_{j,\tau}}{P_{\tau}} - \mu_{d} \right)^2} \]

- The 2 monitoring costs translate into a higher price of credit for entrepreneurs

\[ \frac{D^E_{i,\tau}}{P_{\tau}} + \frac{P_{k}}{P_{\tau}} \left[ K_{i,\tau} - (1-\delta)K_{i,\tau-1} + \tau_{k} \delta K_{i,\tau-1} \right] + R_{E,\tau-1} \frac{L^E_{i,\tau-1}}{P_{\tau}} \leq (1-\tau_{k}) \frac{Z_{i,\tau}}{P_{\tau}} K_{i,\tau-1} + \frac{L^E_{i,\tau}}{P_{\tau}} - \frac{\Phi \left( \frac{D^E_{i,\tau}}{P_{\tau}} / \frac{D^E_{i,\tau-1}}{P_{\tau}} - \mu_{d} \right)^2}{2 \left( \frac{D^E_{i,\tau}}{P_{\tau}} - \mu_{d} \right)^2} \]
Monitoring costs’ structure

The monitoring costs increase with debtors' leverage, capturing in reduced form the mechanism of BGG (1999)

\[ 1 + \gamma_t^D = \left( \frac{\gamma_{t-j}}{capb_{t-j} / L_{t-j}^E} \right)^{\chi_D} \exp\left( \tilde{e}_{D,t} \right), \]

where \( \frac{capb_{t-j}}{L_{t-j}^E} \) is the sector bank-capital-to-loans ratio, and \( \gamma_{t-j} \) is the bank capital requirement

\[ 1 + \gamma_t^E = (1 + \gamma_{t-1}^E)^{\chi_{E,1}} \left[ \chi_{E,0} \left( \frac{(1-m_{t-j})}{n_{t-j}/(p_{t-j}^k K_{t-j})} \right)^{\chi_{E,3}} \right]^{1-\chi_{E,1}} \exp(\tilde{e}_{E,t}), \]

where \( \frac{n_{t-j}}{p_{t-j}^k K_{t-j}} \) is entrepreneurs capital-to-assets ratio, and \( m_{t-j} \) is the effective loan-to-value ratio
Country risk premium

• Since households can borrow from abroad, we need to close the model with a dynamic premium on foreign bonds

$$\frac{S_t B^*_{h,t}}{P_t \Phi_t R^*_t}$$

$$\Phi_t = \Phi \exp\left\{-\tilde{\phi}_a (a_t - \bar{a}) - \tilde{\phi}_s [R^*_t - R_t - (R^* - R)] + \tilde{\phi}_t + \tilde{\phi}_{cp,t}\right\}$$

• where $a_t$ denotes net stock of foreign assets, $\tilde{\phi}_t$ is an unobserved risk shock, and $\tilde{\phi}_{cp,t}$ is an observed country risk premium shock (e.g., EMBI)

• $\tilde{\phi}_a$ ensures a unique steady state for $a_t$

• $\tilde{\phi}_s$ allows for a delayed exchange rate overshooting
Calibration and estimation results for Mexico

• The calibration of the financial sector for Mexico is
  – Steady state *loans-to-deposit spread* is **3.09 percent**, at annual terms (Banxico)
  – Steady state *deposit-to-target-rate spread* is **0 percent** (assumption)
  – Effective *loans-to-value* ratio is **65 percent** (weighted average from CNVB)
  – *Bank capital requirement* is **8 percent** (CNVB).

• And the estimation results imply the following:
  – When $\frac{n_t}{p_t^k K_t}$ increases by 20 percent, $R_{E,t}$ increases by 50 basis points (annual terms)
  – When $\frac{capb_t}{L_t^E}$ decreases by 20 percent, $R_{E,t}$ increases by 40 basis points (annual terms)
Calibration and estimation results for Mexico

- Estimation results in numbers

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Prior</th>
<th>Posterior</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10X_{E,3}$</td>
<td>Elasticity credit spread</td>
<td>Inv-$\Gamma$ 0.200 Inf</td>
<td>0.064 0.0167 0.0399 0.0884</td>
</tr>
<tr>
<td>$10X_D$</td>
<td>Elasticity deposit spread</td>
<td>Inv-$\Gamma$ 0.100 Inf</td>
<td>0.048 0.0223 0.0215 0.0741</td>
</tr>
<tr>
<td>$\chi_{E,1}$</td>
<td>Persistence lending spread</td>
<td>$\beta$ 0.500 0.0750</td>
<td>0.867 0.0200 0.8390 0.8905</td>
</tr>
<tr>
<td>$\vartheta^e$</td>
<td>Adj. costs Entrepreneurs</td>
<td>Inv-$\Gamma$ 0.500 Inf</td>
<td>0.240 0.0804 0.1253 0.3600</td>
</tr>
<tr>
<td>$\vartheta^b$</td>
<td>Adj. costs Banks</td>
<td>Inv-$\Gamma$ 0.500 Inf</td>
<td>0.291 0.1744 0.1069 0.4798</td>
</tr>
<tr>
<td>$\rho_{\xi_E}$</td>
<td>Persistence credit spread</td>
<td>$\beta$ 0.500 0.0750</td>
<td>0.820 0.0388 0.7645 0.8850</td>
</tr>
<tr>
<td>$\rho_{\xi_D}$</td>
<td>Persistence deposit spread</td>
<td>$\beta$ 0.500 0.0750</td>
<td>0.650 0.0562 0.5593 0.7433</td>
</tr>
<tr>
<td>$\sigma_{\xi_E}$</td>
<td>S.D. financial shock entrep.</td>
<td>Inv-$\Gamma$ 0.150 Inf</td>
<td>0.110 0.0201 0.0781 0.1422</td>
</tr>
<tr>
<td>$\sigma_{\xi_D}$</td>
<td>S.D. financial shock depo.</td>
<td>Inv-$\Gamma$ 0.150 Inf</td>
<td>0.157 0.0288 0.1099 0.2017</td>
</tr>
<tr>
<td>$b_{44}$</td>
<td>Persistence commodity price</td>
<td>N 0.500 0.5000</td>
<td>0.679 0.1176 0.4882 0.8775</td>
</tr>
<tr>
<td>$\sigma_{pco}$</td>
<td>S.D. commodity price shock</td>
<td>Inv-$\Gamma$ 0.500 Inf</td>
<td>1.412 0.1656 1.1498 1.6797</td>
</tr>
</tbody>
</table>
Estimated parameters - financial sector: (all countries)

<table>
<thead>
<tr>
<th>Estimated parameters: Financial sector</th>
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</thead>
<tbody>
<tr>
<td>Posterior mean (results from Metropolis-Hastings)</td>
<td>CL</td>
<td>CO</td>
<td>MX</td>
<td>PE</td>
</tr>
<tr>
<td>Elasticity</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Credit spread (*100)</td>
<td>1.58</td>
<td>0.86</td>
<td>0.64</td>
<td>0.47</td>
</tr>
<tr>
<td>Deposit spread (*100)</td>
<td>0.69</td>
<td>1.63</td>
<td>0.48</td>
<td>0.17</td>
</tr>
<tr>
<td>Persistence lending spread</td>
<td>0.43</td>
<td>0.84</td>
<td>0.87</td>
<td>0.43</td>
</tr>
<tr>
<td>Persistence</td>
<td></td>
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</tr>
<tr>
<td>Credit spread shock</td>
<td>0.42</td>
<td>0.56</td>
<td>0.82</td>
<td>0.57</td>
</tr>
<tr>
<td>Deposit spread shock</td>
<td>0.52</td>
<td>0.82</td>
<td>0.65</td>
<td>0.69</td>
</tr>
<tr>
<td>Standard deviation</td>
<td></td>
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</tr>
<tr>
<td>Credit spread shock</td>
<td>0.19</td>
<td>0.15</td>
<td>0.11</td>
<td>0.25</td>
</tr>
<tr>
<td>Deposit spread shock</td>
<td>0.09</td>
<td>0.28</td>
<td>0.16</td>
<td>0.14</td>
</tr>
</tbody>
</table>
IRF of a lending spread shock for Mexico
Commodity sector extension
Introduction

• The countries participating in the joint project are major commodity exporters. Hence, it is important to model the macro impact of commodity price and output fluctuations.

• This impact is not accounted for in the CTW baseline model:
  – Relatively low domestic demand for commodities, while domestic goods in the CTW model are both exported and consumed at home.
  – Commodity prices are in practice taken as exogenous, but the firms in the CTW model act as price setters.
  – Additional shocks to commodity prices and production.

• We therefore extend the CTW model by a commodity sector following Medina and Soto (2007), Medina, Munro and Soto (2007), Hevia and Nicolini (2013), Catao and Chang (2013), and Garcia-Cicco, Kirchner and Justel (2014).
Main assumptions of the commodity sector extension I

• Set of competitive firms that produce a homogeneous commodity good that is entirely exported.

• Thus commodity production has a pure income effect on domestic aggregate demand, which has expansionary effects on the rest of the economy.

• We further assume that a fraction of factor payments of commodity income is transferred abroad to foreign agents.
Main assumptions of the commodity sector extension II

• Specific modelling assumptions:
  – A representative firm produces a quantity $Y_t^{Co}$ of commodities.
  – Production evolves exogenously along the balanced growth path of the economy (i.e. $y_t^{Co} = Y_t^{Co} / z_t^+$ is a stochastic AR(1) process in logs).
  – The entire production is sold abroad at a given foreign price $P_t^{Co*}$ that evolves exogenously in real terms ($p_t^{Co*} = P_t^{Co*} / P_t^*$ is stochastic).
  – The income generated in the commodity sector is thus $S_t P_t^{Co*} Y_t^{Co}$, where $S_t$ is the nominal exchange rate. Domestic agents receive share $\chi \in [0,1]$ of this income and remaining share goes to foreign investors.

• Note: Since Ricardian equivalence holds in the model, it does not matter whether the government or private agents receive the share $\chi$ of commodity income, as long as $g_t$ is exogenous.
Modified current account relation I

- The introduction of the commodity sector and the presence of foreign ownership in that sector affect the equation that describes the evolution of net foreign assets.
- Expenses on imports, new purchases of net foreign assets, $A_{t+1}^*$, plus factor payments of commodity income to foreign agents must equal income from exports and from previously purchased net foreign assets:

$$S_t A_{t+1}^* + \text{expenses on imports}_t + \text{FP of comm. income}_t = \text{receipts from exports}_t + R_{t-1}^* \Phi_{t-1} S_t A_t^*$$
Modified current account relation II

- Factor payments of commodity income equal the share of that income that goes to foreign agents:

\[ FP of \text{ commodity income}_t = (1 - \chi)S_t P_t^{Co*} Y_t^{Co} \]

- Receipts from exports equal exports of the homogenous domestic good plus exports of the commodity good:

\[ \text{receipts from exports}_t = S_t P_t^X X_t + S_t P_t^{Co*} Y_t^{Co} \]

- In net, only the share of income from commodity exports received by domestic agents \((\chi S_t P_t^{Co*} Y_t^{Co})\) affects the accumulation of net foreign assets.
Modified GDP relations

- Further, the production of the commodity sector affects the evolution of GDP and its deflator.
- According to the definition of real GDP, it equals production of the domestic homogeneous good minus capital utilisation costs plus commodity production:

\[
GDP_t = Y_t - a(u_t)K_t + Y_t^{Co}
\]

- Similarly, nominal GDP is defined by (in relative price units of the homogeneous final good):

\[
p_t^{gdpg}GDP_t = Y_t - a(u_t)K_t + q_t p_t^c p_t^{co*} Y_t^{co}
\]

where \( a_r \): real exchange rate. \( p_r^c \): CPI relative price.
Additional parameters (Chile, 2001-13)

• Calibrated parameters:
  – Domestic share $\chi$: 0.56 ( = share of state-owned copper company Codelco plus taxes on foreign profits)
  – Mining exports to GDP ratio $\eta_{y,co}$: 0.15.

• Estimated parameters (posterior mean):
  – Persistence of commodity price shocks $\rho_{p_{co^*}}$: 0.88 (using real copper price as observed variable), s.d. $\sigma_{p_{co^*}}$: 14.8% per quarter.
  – Persistence of commodity production shocks $\rho_{y,co}$: 0.77 (using mining production as observed variable), s.d. $\sigma_{y,co}$: 3%.
Calibrated and estimated parameters - commodity sector (all countries)

<table>
<thead>
<tr>
<th></th>
<th>CL</th>
<th>CO</th>
<th>MX</th>
<th>PE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Commodities</strong></td>
<td>Mainly copper</td>
<td>Oil and others</td>
<td>Oil</td>
<td>Copper and others</td>
</tr>
<tr>
<td><strong>Calibrated parameters</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Domestic share</td>
<td>0.56</td>
<td>0.64</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Mining exports to GDP ratio</td>
<td>0.15</td>
<td>0.07</td>
<td>0.04</td>
<td>0.18</td>
</tr>
<tr>
<td><strong>Estimated parameters (M-H posterior mean)</strong></td>
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<tr>
<td>Commodity price shocks</td>
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</tr>
<tr>
<td>Persistence</td>
<td>0.88</td>
<td>0.62</td>
<td>0.68</td>
<td>0.85</td>
</tr>
<tr>
<td>Standard deviations</td>
<td>14.8%</td>
<td>10.0%</td>
<td>14.1%</td>
<td>6.1%</td>
</tr>
<tr>
<td>Commodity production shocks</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Persistence</td>
<td>0.77</td>
<td>0.74</td>
<td>0.83</td>
<td>0.79</td>
</tr>
<tr>
<td>Standard deviations</td>
<td>3.0%</td>
<td>2.5%</td>
<td>9.2%</td>
<td>4.1%</td>
</tr>
</tbody>
</table>
Transmission mechanism: commodity price shock (1)
Transmission mechanism: commodity price shock (2)
Estimation strategy

- Data: main macroeconomic (real, external and financial) variables (25). Quarterly data. Inflation targeting sample.
- Some differences in data transformation (e.g., seasonal adjustment, treatment of trends, etc).
- Posterior simulation: 1M draws from the Random Walk MH algorithm (discarding the first 500k draws).
- Different strategies to calculate the mode.
- Computations made with Dynare 4.4.2.
Data

Observed data vs smoothed variables

<table>
<thead>
<tr>
<th></th>
<th>GDP growth ($\Delta y$)</th>
<th>CPI ($\pi_c$)</th>
<th>Domestic interest rate ($R$)</th>
<th>Real exchange rate growth ($\Delta q$)</th>
<th>Credit growth ($\Delta E$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chile</strong></td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
<td><img src="image4" alt="Graph" /></td>
<td><img src="image5" alt="Graph" /></td>
</tr>
<tr>
<td><strong>Colombia</strong></td>
<td><img src="image6" alt="Graph" /></td>
<td><img src="image7" alt="Graph" /></td>
<td><img src="image8" alt="Graph" /></td>
<td><img src="image9" alt="Graph" /></td>
<td><img src="image10" alt="Graph" /></td>
</tr>
<tr>
<td><strong>Mexico</strong></td>
<td><img src="image11" alt="Graph" /></td>
<td><img src="image12" alt="Graph" /></td>
<td><img src="image13" alt="Graph" /></td>
<td><img src="image14" alt="Graph" /></td>
<td><img src="image15" alt="Graph" /></td>
</tr>
<tr>
<td><strong>Peru</strong></td>
<td><img src="image16" alt="Graph" /></td>
<td><img src="image17" alt="Graph" /></td>
<td><img src="image18" alt="Graph" /></td>
<td><img src="image19" alt="Graph" /></td>
<td><img src="image20" alt="Graph" /></td>
</tr>
</tbody>
</table>

Smoothed model variables are computed by the Kalman smoother at the posterior mean of the estimates parameters.
Goodness of fit: posterior predictive checking (1)

- We simulated 1000 draws of the model at the posterior means

- Each simulation consists of the same observations as in the original sample (and a burning sample)

- The outcome was a set of distributions of model-based moments

- Then we ask how likely is for the model to replicate the observed moment in the data.
Goodness of fit: posterior predictive checking (2)

<table>
<thead>
<tr>
<th></th>
<th>Standard deviations</th>
<th>Correlations with output growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile</td>
<td>17/25</td>
<td>18/25</td>
</tr>
<tr>
<td>Colombia</td>
<td>17/25</td>
<td>22/25</td>
</tr>
<tr>
<td>Mexico</td>
<td>15/25</td>
<td>11/25</td>
</tr>
<tr>
<td>Peru</td>
<td>13/25</td>
<td>20/25</td>
</tr>
</tbody>
</table>

The model can replicate with 95% confidence:
Variance decomposition\(^1\)

In per cent

<table>
<thead>
<tr>
<th>Variable</th>
<th>CL</th>
<th>CO</th>
<th>MX</th>
<th>PE</th>
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<tbody>
<tr>
<td>GDP growth</td>
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</tr>
<tr>
<td>CPI</td>
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<td>Domestic interest rate</td>
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<tr>
<td>Real exchange rate growth</td>
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<td></td>
</tr>
<tr>
<td>Credit growth</td>
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</tbody>
</table>

\(^1\) Contribution of the different shocks to the unconditional variances of the respective variables.
Policy analysis

• Policy exercises:
  – A sudden decrease in commodity prices
  – 3 policy scenarios:
    • Only policy rate.
    • Policy rate + LTV limits
    • Policy rate + capital requirements.
  – Macroprudential policy rule:
    \[ \text{INST}_t = \alpha + \beta \text{VAR}_t \]
    where \( \text{VAR}_t = \) real credit
How to measure effectiveness?

• A MPP multiplier:

\[
A) = \left| \frac{\sum (GDP_{MPP+MP} - GDP_{MP})}{\sum MPP} \right| \\
B) = \left| \frac{\sum (CR_{MPP+MP} - CR_{MP})}{\sum MPP} \right|
\]

• A GDP/Credit sacrifice ratio:

\[
\frac{(A)}{(B)} = \frac{\sum (GDP_{MPP+MP} - GDP_{MP})}{\sum (CR_{MPP+MP} - CR_{MP})}
\]
IRFS to a sudden decrease in commodity prices

No MPP case

- GDP
- Consumption
- Investment
- Real exchange rate
- CPI inflation
- Policy rate
- Net foreign assets
- Credit
- Spread
- Leverage entrepreneurs
- Leverage banks
- Commodity price

Chile
Colombia
Mexico
Peru
A sudden decrease in commodity prices: MPP multiplier

MPP multipliers\(^1\)

<table>
<thead>
<tr>
<th>Credit</th>
<th>Bank capital requirement</th>
<th>LTV ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile</td>
<td>Colombian</td>
<td>Mexico</td>
</tr>
</tbody>
</table>

For GDP:

<table>
<thead>
<tr>
<th>Bank capital requirement</th>
<th>LTV ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile</td>
<td>Colombian</td>
</tr>
</tbody>
</table>

\(^1\) Calculated as \(100 \times \sum_{i=1}^{20} (\hat{Y}_{\text{MP}} - \hat{Y}_{\text{NP}})/\sum_{i=1}^{20} MPP, Y \in \{\text{GDP, Credit}\}\).
A sudden decrease in commodity prices: GDP/Credit sacrifice ratio

GDP/Credit sacrifice ratio\(^1\)

<table>
<thead>
<tr>
<th>Bank capital requirement</th>
<th>LTV ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile</td>
<td>Colombia</td>
</tr>
<tr>
<td>50</td>
<td>40</td>
</tr>
</tbody>
</table>

1 Calculated as \(100 \times \frac{\sum_{t=0}^{T} (Y_{MPP+NR} - Y_{NR})/\sum_{t=0}^{T} (Credit_{MPP+NR} - Credit_{NR})}{\sum_{t=0}^{T} (Y_{MPP+NR} - Y_{NR})/\sum_{t=0}^{T} (Credit_{MPP+NR} - Credit_{NR})}\).
Conclusions

• The model can capture relatively well some of the stylized facts of the 4 economies.
  – Real variables dynamics.
  – Quantitative importance of commodity prices and other external factors.
• However, more work is needed to capture the dynamics of the financial sector.
• Importance of commodity price shocks differ across countries.
• Effectiveness of instruments differ across countries.