The Rebirth of DSGE: Large Scale Models for Monetary-Fiscal-Financial Policy Analysis[1]

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[1] DISCLAIMER: The views expressed here are my own and do not necessarily represent those of the St. Edmund Hall, U. of Oxford or the Saïd Business School, nor the Central Bank of Chile or its Board. Based on "A Financial Stability Analysis for the Chilean Economy" (Kazakova, Martinez, Peiris, Tsomocos, 2019); "Financial Stability and Macro-Prudential Policy in Emerging Economies: an Application to Chile."(Martinez, Peiris, Tsomocos, 2020)

Complexity and Modelling

The modern toolkit of policy makers include

- VaRs/Panel - assumptions about the endogenous structure cannot be inferred from the data
- Network models - not trivial to reconcile with wider macroeconomic variables
- Elasticities approach - estimates depend on state of economy
- Theoretical models - qualitative results often hold only under specific conditions
- DSGE models - ...

DSGE Models

Modern DSGE models tend to be

- large
- missing key sectors of the economy - not rich enough!
- calibrated - relying on elasticities assumptions rather than observed time-series dynamics
- faithful to theory rather than reality - complexity makes deep parameters difficult to estimate/identify

Estimated DSGE Models

Estimating Models is difficult! But...

- can use very rich amounts of financial and real data
- estimate important elasticities
- discipline the path of policy in a manner consistent with data
- understand which parameters are not identified - tells us to be careful about assumptions!

Computationally very intensive and cumbersome but the results have an empirical basis

Estimated DSGE Models

The modern economy requires analysis of the financial sector

- this requires modelling supply and demand for a large set of assets across multiple agents
- demand elasticities can be captured to an extent through estimated adjustment costs
- capturing portfolio decisions helps us to model regulatory effects
- to do all this, we need portfolio level granular data!

Our contribution

Modern analysis must be consistent with general equilibrium reasoning. GE reasoning must be consistent with time series data.

The data we use is driven by the model blocks

- Use as a core a SOE NK-model:
  - GDP, consumption, inflation, interest rate, government debt, government spending, exchange rate, current account
- Introduce endogenous financial frictions through wedges:
  - loans, debt-equity ratio
- introduce optimizing financial sector:
  - bank equity, bank capital adequacy ratios, bank bond holdings, bank deposits, bank loans, bank non-performing loans rates

We need to obtain simulations at least at 2nd order level to utilize the power of the model and estimation.

Dynamic Models

- **Financial frictions and business cycles** (Bernanke et. al., 1999, Gertler and Kiyotaki, 2010, Jermann and Quadrini, 2012, Mendoza, 2012, Christiano, Motto, Rostagno, 2014, Iacoviello, 2015, Gerali et. al., 2010)
- **Macro effects of capital requirements** (Van den Heuvel, 2008, Clerc et. al., 2015, Begenau, 2018)
- **Shadow banking in business cycle models** (Begenau and Landvoigt, 2017, Gertler et. al., 2016, Meeks et. al., 2017, Nelson et. al., 2017, Feve and Pierrard, 2017, Moreira and Savov, 2017)

The Challenge

Useful normative analysis requires the interaction between households, banks, the production sector, the government and the external sector

Goodhart et al (2006), Tsomocos (2003) etc presents a unified framework to study this within a General Equilibrium model. Estimated dynamic models used by policymakers include

- the FRBNY DSGE model (but banks are risk neutral and only one type of debt)
- the ECB
- the IMF

Macroprudential policy analysis difficult - capital and portfolio decisions matter.

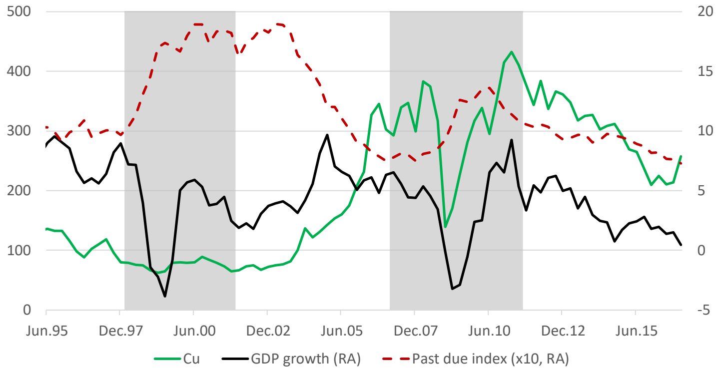
Financial (In)Stability in Chile

- Chile has experienced three relevant episodes in the last 40 years with different degrees of relevance and policy/regulatory environments.
- The current situation is the result of convergence to an open economy with safer banking system. Chile has inflation targeting with free floating exchange rate, which acts as a natural stabilizer of international shocks.
- However, there is still dependence of copper prices that may feedback to the financial sector directly or **indirectly**.

Commodity price shocks' role

- In particular, recent periods of fragility seem related to commodity price fluctuations...

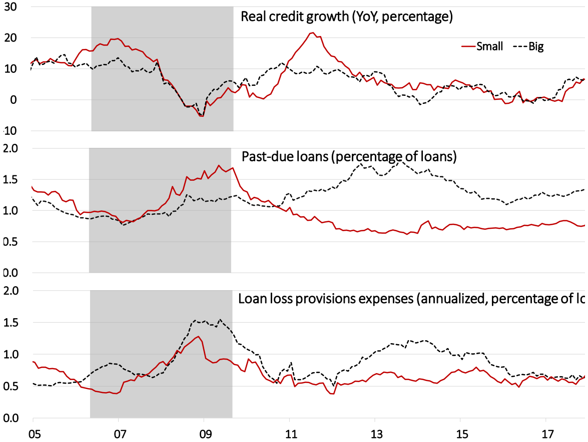
Figure: Financial Fragility and Economic Activity (percentage)



Source: Own elaboration. Grey areas based on Martinez et al. (2018).

The role of bank heterogeneity

Figure: Commercial sector credit activity and risks by bank's size in Chile



Source: Own elaboration. Grey areas based on Martinez et al. (2018).

Focus of Analysis

Our paper concerns **macroprudential regulation/monitoring** in **fragility times** with macroeconomic shocks being amplified due to the presence of **pecuniary externalities**. The two sources of the externalities are:

- Cost of default
- Collateral constraints dependent on market valuation of capital

Banking sector features:

- Big and small banks
- Perfect competition
- Ex post heterogeneity manifested in idiosyncratic shocks experienced by small banks

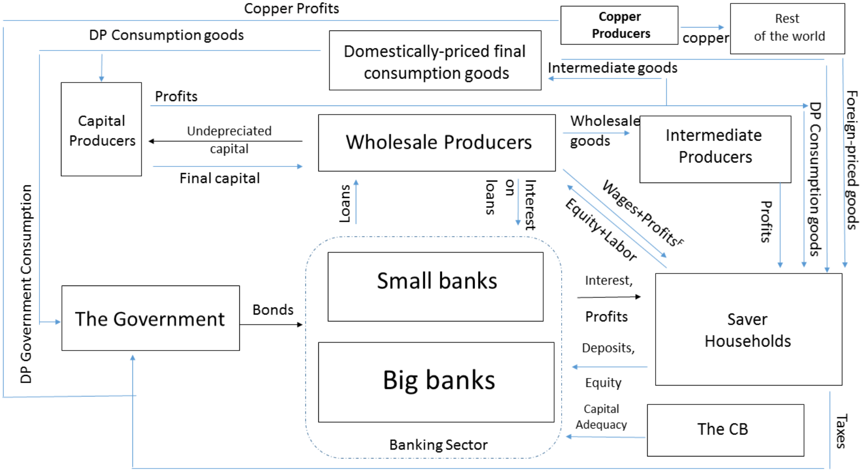
Model structure

- New-Keynesian DSGE model with nominal rigidities.
- Considers a commodity exporter Small Open Economy.
- Assume that all goods are tradable and there are no barriers to trade.
- There is households, firms, external sector, Central Bank, Regulator and Government.
- Heterogenous 2-period lived Firms with idiosyncratic risk and default.
- Heterogenous 2-period lived banks, and capital requirements.
- Hence, there is default - for secured and collateralized loans - and capital requirements.
- Consider further bank heterogeneity in the form of systemic and small banks.

Implication

Endogenous (strategic) default allows modeling risk taking behavior by firms, and justifies prudential regulation of banks and monetary policy.

Flow of funds



Formulation: firms (ex ante)

OLG structure

- Two period lived firms
- Secured vs unsecured borrowing
- **t=0**: Firms issue non-state-contingent nominal unsecured debt(credit)to banks.
- **t=1**: Firms liquidate assets, and pay dividends net of renegotiation costs depending on their default decisions and the business cycle fluctuations.

$$p_t^K k_{t+1}^w + T^w = \mu_{t+1}^w + e_t^{w,total}, \tag{1}$$

where $\mu_{t+1}^w = \mu_{t+1}^{w,s} + \mu_{t+1}^{w,u}$ and $e_t^{w,total} = e_t^w + (1-\tau)p_t^K k_t^w$

$$\mathbb{E}(1 + r_{t+1}^{w,s})\mu_{t+1}^{w,s} \leq coll(1-\tau)k_{t+1}^w \, \mathbb{E}\, p_{t+1}^K \tag{2}$$

Formulation: firms (ex post)

- 'Lucky' vs 'unlucky' firms: probability of default θ^w is the prob. of $\underline{A}_t$
- δ_t^w - loss given default
- Cost of negotiating the debt $\frac{\Omega_{t+1}^w}{1+\psi}\left(\delta_{t+1}^w \mu_{t+1}^{w,u}(1+r_{t+1}^{w,u})\right)^{1+\psi}$

$$\begin{aligned}\Pi_{t+1}^w = {} & p_{t+1}^w A_{t+1}^w (k_{t+1}^w)^{\alpha} (l_{t+1}^w)^{1-\alpha} - (1-\delta_{t+1}^w)\mu_{t+1}^{w,u}(1+r_{t+1}^{w,u}) - \mu_{t+1}^{w,s}(1+r_{t+1}^{w,s}) \\ & - w_{t+1} l_{t+1}^w - \frac{\Omega_{t+1}^w}{1+\psi}\left(\delta_{t+1}^w \mu_{t+1}^{w,u}(1+r_{t+1}^{w,u})\right)^{1+\psi} + p_{t+1}^K k_{t+1}^w (1-\tau) + T^{w,prof}\end{aligned} \tag{3}$$

- Firms' decision to default creates pecuniary externality
- Higher expected default rate raises the interest rate ax ante
- Macro variable:

$$\Omega_t^w = \Omega_{ss}^w \left(\frac{\mu_{ss}^{w,u}(1+r_{ss}^{w,u})}{GDP_{ss}}\right)^{\omega} (\delta_{ss}^w)^{\gamma} \left(\frac{GDP_t}{\mu_t^{w,u}(1+r_t^{w,u})}\right)^{\omega} \frac{1}{(\delta_t^w)^{\gamma}}. \tag{4}$$

Systemically important banks

- New-born systemically important large banks are capitalised with equity of e_t^{big}.
- They accept deposits from households, extend secured and unsecured loans to firms.

The first period budget constraint of a systemically important bank is given by

$$\mu_{t+1}^{big,s} + \mu_{t+1}^{big,u} = d_{t+1}^{big} + e_t^{big} \tag{5}$$

The capital adequacy ratio is defined as the ratio of bank capital to risk weighted assets net of reserves (rwa_t^{big}) :

$$k_t^{big} = \frac{e_t^{big}}{rwa_t^{big}} = \frac{e_t^{big}}{(\bar{rw}\mu_{t+1}^{big,u} + \bar{rw}\mu_{t+1}^{big,s})} \qquad (6)$$

Big banks then choose how much of secured and unsecured debt to lend out to firms:

$$\Pi_{t+1}^{big} = \theta^w(1 + r_{t+1}^{w,u})(1 - \delta_{t+1}^w)\mu_{t+1}^{bank,u} + (1 - \theta^w)(1 + r_{t+1}^{w,u})\mu_{t+1}^{big,u} + \\ + (1 + r_{t+1}^{w,s})\mu_{t+1}^{big,s} - (1 + r_{t+1}^d)d_{t+1}^{big}, \qquad (7)$$

Given $\left\{\delta_{t+1}^w, r_{t+1}^{w,u}, r_{t+1}^{w,s}, r_{t+1}^d\right\}$, banks maximize:

$$\max_{\mu_{t+1}^{big,u}, \mu_{t+1}^{bank,s}, d_{t+1}^{big}} \mathbb{E}_t \beta_t^h \frac{(\Pi_{t+1}^{big})^{1-\varsigma_{big}}}{1 - \varsigma_{big}} - a_{cap} 0.5[k_t^{big} - \bar{k}^{big}]^2 \qquad (8)$$

Small banks

Small banks have the following BC:

$$\mu_{t+1}^{small,s} + \mu_{t+1}^{small,u} = d_{t+1}^{small} + e_t^{small} \quad (9)$$

Lucky small bank receives a profit:

$$\bar{\Pi}_{t+1}^{small} = (1 + r_{t+1}^{w,u})\mu_{t+1}^{small,u} + (1 + r_{t+1}^{w,s})\mu_{t+1}^{small,s} - (1 + r_{t+1}^{d})d_{t+1}^{small}, \quad (10)$$

Unlucky small bank receives a profit:

$$\underline{\Pi}_{t+1}^{small} = (1 + r_{t+1}^{w,u})(1 - \delta_{t+1}^{w})\mu_{t+1}^{small,u} + (1 + r_{t+1}^{w,s})\mu_{t+1}^{small,s} - (1 + r_{t+1}^{d})d_{t+1}^{small}, \quad (11)$$

For a small bank capital adequacy ratio looks like:

$$k_t^{small} = \frac{e_t^{small}}{rwa_t^{small}} = \frac{e_t^{small}}{(\bar{rw}\mu_{t+1}^{small,u} + \bar{rw}\mu_{t+1}^{small,s})} \quad (12)$$

Given $\left\{\delta_{t+1}^{w}, r_{t+1}^{w,u}, r_{t+1}^{w,s}, r_{t+1}^{d}\right\}$, **banks maximize:**

$$\max_{\mu_{t+1}^{small,u}, \mu_{t+1}^{small,s}, d_{t+1}^{small}} \mathbb{E}_t \beta^{small}[(1 - \theta^w)\frac{(\bar{\Pi}_{t+1}^{small})^{1-\varsigma_{small}}}{1 - \varsigma_{small}} + \theta^w \frac{(\underline{\Pi}_{t+1}^{small})^{1-\varsigma_{small}}}{1 - \varsigma_{small}}] - $$
$$- a_{cap} 0.5[k_t^{small} - \bar{k}^{small}]^2 + \lambda^{small,uns}\frac{\mu_{t+1}^{small,u}}{\mu_{ss}^{small,u}} \quad (13)$$

The CB and the Government

- The Central Bank controls the interest rate i_t^b according to the following rule:

$$\frac{1+i_t^b}{1+i_{ss}^b} = \Big(\frac{1+i_{t-1}^b}{1+i_{ss}^b}\Big)^{\rho_i} \big(\frac{1+\pi_t^{cpi}}{1+\pi_{ss}^{cpi}}\big)^{1+\rho_\pi} \big(\frac{GDP_t}{GDP_{ss}}\big)^{\rho_{gdp}} \varepsilon_t^i, \quad (14)$$

- The Government owns the copper endowment and receives all the copper profits
- The Government Budget Constraint:

$$G_t + p_t^{imp} G_t^{imp} + B_{t-1}^g \frac{(1+i_{t-1}^b)}{1+\pi_t} + T^h + T^{w,prof} = B_t^g + p_t^{c,dom} C_t + T^w \quad (15)$$

- The Government spending rule:

$$G_t = G_{ss} \big(\frac{GDP_{ss}}{GDP_t}\big)^{-\rho^{g,spend}} \quad (16)$$

- The Government supply of bonds rule:

$$B_t^g = B_{ss}^g \big(\frac{GDP_{ss}}{GDP_t}\big)^{b^{g,b}} \quad (17)$$

Estimation results: estimated parameters

		Distr	Prior mean	Std	Post mean
Adjustment costs					
household's adj cost to foreign bonds	$a^{h,b,f}$	Beta	0.01	0.005	0.0073
household's adj cost to government bonds	$a^{h,b,g}$	Beta	0.01	0.005	0.0224
household's adj cost to deposits	$a^{h,d}$	Beta	0.2	0.1	0.0041
household's adj cost to firm's equity	$a^{h,f,e}$	Beta	0.2	0.1	0.0756
household's adj cost to big banks' equity	$a^{h,b,e}$	Beta	0.2	0.1	0.2513
household's adj cost to small banks' equity	$a^{h,s,e}$	Beta	0.2	0.1	0.7188
firms' adj cost to capital	$a^{w,k}$	Beta	0.1	0.05	0.0036
firms' adj cost to secured loans	$a^{w,s}$	Beta	0.2	0.1	0.1933
firms' adj cost to unsecured loans	$a^{w,u}$	Beta	0.2	0.1	0.0790
big banks' adj cost to secured loans	$a^{b,s}$	Beta	0.1	0.5	0.0030
big banks' adj cost to unsecured loans	$a^{b,u}$	Beta	0.2	0.1	0.0017
big banks' adj cost to deposits	$a^{b,d}$	Beta	0.2	0.1	0.0008
small banks' adj cost to secured loans	$a^{s,s}$	Beta	0.1	0.05	0.0037
small banks' adj cost to unsecured loans	$a^{s,u}$	Beta	0.2	0.1	0.3577
small banks' adj cost to deposits	$a^{s,d}$	Beta	0.2	0.1	0.0035

Estimation results: estimated parameters and shocks

		Distr	Prior	Std	Post
Price and wage setting					
Wage stickiness	$\theta^{p,w}$	Beta	0.1	0.05	0.2242
Price stickiness	$\theta^{p,s}$	Beta	0.6	0.2	0.1264
Taylor rule					
interest rate coefficient	ρ^{i}	Beta	0.8	0.15	0.9771
inflation rate coefficient	ρ^{π}	InvG	.25	0.25	0.2812
GDP growth rate coefficient	ρ^{gdp}	InvG	0.25	0.1	0.2109
Government rules					
government bond issuance elasticity	$b^{g,b}$	Beta	2	0.5	6.8622
government spending elasticity	$\rho^{g,spend}$	InvG	1	0.5	1.3394
Credit conditions					
default amplification in Ω	γ	InvG	1.8	0.2	1.6757
credit to GDP amplification in Ω	ω	InvG	1 .0	0.2	0.7301
Shocks' persistence					

Regulation: Counter-Cyclical Capital Buffer (CCyB) and Liquidity Coverage Ratio (LCR)

- **Credit-to-GDP ratio CCyB**:

$$k_t^{bank} = k_{ss}^{bank} (gap_t^{gdp})^{\eta^{ccyb}} \tag{18}$$

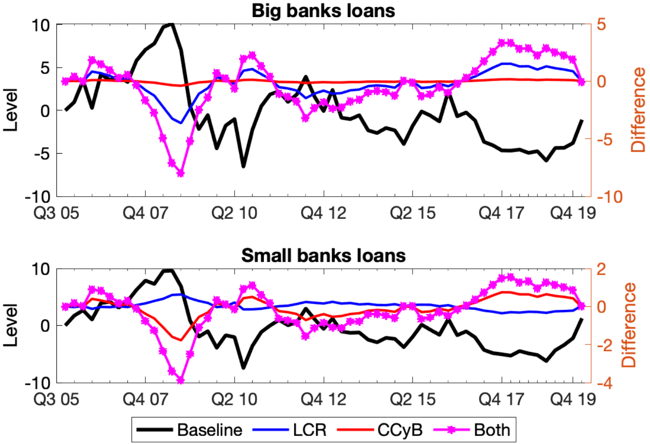
- **Credit-to-GDP ratio LCR**:

$$d_t^{bank} = d_{ss}^{bank} (gap_t^{gdp})^{\eta^{gdp}} \tag{19}$$

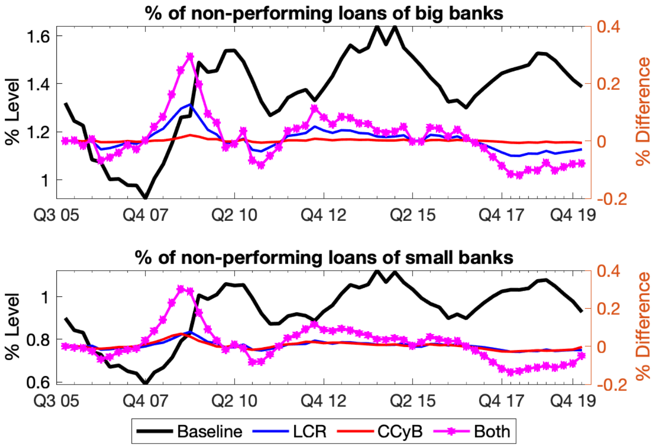
where η is chosen to maximimise household welfare and gap_t^{gdp} is defined as:

$$gap_t^{gdp} = \frac{\frac{\mu_{t+1}^{w}}{GDP_t}}{\frac{\mu_{ss}^{w}}{GDP_{ss}}}. \tag{20}$$

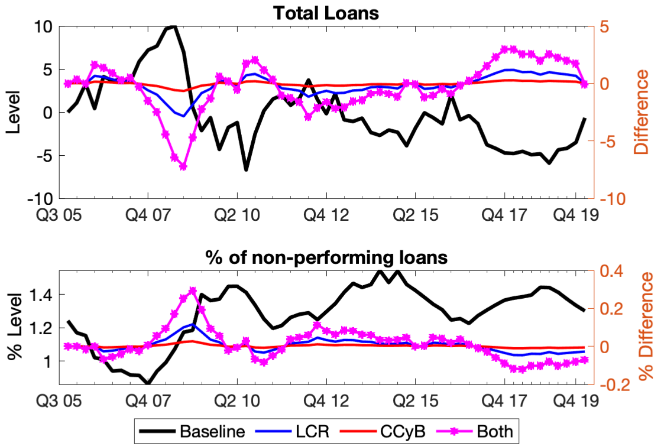
Counterfactual Historical path - Loans



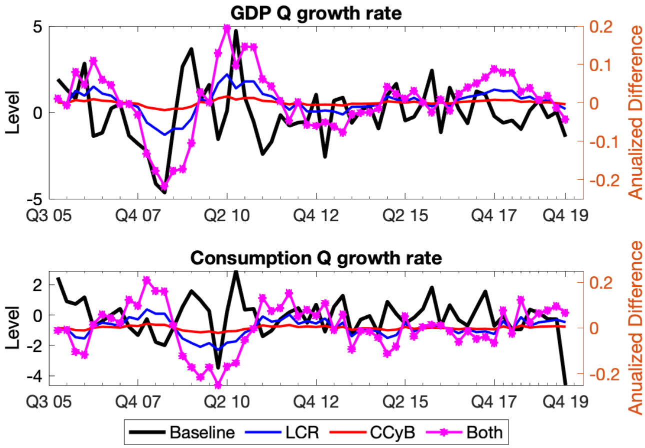
Counterfactual Historical path - NPLs



Counterfactual Historical path - Credit portfolio



Counterfactual Historical path - Real economy



Conclusions

- Modern analysis must be consistent with general equilibrium reasoning. GE reasoning must be consistent with time series data.
- Financial and monetary policy should be seen as complementary.
- Modelling financial sector within an otherwise standard DSGE is necessary to account for the effect of both types of policies, given the relevance of the credit channel. Also, heterogeneity in the banking sector could act as an amplifier mechanism.
- Regarding to financial policy, the study of capital requirement effects should be done in the context of liquidity regulation.
- We find that for the case of a SOE, liquidity and CCyB regulations are reinforcing and allow to smooth the cycle, and improving welfare (i.e. GDP and specially Consumption).
- This is an ongoing agenda. We plan to include more features of the financial sectors and to study the effects in the middle run of Covid-19 shock and policy responses (e.g. special credit facilities, forbearance programs, among others).