School of Management
Royal Holloway, University of London

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The impact of financial crises on Australian households: an empirical exploration

Adam Struthers

supervised by Dr Stavroula Iliopoulou

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Author: acstruthers at domain gmail dot com
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Abstract

Financial crises are a recurring feature of the modern economy and, with interest rates close to zero in most developed countries, the traditional monetary and fiscal policy responses have become less effective in stimulating the economy. This paper explores the impact of using inflation to deleverage the Australian government's balance sheet after bailing-out banks during a financial crisis. It introduces a new detailed heterogeneous agent model of the Australian economy to facilitate a multi-dimensional analysis of the impact of inflation on households with various characteristics.

Household composition, wealth and location are all found to be significant determinants of how susceptible a household is to the impact of inflation. Politicians determine government policy and earn more than 90 per cent of Australians – approximately 40 times as much as the bottom 10 per cent – and they insist that inflation and unemployment are economic necessities while they themselves stand to gain the most from inflation. However, if the same amount of inflation is spread over a longer time period it gives households time to adjust, lessening the negative impacts and minimising its contribution to wealth inequality.

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Abbreviations

ABS	Australian Bureau of Statistics
ADI	Authorised Deposit-taking Institution
APRA	Australian Prudential Regulation Authority
ATO	Australian Taxation Office
AUD	Australian Dollar
CoSMoS	Complex Systems Modelling and Simulation
DSGE	Dynamic Stochastic General Equilibrium
FCS	Financial Claims Scheme
FX	Foreign Exchange
GDP	Gross Domestic Product
GFC	Global Financial Crisis (2007-2009)
IS-LM	Investment-Savings, Liquidity-Money
LGA	Local Government Area
NAIRU	Non-Accelerating Inflation Rate of Unemployment
OCR	Overnight Cash Rate
RBA	Reserve Bank of Australia
UML	Unified Modelling Language
US	United States (of America)
USD	United States Dollar
VAR	Vector Auto-Regression
ZLB	Zero Lower Bound

Chapter 1: Introduction

"There are few greater threats to the economic wellbeing of the Australian people than a financial crisis."
– Federal Treasurer, Hon. Scott Morrison, MP (2017: 1)

1.1. Governments often intervene in financial crises

Financial crises are a feature of the modern economy and are often accompanied by government intervention (Niepmann & Schmidt-Eisenlohr, 2013) because the cost of refinancing a troubled bank is predictable, but the broader economic consequences of letting banks fail are unknown (Minsky, 1986). The appearance that government intervention helped to resolve prior crises leads to the belief that intervention is an appropriate response to future crises (Myerson & Weibull, 2015). Thirteen governments nationalised their country's failing banks during the 2007-09 Global Financial Crisis (GFC), and a further ten provided extensive liquidity support and significant guarantees on liabilities (Laeven & Valencia, 2010). The Australian government provided a relatively minor guarantee on deposits (Schwartz & Tan, 2016) and an AUD 52.4 billion stimulus package (Economist, 2009) which was arguably dwarfed by the Reserve Bank of Australia's (RBA) 4.25 per cent reduction in the Overnight Cash Rate (OCR) (Berg, 2014).

1.2. The Australian government cannot afford to bail out the major banks

The Australian banking system has AUD 4.56 trillion in assets (APRA, 2017b), which is 269 per cent of the country's AUD 1.69 trillion Gross Domestic Product (GDP) (ABS, 2017b). If bailing out the banks became necessary, the Australian government could find itself with an over-extended balance sheet (Laeven & Valencia, 2010). This

liability would need to be serviced and eventually repaid. The collapse of Iceland's banking system showed the dangers of large banks supported by a small government balance sheet (Benediktsdottir, Danielsson, Zoega & Tille, 2011), so the Australian government needs to be prepared with a response that the market sees as credible in order to mitigate fears of a sovereign default.

Private debts are reduced by either the borrower repaying the debt or the lender forgiving the debt. Governments have a third option when the debt is denominated in their own currency – using inflation to reduce the value of the debt (Rickards, 2016). However, inflation is a double-edged sword – it helps public balance sheets and hurts private balance sheets – transferring the burden from the government to the people (Lucas, 1996). Government revenues come from businesses and individuals, and the path out of a recession ordinarily includes economic growth in the private sector, so it can be counterproductive to repair the government's balance sheet at the expense of industry. Koo (2008) found evidence both during the Great Depression and the Japanese recession that businesses with troubled balance sheets reduced their debts rather than spending, which keeps demand low and the economy weak. Using inflation to transfer the burden to the private sector does not aid economic recovery. Similarly, increasing taxation when economic conditions are already depressed is unlikely to yield a positive outcome.

Rational agents would demand a risk premium commensurate with inflation expectations (Fratzscher, Mehl & Vansteenkiste, 2011), making it more difficult to use inflation as an explicit tool to reduce debt. A short burst of unexpected inflation is likely to create volatility and do more harm than good, while an extended period of inflation will be included in prices – negating any benefit to the government's balance sheet.

1.3. Existing financial crisis research overlooks the impact on individuals

There exists a significant body of research exploring ways to predict (Barrell, Davis, Karim & Liadze, 2010, Duca & Peltonen, 2013, Oet, Bianco, Gramlich & Ong, 2013) and measure the impact of financial crises (Banulescu & Dumitrescu, 2015, Idier, Lamé & Mésonnier, 2014, Rodríguez-Moreno & Peña, 2013), and on monetary policy responses to financial crises (Congleton, 2009, Gruskin, 2013, Schneider & Tornell, 2004). Researchers have also studied the relationship between interest rates and exchange rates, pioneered by Fleming (1962) and Mundell (1963), that highlights the need for domestic actions to consider international responses.

However, research that explores the impact of domestic monetary policy during and after a financial crisis seldom considers the international implications. Even less common is research that considers the impact on the populace, such as the work of Kumhof, Rancière & Winant (2015) which examined the impact of income inequality and found that it both contributes to and is reinforced by financial crises. If the impact of the current crisis on at-risk individuals could be lessened, then perhaps the likelihood or impact of future financial crises could be reduced measurably.

1.4. Research objectives

This paper aims to provide the Australian government with the beginnings of a road map to repair the national balance sheet after a financial crisis, considering both Australia's place in the global economy and the impact on its people. It does not prescribe a solution but rather examines the impact of various scenarios. For simplicity and to facilitate a clearer understanding of the impact of key economic levers it does not

attempt to model all aspects of the economy but rather focuses on the impact of inflation on households with different demographic profiles.

To determine which actions increase the chance of a sustainable recovery after the next financial crisis, and take into account the impact on real families, two key questions were explored:

1. Is it an absolute limit to the amount of inflation or a speed limit (Lucas, 1996) to the rate of inflation that has the greatest influence on lessening the impact on real incomes and personal wealth?
2. How does the impact vary across different households?

1.5. Scope and limitations

This paper introduces a computational heterogeneous agent model to analyse the impact of various actions on diverse actors. Dynamic Stochastic General Equilibrium (DSGE) models are popular with central banks and better at revealing cause-and-effect relationships but they do not lend themselves to the complexity of heterogeneous agents, which is a main focus of this paper (Cusbert & Kendall, 2018).

The research is limited to the Australian economy using publicly available data, with no knowledge of the internal models and research used by the RBA or government.

1.6. Structure

The rest of the paper is structured as follows. Chapter two outlines a range of government responses and the models used to evaluate their impact. It then introduces complex systems as an alternative to equilibrium models. Chapter three presents the computational heterogeneous agent model and summarises how it is calibrated, with

details in the appendices. Chapter four analyses the results of the model for various bank crash scenarios and levels of inflation, comparing to existing research but focusing on the impact on households. The final chapter concludes.

Chapter 2: Literature review

"There is definitely going to be another financial crisis around the corner because we haven't solved any of the things that caused the previous crisis." – Mark Mobius, Mobius Capital Partners LLC (Touryalai, 2011: 1)

"Typically the crisis never comes from where we expect it." – Christine Lagarde, IMF (Gilchrist & Tso, 2017: 1)

The literature review summarises key areas of research around financial crises, then focuses on how to recover from them rather than attempt to prevent them. It evaluates a range of government responses and hones in on inflation as the economic tool this paper will explore. Popular economic models are analysed, with an emphasis on the models the RBA uses. Finally, it recognises that financial crises and inflation impact people differently based on their circumstances, leading into the methodology section, which uses a quantitative modelling approach to explore the impact of inflation on heterogeneous households.

2.1. Financial crises are inevitable and unpredictable

Attempts to prevent financial crises implicitly assume that better governance and risk management can somehow overcome the foibles of human nature. After the Great Depression in the 1930s, many economists thought that the 'modern era' (Domitrovic, 2012: 1) of counter-cyclical government intervention had put an end to financial crises and was enough to overcome irrational crowd behaviour that led to booms and busts throughout history (Mackay, 1869). The GFC in 2008 showed these hopes were unfounded, and ten years after Lehman Brothers' collapse the world's economy

languishes while only token attempts at banking reform have been made (Elliott, 2018, Stern, 2018). This paper assumes that financial crises are inevitable, focusing instead on how to repair public and private balance sheets after a crisis.

Several researchers have proposed models to measure the risk in the financial systems using market pricing mechanisms such as Credit Default Swap rates (Huang, Zhou & Zhu, 2009, Rodríguez-Moreno & Peña, 2013) in an attempt to predict the likelihood of a financial crisis. Using the market's assessment of risk is inherently flawed because it ignores the irrational exuberance of crowds during good times (Mackay, 1869). Busts follow booms, but people tend to place more weight on recent events, resulting in under-pricing of risk during bull markets (Kahneman & Tversky, 1979). Hubris among finance professionals results in artificially low prices for risk when, in fact, the risks are greatest.

Financial crises involve cascades of defaults, with sovereign credit risk as the primary source of contagion (Paltalidis, Gounopoulos, Kizys & Koutelidakis, 2015). The 1997 Asian financial crisis was particularly dangerous because it unwound theoretically zero-exposure net positions, which cascaded through the global financial system, revealing the underlying massive gross exposures (Rickards, 2016). Despite this proof that net positions hide the true degree of risk in the financial system, accounting standards and banking regulators continued to measure net exposures (AASB, 2015, APRA, 2016b) although regulators have started to consider aggregate risks (APRA, 2016a). In the absence of meaningful exposure data for such an interconnected financial system it is impractical to try to predict how the next crisis will spread and what might cause it (Gilchrist & Tso, 2017), but we can be confident of another crash occurring even if we are unable to foresee the details (Rickards, 2016, Sornette, 2017).

The impact of bailing out a bank can be known in advance, but the consequences of allowing a bank to fail are unknown. Because of their desire to avoid an unknown and potentially catastrophic outcome – such as a global cascade of defaults – many governments and central banks have chosen to provide capital relief to banks rather than allowing them to fail (Minsky, 1986). This in itself creates moral hazard, increasing the likelihood of risky behaviour, and leading to an ever-increasing cycle of booms, busts, and bail-outs. Every time this cycle occurs, there is a transfer of wealth from the working class to the wealthy (Kumhof, *et al.*, 2015).

2.2. Government response hierarchy

In the absence of a reliable solution, governments intervene to try to stabilise the system using a range of responses based on their models and keep trying the tools at their disposal until something appears to work. Monetary policy, fiscal policy, and exchange rates are the tools of choice to generate inflation, which decreases the real cost of debt and has an impact on welfare.

The US government used low rates of inflation over a sustained period to reduce the burden of its debts after the Second World War. 'Just a 1 percent difference between inflation and rates cut the real value of the debt by 30 percent in twenty years' (Rickards, 2016: 42). However, Fratzscher, *et al.* (2011) contend that if the market expects this response, it will demand higher risk premia, increasing the cost of debt and making a currency crash more likely. Given that this has not happened to the USA yet, their results appear not to be universally applicable.

Inflation is generally considered to be triggered by fiscal imbalances, and monetary policy is then usually accommodating, leading to further inflation[1] (Fischer, Sahay & Vegh, 2002). Once a period of high inflation begins, speculators and business owners who profit from inflation are incentivised to prolong the episode, making the problem worse and contributing to eventual economic collapse (Coomer & Gstraunthaler, 2011).

Zimbabwe's land repossessions show how unplanned spending and unexpected budget deficits led to a loss of market confidence (Kairiza, 2009) and hyper-inflation peaking 'at about 500 billion (10^9) percent' (Coomer & Gstraunthaler, 2011: 331). The RBA and government must demonstrate fiscal discipline to maintain the market's trust. However, a bank bail-out could force the government's hand by incurring a large unexpected deficit, and in the wake of a financial system in distress, the market may begin to price in further bail-outs.

Petrovic & Mladenovic (2000) found that during periods of hyperinflation, the public bases its decisions on the foreign exchange (FX) rate rather than price indices because FX rates are easily observable and not subject to measurement error the way indices are. The model described in this paper uses FX rates both as a proxy for inflation and to introduce exogenous shocks into the domestic financial system.

When financial crises are caused by bad fiscal or monetary policy, the solution is obvious; but crises are now more frequently caused by financial institutions which makes them significantly harder to prevent and fix (Macfarlane, 1997). Governments

[1] In both Zimbabwe and Germany, the market began to expect inflation, which stimulated demand and raised future prices (Coomer & Gstraunthaler, 2011). This expectation became a self-fulfilling prophecy which led to hyperinflation and ultimately the collapse of their currencies.

rely on prudential supervision to prevent crises but, when a crisis occurs, they typically try less disruptive responses first and escalate as the need increases:

1. **Monetary policy** – change interest rates to influence inflation expectations and incentivise the desired spending behaviour.
2. **Exchange rates** – governments can directly intervene in their currency's exchange rate, but changes seldom last long enough to be helpful.
3. **Fiscal policy** – give people money to stabilise prices and generate inflation.
4. **Capital relief** – contributing capital to financial institutions or converting their liabilities to equity.

Below is an analysis of each to explore how useful they might be during and immediately after a financial crisis.

2.3. Response 1: Monetary policy

The RBA has focused its monetary policy on an inflation target since the early 1990s (Fraser, 1992, RBA, 2018f) to maintain currency stability, full employment, and economic prosperity (Lowe & Morrison, 2016). The RBA controls the OCR by buying or selling government bonds to increase or decrease the money supply, which in turn affects prices and the rate of inflation (RBA, 2018a). The issuing of bonds was once reserved solely for financing wars (Noyes, 1895), but has now become part of the government's standard economic toolkit[2].

[2] The effect of this can be seen in the rise of all countries' aggregate debt from USD 25 billion in 1864 (Mitchell, 1884) to USD 62,592 billion in 2017 (Economist, 2018), a 160-fold increase after adjusting for inflation (Alioth Finance, 2018). Australia alone now has over USD 400 billion in public debt, up from USD 128 billion in 2007 (Economist, 2018).

During the Japanese recession of the 1990s, businesses focused on paying down debt even though interest rates were close to zero. Despite strong cash flow and continuing demand for their products, asset prices fell so dramatically that the businesses became technically insolvent and needed to repair their balance sheets. This is known as a 'balance sheet recession' (Koo, 2008: 11).

Monetary policy is much less effective during a balance sheet recession because lack of demand for credit means that reducing interest rates does not stimulate the economy through increased spending. Australia could find itself in a balance sheet recession during the next financial crisis as public concerns about a property price bubble grow. Since the GFC, residential property prices in Australian capital cities have grown 67 per cent (ABS, 2018e), which is more than double the GDP growth of 25 per cent (ABS, 2017b). Australian household debt to disposable income ratios have also risen to one of the highest levels in the world at almost 200 per cent (Chalmers, 2018). An expected side effect of the Banking Royal Commission is that banks are likely to take fewer risks, reducing the availability of credit regardless of interest rates (Holden, 2018). While the Royal Commission was still in progress, up to 40 per cent of borrowers were already unable to refinance their loans due to high levels of debt and the recent introduction of more stringent lending criteria (Ferri, 2018). This suggests that interest rates are likely to be a less effective tool during the next financial crisis.

During the GFC, the RBA dropped interest rates by 4.25 per cent (RBA, 2018b). The OCR was down to 1.50 per cent in 2018 (RBA, 2018b), so the next crisis would result in interest rates reaching zero per cent if the RBA tried dropping them by a similar amount. At this Zero Lower Bound (ZLB), monetary policy becomes an impotent tool.

At the ZLB, governments rely on the market's trust to sustain positive inflation expectations. In the wake of a prolonged period of low interest rates, it becomes more likely that deflationary expectations will become entrenched, as they did in Japan (Clarida, 2012). Increasing the inflation target in good times would provide the RBA with a larger buffer, but higher inflation rates come at the cost of higher volatility, and the combined cost of these is greater than the benefit of reducing time spent at the ZLB (Coibion, Gorodnichenko & Wieland, 2012).

2.4. Response 2: Foreign exchange rates

Monetary policy affects exchange rates, and when rates reach the ZLB governments can directly intervene in their currency's exchange rate, but would need a large 'war chest' to be able to achieve any meaningful difference (RBA, 2017a).

Reducing the value of the AUD would affect the relative affordability of domestic and foreign goods, increasing net exports. This could, in theory, help the Australian economy during a crisis, but Cole & Nightingale (2016) found that a 10 per cent drop in the value of the AUD would increase net exports by only 1.5 per cent of GDP over two years. This delay makes exchange rates too slow a tool to be useful in the midst of a crisis. Other countries may also change their own exchange rates in response to the effect this has on their domestic economies, which could result in a *currency war* where there are no winners (Besanko, Dranove, Schaefer & Shanley, 2012).

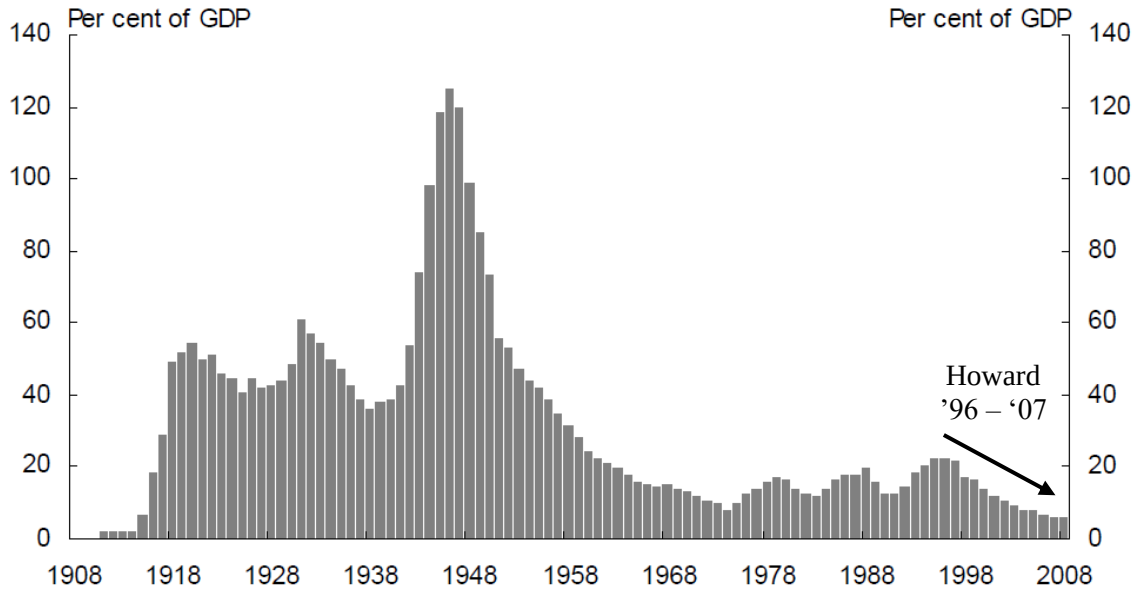
Given the Australian economy's relatively small size compared to its main trading partners – China, Japan and USA (DFAT, 2017, Scutt, 2018) – it is unlikely that exchange rate intervention would be sustainable for long enough to make a material difference to Australia's economic recovery after a financial crisis. Large changes in

exchange rates can also negatively impact the solvency of banks, who source funding from international markets (Grenville, 1998).

2.5. Response 3: Fiscal policy

In the wake of the GFC, it is becoming more common for governments to set rules for themselves in how they conduct fiscal policy. How these rules are structured can have a big impact on the outcome. Repeated large shocks can cause a government to go massively into debt, depending on their choice of policy (Halac & Yared, 2014). Governments are also more likely to have a bias towards present spending, resulting in larger debts accumulating, if they are unlikely to retain power after the next election (Halac & Yared, 2014).

The link between political instability and public debt can be observed in Australia as public debt has tripled from USD 128 billion in 2007 to over USD 400 billion in 2017 (Economist, 2018); a period when, from Rudd in 2007 to Morrison in 2018, Australia changed prime ministers six times and not one served their entire term without either staging or suffering a coup from within their own party. By comparison, John Howard was the only prime minister in the preceding decade (National Archives of Australia, 2018). Howard completed three full terms in office, paying down public debt to the lowest levels in a century (Di Marco, Pirie & Au-Yeung, 2009). See Figure 1.



SOURCE: Di Marco, *et al.* (2009)

Figure 1: Australian government public debt (per cent of GDP as at 30 June)

The government responded to the GFC with two tranches of spending totalling over AUD 50 billion, which was expected to increase GDP by about 2 per cent but not until 2009. It included investments in 'schools, housing, energy efficiency, community infrastructure and roads and support to small businesses' (Swan & Tanner, 2009: 3). Implementation delays make it questionable how effective they were at helping the economy when it was struggling most. Perhaps Halac & Yared (2014) were right, and the political instability led to overspending and burgeoning public debt as the leaders of the day attempted to buy votes.

Governments can attempt to stimulate private spending in the medium term by reducing tax rates, and in the short term by providing tax rebates. Although not currently in a recession, the Australian government recently introduced a series of personal income tax reductions that benefited high-income men more than any other demographic (Elton-Pym, 2018, Morrison, 2018, Murphy & Hutchens, 2018). This bias only serves to compound the problem of wealth concentration that contributes to the occurrence of

financial crises (Kumhof, *et al.*, 2015), but is unsurprising given the senior political leaders and their main donors were high-income males.

Stimulus payments, often in the form of tax rebates, attempt to reduce the impact of a recession on private wealth (Kaplan & Violante, 2014), but people respond differently to receiving the payment. Homeowners are more likely to spend the payment, while renters are more likely to save it (Parker, Souleles, Johnson & McClelland, 2013). The effect of stimulus payments on marginal propensity to consume is dampened during recessions when it is needed most (Berger & Vavra, 2015).

Friedman's permanent income hypothesis (PIH) states that transitory income and consumption are uncorrelated because any money received today will be repaid tomorrow through higher taxes, so there is no net benefit (Friedman, 1957). However, empirical analysis of behavioural responses to unexpected transitory income casts doubt on the PIH as there was 'a strong tendency to spend windfall income' (Bodkin, 1959: 613). Analysis of recent US government stimulus payments found that consumers spent roughly one-third of payment in the quarter they received it and another third in the following quarter (Johnson, Parker & Souleles, 2006). Measuring the impact is difficult because the infrequent purchase of durable goods means many studies limit their analysis to non-durable goods where it is easier to confirm or deny a short-term correlation between income and consumption.

2.6. Response 4: Directly supporting financial institutions

Capital and liquidity are a bank's two main sources of financial strength. Sometimes banks have sufficient capital but inadequate access to funds, which is problematic during a crisis when financial markets freeze. The central bank can be a lender of last

resort in illiquid markets when it believes that the fundamentals are still solid and the illiquidity is due to temporary irrational fear generated by the crisis. Australia, however, has only needed to do this twice in its entire history (Fitz-Gibbon & Gizycki, 2001).

Standard and Poors said that if the Australian government reduces its appetite to support failing banks, it might trigger a credit downgrade for the banks (Bagshaw, 2018). Reduced government support would increase the banks' wholesale funding costs which would, in turn, be passed onto consumers. The government provided this explicit support during the GFC (Grattan & O'Shaughnessy, 2008) and now that the crisis has passed there is no reason to keep this support in place – in fact, a case can be made that it should be withdrawn. It distorts the true economic costs of the banks' decisions, artificially lowering their cost of capital and creating an agency problem (Boot, 2011).

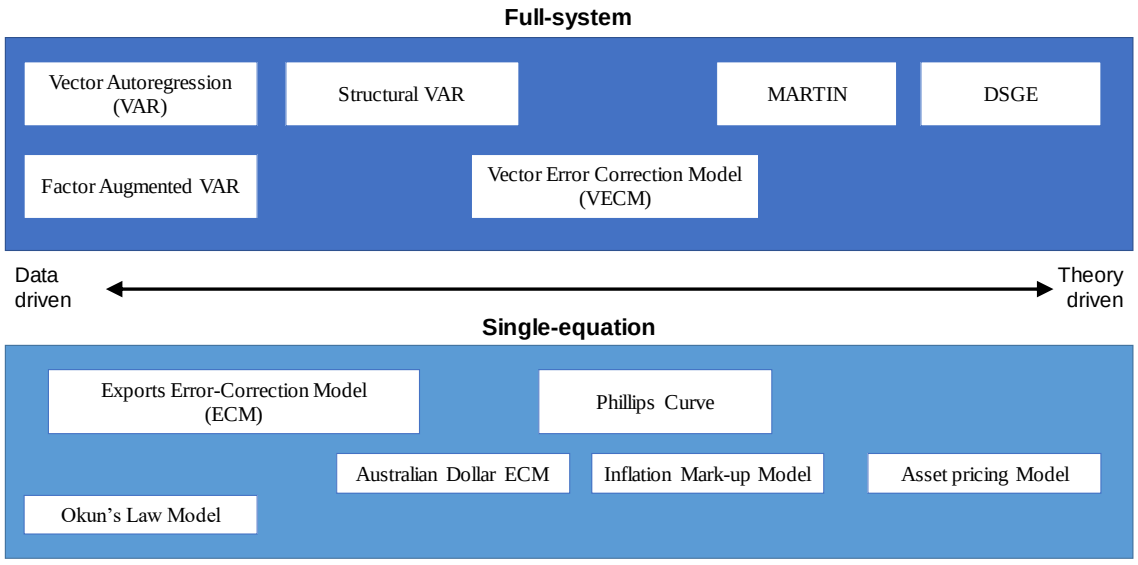
A troubled bank's financial position can be improved by increasing its capital either through direct contributions of capital or converting liabilities to equity. Liability conversion can be achieved via hybrid debt securities that become equity when a pre-defined trigger is reached. Taking this a step beyond investment instruments, the Australian government recently passed legislation that 'could confiscate deposits' too during the next financial crisis (Hansard, 2018, Isherwood, 2018: 1).

Convertible bonds essentially force superannuation funds to hand over people's retirement savings to the banks as equity when they are in trouble. This is not nationalisation per se because the government does not own the banks, but it has the same effect because the population are left footing the bill for failed banks – this time with their retirement savings rather than their taxes, so it affects them most when they are retired and can afford it least because they rely on those savings for their livelihood.

It does, however, help avoid the situation of the government going into debt to bail the banks out and then taxing the people to pay off the debt, possibly resulting in a slight benefit to taxpayers who instead of repaying debt are now equity holders with the right to future dividends.

2.7. A brief survey of existing RBA models

The RBA uses a range of models including Dynamic Stochastic General Equilibrium (DSGE) models (Rees, Smith & Hall, 2016), Vector Auto-Regression (VAR) models (Gerard & Nimark, 2008), as well as its most recent innovation, MARTIN (MAcroeconomic Relationships for Targeting INflation) which is a full-system economic model using error correction models and single equation predictions with various correlations and feedback loops (Cusbert & Kendall, 2018). These economic models are naturally biased towards the RBA's stated goal of inflation targeting.[3]



SOURCE: Cusbert & Kendall (2018)

Figure 2: Taxonomy of economic models at the RBA

[3] The author acknowledges that this summary is incomplete as it is based on publicly available information only and the RBA probably uses other private models too.

Single equation models are easier to build and use, but they focus on a single variable and take everything else as given, so are of limited use outside of their very narrow scope (Cusbert & Kendall, 2018).

DSGE models use linear approximations of non-linear models, which will not necessarily hold when the data diverges far from a specified steady-state (Rossiter, 2012). This domain-sensitivity means that analysis using DSGE models only holds under normal conditions and not the kind of extreme volatility that is often observed during financial crises. The RBA mainly uses its DSGE models for scenario analysis (Cusbert & Kendall, 2018) but recognises that they 'often do not fit the data as well as other models, and the causal mechanisms do not always correspond to how economists and policymakers think the economy really works' (Cusbert & Kendall, 2018: 3).

Multiple time series analysis techniques like VAR are mainly used for forecasting (Lütkepohl, 2005). The maths is simpler than a DSGE model, making it easier to include new dimensions. The number of economic indicators that can be reliably estimated to calibrate a VAR model is limited, so variations have been developed to overcome this shortcoming[4].

[4] Factor-Augmented VAR assumes most of the relationships can be represented by a few key factors, Panel VAR imposes 'exclusion, exogeneity or homogeneity restrictions' (Bańbura, Giannone & Reichlin, 2010: 72) to limit the number of variables without losing information, and Bayesian VAR uses priors to achieve the same goal. VAR models use endogenous relationships, so Structural VAR models allow the introduction of exogenous inputs (Feve & Jidoud, 2014) and time-varying parameters (Mumtaz & Sunder-Plassmann, 2013), which is useful when modelling a small economy that has no control over many global economic inputs.

MARTIN is the RBA's full system model that attempts to combine the predictive power of VAR models with the explanatory power of DSGE models and the finesse and accuracy of single equation models (Cusbert & Kendall, 2018).

There appears to be a gap in the RBA's suite of (publicly known) models. Existing models focus on economy-wide forecasting and causative effects, but there is no mention of a complex system model to consider emergent properties from groups of agents, nor a model that explores the impact on those heterogeneous agents at an individual level. This paper proposes a model that seeks to partially fill this apparent void.

2.8. Towards a better model

Equilibrium models assume that after the economy is shocked by some exogenous event it will return to equilibrium (Oslington, 2016), but shocks large enough to cause a financial crisis may violate this assumption. Table 1 summarises key examples.

Table 1: Key shortcomings of equilibrium models

Shortcoming	Brief Explanation
Structural changes affect the equilibrium	Financial crises result in wealth transfer and structural changes to the economy so it is unlikely the economy will return to an equilibrium based on the pre-crisis data used to calibrate the model, making the results unreliable.
Decision-making processes change during a crisis	Oprea (2014) found that when faced with a choice between survival and profit maximisation, more people prioritise survival. This suggests that decision-making processes change during crises, so equilibrium models' assumptions of rationality and profit maximisation make them inappropriate for crisis modelling.

No path to equilibrium	General equilibrium models assume that no transactions occur in disequilibrium, but that somehow the entire economy adjusts instantly to exogenous changes and reaches a new equilibrium (Borges, 1986). This is of little use when trying to stabilise the economy because it provides no hints as to the path to the new equilibrium.

Many economic models assume homogeneity because it simplifies the mathematics, allowing them to focus on some aspect without being distracted by details. This shortcut can bias the results of the model towards certain policy decisions and away from others. However, it is the impact of policy decisions on individuals that is most important (Fromm & Schink, 1973). For example, homogeneous models predict no impact from redistributive policies, but heterogeneous models recognise that the marginal propensity to consume could be different between rich and poor people, so a redistributive policy may actually have a net positive effect on consumption (Dynan, Skinner & Zeldes, 2004, Jappelli & Pistaferri, 2014).

Allowing for heterogeneity makes the mathematics of an analytical solution to a complex adaptive system unwieldy. A practical (and popular) solution is to use a Computational Heterogeneous Agent Model (HAM) where the individual relationships can be clearly and easily described with equations, and then simulations reveal the complex relationships that emerge as these agents interact with each other.

Gerard & Nimark (2008) combined the probability density functions of several equilibrium models to overcome the shortcoming of point forecasts, which only present a single estimate of the future. Computational HAMs can achieve a similar probability view by running multiple simulations to estimate the distribution of outcomes.

Governments rely on economic models that are an abstraction of reality and require data for calibration, testing, and refinement. The models must make do with incomplete data because the data comes at great cost since financial crises affect individuals, their livelihoods, and their families. Sometimes the effects can be felt for generations.

Chapter 3: Methodology

"The crucial question in economics today is whether capital markets are complex systems. If the answer is yes, then every *equilibrium model used in financial economics is obsolete." – James Rickards (2016: 10)*

Complexity has a particular meaning in the context of complex systems. Just because a system is complicated does not mean it is complex. The complexity referred to is the way many nodes which individually come from a particular probability distribution function can sum to a collective effect that follows a different distribution.

'Representative agent models fail to address the most basic questions of macroeconomics' (Colander, Howitt, Kirman, Leijonhufvud & Mehrling, 2008: 236) because the economy is a complex system, and the aggregate behaviour cannot be determined by simply examining individual behaviour (Debreu, 1974, Mantel, 1974, Sonnenschein, 1972). This paper proposes a new computational heterogeneous agent model of the Australian economy to examine both the emergent properties of the complex economic system and the impact on the individual agents within the system because 'multi-agent systems are better at modelling real social phenomena' (Liu, Mo, Paddrik & Yang, 2018).

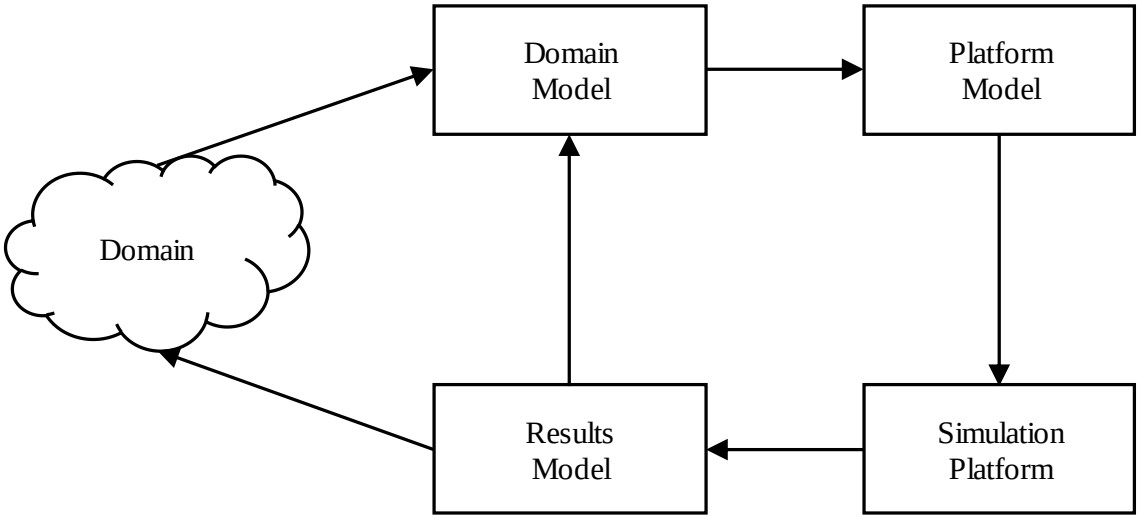
3.1. CoSMoS methodology

Complex systems are a relatively new field of research, enabled by the availability of modern computing power, and they are studied more extensively in biology than in economics (May, Levin & Sugihara, 2008). Until recently no general framework for these models existed (Grimm, Revilla, Berger, Jeltsch, Mooij, Railsback, Thulke,

Weiner, Wiegand & DeAngelis, 2005), which meant that much of the existing research was not easily reproducible if at all. The CoSMoS (Complex Systems Modelling and Simulation) approach is a generic framework that does not prescribe any modelling technique, programming language, or even field of study, yet it provides enough guidance around models and arguments to ensure the simulation is well-engineered, reproducible, and enables rigorous peer review (Stepney, Polack, Alden, Andrews, Bown, Droop, Greaves, Read, Sampson, Timmis & Winfield, 2018).

CoSMoS separates the model into five areas of concern[5]:

1. **Domain** – a view of the real-world system being studied.
2. **Domain model** – a scientific description of aspects of the domain.
3. **Platform model** – the technical implementation details.
4. **Simulation platform** – the computer code that enables experiments to be run.
5. **Results model** – translates results into the domain model to enable analysis.



SOURCE: Adapted from Stepney, *et al.* (2018)

Figure 3: Overview of CoSMoS artefacts and the information flows between them

[5] An in-depth discussion of the CoSMoS approach is beyond the scope of this paper. See Stepney, *et al.* (2018) or the Cosmos website (Stepney & Welch, 2015) for details.

3.2. Computational heterogeneous agent model of the Australian economy

Building on Mundell (1963) and Fleming's (1962) work which extends an Investment-Savings, Liquidity-Money (IS-LM) model to a small open economy (see Table 2), this model focuses on households' financial positions – not fixed or floating exchange rates. The impact of FX rates on the domestic economy is transmitted via the pricing mechanism (Sanchez, 2005), which affects the incomes and expenses of the agents in the system and acts as a proxy for inflation. The obligations of each node to each other node are used to generate a clearing payment vector using the algorithm developed by Eisenberg & Noe (2001), which cascades defaults through the system. If defaults cause an Authorised Deposit-taking Institution (ADI) to fail, the magnitude of the government bail-out is estimated according to the Financial Claims Scheme (FCS) legislation that imposes limits on the government's response (Hansard, 2008).

Table 2: Key relationships in the Mundell-Fleming IS-LM model

		Market						
		Goods		Securities		Money		International Reserves	
Sector	Government	T – G	+	Government Borrowing	+	Government Dishoarding	+	*	= 0
		+		+		+		+	
	Private	S – I	+	Private Borrowing	+	Private Dishoarding	+	*	= 0
		+		+		+		+	
	Foreign	M – X	+	Capital Outflow	+	*	+	Increase in Reserve	= 0
		+		+		+		+	
	Banking	*	+	Open Market Sales	+	Monetary Expansion	+	Foreign Exchange Sales	= 0
		≡ 0		≡ 0		≡ 0		≡ 0	

* Negligible or ignored
SOURCE: Mundell (1963) Table 1

3.3. Domain model

The domain has been summarised in the literature review. The relationships between the agents are now described by the domain model.

Because complex systems involve 'substantial heterogeneity of nodes, both in terms of size and linkages' (Gaffeo & Tamborini, 2011: 81), the model developed in this paper uses approximately 27 million distinct agents. They all have individually calibrated financial statements using publicly available Australian data (discussed in detail later) so it reasonably represents the Australian economy.

Mundell (1963) and Fleming's (1962) equilibrium model is a simplified view of the economy, with only four agents and four types of cash flows considered. It was used to explore the impact of policies affecting the aggregate level of employment, but it is not detailed enough to explore the impact on real wages for heterogeneous individuals.

This model has been extended in two main ways:

1. Heterogeneity within each type of agent; and
2. More realistic links between individual agents.

These are summarised below, with specific data sources and details included in the appendices.

3.3.1. Expanding the model to include greater heterogeneity of agents

The government is represented by the RBA and Commonwealth Government, based on their published financial statements. State and local governments are out of scope because they have nothing to do with ADI regulation or bail-outs. The private sector has

been split into households and businesses. The households are determined by first defining individuals then aggregating them into households. There are 90 foreign countries trading in 51 currencies. And the ADIs have been grouped into major banks, regional banks, foreign banks, and mutual ADIs. See Figure 4.

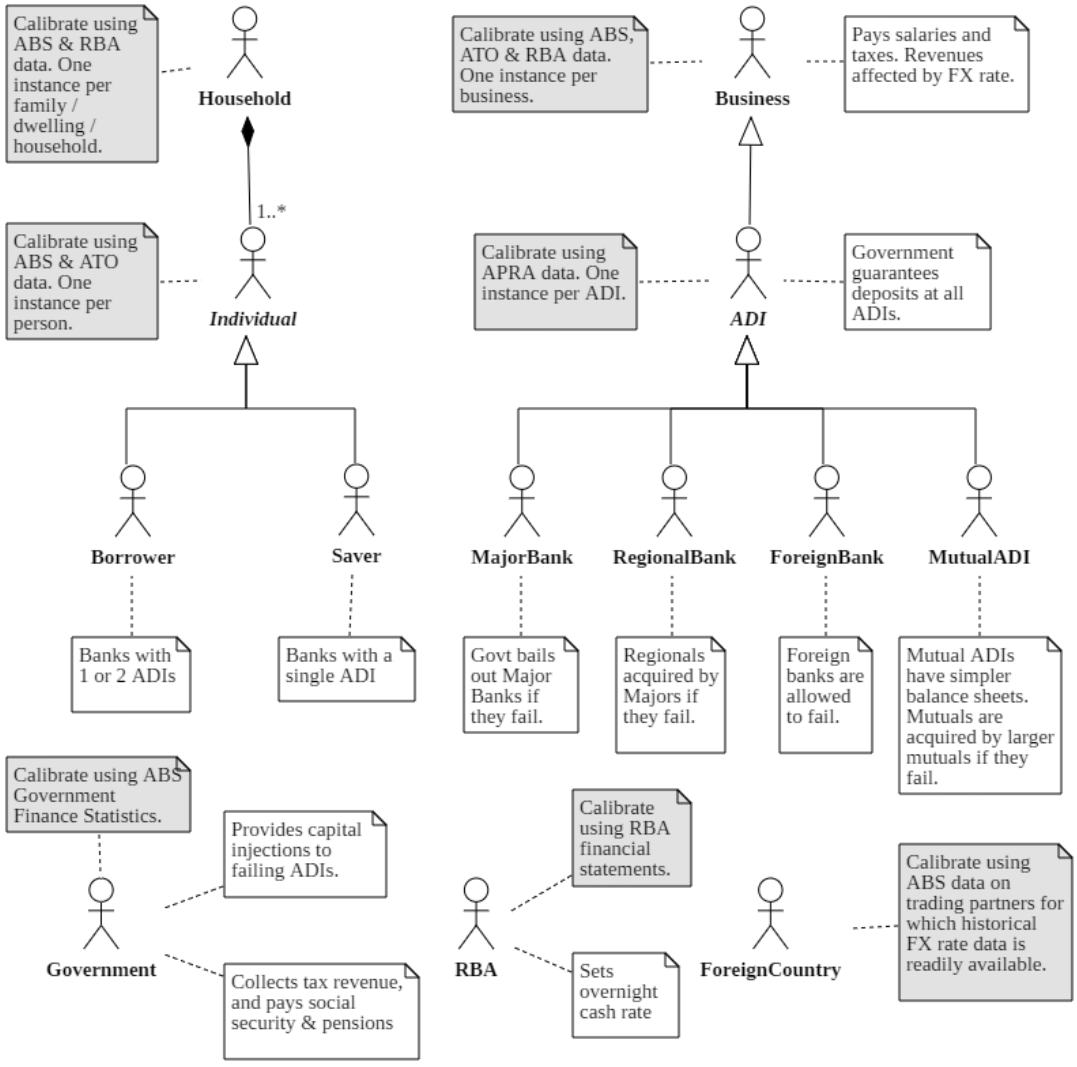


Figure 4: Unified Modelling Language diagram of the classes of agents in the model

3.3.2. Agents calibrated to represent the real world

Policy-makers should ultimately be concerned with the impact on real people in their electorate. Cagetti & De Nardi (2006) introduced heterogeneous individuals, and this paper extends their work by using publicly available statistical data rather than

equations to calibrate the agents. This approach ensures not only that the instances of each type of agent are themselves heterogeneous, but that the agents represent the real world.

Figure 5 summarises the model, with details in the following sections. The dotted line arrows show the key drivers in the model: interest rates and FX rates; while the solid line arrows show the key cash flows, which are also how defaults cascade through the economy.

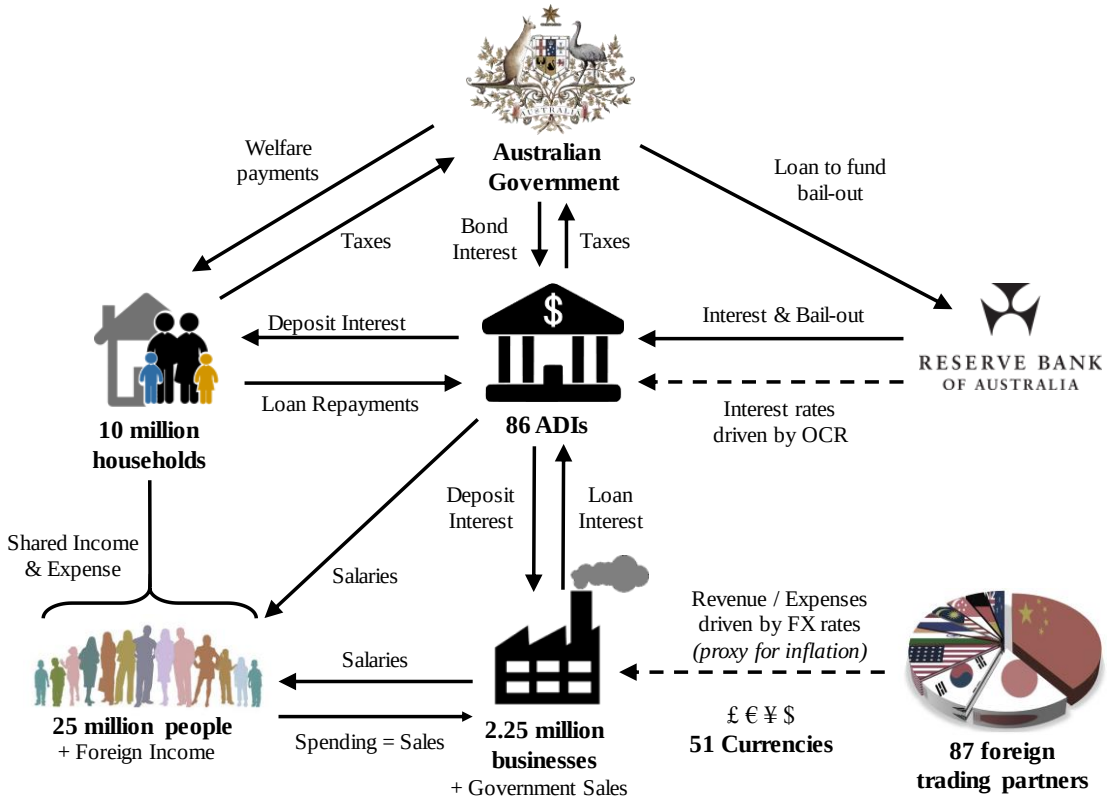


Figure 5: An overview of the agents in the model and their main interactions

See Appendix B to Appendix G for more details of agent heterogeneity and calibration.

3.3.3. *Interest rates and FX rates drive domestic cash flows and inflation*

As with Mundell (1963), the model assumes perfect capital mobility, which means that all securities are perfect substitutes and all exchange rates persist indefinitely. The

exchange rates in this model only change in response to changes in domestic conditions, and the weighted rate is a proxy for inflation (Coomer & Gstraunthaler, 2011).

Calculating the real exchange rate is fraught with difficulties, and there is no widely accepted method (Ellis, 2001), so for simplicity this model uses AUD import and export volumes to weight the exchange rates of the countries that have been included in the model as trading partners. The volume-weighted average rate for imports is estimated separately to exports. Changes in the import exchange rate are used to adjust the expenses for households and businesses, while the export exchange rate impacts on the export-based portion of business revenues.

Den Haan (2017) describes a model where governments set expectations of future interest rates but not the actual market rates themselves. The minutes of the RBA's monthly meetings sometimes involve some 'sabre rattling' (Weir, 2014) which supports Den Haan's hypothesis. However, to simplify the model, only the current interest rates have been included – not expectations of future rates.

3.3.4. Cascading defaults through the system

Complex system models need to consider not only the nature of the agents but also the structure of the network linking them (Colander, *et al.*, 2008). The Clearing Payment Vector algorithm developed by Eisenberg & Noe (2001) for the inter-bank market has been extended to include the private sector too. This algorithm allows for defaults to cascade through the system, while maintaining the key constraints of bankruptcy law: equal priority of creditors, and limited liability of shareholders.

The algorithm was also customised to apply the rules of the FCS, in which the government guaranteed customers' deposits in the event of a bank collapse[6]. It was also extended to include an agent's cash balance because they only default if cash plus income is less than expenses – not just if expenses exceed income.

If a business becomes technically insolvent[7] or runs out of cash, then it goes bankrupt. Everyone employed by that business now receives government unemployment benefits rather than a salary, and the government's tax revenue decreases accordingly.

Under normal circumstances, people who find themselves with insufficient income or cash in the short term may be able to borrow against their future earnings to avoid defaulting (Friedman, 1957). However, because this paper is focusing on a period of financial crisis and its aftermath, it is assumed that lending is greatly restricted and not available to people who find themselves in financial distress. If all employees in a household lose their jobs, they cut out discretionary expenses, sell the house if they own one, and downsize to a rental property that they can afford on unemployment benefits.

3.3.5. Estimating the impact of bank collapses

Niepmann & Schmidt-Eisenlohr (2013) examined bank bail-outs and international contagion using a model with two depositors, investing in two assets, in two banks, in two countries, and using liquidity preference as a proxy for bank failure. The focus was on the welfare in each country, given that the decisions one country makes can impact on the other country. Bank balance sheets are more complicated than a simple liquidity

[6] See section 3.3.5 for details of the FCS.

[7] Liabilities greater than or equal to assets.

proxy can adequately represent, with APRA requiring ADIs to ensure all of the following metrics exceed regulatory minima:

Table 3: ADI regulatory minima

Type	Metric	Limit[8]
Capital	Total capital adequacy ratio	8%
Capital	Tier 1 capital adequacy ratio	6%
Capital	Common Equity Tier 1 capital adequacy ratio	4.5%
Capital	Capital Conservation Buffer	2.5%
Capital	Countercyclical Buffer	0% to 2.5%
Capital	Leverage ratio[9]	3% to 3.5%
Liquidity	Total liquidity ratio	9%
Liquidity	High quality liquid assets ratio	9%
Liquidity	Liquidity Coverage Ratio (LCR) [10]	100%
Liquidity	Net Stable Funding Ratio (NSFR)[10]	100%

SOURCE: APRA prudential standards APS 110 (APRA, 2015) and APS 210 (APRA, 2017a), and consultation letter (APRA, 2018a)

This model uses only two measures of an ADI's viability or failure:

1. The total capital adequacy ratio; and
2. The total liquidity ratio.

[8] Although these metrics are reported in detail to APRA, only some are readily available in the public domain. These are the regulatory minima, while in practice APRA sets individual limits for most ADIs that are higher than these (but the ADIs are forbidden from publicly disclosing their actual limits).

[9] Leverage ratio is proposed but still in the consultation process so not in force yet.

[10] The LCR and NSFR are only applied to the larger ADIs that are thought to be systemically important, so they are excluded from this model since they are not applicable across all the ADI agents in the model.

During the GFC, the Australian government introduced the FCS to guarantee deposits with ADIs. The FCS insures individuals' deposits up to AUD 250,000, with the limit applied per customer per ADI licence (APRA, 2018b). This model assumes one licence per ADI. There is also an AUD 20 billion limit per ADI which means that customers of larger ADIs may find that they are covered for substantially less than the AUD 250,000 individual limit (Hansard, 2008). For example, the Commonwealth Bank of Australia has AUD 520 billion in deposits, so assuming deposits are equally held among customers, the effective guarantee is less than AUD 1,200 per customer[11].

3.4. Platform model: Calibrating the model

The model is calibrated to the Australian economy, attempting to mimic the types of agents in the economy and their relative weights. Each agent has a profit and loss statement and a balance sheet unique to them. The level of detail in the simulated financial statements was driven by the granularity of publicly available data.

Households are modelled with relative detail because they are the focus of this research. The other agents are modelled more simply, but in enough detail for defaults to cascade through the economy in a relatively realistic manner.

3.4.1. Individuals and households

A two-stage approach has been taken to calibrating households. First, individuals are created and assigned jobs, houses, and home loans. Next, they are aggregated into

[11] This ADI limit is written in the legislation but omitted from every ADI's website and also the government's FCS website which is meant to inform the public (APRA, 2018b). It is, however, mentioned in an RBA speech with a comment that if the limit is reached APRA could seek parliamentary approval to draw down extra funds (Turner, 2011).

households. Not all individuals have a house (e.g. renters) or an income (e.g. children). The Henderson poverty line is calculated based on household composition to determine the non-discretionary living expenses (Melbourne Institute, 2018a). Expenses above this amount are considered discretionary.

It is natural for members of a family to support each other, so most financial details during the simulation are calculated at the household level. The exception to this is income tax, which is calculated on an individual basis using the relevant marginal income tax rates (ATO, 2018b) but then deducted as an expense from the household. Data from the 2016 census has been used to estimate the composition and financial position of households[12].

See Appendix B for details of the data sources used and how they have been used to calibrate the model.

3.4.2. Businesses

Profit and Loss Statements and Balance Sheets from tax returns (ATO, 2017a, b), and RBA data (RBA, 2018d) were used to calculate the ratios between items in the financial statements. These were grossed up to include all businesses (ABS, 2018w, x), giving 13,776 sets of unique business financial statements.

[12] For this analysis, dwellings, households, and families are considered to be interchangeable.

The number of businesses in each Local Government Area (LGA), size and industry were calculated (ABS, 2018b, c), and the corresponding financial statements assigned. This gave 953,988 distinct types of businesses, out of a total of 2.25 million businesses.

On average, each type of business agent appears 2.25 times and each representative financial statement is re-used 163 times. However, when the businesses were linked to employees, banks, and foreign trading partners they all became unique. See Appendix C for details.

3.4.3. Banking sector (ADIs)

ADI financial data has been estimated as at 30th June 2018 using Australian Prudential Regulation Authority (APRA) statistics (APRA, 2018c), the KPMG Mutual ADI survey (Boele, Kandasamy, van Vlissingen, Vaptzarov, Verbeek, Davim, Rowland, Raetze, Buchanan, Lee, Alexander & King, 2018), and public disclosures for each ADI (excluding off-balance-sheet amounts)[13].

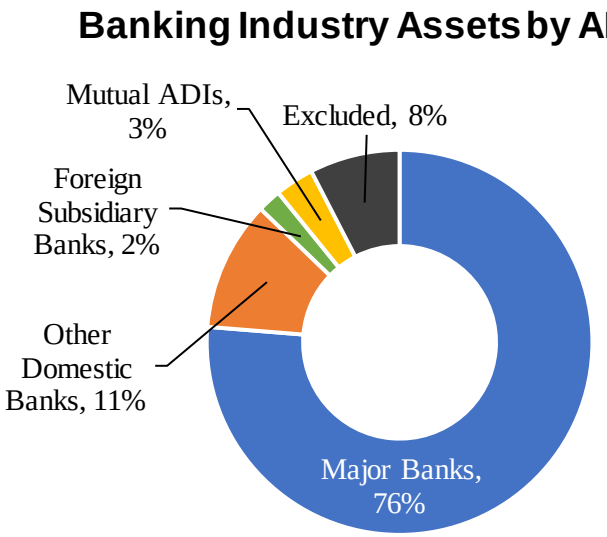
Table 4: ADIs included in the data set, by category

ADI type	Number of ADIs	Number of ADIs in the data set	Assets in the data set (AUD $Bn)
Major bank	4	4	3,604
Other domestic bank	7	6	515
Foreign subsidiary bank	7	4	93
Foreign bank branch	45	0	0
Mutual ADI	77	72	154

SOURCE: APRA ADI register, ADI annual reports

[13] Minor gaps in the data were interpolated using average ratios from similar ADIs, but if there were substantial gaps the ADI was omitted from the data set. Branches of foreign banks were omitted due to lack of data, but foreign bank subsidiaries incorporated locally were included in scope.

The ADIs included in the data set represent 92 per cent of industry assets, so the data set is considered representative of the industry as a whole for the purpose of this research.



SOURCE: APRA ADI register (APRA, 2018d), ADI annual reports (see Appendix D(d))
Figure 6: The included ADI agents represent 92 per cent of industry assets

The data sources and calculations are detailed in Appendix D, and the data itself is in a spreadsheet available with the source code (see Appendix A).

3.4.4. Reserve Bank of Australia

The RBA's financial position has been initialised using its 2018 annual report (RBA, 2018g). One of the RBA's main roles in the model is to set the OCR, which the model uses as a reference point for all other interest rates. See Appendix E for details.

3.4.5. Australian government

The Australian government's financial position has been calibrated using Government Finance Statistics for the Total Public Sector at the Commonwealth level (ABS, 2018m, r, s). For the sake of simplicity, most figures are held static over time in the model. The only figures that change are those directly affected by the other agents in the model: tax

revenue, welfare expenses, interest income and expense, and FX gains and losses. See Appendix F for details.

3.4.6. Foreign trading partners

This model uses 87 of the 179 trading partners in 2018 identified by the ABS (ABS, 2018aa, b) which represent 80 of the 191 United Nations member states (UN, 2019), as summarised in Appendix G. These are the countries using one of the 51 currencies for which FX rate data is readily available, and they account for a combined 95 per cent of Australian foreign trade by volume (ABS, 2018aa, b).

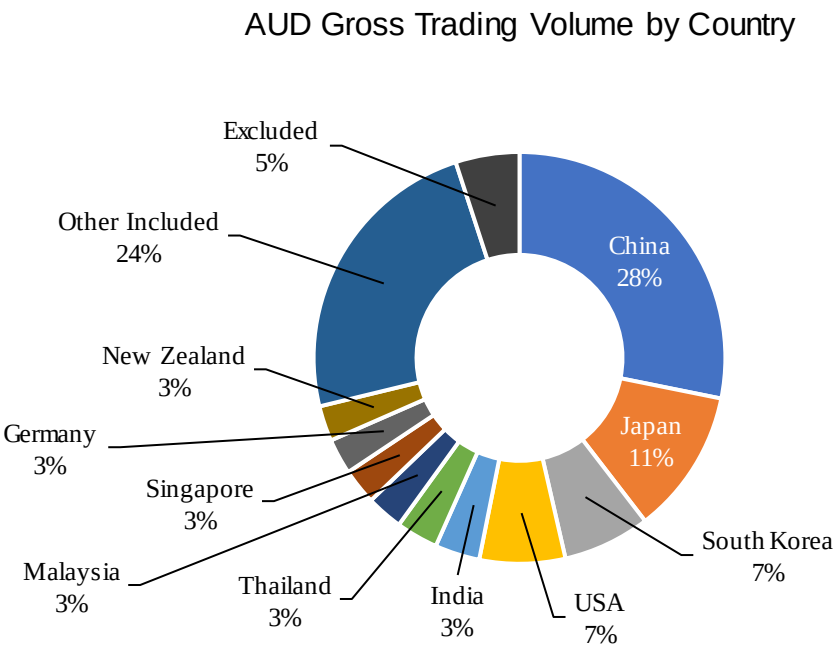
Trade volumes are measured in AUD while the FX rates have been sourced from OFX and the RBA (OFX, 2019, RBA, 2018c), taking the simple average of the end-of-month rates for the year ending June 2018 (the same year used to measure the trading volumes), and the 5-year monthly standard deviation.

Table 5: Top ten trading partners in 2018 by AUD trading volume (gross imports and exports), with monthly average FX rates

	Country	Volume (AUD $m)	Average FX rate FY18
1	China	173,366	5.03 (CNY)
2	Japan	70,072	85.28 (JPY)
3	Korea	42,215	847.77 (KRW)
4	USA	41,432	0.77 (USD)
5	India	21,696	50.49 (INR)
6	Thailand	20,307	25.09 (THB)
7	Malaysia	17,618	3.15 (MYR)
8	Singapore	17,315	1.04 (SGD)
9	Germany	17,199	0.65 (EUR)
10	New Zealand	17,087	1.09 (NZD)

SOURCE: ABS 5368.0 International Trade in Goods and Services, Australia (ABS, 2018aa, b)

China makes up 28 per cent of Australia's international trade. Table 5 shows that Australia is four times as reliant on China as it is on Korea or the USA, and 10 times more than it is on New Zealand. If a financial crisis was to originate overseas, its impact on Australia would vary considerably depending on which country the crisis began in. A 10 per cent change in the AUD/CNY exchange rate would be as detrimental as a 40 per cent change in the AUD/USD exchange rate.



SOURCE: ABS 5368.0 International Trade in Goods and Services, Australia (ABS, 2018aa, b)

Figure 7: The included trading partners account for 95 per cent of gross foreign trade

3.5. Simulation platform

The model is implemented in Java. See Appendix A for instructions on to freely download the source code.

3.6. Using the model

The model is driven by two key inputs:

1. **The cash rate.** Interest rates are assumed to be variable and pegged to the OCR.
2. **FX rates.** They are a proxy for inflation, and also affect the relative value of imports and exports.

The following table summarises how the model was used to measure its errors, simulate shocks, and estimate the impact on households.

Table 6: Summary of how the model was used

Purpose	Description	Notes
1. Measuring the model error	Calibrating the model and running it forward for 12 months with no changes gives a reference point to compare the results against to evaluate the magnitude of the errors.	Using 2016 census data extrapolated forward to 2018 makes it as current as possible.
2. Simulating shocks	Types of shocks: • Interest rates affecting domestic relativities among agents. • ADI failure with Financial Claims Scheme being applied to deposits. • FX rates changing net exports which reduce business revenues and increase costs for everyone.	Defaults are simulated as large negative cash flows.
3. Measuring the impact on individuals' wealth	Henderson poverty line. Expenses above this are considered discretionary. These expenses have not been adjusted for the different living expenses in capital cities	Because prices are not explicitly included in the model, the

	compared to regional towns, but should still give a reasonable indication of the impact on individuals.	AUD/USD exchange rate is used as a proxy for inflation to enable the impact on real incomes and living expenses to be estimated.

Measuring the model error is an important prerequisite to interpreting the results so the materiality of differences in the outputs of various scenarios can be assessed. The next chapter shows the variations are minor so the changes in various metrics are significant and not just statistical noise. Introducing shocks by forcing an ADI to fail, or changing interest or exchange rates demonstrates that the model can simulate the aftermath of a financial crisis originating from the banking sector, the broader economy or the rest of the world. Measuring the impact on individual households is the primary focus of this paper and it reveals that representative agent models oversimplify the economy and miss out on important differences that exist in the real world. A rising tide lifts all boats – but some more than others.

A key reason for using a computational model rather than an analytical model is that computational models allow the emergent properties of complex systems to be explored, and also facilitate more detailed analysis of the impact on individual agents. The use cases described in Table 6 above reveal the cost (in terms of the size of the errors) of using a computational model and also allow shocks to flow naturally through the system to reveal any unanticipated behaviour and outcomes.

Chapter 4: Data analysis, results, and discussion of findings

"It doesn't have to be precise to be accurate."
– Bob Kotic, Financial Services Executive

"It is better to be vaguely right than exactly wrong."
– Carveth Read, Philosopher and Logician (1920: 351)

With over 27 million heterogeneous agents, there are myriad insights that could be drawn from such a rich dataset. The reliability of the model is evaluated first, then the impact of an ADI failure on the government's balance sheet is estimated. The remainder of the discussion focuses on the impact of inflation on heterogeneous households and explores the correlations with various attributes such as income, age, geographic location, and home ownership.

4.1. Measuring the model error

To measure the model error, the model was calibrated as at 30th June 2018 and rolled forward with default assumptions for 12 months. The results were compared against recent research to determine how well the model approximates reality, and if it is directionally correct.

The red diamond in Figure 8 is the baseline, and the dots are the percentage deviations from this baseline which occur as a result of choosing a different random seed with which to initialise the model. The metrics typically do not vary by more than one or two per cent, which means the model is reasonably robust with respect to the choice of random seed.

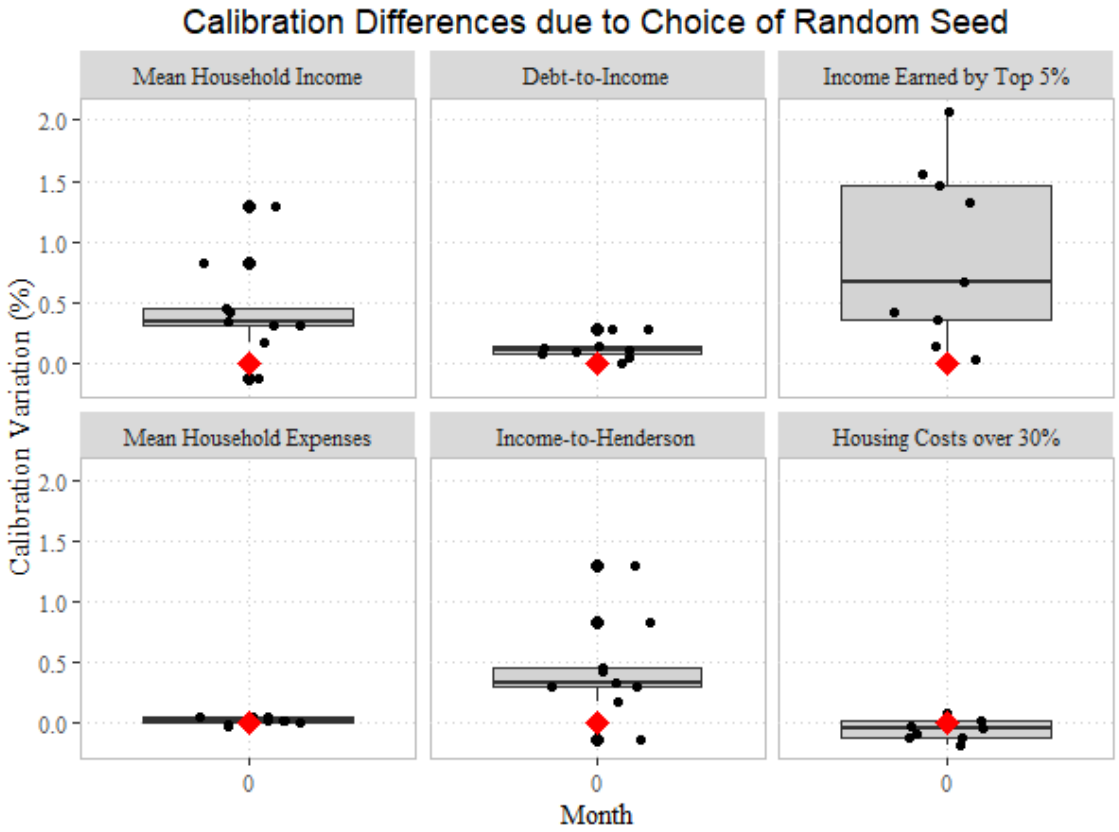


Figure 8: The model is robust with respect to the choice of random seed

Table 7: Initial model calibration is generally consistent with published statistics

Metric	Baseline t=0	Baseline t=12	Actual	Data Source
Debt-to-Income	195%	195%	c.200%	Chalmers (2018)
Mortgage over 30% of Total Income	75%	75%	10-50%	van Onselen (2019), and Sheppeard (2019)
Debt-Free	0.027%	0.027%	30%	RBA (2017b)
Percentage of Total Income Earned by Top 5%	29%	29%	25%	ATO (2017g)
Percentage of Households that are Owner-Occupied with a Mortgage	38%	38%	35%	Kryger (2009)

The model was calibrated with 84 per cent of households having housing costs greater than 30 per cent of their income, which drops to 45 per cent over 12 months. The difference between this figure and the 10 percent of Australian households that are actually in mortgage stress (van Onselen, 2019), or the 50 per cent of mortgage holders who are struggling to make their payments (Sheppeard, 2019), can be explained by including all mortgage repayments and rent payments in these calculations, whereas the official figures are only calculated based on owner-occupied mortgages.

Australian household debt is around 200 per cent of income and rising (Chalmers, 2018), and the model shows initial household debt-to-income ratios of 195 per cent, which remains constant over 12 months. RBA research indicated 30 per cent of households are debt-free (RBA, 2017b), while the model is well below that with only 0.0015 per cent of households.

The actual rate of business exits was between 12 and 13 per cent from 2013 to 2017 (ABS, 2018ac) while the number of business defaults modelled was 1.39 per cent over 12 months, which is the equivalent of 7 per cent over 5 years and approximately half of the actual 12 to 13 per cent business exit rate. Income distribution and the number of households in mortgage distress (mortgage costs above 30 per cent of income) remain static in the base case, which means that any changes noticed under different scenarios are genuine predictions and not just noise in the model. Wealth distribution only changes slightly with the wealth owned by the top 5 per cent of income earners increasing from 30.1 per cent to 30.7 per cent over 12 months, so it is a fairly reliable metric too.

The exogenous cash flow component could allow for these results to be obtained artificially, so Figure 9 shows that exogenous income is a negligible contributor to 20 per cent of households' incomes, the sole contributor for 25 per cent of households, and evenly distributed between these two extremes. For 44 per cent of households, most income comes from another agent within the model. This percentage is lower than desired but should still be close enough for the results to at least be directionally correct.

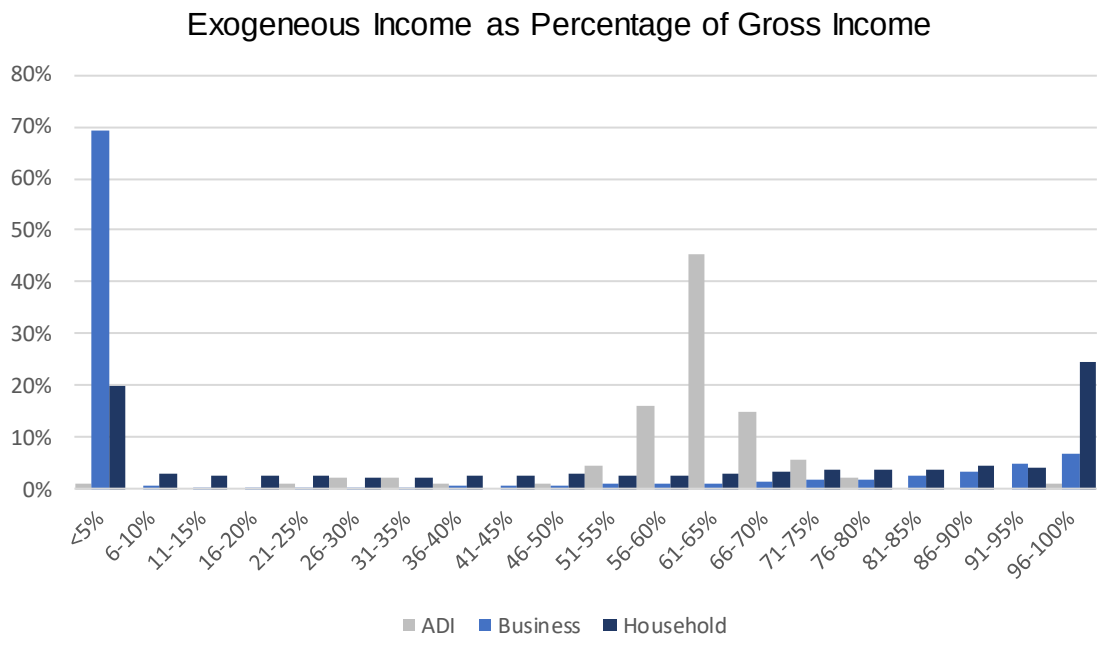


Figure 9: Exogenous income as a percentage of gross income

Figure 9 shows that the economy is a reasonably closed system, but still with an exogenous component that proxies the rest of the world and everything else that was considered out of scope (such as organisations that are not businesses). Businesses primarily derive their income from within the system, ADIs have a bit of a spike around 55 to 70 per cent, and households are fairly evenly distributed with spikes above 95 per cent and below 5 per cent. Overall, this suggests that the model captures most of the relationships in the economy and should be able to identify the interactions between agents well enough to draw some insights from even though it is far from perfect.

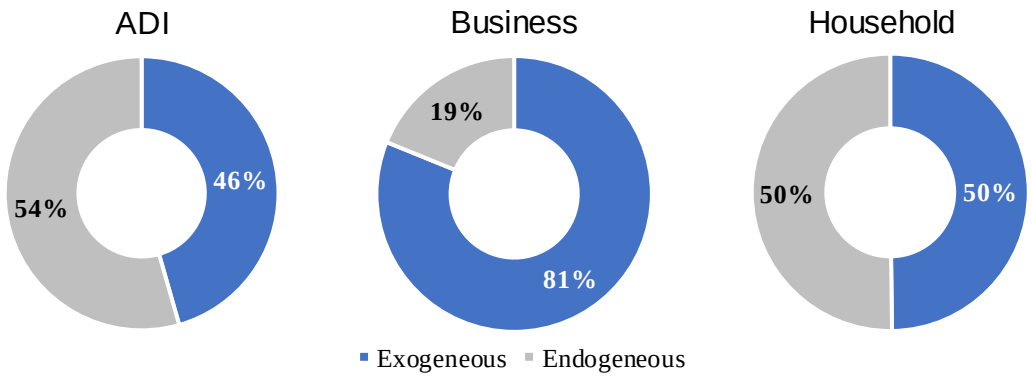


Figure 10: Share of total income that is exogenous, by agent type

Figure 10 shows that exogenous income is higher for businesses, which makes sense due to the calibration data being harder to source. ADIs have lower exogenous data because they publish detailed financial statements. Households comprise approximately 50 per cent exogenous income, which is reflective of the amount of manipulation that was required to build their financial statements – combining tax returns and census data.

Overall, about half of the cash flows are between agents in the economy, so it should still exhibit behaviour that is reflective of the real world, though the impacts of stress tests will probably be somewhat understated due to the natural hedge provided by the exogenous income.

4.2. Impact of ADI default on the government's balance sheet

The impact of an ADI failure on the government's balance sheet depends on how big the ADI is and what effect its failure has on the broader market. Table 8 below shows what would happen if a major bank failed, both with and without the $20 billion FCS limit, and also the effect of one mutual ADI failing and causing the entire mutual ADI sector to fail due to a contagion effect.

Table 8: Impact of ADI default on the Australian government's financial position

Scenario	1: Major Bank with $20Bn limit	2: Major bank without $20Bn limit	3: Mutual ADI industry
Description	Commonwealth Bank fails, and the FCS limit of $20Bn per ADI is enforced	Commonwealth Bank fails, but the FCS limit of $20Bn per ADI is waived	The entire mutual ADI industry defaults, and the FCS limit of $20Bn per ADI is enforced
Interest Cover ratio %	16.48 ➔ 15.78	16.48 ➔ 8.57	16.48 ➔ 13.60
Cost-to-Income ratio %	111% ➔ 112%	111% ➔ 118%	111% ➔ 113%
Liabilities as percentage of Assets	154% ➔ 157%	154% ➔ 226%	154% ➔ 171%
Debt-to-Income ratio %	135% ➔ 141%	135% ➔ 259%	135% ➔ 163%
Debt to GDP ratio %	122% ➔ 126%	122% ➔ 232%	122% ➔ 148%

SOURCES: (ABS, 2018q) and calculated values

In the first iteration, an ADI is assumed to fail. For the purpose of this analysis, the reasons for its failure are irrelevant, so it is inserted into the model in its failed state to watch how the effects cascade through the system and allow the analysis of their impact on other agents.

With 15.9 million customers (CBA, 2019) and $520 billion in deposits, the mean deposit balance per customer is approximately $30,780. Given the FCS guarantees deposits up to $250,000 per customer, they probably expect their deposits are protected. However, the $20 billion per ADI cap on the FCS means that the effective guarantee per customer is only $1,183, which means that only 3.8 per cent of their deposits are guaranteed. This $20 billion cap makes the impact on the government's balance sheet minimal with the cost-to-income ratio only rising one per cent and the debt-to-GDP ratio only rising four per cent from 122 to 126 per cent.

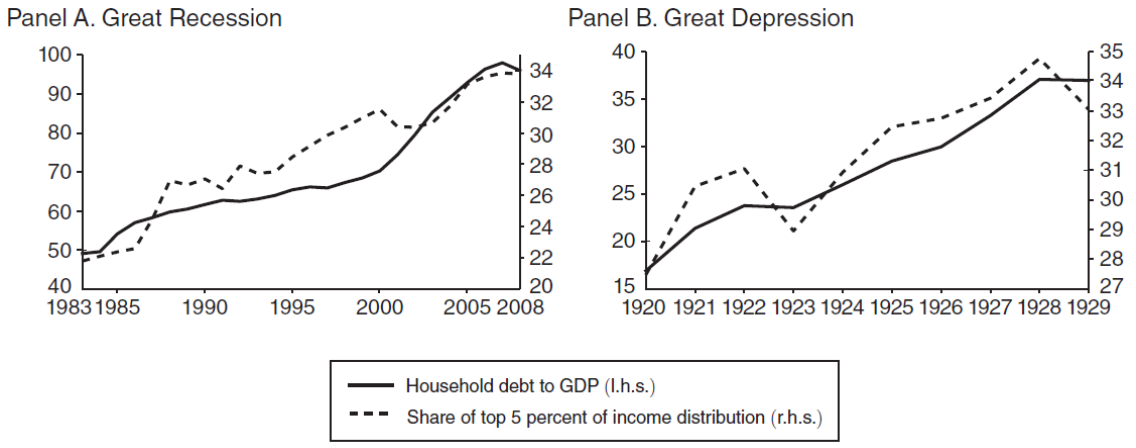
If parliament waived the $20 billion cap on the FCS and paid out every dollar of Commonwealth Bank's customer deposits, it would have a significant effect on the government's balance sheet, almost doubling the current $595 billion in debt by adding another $520 billion to it. This is the level of support that customers implicitly expect, but it would increase the government's debt-to-income ratio from 135 per cent to 259 per cent.

With $121 billion in deposits and 4 million customers (COBA, 2019), the mutual ADIs have a mean deposit balance per customer of $30,300 which is not dissimilar to Commonwealth Bank's $30,800. A key difference is that the balance is spread over many ADIs and so each ADI falls within the $20 billion limit. Banking regulators care about the potential for one financial institution's failure to have a contagion effect and result in loss of confidence in other financial institutions, ultimately causing a series of defaults rather than just one isolated default. If one mutual ADI failed and resulted in a contagion that caused all 72 mutual ADIs in the model to fail, it would have a similar impact to six banks failing with the $20 billion FCS limit in place. The impact on the

government's financial position would be material, but it is unlikely to be cause for concern with the cost-to-income ratio rising only two per cent.

4.3. Impact of inflation on Households

Kumhof, *et al.* (2015) found that wealth inequality, defined as the percentage of total income earned by those with the top five per cent of incomes, increased in the years before both the Great Depression and the GFC to around 34-35 per cent in the USA, as shown in Figure 11 below.



SOURCES: Panel A: Income shares from Piketty and Saez (2003, updated). Income excludes capital gains. Household debt-to-GDP ratios from Philippon (2013), based on Flows of Funds database and Bureau of Economic Analysis (BEA). Income shares from Piketty and Saez (2003, updated). Panel B: Income excludes capital gains. Household debt-to-GDP ratios from Philippon (2013), based on Historical Statistics of the United States (Millenial Edition) and Surveys of Current Business. (Kumhof, *et al.*, 2015: 1221)

Figure 11: Wealth distribution and leverage in the USA before financial crises

Beyond the wealth inequality shown in Figure 11, it is interesting to note that it took almost 80 years for debt-to-income ratios to rise from 40 per cent in 1929 to approximately 95 per cent in 2008. In the following decade, debt-to-income ratios in Australia doubled to approximately 200 per cent. This shows that the structural problems in the economy got worse after the last crisis, so the government's responses were inadequate and have done little to prevent future crises.

This paper's model was calibrated using census and tax return data with the top five per cent of Australian households by income earning 29 per cent of the total income. Figure 12 shows the distribution of income by decile. The model was calibrated as at June 2018, and a year later the media is reporting market signals that indicate an impending recession (Leong, Burns & Brettell, 2019) so it appears to be a reasonable leading indicator for financial problems.

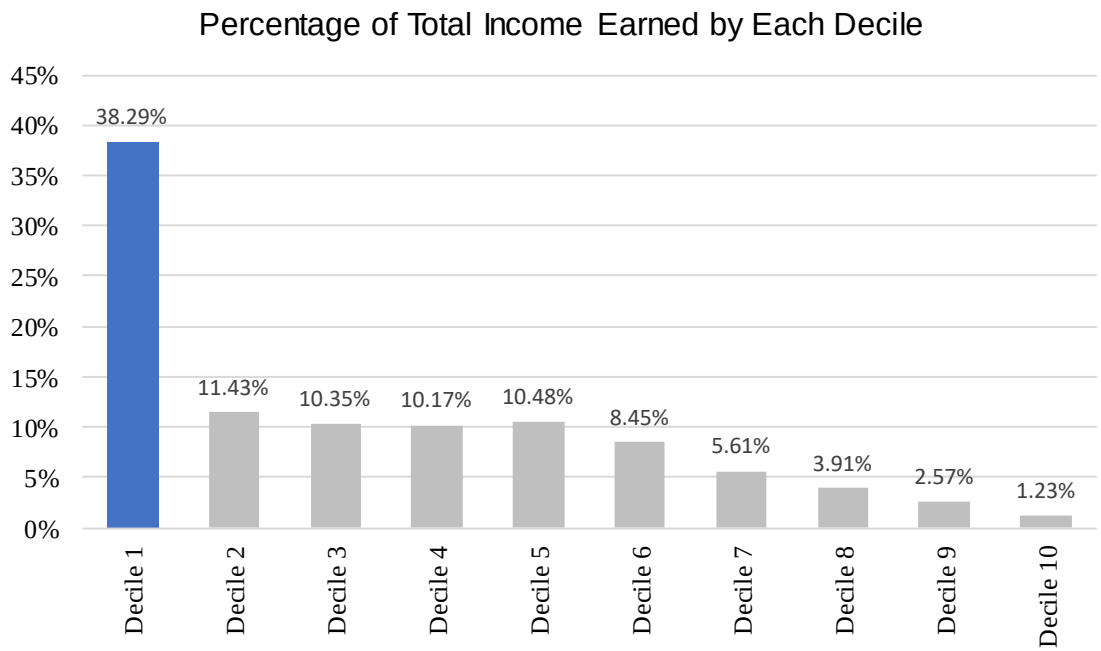


Figure 12: The richest 10% earn 40 times as much as the poorest 10% of households

If wages rise with inflation, asset owners benefit because the cost of their debt is fixed, but renters struggle as they have no hedge against inflation and the cost of their rent will rise with inflation. Approximately 30 per cent of Australian employees are subject to collective employment agreements that stipulate wage increases of two to three per cent per annum (O'Halloran, 2018) over a two to four year period (Fair Work Commission, 2019). These pre-determined pay rises mean that wages are likely to lag behind inflation by several years, making living costs more expensive in real terms.

Figure 13 shows that inflation increases wealth inequality, with all incomes increasing, but those on higher incomes receiving larger increases because they start from a higher base. Decile one benefits the most from inflation and comprises of the politicians and government leaders who decide inflation targets. The non-accelerating rate of inflation (NAIRU) is often used as an excuse to keep the bottom decile unemployed under the guise of being better for the whole economy (Friedman, 1968). Even when the correlation between unemployment and inflation breaks down, the tendency is to revise the estimates of NAIRU (Watson, 2014) rather than admitting it might be incorrect. However, it is the top decile who benefit the most, with incomes approximately 40 times greater than the bottom decile. This conflict of interest leads to a predictable cycle that benefits those at the top at the expense of those at the bottom (Coomer & Gstraunthaler, 2011). There is increasing scepticism about NAIRU in Australia with it being recognised not just as flawed economics but also bad politics (Klein, 2017, 2018).

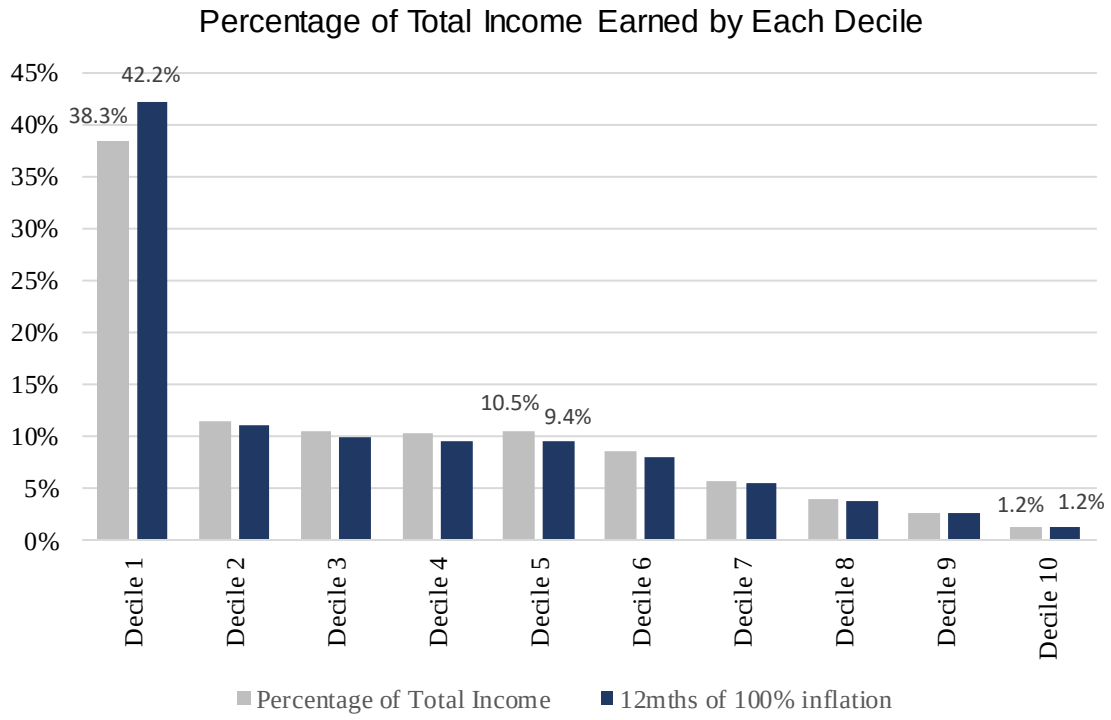


Figure 13: Inflation increases wealth inequality

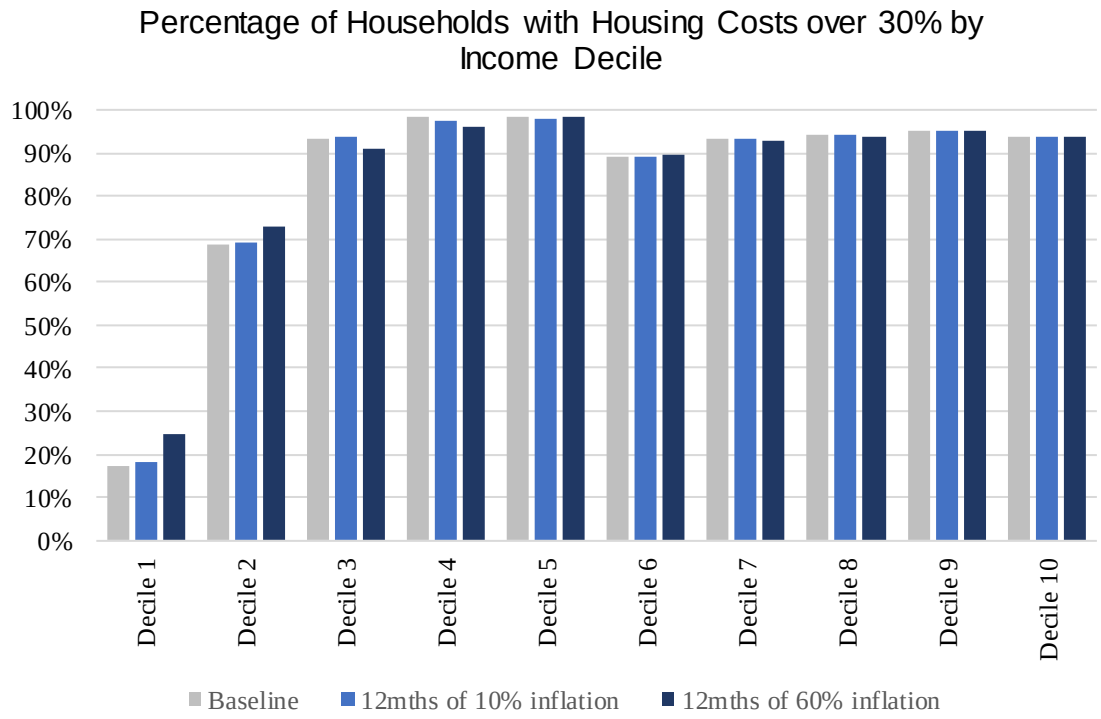


Figure 14: Percentage of households in distress, by starting income decile

Figure 14 above indicates that most households outside of the top quartile are experiencing high housing costs. This is misleading because it makes it look like most of the population are experiencing roughly the same financial pressure. The power of the heterogeneous agent model is demonstrated by Figure 15, which adds a bit more colour to the story that Figure 14 tells by revealing that the bottom 10 per cent of income earners (decile 10) have the highest relative debt levels. They would benefit from inflation because it would reduce the real value of their debt. However, this is only true if their wages rise at the same rate as inflation. These lower-income earners are more likely to be employed under a collective agreement with stable wage growth but at a low level (Bishop & Cassidy, 2019).

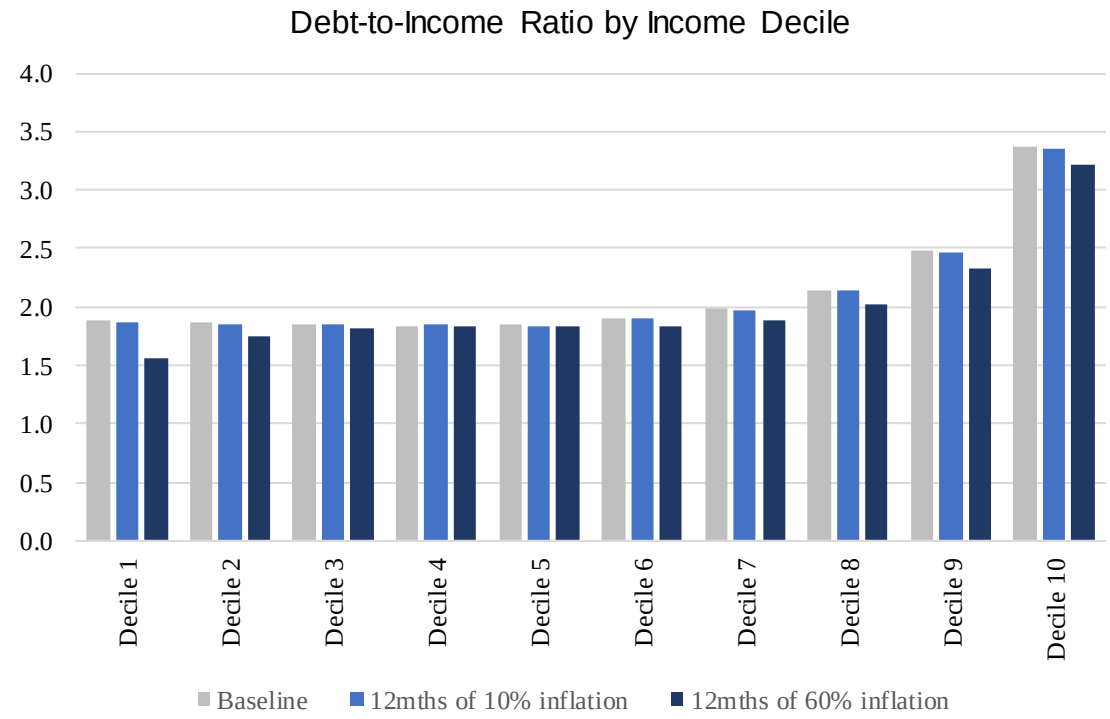


Figure 15: Debt-to-income ratio by income decile

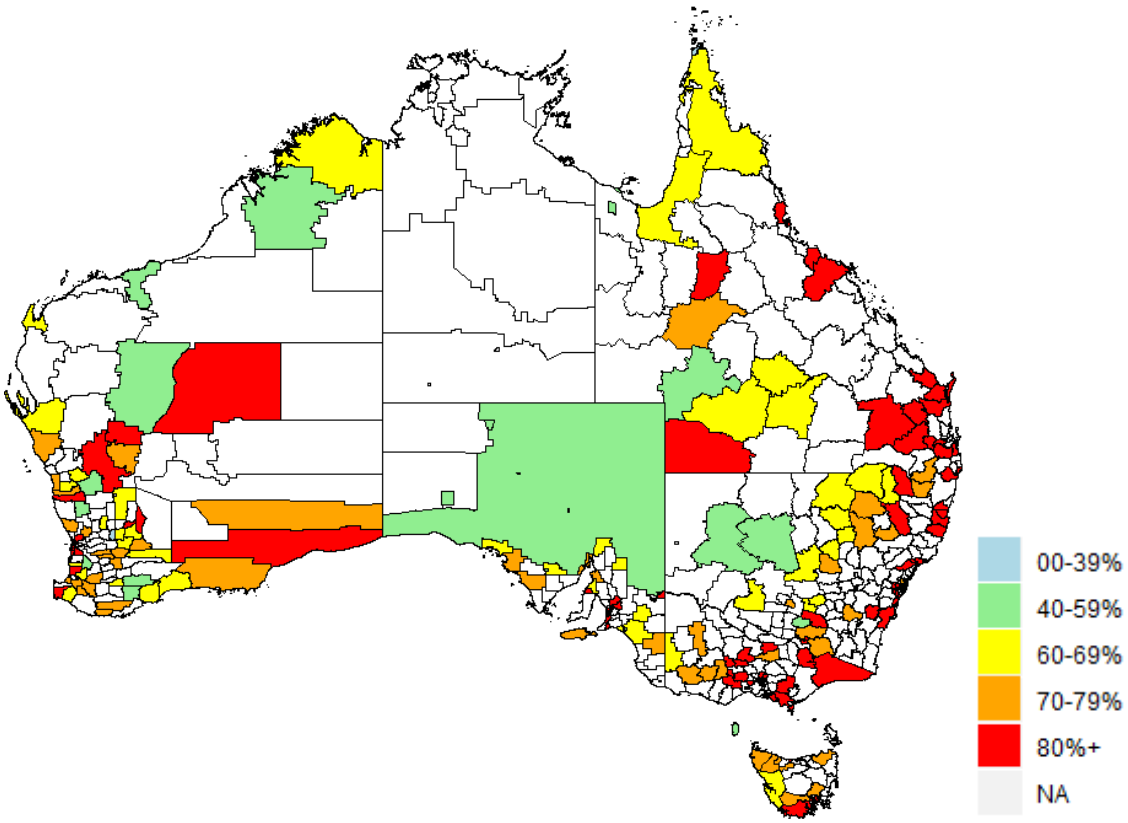


Figure 16: Heat map of housing distress by LGA after 100 per cent inflation over 12 months

The places most affected by the cost of housing appear to be mining towns and capital cities, though the capital cities are hard to see in Figure 16 because the LGAs are much smaller due to the greater population density.

The LGAs shaded white in Figure 16, Figure 18 and Figure 19 are those that the model did not include. This was not a deliberate feature but rather a result of joining multiple data sources together. Of the 562 LGAs, only the 243 LGAs which were in all original data sets made it into the final calibration data. This is not a shortcoming of the model itself and could be overcome by access to detailed RBA and ABS data. See Appendix B for a detailed discussion.

4.4. The buffering effect of wealth

The model introduced in this paper allows examination of the uneven distribution of wealth among households. The inelastic cost of living has been estimated using the Henderson Poverty Line[14] data based on household composition (Melbourne Institute, 2018b). Figure 17 shows that the bottom decile's income is below the poverty line after considering housing costs. The top decile, which includes most of the political and business leaders, has little to worry about with incomes typically an order of magnitude larger than their living expenses.

[14] The Henderson Poverty Line is based on a government-commissioned inquiry into poverty that sought to measure income relative to need, with figures indexed each quarter based on the September 1973 benchmark (Unknown, 2018). There are valid doubts that the method of indexing the 1973 poverty line has kept up with changes in the cost of living (Burmester, 2016), but it is still widely used in the banking industry so has been used in this model as a proxy for the cost of living in the absence of a better measure.

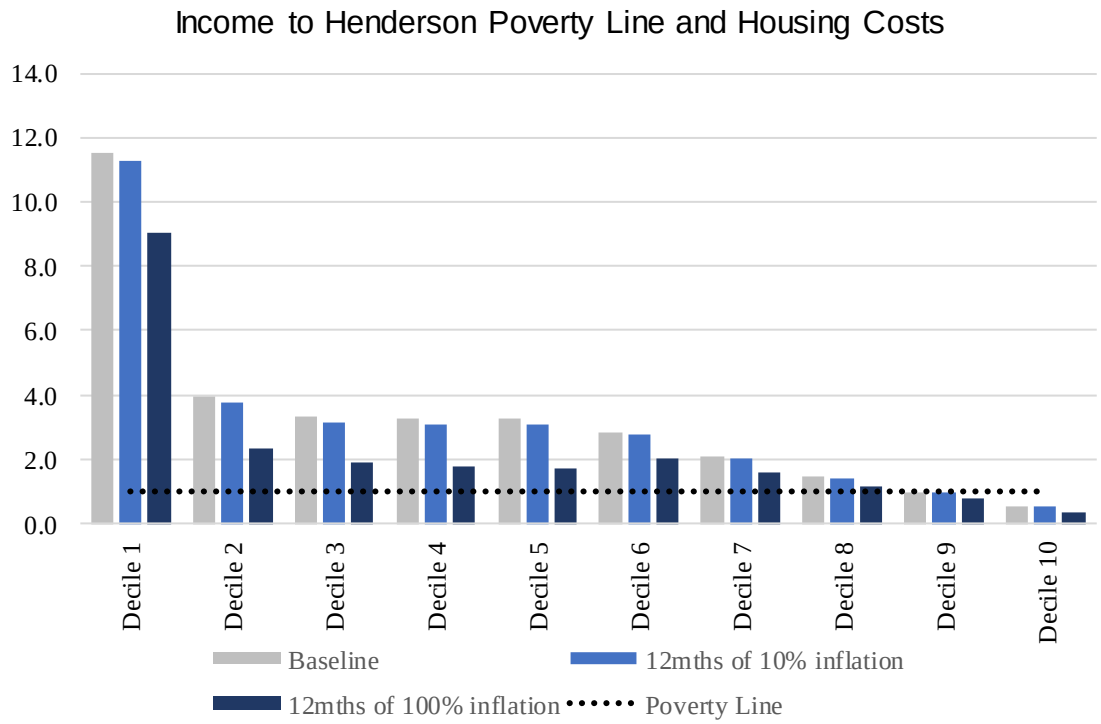


Figure 17: The bottom quartile are at risk of falling below the poverty line if inflation climbs above its current low levels

The percentage of total national income earned by households in the top five per cent of income was calculated for each LGA, and the results were graphed in the heat map in Figure 18. This heat map revealed a tendency towards greater wealth concentration closer to capital cities and in mining areas, with rural areas often being more evenly distributed.

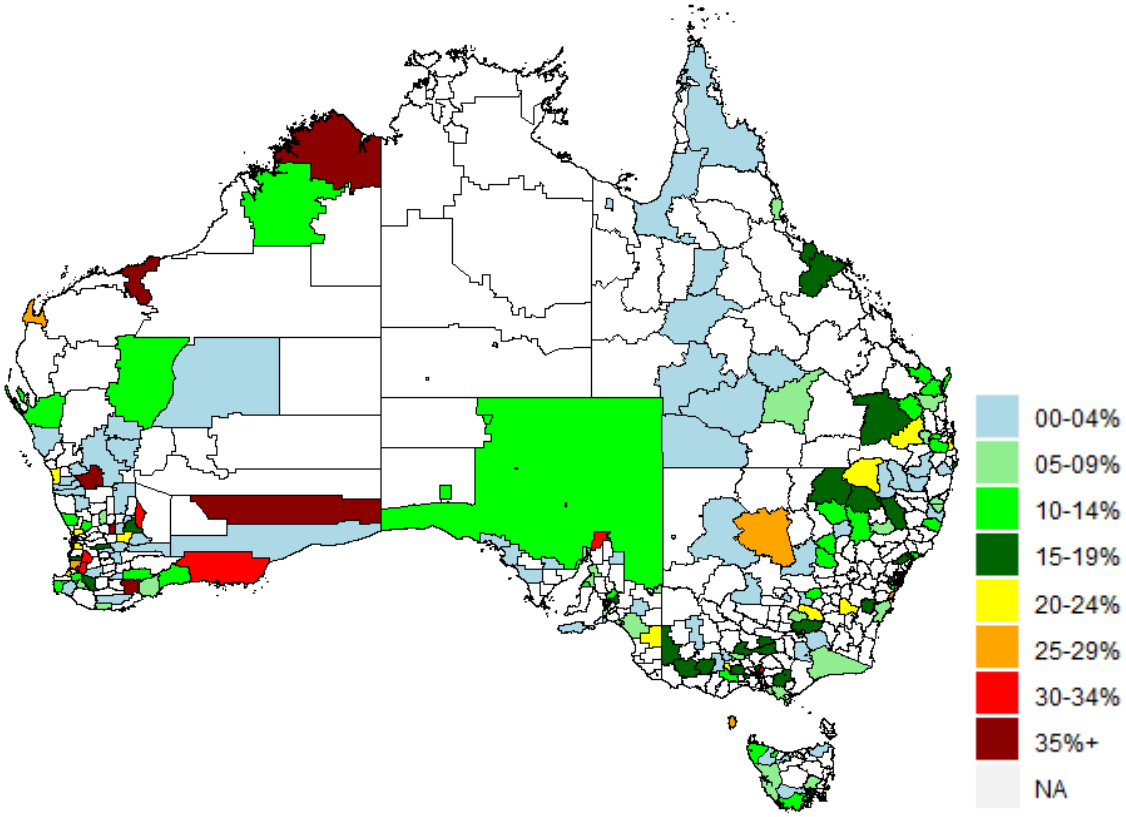


Figure 18: National wealth inequality by LGA after 100 per cent inflation over 12 months

Figure 19 shows that the areas with higher wealth inequality within the LGA tend to be those where there are mining operations employing people on high incomes in areas where the original residents work in lower-paying industries such as agriculture.

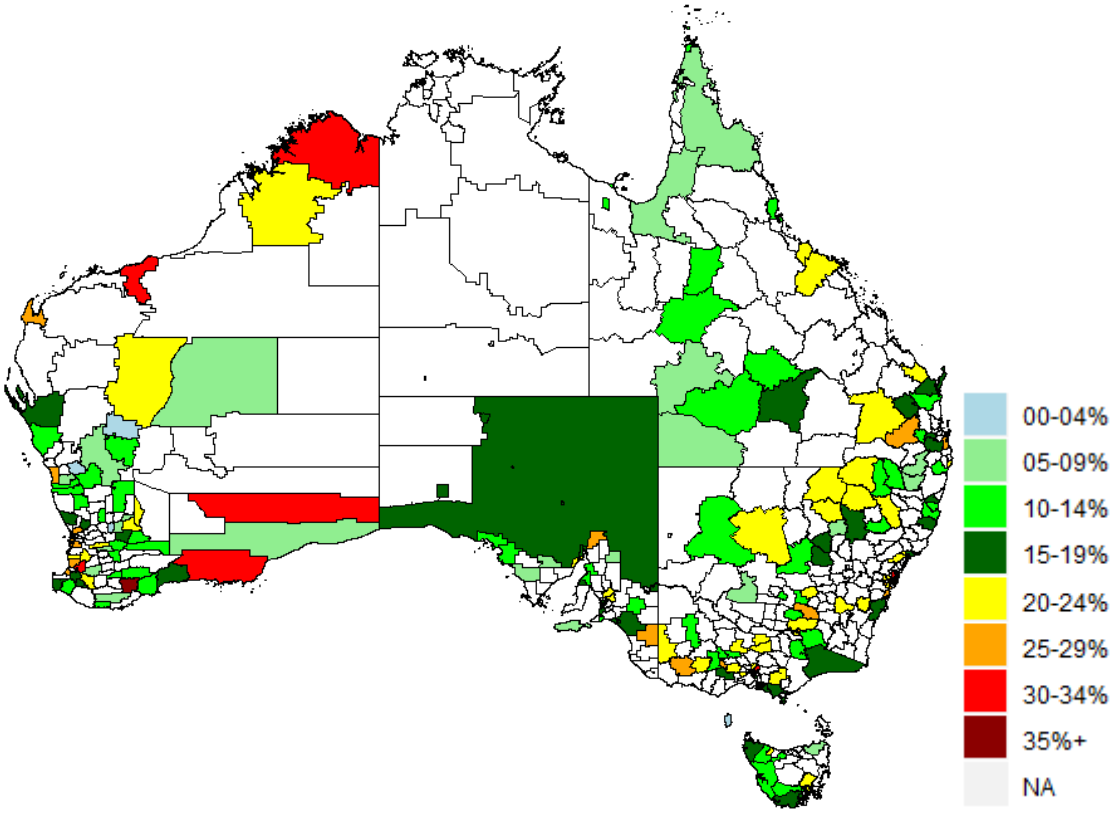


Figure 19: Localised wealth inequality within each LGA after 100 per cent inflation over 12 months

4.5. Age and household composition can affect outcomes

The GFC resulted in smaller losses for people aged 20 to 29 in the USA, while for those over 60 the losses amounted to around ten per cent of lifetime consumption (Glover, Heathcote, Krueger & Rios-Rull, 2016). Figure 20 suggests the opposite trend is more likely in Australia, with older households more likely to benefit from inflation in nominal terms with a smaller negative real impact compared to younger households who bear a much higher cost in both nominal and real terms.

Incomes in the model are biased much higher than expected for people aged 70 and over, which may be due to the way inheritances are reported in tax returns or possibly people retiring and withdrawing all their retirement savings. Whatever the reason, even without the two oldest age groups, the trend still holds that younger people experience a larger negative outcome from inflation.

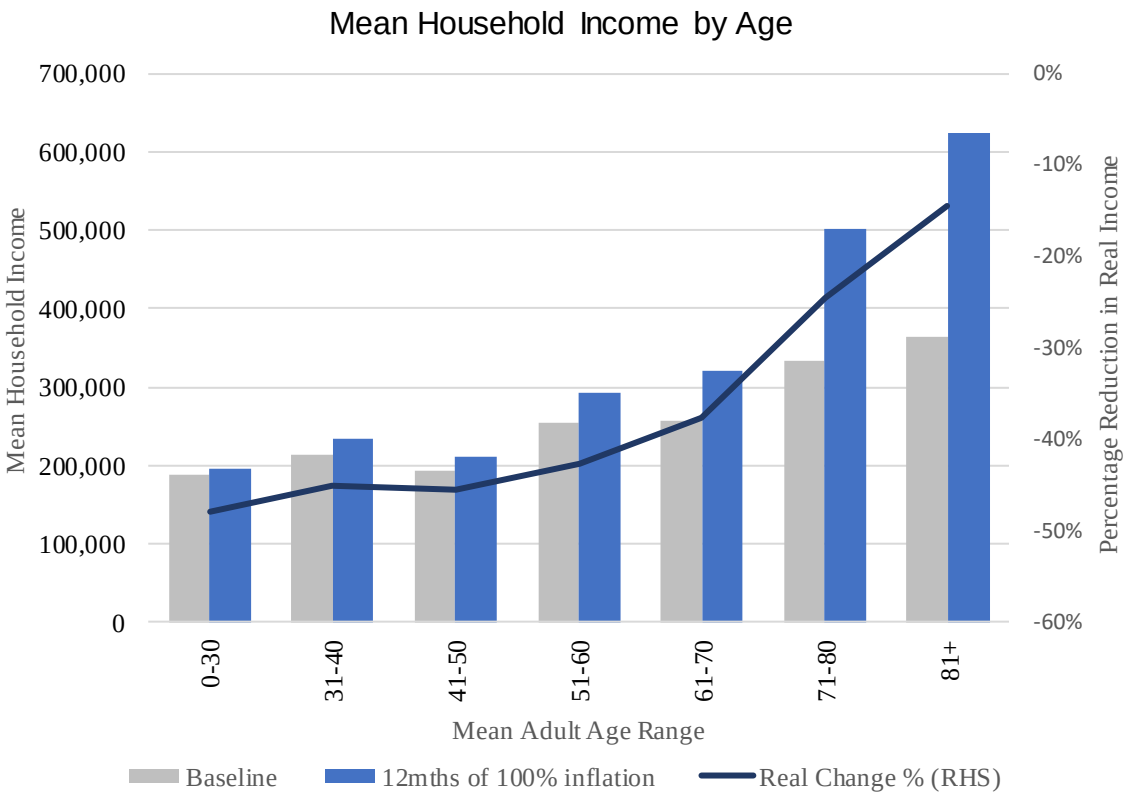


Figure 20: Change in household income by age

Using the OECD's definition of the age wage gap (OECD, 2017), the model predicts that 12 months of 100 per cent inflation would increase this age wage gap from 15 to 24 year-olds earning 82 per cent as much as 25 to 54 year-olds down to earning only 76 per cent as much; and from 55 to 64 year-olds earning 101 per cent as much as 25 to 54 year-olds down to 99 per cent as much. This shift indicates that inflation favours middle-aged workers, older workers disadvantaged slightly and a significant negative impact on younger workers.

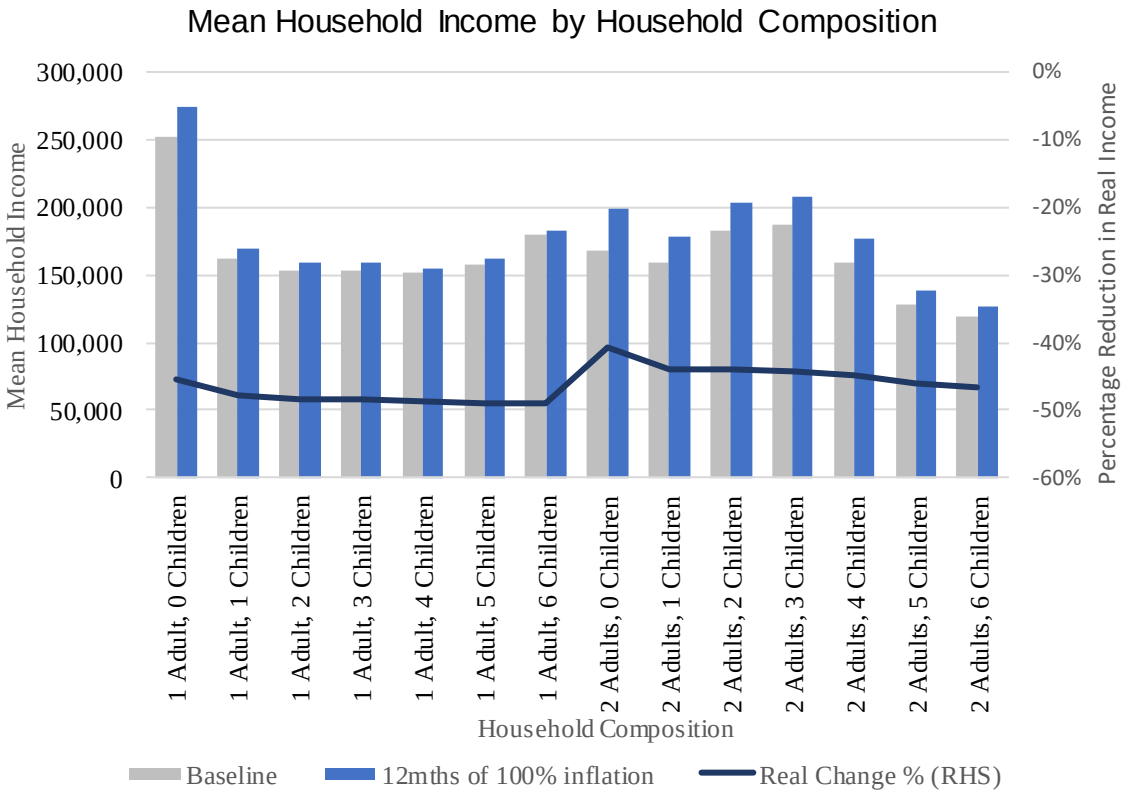


Figure 21: Mean household income by household composition

Although age is positively correlated with income, household composition does not seem to have as clear a correlation. Other than single-person households having higher incomes than families, there does not appear to be any particular trend linking household composition and income. There does, however, appear to be a slightly greater increase in income as a result of inflation for double-income households.

4.6. Does home ownership increase resilience?

Economists and the media often focus on mortgage stress as a key indicator of housing affordability (Sheppeard, 2019, van Onselen, 2019). Figure 22 shows that the top 20 per cent of households are largely unaffected by mortgage stress regardless of the inflation rate, presumably because of their large incomes. Interestingly, the bottom 20 per cent are also largely unaffected but the graph does not reveal the reason.

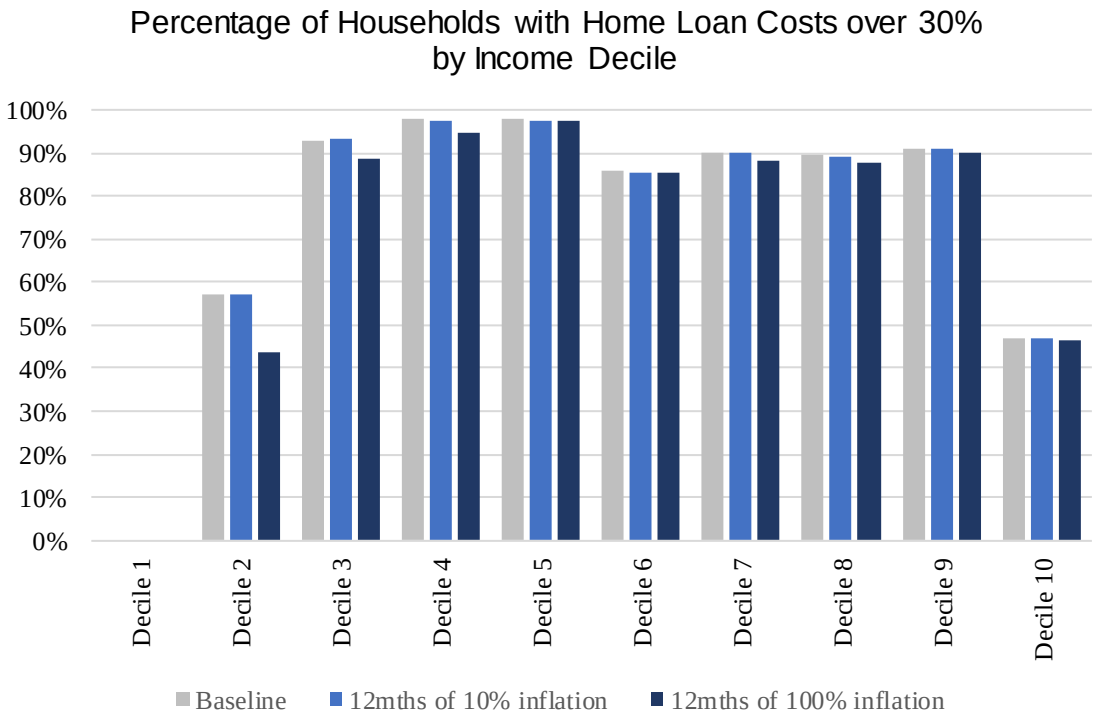


Figure 22: Owners are more likely to be in mortgage stress with an average income

Mortgage stress is not the only measure of housing affordability – rent stress is important too. Figure 23 reveals that rent stress is prevalent in the bottom quartile much like mortgage stress is amongst middle-income earners. Rent stress increases among middle-income earners as a result of high inflation rates. This is likely a result of the way the simulation program handles defaults: when a household defaults on their mortgage repayments, they sell their house and switch to renting at a cost equivalent to half the cost of their previous mortgage repayments. Middle-income earners who were suffering mortgage stress switched to renting and still suffered under rising rents in a high inflation environment.

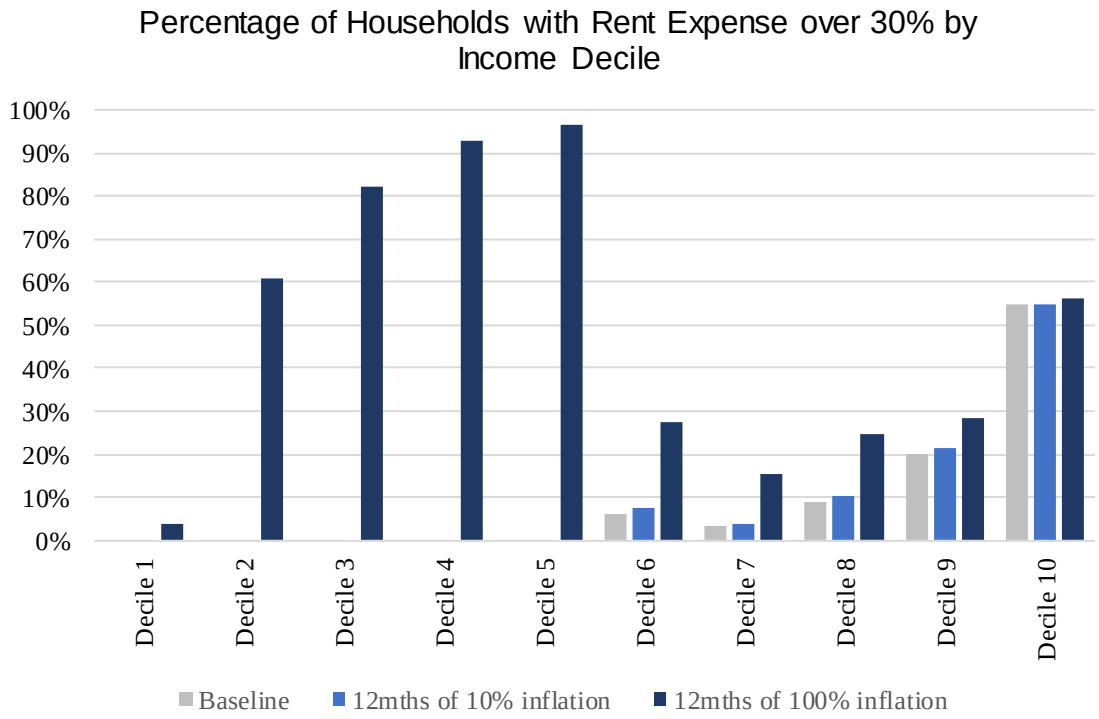


Figure 23: Renters are more likely to experience rent stress with a low income

Indeed, Figure 24 reveals that mortgage stress was mainly an issue for middle-income earners while the lowest income quartile faced even more stress to pay the rent (see Figure 24). This focus on mortgage stress rather than more general housing affordability reveals a bias towards the impact on the banks (if home-owners default) rather than families (if a household can no longer afford their rent).

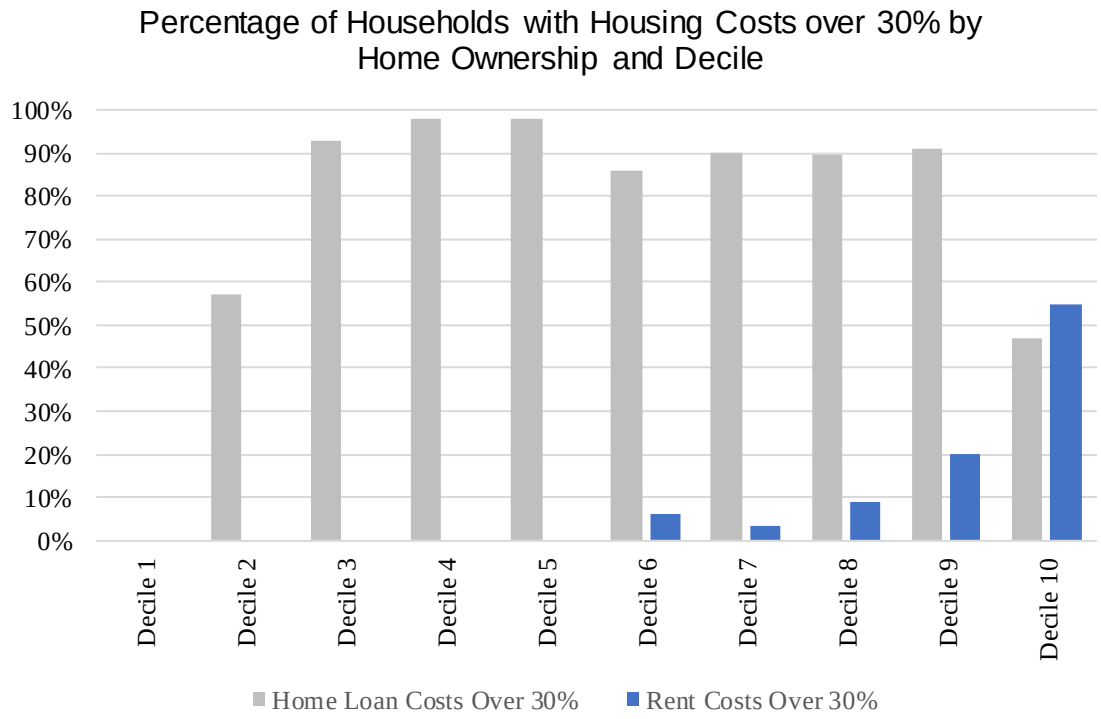
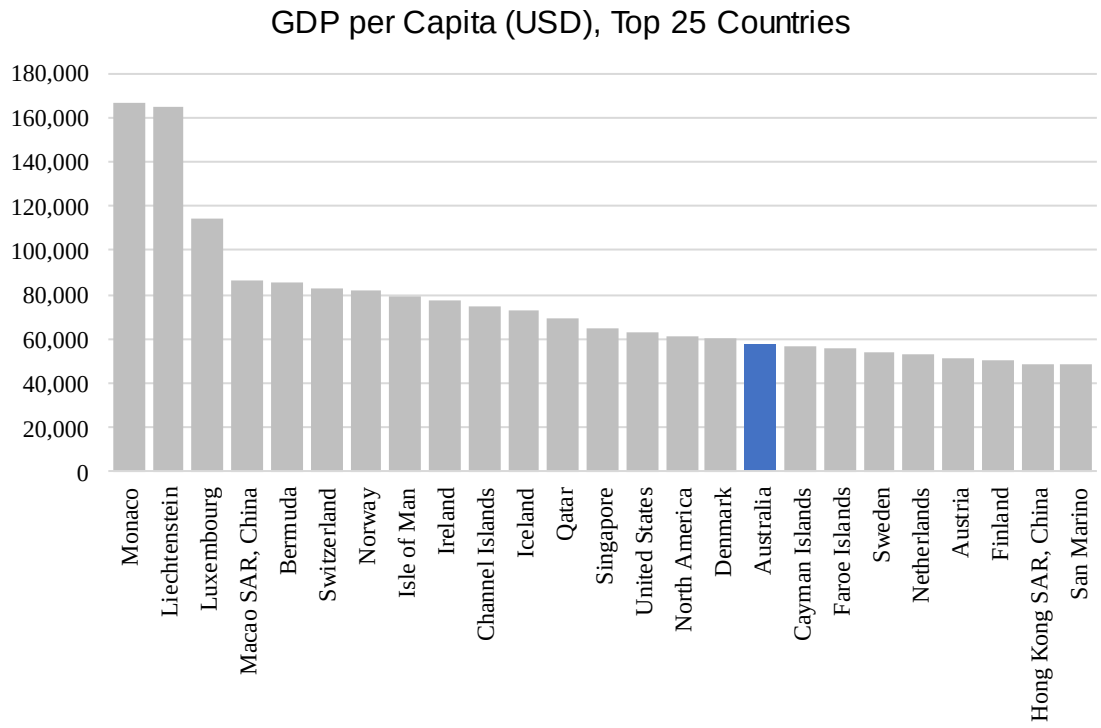


Figure 24: Renters and owners have different housing stress profiles

4.7. Is the cumulative total or the annual rate of inflation more important?

The analysis above compares the base case to a scenario with 100 per cent inflation in a single year. This section explores the difference if the same amount of inflation occurred over a longer time, specifically 25 per cent per annum for four years. This reveals that high inflation over a short period does not have enough time to filter through the economy, so it is less detrimental than medium rates of inflation over a sustained period during which the economy restructures and affects long-term wealth distribution.



SOURCE: World Bank (2019)

Figure 25: Australia currently ranks 17th globally in GDP per capita

Australia currently ranks 17th globally, with GDP per capita of USD 57,305. How much inflation would affect this depends on both the quantum and rate of inflation, as shown in Table 9. Comparing the scenarios for different inflation rates shows that the absolute amount of inflation is the biggest determining factor, but that the rate of inflation also has a material influence on real income.

Table 9: Impact of inflation on Australia's real GDP per capita and global ranking

Scenario	Real USD GDP per capita	Global Ranking
Baseline	57,305	17
10% inflation over 12 months	52,438	22
100% inflation over 12 months	31,457	48
100% inflation over 4 years	31,882	45

SOURCE: World Bank (2019) and simulation calculations

Chapter 5: Conclusion

"It is not the responsibility of the Federal Reserve – nor would it be appropriate – to protect lenders and investors from the consequences of their financial decisions."
– Chairman Ben S. Bernanke, Federal Reserve (2007: 4)

"Politics is about power. It is about the power of the state. It is about the power of the state as applied to individuals, the society in which they live and the economy in which they work. Most critically, our responsibility in this parliament is how that power is used: whether it is used for the benefit of the few or the many."
– Hon. Kevin Rudd, MP (1998: 162)

5.1. Research questions answered

5.1.1. Inflation speed limit or total capacity limit?

The rate of inflation that the economy can sustain is relative to the rates of inflation in Australia's trading partner countries around the world. If Australia's inflation rate were to outpace the rest of the world over a prolonged period, it would reduce real GDP per capita. So the answer to the question of whether the government should focus on an absolute or relative inflation limit is, in fact, both. There should be an absolute limit to the cumulative difference between Australian inflation and global inflation because this affects Australia's real income per capita. Within those confines, the practical limit in any given year is the rate of inflation relative to Australia's main trading partners in particular.

5.1.2. The impact on individual households varies greatly

The following key attributes were identified that materially influence how much impact inflation has on a household's financial position.

Table 10: Factors that determine how much a household is impacted by inflation

Attribute	Description
Home Ownership	Owning their home insulates households from inflation.
Income	Households in the top income deciles benefit from inflation while the bottom decile is pushed below the poverty line.
Age	Younger people feel the pain of inflation more than older people, possibly due to lower rates of home ownership.
Family Composition	The number of children or parents in a household is less important than whether a person is single or has children.
Location	Capital cities and mining towns fare better than rural areas in terms of overall wealth, though mining towns exhibit greater wealth inequality within the local area.

Defaults cascading through the system have a larger impact than inflation does – both on households directly affected by the default of another agent, and more broadly across the economy. Although inflation erodes the value of AUD savings, loss of income erodes them at a faster rate, so inflation appears to be the lesser evil. High rates of inflation could exceed a tipping point that then results in defaults cascading through the economy – resulting in large scale loss of income as well as inflation.

5.2. Contributions

5.2.1. The Computational HAM model itself

The computational heterogeneous agent model itself is a not insignificant contribution to the body of knowledge in the area of financial crisis modelling in Australia. It has been written so the inputs can be updated to use other years' census data, making it usable in the future when the next financial crisis occurs. The level of detail and calibration using real-world data allows for very different insights to be drawn compared to popular economic models like DSGE and VAR. The RBA may have similar internal models, but this model facilitates analysis using only data in the public domain.

With access to confidential data held by the government, the model could be extended down to the mesh block level using census data, and even individual tax returns for companies and natural persons (including unincorporated businesses). This would provide a more detailed view of the impact of financial crises on Australian households. The model could facilitate in-depth policy analysis where the area of interest is the financial impact on households in different demographic categories or geographic areas.

5.2.2. The impact of wealth inequality

Wealth inequality increases the likelihood of financial crises, and the interconnections in the global financial system cause them to propagate to countries with otherwise sound economies. This research shows how a crisis that originated overseas might impact Australian households, and what effect it is likely to have on wealth distribution in Australia. The input data could be adjusted to see how different starting conditions would make the economy more or less robust. This would allow for the development of policies which result in a stronger economy, measured by reducing the negative impact

on households – not just by more traditional measures such as GDP and share price that put more of a focus on businesses. A household-centric perspective is important because we live in a society – not just an economy – and so households are a more important unit of measure than businesses when measuring the wellbeing of a country.

5.3. Research limitations

As complex as it is, the model introduced in this paper is still a simplified approach which Gaffeo & Tamborini (2011) rightly point out does not capture the complexity of the real economy. Due to the inherent time and budget constraints involved in a Masters-level dissertation, several trade-offs were made in the design of the model which limit its application. These are summarised below.

Table 11: Summary of research limitations

Limitation	Explanation
Network topology	The links between nodes in the economy were created rather crudely, using weighted probabilities to randomly assign employees to employers, customers to ADIs, and suppliers to businesses. The supply chain was over-simplified with one representative business in each of a set of industry divisions based on the author's judgement rather than any empirical evidence. These simplifications allowed greater focus on households by keeping the rest of the economy simple enough that the simulation program would run on the computer hardware available to the author.
Completeness	There are other entities in the economy that were omitted from the model, such as trusts, organisations that are not businesses, and complicated corporate structures that change the tax and liability profile of a group of businesses. A single agent was chosen to represent the entire Australian government, combining hundreds

	of legal entities at local, state and federal levels into one logical unit. This aggregation made tax calculations simpler, but splitting the government up into at least LGA, state and federal would provide a more useful analysis with the ability to show if any of the state or local governments would be in default even if the government as a whole is solvent.
Granularity	The ADI data took a month to compile by reading hundreds of financial and regulatory reports, and the Java code for the model itself took well over six months to complete. With more time, the model would have been extended to be able to be run at various geographic levels so it could be used to analyse postcodes, states, and federal electorates. The ability to compare the even more granular postcode data with aggregated state data would provide an alternate way to measure the calibration error in the model. This could be useful in estimating the magnitude of the errors in the model's output so that users of the model could have a better idea of whether a result is statistically significant or not.
Entropy	Businesses drive economic growth, but the formation of new businesses was not allowed for in the model. As a result, it produces a fairly static economy with defaults cascading through, and the only source of growth in the economy is through the exogenous cash flows from foreign countries. To overcome this shortcoming, the results are compared to a 'no change' benchmark to see the incremental impact rather than the absolute impact of various changes to inputs and assumptions.

5.4. Making the Financial Claims Scheme fairer

The FCS legislation describes the protections for a customer's deposits but does not detail the treatment of and loans a customer may have with the ADI. The legal treatment of the loans falls under bankruptcy laws, which for any other business would make

sense. However, in the case of an ADI, the customer would lose any deposits above the FCS limit but would still be obliged to pay the full value of any outstanding loans. This makes the legislation inherently one-sided in favour of bankers and institutional investors at the expense of hard-working Australian families who are trying to get ahead. A fairer law would see the customer's loan balance reduced by the amount of their deposits that they lost due to the bank's default, limiting their liability to their net exposure to the ADI.

A thorough analysis of this is beyond the scope of this dissertation, but because wealth inequality leads to fragility in the financial system, it is likely that a more symmetrical version of the FCS that includes loan forgiveness would result in a better outcome for families and a more resilient economy.

5.5. Areas for further research

This paper made implicit assumptions that the broad structure of the world's economy will be unchanged. However, several scenarios could drastically change the way the global financial system works, which would have implications for what might constitute an appropriate government response. These include:

- Taxation is a fiscal policy response that has been largely ignored by this paper. It could re-balance the distribution of wealth between private and public balance sheets – providing an economic stimulus and changing the impact of inflation.
- If Australia were to abolish physical currency and become a cashless society, this would raise the possibility of negative interest rates (because people would be unable to convert electronic funds into physical cash to avoid negative rates), which removes the ZLB and provides a new set of options.

- The model could be improved by recognising that only 1 million businesses are companies (ATO, 2017b), while the rest are sole traders (ABS, 2018b). Sole traders pay tax using the personal income tax rates, and their financial statement should be consolidated with the business's given there is no limited liability as exists for a company.
- Analyse the impact of changing the FCS to include loan forgiveness up to the value of the deposits that the customer loses when the bank defaults. This would be a fairer scheme and would see the institutional investors bearing the losses associated with the risks they accepted when investing in the banks. The current scheme allows investors to receive risk-adjusted returns, while customers bear the cost of the risks, which is inequitable and a departure from free-market capitalism.

5.6. Overview

This paper has demonstrated the superiority of heterogeneous agent models over traditional representative agent models in assessing the impact of financial crises on real households. It could be used by politicians to find policy responses that reduce wealth inequality and make the economy more resilient to future financial crises, which would be a favourable outcome for all Australians.

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Appendices

Appendix A Source code and sample data available from GitHub repository

To ensure the reproducibility of this research and make it easier to challenge and extend, the source code and R-scripts for this model are freely available on GitHub under the GPLv3 licence:

```
https://github.com/acstruthers/compham.git
```

Memory consumption peaks around 50GB, which is why the program is designed to run on two computers, each with 32GB RAM. It holds the economic model on the first computer then sends data over the network to the second computer to calculate the Clearing Payments Vector which it then uses to update the economic model.

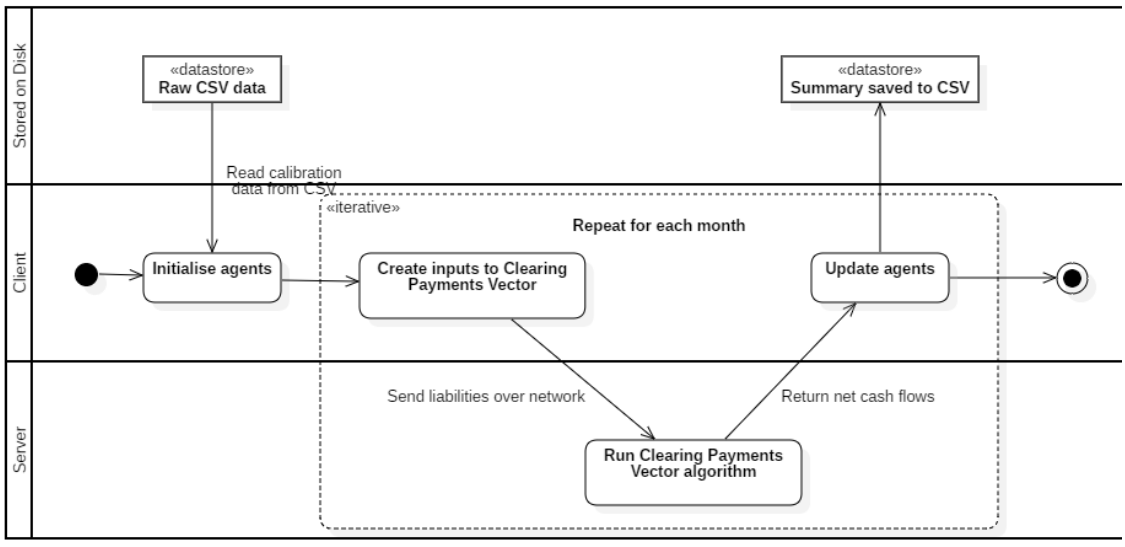


Figure 26: Agents' liabilities are sent over the network to a second computer to process the Clearing Payments Vector

Notes:

- Copies of the input data (approximately 1GB) are stored in the repository because some of it has been transformed during the data cleansing stage. For example, removing carriage returns and line feeds (CRLF) from within the cells in the CSV files, and converting non-numeric data stored in number fields (e.g. changing ‘na’ to ‘0’). The unmodified original data can be accessed via the data sources specified in the Appendix References section.
- If all the code was appended into a single text file and opened in MS Word using default formatting it would fill approximately 740 A4 pages, and the configuration files would fill 301 pages, which is why it is not included in this appendix.

Appendix B Calibration of Individuals and Households

Households heterogeneity is often overlooked (Guvenen, 2011), but is included in this model, using ABS statistical data to determine the number of each type of individual then leaving them in lone person households or grouping them into different size households. Individuals may be self-funded retirees, receiving unemployment benefits, the recipient of some other government welfare payment such as a disability pension, or be employed in one of 19 different industry divisions. Households may rent, own a home outright, or have a mortgage. House prices vary by LGA and loan amounts and house prices are derived using assumptions based on the mortgage repayments and the bank's home loan rate. Non-discretionary household expenses are estimated using the Henderson Poverty Line calculations based on each household's composition. All of this calibration is performed using the statistical distribution within each of the 540 LGAs across Australia.

See the `CalibrateBusinesses` class in the source code for a detailed description of the calibration algorithm, and the `CalibrateEconomy` class for details on how the agents are linked together.

B(a) Number of households by socio-economic category

Because people do not behave as individuals but rather as family units, the household is the base unit being used to calibrate the financial statements.

Australia's total population was 25.0 million at June 2018 (ABS, 2018au), with about 10 million households, and the number of people in each LGA varies considerably. The percentage of the total population in each LGA is multiplied by the total population in

order to adjust the numbers forward from the 2016 census to June 2018, assuming no domestic migration between LGAs.

$$P_{LGA,2018} = \frac{P_{LGA,2016}}{P_{Total,2016}} * P_{Total,2018}$$

Equation 1: Grossing up LGA population count using national population forecasts

To break-down the LGA population into more detailed demographics, the 2016 Census data is used. Because Basic accounts (i.e. free accounts) on the Census data website are limited to 40 million cells, several smaller data sets are taken and joined together to reconstruct (roughly) a more detailed dataset with more than 40 million cells. Calculating the ratios between categories and multiplying them together was attempted, but the results tended towards zero too often and only a few thousand agents were created rather than 25 million. To overcome this constraint, probability density functions were estimated using the ratios and 25 million agents assigned based on these probabilities. This means the results will vary based on the random seed chosen initially, but it also means that the right number of agents are created. Paying for a premium subscription to the Census data would overcome this estimation error, but the cost was beyond the reasonable scope of a Masters dissertation.

First the number of people by sex, age in 5-year brackets, employment industry, and personal income bracket for each post code is taken as a starting point (ABS, 2016d). Individual financial statements that were previously generated (see below for details) are then assigned to these agents based on their age, industry, income, sex and post code. Because the ATO and ABS differ slightly in their age and income ranges, some mapping was required, as outlined in Table 12 and Table 13 below.

Table 12: Mapping between ATO and ABS age ranges

ABS 5-year Age Range(s)	ATO Age Range
0 to 4 5 to 9 10 to 14 15 to 19	Under 18
20 to 24	18 to 24
25 to 29	25 to 29
30 to 34	30 to 34
35 to 39	35 to 39
40 to 44	40 to 44
45 to 49	45 to 49
50 to 54	50 to 54
55 to 59	55 to 59
60 to 64	60 to 64
65 to 69	65 to 69
70 to 74	70 to 74
75 to 79 80 to 84 85 to 89 90 to 94 95 to 99 100 and over	75 and over

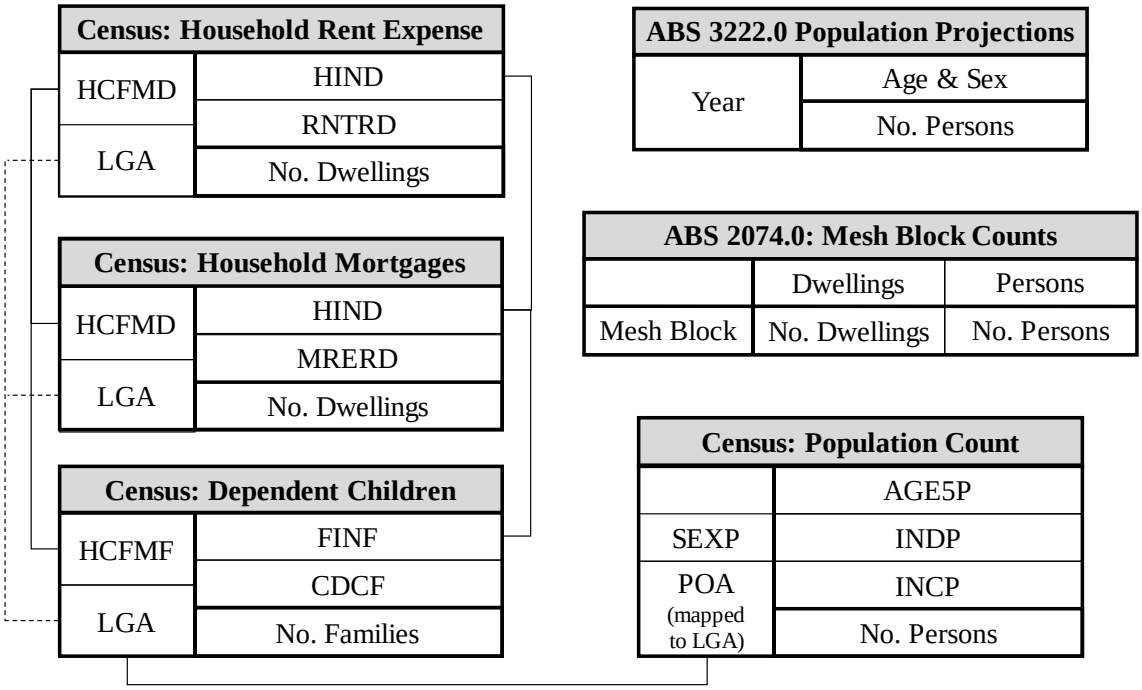
Table 13: Mapping between ATO and ABS personal income ranges

ABS individual income range (p.a.)	ATO taxable income range (p.a.)
Negative income Nil income $1-$7,799	$6,000 or less $6,001 to $10,000
$7,800-$15,599	$10,001 to $18,200
$15,600-$20,799 $20,800-$25,999	$18,201 to $25,000
$26,000-$33,799	$25,001 to $30,000 $30,001 to $37,000

$33,800-$41,599	$37,001 to $40,000
$41,600-$51,999	$40,001 to $45,000 $45,001 to $50,000
$52,000-$64,999	$50,001 to $55,000 $55,001 to $60,000 $60,001 to $70,000
$65,000-$77,999	$70,001 to $80,000
$78,000-$90,999	$80,001 to $87,000 $87,001 to $90000
$91,000-$103,999	$90,001 to $100,000
$104,000-$155,999	$100,001 to $150,000
$156,000 or more	$150,001 to $180,000 $180,001 to $250,000 $250,001 to $500,000 $500,001 to $1,000,000 $1,000,001 or more

Note: 'Not stated' and 'Not applicable' responses in the ABS data were excluded.

The number of households with rent expenses were combined with the number of households with mortgage expenses, ensuring as little overlap between rent and mortgage as possible (some households would both rent and have investment properties, so it is a valid result for a household to have both). These were combined with the count of dependent children per family, then grossed up from the 2016 census figures to the 2018 population projections. Individuals were assigned into families, using mesh block counts to map between postal areas (POA) and LGAs. Dwelling and household data was joined on composition, income, and LGA. This is summarised graphically in Figure 27.



SOURCES: Census 2016 data (ABS, 2016a, b, c, d), ABS 3222.0 (ABS, 2018au), ABS 2074.0 (ABS, 2017a)

Figure 27: Individual and Household count by demographic group mapping summary[15]

The mapping described earlier in Figure 27 has the potential to create up to 6 million unique individuals, as calculated in Equation 2 below, which is less than the 25 million people in 2018 predicted by ABS population forecasts.

540	x	2	x	21	x	19	x	14	=	6,032,880
LGA		SEX		AGE5P		INDP		INCP		Individuals

Equation 2: The number of possible unique Individuals using ABS data

[15] HCFMD = Family Household Composition (Dwelling), HCFMF = Household Composition F M per Family, RNTRD = Rental Expense per Dwelling, MRERD = Mortgage Repayments per Dwelling, HIND = Household Income per Dwelling, FINF = Family Income per Family, INDP = Income Industry per Person, INCP = Income per Person, CDCF = Count of Dependent Children per Family

However, the relative lack of heterogeneity in demographic categories is remedied by using the 16.5 million individual financial statements that were created from ATO data (see Equation 3).

2	x	13	x	13	x	19	x	2567	=	16,485,274
Sex		Age		Income		Industry		Post Codes		Individuals

Equation 3: The number of possible unique Individuals using ATO data

It also has the potential to create up to 40 million unique households, per Equation 4, which is approximately four times as many households as identified by the Census. By the time the 16 million unique individuals are assigned into 10 million households, each household can be reasonably expected to be unique. This contributed to the issue with rounding to zero, which is why a probability sampling technique was used instead of pure multiplication of ratios.

540	x	13	x	20	x	15	x	19	=	40,014,000
LGA		HFCM		FINF/HIND		CDCF		MRERD		Households

Equation 4: The number of possible unique Households using ABS data

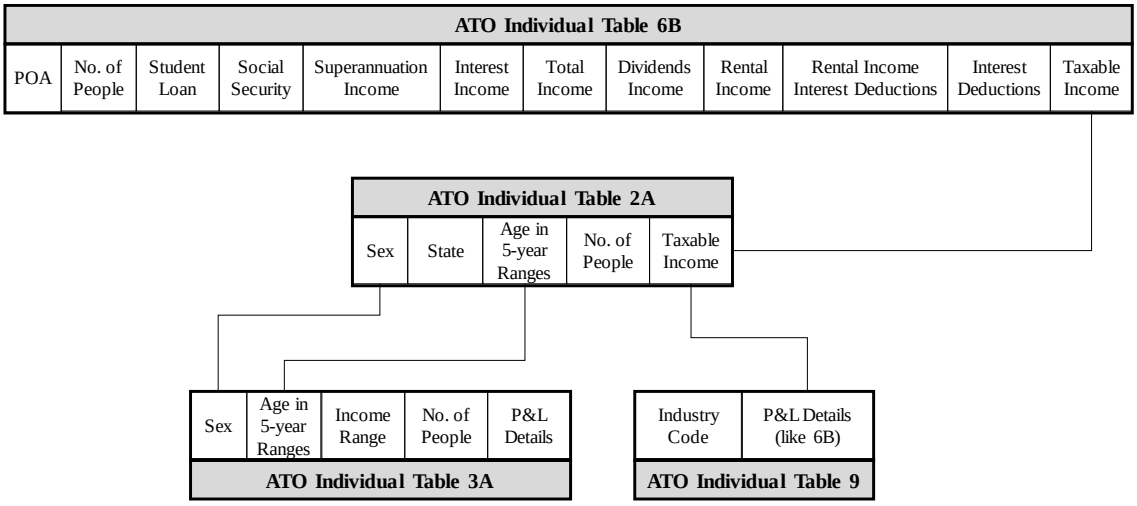
To ensure that the most appropriate individuals were assigned into households, the income of the second adult (where applicable) was chosen so that the sum of the two adults' incomes would align with the overall household income as closely as possible. This was not always possible due to the unavailability of people in the same LGA with the right income, in which case a person with the next closest income was chosen.

B(b) Combining data sources to create financial statements

Figure 28 summarises how the data sources were mapped together to produce financial statements for individuals which vary based on their demographic details. The main

source of financial figures was ATO Individual Table 3A, while the other data sources were used to provide more heterogeneity by adjusting for a greater variety of demographic characteristics.

Employment industry data is only available for 1.2 million of 13.5 million taxpayers, so ATO Individual Table 9 was used to adjust relativities based on industry, but the figures themselves were not relied on heavily.



SOURCES: ATO Individual Tables 2A, 3A, 6B and 9 (ATO, 2017c, d, e, f)

Figure 28: Individual financial data source mapping summary

Individuals are aggregated into households, and their financial statement summed to produce a partial picture of the household's financial statements. The Henderson poverty index is used to calculate non-discretionary household living expenses based on household composition. These combined profit and loss statements are then multiplied by the RBA E2 balance sheet ratios (RBA, 2018e) to produce a balance sheet for the household.

RBA E1 Household Balance Sheet									
Year	Dwellings	Non-Financial Assets	Cash	Financial Assets	Total Assets	Total Liabilities	Net Worth	Superannuation	Equities

RBA E2 Household Financial Ratios					
Year	Debt-to-Income	Assets-to-Income	Financial Assets-to-Income	Interest Expense-to-Income	Housing Interest Expense-to-Income

ABS 1410.0 Economy				
LGA	No. of House Sales	Mean House Sale Price	No. of Unit Sales	Mean Unit Sale Price

SOURCES: RBA E1 and E2 household financials (RBA, 2018d, e), ABS 1410.0 (ABS, 2018d)

Figure 29: Household financial data source mapping summary

B(c) Individual financial performance by category

Table 14: Individual Statement of Financial Performance structure and data sources

Field	**Data Source**
Incomes	
Wages and salaries	ATO Individual Table 3A, adjusted per Figure 28
Unemployment benefits	ATO Individual Table 3A, adjusted per Figure 28
Other Social Security income	ATO Individual Table 3A, adjusted per Figure 28
Investment income	ATO Individual Table 3A, adjusted per Figure 28
Interest income	ATO Individual Table 3A, adjusted per Figure 28
Rent income	ATO Individual Table 3A, adjusted per Figure 28
Foreign income	ATO Individual Table 3A, adjusted per Figure 28
Other income	ATO Individual Table 3A, adjusted per Figure 28
Gross Income	***Sum of all income sources***
Income Tax expense	Calculated using ATO marginal tax rates, including student debt repayment rates and Medicare levy reduction for low-income earners

Net Income	***Gross Income – Income Tax expense***
Expenses	
Work-related expenses	ATO Individual Table 3A, adjusted per Figure 28
Rental income interest expense	ATO Individual Table 3A, adjusted per Figure 28
Donations expense	ATO Individual Table 3A, adjusted per Figure 28
Total Expenses	***Sum of all expenses***
Profit	
Net profit	***Net Income – Total expenses***

SOURCES: ATO income tax rates (ATO, 2018b), ATO student debt repayment thresholds (ATO, 2019), ATO Medicare levy reduction for low-income earners (ATO, 2018c), ATO Individual Tables 2A, 3A, 6B and 9 (ATO, 2017c, d, e, f)

B(d) Household financial performance by category

Table 15: Household Statement of Financial Performance structure and data sources

Field	**Data Source**
Incomes	
Wages and salaries	Sum of Individuals
Unemployment benefits	Sum of Individuals
Other Social Security income	Sum of Individuals
Investment income	Sum of Individuals
Interest income	Sum of Individuals
Rent income	Sum of Individuals
Foreign income	Sum of Individuals
Other income	Sum of Individuals. Adjusted upwards if net savings are less than 1.1%, as described for 'Other (discretionary) expenses' below
Gross Income	***Sum of all income sources***
Income tax expense	Sum of Individuals
Net Income	***Gross Income – Income Tax***

Expenses	
Living expenses	Henderson poverty line excluding cost of housing, based on household composition.
Rent	Census LGA by RNTRD
Mortgage repayments	Census LGA by MRERD
Work-related expenses	Sum of Individuals
Rental income interest expense	Sum of Individuals
Donations expense	Sum of Individuals
Other (discretionary) expenses	Total Expenses – all other expenses, adjusted to make household net saving ratio 1.1% per ABS 5206.0 Table 20 (dividing net saving A2302828W by gross disposable income A2302912L). If total expenses are already too high, the Other Income field is increased to make net saving 1.1%.
Total Expenses	***Sum of all expenses***
Profit	
Net profit	***Net Income – Total expenses***

SOURCES: Census 2016 data (ABS, 2016a, b), Henderson Poverty Lines data (Melbourne Institute, 2018a), ABS 5206.0 Table 20 (ABS, 2018ad)

B(e) Household financial position by category

The model uses the profit and loss statements combined with census income data and the ratios from 'Household Finances – Selected Ratios – E2' to approximate household balance sheets.

Table 16: Household Statement of Financial Position structure and data sources

Field	**Data Source**
Assets	
Bank deposits	Sum of Individuals
Superannuation	RBA E01 series BSPNSHUFAR
Equity investments	RBA E01 series BSPNSHUFAS
Other financial assets	RBA E01 series BSPNSHUFAO

Total financial assets	***Sum of financial assets***
Residential land and dwellings	RBA E01 series BSPNSHNFD
Other non-financial assets	Total assets – Total financial assets – Residential land and dwellings
Total Assets	***RBA E02 series BHFADIT assets-to-income ratio multiplied by Total Income***
Liabilities	
Loans	RBA E02 series BHFDDIT debt-to-income ratio multiplied by Total Income, minus student loans
Student loans	Sum of Individuals using ATO Individual Table 3A, adjusted per Figure 28
Other liabilities	Total liabilities – Loans
Total Liabilities	***RBA E01 series BSPNSHUL total liabilities***
Equity	
Total Equity	***Total Assets – Total Liabilities***

SOURCES: RBA E01 history (RBA, 2018d) to get the national aggregate amounts, then RBA E02 ratios (RBA, 2018e) to calibrate based on the P&L data

B(f) Assigning interest rates for loans and deposits

The home loan balance of each ADI is used to construct a probability distribution, which is then used to assign households with loans to ADIs. The ADI's average home loan rate is assigned to the household's home loan. A similar process is used to assign household deposits to ADIs, with the ADIs average deposit rate assigned to the household's deposits.

It is important to note that households can have their loan with one ADI and deposits with another ADI. However, all the loans of a single household are with a single ADI, and all the deposits of a single household are with a single ADI. Geographic location was not taken into consideration due to the proliferation of internet banking and broker channels.

B(g) Data sources used to calibrate the model

The following data sources were used as inputs to calibrate the model:

- ABS 1410.0 'Economy and Industry, Local Government Area, 2011-2017' (ABS, 2018d)
- ABS 2074.0: 2016 Census Mesh Block Counts (ABS, 2017a)
- ABS 3222.0: Table B9. Population projections, By age and sex, Australia - Series B (ABS, 2018au)
- ATO 'Individuals Table 2A: Selected items, by lodgment method, gender, taxable status, state/territory and age range, 2015–16 income year' (ATO, 2017c)
- ATO 'Individuals Table 3A: Selected items, by gender, taxable status, age range and taxable income range, 2015–16 income year' (ATO, 2017d)
- ATO 'Individuals Table 6B: Selected items, by state/territory and postcode, 2015–16 income year' (ATO, 2017e)
- ATO 'Individuals Table 9: Selected items, by industry, 2015–16 income year' (ATO, 2017f)
- Census 2016 'HCFMD Family Household Composition (Dwelling) by LGA by HIND Total Household Income (weekly) and MRERD Mortgage Repayments (monthly) Ranges' data (ABS, 2016a)
- Census 2016 'HCFMD Family Household Composition (Dwelling) by LGA by HIND Total Household Income (weekly) and RNTRD Rent (weekly) Ranges' data (ABS, 2016b)

- Census 2016 'HCFMF Family Household Composition (Family) by LGA by FINF Total Family Income (weekly) and CDCF Count of Dependent Children in Family' data (ABS, 2016c)
- Census 2016 'SEXP Sex by POA (UR) by AGE5P - Age in Five Year Groups, INDP - 1 Digit Level and INCP Total Personal Income (weekly)' data (ABS, 2016d)
- RBA 'Household and Business Balance Sheets – E1' data (RBA, 2018d)
- RBA 'Household Finances – Selected Ratios – E2' data (RBA, 2018e)

Appendix C Calibration of Businesses

The two million businesses were calibrated using LGA-level statistics. They operate in the same 19 industries, with different turnover ranges and numbers of employees. Some are engaged in export, with the country of destination and trade volume depending on the business's state and industry.

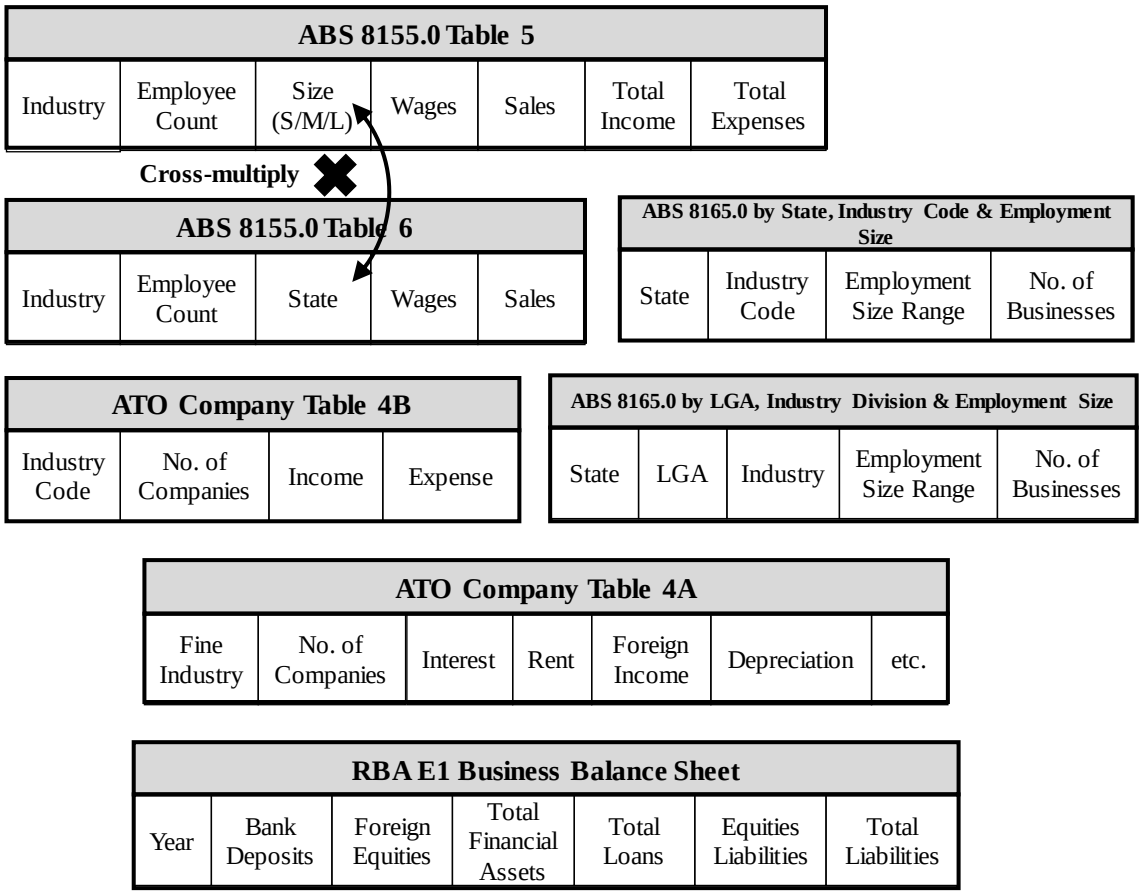
See the `CalibrateBusinesses` class in the source code for a detailed description of the calibration algorithm, and the `CalibrateEconomy` class for details on how the agents are linked together. A summarised version is given below.

C(a) Mapping data sources

Figure 30 summarises how the data sources were mapped together to produce the number of Businesses in each category as well as their corresponding financial statements.

Pairs of similar data sources were first joined on their common fields, and cross-multiplied using the ratios between their data values to produce a richer data set. These pairs of data sources were then combined by joining on common fields. The LGA-level ABS 8165.0 data was joined to the state-level data using the state. The ABS 8155.0 data was joined with the ABS 8165.0 data using the industry, size, employee count, and state.

The more detailed financial details in ATO Company Table 4A were combined with the more detailed industry data in ATO Company Table 4B to provide a richer estimation of company financial statements. These financial statements were then adjusted for state, LGA, employment size range, and turnover range as the business agents were created and initialised with financial data.



SOURCES:ABS 8155.0 Tables 5 & 6 (ABS, 2018w, x), ABS 8165.0 (ABS, 2018b, c), ATO Company Tables 4A & 4B (ATO, 2017a, b), RBA E1 (RBA, 2018d)

Figure 30: Summary of mapping used to combine business data sources

The ratios between the figures in ATO Company Table 4A (ATO, 2017a) are multiplied by the total income and expense per industry in ATO Company Table 4B (ATO, 2017b) to estimate company financial statements for 574 industries. For each industry division, the ratio between states from ABS 8155.0 Table 6 (ABS, 2018x) is multiplied by the industry size figures from ABS 8155.0 Table 5 (ABS, 2018w) to give industry totals for 432 categories.

Each category's total financial figures are divided by the number of businesses to get the average per business. Equating total financial assets from RBA table E1 (RBA, 2018d) with current assets from the ATO data allows the estimation of cash at bank and foreign assets using ratios. The model assumes that only large businesses hold foreign

equities (i.e. multi-national corporations and investment firms). Multiplying the ABS business ratios by the ATO company financials gives 13,776 unique detailed profit and loss statements and balance sheets.

Using similar logic, for each combination of state, size and industry division in the state-based ABS 8165.0 data (ABS, 2018c) the ratio of businesses in each industry code is calculated. Joining with the LGA-based ABS 8165.0 data (ABS, 2018b) and multiplying by these industry ratios gives the number of businesses by state, LGA, size and industry code, for a total of 953,988 possible types of business agents. For each of these types, the matching financial statements from above are copied and assigned until the model has calibrated all the businesses, for a total of approximately 2.25 million businesses.

On average, each type of business agent appears 2.25 times and each representative financial statement is re-used 163 times. However, when the businesses are linked to employees, banks, and foreign trading partners they will all be unique.

Exporters are identified and their values and countries assigned when linking the agents across the entire economy.

C(b) Business financial performance by category

Table 17: Business Statement of Financial Performance structure and data sources

Field	Data Source
Income	
Domestic sales	ATO Company Table 4A, adjusted per Figure 30
Overseas sales	ATO Company Table 4A, adjusted per Figure 30

Government sales	ATO Company Table 4A, adjusted per Figure 30
Interest income	ATO Company Table 4A, adjusted per Figure 30
Rent income	ATO Company Table 4A, adjusted per Figure 30
Other income	Total Income minus all other income
Total Income	ATO Company Table 4A, adjusted per Figure 30
Expenses	
Salary and Wage Expenses	Initialised per Figure 30 then updated when Individuals are assigned as employees
Superannuation Expenses	Calculated at 9.5% superannuation guarantee contribution rate
Payroll Tax	Calculated at relevant state rates
Rent	ATO Company Table 4A, adjusted per Figure 30
Interest expense	ATO Company Table 4A, adjusted per Figure 30
Overseas expenses	ATO Company Table 4A, adjusted per Figure 30
Depreciation and Amortisation	ATO Company Table 4A, adjusted per Figure 30
Other expenses	Total Expenses minus all other expenses
Total Expenses	ATO Company Table 4A, adjusted per Figure 30
Gross Profit	***Total Income minus Total Expenses***
Income tax expense	Calculated at relevant company tax rate[16]
Net Profit	***Gross Profit minus Income tax expense***

SOURCES: ABS 8155.0 Tables 5 & 6 (ABS, 2018w, x), ABS 8165.0 (ABS, 2018b, c), ATO Company Tables 4A & 4B (ATO, 2017a, b), ATO company tax rates (ATO, 2018a), Payroll Tax rates (Payroll Tax Australia, 2019)

[1616] 27.5 per cent tax rate for companied with revenues less than AUD 50 million, 30 per cent otherwise.

C(c) Business financial position by category

Simplified balance sheet looks like this:

Table 18: Business Statement of Financial Position structure and data sources

Field	Data Source
Assets	
Bank deposits	Ratios derived from RBA E01 series BSPNSPNFAD
Foreign equities	Ratios derived from RBA E01 series BSPNSPNFAF
Other financial assets	Total Financial Assets minus all other financial assets
Total financial assets	Current Assets from ATO Company Table 4A, adjusted per Figure 30
Other non-financial assets	Total Assets minus Total Financial Assets
Total Assets	ATO Company Table 4A, adjusted per Figure 30
Liabilities	
Trade Creditors	ATO Company Table 4A, adjusted per Figure 30
Loans	ATO Company Table 4A, adjusted per Figure 30
Other current liabilities	ATO Company Table 4A, adjusted per Figure 30
Other non-current liabilities	Total Liabilities minus all other liabilities
Total Liabilities	ATO Company Table 4A, adjusted per Figure 30
Equity	
Total Equity	***Total Assets minus Total Liabilities***

SOURCES: ABS 8155.0 Tables 5 & 6 (ABS, 2018w, x), ABS 8165.0 (ABS, 2018b, c), ATO Company Tables 4A & 4B (ATO, 2017a, b), RBA E1 (RBA, 2018d)

C(d) Assigning interest rates for loans and deposits

The business loan balance of each ADI is used to construct a probability distribution, which is then used to assign businesses to ADIs. The ADI's average deposit rate is assigned to the business's deposits, and the ADI's average business loan rate is assigned to the business's loans.

C(e) Data sources used to calibrate the model

The following data sources were used as inputs to calibrate the model:

- RBA Household and Business Balance Sheets – E1, June 2018 (RBA, 2018d)
- ABS 8155.0 Table 5: Business Size by Industry Division (ABS, 2018w)
- ABS 8155.0 Table 6: States and Territories by Industry Division (ABS, 2018x)
- ABS 8165.0: Businesses by Local Government Area by Industry Division by Employment Size Ranges, June 2017 (ABS, 2018b)
- ABS 8165.0: Businesses by Main State by Industry Class by Employment Size Ranges, June 2017 (ABS, 2018c)
- ATO Company Table 4A: Selected items, by industry, 2015-16 income year (ATO, 2017a)
- ATO Company Table 4B: Key items, by industry code, 2015-16 income year (ATO, 2017b)
- ATO company tax rates (ATO, 2018a)
- Payroll Tax rates for each state (Payroll Tax Australia, 2019)

Appendix D Calibration of ADIs

Each of the 86 ADIs in the model is based on the published financial statements and regulatory disclosures of an actual ADI. Their levels of profitability vary because their mix of loans and deposits differ – not just the balances but the interest rates and geographical spread. Their capital adequacy and liquidity ratios are unique too. No two are alike.

Non-interest income and expenses have been assumed to be constant, simplifying the calculations and making them predominantly driven by interest income from loans and investments, and interest expense on deposits. Off-balance-sheet loans have been omitted because they belong to separate entities and if the loans default it will have a negligible financial impact on the ADI. It may impact on the ADI's reputation in the market, but estimating the effect of that is beyond the scope of this research.

Because the annual reports of the ADIs vary considerably in the way they present their data, different assumptions and data transformations were made for each ADI. It is impractical to reproduce those here, so for all the details please refer to the spreadsheet 'ADI data to import' available with the source code (see Appendix A for details).

D(a) ADI financial performance

Table 19: ADI Statement of Financial Performance structure and data sources

Field	**Data Sources**[17]
Income	
Interest income	Annual reports
Interest expense	Annual reports

[17] See Appendix D(d) for details of the exact data sources used for each ADI.

Net Interest Income	Annual reports
Trading income	Annual reports
Investment income	Annual reports
Other income	Total Income – all other income
Total Income	Annual reports
Expenses	
Personnel expenses	Annual reports
Loan impairment expense	Annual reports
Depreciation and amortisation	Annual reports
Other expenses	Total Expenses – all other expenses
Total Expenses	Annual reports
Gross Profit	***Total Income – Total Expenses***
Income tax expense	Annual reports
Net Profit	***Gross Profit – Income tax expense***

SOURCE: ADI Annual Reports

D(b) ADI financial position

Table 20: ADI Statement of Financial Position structure and data sources

Field	**Data Sources[18]**
Assets	
Cash	Annual reports, APRA Monthly Banking Statistics, and APS330 disclosures
Trading Securities	Annual reports and APRA Monthly Banking Statistics
Derivative Assets	Annual reports and APRA Monthly Banking Statistics
Investments	Annual reports, APRA Monthly Banking Statistics, and APS330 disclosures

[18] See Appendix D(d) for details of the exact data sources used for each ADI.

Loans - Personal - Home - Business - ADIs - Government	Annual reports, APRA Monthly Banking Statistics, and APS330 disclosures
Total financial assets	Annual reports and APRA Monthly Banking Statistics
Other non-financial assets	Total Assets – all other assets
Total Assets	Annual reports, APRA Monthly Banking Statistics, and KPMG Mutuals Industry Review
Liabilities	
Deposits - At call - Term deposits - ADI / Repo eligible	Annual reports and APRA Monthly Banking Statistics
Derivative liabilities	Annual reports and APRA Monthly Banking Statistics
Bonds, notes and borrowings	Annual reports and APRA Monthly Banking Statistics
Other liabilities	Total Liabilities – all other liabilities
Total Liabilities	Annual reports and APRA Monthly Banking Statistics
Equity	
Retained earnings	Annual reports and APRA Monthly Banking Statistics
Reserves	Annual reports and APRA Monthly Banking Statistics
Other equity	Annual reports and APRA Monthly Banking Statistics
Net Assets	***Annual reports, APRA Monthly Banking Statistics, and KPMG Mutuals Industry Review***

SOURCE: ADI Annual Reports, APS330 disclosures, APRA Monthly Banking Statistics, KPMG Mutuals Industry Review

D(c) ADI key metrics

Table 21: ADI interest rates and regulatory capital

Field	Data Sources[19]
Interest Rates	
Cash (%)	Annual reports
Trading (%)	Annual reports
Investment (%)	Annual reports
ADI loans (%)	Annual reports
Government loans (%)	Annual reports
Total loans (%)	Annual reports
Deposits (%)	Annual reports
Bonds, notes and borrowings (%)	Annual reports
Regulatory Capital	
Total capital adequacy ratio (%)	APS330 disclosures
Total capital ($)	APS330 disclosures and Annual reports
Credit Risk-Weighted Assets ($)	APS330 disclosures and Annual reports
Total Risk-Weighted Assets ($)	APS330 disclosures and Annual reports

SOURCE: ADI Annual Reports, APS330 disclosures

D(d) ADIs included in the model, and their data sources

Table 22: List of ADIs included in the model, and their data sources

APRA ADI Category	Name and Data Sources
Major Banks[20]	
Australian-owned banks	Australia and New Zealand Banking Group Limited Annual Report 2018 (ANZ, 2018a) APS330 Disclosure June 2018 (ANZ, 2018b) APRA MBS June 2018 (APRA, 2018c)

[19] See Appendix D(d) for details of the exact data sources used for each ADI.

[20] The major banks are potentially Globally Systemically Important Banks (G-SIBs), and as such have higher capital adequacy requirements and additional reporting requirements.

Australian-owned banks	Commonwealth Bank of Australia Annual Report 2018 (CBA, 2018a) APS330 Disclosure June 2018 (CBA, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	National Australia Bank Limited Annual Report 2018 (NAB, 2018a) APS330 Disclosure June 2018 (NAB, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Westpac Banking Corporation Annual Report 2018 (Westpac, 2018a) APS330 Disclosure June 2018 (Westpac, 2018b) APRA MBS June 2018 (APRA, 2018c)
Other Domestic Banks	
Australian-owned banks	AMP Bank Ltd Annual Report 2018 (AMP, 2018a) APS330 Disclosure June 2018 (AMP, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Auswide Bank Ltd Annual Report 2018 (Auswide, 2018a) APS330 Disclosure June 2018 (Auswide, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Bank of Queensland Limited Annual Report 2018 (BOQ, 2018a) APS330 Disclosure May 2018 (BOQ, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Bendigo and Adelaide Bank Limited Annual Report 2018 (BABL, 2018a) APS330 Disclosure June 2018 (BABL, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Macquarie Bank Limited Annual Report 2018 (Macquarie Bank, 2018) APS330 Disclosure June 2018 (Macquarie Bank, 2018) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Suncorp-Metway Limited Annual Report 2018 (Suncorp, 2018a) APS330 Disclosure June 2018 (Suncorp, 2018b) APRA MBS June 2018 (APRA, 2018c)
Foreign Bank Subsidiaries	
Foreign subsidiary banks	Arab Bank Australia Limited Annual Report 2017 (Arab Bank, 2018a) APS330 Disclosure June 2018 (Arab Bank, 2018b) APRA MBS June 2018 (APRA, 2018c)

Foreign subsidiary banks	Bank of Sydney Ltd Annual Report 2017 (Bank of Sydney, 2018a) APS330 Disclosure June 2018 (Bank of Sydney, 2018b) APRA MBS June 2018 (APRA, 2018c)
Foreign subsidiary banks	HSBC Bank Australia Limited Annual Report 2017 (HSBC, 2018a) APS330 Disclosure June 2018 (HSBC, 2018b) APRA MBS June 2018 (APRA, 2018c)
Foreign subsidiary banks	ING Bank (Australia) Limited (trading as ING) Annual Report 2017 (ING Bank, 2018a) APS330 Disclosure June 2018 (ING Bank, 2018b) APRA MBS June 2018 (APRA, 2018c)
Mutual ADIs	
Australian-owned banks	Australian Military Bank Ltd Annual Report 2018 (Australian Military Bank, 2018a) APS330 Disclosure June 2018 (Australian Military Bank, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	B&E Ltd (trading as Bank of us) Annual Report 2018 (B&E, 2018a) APS330 Disclosure June 2018 (B&E, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Bank Australia Limited Annual Report 2018 (Bank Australia, 2018a) APS330 Disclosure June 2018 (Bank Australia, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Community CPS Australia Limited (trading as Beyond Bank Australia) Annual Report 2018 (Beyond Bank, 2018a) APS330 Disclosure June 2018 (Beyond Bank, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Defence Bank Limited Annual Report 2018 (Defence Bank, 2018a) APS330 Disclosure June 2018 (Defence Bank, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Endeavour Mutual Bank Ltd Annual Report 2018 (Endeavour Mutual Bank, 2018a) APS330 Disclosure June 2018 (Endeavour Mutual Bank, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	G&C Mutual Bank Limited Annual Report 2018 (G&C Mutual Bank, 2018a) APS330 Disclosure June 2018 (G&C Mutual Bank, 2018b) APRA MBS June 2018 (APRA, 2018c)

Australian-owned banks	Gateway Bank Ltd Annual Report 2018 (Gateway Bank, 2018b) APS330 Disclosure June 2018 (Gateway Bank, 2018a) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Greater Bank Limited Annual Report 2018 (Greater Bank, 2018a) APS330 Disclosure June 2018 (Greater Bank, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Heritage Bank Limited Annual Report 2018 (Heritage Bank, 2018b) APS330 Disclosure June 2018 (Heritage Bank, 2018a) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Hume Bank Limited Annual Report 2018 (Hume Bank, 2018a) APS330 Disclosure June 2018 (Hume Bank, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	IMB Ltd (trading as IMB Bank) Annual Report 2018 (IMB Bank, 2018a) APS330 Disclosure June 2018 (IMB Bank, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Members Banking Group Limited (trading as RACQ Bank) Annual Report 2018 (RACQ, 2018a) APS330 Disclosure June 2018 (RACQ, 2018b) APRA MBS June 2018 (APRA, 2018c) KPMG Mutuals Industry Review 2018 (Boele, *et al.*, 2018)
Australian-owned banks	Members Equity Bank Limited Annual Report 2018 (ME Bank, 2018a) APS330 Disclosure June 2018 (ME Bank, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	MyState Bank Limited Annual Report 2018 (MyState, 2018a) APS330 Disclosure June 2018 (MyState, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Police & Nurses Limited (trading as P&N Bank) Annual Report 2018 (P&N Bank, 2018a) APS330 Disclosure June 2018 (P&N Bank, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Police Bank Ltd (trading as Border Bank) Annual Report 2018 (Police Bank, 2018a) APS330 Disclosure June 2018 (Police Bank, 2018b) APRA MBS June 2018 (APRA, 2018c)

Australian-owned banks	Police Financial Services Limited (trading as BankVic) Annual Report 2018 (BankVic, 2018a) APS330 Disclosure June 2018 (BankVic, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	QPCU Limited (trading as QBANK) Annual Report 2018 (QBANK, 2018a) APS330 Annual Disclosure June 2018 (QBANK, 2018b) APS330 Quarterly Disclosure June 2018 (QBANK, 2018c) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Qudos Mutual Ltd (trading as Qudos Bank) Annual Report 2018 (Qudos Bank, 2018b) APS330 Annual Disclosure June 2018 (Qudos Bank, 2018a) APS330 Quarterly Disclosure June 2018 (Qudos Bank, 2018c) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Regional Australia Bank Ltd Annual Report 2018 (Regional Australia Bank, 2018a) APS330 Disclosure June 2018 (Regional Australia Bank, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Teachers Mutual Bank Limited (trading as Firefighters Mutual Bank, Teachers Mutual Bank and UniBank) Annual Report 2018 (Teachers Mutual Bank, 2018a) APS330 Disclosure June 2018 (Teachers Mutual Bank, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Unity Bank Limited Annual Report 2018 (Unity Bank, 2018a) APS330 Disclosure June 2018 (Unity Bank, 2018b) APRA MBS June 2018 (APRA, 2018c)
Australian-owned banks	Victoria Teachers Limited (trading as Bank First) Annual Report 2018 (Bank First, 2018a) APS330 Annual Disclosure June 2018 (Bank First, 2018b) APS330 Quarterly Disclosure June 2018 (Bank First, 2018c) APRA MBS June 2018 (APRA, 2018c)
Building societies	Australian Unity Bank Limited (Big Sky BS) Annual Report 2018 (Australian Unity, 2018a) APS330 Disclosure June 2018 (Australian Unity, 2018b)
Building societies	Maitland Mutual Building Society Limited (The Mutual) Annual Report 2018 (The Mutual, 2018a) APS330 Disclosure June 2018 (The Mutual, 2018b)

Building societies	Newcastle Permanent Building Society Limited Annual Report 2018 (Newcastle Permanent, 2018a) APS330 Annual Disclosure June 2018 (Newcastle Permanent, 2018b) APS330 Quarterly Disclosure June 2018 (Newcastle Permanent, 2018c)
Credit unions	Australian Central Credit Union Ltd (trading as People's Choice Credit Union) Annual Report 2018 (People's Choice Credit Union, 2018a) APS330 Disclosure June 2018 (People's Choice Credit Union, 2018b)
Credit unions	Bananacoast Community Credit Union Ltd Annual Report 2018 (BCU, 2018a) APS330 Annual Disclosure June 2018 (BCU, 2018b) APS330 Quarterly Disclosure June 2018 (BCU, 2018c)
Credit unions	Central Murray Credit Union Limited Annual Report 2018 (CMCU, 2018a) APS330 Disclosure June 2018 (CMCU, 2018b)
Credit unions	Central West Credit Union Limited Annual Report 2018 (CWCU, 2018b) APS330 Disclosure June 2018 (CWCU, 2018a)
Credit unions	Coastline Credit Union Limited Annual Report 2018 (Coastline Credit Union, 2018b) APS330 Annual Disclosure June 2018 (Coastline Credit Union, 2018a) APS330 Quarterly Disclosure June 2018 (Coastline Credit Union, 2018c)
Credit unions	Community Alliance Credit Union Limited Annual Report 2018 (CACU, 2018b) APS330 Disclosure June 2018 (CACU, 2018a)
Credit unions	Community First Credit Union Limited Annual Report 2018 (CFCU, 2018a) APS330 Disclosure June 2018 (CFCU, 2018b)
Credit unions	Credit Union Australia Ltd Annual Report 2018 (CUA, 2018b) APS330 Disclosure June 2018 (CUA, 2018a)
Credit unions	Credit Union SA Ltd Annual Report 2018 (Credit Union SA, 2018a) APS330 Disclosure June 2018 (Credit Union SA, 2018b)
Credit unions	Dnister Ukrainian Credit Co-operative Limited Annual Report 2018 (Dnister Ukrainian Credit Co-operative, 2018a) APS330 Disclosure June 2018 (Dnister Ukrainian Credit Co-operative, 2018b)

Credit unions	EECU Limited (trading as Nexus Mutual) Annual Report 2018 (Nexus Mutual, 2018a) APS330 Disclosure June 2018 (Nexus Mutual, 2018b)
Credit unions	Family First Credit Union Limited Annual Report 2018 (Family First, 2018b) APS330 Disclosure June 2018 (Family First, 2018a)
Credit unions	Fire Service Credit Union Limited Annual Report 2018 (Fire Service Credit Union, 2018b) APS330 Annual Disclosure June 2018 (Fire Service Credit Union, 2018a) APS330 Quarterly Disclosure June 2018 (Fire Service Credit Union, 2018c)
Credit unions	Firefighters & Affiliates Credit Co-operative Limited Annual Report 2018 (Firefighters & Affiliates Credit Co-operative, 2018a) APS330 Disclosure June 2018 (Firefighters & Affiliates Credit Co-operative, 2018b)
Credit unions	First Choice Credit Union Ltd Annual Report 2018 (First Choice, 2018a) APS330 Disclosure June 2018 (First Choice, 2018b)
Credit unions	First Option Credit Union Limited Annual Report 2018 (First Option, 2018a) APS330 Disclosure June 2018 (First Option, 2018b)
Credit unions	Ford Co-operative Credit Society Limited Annual Report 2018 (FCCS, 2018a) APS330 Disclosure June 2018 (FCCS, 2018b)
Credit unions	Goulburn Murray Credit Union Co-operative Limited Annual Report 2018 (GMCU, 2018a) APS330 Disclosure June 2018 (GMCU, 2018b)
Credit unions	Holiday Coast Credit Union Ltd Annual Report 2018 (Holiday Coast Credit Union, 2018a) APS330 Annual Disclosure June 2018 (Holiday Coast Credit Union, 2018b) APS330 Quarterly Disclosure June 2018 (Holiday Coast Credit Union, 2018c)
Credit unions	Horizon Credit Union Ltd Annual Report 2018 (Horizon Credit Union, 2018a) APS330 Disclosure June 2018 (Horizon Credit Union, 2018b)
Credit unions	Hunter United Employees' Credit Union Limited Annual Report 2018 (Hunter United, 2018a) APS330 Annual Disclosure June 2018 (Hunter United, 2018b) APS330 Quarterly Disclosure June 2018 (Hunter United, 2018c)

Credit unions	Laboratories Credit Union Limited Annual Report 2018 (LCU, 2018a) APS330 Disclosure June 2018 (LCU, 2018b)
Credit unions	Lysaght Credit Union Ltd Annual Report 2018 (Lysaght Credit Union, 2018a) APS330 Disclosure June 2018 (Lysaght Credit Union, 2018b)
Credit unions	MacArthur Credit Union Ltd Annual Report 2018 (The Mac, 2018a) APS330 Disclosure June 2018 (The Mac, 2018b)
Credit unions	Macquarie Credit Union Limited Annual Report 2018 (Macquarie Credit Union, 2018a) APS330 Disclosure June 2018 (Macquarie Credit Union, 2018b)
Credit unions	MCU Ltd Annual Report 2018 (MCU, 2018a) APS330 Disclosure June 2018 (MCU, 2018b)
Credit unions	Northern Inland Credit Union Limited Annual Report 2018 (NICU, 2018a) APS330 Disclosure June 2018 (NICU, 2018b)
Credit unions	Orange Credit Union Limited Annual Report 2018 (Orange Credit Union, 2018a) APS330 Disclosure June 2018 (Orange Credit Union, 2018b)
Credit unions	Police Credit Union Limited Annual Report 2018 (Police Credit Union, 2018a) APS330 Disclosure June 2018 (Police Credit Union, 2018b)
Credit unions	Pulse Credit Union Limited Annual Report 2018 (Pulse Credit Union, 2018a) APS330 Disclosure June 2018 (Pulse Credit Union, 2018b)
Credit unions	Queensland Country Credit Union Limited Annual Report 2018 (Queensland Country Credit Union, 2018a) APS330 Annual Disclosure June 2018 (Queensland Country Credit Union, 2018c) APS330 Quarterly Disclosure June 2018 (Queensland Country Credit Union, 2018b)
Credit unions	Railways Credit Union Limited (trading as MOVE) Annual Report 2018 (MOVE Bank, 2018a) APS330 Annual Disclosure June 2018 (MOVE Bank, 2018c) APS330 Quarterly Disclosure June 2018 (MOVE Bank, 2018b)
Credit unions	South West Slopes Credit Union Ltd Annual Report 2018 (SWSCU, 2018a) APS330 Disclosure June 2018 (SWSCU, 2018b)

Credit unions	Southern Cross Credit Union Ltd Annual Report 2018 (Southern Cross Credit Union, 2018a) APS330 Annual Disclosure June 2018 (Southern Cross Credit Union, 2018c) APS330 Quarterly Disclosure June 2018 (Southern Cross Credit Union, 2018b)
Credit unions	South-West Credit Union Co-Operative Limited Annual Report 2018 (South West Credit, 2018a) APS330 Quarterly Disclosure June 2018 (South West Credit, 2018b) APS330 Quarterly Disclosure September 2018 (South West Credit, 2018c)
Credit unions	Summerland Financial Services Limited (trading as Summerland Credit Union) Annual Report 2018 (Summerland, 2018a) APS330 Capital Disclosure June 2018 (Summerland, 2018b) APS330 Risk Disclosure June 2018 (Summerland, 2018c)
Credit unions	Sydney Credit Union Ltd Annual Report 2018 (SCU, 2018a) APS330 Disclosure June 2018 (SCU, 2018b)
Credit unions	The Broken Hill Community Credit Union Ltd Annual Report 2018 (Broken Hill Community Credit Union, 2018a) APS330 Disclosure June 2018 (Broken Hill Community Credit Union, 2018b)
Credit unions	The Capricornian Ltd Annual Report 2018 (The Capricornian, 2018a) APS330 Annual Disclosure June 2018 (The Capricornian, 2018c) APS330 Quarterly Disclosure June 2018 (The Capricornian, 2018b)
Credit unions	Traditional Credit Union Limited Annual Report 2018 (Traditional Credit Union, 2018a) APS330 Annual Disclosure June 2018 (Traditional Credit Union, 2018c) APS330 Quarterly Disclosure June 2018 (Traditional Credit Union, 2018b)
Credit unions	Transport Mutual Credit Union Limited Annual Report 2018 (Transport Mutual, 2018a) APS330 Disclosure June 2018 (Transport Mutual, 2018b)
Credit unions	Warwick Credit Union Ltd Annual Report 2018 (Warwick Credit Union, 2018a) APS330 Disclosure June 2018 (Warwick Credit Union, 2018b)
Credit unions	WAW Credit Union Co-Operative Limited Annual Report 2018 (WAW Credit Union, 2018a) APS330 Disclosure June 2018 (WAW Credit Union, 2018b)

Credit unions	Woolworths Employees' Credit Union Limited Annual Report 2018 (WECU, 2018a) APS330 Disclosure June 2018 (WECU, 2018b)
Other ADIs	Goldfields Money Limited Annual Report 2018 (Goldfields Money, 2018a) APS330 Disclosure June 2018 (Goldfields Money, 2018b)

Appendix E Calibration of RBA

E(a) RBA financial performance

Table 23: RBA Statement of Financial Performance

	AUD ($m)
Income	
Interest income	2,101
Interest expense	(1,200)
Net Interest Income	901
Committed Liquidity Facility Fees	349
FX Gains/(Losses)	3,162
AUD securities	(160)
Other income	23
Total Income	**4,435**
Expenses	
Personnel expenses	(272)
Depreciation and amortisation	(64)
Other expenses	(252)
Total Expenses	**(588)**
Gross Profit	**3,847**
Distribution payable to the Commonwealth	(669)
Net Profit	**3,178**

SOURCES: RBA Annual Report 2018, Statement of Comprehensive Income (RBA, 2018g)

E(b) RBA financial position

Table 24: RBA Statement of Financial Position

	AUD ($m)
Assets	
Cash	373
AUD investments	104,253
Foreign currency investments	75,912
Gold	4,344
Other assets	1,459
Total Assets	**186,341**
Liabilities	
Deposits	81,474
Distribution payable to the Commonwealth	889
Australian banknotes on issue	75,565
Other liabilities	3,036
Total Liabilities	**160,964**
Equity	
Capital	40
Reserves	25,337
Total Equity	**25,377**

SOURCES: RBA Annual Report 2018, Statement of Financial Position (RBA, 2018g)

Appendix F Calibration of Australian government

Multi-jurisdictional, state and local government levels have been omitted because bank defaults and bail-outs come under federal jurisdiction (Hansard, 2008). They do appear implicitly in the model as an exogenous source of income for businesses where the revenue is from government sources, but the financial impact on them is not estimated.

F(a) Government financial performance

Table 25: Government Statement of Financial Performance

	AUD ($m)
Income	
Tax income	389,734
Sale of goods and services	18,800
Interest income	4,447
Other income	13,550
Total Income	**426,531**
Expenses	
Personnel expenses	40,264
Interest expenses	25,881
Depreciation and amortisation	10,456
Other expenses	388,808
Total Expenses	**465,409**
GFS Net operating balance	**(38,877)**
less Net acquisition of non-financial assets	(8,893)
GFS Net Lending/(Borrowing)	**(47,770)**

SOURCE: Commonwealth Total Public Sector Operating Statement 2017 (ABS, 2018m)

F(b) Government financial position

Table 26: Government Statement of Financial Position

	AUD ($m)
Assets	
Cash	7,624
Investments, loans and placements	391,568
Equity assets	44,496
Other financial assets	115,239
Land and fixed assets	167,073
Other non-financial assets	3,330
Total Assets	**729,330**
Liabilities	
Currency on issue	77,718
Deposits held	98,468
Borrowings	574,741
Other liabilities	362,221
Total Liabilities	**1,113,148**
GFS Net Worth	***(383,818)***

SOURCE: Commonwealth Total Public Sector Balance Sheet 2017 (ABS, 2018s)

Appendix G Calibration of foreign country trading partners

Each of the foreign countries has different import and export balances which vary by business size, industry, and state (ABS, 2018n, o, t, u, v, y, z).

G(a) List of trading partners and their currencies

The trading partners with non-zero trading volume in both 5368.0 for 2017-2018 and 5368.0.55.006 for 2016-2017 and readily available historical monthly FX rates were selected for inclusion in the model.

Table 27: All 87 trading partners in FY18 included in the model, by AUD trading volume (gross imports and exports)

Country	Currency Code	UN Member State	FY18 Imports (AUD $m)	FY18 Exports (AUD $m)	FY18 Total Trade (AUD $m)
China (excluding SARs and Taiwan)	CNY	Y	67,764	105,602	173,366
Japan	JPY	Y	22,020	48,052	70,072
Korea, Republic of	KRW	Y	21,557	20,658	42,215
United States of America	USD	Y	29,757	11,675	41,432
India	INR	Y	5,514	16,182	21,696
Thailand	THB	Y	14,999	5,308	20,307
Malaysia	MYR	Y	11,485	6,133	17,618
Singapore	SGD	Y	9,366	7,949	17,315
Germany	EUR	Y	14,690	2,509	17,199
New Zealand	NZD	Y	7,856	9,231	17,087
United Kingdom	GBP	Y	7,281	6,287	13,568
Taiwan	TWD	N	4,281	9,174	13,455
Hong Kong (SAR of China)	HKD	Y	1,076	11,358	12,434
Indonesia	IDR	Y	4,419	6,548	10,967
Viet Nam	VND	Y	5,404	4,475	9,879

Italy	EUR	Y	6,682	784	7,466
France	EUR	Y	5,081	1,553	6,634
United Arab Emirates	AED	Y	2,627	3,572	6,199
Netherlands	EUR	Y	2,675	3,105	5,780
Papua New Guinea	PGK	Y	3,205	1,864	5,069
Switzerland	CHF	Y	3,431	1,377	4,808
Canada	CAD	Y	2,133	1,682	3,815
Mexico	MXN	Y	3,198	212	3,410
Spain	EUR	Y	2,488	710	3,198
Belgium	EUR	Y	2,082	1,110	3,192
Sweden	SEK	Y	2,668	333	3,001
South Africa	ZAR	Y	1,110	1,588	2,698
Philippines	PHP	Y	670	2,003	2,673
Brazil	BRL	Y	761	1,510	2,271
Turkey	TRY	Y	927	1,101	2,028
Ireland	EUR	Y	1,871	101	1,972
Austria	EUR	Y	1,798	56	1,854
Poland	PLN	Y	1,053	416	1,469
Denmark	DKK	Y	1,362	86	1,448
Saudi Arabia	SAR	Y	458	813	1,271
Bahrain	BHD	Y	100	1,047	1,147
Finland	EUR	Y	1,067	76	1,143
Israel	ILS	Y	797	243	1,040
Argentina	ARS	Y	688	333	1,021
Russian Federation	RUB	Y	291	612	903
Czech Republic	CZK	Y	697	205	902
Chile	CLP	Y	417	379	796
Pakistan	PKR	Y	284	490	774
Fiji	FJD	Y	180	459	639
Brunei Darussalam	BND	Y	589	48	637
Egypt	EGP	Y	54	573	627

Hungary	HUF	Y	573	31	604
Norway	NOK	Y	417	120	537
Sri Lanka	LKR	Y	245	258	503
Kuwait	KWD	Y	57	436	493
New Caledonia	XPF	N	45	428	473
Oman	OMR	Y	49	374	423
Puerto Rico	USD	N	339	1	340
Peru	PEN	Y	265	56	321
Portugal	EUR	Y	279	35	314
Slovak Republic	EUR	Y	310	0	310
Greece	EUR	Y	251	28	279
Slovenia	EUR	Y	171	92	263
Panama	USD	Y	15	160	175
Estonia	EUR	Y	152	10	162
Bulgaria	BGN	Y	72	29	101
Lithuania	EUR	Y	75	7	82
Cote d'Ivoire	XOF	Y	15	61	76
Latvia	EUR	Y	57	14	71
Morocco	MAD	Y	43	21	64
Tanzania	TZS	Y	7	49	56
French Polynesia	XPF	N	0	53	53
Ecuador	USD	Y	27	25	52
Madagascar	MGA	Y	22	23	45
Togo	XOF	Y	25	12	37
Luxembourg	EUR	Y	34	2	36
Cyprus	EUR	Y	31	3	34
Senegal	XOF	Y	0	34	34
El Salvador	USD	Y	12	18	30
Timor-Leste	USD	Y	1	27	28
Malta	EUR	Y	17	2	19
Burkina Faso	XOF	Y	0	13	13
Guam	USD	N	1	12	13
Mali	XOF	Y	0	13	13

Seychelles	SCR	Y	3	6	9
Reunion	EUR	N	0	5	5
Niger	XOF	Y	0	4	4
Marshall Islands	USD	Y	0	3	3
Micronesia Fed States of	USD	Y	0	3	3
Wallis & Futuna Islands	XPF	N	0	2	2
Zimbabwe	USD	Y	1	1	2
Netherlands Antilles	EUR	N	1	0	1

SOURCE: List of currencies of the world (Countries of the World, 2018), UN member states (UN, 2019), ABS 5368.0 Tables 14A and 14B (ABS, 2018aa, b).

G(b) List of currencies and their exchange rates

Table 28 below lists the currencies used by the trading partners identified in Table 27.

The average and standard deviation are based on monthly exchange rates.

Table 28: All 51 currencies used in the model, with summaries of their exchange rates and volatility

ISO-4217 Currency Code	Currency Name	Jun-18	1-Year Average	5-Year Std Dev
AED	UAE dirham	2.7143	2.8412	0.2733
ARS	Argentine peso	19.9538	15.0883	3.4970
BGN	Bulgarian lev	1.2569	1.2713	0.0468
BHD	Bahraini dinar	0.2836	0.2925	0.0284
BND	Brunei dollar	1.1079	1.0530	0.0564
BRL	Brazilian real	2.8265	2.5678	0.2389
CAD	Canadian dollar	0.9771	0.9844	0.0245
CHF	Swiss franc	0.7348	0.7516	0.0467
CLP	Chilean peso	477.2863	484.2115	113.7915
CNY	Chinese Yuan Renminbi	4.8888	5.0323	0.3679
CZK	Czech koruna	16.5591	16.6932	0.9618
DKK	Danish krone	4.7825	4.8370	0.1792

EGP	Egyptian pound	13.3908	13.7457	3.5252
EUR	European euro	0.6344	0.6482	0.0245
FJD	Fijian dollar	1.5577	1.5807	0.0695
GBP	Pound sterling	0.5634	0.5736	0.0418
HKD	Hong Kong dollar	5.8003	6.0546	0.5716
HUF	Hungarian forint	207.1881	202.3916	6.8351
IDR	Indonesian rupiah	10612.0000	10555.1667	403.3579
ILS	Israeli new shekel	2.7023	2.7343	0.2194
INR	Indian rupee	50.6800	50.4917	3.2591
JPY	Japanese yen	81.8200	85.2792	5.8355
KRW	South Korean won	822.9100	847.7708	54.9935
KWD	Kuwaiti dinar	0.2267	0.2337	0.0155
LKR	Sri Lankan rupee	119.2131	119.9775	7.5797
MAD	Moroccan dirham	7.1171	7.2662	0.2459
MGA	Malagasy ariary	2434.1821	2486.6723	162.5659
MXN	Mexican peso	15.1923	14.5125	1.3146
MYR	Malaysian ringgit	2.9837	3.1456	0.1658
NOK	Norwegian krone	6.0850	6.1975	0.3045
NZD	New Zealand dollar	1.0903	1.0883	0.0297
OMR	Omani rial	0.2886	0.2985	0.0290
PEN	Peruvian sol	2.4519	2.5174	0.0949
PGK	Papua New Guinean kina	2.4273	2.4975	0.1635
PHP	Philippine peso	39.8119	39.8589	2.6820
PKR	Pakistani rupee	89.0372	85.1736	193.3975
PLN	Polish zloty	2.7641	2.7501	0.1114
RUB	Russian ruble	47.0497	45.7485	7.2366
SAR	Saudi Arabian riyal	2.8156	2.9085	0.2828
SCR	Seychellois rupee	10.1251	10.5613	0.7277
SEK	Swedish krona	6.6010	6.4384	0.2733
SGD	Singapore dollar	1.0078	1.0374	0.0566
THB	Thai baht	24.4700	25.0867	1.7876
TRY	Turkish lira	3.4689	2.9997	0.4378
TWD	New Taiwan dollar	22.5000	23.0900	1.8365
TZS	Tanzanian shilling	1707.2704	1747.7007	109.4864

USD	United States dollar	0.7391	0.7736	0.0744
VND	Vietnamese dong	16970.0000	17608.1667	1219.1347
XOF	West African CFA franc	425.7132	426.1542	15.7373
XPF	CFP franc	76.6934	77.5860	3.7142
ZAR	South African rand	9.9629	9.9567	0.6510

SOURCE: OFX and RBA monthly exchange rates (OFX, 2019, RBA, 2018c)

G(c) Data sources used to calibrate the model

The following data sources were used as inputs to calibrate the model:

- ABS 5368.0 International Trade in Goods and Services, Australia, Sep 2018: Table 1 Goods and Services, Summary: Seasonally adjusted and trend estimates, Current prices (ABS, 2018p).
- ABS 5368.0 International Trade in Goods and Services, Australia, Sep 2018: Tables 36A-36H Merchandise Exports, State of Origin by Country, FOB Value (ABS, 2018ae, f, g, h, i, j, k, l).
- ABS 5368.0 International Trade in Goods and Services, Australia, Sep 2018: Tables 37A-37H Merchandise Imports, State of Destination by Country, Customs Value (ABS, 2018am, n, o, p, q, r, s, t).
- RBA Monthly FX Rates (RBA, 2018c).
- OFX Monthly FX Rates (OFX, 2019).

The logic behind combining the industry, state, value range and country data into a single comprehensive matrix is reasonably involved and impractical to reproduce here, so for all the details please refer to the spreadsheet ‘5368.0_exporter calculations’ available with the source code. Details of how to download the source code can be found in Appendix A.

Appendix H Mapping between geographic regions using Mesh Blocks

Some data was available at post code level, some at an LGA level, while other data was available at a GCCSA level. ABS 1270.0.55.003 has been used to map from POA to Mesh Block, and back to LGA (ABS, 2018a, g, h, i, j, k, l, 2018av, w, x). This allowed for the translation of post code data to LGA data so all the data was grouped at the same geographic level. ABS 1270.0.55.001 was used to determine if an LGA belonged to a GCCSA (ABS, 2018f).

This was particularly useful when calibrating households. Individuals were first calibrated using ATO post code data, then aggregated into households using ABS data at an LGA level.