Online Appendix:
MARTIN Gets a Bank Account: Adding a Banking Sector to the RBA's Macroeconometric Model

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This appendix provides additional information to accompany Research Discussion Paper No 2022-01. All references to the MARTIN parameters in Ballantyne *et al* (2019) should be understood as being the current estimation of these parameters.

1. Debt Funding Costs

The following equation for debt (including deposits) funding costs incorporates the funding sources without a lower bound ($s_{D,t} + r_{C,t}$), the funding sources that will progressively hit the deposit lower bound ($\overline{r}_D = 0.05\%$) as the cash rate falls, and an endogenous response to capital shortfalls (ψz_{t-1}) reflecting the higher credit risk of banks with capital shortfalls:

$$r_{D,t} = \left(1 - 0.65\sum_{i=1}^{10}\phi_i\right)\left[s_{D,t} + r_{C,t}\right] + 0.65\sum_{i=1}^{10}\phi_i \max\left\{\left[\frac{i-1}{4} - 1.5 + r_{C,t}\right], \overline{r}_D\right\} + \psi z_{t-1}$$

$$s_{D,t} = s_{D,t-1} + \varepsilon_{D,t}$$

where the shares of deposits at each deposit-spread level (ϕ_i) are calibrated (in Table A1) such that the sum ($\sum_{j=1}^{i}\phi_j$) matches the the information in Garner and Suthakar (2021) and is consistent with information garnered from discussions with RBA staff. The exogenous component of the debt funding spread ($s_{D,t}$) is treated as a random walk. $r_{C,t}$ is the cash rate. And $\psi = 10$ (because $z_t \in [0,1]$ while a debt funding cost of 1 per cent aligns with $r_{D,t} = 1$).

Table A1: Additional Share of Lower Bound Deposits

i	1	2	3	4	5	6	7	8	9	10
ϕ_i	0.02	0.02	0.06	0.07	0.03	0.04	0.06	0.06	0.07	0.07
$\sum_{j=1}^{i}\phi_j$	0.02	0.04	0.10	0.17	0.20	0.24	0.30	0.36	0.43	0.50

2. Loan Losses

The losses equations are:

$$\ln L^*_{H,t} \equiv \alpha_L + f\left(\hat{U}_{t-1}, \hat{r}_{M,t-1}, \hat{p}_{H,t-1}\right)$$

$$L_{H,t} = \alpha_H + \max\left\{L^*_{H,t} - L^*_{H,t-1}, 0\right\} + \varepsilon_{H,t}$$

$$L_{B,t} = \alpha_B + \vartheta \max\left\{L^*_{H,t} - L^*_{H,t-1}, 0\right\} + \varepsilon_{B,t}$$

$$\begin{aligned} L_t &\equiv \theta L_{H,t} + (1-\theta) L_{B,t} \\ &= \theta\alpha_H + (1-\theta)\alpha_B + \left[\theta + (1-\theta)\vartheta\right]\max\left\{L^*_{H,t} - L^*_{H,t-1}, 0\right\} + \theta\varepsilon_{H,t} + (1-\theta)\varepsilon_{B,t} \end{aligned} \tag{A1}$$

where $\left[\theta\alpha_H + (1-\theta)\alpha_B\right] = 0.00025$ is calibrated using banks' average 'quarterly charge for bad and doubtful debts as a share of assets' over the five years to December 2019 (APRA 2020), and $\theta = 2/3$ is the household share of banks' outstanding loans (estimated from APRA data).

Adding a constant to α_L and then dividing $\left[\theta+\left(1-\theta\right)\vartheta\right]$ by the exponential of that constant, will lead to the same equation for total losses (Equation (A1)). Therefore, to calibrate α_L and ϑ, we normalise $\vartheta=1$ and calibrate α_L so that the sum of quarterly losses ($\sum L_t$) matches the total loan losses in APRA's 2017 stress testing exercise (APRA 2018);[1] the resulting calibration is $\alpha_L=1.1$.

2.1 Micro-simulation model

$$f\left(\cdot\right)\equiv\sum_{i=0}^{3}\sum_{j=0}^{\max\{3-i,0\}}\sum_{k=0}^{\max\{3-j-i,0\}}\hat{\beta}_{ijk}\left\{\exp\left(i\times\hat{p}_{H,t-1}\right)\times\hat{r}_{M,t-1}^{j}\times\hat{U}_{t-1}^{k}\right\}$$

The parameter calibrations for the $f\left(\cdot\right)$ approximation are provided in Table A2.[2]

Table A2: $\hat{\beta}_{i,j,k}$ Calibrations

Variable combination	Calibration	Variable combination	Calibration
$\exp\left(\hat{p}_H\right)$	6.4921	$\exp\left(2\hat{p}_H\right)\times\hat{r}_M$	–0.15181
$\hat{r}_M$	0.12899	$\exp\left(\hat{p}_H\right)\times\hat{r}_M^2$	0.0041623
$\hat{U}$	0.031718	$\hat{r}_M^3$	0.00019305
$\exp\left(2\hat{p}_H\right)$	–14.264	$\exp\left(2\hat{p}_H\right)\times\hat{U}$	0.044
$\exp\left(\hat{p}_H\right)\times\hat{r}_M$	0.11112	$\exp\left(\hat{p}_H\right)\times\hat{r}_M\times\hat{U}$	0.00095606
$\hat{r}_M^2$	–0.0057204	$\hat{r}_M^2\times\hat{U}$	7.7577e–05
$\exp\left(\hat{p}_H\right)\times\hat{U}$	–0.036611	$\exp\left(\hat{p}_H\right)\times\hat{U}^2$	0.00072769
$\hat{r}_M\times\hat{U}$	–0.00282522	$\hat{r}_M\times\hat{U}^2$	–3.6678e–05
$\hat{U}^2$	0.0021333	$\hat{U}^3$	–0.0001718
$\exp\left(3\hat{p}_H\right)$	6.1094	Intercept	–4.4007

2.2 Gap variables

The gap variables used in the losses equations are defined as:

$$\hat{p}_{H,t}\equiv p_{H,t}-p_{H,t}^{*}$$

$$\hat{U}_t\equiv U_t-NAIRU_t$$

$$\hat{r}_{M,t}\equiv r_{M,t}-\left(r_t^{*}+\pi_t^{*}+s_{M,t}+0.675s_{D,t}-0.0585\right)$$

1 We set $\lambda=0$ and $\psi=0$ when matching APRA's 2017 stress testing exercise because this exercise did not explicitly incorporate financial accelerator mechanisms (the exercise was based on an exogenous macroeconomic scenario).

2 Although OLS is used to determine each $\hat{\beta}_{i,j,k}$, we use OLS only to produce an equation that approximates the micro-simulation model output. Therefore, this is a calibration process not an estimation process; this is why standard errors and *t*-statistics are not reported (as they do not have meaningful interpretations).

$$s_{M,t} = s_{M,t-1} + \varepsilon_{M,t}$$

where r_t^* and π_t^* are the neutral real interest rate and inflation expectations variables in MARTIN, the exogenous component of the mortgage spread to funding costs ($s_{M,t}$) is treated as a random walk, and the $\left(0.675 s_{D,t} - 0.0585\right)$ term is the long-run debt funding spread to the cash rate (this implicitly assumes that the long-run cash rate is above 1.5).

Constructing the log housing price gap ($\hat{p}_{H,t}$) is more involved because we need to construct a slow-moving stochastic trend for log housing prices ($p_{H,t}^*$):

$$p_{H,t}^* \equiv p_{H,t-1}^* + \lambda_H \left(p_{H,t-1}^* - p_{H,t-1}^\dagger \right) + \Delta p_H \tag{A2}$$

Equation (A2) produces a variable that slowly converges to MARTIN's log housing price cointegrating relationship ($p_{H,t}^\dagger$) and has a long-run growth rate equal to the long-run growth rate of housing prices (Δp_H). Setting $\lambda_H = -0.024$ sets the $p_{H,t}^*$ speed of adjustment parameter equal to the speed of adjustment parameter in MARTIN's log housing price equation (γ in Equation (27) in Ballantyne *et al* (2019)). Defining Ψ as the long-run value of the log housing price cointegrating relationship:

$$\Psi \equiv \frac{-\alpha_0}{\gamma}$$

$$p_{H,t}^\dagger \equiv \Psi + \log\left(rents_t\right) + \beta_1 \times \text{Real Mortgage Rate}_t$$

$$\Delta p_H = \frac{\bar{\pi}}{400}$$

where α_0, γ and β_1 come from Equation (27) in Ballantyne *et al* (2019), and $\bar{\pi}$ is the inflation target.

3. Risk Weights

$$w_t = \bar{w} + \left(1-\alpha_w\right)\left(w_{t-1} - \bar{w}\right) + \Gamma\left(L_t - \bar{L}\right) w_{t-1}$$

where $\bar{w} = 0.4$, $\alpha_w = 0.32$, $\Gamma = 14.1$ and $\bar{L} = \theta\alpha_H + \left(1-\theta\right)\alpha_B$.

4. Return on Assets

$$ROA_t = \tau\alpha_e + \left(\frac{\tau}{400}\right)\left[\theta s_{M,t} + \left(1-\theta\right) s_{B,t} + z_t^* + w_{t-1} e_t r_{D,t}\right] - \tau L_t$$

$$s_{B,t} = s_{B,t-1} + \varepsilon_{B,t}$$

where $\tau\alpha_e = -0.0032$ and $\tau = 0.7$ is calibrated to be one minus the corporate tax rate.

While we calibrate the model such that the sum of quarterly losses ($\sum L_t$) matches the total loan losses in APRA's 2017 stress testing exercise (APRA 2018), the exact path of losses is different. This leads to a different path for banks' capital adequacy ratios. But while the path is different, once losses return to typical levels, banks' capital adequacy ratios in the model should be similar to the stress testing exercise (holding risk weights fixed). So we calibrate α_e such that banks' capital adequacy shortfall five years after the onset of the downturn is consistent between the model and APRA's 2017 stress testing exercise.

5. Capital Adequacy Ratio

In the 'stressed' state $\Delta e_{t+1} = P\left(t, z_t^*, S_t = 1\right)$, in the 'unconstrained' state with capital still below target $\Delta e_{t+1} = P\left(t, z_t^*, S_t = 0, z_t > 0\right)$.

$$P\left(t, z_t^*, S_t = 1\right) = \frac{1}{w_t}\left\{\begin{array}{l} \tau\alpha_e + \left(\dfrac{\tau - 400 w_t e_t \beta_{M,t}}{400}\right)\left[\theta s_{M,t} + (1-\theta) s_{B,t} + z_t^*\right] \\ + \left(\dfrac{\tau w_{t-1} - 400 w_t \beta_{M,t}}{400}\right) e_t r_{D,t} - \tau L_t - w_t e_t \mathbf{B}\mathbf{X}_t - e_t\left[w_t - w_{t-1}\right] \end{array}\right\} \tag{A3}$$

where $S_t = 1$ is the 'stressed' state and $S_t = 0$ is the 'unconstrained' state.

$$P\left(t, z_t^*, S_t = 0, z_t > 0\right) = \frac{1}{w_t}\left\{\begin{array}{l} \tau\alpha_e + \left(\dfrac{\tau}{400}\right)\left[\theta s_{M,t} + (1-\theta) s_{B,t} + w_{t-1} e_t r_{D,t}\right] \\ + \left(\dfrac{\tau - 400 w_t e_t \beta_{M,t}}{400}\right) z_t^* - \tau L_t - e_t\left[w_t - w_{t-1}\right] \end{array}\right\} \tag{A4}$$

$$z_t \equiv \max\left\{\bar{e} - e_t - P\left(t, 0, S_t\right), 0\right\}$$

Given that we are using MARTIN's household credit growth equation as a proxy for total credit growth, for the purposes of determining z_t^* we assume the relevant interest rate for credit growth is $r_{A,t}$ (i.e. in Equation (A5) we replace $r_{M,t}$ with $r_{A,t}$ before substituting into Equations (A3) and (A4)).

When $z_t = 0$, dividends are set so that the capital adequacy ratio remains constant ($\Delta e_{t+1} = 0$).

5.1 Switching states

If banks are not in the 'stressed' state in period t, we assume they enter this state in period $t+1 \, iff \; z_t > 0$ (i.e. if there is a capital shortfall). If banks entered the stressed state in period t, then we allow the modeller to define the number of quarters for which the stressed state lasts. Defining this number as $T \in \mathbb{Z}^+$, S_t can be defined using the following three functions:[3]

$$T_t' = T \times \operatorname{sign}\left(z_{t-1}\right) \times \left[1 - \operatorname{sign}\left(z_{t-2}\right)\right]$$

$$T_t^* = \max\left\{T_t', T_{t-1}^* - 1\right\}$$

$$S_t = \min\left\{T_t^*, 1\right\}$$

We allow the modeller to exogenously set T because the rarity of stress events in Australia's recent history would make this variable difficult to model accurately. Allowing T to be set by the modeller allows the modeller to test the sensitivity of their results to their T assumption. Our baseline assumption is $T = 4$.

5.2 MARTIN's credit growth equation

$$\Delta a_{t+1} = \beta_{M,t} r_{M,t} + \mathbf{BX}_t \tag{A5}$$

$$\beta_{M,t} \equiv \alpha_3 - \gamma \beta_1 \left(\frac{PTM_{t-4}}{PTM_t}\right) \tag{A6}$$

$$\begin{aligned} \mathbf{BX}_t \equiv \alpha_0 + \gamma \left[nhc_t - ph_t - kid_{t-1} - 100\beta_1 \left(\frac{PTM_{t-4}}{PTM_t} - 1\right)\right] \\ + \alpha_1 \Delta nhc_t + \alpha_2 \Delta ph_t + \left(1 - \alpha_1\right) \Delta kid_{t-1} - \alpha_3 r_{M,t-1} + \left(\frac{1 - \alpha_1 - \alpha_2}{400}\right) pi\_e_t \end{aligned} \tag{A7}$$

where the parameters and variables on the right-hand sides of Equations (A6) and (A7) are from Equation (19) in Ballantyne *et al* (2019).

6. Credit Supply

$$z_t^* = \frac{400 \lambda w_t z_t}{\tau - 400 w_t e_t \beta_{M,t}}$$

$$r_{M,t} = s_{M,t} + r_{D,t} + z_t^*$$

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3 We define S_t using the basic mathematical functions in EViews, as this is the programming language used for MARTIN. The sign function returns a value of 1 if the sign of the variable is positive, −1 if the sign is negative, and zero if the variable equals zero.

$$r_{B,t} = s_{B,t} + r_{D,t} + z_t^*$$

$$e_t = \bar{e} - (1-\lambda)\, z_{t-1}$$

where $\lambda = 0.15$ and $\bar{e} = 0.11$.

6.1 Credit supply adjusted on new loans only

$$\ln L_{H,t}^* \equiv \alpha_L + f\left(\hat{U}_{t-1}, \hat{r}_{M,t-1} - z_{t-1}^*, \hat{p}_{H,t-1}\right)$$

$$ROA_t = \tau\alpha_e + \left(\frac{\tau}{400}\right)\left[\theta s_{M,t} + (1-\theta)\, s_{B,t} + w_{t-1} e_t r_{D,t}\right] - \tau L_t$$

$$z_t^* = \frac{-\lambda z_t}{e_t \beta_{M,t}}$$

References

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