Countercyclical prudential tools in an estimated DSGE model

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Motivation

- Basel III strengthens prudential requirements and introduces systemic risk tools: e.g. a counter-cyclical capital buffer.
- Some jurisdictions already use other macro-prudential instruments to mitigate procyclicality.
  - For example, dynamic loan loss provisions in Spain and several Latin American countries.
- The implementation of Basel III, its effectiveness and complementarity with other tools have deserved considerable attention in policy circles and academic research.
Contribute by:

- Developing a DSGE model of a small-open economy with a banking sector and endogenous loan’s default.
- Estimating the model with data for Uruguay: dollarized banking system and dynamic provisions since 2001.
- Conducting “what if” analysis under counter-cyclical capital requirements and dynamic loan loss provisions.

Work in progress:

- Present here the model and a comparison of IRFs to internal and external shocks.
- One of many inputs to policy and for assessing alternative risk scenarios.
Households:
- Provide labor and consume final goods.
- Demand money (pesos) and deposits (dollars).
- Also invest in foreign bonds in dollars.

Entrepreneurs:
- Manage the stock of capital.
- Have heterogeneous productivity with costly-state verification.
- Endogenous default (à la Bernanke, Gertler and Gilchrist, 1999).
- Liability dollarization.

Banks:
- Competitive banking sector financed by deposits and bank capital.
- Lend to entrepreneurs (optimal contracting) and buy foreign assets.
- Dollarized.
- Subject to bank regulations.
Balance sheet constraint is:

\[ L_t + B_t^b + LLP_t = (1 - \tau_t)D_t + N_t^b, \]

where

- \( L_t \) are loans and \( B_t^b \) are holding of foreign assets.
- \( LLP_t \) is the flow of loan loss provisions (the stock is \( LLR_t \)).
- \( D_t \) are deposits and \( \tau_t \) is the reserve requirement.
- \( N_t^b \) is bank capital.
- \( LLR_t \) and \( N_t^b \) are pre-determined at \( t \).
Banks: balance sheet

- **Balance sheet constraint is:**

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- **Bank’s loses due to default on loans at \( t + 1 \) are** \((R^L_t - \tilde{R}^L_{t+1})L_t\).
Banks: balance sheet

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- \( N_t^b \) is bank capital.
- \( LLR_t \) and \( N_t^b \) are pre-determined at \( t \).

- Bank’s loses due to default on loans at \( t + 1 \) are \( (R_t^L - \tilde{R}_{t+1}^L)L_t \).

- Hence, the utilization of loan loss provisions in \( t + 1 \) is:

\[ LLU_{t+1} = \min \left\{ (R_t^L - \tilde{R}_{t+1}^L)L_t, LLR_t + LLP_t \right\} \]

- The stock of loan loss provisions evolves according to

\[ LLR_{t+1} = LLR_t + LLP_t - LLU_{t+1}. \]
Bank’s objective function is:

\[ E_t \left\{ r_{t,t+1}^* \left( \tilde{N}_{t+1}^b - PEN_{t+1} \right) \right\} - COST_t \]

where \( r_{t,t+1}^* \) is a discount factor.
Banks: objective function

- Bank’s objective function is:

\[ E_t \left\{ r_{t,t+1}^* \left[ \tilde{N}_{t+1}^b - PEN_{t+1} \right] \right\} - COST_t \]

where \( r_{t,t+1}^* \) is a discount factor.

- Income at \( t + 1 \) is:

\[ \tilde{N}_{t+1}^b = \tilde{R}_{t+1}^L L_t + B_t^b R_t^* + LLU_{t+1} - (R_t^D - \tau_t) D_t. \]
Banks: objective function

- Bank’s objective function is:

\[ E_t \left\{ r^*_{t,t+1} \left[ \tilde{N}^b_{t+1} - PEN_{t+1} \right] \right\} - COST_t \]

where \( r^*_{t,t+1} \) is a discount factor.

- Income at \( t + 1 \) is:

\[ \tilde{N}^b_{t+1} = \tilde{R}^L_{t+1} L_t + B^b_t R^*_t + LLU_{t+1} - (R^D_t - \tau_t)D_t. \]

- Portfolio-adjustment costs are:

\[ COST_t = s_t [S^L L^2_t + (B^b_t)^2]. \]

where \( s_t \) is an exogenous shock.
Empirical evidence shows that banks target a desired level of bank capital $\gamma_t$ above the minimum required by regulation $\gamma^R_t$. $\gamma_t - \gamma^R_t$ is the desired buffer due to precautionary reasons ($\gamma^0_t$) and bankers’ forecast of economic conditions.

$$\gamma_t = \gamma^R_t + \gamma^0_t + \alpha_d (E\{\text{def}_{t+1}\} - \text{def}_{ss}) + \alpha_l (E\{\Delta L_{t+1}\} - \Delta L_{ss}).$$
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Bank capital is costly, so that too large buffers are not profitable. We take the following modeling shortcut:

$$PEN_{t+1} = \frac{\phi_D}{2} \left( \frac{\tilde{N}^b_{t+1}}{\tilde{A}^b_{t+1}} - \gamma_t \right)^2 \tilde{N}^b_{t+1}$$

where assets in $t + 1$ are

$$\tilde{A}^b_{t+1} = \tilde{R}^L_{t+1} L_t + B^b_t R^*_t + LLU_{t+1} + \tau_t D_t$$
The model features several bank regulations:

- Capital requirements (minimum and counter-cyclical): $\gamma^R_t$
- Loan loss provisions (static and dynamic): $LLP_t$
- Reserve requirements: $\tau_t$
The model features several bank regulations:

- Capital requirements (minimum and counter-cyclical): $\gamma^R_t$
- Loan loss provisions (static and dynamic): $LLP_t$
- Reserve requirements: $\tau_t$

In the exercises we consider:

- Benchmarks:
  - Constant minimum capital requirement: $\gamma^R_t = \gamma^R_0$
  - Static loan loss provisions: $LLP_t = l_0 \text{def}_t L_t$
- Counter-cyclical capital requirement:
  - Feedback to real credit growth: $\gamma^R_t = \gamma^R_0 + \alpha^R_l (\Delta L_t - \Delta L_{ss})$
  - Feedback to real GDP growth: $\gamma^R_t = \gamma^R_0 + \alpha^R_y (\Delta Y_t - \Delta Y_{ss})$
- Dynamic loan loss provisions:
  - $LLP_t = l_0 \text{def}_t L_t + l_1 (\text{def}^{ss} - \text{def}_t) l_0 L_t$
Calibration and estimation

 Calibration:

▶ Financial targets (average 2008-2015):
  ★ Quarterly default rate: 1.3 % (default / loans)
  ★ Quarterly active rate: 2.4 % (loans interest / loans)
  ★ Quarterly passive rate: 0.3 % (deposit interest / deposits)
  ★ Loans share: 48 % (loans / (loans + bonds))
  ★ Capital adequacy ratio: 8.49 % (capital / assets)
  ★ Minimum capital requirement: 4.88 % (minimum capital / assets)
  ★ Provisions coverage ratio: 6.73 % (provisions / loans)

 Estimation, Bayesian approach:

▶ Estimation results
▶ Goodness of fit

▶ Macro variables: growth of output, consumption, investment, inflation, policy rate, nominal depreciation, world interest rate, country premium, inflation and output of commercial partners.
▶ Financial variables: growth of credit, deposits, bank’s capital, default rate, spread, regulatory capital and provisions.
What explains financial variables?

Variance decomposition

<table>
<thead>
<tr>
<th>Source of shocks</th>
<th>Credit growth</th>
<th>Default</th>
<th>Bank capital growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>International financial factors</td>
<td>68</td>
<td>62</td>
<td>45</td>
</tr>
<tr>
<td>Domestic real factors</td>
<td>28</td>
<td>8</td>
<td>1</td>
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<tr>
<td>Entrepreneurs productivity shock</td>
<td>1</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>Bank costs</td>
<td>1</td>
<td>0</td>
<td>37</td>
</tr>
<tr>
<td>Others</td>
<td>2</td>
<td>6</td>
<td>17</td>
</tr>
</tbody>
</table>
“What if” analysis

- Observe and compare the dynamics of real and banking variables under different regulations:
  - Benchmark with constant minimum capital requirement and static provisions.
  - Countercyclical capital buffer with feedback to credit growth and to GDP growth.
  - Dynamic provisions.

- For two positive (expansionary) shocks:
  - A reduction to the country risk premium.
  - A reduction to the idiosyncratic risk premium of entrepreneurs.
Positive country risk premium shock: Benchmark
Positive country risk premium shock: CCB

Real credit growth rule $\gamma_t^R = \gamma_0^R + \alpha_l^R (\Delta L_t - \Delta L_{SS})$

Solid blue: baseline no rule. Dashed red: $\alpha_l^R = 0.5$. Dashed black: $\alpha_l^R = 1.0$. Dotted magenta: $\alpha_l^R = 2.0$. 

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Countercyclical tools in DSGEM

Madrid, 25 May 2017 14 / 22
Positive country risk premium shock: CCB

Real GDP growth rule \( \gamma^R_t = \gamma^R_0 + \alpha^R_y (\Delta Y_t - \Delta Y_{ss}) \)
Positive country risk premium shock: Dynamic provisions\[ LLP_t = l_0 \text{def}_t L_t + l_1 (\text{def}^{ss} - \text{def}_t) l_0 L_t \]

Solid blue: static prov \((l_1 = 0)\). Dashed red: \(l_1 = 0.5\). Dashed black: \(l_1 = 1.0\). Dotted magenta: \(l_1 = 1.5\).
Positive country risk premium shock: comparison

- **Counter-cyclical capital buffer:**
  - Generates buffer without major counter-cyclical real effects.
  - GDP rule has quicker and stronger effects over bank capital.
  - Notice: credit/GDP decreases!
  - Not trivial its use as a guide for countercyclical policy.

- **Dynamic provisions:**
  - Generate buffer with some real effects.

- In terms of buffering and smoothing cycles under external positive financial shocks, dynamic provisions seems to outperform CCB.
Positive entrepreneurs risk premium shock: CCB

Real credit growth rule $\gamma_t^R = \gamma_0^R + \alpha_l^R(\Delta L_t - \Delta L_{ss})$

Solid blue: baseline no rule. Dashed red: $\alpha_l^R = 0.5$. Dashed black: $\alpha_l^R = 1.0$. Dotted magenta: $\alpha_l^R = 2.0$. 

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Countercyclical tools in DSGEM

Madrid, 25 May 2017 18 / 22
Positive entrepreneurs risk premium shock: CCB

Real GDP growth rule $\gamma_t^R = \gamma_0^R + \alpha_y^R(\Delta Y_t - \Delta Y_{ss})$

Solid blue: baseline no rule. Dashed red: $\alpha_y^R = 0.5$. Dashed black: $\alpha_y^R = 1.0$. Dotted magenta: $\alpha_y^R = 2.0$. 

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Positive entrepreneurs risk premium shock: Dynamic provisions $LLP_t = l_0\text{def}_t L_t + l_1 (\text{def}^{ss} - \text{def}_t) l_0 L_t$

Solid blue: static prov ($l_1 = 0$). Dashed red: $l_1 = 0.5$. Dashed black: $l_1 = 1.0$. Dotted magenta: $l_1 = 1.5$. ▶ Auxiliary chart
Final remarks

- CCB and dynamic provisions are effective in generating buffers that may cover future losses.
- They may or may not have counter-cyclical real effects.
- Source of shocks matters to:
  - Select the policy tool: dynamic provisions seems to outperform CCB under external financial shocks.
  - Select the indicator variable for the CCB rule: credit to GDP does not seem adequate under external financial shocks.
  - Calibrate the size of the dynamic provisioning: the same calibration may be excessively counter-cyclical if the shock is domestic instead of external.
Thank you for your attention!
Households

- Continuous of mass 1.
- Utility function: $v_t \left[ u(c_t, h_t) + \nu_t \frac{(M_t^a)^{1-\sigma_M - 1}}{1-\sigma_M} \right]$, where

\[
M_t^a = \left[ (1 - o_M) \frac{1}{\eta_M} \left( \frac{S_t D_t}{P_t} \right)^{\frac{\eta_M - 1}{\eta_M}} + o_M \left( \frac{M_t^d}{P_t} \right)^{\frac{\eta_M - 1}{\eta_M}} \right]^{\frac{\eta_M}{\eta_M - 1}}
\]

- Budget constraint with financial assets

\[
B_t + S_t B_t^* + M_t + S_t D_t... = R_{t-1} B_{t-1} + S_t R_{t-1} B_{t-1}^* + M_{t-1} + S_t R_{t-1}^D D_{t-1} + ...
\]
At the end of each period they buy new capital ($K_t$), financed with net worth ($N_t$) and loans from banks ($L_t$) such that $Q_t K_t = N_t + L_t S_t$, where $Q_t$ is the price of capital and $S_t$ is the exchange rate.
Entrepreneurs

- At the end of each period they buy new capital ($K_t$), financed with net worth ($N_t$) and loans from banks ($L_t$) such that
  $$Q_t K_t = N_t + L_t S_t,$$
  where $Q_t$ is the price of capital and $S_t$ is the exchange rate.

- Heterogeneous technology: if they buy $Q_t K_t$ at $t$ they obtain
  $$\omega_{t+1} R_{t+1}^e Q_t K_t$$
  in $t + 1$:
  - $\omega_{t+1}$ is i.i.d. with cdf $F_t(\omega_{t+1})$, $E(\omega_t) = 1$ and std dev $\sigma_t$
    (exogenous).
  - $R_{t+1}^e$ is the aggregate return on capital.
At the end of each period they buy new capital ($K_t$), financed with net worth ($N_t$) and loans from banks ($L_t$) such that $Q_tK_t = N_t + L_tS_t$, where $Q_t$ is the price of capital and $S_t$ is the exchange rate.

Heterogeneous technology: if they buy $Q_tK_t$ at $t$ they obtain $\omega_{t+1}R_{t+1}Q_tK_t$ in $t + 1$:

- $\omega_{t+1}$ is i.i.d. with cdf $F_t(\omega_{t+1})$, $E(\omega_t) = 1$ and std dev $\sigma_t$ (exogenous).
- $R_{t+1}$ is the aggregate return on capital.

Costly state verification: $\omega_t$ is private information. It may be verified by third parties by paying a monitoring cost $\mu$ (as a fraction of income).
The optimal debt contract specifies an interest rate on the loan $R_t^L$ and a cut-off value $\bar{\omega}_{t+1}$ such that:

- Entrepreneurs with low realizations of productivity default, the bank pays the monitoring cost and seizes the defaulting entrepreneurs’ assets.
- Entrepreneurs with sufficiently high productivity pay the established interest rate and keep the difference.
The optimal debt contract specifies an interest rate on the loan $R^L_t$ and a cut-off value $\tilde{\omega}_{t+1}$ such that:

- Entrepreneurs with low realizations of productivity default, the bank pays the monitoring cost and seizes the defaulting entrepreneurs’ assets.
- Entrepreneurs with sufficiently high productivity pay the established interest rate and keep the difference.

The optimal contract: choose $\text{lev}_t^e = \frac{Q_t K_t}{N_t}$, $\tilde{\omega}_{t+1}$ and $R^L_t$ to maximize expected return to entrepreneurs, subject to banks’ participation constraint (opportunity cost: $\tilde{R}^L_{t+1}$).
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In equilibrium, $\tilde{R}_{t+1}^L$ is the realized return on loans.

In equilibrium, the fraction of loans in default is $\text{def}_t = F_{t-1}(\tilde{\omega}_t)$. 
The Model

- **Other features:**
  - Production using capital and labor.
  - Endowment of commodities.
  - Habits in consumption.
  - Investment adjustment costs.
  - Sticky prices and wages.
  - Delayed pass-through.
  - Interest rate rule.
  - Ricardian fiscal policy.

- **“Macro” shocks:**
  - Domestic: Productivity, consumption, investment, government expenditures, production of commodities, demand for liquidity.
  - External: Interest rates, country premium, deviations from UIP, foreign output and inflation, price of commodities.
## Cuadro: Estimation

<table>
<thead>
<tr>
<th>Param.</th>
<th>Description</th>
<th>Estimation</th>
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</thead>
<tbody>
<tr>
<td>μ</td>
<td>Monitoring costs</td>
<td>0.03</td>
</tr>
<tr>
<td>ν</td>
<td>Survival rate of entrepreneurs</td>
<td>0.90</td>
</tr>
<tr>
<td>φ_B</td>
<td>Elasticity of bank penalty function</td>
<td>150</td>
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<tr>
<td>γ_{DEF}</td>
<td>Banks capital default component</td>
<td>0.08</td>
</tr>
<tr>
<td>γ_{L}</td>
<td>Banks capital credit component</td>
<td>0.09</td>
</tr>
<tr>
<td>ρ_{σω}</td>
<td>Persistence entrepreneurs’ shock</td>
<td>0.74</td>
</tr>
<tr>
<td>ε_{σω}</td>
<td>Std. dev. entrepreneurs’ shock</td>
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<tr>
<td>ρ_{γ0}</td>
<td>Exogenous capital rule persistence</td>
<td>0.98</td>
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<tr>
<td>ρ_{γ_{reg}}</td>
<td>Banks capital buffer persistence</td>
<td>0.97</td>
</tr>
<tr>
<td>ε_{γ0}</td>
<td>Exogenous capital rule std. dev.</td>
<td>0.34</td>
</tr>
<tr>
<td>ε_{γ_{reg}}</td>
<td>Banks capital buffer std. dev.</td>
<td>0.27</td>
</tr>
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</table>
## Goodness of fit

**Cuadro: Standard deviations (%)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Data</th>
<th>Base</th>
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</thead>
<tbody>
<tr>
<td>GDP growth</td>
<td>1.41</td>
<td>1.85</td>
</tr>
<tr>
<td>Cons. growth</td>
<td>1.49</td>
<td>2.15</td>
</tr>
<tr>
<td>Inv. growth</td>
<td>4.66</td>
<td>2.23</td>
</tr>
<tr>
<td>Country premium</td>
<td>0.28</td>
<td>0.79</td>
</tr>
<tr>
<td>R</td>
<td>0.83</td>
<td>1.00</td>
</tr>
<tr>
<td>Default</td>
<td>0.31</td>
<td>2.5</td>
</tr>
<tr>
<td>Bank’s capital growth</td>
<td>5.3</td>
<td>6.6</td>
</tr>
<tr>
<td>Credit growth</td>
<td>7.28</td>
<td>6.75</td>
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<tr>
<td>Deposits growth</td>
<td>3.15</td>
<td>7.37</td>
</tr>
<tr>
<td>Required buffer capital growth</td>
<td>17.61</td>
<td>11.22</td>
</tr>
<tr>
<td>Bank’s buffer capital growth</td>
<td>7.66</td>
<td>19.01</td>
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