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The Economy-wide Impacts of a Rise in the Capital Adequacy Ratios of Australian Banks*

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Regulators are requiring banks to raise additional equity to finance their activities. The benefits are understood in terms of reducing the risks of another financial crisis. But there are potential costs, including the potential for unanticipated macroeconomic impacts as banks reduce leverage. We use a financial computable general equilibrium model, containing disaggregated treatment of financial agents, to explore the economy-wide consequences of an increase in bank capital adequacy ratios. We find that the macroeconomic consequences are small.

I Introduction

Following the events of 2008 and their aftermath, regulators have focused on reducing the risks of another financial crisis. Policies affecting commercial bank leverage are viewed as important instruments in this regard. This follows from an understanding that thin levels of loss-absorbing equity played an important role in raising counterparty risk perceptions in an environment of falling bank asset values, thus impairing bank wholesale debt finance markets during the crisis. As described by the International Monetary Fund (2009), after a year of slow growth among developed economies and growing concerns about US mortgage markets, the Lehman Brothers default in late 2008 caused a swift deterioration in financial market conditions. Counterparty risk perceptions peaked as bank asset values were written down, the US federal government underwrote shortfalls in AIG's capacity to honour its insurance obligations, and a number of private and semi-private financial institutions in the USA and Europe received public financial support (International Monetary Fund, 2009).

The crisis in financial markets quickly spilled into the real economy. The International Monetary Fund reduced its global real gross domestic product (GDP) growth forecast in April 2009 to −1.3 per cent (International Monetary Fund, 2009, p. xii), but the realised growth rate for the year was ultimately lower still, at −1.7 per cent (United Nations, 2015). These global figures obscure the severe impacts in countries most directly affected by the crisis. Edey (2014) notes that US output fell by 4 per cent in the year to June 2009, and that the peak-to-trough falls in output in the UK and the euro area were 7 per cent and 6 per cent, respectively. Sharp falls in household wealth compounded the pain of declining real incomes and employment.

Atkinson *et al.* (2013) argue that the benefits of avoiding financial crises can be understood in terms of avoiding their impacts on employment

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and national income. They estimate US losses from the crisis at between 40 and 90 per cent of a year's output, or around \$50,000–\$120,000 per household. Similar magnitudes were forecast by Dixon and Rimmer (2011) (59 per cent of a year's worth of private consumption) and Dixon and Rimmer (2013) (44 per cent of a year's worth of employment). Atkinson *et al.* argue that such estimates are helpful because they provide a measure of the potential benefits against which the costs of regulations aimed at avoiding future crises can be weighed. For example, Menzies *et al.* (2016) argue that because the costs of financial crises are potentially very high relative to the costs imposed by regulation, and because the effectiveness of each independent regulation cannot be known with certainty, a policy bias in favour of apparent regulation duplication in the financial sector is warranted.

While Australia was spared economic damage of the magnitudes visited on the USA and Europe, it was not immune. Real GDP fell 0.8 per cent in the third quarter of 2008, but then grew slowly in the following three quarters, providing a low but positive growth rate of 1.1 per cent for the year to September 2009. The unemployment rate increased by approximately 1.5 percentage points, rising from 4.3 per cent in September 2008, to 5.7 per cent by September 2009, with a peak in the intervening quarters of 5.9 per cent. Edey (2014) argues that a factor that insulated Australia from the worst effects of the financial crisis, in addition to fortuitous strength in the terms of trade, was effective leadership by the Australian Prudential Regulatory Authority (APRA). This saw Australian banks enter the crisis with reasonable capital buffers and sound asset positions that were not subject to material price impairments.

Consistent with its statutory purpose of promoting financial system stability, APRA continues to monitor and regulate the proportion of commercial bank activities financed by equity. In July 2015 it released the results of its comparative study of the capital ratios of Australian and international banks. It noted that the capital ratios of Australia's major banks were approximately 200 basis points short of levels necessary to place them in the top quartile of their international peers. This has generated policy action in the form of mandating increased risk weights on residential mortgages from July 2016, and a signal of intention over the next several years to see capital adequacy ratios rise by about 200 basis points.

While regulators understand the consequences of alternative capital adequacy ratios for financial sector resilience under various stress test scenarios, and understand the potential wider economic benefits in terms of avoiding economic damage on the scale experienced during the financial crisis, policy-makers are less certain about the economic costs of mandating rises in bank equity capital. At one end of the spectrum, commentary from the banking industry warns that, by raising the share of bank activity financed by equity, which carries a higher required rate of return than debt, the cost of bank finance will increase, reducing interest-sensitive expenditures, such as investment (e.g. Pandit, 2010). At the other end of the spectrum, assessments by economists emphasise the theoretical basis for expecting that the cost of bank finance should be less sensitive to capital structure than suggested by the banking industry. For example, Miles *et al.* (2012) note that the Modigliani–Miller theorem implies that the cost of bank finance should be invariant to the share of equity in bank finance: as the equity share rises, the volatility of the equity return falls and the security of the debt return rises, causing the required return on both forms of finance to fall and leaving the weighted average cost of bank capital (WACC) unchanged. However Baker and Wurgler (2015) argue that this overlooks the 'low-risk anomaly', namely the failure of the empirical risk–return regularity that holds between asset classes (i.e. returns on higher-risk asset classes exceed returns on lower-risk asset classes) to hold within the equity asset class (where the risk–return relationship is flat or inverted). They show that the low-risk anomaly holds for banks, and argue that the significance of this for regulators is that a mandated rise in bank capital might, by lowering bank risk, raise rather than lower the required return on bank equity, thus causing the WACC to rise.[1]

Measures of the macroeconomic effects of a rise in bank capital also vary widely. Modelling by the Institute of International Finance (2011) anticipated large GDP losses from the implementation of Basel III capital requirements and

[1] As discussed in Section II, our model contains a mechanism that contributes to such an effect: a financial agent, seeking to expand its issuance of a particular liability instrument (such as equity), must raise the rate of return on the instrument in order to induce other agents to hold more of it on the asset side of their balance sheets.

regulatory standards, of the order of −3.2 per cent relative to baseline. However, modelling coordinated by the Bank for International Settlements (2010a,b) of a 1 percentage point increase in the capital adequacy ratio, phased over four to eight years, found more modest impacts, with a range of GDP troughs of between 0.05 per cent and 0.3 per cent at the end of the implementation periods.

Both the IIF and BIS results were generated by a two-step process: first, the effects of higher capital requirements on bank spreads and lending volumes were estimated; second, these were input as exogenous shocks to macroeconomic models. In the modelling we present in this paper, we combine these two steps. We construct a model of the financial sector in which the banking sector is one of a number of financial agents, and integrate the model of the financial sector within a comprehensive model of the Australian economy. In this way, the capital adequacy ratio is just one of many exogenous variables in a large economy-wide model. When we shock this variable, the impact on bank lending costs and credit volumes is determined endogenously along with outcomes for policy-relevant variables such as employment and GDP. We find GDP impacts that are lower than those reported by IIF, and lower even than approximately 85 per cent of the results found by BIS. As we shall argue, the integrated approach, as opposed to the two-stage approach, provides opportunities for damage-mitigating economic mechanisms (such as substitution away from bank finance) to take effect.

To explore the economy-wide effects of higher bank capital requirements we raise the banking sector's capital adequacy ratio by 100 basis points.[2] Our simulation is undertaken using a version of the financial computable general equilibrium (FCGE) model described in Dixon *et al.* (2015). We summarise the underlying FCGE model in Section II. In Sections II.i and II.ii we explain that the model's treatment of the financial sector is constructed in a bottom-up way; that is, we identify individual financial agents and the financial instruments with which they are concerned, and assume that financial agents act in an optimising manner subject to constraints. Sections II.iii and II.iv expand on developments to the FCGE model that are relevant to the current study; in particular, building on the Dixon *et al.* (2015) model, we develop the manner in which we model the banking sector (particularly as it relates to the capital adequacy ratio and risk weights on assets held by banks), and describe central bank setting of the policy rate via a Taylor rule. Section III describes the simulations we have undertaken with the model and what we learn from them. Section IV concludes.

[2] To put this in context, this is a movement in bank capital adequacy of the same size as that investigated by Bank for International Settlements (2010a,b), and half that (200 basis points) foreshadowed as possible in Australian Prudential Regulatory Authority (2015).

II The Financial Computable General Equilibrium Model

In this section we provide a summary of the FCGE model used in the simulations described in Section III. For a detailed discussion of the model, see Dixon *et al.* (2015). As we shall describe, the FCGE model is based on identification of many agents and the optimising behaviour governing their actions. Out of this framework emerge a number of transmission channels via which a change in commercial bank capital requirements can affect activity in the real economy. We go on to describe the features of the FCGE model that are important in the simulation of the effects of a rise in capital adequacy ratios.

(i) Overview of the Financial CGE Model

While fully integrated, the FCGE model can be broadly conceived as comprised of two parts:

- a traditional CGE model describing the real side of the economy; and
- a model of the interactions between financial agents and their links with the real side of the economy.

The real side of the FCGE model is largely as described in Dixon and Rimmer (2002). It identifies:

- 106 industries, using inputs to produce 106 commodities for use in current production, capital formation, private consumption, public consumption, and export. Each industry is modelled as an optimiser, using domestic and imported intermediate inputs, labour, capital and land, in a cost-minimising fashion, to produce output. In choosing cost-minimising input combinations, each industry adjusts its input ratios in response to changes in the relative prices of intermediate inputs and primary factors.
- 106 industry-specific investors, producing physical capital for installation in each

industry. Like the current producers identified above, investors act in an optimising fashion, adjusting their use of source-specific inputs in response to changes in relative prices in order to produce given quantities of new units of industry-specific physical capital in a cost-minimising way. In determining how many new units of physical capital to install in each industry, investors are guided by movements in expected rates of return on physical capital relative to the cost of securing financial capital.

- A representative household, purchasing domestic and imported commodities for private consumption. Households act as optimisers, maximising utility by choosing between alternative source-specific commodities subject to an aggregate consumption constraint.
- A government sector, purchasing domestic and imported commodities for public consumption.
- A foreign sector, purchasing units of domestic production to be sold in foreign markets subject to price-sensitive constant elasticity export demand curves, and supplying imports to Australia at exogenous foreign currency prices.
- Providers of 10 margin services (trade, transport, insurance and other margins), required to facilitate flows of commodities between producers, importers, households, government, investors and foreign agents in export markets.

Movements in relative prices reconcile the demand and supply sides of most commodity and factor markets through market clearing conditions. An important exception is the labour market, which is assumed to experience sticky wages in the short run, but to transition in the long run to an environment of wage flexibility and a given natural rate of unemployment. Zero pure profit conditions in current production and capital formation determine basic prices (prices at the factory door) for domestically produced output. Purchaser prices differ from basic prices by the value of margin services and indirect taxes. In addition to indirect taxes, government revenue from direct taxes is identified, as are a variety of government outlays beyond public consumption spending (such as personal benefit payments and public investment). Together with variables describing foreign transfer payments, this provides sufficient detail for the identification of the government borrowing requirement, household disposable income, and household savings.

Real-side CGE models with characteristics such as those described above have been used for many decades to answer diverse policy questions (Dixon & Rimmer, 2016). However, they are silent on, or treat implicitly, the question of how a number of important transactions are financed. For example, how is investment spending financed? How does the cost of financial capital affect the decision to invest in physical capital? Who is financing the public sector borrowing requirement (PSBR)? How is the current account deficit (CAD) financed? Who decides on how household savings are allocated? An important role of the financial part of the FCGE model is to answer these and related questions.

The model's financial equation block identifies five financial instruments and 11 financial agents.[3] Each financial agent is concerned with both the asset and the liability/equity sides of its balance sheet. Hereafter, we refer to financial agents as 'asset agents' in matters concerned with the asset sides of their balances sheets, and as 'liability agents' in matters concerned with the liability and equity sides of their balance sheets. The core of the FCGE model is three arrays and the equations describing how the values in these arrays change through time. The three arrays are: $F_{(s,f,d)}$, which is the flow of net new holdings by asset agent d (e.g. households, the banking sector) of financial instrument f (e.g. equity, loans, bonds) issued by liability agent s (e.g. government, industry); $R_{(s,f,d)}$, which is the power of the rate of return (i.e. 1 plus the rate) on financial instrument f issued by liability agent s and held as an asset by agent d; and $A_{(s,f,d)}$, which is holdings by asset agent d of financial instrument f issued by liability agent s.

Insights into the relative importance of alternative financing sources for a given agent can be had through evaluation of $S^{(L)}_{(s,f,d)} = A_{(s,f,d)} / \sum_f \sum_d A_{(s,f,d)}$, the share of agent s's financial capital

[3] The financial instruments are: cash, deposits/loans, bonds, equity, gold and SDRs. The financial agents are: commercial banks, the central bank, foreigners, government, households, industries, non-bank financial intermediaries, superannuation, life insurance, non-reproducible housing, and reproducible housing. Throughout this paper, our set element naming conventions for these instruments and agents are, respectively: Cash, DepLoan, Bonds, Equity, GldSDR; and ComB, CenB, Foreign, Gov, Hhold, Inds, NBFI, Super, LifeIns, NRH and RH.

raised from agent d via instrument f. The relative importance of alternative assets in an agent's portfolio can be understood through evaluation of $S^{(A)}_{(s,f,d)} = A_{(s,f,d)} / \sum_s \sum_f A_{(s,f,d)}$, the share of agent d's portfolio represented by holdings of instrument f issued by agent s. For example, evaluation of $S^{(L)}_{(\mathrm{Super},f,d)}$ for all f and d reveals that the superannuation sector is nearly wholly equity-financed by the Australian household sector (i.e. $S^{(L)}_{(\mathrm{Super,Equity,Hhold})} = 0.995$.[4] Similarly, evaluation of $S^{(L)}_{(\mathrm{Inds},f,d)}$ provides insights into the relative importance of alternative financing sources for industry. In the model's initial year, the top four values for $S^{(L)}_{(\mathrm{Inds},f,d)}$ are $S^{(L)}_{(\mathrm{Inds,DepLoan,ComB})} = 0.23$, $S^{(L)}_{(\mathrm{Inds,Equity,Foreign})} = 0.22$, $S^{(L)}_{(\mathrm{Inds,Equity,Hhold})} = 0.19$ and $S^{(L)}_{(\mathrm{Inds,Equity,Super})} = 0.10$. Aggregating over funding agents, we see the relative importance of equity, intermediated loans and bonds in financing Australian industries in the values $S^{(L)}_{(\mathrm{Inds,Equity.})} = 0.58$, $S^{(L)}_{(\mathrm{Inds,DepLoan.})} = 0.35$ and $S^{(L)}_{(\mathrm{Inds,Bonds.})} = 0.07$. These figures point to bank lending as an important, but not dominant, form of financing for Australian industry. As we shall argue in Section III, this provides scope for industry to substitute away from bank finance when its relative cost increases. However, an important caveat is aggregation. Within the financial part of the FCGE model, the activity of financing capital formation by the model's industries, excluding housing, is undertaken by one aggregate liability agent. In effect, all industries are assumed to have the same balance sheet structure. A more disaggregated model might reveal subsector-specific detail in which bank finance is the dominant source of financial capital.[5] Nevertheless, our model is sufficiently disaggregated to recognise the importance of bank financing of housing. We divide housing into two sectors: 'reproducible' (RH) and 'non-reproducible' (NRH). We have undertaken this division both to facilitate modelling in the present paper of the distinction between financing new housing construction and financing the existing housing stock, and in anticipation of future model applications concerned with property price bubbles. For NRH (established inner-city dwellings) it is conceivable that asset prices can depart from construction costs. For RH (apartments, units, and houses outside the inner city) construction and land preparation costs should anchor asset prices. On the asset side of their balance sheets, both agents hold the value of physical housing assets, but no financial capital (i.e. $A_{(s,f,\mathrm{NR})} = A_{(s,f,\mathrm{NRH})} = 0$). Equity financing is important for both agents, but more so for the NRH agent which holds the housing stock in established neighbourhoods: $S^{(L)}_{(\mathrm{RH,Equity,Hhold})} = 0.32$, $S_{(\mathrm{NRH,Equity,}}$ $Hhold)^{(L)} = 0.60$. Bank debt financing is important for both agents, but more so for the newer houses underlying RH: $S^{(L)}_{(\mathrm{RH,DepLoan,ComB})} = 0.52$, $S^{(L)}_{(\mathrm{NRH,DepLoan,ComB})} = 0.30$.

With details of $S^{(L)}_{(s,f,\mathrm{ComB})}$ and $S^{(A)}_{(\mathrm{ComB},f,d)}$, our FCGE model effectively carries a bank lending channel, that is, a description of the role that banks play as intermediaries for different parts of the economy. As Kashyap and Stein (1994) note, summarising Bernanke and Blinder (1988), three conditions must hold for a model to possess a distinct lending channel: (i) liability agents must view as imperfect substitutes financial capital raised by loans from banks and raised from other sources; (ii) banks must view deposit finance and other forms of finance as imperfect substitutes; and (iii) there must be a nominal rigidity that prevents monetary shocks from having no impact on the real economy. All three conditions hold in the FCGE model. Condition (i) ensures that borrowers cannot entirely offset a rise in the cost of bank funds by shifting to other sources of financial capital. Condition (ii) renders the cost of funds to commercial banks sensitive to changes in the costs of particular finance sources by ensuring that they cannot make costless switches between alternative funding sources. Condition (iii) ensures that changes in monetary policy are not immediately neutralised by costless price adjustment. These three conditions hold in the FCGE model, thus allowing a shock directed at commercial banks (such as a rise in the capital adequacy ratio) to exert an influence on the cost of financial capital to agents reliant on bank finance (such as housing construction).

[4] Australian Bureau of Statistics (2014), the primary source for $A_{(s,f,d)}$, records a small value for non-equity financing of superannuation.

[5] For example, the recent Financial System Inquiry argued that development of the corporate bond market should be a priority (see http://fsi.gov.au/publications/interim-report/03-funding/the-corporate-bond-market/). Ralston and Jenkinson (2014) discuss sector-specific difficulties in sourcing funds by small and medium enterprises.

(ii) Agent Decision-Making and Links between the Model's Real and Financial Sides

Financial agents are assumed to be constrained optimisers. Broadly, in their capacity as liability agents, they are assumed to issue the mix of financial instruments that minimises the cost of servicing the total liabilities they require, subject to a constraint that prevents them moving to corner solutions in the issuance of particular financial instruments to particular asset agents. Similarly, in their capacity as asset agents, financial agents are assumed to hold the mix of financial instruments that maximises the return from their portfolio of financial assets, subject to a constraint that prevents them moving to corner solutions in the holding of particular financial instruments issued by particular liability agents.

More formally, we assume that domestic liability agent s, constrained by a need to raise a given amount of funds, aims to minimise a constant elasticity of transformation (CET) function in which the arguments are values for end-of-year liabilities weighted by the powers of the rates of return paid on those liabilities. That is, we assume that domestic liability agent s chooses $\mathrm{AT1}_{(s,f,d)}$ for all f, d to

$$\begin{aligned} \text{minimise} \quad & Z_s^{(\mathrm{L})} = \mathrm{CET}\left[\mathrm{AT1}_{(s,f,d)} \cdot R_{(s,f,d)}, \forall f, d\right](s \in \mathrm{LALF}) \\ \text{subject to} \quad & \sum_f \sum_d \left[\mathrm{AT1}_{(s,f,d)} - \mathrm{AT0}_{(s,f,d)} \cdot V_{(s,f,d)}\right] = \mathrm{NEWLIAB}_{(s)} \end{aligned} \tag{1}$$

TABLE 1

Balance Sheet Closures and Agent-Specific Financial/Real-Side Links

Financial agent	(A) New liabilities ($\mathrm{NEWLIAB}_{(s)}$)	(B) New assets ($\mathrm{NEWASSET}_{(d)}$)
1. Commercial banks	Equal to new financial asset acquisitions	Purchases of new financial assets endogenous via fixed mark-up rule on cost of financial capital
2. Central bank	Equal to new asset acquisitions. Exchange settlement balances (commercial bank deposits with the central bank) exogenous	Government bond purchases endogenous (via policy rule). Holdings of other assets exogenous
3. Foreigners	Foreign financial assets are available for purchase by domestic asset agents at given rates of return	Purchases of domestic assets by foreigners = CAD + purchases of foreign assets by domestic agents
4. Government	Equal to PSBR plus purchase of new financial assets by government	Purchases of new financial assets by government indexed to growth in nominal GDP
5. Households	Mortgage liabilities are issued directly by agents (10) and (11). Business liabilities are issued directly by agent (6). Hence no new liabilities	Purchases of new financial assets (including superannuation equity) equal to household savings (inclusive of superannuation contributions)
6. Industries	Equal to gross fixed capital formation plus purchases of new financial assets	Purchases of new financial assets indexed to nominal GDP
7. Non-bank financial institutions	Equal to new financial asset acquisitions	Purchases of new financial assets endogenous via fixed mark-up rule on cost of financial capital
8. Superannuation	New liabilities (equity held by households) are a fixed proportion of annual economy-wide wage bill	Equal to new liabilities
9. Life insurance	Equal to new financial asset acquisitions	Purchases of new financial assets endogenous via fixed mark-up rule on cost of financial capital
10. Non-reproducible housing	No new financial liabilities	No new financial assets
11. Reproducible housing	Equal to gross fixed capital formation in the dwellings sector	No new financial assets

Note: Shaded cells are directly determined by the real economy.

where LALF denotes liability agents less foreign, that is, all liability agents excluding foreigners; $\mathrm{AT1}_{(s,f,d)}$ is the end-of-year value of liability instrument f issued by agent s and held as an asset by agent d; $\mathrm{AT0}_{(s,f,d)}$ is the start-of-year value of liability instrument f issued by agent s and held as an asset by agent d; $R_{(s,f,d)}$ is the power (1 plus the rate) of the return on instrument f issued by agent s and held as an asset by agent d; $V_{(s,f,d)}$ is a revaluation term; $Z_s^{(\mathrm{L})}$ are agent-specific CET functions; and $\mathrm{NEWLIAB}_{(s)}$ are the new liabilities that must be raised by agent s (see Table 1).

Domestic asset agents are assumed to choose an allocation of their end-of-year portfolio across domestic and foreign assets in order to maximise a function in which the arguments are end-of-year asset allocations weighted by rates of return. Specifically, we assume that domestic asset optimising agent d chooses $\mathrm{AT1}_{(s,f,d)}$ for all s, f to

$$\begin{aligned} \text{maximise} \quad & Z_{(d)}^{(\mathrm{A})} = \mathrm{CES}\big[\mathrm{AT1}_{(s,f,d)} \\ & \cdot R_{(s,f,d)}, \forall s,f\big](d \in \mathrm{AALF}) \\ \text{subject to} & \sum_s \sum_f [\mathrm{AT1}_{(s,f,d)} - \mathrm{AT0}_{(s,f,d)} \cdot V_{(s,f,d)}] \\ & = \mathrm{NEWASSET}_{(d)} \end{aligned} \tag{2}$$

where AALF denotes asset agents less foreign, that is, the set of domestic asset agents[6] ; $\mathrm{NEWASSET}_{(d)}$ is net new acquisitions of financial assets by agent d (see Table 1); $Z_{(d)}^{(\mathrm{A})}$ are agent-specific constant elasticity of substitution functions; and $R_{(s,f,d)}$, $\mathrm{AT1}_{(s,f,d)}$, $\mathrm{AT0}_{(s,f,d)}$, $V_{(s,f,d)}$ are as previously defined.

Converting the solutions to these optimisation problems into percentage change form, we have a set of return-sensitive supply equations (governing the issuance of financial instruments by liability agents) and return-sensitive demand equations (governing the demand for financial instruments by asset agents) of the form

$$\begin{aligned} \mathrm{at1}_{(s,f,d)} &= \mathrm{liabilities}_{(s)} - \tau_{(s)}\big(r_{(s,f,d)} - \mathrm{wacc}_{(s)}\big) \\ & (s \in \mathrm{LALF}) \end{aligned} \tag{3}$$

$$\begin{aligned} \mathrm{at1}_{(s,f,d)} &= \mathrm{assets}_{(d)} - \sigma_{(d)}\big(r_{(s,f,d)} - \mathrm{averor}_{(d)}\big) \\ & (d \in \mathrm{AALF}) \end{aligned} \tag{4}$$

where $\mathrm{at1}_{(s,f,d)}$ and $r_{(s,f,d)}$ are percentage changes in $\mathrm{AT1}_{(s,f,d)}$ and $R_{(s,f,d)}$, respectively; $\mathrm{liabilities}_{(s)}$ and $\mathrm{assets}_{(d)}$ are percentage changes in the end-of-year total liabilities and total assets of agents s and d, respectively[7]; $\mathrm{wacc}_{(s)}$ is the percentage change in the weighted average cost of capital for agent s[8] ; $\mathrm{averor}_{(d)}$ is the percentage change in the weighted average return on agent d's portfolio[9]; and $\tau_{(s)}$ and $\sigma_{(d)}$ are positive parameters governing the elasticity of capital structure and asset allocation shares to movements in relative rates of return. Broadly, the solution to the financial instrument supply and demand equations given by (3) and (4) determine movements in rates of return across financial instruments.[10]

In describing (1)–(4), we omitted liability and asset decision-making by foreign agents. We assume that the liabilities of foreign agents are available to Australian asset agents at given rates of return. That is, $r_{(\mathrm{Foreign},f,d)}$, for all f, $d \in \mathrm{AALF}$, is exogenous. Foreign asset agents solve a problem like (2) but are concerned with the allocation of their foreign currency portfolios across global assets in foreign currency terms. This results in equations describing foreign demand for Australian dollar assets of the form

$$\begin{aligned} \mathrm{at1}_{(s,f,\mathrm{Foreign})} + \phi &= \mathrm{fassetsfc} \\ & + \sigma_{(\mathrm{Foreign})}\big(r_{(s,f,\mathrm{Foreign})} - \mathrm{averorfor}\big) \end{aligned} \tag{5}$$

where ϕ is the percentage change in the nominal exchange rate (expressed as foreign currency

[6] The foreign asset agent solves a similar problem, but is concerned with the foreign currency values of its asset holdings. As we shall describe, this allows endogenous determination of the nominal exchange rate.

[7] Defined as $\sum_{f,d}\mathrm{AT0}_{(s,f,d)} \cdot V_{(s,f,d)} + \mathrm{NEWLIAB}_{(s)}$ and $\sum_{s,f}\mathrm{AT0}_{(s,f,d)} \cdot V_{(s,f,d)} + \mathrm{NEWASSET}_{(d)}$, respectively.

[8] Defined as $\sum_{f,d} R_{(s,f,d)} \cdot \mathrm{AT1}_{(s,f,d)} / \big[\sum_{k,t} \mathrm{AT0}_{(s,k,t)} \cdot V_{(s,k,t)} + \mathrm{NEWLIAB}_{(s)}\big]$.

[9] Defined as $\sum_{s,f} R_{(s,f,d)} \cdot \mathrm{AT1}_{(s,f,d)} / \big[\sum_{k,t} \mathrm{AT0}_{(k,t,d)} \cdot V_{(k,t,d)} + \mathrm{NEWLIAB}_{(d)}\big]$.

[10] The exceptions are rates of return on foreign liabilities (exogenous) and the rate of return on cash (exogenous on zero). The supply of these liabilities is determined by demand. Rates of return on bank exchange settlement deposits/loans with the central bank are determined by supply/demand conditions in these markets, but the supply/demand conditions are adjusted by the central bank to ensure that rate of return outcomes are consistent with the policy rule (see Section II.iv).

units per domestic currency unit); fassetsfc is the percentage change in the foreign currency value of the foreign agent's global portfolio of financial assets; and averorfor is the percentage change in the average rate of return on the foreign agent's global portfolio of assets.

In this equation fassetsfc and averorfor are determined by factors outside Australia and are therefore exogenous in a model of Australia. As with other rates of return, $r_{(s,f,\mathrm{Foreign})}$ is determined by the interaction of demand and supply, in this case foreign demand for particular Australian assets and the willingness of Australian financial agents to supply the underlying liabilities. With appropriate weights the sum of the $\mathrm{at1}_{(s,f,\mathrm{Foreign})}$ over s and f reflects the CAD which must be financed by foreigners. This makes (5) an avenue for determining ϕ.

Endogenous determination of ϕ in this way is a significant addition to the CGE framework. In a traditional real-side CGE model concerned with short-run employment and other effects of policy shocks, *real* wages are assumed to be sticky (or fixed) and the domestic price level is arbitrary. To tie down the price level, a nominal variable must be exogenous. A common choice is ϕ. In the jargon of CGE modelling, ϕ acts as the numeraire. If the nominal exchange rate is increased by 1 per cent ($\phi = 1$) then all domestic prices and other nominal variables decrease by 1 per cent with no effect on any real variables.[11] Now when we add a behavioural equation such as (5) for foreign financiers of the CAD, we can replace the sticky *real* wage equation with a sticky *nominal* wage equation more in keeping with macroeconomic theory (e.g. a Philips curve) and allow (5) to determine ϕ endogenously.[12] Thus with the addition of Equation (5), ϕ and the domestic price level can be determined endogenously, doing away with the concept of the numeraire. This enriches the CGE framework by linking the monetary and real sides of the economy, extending the range of CGE analysis to include monetary phenomena.

In our discussion of the optimisation problems to this point, we have taken as given the constraints faced by each agent. We now consider how these constraints are determined. In so doing, we discuss the connections between the asset and liability sides of agent-specific balance sheets, and the points of connection between the model's financial and real sides. As summarised in Table 1, there are seven ways in which asset and liability sides of agent-specific balance sheets are determined: (i) via a connection with the real economy (cells B3, A4, B5, A6, A8, A11); (ii) via a mark-up rule on financial capital costs (cells B1, B7, B9); (iii) via a balance sheet constraint (cells A1, A2, A7, A9, B8); (iv) via an indexing rule with nominal GDP (cells B4, B6); (v) via passive adjustment to demand (cell A3); (vi) via a policy rule (cell B2); or (vii) exogenous and zero (cells A5, A10, B10, B11). We expand below.

The main points of interaction between the real and financial sides of the FCGE model are B3, A4, B5, A6, A8, and A11, covering the model's two key saving agents (foreigners and households, cells B3, B5), three key borrowing agents (government, and the two investment financing agents, industry and RH, cells A4, A6, A11) and superannuation contributions (cell A8). We consider these cells in turn. Foreign purchases of domestic financial assets (B3) are largely determined by the current account financing requirement, which in turn is largely determined in the model's real side via the outcome for the balance of trade. Household savings are determined in the model's real side as the difference between household disposable income and nominal consumption. This determines household purchases of financial assets (cell B5). The PSBR is determined in the model's real side as the difference between public expenditure and taxation and other revenues. This largely determines government liability issuance (cell A4). The desirability of undertaking gross fixed capital formation in the dwellings and non-dwellings sectors is governed by the value of the weighted average cost of financial capital to each sector relative to sector-specific values of the ratio of the value of the marginal product of physical capital to the cost of new physical capital. This determines liability issuance by the RH sector (cell A11) and largely determines liability issuance by industries (cell A6). Superannuation contributions (new liabilities for these funds, cell A8) are modelled as a fixed proportion of the national wage bill, which in turn is largely

[11] Other common choices for the numeraire are the Consumer Price Index, the nominal wage rate and the price deflator for GDP. The choice is unimportant. The numeraire determines the absolute price level and has no effect on relative prices or real variables.

[12] A traditional real-side CGE model can have a sticky nominal wage equation instead of a sticky real wage equation, but to close such a model we still need an arbitrary assumption for a nominal variable. In other words, a sticky nominal wage equation by itself does not determine the price level, real wages or employment.

determined by employment and wage conditions in the model's real side.

We now discuss each agent's balance sheet closure rule, proceeding row by row through Table 1. We begin with the three pure financial intermediaries (rows 1, 7, 9), for whom NEW-ASSET$_{(d)}$ and NEWLIAB$_{(s)}$ are determined via a fixed mark-up on the cost of their financial capital (cells B1, B7, B9) and a balance sheet constraint (cells A1, A7, A9). Under this closure, if a financial intermediary (e.g. commercial bank) sees a rise in the return on a particular financial asset (e.g. loans to housing), then the intermediary expands purchases of the asset, financing this through new liabilities (e.g. loans from foreigners). Via the fixed mark-up constraint, equilibrium is achieved via upward pressure on the cost of the financial intermediary's capital, and downward pressure on returns earned on the financial asset.

Row 2 summarises the closure of the central bank. Asset purchases by the central bank are exogenous for all assets other than domestic government bonds and loans to commercial banks.[13] As we discuss in Section II.iv, bond purchases, representing open market operations, adjust endogenously in order to maintain the policy rate as determined by inflation and unemployment conditions. Central bank asset purchases are financed by issuing central bank liabilities in the form of cash and loans from government (B2).[14] The government's equity in the central bank is revalued in line with movements in central bank asset valuations.[15]

As already discussed, foreign purchases of domestic assets are determined by the CAD financing requirement (cell B3). We assume that the liabilities of the foreign agent are available for purchase by domestic asset agents at given rates of return (cell A3).

Row 4 describes local, state and federal government purchases of financial assets and issuance of financial liabilities. We index new government purchases of financial assets to movements in nominal GDP (cell B4).[16] Government issuance of new liabilities (primarily bonds) is equal to the PSBR plus government purchases of new financial assets (cell A4).

Purchases of new financial assets by household (cell B5) are equal to household savings. An important component of household savings is superannuation. Acquisition of equity in the superannuation sector is set at a fixed proportion of the national wage bill (cell A8).[17] The household is not modelled as owing debt directly.[18] Mortgage debt is owed by the RH and NRH agents (rows 10 and 11). Business debt is issued by the industry agent (row 6). The household's ownership interests in sectors (6), (10) and (11) are recognised via equity.

The industry agent (row 6) is responsible for financing non-housing investment. As such, its issuance of new liabilities is equal to the value of non-housing gross fixed capital formation plus purchases by industry of financial assets (cell A6). Financial asset purchases by industry are determined by an indexing relationship with nominal GDP (cell B6).

Issuance of liabilities (equity held by households) by the superannuation sector is modelled as a fixed proportion of the national wage bill (cell A8). These new liabilities finance asset accumulation by the superannuation sector (cell B8).

The RH sector is responsible for construction of new dwellings (cell A11). Issuance of new

[13] Central bank loans to commercial banks are also exogenous, but the constraint is imposed not on central bank supply of the loans, but on commercial bank demand for the loans. In the model's database, central bank loans to commercial banks represent loans of exchange settlement balances. We model the central bank as supplying these loans at an interest rate ($R_{(\mathrm{ComB,DepLoan,CenB})}$) that is 50 basis points higher than the rate offered on exchange settlement balances ($R_{(\mathrm{CenB,DepLoan,ComB})}$). Nevertheless, supply of the loans is constrained by our assumption that commercial bank demand for the loans is exogenous.

[14] Cash and loans from government comprise the bulk of central bank liabilities ($S^{(\mathrm{L})}_{(\mathrm{CenB,Cash,})}+S^{(\mathrm{L})}_{(\mathrm{CenB,DepLoan,Gov})}=0.60+0.23=0.83$). The remainder comprises government equity ($S^{(\mathrm{L})}_{(\mathrm{CenB,Equity,Gov})}=0.12$) and deposits by banks ($S^{(\mathrm{L})}_{(\mathrm{CenB,DepLoan,ComB})}=0.05$).

[15] Largely caused by exchange rate driven movement in the value of the central bank's foreign asset holdings.

[16] Government financial assets include such things as central bank deposits and equity, receivables, and domestic and foreign financial asset holdings to match future liabilities (e.g. the Future Fund).

[17] Hence we exclude household allocations to $\mathrm{AT1}_{(\mathrm{Super,Equity,Hhold})}$ from the household's decision problem (2).

[18] A comparison of household debt in ABS 6554.0 and ABS 5232.0 indicates that consumer debt is less than 4 per cent of the total household debt in ABS 5232.0. The remainder is mortgage and business debt. We model mortgage and business debt as issued by the model's industry and housing agents. We do not model consumer debt.

liabilities by the RH sector is determined by the value of gross fixed capital formation in the model's dwellings sector. We model the NRH sector as owning the physical assets representing that part of the dwellings sector capital stock designated as non-reproducible, and as responsible for the debt and equity underlying the financing of this stock. Because the sector undertakes no new housing construction (this is the responsibility of the RH sector) it does not issue new financial liabilities (cell A10).[19]

(iii) Modelling the Capital Adequacy Ratio

Capital adequacy ratios impose additional constraints on the behaviour of banks. First, bank decision making over asset ownership must recognise differences in capital requirements across assets carrying different risk weights. Second, movements in the capital adequacy ratio affect the amount of equity banks use to finance their operations. We expand below.

We begin by modifying the FCGE model's standard theory (given by Eqn 2) governing decision-making by asset agents. We assume that commercial banks (ComB) choose their end-of-year asset portfolio, $AT1_{(s,f,\mathrm{ComB})}$ for all s and f, to maximise

$$\begin{aligned}&\mathrm{CES}(R_{(s,f,\mathrm{ComB})}\times AT1_{(s,f,\mathrm{ComB})},\text{for all } s \text{ and } f)\\&\text{subject to}\\&\sum_{s,f} AT1_{(s,f,\mathrm{ComB})}=BB_{(\mathrm{ComB})}\\&\text{and}\\&\sum_{d} AT1_{(\mathrm{ComB,Equity},d)}\\&=\max\left[\sum_{d} A1^{*}_{(\mathrm{ComB,Equity},d)},\mathrm{CAR}\cdot\sum_{s,f}\mathrm{RISKWGT}_{(s,f)}\cdot AT1_{(s,f,\mathrm{ComB})}\right]\end{aligned}\tag{6}$$

where CAR is the capital adequacy ratio, $\mathrm{RISKWGT}_{(s,f)}$ is the risk weight that the financial regulator assigns to $AT1_{(s,f,\mathrm{ComB})}$, $A1^{*}_{(\mathrm{ComB,Equity},d)}$ is the value of equity the commercial banks would have on issue in the absence of capital adequacy requirements, $BB_{(\mathrm{ComB})}$ is the total value of commercial bank assets (equal to $\mathrm{NEWASSET}_{(\mathrm{ComB})}+\sum_{s,f} AT0_{s,f,\mathrm{ComB}}\cdot V_{(s,f,\mathrm{ComB})}$.

We assume that the CAR constraint is binding so

$$\sum_{d} AT1_{(\mathrm{ComB,Equity},d)}=\mathrm{CAR}\cdot\sum_{s,f}\mathrm{RISKWGT}_{(s,f)}\cdot AT1_{(s,f,\mathrm{ComB})}$$

Equity liabilities are relatively expensive. Consequently, we approximate problem (6) as

$$\text{choose } AT1_{(s,f,\mathrm{ComB})} \text{for all} s \text{and} f,$$

to maximise

$$\mathrm{CES}(\mathrm{NR}_{(s,f,\mathrm{ComB})}\cdot A1_{(s,f,\mathrm{ComB})},\text{for all } s \text{ and } f)\tag{7}$$

subject to

$$\sum_{s,f} AT1_{(s,f,\mathrm{ComB})}=BB_{(\mathrm{ComB})},\tag{8}$$

where

$$\mathrm{NR}_{(s,f,\mathrm{ComB})}=R_{(s,f,\mathrm{ComB})}-\psi\cdot\mathrm{CAR}\cdot\mathrm{RISKWGT}_{(s,f)}\tag{9}$$

and ψ is a positive parameter.

In (9) we recognise that the commercial banks face a penalty when they expand their holding of asset (s, f, ComB). The penalty is that they have to increase expensive equity liabilities.[20] We model the penalty as proportional to the capital adequacy ratio times the risk weight. The factor of proportionality, ψ, reflects the difference between the cost of equity finance to the commercial banks and the cost of other liabilities. For example, with ψ at 0.08 and CAR = 0.1, the penalty for a risky asset with weight 1 (RISKWGT = 1) would be 0.008 (80

[19] But revaluation effects can alter the value of NRH equity, and, like other liability agents, the sector is free to adjust its capital structure in response to changes in the relative cost of funds. At present, we revalue the NRH sector's physical housing assets in line with model-determined movements in housing construction costs. This changes the value of the household's equity in NRH. In future work, we hope to explore other potential NRH price determinants, such as bubble thinking on the part of housing investors.

[20] The risk of bank equity as an investment relative to bank deposits is reflected in initial database values for $R_{(\mathrm{ComB,Equity},d)}$ and $R_{(\mathrm{ComB,DepLoan},d)}$, which carry higher values for the former relative to the latter.

TABLE 2
Risk Weights on Commercial Bank Assets

Parameter	Description	Value
$\text{RISKWGT}_{(\text{CenB},f)}$ ($\forall f \in \text{FI}$)	Liabilities issued by the central bank	0
$\text{RISKWGT}_{(\text{Gov},f)}$ ($\forall f \in \text{FI}$)	Liabilities issued by the domestic government	0
$\text{RISKWGT}_{(s,\text{Cash})}$ ($\forall s \in \text{LA}$)	Cash	0
$\text{RISKWGT}_{(s,\text{Equity})}$ ($\forall s \in \text{LA}$)	Equity	3.0
$\text{RISKWGT}_{(\text{Foreign},\text{DepLoan})}$	Loans to foreign agents	0.4
$\text{RISKWGT}_{(\text{Inds},\text{DepLoan})}$	Loans to domestic industry	0.4
$\text{RISKWGT}_{(\text{NBFI},\text{DepLoan})}$	Loans to NBFIs	0.4
$\text{RISKWGT}_{(\text{NRH},\text{DepLoan})}$	Loans to the non-reproducible housing sector	0.35
$\text{RISKWGT}_{(\text{RH},\text{DepLoan})}$	Loans to the reproducible housing sector	0.5
$\text{RISKWGT}_{(\text{NBFI},\text{Bonds})}$	Bonds issued by NBFIs	0.4
$\text{RISKWGT}_{(\text{Foreign},\text{Bonds})}$	Foreign bonds	0.4

basis points). This is because the acquisition of an additional \$1 of the risky asset requires that the bank raise \$0.1 of additional equity finance, costing 800 basis points more than non-equity finance. If the capital adequacy ratio were increased to 0.125 then the penalty for risky assets would increase to 0.01 (an increase of 20 basis points), whereas the penalty for a less risky asset (RISKWGT = 0.1, say) would barely move, from 0.0008 to 0.001 (an increase of 2 basis points). By changing the capital adequacy ratio and/or the risk weights the regulator can influence the asset choices of the commercial banks. Table 2 reports values for $\text{RISKWGT}_{(s,f)}$. In choosing values for $\text{RISKWGT}_{(s,f)}$, we were guided by values reported in Attachments A and D of Australian Prudential Regulatory Authority (2013).

On the liability side of the bank's balance sheet, we recognise that the binding CAR constraint determines $\sum_d \text{AT1}_{(\text{ComB},\text{Equity},d)}$. Hence we remove decision-making over equity issuance from the bank's liability optimisation problem, leaving banks solving a truncated version of Equation (1) covering non-equity liabilities only.

(iv) The Central Bank Policy Rate and the Taylor Rule

In Section II.i we introduced data arrays describing stocks of financial instruments ($A_{(s,f,d)}$) and the rates of return on those stocks ($R_{(s,f,d)}$). These data include five variables relevant to the relationship between the central bank and commercial banks as it pertains to the operations of monetary policy within the FCGE model:

- $A_{(\text{CenB},\text{DepLoan},\text{ComB})}$ and $R_{(\text{CenB},\text{DepLoan},\text{ComB})}$, describing commercial bank holdings of clearing balances with the central bank, and the rate of return paid by the central bank on those balances;
- $A_{(\text{ComB},\text{DepLoan},\text{CenB})}$ and $R_{(\text{ComB},\text{DepLoan},\text{CenB})}$, describing commercial bank borrowings of clearing balances from the central bank, and the rate of interest charged by the central bank on those balances;
- $F_{(\text{Gov},\text{Bonds},\text{CenB})}$, describing central bank net purchases of domestic government bonds.

Consistent with the channel system operated by the Australian central bank (e.g. Otto, 2007), we begin with the idea that both $R_{(\text{CenB},\text{DepLoan},\text{ComB})}$ and $R_{(\text{ComB},\text{DepLoan},\text{CenB})}$ are policy variables. We assume that the central bank maintains a given supply of commercial bank exchange settlement balances ($A_{(\text{CenB},\text{DepLoan},\text{ComB})}$) at the rate $R_{(\text{CenB},\text{DepLoan},\text{ComB})}$ via open market operations in the domestic government bond market (i.e. endogenous movements in $F_{(\text{Gov},\text{Bonds},\text{CenB})}$).[21] We

[21] This is consistent with the channel system description in Woodford (2003). He describes a channel system as one in which the central bank supplies a given level of clearing balances at a given policy interest rate, in addition to standing ready to lend clearing balances at a fixed spread over the policy rate (Woodford, 2003, p. 27). It is also consistent with descriptions of how the reserve bank affects changes in the policy rate. For example: 'Monetary policy operates via the Bank influencing the interest rate paid on overnight funds (the "cash rate")...The Bank's influence over the cash rate comes from its ability to control the availability of funds used to settle transactions between financial institutions. By undertaking open market operations, principally in government securities with less than one year to maturity, the Bank controls the availability of settlement funds and hence the interest rate paid on overnight deposits' (Lowe, 1995, p. 3).

determine $R_{(\text{ComB,DepLoan,CenB})}$ via $R_{(\text{ComB,DepLoan,CenB})} = R_{(\text{CenB,DepLoan,ComB})} + 0.005$.[22] We endogenise $R_{(\text{CenB,DepLoan,ComB})}$ by introducing a Taylor rule linking movements in the policy rate to deviations of inflation from target and the employment rate from the natural rate. As described by Orphanides (2007), Taylor rules are simple prescriptive policy rules describing how a central bank should adjust its policy interest rate in response to movements in inflation and economic activity. The 'classic Taylor rule' (Taylor, 1993) is

$$r = (2 + p) + 0.5(p - 2) + 0.5y \qquad (10)$$

where r is the federal funds rate, p is the rate of inflation over the previous four quarters, '2' denotes an assumed natural real rate for the policy rate of 2 per cent (in the first bracketed term) and a target inflation rate of 2 per cent (in the second bracketed term), and y is an output gap measure calculated as $y = 100(Y - Y^*)/Y^*$, where Y^* is potential real GDP.

The version of the Taylor rule we use in the FCGE model is

$$\left(\frac{R_{(\text{CenB,DepLoan,ComB})\text{t}}}{R_{(\text{CenB,DepLoan,ComB})\text{t}-1}}\right) = \text{FR}\left(\frac{P_t}{P_t^{(\text{T})}}\right)^{\alpha}\left(\frac{\text{ER}_t}{\text{ER}_t^{(\text{T})}}\right)^{1-\alpha}, \qquad (11)$$

where $R_{(\text{CenB,DepLoan,ComB})t}$ and $R_{(\text{CenB,DepLoan,ComB})t-1}$ are the current and lagged powers of the interest rate offered by the central bank on settlement balances, P_t and $P_t^{(\text{T})}$ are the actual and target levels for the consumer price index in year t, ER_t, $\text{ER}_t^{(\text{T})}$ are the actual and target levels of the employment rate (1 minus the unemployment rate) in year t, FR is an exogenous shift variable, and α is a parameter (set at 0.5) governing the sensitivity of interest rate movements to deviations in prices and employment from target. The advantage of this interpretation of the Taylor rule for our FCGE model is that it allows for gradual adjustment of the policy rate in response to movements in inflation and unemployment from target, whereas (10), unaided by an additional adjustment rule, can produce unrealistic jumps in the policy rate. Converting (11) to a percentage change form, we have

$$r_{(\text{CenB,DepLoan,ComB})\text{t}} = r_{(\text{CenB,DepLoan,ComB})\text{t}-1} + 0.5\left(p_t - p_t^{(\text{T})}\right) + 0.5(\text{er}_t - \text{er}_t^{(\text{T})}) + \text{fr}, \qquad (12)$$

where $r_{(\text{CenB,DepLoan,ComB})t}$ and $r_{(\text{CenB,DepLoan,ComB})t-1}$ are the current and lagged percentage changes in the power of the interest rate offered by the central bank on settlement balances, p_t and $p_t^{(\text{T})}$ are the actual and target rates of consumer price inflation in year t, er_t, $\text{er}_t^{(\text{T})}$ are the actual and target percentage changes in the employment rate (1 minus the unemployment rate) in year t, and fr is a shift variable that is endogenous when the policy rule is inactive and exogenous (and typically unshocked) when the rule is activated.

[22] $R_{(s,f,d)}$ is the power of the rate of return (i.e. 1 plus the rate). Hence, if the deposit rate for settlement balances is 3 per cent, then $R_{(\text{CenB,DeposLoans,ComB})} = 1.03$ and $R_{(\text{ComB,DeposLoans,CenB})} = 1.035$.

III Simulations

(i) Simulation Design

In 2015 APRA released its comparative study of the capital ratios of Australian banks and their international peers. They noted that the capital ratios of Australia's major banks were approximately 200 basis points short of levels necessary to place them in the top quartile of their international peers on this measure (Australian Prudential Regulatory Authority, 2015). In the simulations below, we raise the capital adequacy ratio by 100 basis points. We make the following closure assumptions:

1. We assume that the nominal wage is sticky in the short run, but sufficiently flexible over the medium term to ensure that the unemployment rate returns to its natural rate.
2. Real public consumption is unaffected by the change in the capital adequacy ratio. That is, real public consumption follows its baseline path. We also assume that the PSBR to GDP ratio follows its baseline path. The exogenous status of both public consumption and the PSBR/GDP ratio requires flexible determination of a government revenue instrument. To this end, we endogenously determine a direct tax on households.
3. The policy interest rate in year t adjusts relative to its $t - 1$ level in response to movements in the consumer price inflation rate away from target, and movements in the employment rate (an output gap measure) away from target according to (12).

FIGURE 1
Outstanding Financing Instruments of the Commercial Banks (% Deviation from Baseline)

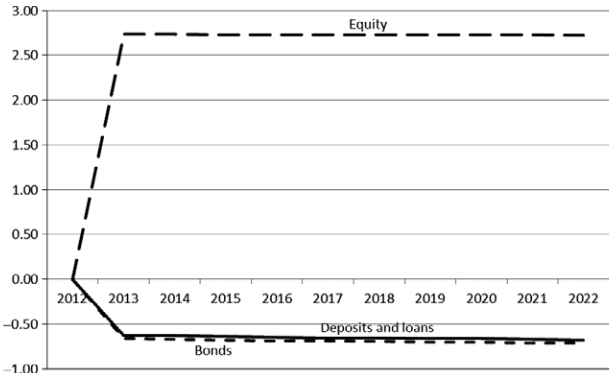
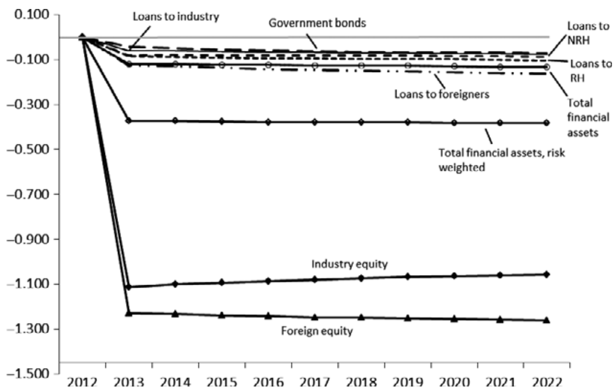


FIGURE 2
Financial Assets of Commercial Banks (% Deviation from Baseline)



(ii) Results

The shock is a 100 basis point increase in the capital adequacy ratio of commercial banks. Via the mechanisms described in Section II.iii, this causes banks to undertake adjustments to the composition of both the liability and asset sides of their balance sheets. On the liability side, the increase in the capital adequacy ratio causes commercial banks to increase their issuance of equity instruments, and decrease their reliance on deposit and bond financing (Figure 1). On the asset side of bank balance sheets, the rise in the capital adequacy ratio induces commercial banks to reduce their holdings of risky assets. In Figure 2 we see there is a decline in risk-weighted assets relative to total bank financial assets. The decline in risk-weighted assets is due to a shift in the composition of bank asset holdings, away from those with comparatively high risk weights (particularly foreign equity, industry equity) towards those with lower risk weights (government bonds, loans to non-reproducible housing).

As discussed above, the rise in the capital adequacy ratio causes banks to raise additional

FIGURE 3
Rates of Return (Powers thereof) on Bank Financing Instruments (% Deviation from Baseline)

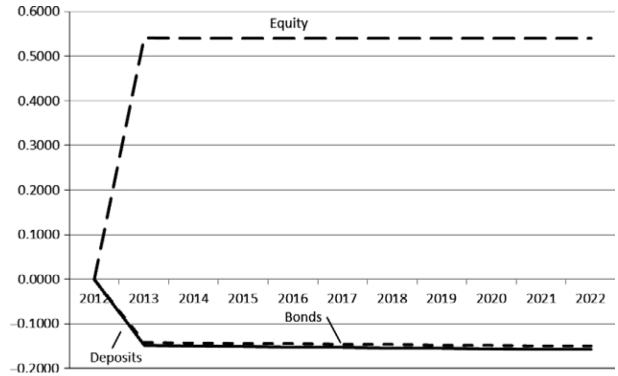
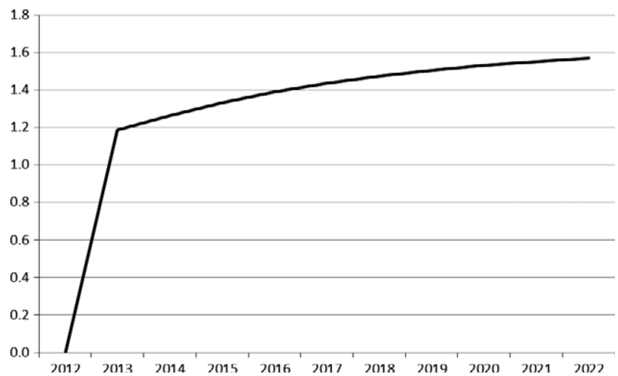


FIGURE 4
Weighted Average Cost of Bank Capital (Basis Point Change from Baseline)

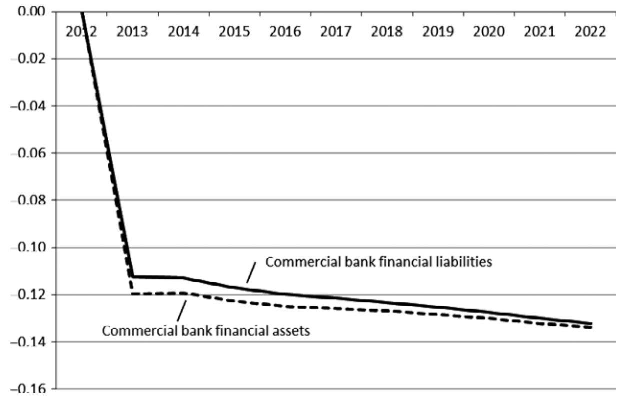


equity finance, and to reduce their demands for deposit and loan finance (Figure 1). To persuade asset agents to acquire the new equity, rates of return on bank equity must rise (Figure 3). At the same time, banks reduce their demand for loan and deposit finance, allowing them to secure loan and deposit financing at slightly lower rates of return relative to baseline (Figure 3). Figure 4 reports the deviation in the weighted average cost of capital to commercial banks, which rises relative to baseline as banks increase the equity share of their financing needs.

Figure 5 reports the deviations in the financial assets and liabilities of commercial banks.[23] As discussed in Dixon *et al.* (2015), banks are assumed to operate under an environment of a fixed margin on the return they earn on financial assets and the return they must pay on their financial liabilities. This has the effect of requiring the commercial banks to pass on the increase in the cost of their financial capital (Figure 4) to the agents to whom

[23] We assume that commercial bank physical assets (primarily bank branches) are unaffected. Hence, in Figure 5, the percentage deviation in financial assets lies below the percentage deviation in liabilities.

FIGURE 5
Financial Assets and Liabilities of the Commercial Banks (% Deviation from Baseline)



they lend.[24] This reduces demand for loans from commercial banks, that is, it leads to a contraction in commercial bank ownership of financial assets (Figure 5). Hence, commercial banks need to raise less financial capital to acquire this smaller pool of financial assets. That is, it leads to a contraction in commercial bank financial liabilities (Figure 5).

Figure 6 reports the movement in the interest rates that the central bank offers on settlement balance deposits by commercial banks, and charges commercial banks for settlement balance loans. As discussed in Section II.iv, the settlement balance deposit rate is determined by a rule in which the central bank policy rate responds to deviations in prices and unemployment from target. The movements in the policy rate reported in Figure 6 are small: a 0.6 basis point reduction in the year the policy is implemented, with this rising to a 0.1 basis point positive deviation by the end of the simulation period. This is close to simply maintaining the baseline path for the policy rate. Figure 7 reports the movements in the price level and the employment rate that are driving, via the policy rule, the movements in the policy rate reported in Figure 6. In the year the capital adequacy ratio is increased, both the employment rate and the consumption price deflator fall relative to baseline (Figure 7). This accounts for the initial negative deviation in the policy rate (Figure 6). Thereafter, both the consumption deflator and the employment rate return to baseline. This accounts for the return of the policy rate towards baseline. By the end of the simulation period, the employment rate has returned to baseline, and the consumption price deflator is slightly above baseline. This accounts for the small positive deviation in the policy rate at the end of the simulation period.[25]

As discussed in reference to Figure 2, the rise in the capital adequacy ratio induces banks to

[24] We can estimate the direct effect on the WACC by noting that CAR = {EQUITY/RWA}={ASSETS/RWA}·{EQUITY/ASSETS}, where EQUITY, RWA and ASSETS are bank equity, risk weighted assets and total assets, respectively. Rearranging for the bank equity financing share, EQUITY/ASSETS= CAR·{RWA/ASSETS}. The change in the equity share is given by Δ{EQUITY/ASSETS} = [{RWA/ASSETS}·ΔCAR]+[{0.01·EQUITY/ASSETS}·%Δ{RWA/ASSETS}]. The second term on the right-hand side (RHS) contributes little (≈−0.04 basis points (bps)) to the change in the equity financing share: as is clear from Figure 3, the percentage change (%Δ) in the ratio RWA/ASSETS is small (≈−0.25 per cent) and so too is the equity financing share (0.16). The first term on the RHS is the dominant factor, contributing 0.51 bps to the change in the equity share (ΔCAR = 0.01, RWA/ASSETS = 0.51). With the cost of equity approximately 800 bps higher than debt, the direct impact on bank WACC is approximately 4 bps. The final impact on bank WACC is lower (Figure 4) because investors substitute to non-bank finance (Figure 12) and investment declines (Figure 10).

[25] To put these numbers in context, typical Reserve Bank of Australia adjustments in the policy rate are articulated in terms of 25 basis point movements. The deviation in the policy rate at the end of the period is 0.1 basis points. The positive deviation in the consumption price index at the end of the simulation period is approximately 0.002 per cent. This is like a realised inflation outcome of 2.502 per cent when the target is 2.5 per cent.

FIGURE 6
Movement in the Central Bank Deposit and Lending Rates for Settlement Balances (Basis Point Change from Baseline)

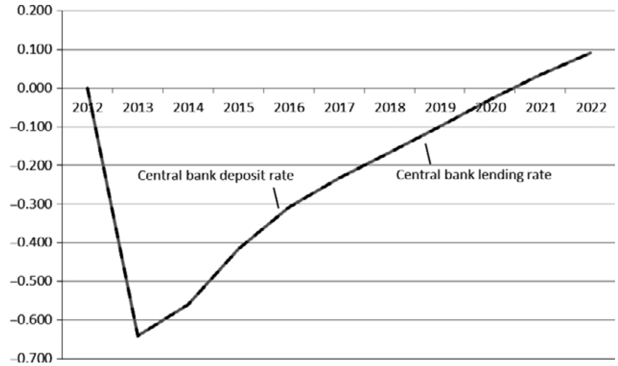
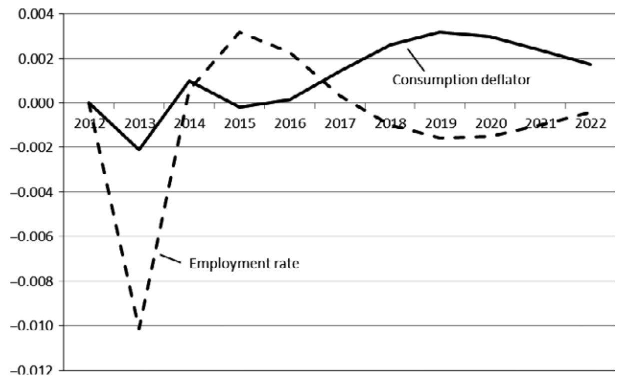


FIGURE 7
Employment Rate and Private Consumption Deflator (Percentage Deviation from Baseline)



reduce lending to reproducible and non-reproducible housing and industry. These agents can substitute towards other sources of financial capital, but their ability to do so is constrained. Consequently, the reductions in bank lending have implications for their capacity to finance physical capital formation. This is clear from Figure 8, which reports gross fixed capital formation for housing and non-housing. Turning to Table 2, the risk weight on lending to reproducible housing is slightly higher than that on lending to industry. This explains part of the deeper negative deviation in housing investment relative to non-housing investment in Figure 8. However, another important factor is the ability of housing and non-housing liability agents to substitute away from bank finance. For housing investment, opportunities in this regard are limited: approximately half of the sector's capital formation is financed by bank lending, with another third financed via household equity. Outside of housing, bank financing accounts for approximately a quarter of the capital required to finance investment, with other sources such as foreign markets and domestic superannuation satisfying, respectively, approximately one-third and one-tenth of non-housing investment financing needs. As is clear from Figure 8, with both components of aggregate investment (i.e., both housing and non-housing investment) below baseline, so too is aggregate investment.

FIGURE 8
Housing and Non-housing Investment, and Economy-wide Investment (% Deviation from Baseline)

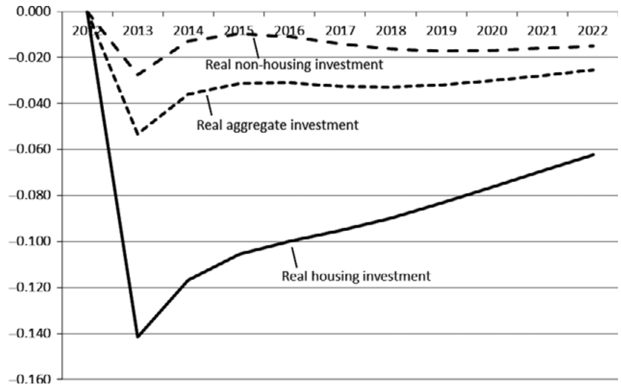


FIGURE 9
Real GDP, Employment, Capital Stock and Real Investment (% Deviation from Baseline)

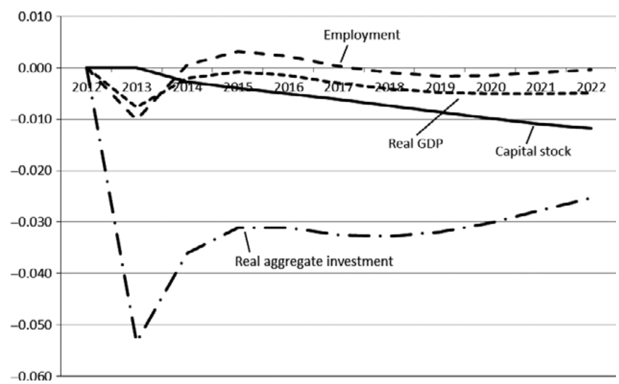


Figure 9 reports deviations in real GDP, employment, capital, and investment. In the simulation's first year, the physical capital stock cannot change from baseline. However, a small negative employment deviation in the simulation's first year generates a small negative deviation in real GDP in that year. Thereafter, employment gradually returns to baseline. However, the negative deviation in real investment causes the aggregate capital stock to fall relative to baseline (Figure 9). This causes a negative deviation in GDP in the medium to longer term of the order of −0.005 per cent, despite the return of employment to baseline.

Figure 10 reports real GDP, real gross national expenditure (GNE), and the components of real GNE (private and public consumption, and investment). As is clear from Figure 10, the real GNE deviation lies below the real GDP deviation. This is due to the negative deviation in real investment. As discussed above, the increase in the capital adequacy ratio causes bank lending to industry and housing to fall relative to baseline. As can be seen in Figure 10, the resulting falls in dwelling and non-dwelling investment cause the aggregate investment deviation to lie below the real GDP deviation. This contributes to the GNE deviation lying below the real GDP deviation.

FIGURE 10
Real GDP, Real GNE, and the Components of Real GNE (% Deviation from Baseline)

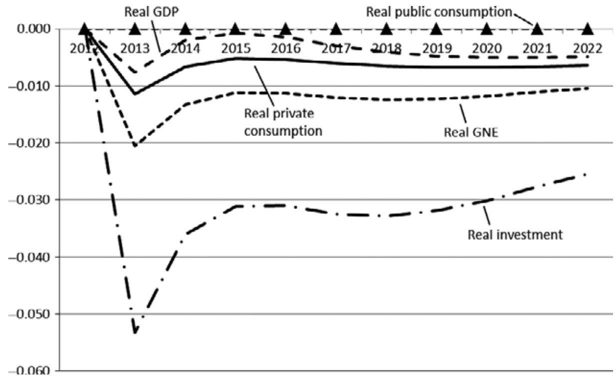
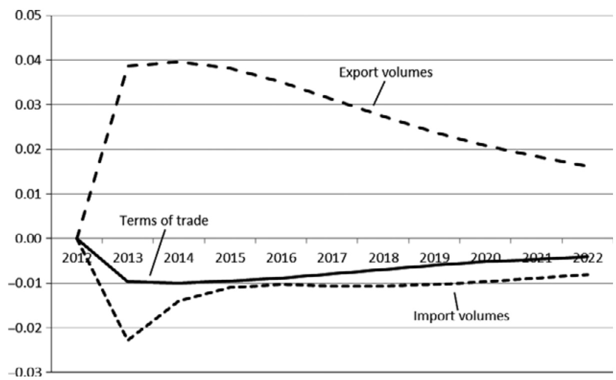


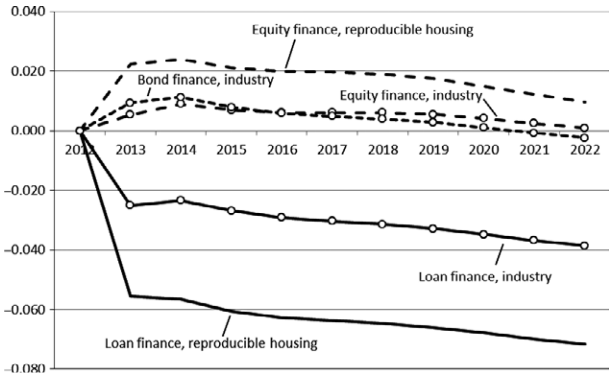
FIGURE 11
Export Volumes, Import Volumes and the Terms of Trade (% Deviation from Baseline)



With the real GNE deviation lying below the real GDP deviation, we expect the real balance of trade to move towards surplus. This is confirmed by Figure 11, where we see a positive deviation in export volumes and a negative deviation in import volumes. The positive deviation in export volumes generates a negative deviation in the terms of trade because exporters must lower the foreign currency prices of their commodities to support the expansion in export volumes. The negative deviation in the terms of trade has consequences for real private consumption. Returning to Figure 10, we see that the deviation in real private consumption is below the deviation in real GDP. This is due to the decline in the terms of trade. In modelling consumption, we assume that nominal private consumption is a fixed proportion of nominal national income. Under this specification, a decline in the terms of trade dampens private consumption relative to real GDP. This reinforces the impact of the negative investment deviation on the gap between the GNE and GDP deviations.

Figure 12 explores the implications of reduced bank lending for the composition of the liability side of the model's two capital creating agents: industry and reproducible housing. As is clear from Figure 12, the balance sheets of both sectors shift away from loan finance towards equity and (in the case of industry) bond finance. This

Figure 12
Equity and Debt of Industry and Reproducible Housing (% Deviation from Baseline)



suggests a second avenue via which the rise in the capital adequacy ratio potentially improves financial stability. Not only are banks encouraged to finance a greater proportion of their operations via equity, but by raising the cost of bank debt finance, households are encouraged to finance a greater proportion of their stake in the housing sector via equity, and industries are encouraged to finance a greater proportion of their gross fixed capital formation via equity and bonds.

IV Conclusions and Future Work

Prudential regulators in Australia and many other countries monitor and regulate the proportion of commercial bank activities financed by equity. Their concern is to ensure that banks have sufficient loss-absorbing capital to maintain financial system resilience in the event of adverse shocks to individual banks or the banking system as a whole. Their aim is to avoid in the future economic damage of the magnitudes experienced by advanced economies following the 2008 financial crisis. But can the raising of commercial bank capital adequacy impose its own macroeconomic costs? We investigated this by examining the effects of a 100 basis point increase in the capital adequacy ratio of commercial banks. We found that this has modest macroeconomic impacts while securing a rise in bank equity, a shift in bank lending away from housing investment, a rise in household equity financing of home ownership, and a rise in equity and bond financing of capital formation by industry.

While our results suggest that regulators have some latitude to raise mandated capital requirements without risking significant macroeconomic disruption, the qualifications and limitations of our modelling must be noted. As discussed in Section II, the level of aggregation of our agents in the model's financial side, particularly the capital-forming industry and dwelling agents, could obscure subsectors where bank financing availability is a binding constraint. Sector-specific bottlenecks can augment the consequences of policy change (see Dixon *et al.*, 2011), raising the possibility that the impact of raising bank CAR could be higher than modelled in this paper. Adverse wealth effects, particularly through the impacts of reduced bank lending on house prices, and possibly also through the impact on bank equity prices of additional bank equity issuance, are another potential avenue via which our modelling might understate the macro effects of higher CAR. A possibility in the other direction is the effect of credit risk perceptions on the cost of bank debt finance, particularly in international wholesale markets. While our finding of only a modest impact on bank WACC from raising CAR is close, quantitatively, to the predictions of Modigliani and Miller, the Modigliani–Miller theorem is not an explicit part of our modelling, and so we might overstate the impact of higher CAR on bank WACC, and thus so too on investment and other macro variables.

We plan to explore the above caveats in five ways. First, while the model is already highly disaggregated, with five financial instruments, 11 financial agents, and 106 production sectors, further disaggregation will expand the range of potential model applications and also elucidate some of the caveats outlined above. For example, we currently assume that the financial capital needed by the 106 industries of the model's real side is raised by two representative financial agents (industry and RH). In future work, we plan to identify each of the model's 106 industries as financial agents in their own right. This will give each industry its own unique capital structure. This could reveal industries where bank capital is a binding constraint. Identification of industries that are particularly sensitive to bank finance restrictions might raise the magnitude of the economy-wide impacts of a rise in CAR. More importantly, it will expand the model's capacity to explore how the costs and benefits of monetary policy and financial regulation are distributed across industries. By identifying the regions in which industries are located, thus allowing recognition of industry- *and* region-specific differences in capital structure, such a model could also elucidate the regional consequences of monetary and financial policy. Further disaggregation in the model's risk weights could also be explored. Consistent with the aggregation of our financial agents, the model currently identifies 11 risk weight bands (Table 2), based on the approximately 50 bands identified in Australian Prudential Regulatory Authority (2013). Further disaggregation would not only allow the model to elucidate finer levels of industrial (and possibly regional) impacts from higher CAR, but also potentially facilitate model development to explore the consequences of higher CAR inducing banks to undertake within-band substitution towards higher risk assets.

Second, we expect that further development of the model's NRH sector, particularly the determinants of NRH prices, has the potential to reveal connections between bank lending and house prices. This will open the possibility of exploring adverse wealth effects via CAR affecting house prices.[26] This would motivate further development of the model's valuation terms. As noted in Section II.ii, the model contains a full set of valuation terms ($V_{(s,f,d)}$), but theory governing movements in these terms currently covers industry, RH and NRH equity, and exchange-rate driven movements in domestic currency values of foreign assets. In future work, we plan to endogenise the valuation terms on the equity of pure financial intermediaries. This would allow, for example, bank equity valuations to be sensitive to mortgage defaults in an environment of rising unemployment or falling house prices.

Third, we plan to model investors as sensitive to bank risk and thus potentially willing to lend and supply equity at lower required rates of return as bank CAR rises. For the current application, we expect this to reduce the magnitude of the modelled impacts of a rise in CAR. We also expect it to expand the range of potential future model applications (e.g. the consequences of heightened perceptions of bank risk on the part of foreign creditors).

Fourth, in this paper our simulations are concerned with investigating the economic costs of raising capital adequacy ratios, while taking as given the idea that financial regulators have a considered view on the benefits, in terms of financial stability, of a given increase in capital requirements. In future work, we expect to investigate the impact on financial stability of changes in the share of equity in commercial bank financing. To do this, we will need to develop the model further, embedding theory explaining how financial stability is affected by changes in equity–debt financing ratios in both commercial banking and housing finance. The aim will be to model factors that can quickly affect financial stability, such as bank runs, or rapid house price deflation. Modelling of the former is likely to require explicit modelling of how the willingness of asset agents to hold commercial bank deposits is a function of perceived bank stability, with one input to these perceptions being the margin of remaining loss-absorbing capital. Modelling of the latter is likely to require explicit modelling of real estate bubbles, with a link between asset price growth and commercial bank lending activity.

The fifth direction of model development will be in the description of the relationship between central bank announcements and the behaviour of financial market participants. In the current model, the central bank affects changes in the policy rate through open market operations. This is consistent with descriptions of central bank activity that give open market operations a central place in maintaining the policy rate near target. However, another possibility is that central bank rate announcements induce market participants to take actions that adjust rates in the direction

[26] For example, Engelhardt (1996) finds a positive relationship between household savings rates and negative house price shocks (but no relationship between savings rates and positive house price shocks).

desired by the central bank, thus reducing the short-run need for open market operations.

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