The Transmission of Monetary Policy through Banks' Balance Sheets

Anthony Brassil, Jon Cheshire, Joseph Muscatello*

Monetary policy pass-through is defined as the effect of cash rate changes on banks' lending and deposit rates abstracting from all other influences on these rates (e.g. changes in regulation, competition, and conditions in funding markets). Our novel approach to pass-through estimation allows each balance sheet component to be separately modelled, thereby identifying any offsetting effects, differing pass-through speeds, and non-linearities.

While we find that pass-through differs across components, for the components over which banks have little pricing control, the deviations from full pass-through have been broadly offsetting since 2007. Conversely, the major banks' return on equity has not moved with the cash rate. As a result, aggregate pass-through to the major banks' lending and deposit rates has been less than one-for-one. If this diminished pass-through were spread evenly across lending and deposit rates, the deviation from full pass-through would be around 7 basis points for every 100 basis point change in the cash rate.

1. Introduction

The Reserve Bank of Australia's (RBA) policy rate (known as the 'cash rate') is not directly linked to the interest rates Australians pay on their mortgages, nor the rates they receive on their deposits.[1] These rates are mostly determined by the banking system.[2] However, the cash rate does have a strong indirect effect on these rates through its effect on banks' cost of funding (i.e. the interest rates banks pay on their liabilities and the banks' cost of equity). The question we seek to address is 'how much does the cash rate influence banks' lending and deposit rates?'

Answering this question is not straightforward. This is because banks' lending and deposit rates are influenced by many factors other than the cash rate (and expectations of future cash rates), and it is difficult to distinguish the influence of the cash rate from these other factors.

Included in these other factors are the various risks that banks take into account when setting interest rates. These include the risk of the borrower not repaying the loan (credit risk), the risk to the bank of not having the money available for withdrawal requests (liquidity risk), and the risk that future short-term interest rates will not turn out as expected (interest rate risk). Banks' rates are further influenced by banking regulations, competition, and conditions in banks' various funding markets (including offshore markets).

We are not claiming that these other factors are not important. During the late 1980s and 1990s, increased competition following the deregulation of the financial system caused a large reduction in the major banks' net

---

* The authors are from the Economic Research Department (Brassil) and Domestic Markets Department (Cheshire and Muscatello) of the Reserve Bank of Australia. Views expressed in this paper are those of the authors and not necessarily those of the Reserve Bank.

1 The RBA implements monetary policy via a target for the average interest rate banks charge each other for unsecured overnight loans – the 'cash rate'. See Baker and Jacobs (2010) for information on how the RBA operates in markets to achieve this target.

2 In addition to banks, loans can be made by non-bank authorised deposit-taking institutions (non-bank ADIs) and non-ADIs. However, the non-bank share of the market is currently small. For example, non-bank ADIs account for less than 3 per cent of outstanding residential mortgages (APRA 2018a), while non-ADIs account for less than 5 per cent (Gishkariany, Norman and Rosewall 2017).

interest margins (RBA 2014). More recently, the global financial crisis prompted disruptions to banks' funding markets, changes in risk perception, and regulatory changes (see Davies, Naughtin and Wong (2009) and RBA (2014), for example).

But these other factors are not the focus of this paper (they are examined in regular RBA analyses, see annual RBA Bulletin articles from Davies, Naughtin and Wong (2009) to McKinnon (2018), for example). The focus of this paper is the influence of the cash rate on banks' lending and deposit rates. And to determine the influence of the cash rate, it is important to abstract from changes in these other factors.

To show why it is important to abstract from these other factors, Table 1 provides pass-through estimates from regressions do not control for changes in any other factors that influence banks' interest rates. In the 1986-94 subset, the deviations of these estimates from unity partly reflected regulations, competition, and changes in risk (Lowe 1995). In the two post-2007 subsets, the pass-through estimates differ markedly from the estimates in this paper that properly control for the other factors.

Table 1: Simple Linear Relationships of Bank Rates with the Cash Rate[(a)]

	1986-94[(b)]	1997-06	2007-11	2012-17
Housing (variable)	0.56	1.00	0.75	0.80
Large business (variable)	0.83	0.72	0.75	1.24
Credit card (variable)	0.36	0.81	0.08	-0.06
Term deposit (1 month)	0.75	0.71	0.27	0.57
Term deposit (12 months)	0.78	1.07	0.59	1.12

Notes (a) Each number is the ordinary least squares estimate of the slope coefficient in a simple linear regression of the bank interest rate on the cash rate.
(b) Lowe (1995)

Sources: authors' calculations; Lowe (1995); RBA

While there are a number of monetary policy transmission channels (see Atkin and La Cava (2017) for an exposition), from the perspective of Australian households, the transmission through banks' lending and deposit rates is the most explicit. Almost one-quarter of working-age Australians currently have a bank loan, while almost all have a deposit account (World Bank 2017).

Since properly abstracting from the other influences on banks' rates is difficult, Table 1 likely reflects people's perceptions of monetary policy pass-through. For the decade from 1997, people were used to seeing variable home loan rates move one-for-one with the cash rate. The fall in the simple pass-through estimates since the onset of the financial crisis may have caused people to think the potency of monetary policy has diminished.

Correcting any mistaken perceptions is important for households' decision making. For example, if households erroneously believe the link between the cash rate and lending rates has weakened, they may underestimate the effect future cash rate increases will have on their mortgage rates, potentially leading to mortgage stress when these increases occur. On the other hand, erroneously believing future cash rate reductions will not be passed through would dampen the effect monetary policy has via households' forward-looking decision making (e.g. the consumption versus saving decision).

Knowledge of any pass-through changes, and the impact of any changes in the other factors mentioned earlier, ensures the RBA can set the cash rate appropriately to achieve its goals.[3] Knowledge of how pass-through is influenced by the level of the cash rate is also important for ascertaining any limits on pass-through.

3 The RBA Board has accounted for financial market and regulatory developments when setting the cash rate target (see Debelle (2012) and Lowe (2012), for example).

1.1 Summary of our approach and results

We create a novel framework for measuring the pass-through of monetary policy abstracting from the aforementioned other factors that influence banks' rates. Specifically, we:

- construct a detailed model of banks' balance sheets, incomes, and expenses;
- calibrate this model using data the major banks report to the Australian Prudential Regulation Authority (APRA) and interest rate data held by the RBA (accuracy is assessed by comparing other more-aggregated data to the equivalent aggregates produced by our model);
- determine the pass-through of the cash rate (and expectations of future cash rates) to what we define as the 'non-discretionary' components of the banks' balance sheets;
    - The non-discretionary components are those where the banks have little control over pricing, either because they are price-takers in the respective markets (e.g. wholesale debt funding and securities held as assets), because the price is fixed by virtue of the product (e.g. non-interest bearing deposits), or because of regulations defining how the price must be set (e.g. provisions for expected losses).
- determine the pass-through of the cash rate to the major banks' return on equity; and
- use the balance sheet identity to equate the pass-through to the non-discretionary components and return on equity with the pass-through to the discretionary lending and deposit rates.[4]

This approach has several advantages over existing approaches (discussed in Section 2). By looking at each part of the balance sheet separately, we are able to model each component in the way most appropriate for that component (so we can more accurately control for the other factors mentioned above). And by focussing our analysis on the 'non-discretionary' components of the banks' balance sheets, our analysis is not influenced by unobserved changes in banks' pricing decisions.

Moreover, we are able to determine whether the pass-through via some components offsets the pass-through via others; this is important as these components may change in size in the future. We can evaluate whether the speed of pass-through differs between components, and can identify any differing non-linearities. And for components with long maturities or interest rate hedges, we can determine when the peak effect of any cash rate change will occur.

We document several interesting findings:

- The major banks' assets and liabilities have similar repricing structures, and almost all of the remaining interest rate risk is hedged. Therefore, changes in the cash rate do not have the mechanical effect on net interest spreads that they would if assets and liabilities repriced at different speeds. This differs from other banking systems where repricing mismatch is a more important component of policy transmission.
- We estimate that the major banks source around 9 per cent of their funding from deposits that pay either no interest or a low fixed rate of interest (henceforth, no/low interest deposits). Cash rate reductions increase the relative cost of these deposits, but the banks smooth this adjustment through hedging. Our model can estimate both the relative cost increase and the timing of these smoothed cost increases. These deposits have directly contributed 27 basis points to the major banks' relative cost of debt funding since January 2007 (relative to current and expected cash rates); they are now the largest single contributor to the increase in the majors' relative debt funding costs since 2007. Due to the smoothing, we estimate that the direct contribution of these deposits will peak at 35 basis points around the end of 2020.

4 By 'discretionary' we mean that the price is a choice variable of the bank. Importantly, we are not claiming that this choice is unconstrained (e.g. competition and regulations constrain banks' choices), only that it is not exogenously determined.

- Recently, the low level of the cash rate may have caused depositors to shift away from higher interest deposits into no/low interest deposits; this would partially offset the above direct effect (by a maximum of 7 basis points).
- We find that the major banks' provisions for potential future losses have a positive relationship with the cash rate (new provisions effect profitability and may therefore influence pass-through). This is expected; after controlling for changes in macroeconomic conditions (and forecasts of these conditions), lower interest rates reduce both the probability of borrower default (due to lower required repayments) and the expected loss given default (due to higher asset prices).
  - Cutting the cash rate from 7.25 per cent to 1.5 per cent is estimated to have reduced annual provisioning rates by 41 basis points.
- The major banks' cash and liquid asset spread has a negative relationship with the cash rate, consistent with several of the assets within this category not paying interest. However, this asset category makes up just 3 per cent of the major banks' balance sheets, so we estimate that these assets increase the major banks' relative return on assets by 2 basis points per 100 basis point reduction in the cash rate.[5]
- While the timing of the effects have differed, the features identified above have been broadly offsetting since 2007. Therefore, changes in the cash rate since 2007 have passed-through approximately one-for-one to the non-discretionary components of the major banks' balance sheets.
- Our estimates suggest that the major banks' return on equity (ROE) has not moved with the cash rate since 2007. As a result, aggregate pass-through to lending and deposit rates has been less than one-for-one.
  - With equity comprising around 8 per cent of the majors' funding, if this lack of ROE pass-through were spread evenly across the majors' discretionary lending and deposit rates, the deviation from full pass-through would be around 7 basis points for every 100 basis point change in the cash rate since 2007. In other words, aggregate pass-through has been greater than 90 per cent since 2007. So this channel of monetary policy transmission is still very effective (in contrast to the estimates in Table 1).

Importantly, further substitutions into no/low deposits will increase the direct funding cost impact of any further cash rate reductions (assuming these deposit rates remain fixed). While the process of substituting to these no/low deposits will mitigate the direct effect in the near term, there is a limit to how much this can offset the increasing direct impact. Therefore, there is a point beyond which we would expect the pass-through from cash rate reductions to be much lower than what we have estimated in this paper.[6]

To the extent that shareholders value a ROE that does not move with the cash rate, increasing pass-through to ROE may increase the future cost of equity, thereby increasing future average prices for the banks' customers. Evaluating the size of this trade-off, and whether the banks' customers would prefer lower average prices or greater pass-through, is beyond the scope of this paper.

2. Literature Review and Our Approach

The pass-through of monetary policy to banks' lending and deposit rates has been well-researched internationally, especially as interest rates have approached the zero lower bound; with the zero lower bound leading to concerns about whether banks would pass-through interest rate decreases and what impact this would have on both their profitability and financial stability more broadly (see Cœuré (2012) and Bech and Malkhozov (2016), for example).

5 The 'cash and liquid assets' referred to here are those in the 'cash and liquid assets' category reported to APRA. Importantly, 'trading securities' and 'investment securities' are in separate categories, even though they may be liquid.

6 This assumes that no/low deposit rates cannot go below zero. There are policy suggestions that could allow deposit rates to move below zero; see Rogoff (2017), for example.

Importantly, bank profitability and interest rate pass-through are two sides of the same coin; any change to a bank's non-discretionary funding costs requires a change in its ROE and/or a change in lending/deposit rates. So the literature estimating pass-through is connected to the literature estimating the impact of low interest rates on banks' profitability.

Theoretically, there are several reasons why monetary policy changes may not be fully passed through to lending and deposit rates. There is the traditional view of banks as institutions that lend at long maturities and borrow at short maturities. If these lending rates reprice infrequently, unexpected changes in monetary policy will take time to flow through to the real economy. There are several general and partial equilibrium models that incorporate this maturity mismatch (either explicitly or implicitly via repricing frictions) and find that monetary policy shocks are attenuated by the banking system (see Gerali *et al* (2010), Andreasen, Ferman and Zabczyk (2013), and Alessandri and Nelson (2015), for example).

Monetary policy may not fully pass-through if changes in the policy rate impact banks' profitability. Brunnermeier and Koby (2017) argue that policy rate reductions beyond a certain level will be contractionary. This occurs because policy rate reductions shrink banks' net interest margins (after the short-term benefit of liabilities repricing faster than assets subsides), reducing profitability. Beyond some point, profitability is sufficiently inhibited to cause banks to shift away from risky lending (due to regulatory constraints requiring more capital to be held against these loans); the more the policy rate falls, the more this constraint binds, and the more contractionary the policy becomes.

Monetary policy may not fully pass-through if there are bounds on some interest rates. Eggertsson, Juelsrud and Wold (2017) build a New Keynesian DSGE model in which deposit rates have a floor because people have the ability to switch into cash. In their model, this floor means policy rate reductions below the floor have no effect on banks' funding costs, and therefore do not pass-through to lending rates.

Ultimately, whether monetary policy fully passes through to lending and deposit rates is an empirical question. There are three common approaches in the literature: stationary time-series models, panel models, and the analysis of long-run relationships.

Stationary time-series models, such as univariate regressions and vector autoregressions, use the co-movement between monetary policy rates and bank rates over time to identify how much monetary policy is passed through to bank rates. Some studies, such as Angeloni and Ehrmann (2003) and de Bondt (2005), use a small number of variables in their analysis (such as banks rates, money market rates, and the policy rate); implicitly assuming that monetary policy is not correlated with any of the excluded variables that would influence bank rates.

This assumption is problematic. We know that banks account for changes in both their cost of funding and the risk of their loan portfolio when pricing their loans. We also know that increases in perceived risk often occur at the same time as central banks cut their policy rates to stabilise their economies (e.g. when there is an increase in the probability of a recession).

Including more controls can help identify the true relationship between monetary policy and bank rates. von Borstel, Eickmeier and Krippner (2016) use a factor modelling approach that allows them to parsimoniously include a much larger set of controls. However, even these large studies typically do not include controls for the risk of the loan portfolio, they assume the relationships are linear and that there are no structural changes (such as changes in portfolio composition, competition, or regulation), and they implicitly assume that the balance sheet components they have not included (such as expected loan losses and profitability) are not correlated with the monetary policy variable (which theoretically need not be the case, see Van den Heuvel (2007) for example).

Another issue with stationary time-series models is that they implicitly assume the timing and magnitude of pass-through to bank rates is constant over time. This assumption will be violated if banks have some discretion over when they change their bank rates, or if the bank rates are long-term rates, in which case the model would need to control for expected future policy rate changes. To overcome these issues, and the above-mentioned issues with using only a small number of variables, a very common approach is to analyse long-run relationships between monetary policy and bank rates. Examples include, Lowe (1995), Borio and Fritz (1995), Aristei and Gallo (2014), Darracq Paries *et al* (2014), Horvath, Kotlebova and Siranova (2018), and Cook and Steenkamp (2018).

If the monetary policy rate and bank rates have a unit root and are cointegrated, then with a sufficiently large sample, the long-run relationship between these variables can be identified without needing to control for any stationary variables (this is the super-consistency property of cointegrated variables (Maddala and Kim 1998)). However, monetary policy rates in inflation-targeting economies do not have a unit root.[7] Moreover, there is evidence that interest rates were mean-reverting before inflation targeting (see Graph 2 in Simon (2015)).

These studies typically test for the presence of unit roots, but while these tests have nice asymptotic properties, they are known to have poor finite sample properties (Andries and Billon 2016). Moreover, even if these variables were cointegrated, accurately estimating the cointegrating relationship requires a sufficiently long time-series that the variance of the common stochastic trend dominates the variances of the stationary variables; this is unlikely to be the case when estimating recent pass-through, especially when one considers how much risk spreads changed during the financial crisis. As a result, these long-run analyses are likely subject to the same biases as the stationary time-series models.[8]

The final common method is to use panel data; that is, instead of using aggregate data, one uses data on many individual banks over time. One advantage of panel data is that it allows the researcher to control for the various features of individual banks that may change over time and confound aggregate estimates of pass-through. That said, the panel models still require the researcher to have properly controlled for variables correlated with both monetary policy and bank rates. One way to do this is to include time fixed effects and to interact the policy rate with some of the time-varying bank-specific features. But then the researcher is only able to identify the features that cause pass-through to differ across banks, rather than the aggregate pass-through.

Because panel models ideally have a large cross-section, they are best used in jurisdictions with a large number of different banks (e.g. the euro area or the US). Examples include Gambacorta (2008) and Hristov, Hülsewig and Wollmershäuser (2014).

The profitability literature referred to above also typically uses panel models. If the pass-through to profitability is not one-for-one after controlling for the pass-through of monetary policy to the non-discretionary parts of banks' balance sheets, then the pass-through to the banks' discretionary lending and deposit rates is also not one-for-one (by virtue of the balance sheet identity). Examples of these papers include Borio, Gambacorta and Hofmann (2015), Claessens, Coleman and Donnelly (2017), and Altavilla, Boucinha and Peydró (2017).

Unfortunately, panel data is unlikely to sufficiently aid pass-through estimation in Australia. Australia has a small and highly concentrated banking system with little variation among the balance sheets of the major banks.[9] And while there is more variation among the smaller Australian-owned and foreign-owned banks, extrapolating this information to the major banks would require the brave assumption that we had completely controlled for everything that would cause the major banks to respond differently to the other banks.

In Australia, Lowe (1995) finds that between 1986 and 1994, banks' lending and deposit rates moved far less than one-for-one with the cash rate (some of these results are reported in Table 1). Apergis and Cooray (2015) report evidence of asymmetric pass-through, but do not report the level of pass-through. However, their paper falls into the category of the long-run analyses discussed above, and their finding of asymmetric pass-through could just be

7 In the long-run, monetary policy rates equal the neutral real interest rate plus inflation, with the neutral real rate being the real interest rate that equates saving and investment in the long-run, and inflation being determined by the inflation target (McCririck and Rees 2017).

8 To get an idea of the potential problem, the regressions in Table 1 are typical of the long-run analyses literature, with these pass-through estimates differing markedly from the results of our analysis.

9 There are 86 banks in Australia (of which 44 are branches of foreign banks), with the four major banks accounting for around 80 per cent of domestic banking assets. In contrast, the US and European banking systems consist of thousands of banks, and are far less concentrated than the Australian banking system (based on the Herfindahl-Hirschman Indices reported in Deloitte Access Economics (2014) and Wheelock (2011)).

proxying for changes in pass-through over time (the cash rate was rising in the first part of their sample, then falling in the second).

2.1 Our approach

Instead of using regression techniques that estimate pass-through by trying to directly control for the various other influences on banks' lending and deposit rates (i.e. the approaches above), we construct a detailed model of banks' balance sheets and use data the major banks report to APRA and interest rate data held by the RBA to calibrate the components of this model. Having a model of the banks' balance sheets allows us to determine the effect of the cash rate on each balance sheet component separately, thereby allowing us to account for differing amounts of pass-through, different controls (to abstract from the various other influences on banks' lending and deposit rates), and different pass-through speeds. It also allows us to properly account for differences in maturity structure between assets and liabilities, account for any hedging, and identify the source of any incomplete pass-through. While calibration may be less accurate than an unbiased estimator and a large sample, given all the estimation issues discussed above, we believe that calibration is likely to provide more accurate parameter values.

We split the banks' balance sheet into discretionary and non-discretionary components. The non-discretionary components are those where the banks have little control over pricing, either because they are price takers in the respective markets (e.g. wholesale debt funding and securities held as assets), because the price is fixed by virtue of the product (e.g. non-interest bearing deposits), or because of regulations defining how the price must be set (e.g. provisions for expected losses). Because these components are non-discretionary, we can analyse the effect of the cash rate on these components without needing to control for unobserved changes in banks' pricing decisions.

Once we determine the pass-through to banks' non-discretionary components, due to the balance sheet identity, this pass-through must equal the aggregate pass-through to the discretionary components. The banks' discretionary components are the loans and deposits over which they have some pricing power, and their return on equity. The pass-through to lending and deposit rates is therefore equal to the combination of the non-discretionary pass-through and return on equity pass-through.

That said, this approach does have some disadvantages. First, the model is not behavioural; so we can't say whether the major banks will respond to future cash rate changes in the same way as they have responded to past cash rate changes. While this is a critique of empirical models in general, it is particularly important for this research because the major banks likely have some flexibility in how they respond to cash rate changes.

Second, we do not attempt to determine the extent of pass-through to individual lending and deposit rates, only the aggregate pass-through. This is because – without information on how the major banks price their products, changes to competitive pressures, changes to regulations, or any other unobservable changes to the decision-making of banks – estimates of individual pass-through based on historical relationships are likely to be fraught with error and are unlikely to accurately estimate future pass-through. In any case, aggregate pass-through is what most concerns a central bank. While the marginal propensities to consume of net borrowers differ from net savers (La Cava, Hughson and Kaplan 2016), these differences are of second-order importance to the aggregate pass-through effect.

Third, we do not look at the effect of cash rate changes on lending volumes. While this means we are not capturing every part of the transmission of monetary policy through the banking system, the transmission through volumes acts on the *flow* of loans, whereas the transmission through rates acts on both the *stock* and *flow* of loans and deposits, so the latter is likely the more important of the two mechanisms (especially in Australia, where 80 per cent of the major banks' assets have interest rates that can be repriced in under 3 months).

3. Model of Banks' Incomes and Expenses

As with most research that incorporates a theoretical model of banks' incomes and expenses (e.g. Lowe (1995) and Borio, Gambacorta and Hofmann (2015)), we start with a stylised balance sheet identity:

$$\sum_i A_i \equiv \sum_j L_j + E$$

where A_i is the current value of asset i, L_j is the current value of liability j, and E is the current book value of equity. From this balance sheet identity, we construct a relationship between the bank's return on equity (r_E) and its incomes and expenses:

$$(1 + r_E)E = \sum_i (1 - p_i)(1 + r_{A,i})A_i - \sum_j (1 + r_{L,j})L_j + (f - c)\sum_i A_i \tag{1}$$

where $r_{A,i}$ is the interest income from asset i, $r_{L,j}$ is the interest cost of liability j, f is the non-interest income gained per unit of assets (e.g. fees), c is the non-interest expense per unit of assets (e.g. staffing costs).

We assume that the bank never defaults (so $r_{L,j}$ is always paid in full), but that some borrowers will not repay their loans. $p_i(1 + r_{A,i})A_i$ is the unconditional expected loss from asset A_i; it is an unconditional expectation as it incorporates both the probability of default and the expected loss given default. Therefore, the first term on the right hand side of Equation (1) is the expected gross interest income from asset i.

In this model, banks' return on equity (r_E) is the actual return on equity, not the expected return on equity. It is a function of expected losses $\left(\sum_i p_i(1 + r_{A,i})A_i\right)$, rather than an actual losses, because Australian banks are required to 'provision' for losses when they become likely (not only after they occur) and account for new provisions in current expenses. Provisions include likely losses on individual loans and an expense to cover 'currently unidentified' losses, with this expense based on historical loss experience and prevailing economic conditions (RBA 2009a).

Dividing both sides of Equation (1) by the total current value of assets $(\sum_i A_i)$ and subtracting the cash rate (r_C) from both sides of the equation gives:

$$(r_E - r_C)\left(1 - \sum_j \alpha_j\right) = \sum_i (r_{A,i} - r_C)\beta_i - \sum_j (r_{L,j} - r_C)\alpha_j + (f - c) - \sum_i p_i(1 + r_{A,i})\beta_i \tag{2}$$

where $\alpha_j \equiv \frac{L_j}{\sum_i A_i}$ and $\beta_i \equiv \frac{A_i}{\sum_i A_i}$. Equation (2) is the framework that will be used in the rest of this paper.

Equation (2) expresses the interest rates as spreads to the cash rate. If any of these assets or liabilities have interest rates that are fixed for some period, changes in the cash rate will mechanically change these spreads. For example, banks that borrow at short maturities and lend at long maturities (with fixed interest rates) would see their return on equity spread fall as the cash rate increased (*ceteris paribus*). In practice, banks may reduce their exposure to interest rate risk by lending for long maturities with interest rates that can be repriced frequently or by using derivatives to hedge the interest rate risk from repricing mismatches.

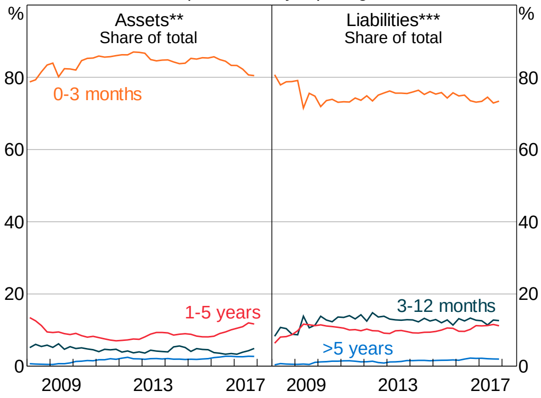
If banks hedge their interest rate risk, their incomes and expenses will only be affected by changes in the spreads of the various interest rates relative to the reference rates used for hedging.[10] A corollary of this axiom is that, for

10 The reference rates for assets/liabilities with terms longer than one year are the rates at which the market is willing to 'swap' a stream of fixed interest payments for a stream of variable-rate payments. The reference rates for shorter term assets/liabilities are the variable interest rates typically used in these swaps, known as bank bill swap (BBSW) rates (Gizycki and Gray 1994).
Importantly, we are not saying that the derivative instruments used for hedging do not influence profits; banks can still gain or lose money on these derivatives if future short term rates do not turn out as expected. All we are saying is that, if these derivatives offset other positions on a bank's balance sheet, then any gain/loss on the derivatives will be offset by a loss/gain on the balance sheet (i.e. their interest rate risk is hedged).

any hedged interest rate risk or for assets and liabilities with the same repricing term, the spreads to cash rate in Equation (2) can be replaced with spreads to the relevant reference rates and the equality will still hold (see Appendix A for further explanation). Moreover, any additional margin can be added to these spreads without affecting Equation (2); we add the BBSW-OIS spread so that the spreads we analyse are hedged spreads to current/expected cash rates.[11]

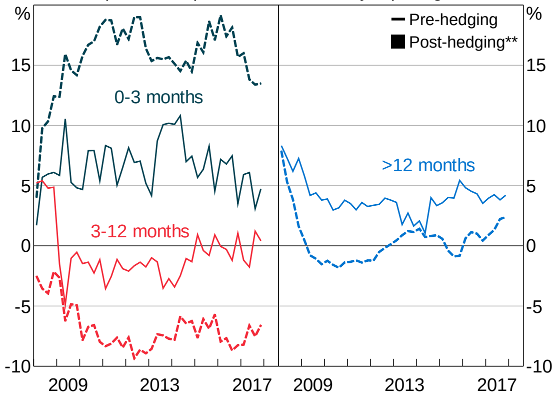
Over the past decade, the majority of the major banks' assets and liabilities had interest rates that repriced in less than 3 months (Graph 1). Furthermore, with only net asset positions remaining, the remaining repricing mismatch between assets and liabilities was hedged (Graph 2). This has two main implications for our analysis. First, changes in the cash rate do not effect the major banks' return on equity via repricing mismatches; this differs from several other banking systems, see Gambacorta (2008) and Alessandri and Nelson (2015), for example.[12] And second, we can use the 'spreads to reference rates' in place of the 'spreads to cash rate' for the assets and liabilities in Equation (2).

Graph 1
Major Banks' Interest Rate Risk
Gross positions*; by repricing term



* Includes AUD and foreign currency assets and liabilities.
** Includes loans, cash and liquid assets, investment securities, and acceptances.
*** Includes deposits, borrowings, and acceptances.
Sources: APRA; authors' calculations

Graph 2
Major Banks' Interest Rate Risk
Net positions*; per cent of assets; by repricing term



* Assets minus liabilities (both AUD and foreign currency). Assets include loans, cash and liquid assets, investment securities, and acceptances. Liabilities include deposits, borrowings, and acceptances.
** Includes swaps, options, futures, forward rate agreements, and foreign exchange derivatives.
Source: APRA; authors' calculations

The benefit of converting the interest rates on banks' assets and liabilities into 'spreads to reference rates' is that it enables us to evaluate the pass-through of cash rate changes to each asset and liability class separately. If we did not convert the rates into spreads, any analysis of cash rate pass-through would need to control for both the repricing structure of each asset and liability class, and any changes in expected future cash rates (e.g. a 5 year interest rate that does not fully adjust because expected future cash rates do not change, does not indicate incomplete monetary policy pass-through); any regression that does not fully account for these features would be biased.

Since this paper is not concerned with the effect of the cash rate on loan volumes, Equation (2) normalises the size of the balance sheet to one (the β_i and α_j are the balance sheet shares of each asset and liability class, respectively). We then assume that banks are profit-maximising and therefore choose the cheapest funding mix given their constraints (constraints include the supply of each funding source, liquidity considerations, and regulatory requirements). This means we can focus our analysis on changes in spreads.[13]

11 Overnight index swaps (OIS) are 'derivatives in which one party agrees to pay the other party a fixed interest rate in exchange for receiving the average cash rate recorded over the term of the swap' (Finlay and Chambers 2008).

12 Hoffmann, Langfield and Pierobon (2017) find that euro area banks use derivatives to reduce interest rate risk by only 25 per cent, while Begenau, Piazzesi and Schneider (2015) finds that US banks use derivatives to increase interest rate risk.

13 From the Envelope Theorem, to a first-order approximation, changes in the cash rate influence funding costs through any direct effects on spreads and through changes in any binding constraints (see Appendix C for explanation).

The remainder of the paper will evaluate the affect cash rate changes have on provisioning (Section 4.1), the major banks' debt funding spreads (Section 4.2), non-loan asset spreads (Section 4.3), non-interest income and expenses (Section 4.4), and return on equity (Section 5). These components will then be aggregated to determine the aggregate pass-through of monetary policy to the major banks' discretionary lending and deposit rates (Section 5).

4. The Relationship between the Cash Rate and the Model Components

4.1 Provisions

In this section, we model banks' net new provisions for expected loan losses (also known as their 'charge for bad and doubtful debts'). We model these new provisions as a linear function of the cash rate, long term interest rates, and economic variables.[14]

Loan losses are determined by two variables, whether a borrower defaults on their loan, and the amount the bank is able to recover from the borrower after they have defaulted (including through asset sales). Therefore, expected losses are determined by the probability of default, and the expected loss given default.

Theoretically, the cash rate will affect both components. By reducing the interest burden, an unexpected reduction in either current or future cash rates should reduce borrowers' probability of default. By increasing asset values, an unexpected reduction in current or future cash rates should reduce the expected loss given default.

Expected losses will also be affected by the prevailing economic conditions. For example, an unexpected increase in either current or future unemployment will increase borrowers' probability of default. While an unexpected downgrade in GDP forecasts, for example, will increase expected losses given default. Therefore, when determining the relationship between the cash rate and provisions, it is important to control for current and expected macroeconomic conditions.

As a key component of profits, the international literature evaluating the effect of interest rate changes on bank profitability typically evaluates the effect on banks' provisions. Two recent international studies (Altavilla, Boucinha and Peydró (2017) and Borio, Gambacorta and Hofmann (2015)) both found a positive and statistically significant relationship between short term interest rates and provisions, as expected. Importantly, Altavilla, Boucinha and Peydró (2017) found that controlling for macroeconomic forecasts is important for determining the relationship between interest rates and provisions. Rodgers (2015) conducted a comprehensive analysis of Australian banks' credit losses between 1980 and 2013 and found a positive relationship between interest rates and losses. However, unlike the above studies and our analysis, Rodgers analysed 'current losses', a less forward-looking measure than provisions. So our results are not directly comparable.

We have quarterly data on net new provisions between 2002 and 2017, but the similarity between the major banks means we cannot utilise the panel aspect of our data; so we analyse the aggregate provisions of the major banks divided by the value of their assets (i.e. a concept consistent with Equation (2)). This gives us 61 observations.

We want to control for the prevailing and expected economic conditions as best as possible, so we have 14 macroeconomic variables and forecasts we would like to include (see Appendix B for a list). However, the small number of observations means including this many variables would make our analysis prone to overfitting. To overcome this problem, we use a common dimensionality reduction technique known as principal components analysis (PCA). We find that the first two principal components contain 57 per cent of the variation contained within our collection of macroeconomic variables (see Appendix B for further explanation and details about the makeup of the principal components).

14 We regress new provisions on the *levels* of these variables, rather than the *changes*, because of the way provisions are constructed. Individual provisions require a loan to be identified as being 'impaired', while provisions for 'currently unidentified' losses incorporate both the prevailing economic conditions and historical loss experience (RBA 2009a); the latter meaning provisions do not all occur the moment conditions deteriorate.

We regress quarterly net provisioning rates on the cash rate, the slope of the yield curve (to control for expectations of future cash rates), and our two principal components. As expected, both the cash rate and yield curve variables have a positive and statistically significant effect on provisions, while an economic deterioration causes provisions to rise. Our explanatory variables are able to explain 55 per cent of the variation in provisions.[15]

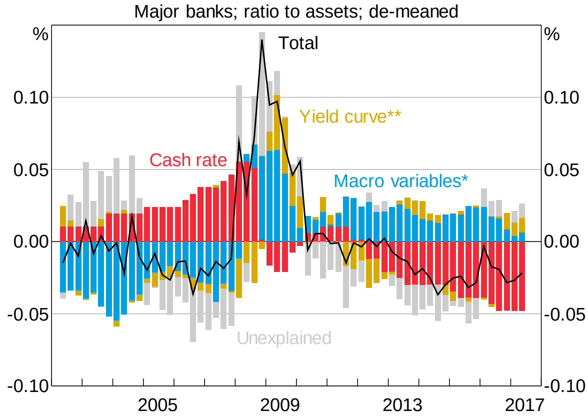
Graph 3 decomposes provisions into the contribution of each explanatory variable. The impact of the economic deterioration during the crisis (including the deteriorating forecasts) is obvious, as is the counteracting effect of the large reduction in the cash rate during this period. While a lot of the identification comes from the crisis period, the subsequent period of falling provisions in line with further cash rate reductions is also evident.

Based on these estimates, a 100 basis point cut in the cash rate is expected to reduce annual provision rates by 7 basis points (with a 2 standard deviation confidence interval of 5-10 basis points). This may not seem like much, but the cut in the cash rate from 7.25 per cent to 1.50 per cent means annual provision rates are 41 basis points lower. Compared with an average annual provision rate of 23 basis points (during 2002-2017), this is a big effect.

Graph 3

Decomposition of Net Provisioning Rates

Major banks; ratio to assets; de-meaned



* First two principal components of macro variables (GDP growth, inflation, unemployment, RBA forecasts, credit growth, house price growth, business profits, household disposable income, terms of trade, ASX VIX).

** 3-year AGS minus 3-month OIS

Sources: ABS; APRA; authors' calculations; RBA; Thomson Reuters

The effect of the cash rate on provisions may diminish at low interest rates. Net provisioning rates can only be negative if previously provisioned losses are no longer in danger of being realised. Therefore, the benefit of lower interest rates is likely to weaken as net provisioning rates approach zero.

4.2 Debt Funding Spreads

4.2.1 Construction of funding spreads and shares[16]

In this section we outline the key assumptions and data used to construct the funding side of our model. The shares of each funding component – the α_j parameters in Equation (2) – are calibrated using APRA data reported

15 Our residuals exhibit serial correlation (Graph 3). To remove the serial correlation we estimated a version of the model including the first lag of the dependent variable and regressors. These lags increased the explained variation to 79 per cent. However, this model exhibited features symptomatic of overfitting, which is why it is not our preferred model. For example, with cash rate changes typically being small except for at the onset of the crisis, the model uses the large change in this quarter to 'explain' the large positive residual (Graph 3), even though the large change was a fall in the cash rate (so it should not have caused an increase in provisions). In any case, even with the likely overfitting, the conclusion that the cash rate level has a positive relationship with provisions remained.

16 Our assumptions in this section are similar to the assumptions used in previous RBA work. See Davies, Naughtin and Wong (2009) and Berkelmans and Duong (2014), for example.

by the major banks (Graph 4) and other balance sheet data obtained by the RBA.[17] The spreads are estimated from major bank interest rate data collected by the RBA (see Appendix E for more detail):

- Long-term debt spreads equal the value-weighted average spreads at issuance of the major banks' outstanding bonds. The spreads at issuance equal the estimated foreign-currency hedged yield at issuance minus the swap rate of similar maturity. We then add the BBSW to OIS spread (as discussed in Section 3).
- Short-term debt spreads equal value-weighted spreads between market-based estimates of the major banks' foreign-currency hedged short-term debt funding costs and maturity-matched OIS rates.
- Term deposit spreads are weighted averages of the maturity-matched spreads (to OIS) at issuance of term deposits assumed to remain outstanding. The weights depend on the proportion choosing each term and the length of each term. The proportion choosing each term depends on the advertised 'special' rates at each point in time, and is assumed to be inversely proportional to the length of the term (to prevent the weighted average being dominated by the longest term deposits).
- High-interest deposits include advertised at-call high-interest accounts (such as online savings accounts, bonus saver accounts, and cash management accounts), and the accounts of corporations, pension funds, and governments.
    - Advertised at-call high-interest account spreads are weighted average spreads between the advertised rates on these accounts and the cash rate, with weights depending on the volumes in the various account types.
    - For corporations, pension funds, and governments, we assume their transaction and savings accounts pay interest rates that move with rates in the markets for short-term bank debt securities (these are converted into spreads to OIS); as these securities are plausible substitutes for many of these institutions.
- No/low interest deposits include non-interest bearing deposits and the accounts of households and unincorporated enterprises not classified as at-call high-interest (these are assumed to pay a non-zero but low fixed rate). We assume banks hedge these deposits into a variable interest rate exposure by entering into 3 year fixed-for-floating swaps (this is known as a 'replicating portfolio' hedge); this variable rate is converted into a spread to OIS.[18]

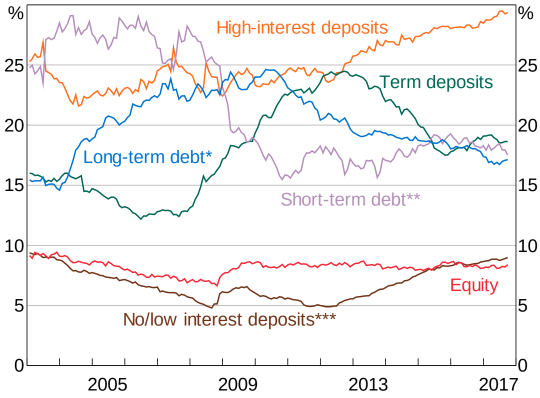
17 See APRA (2018b) for a breakdown of what banks report to APRA.

18 If the cash rate cycle is shorter than the length of the hedge, then the amplitude of the cycle in no/low interest spreads will be smaller after hedging, but the amplitude will not be zero (so this is only a partial hedge).

Graph 4

Major Banks' Funding Composition

Share of total funding; domestic books



* Issued domestically and offshore.

** Issued domestically and offshore. Includes deposits and intragroup funding from non-residents.

*** Excludes home loan offset accounts.

Sources: APRA; authors' calculations; RBA

4.2.2 Accuracy of the debt funding part of the model

This section evaluates how well the funding part of our model lines up with more aggregated data reported to APRA. This is important as our model calibration requires multiple assumptions about the maturity structure of the major banks' debt and that our interest rate data accurately reflect their costs of funding.

While the reported data may be more accurate than our model estimates, they likely also contain measurement error and do not provide a sufficiently rich breakdown for our purposes. For example, we need to know the share of no/low interest bearing deposits relative to other types of deposit accounts. None of the data used for comparison in this section was used to calibrate our model, so this is a true external validation exercise.

Graphs 5 and 6 compare quarterly average outstanding non-term and term deposit interest rates estimated from our model (the parts of our model requiring the most assumptions), to quarterly average interest rates reported to APRA by the banks. Our model provides a close approximation to the reported rates. Moreover, it is not just the broad trends that are matched, but the shape of the interest rate curves. These results give us confidence in the accuracy of our assumptions and calibration.

While the quarterly average rates reported by APRA provide the best comparison, we only have data from 2009. For a longer time series, we approximate quarterly average interest rates from the major banks' quarterly interest expense data reported to APRA.[19]

Graphs 7 and 8 are constructed on a 'licensed authorised deposit-taking institution (ADI)' basis, while our model and graphs 5 and 6 are based on Australian dollar deposits on the 'domestic book of the licensed ADI'; so we do not expect our model to align as closely in graphs 7 and 8 as they do in graphs 5 and 6. That said, our model closely approximates these licensed ADI estimates over the entire sample, providing further validation of our assumptions and calibration.[20]

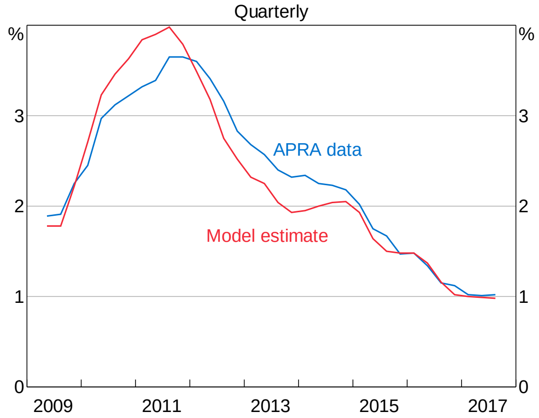
19 The APRA data in Graph 7 is constructed by taking the quarterly deposit expense, dividing it by the average deposit balance during the quarter, and annualising. Graph 8 is similarly constructed – dividing total interest expense by average interest-bearing liabilities during the quarter.

20 Even after extracting the cash rate, there is still a high correlation between the model estimates and the APRA data in graphs 7 and 8 (around 80 per cent). Moreover, regressing the APRA data on the model estimates (after removing the cash rate) produces a slope coefficient insignificantly different from one, and an intercept insignificantly different from zero.

Graph 5

Average Outstanding Non-term Deposit Rates*

Quarterly



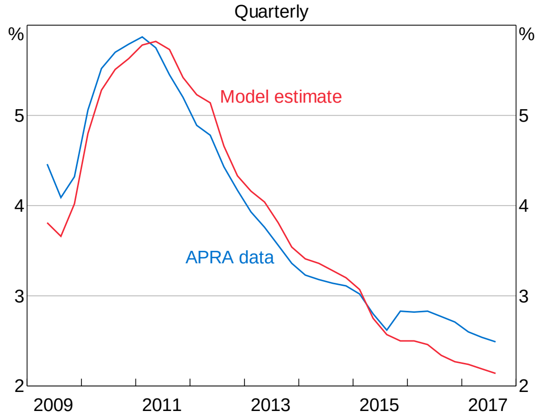
* Includes no/low interest deposits and high-interest accounts.

Sources: APRA; authors' calculations; RBA

Graph 6

Average Outstanding Term Deposit Rates

Quarterly

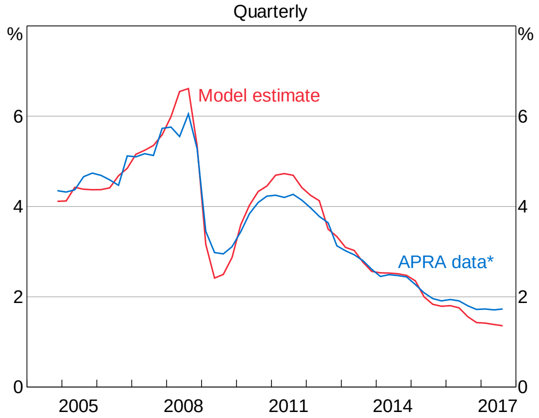


Sources: APRA; authors' calculations; RBA

Graph 7

Deposit Interest Cost

Quarterly



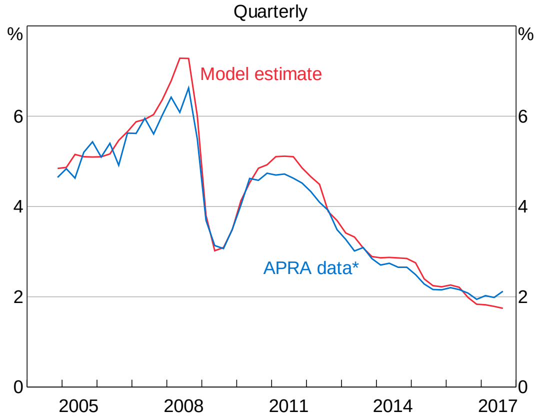
* Licensed ADI; from ARF 330.1.L

Sources: APRA; authors' calculations; RBA

Graph 8

Total Debt Funding Cost

Quarterly



* Licensed ADI; from ARF 330.1.L

Sources: APRA; authors' calculations; RBA

4.2.3 Wholesale funding assumptions

We assume the major banks' are price-takers in offshore wholesale debt markets.[21] This means that they are not sufficiently large issuers of debt that changes in their wholesale debt volumes change the price of debt in these markets (i.e. the debt supply curve faced by the banks is flat).[22] The small share of outstanding offshore debt that was issued by the major banks gives credence to this assumption; the major banks' outstanding offshore debt comprised less than 1 per cent of total global financial-corporation debt at the end of June 2017 (BIS 2017).

Since the major banks are able to tap both offshore and domestic markets, spreads in offshore debt markets provide an approximate upper bound for domestic market spreads. However, in normal times, the spreads in both markets are very close and the major banks issue in both markets. Therefore, the price-taker assumption in offshore markets typically means the banks' issuance volumes do not influence spreads in either domestic or offshore markets.

That said, there have been periods during which offshore spreads diverged from domestic spreads; the height of the global financial crisis is an example (Black, Brassil and Hack 2010). During these periods, the volume of banks'

21 Wholesale debt markets include the markets for bank bills, certificates of deposits, bonds, asset-backed securities, and hybrid securities.

22 This is an assumption about being able to move the market. This assumption does not cover a change in debt volumes sufficiently large to change the risk characteristics of the issuing bank.

debt issuance may have influenced domestic spreads. For example, the lower issuance by banks during the financial crisis may have caused domestic spreads to be lower than they would have been had banks continued to issue the same amount. As long as the change in issuance is not caused by a change in current or expected cash rates, the resulting change in spreads is not important for our analysis of monetary policy pass-through.

We further assume that the spreads between the major banks' debt and the risk-free rates in the various domestic and offshore markets do not depend on the levels of the risk-free rates. Instead, changes in these spreads are determined by changes in perceptions of risk (such as credit risk or liquidity risk). This assumption is consistent with numerous RBA publications that analyse the changes in these spreads and mention changes in risk as causal factors, not changes in the level of the risk-free rate (see Davies, Naughtin and Wong (2009), Black, Brassil and Hack (2010), and Berkelmans and Duong (2014), for example).

While changes in historical spreads may not be caused by changes in global risk-free rates, this need not always be the case. The 'search for yield' argument suggests that demand for riskier assets may cause spreads to shrink as risk-free rates fall. That said, as long as this 'search for yield' behaviour relates to global risk-free rates rather than the cash rate, the 'search for yield' behaviour will not bias our analysis.

Combined, these assumptions mean changes in monetary policy transmit one-for-one to the cost of the major banks' wholesale debt funding.

4.2.4 Direct effect of the cash rate on no/low interest deposits

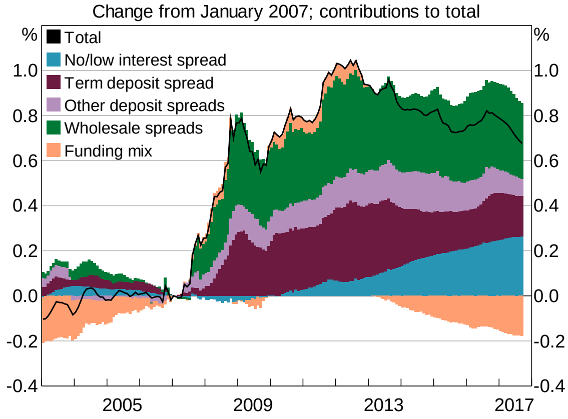
By paying a fixed interest rate in our model, the spreads on no/low interest deposits increase one-for-one as the cash rate falls. But these spread increases are assumed to be smoothed via a replicating portfolio hedge.

The large cash rate reductions following the onset of the financial crisis initially had only a small effect on the major banks' no/low interest spreads (due to the replicating portfolio), especially relative to their other sources of debt funding (Graph 9). Since then, the historically low level of the cash rate and the length of time it has remained at these low levels have increased the cost of these deposits relative to other sources of funding. The change in the no/low interest spread now contributes a similar amount to the increase in the major banks' debt funding spreads as wholesale funding; contributing 27 basis points to the major banks' debt funding spreads since 2007.

Graph 9

Changes in Major Banks' Debt Funding Spreads

Change from January 2007; contributions to total



Sources: APRA; ASX; authors' calculations; Bloomberg; Canstar; RBA; Tullett Prebon (Australia) Pty Ltd; UBS AG, Australia Branch

Since we model both the share of these deposits and the replicating portfolio hedge, we can use expectations of future cash rates to forecast how these no/low deposit spreads will develop in the future. Using estimates of market-expected future cash rates, and assuming these deposits remain at their current share of debt funding, we estimate that the contribution of no/low interest spreads will peak at 35 basis points in late 2020. The ability to model the timing of changes in funding costs, and to project how these changes will evolve, is an advantage of our framework over the existing research methodologies.

While no/low interest deposits currently make up a similar share of major banks' deposits as they did at the beginning of the inflation targeting period, they accounted for over half of their deposits in 1980 (Lowe 1995). As a result, changes in the cash rate would have had a larger impact on the major banks' funding spreads prior to the inflation targeting period.

4.2.5 Indirect effect of the cash rate on no/low interest deposits

If cash rate reductions also cause a substitution of depositors into these no/low deposits, this indirect effect may partially offset the direct effect estimated in the previous section. We are not able to provide a point estimate of the size of this indirect effect, but we can show that the upper bound of the indirect effect is likely small.

There is no evidence of substitution occurring between 2007 and 2013; the share of no/low deposits was broadly stable despite a large fall in the cash rate (and therefore increase no/low deposit spread). Conversely, the share of no/low interest deposits is estimated to have increased from 6 per cent to 9 per cent recently (Graph 4). To estimate an upper bound, we assume this increased share was completely due to the cash rate fall.

The indirect effect may include both an increase in the share of no/low deposits (which reduces funding costs) and an increase in the spreads on substitute deposits (e.g. term and high-interest deposits).[23] Under some mild assumptions, these indirect effects will be cost-reducing in total (see Appendix C for a detailed explanation). Therefore, we can produce an upper bound on the size of the indirect effects by running a counter-factual exercise in which all the spreads move as they do in the data, but the share of no/low deposits remains around 6 per cent (Appendix C explains this exercise in detail).[24] In this exercise, the funding mix component of the change in the major banks' debt funding spreads since 2007 would currently be -11 basis points (as opposed to the -18 basis points in Graph 9). So an upper bound for the offsetting indirect effects is 7 basis points.

The broadly constant share of no/low deposits between 2007 and 2013, but increasing share recently, is consistent with a non-linear supply curve for no/low interest deposits.[25] Identifying a non-linear supply curve is important for evaluating the total effect of any future cash rate reductions. As the share of no/low deposits increases, cash rate reductions have a larger direct effect. However, if the supply curve flattens, the indirect offset will also be larger. But this can only occur up to the point where most of the potential substitution has already occurred, after which the indirect offset would wane while the direct effect would be large. Unfortunately, it is not possible to know either the size of the indirect effects from any future cash rate reductions, nor the point at which these indirect effects will wane.

4.2.6 Effect of the cash rate on term deposit and at-call high-interest deposit spreads

In our model, term deposit spreads and spreads on at-call high-interest rate accounts have contributed to the increase in the major banks' funding costs since 2007 (Graph 9). In contrast to no/low interest accounts, changes in the cash rate are unlikely to be an important determinant of changes in term and high-interest spreads. Wholesale funding spreads and demand-side factors unrelated to the cash rate are the important determinants.

Prior to the crisis, spreads on these deposit accounts were broadly constant, despite an increasing cash rate (Graph 10). Once the crisis hit, spreads on new term deposits increased due to intense competition between banks for this source of funding (Davies, Naughtin and Wong 2009). As spreads on substitute sources of funding increased (i.e. wholesale spreads), banks vied for the cheaper sources of funding, pushing these spreads higher.

23 When there is substitution, an exogenous increase in the no/low deposit spread is expected to reduce the supply of substitute deposits (as depositors switch to the no/low deposits), thereby increasing the spread on these deposits and reducing their shares.

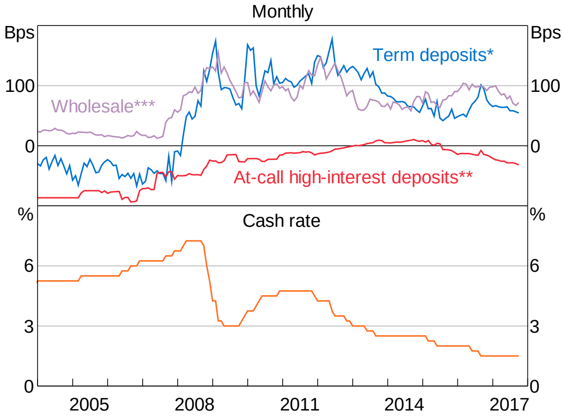
24 For the counter-factual exercise, we retain the reduction in the share of term deposits, but reallocate the increase in no/low deposits to high-interest deposit accounts.

25 It is possible that the usual difference between no/low interest spreads and spreads on other deposits is typically too large for small changes in these spreads to effect the supply of no/low deposits (i.e. the supply curve of the no/low share is typically vertical), but that depositors are more willing to keep funds in these accounts when the spread differential reaches a sufficiently low level.

Moreover, banks were likely to have re-assessed the virtues of short-term wholesale debt as a stable source of funding, adding to the pressure on deposit spreads. Competition initially focussed more on term deposits due to these being a reasonably stable source of funding that allows banks to offer higher interest rates without immediately re-pricing their existing deposits (Brown *et al* 2010).

While not as stable as term deposits, at-call high-interest accounts often have minimum monthly deposits or withdrawal limitations that make them a partial substitute, leading to increased competition for these deposits prior to 2016 (Berkelmans and Duong 2014). The release of APRA's Net Stable Funding Ratio proposal (in 2016) – classifying term deposits as a more stable source of funding than at-call high-interest deposits – led to renewed competition for term deposits relative to at-call high-interest accounts (Cheung 2017).

Graph 10
Major Banks' Spreads



* Weighted average of spreads between current special-offer rates and equivalent maturity OIS.

** Spread to cash rate; existing customers only; excludes temporary bonus rates.

*** Weighted average of short-term and new long-term debt spreads. Weighted by balance sheet shares.

Sources: APRA; ASX; authors' calculations; Bloomberg; Canstar; RBA; Tullett Prebon (Australia) Pty Ltd; UBS AG, Australia Branch

While the level of the cash rate is not typically cited as an explanatory factor for changes in these deposit spreads, it is still possible that changes in the cash rate have had a small effect (e.g. see Section 4.2.5). Crucially though, as discretionary components, for the cash rate to have affected these spreads they must have affected the constraints that bind their choices. We do not see the cash rate as affecting any of the demand-side constraints on term and high-interest deposits (risk considerations and regulations, for example). Therefore, any effect of the cash rate on term and high-interest deposits can only occur indirectly via changes in other spreads.

4.3 Non-loan Assets

As with the banks' wholesale debt funding, the trading and investment securities that banks hold likely have spreads that depend on changes in risk perception (e.g. credit and liquidity risk) rather than changes in the level of the cash rate.[26] Therefore, it is not surprising that the estimated spreads do not appear to be correlated with the cash rate, but instead have spreads exhibiting a similar pattern to the major banks' wholesale debt funding spreads (Graph 11).

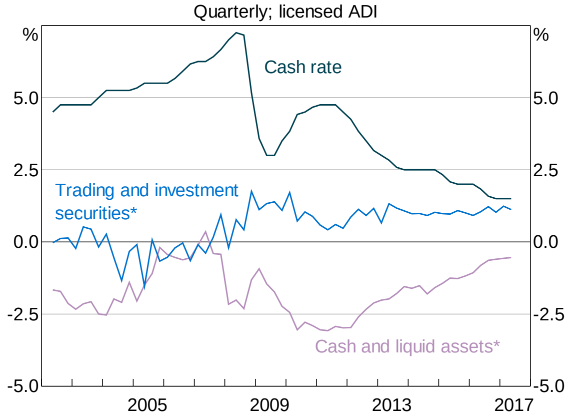
Conversely, several of the asset classes included in cash and liquid assets pay no interest. These include notes and coins, gold, and some receivables due from financial institutions. As a result, the interest spread on these assets rises as the cash rate falls.

26 We do not have a sufficient time series of the maturity structure or interest rates of non-loan assets. We can, however, estimate average interest rates from APRA data on the interest income during a quarter and the average value of the assets during the same quarter.

Since 2009, a negative relationship between the cash and liquid asset spread and the cash rate is evident in our estimates (Graph 11), but it is not evident beforehand. This post-2009 relationship suggests a 100 basis point reduction in the cash rate causes a 73 basis point increase in the spread.[27] At around 3 per cent of the major banks' assets, this translates to a 2 basis point increase in the major banks' interest spread per 100 basis point reduction in the cash rate.

Graph 11

Major Banks' Non-loan Interest Spreads



* Spread to cash. Interest rates constructed from ARF 330 quarterly income and average balances.

Sources: APRA; authors' calculations

4.4 Non-interest Income and Expenses

Banks gain non-interest income through, for example, trading securities, foreign exchange transactions, and by charging their customers fees and commissions for various activities. They also have non-interest expenses such as personnel, occupancy, equipment, IT, and tax.

As a share of assets, the major banks' net non-interest income, while volatile, has had a broadly stable average since 2004 (Graph 12). Underlying this has been a downward trend in both the ratio of banks' fees to assets (Fitzpatrick and White 2017), and improvements in operational efficiencies (RBA 2014).

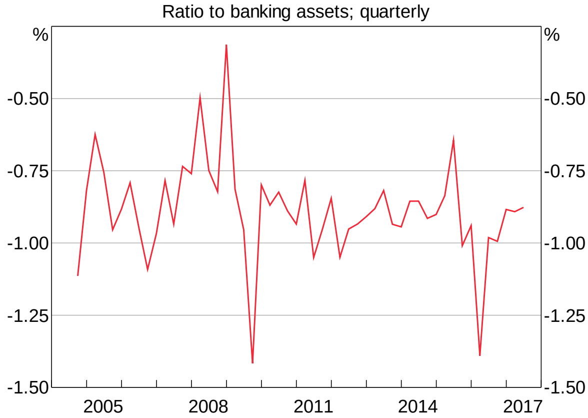
During our sample, there is no evidence of a relationship between the cash rate and the major banks' net non-interest income. Therefore, we focus only on the major banks' interest income and interest expenses in the remainder of this paper.

27 Despite the increasing spread, there is no evidence of the major banks shifting their asset mix towards these cash and liquid assets. Regressing the share of these assets on the cash rate produces an R^2 of just 5 per cent.

Graph 12

Major Banks' Net Non-interest Income*

Ratio to banking assets; quarterly



* Non-interest income minus non-interest expenses, goodwill amortisation, income tax and minority interests, from both continuing and discontinued operations; consolidated group; from APRA's Quarterly ADI Performance Statistics.

Sources: APRA; authors' calculations

4.5 Summary of Non-discretionary Pass-through

To summarise our results so far, we find:

- Cash rate reductions since 2007 are estimated to have increased the major banks' funding spread (via no/low deposits) by 4-6 basis points per 100 basis point cash rate reduction, with this effect increasing to 6-7 basis points in 2020 as the replicating portfolio rolls over.[28]
- The major banks' provisions for potential future losses have a positive relationship with the cash rate. We estimate that a 100 basis point reduction in the cash rate reduces net provisioning rates by 7 basis points.
- The major banks' cash and liquid asset spread has a negative relationship with the cash rate, consistent with several of the assets within this category not paying interest. However, this asset category makes up just 3 per cent of the major banks' balance sheets, so we estimate that, via this channel, the major banks' income spread increases by 2 basis points per 100 basis point reduction in the cash rate.
- These effects have been broadly offsetting since 2007, such that changes in the cash rate have passed-through approximately one-for-one to the non-discretionary components of the major banks' balance sheets.

5. Return on Equity and Aggregate Pass-through

In this section we assess cash rate pass-through to the major banks' return on equity (ROE). Since we find pass-through to the non-discretionary components is approximately one-for-one, full pass-through to discretionary lending and deposit rates requires the ROE to also move one-for-one with the cash rate.

Importantly, we make no claim as to whether banks' ROE *should* move with the cash rate. What we evaluate here is an identity: if ROE does not move with the cash rate, then an offsetting part of the balance sheet must also not move with the cash rate.

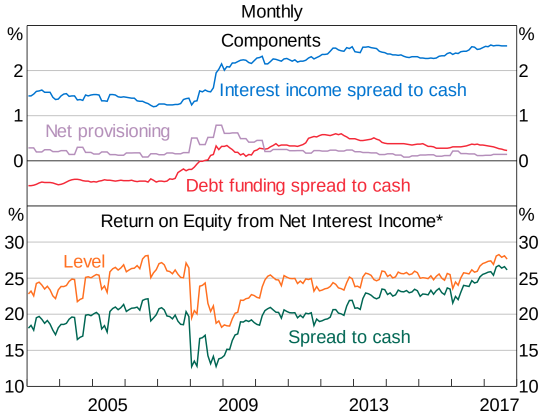
Assessing the *level* of ROE is also beyond the scope of this paper. There are many other factors that influence the level of ROE (see Lowe (1995) and ACCC (2018), for discussions); all we seek to determine is whether ROE moves with the cash rate over time.

28 The lower bounds on the ranges account for the possible indirect effects estimated in Section 4.2.5.

To more-accurately determine whether the major banks' ROE has moved with the cash rate, we extract volatile components of the balance sheet that we determined do not move with the cash rate. Specifically, we remove net non-interest income (Section 4.4) to get a measure of return on equity from net interest income (ROE-NII).[29] Importantly, while the level of ROE-NII will differ from the level of ROE, due to the lack of correlation between net non-interest income and the cash rate, any correlation between the cash rate and ROE must also be present in the correlation between the cash rate and ROE-NII.

Our estimates suggest that the major banks' ROE has not moved with the cash rate since 2007. By the end of 2015, the major banks' ROE-NII was around the same level as prior to the crisis, despite a 475 basis point fall in the cash rate (Graph 13).[30] The implication of this is that aggregate pass-through to lending and deposit rates has been less than one-for-one.

Graph 13
Return on Equity from Net Interest Income
Monthly



* Interest income (loan and non-loan assets) minus net provisioning and interest expenses, all divided by equity.

Sources: APRA; ASX; authors' calculations; Bloomberg; Canstar; RBA; Tullett Prebon (Australia) Pty Ltd; UBS AG, Australia Branch

We cannot determine how this absence of ROE pass-through is distributed across the banks' lending and deposit rates. But we can use our model to provide some scenarios. Denoting the set of discretionary lending and deposit rates as D, then from Equation (2), when there is no pass-through to ROE, the change in these discretionary rates must satisfy the following equality:

$$\frac{1}{1-\sum_j \alpha_j}\left[\sum_{i\in D}\beta_i\frac{d(r_{A,i}-r_C)}{dr_C}+\sum_{j\in D}\alpha_j\left(-\frac{d(r_{L,j}-r_C)}{dr_C}\right)\right]=-1 \tag{3}$$

If the absence of pass-through from the cash rate to ROE was spread evenly across the banks' discretionary lending and deposit rates, the absolute value of the derivatives in Equation (3) would all be equal. Then, using the 2017 calibrations for α_j and β_i, for every 100 basis point reduction in the cash rate, lending rates would be 7 basis points higher than full pass-through and discretionary deposit rates would be 7 basis points lower.

If the absence of ROE pass-through was offset by lending rates alone, lending rates would be 11 basis points higher than full pass-through (per 100 basis point cash rate reduction). If the absence of pass-through was offset by discretionary deposits alone, these deposit rates would be 20 basis points lower than full pass-through. These figures would be larger if the absence of ROE pass-through was only offset by a subset of loans or deposits.

29 ROE-NII is defined as 'interest income' minus 'net provisioning' and 'interest expenses', all divided by equity. Constructing this measure requires us to calibrate the shares and spreads of the loan assets in our model. See Appendix D for details about our calibration and for an assessment of model accuracy.

30 We limit our analysis to 2015 because recent regulatory changes to investor and interest-only loans, and the possibility that the major banks are using recent interest income to offset the fall in net non-interest income during 2016 (Graph 12), obscure the relationship between the cash rate and ROE (see ACCC (2018) for a discussion of banks' price setting behaviour during this period).

This absence of ROE pass-through suggests the major banks have a preference for maintaining a specific level of ROE, rather than an ROE spread; and is consistent with some banks historically maintaining ROE-level targets that have not varied with the cash rate (see Norman (2017), RBA (2016a), RBA (2016b) and Fabbro and Hack (2011), for further discussion of banks' ROE targets).

The question remains as to why the major banks have this preference. From the Dividend Discount Model (see Norman (2017) for example), a constant ROE reduces the correlation between a bank's share price and the cash rate (relative to full pass-through).[31] To the extent that equity investors desire this reduced correlation, increasing pass-through to ROE may increase this bank's future cost of equity (by increasing the equity premium), thereby increasing future average prices for the bank's customers. Determining whether bank customers would prefer lower average prices or more complete pass-through is beyond the scope of this paper.

6. Conclusions and Policy Implications

In this paper, we have constructed a detailed model of banks' balance sheets and have used the model to determine the pass-through of monetary policy to the major banks' lending and deposit rates. This method of determining pass-through is a novel approach in the literature, and is preferred over existing approaches because our approach:

- can more-credibly identify the true response to changes in monetary policy (e.g. we more effectively control for changes in banks' funding markets, properly account for changes in cash rate expectations, and our analysis will not be influenced by unobserved changes in banks' pricing decisions);
- does not make the problematic assumption that interest rates are non-stationary and cointegrated; and
- does not rely on panel models that would require the brave assumption that we had completely controlled for the differences between the major banks and other banks.

Moreover, our novel approach allows each balance sheet component to be separately modelled, thereby identifying any offsetting effects, differing pass-through speeds, and non-linearities.

While we find that pass-through differs across components, for the non-discretionary components, the deviations from full pass-through have been broadly offsetting since 2007. This is mostly due to the negative relationship between the cash rate and the no/low deposit spread being broadly offset by the positive relationship between the cash rate and provisioning.

Conversely, the major banks' return on equity has not moved with the cash rate. As a result, aggregate pass-through to lending and deposit rates has been less than one-for-one. If this diminished pass-through were spread evenly across lending and deposit rates, the deviation from full pass-through would be 7 basis points for every 100 basis point change in the cash rate.

We also identify multiple non-linearities that may have affected recent pass-through and may become even more important if the cash rate were to be reduced further:

- The replicating portfolio hedge delays the pass-through of cash rate changes to funding costs and can provide a partial hedge if the cash rate cycle is shorter than the length of the hedge.
- At low interest rates, the difference between the rate on no/low interest deposits and the rate on other deposits may be sufficiently small that cash rate reductions entice people to substitute into no/low interest deposits, offsetting the effect of the increasing no/low deposit spread. But this substitution has a

31 This is a theoretical argument about how changes in pass-through (over the full cash rate cycle) affect the correlation between banks' share prices and the cash rate. Importantly, increases in equity premia, even if they occur at the same time as cash rate reductions, need not prevent pass-through to ROE, as the share price would move to compensate (Davis (2012) provides an in-depth discussion of the relationship between banks' cost of equity, return on equity, and share price).

limit, beyond which any cash rate reductions will have a bigger impact on funding costs due to the larger share of no/low deposits.

- Net Provisioning rates can only be negative if previously provisioned losses are no longer in danger of being realised. Therefore, the benefit of lower interest rates is likely to weaken as net provisioning rates approach zero.

In addition to most of the cash rate changes since 2007 being passed through to lending and deposit rates, they have passed through quickly, with over 80 per cent of the major banks' assets repricing in less than 3 months. This differs from other banking systems, such as the US (where three-quarters of housing loans are at long-term fixed rates), the UK (where around half of housing loans are at rates fixed for 1-5 years), and Canada (where three-quarters of housing loans are at fixed rates, mostly for 5 years) (RBA 2009b). As a result, the cash flow channel of monetary policy likely works quicker in Australia than in jurisdictions with slower pass-through.

The features of our banking system also have a number of financial stability implications. First, with hedged interest rate risk, the Australian major banks are not subject to the same counter-cyclical profitability as banks that don't hedge their interest rate risk (i.e. profits don't fall as interest rates rise due to the repricing mismatch between assets and liabilities). Therefore, the friction that leads to attenuated pass-through in many theoretical models (see Section 2) is much weaker for the major Australian banks. That said, this means that hedging markets are important for the Australian banking system.

Second, decreasing the cash rate reduces both the expected number of loan defaults and the expected loss given default. Moreover, with full pass-through to the non-discretionary components of the major banks' balance sheets, their desire to 'search for yield' should be lower (Dell'Ariccia, Laeven and Marquez 2014). Therefore, we do not expect the cash rate reductions since 2007 to have increased the major banks' desire for risk (a concern in other jurisdictions, see Wang (2017) for example).

That said, the potential non-linearities we identify may mean that the effect of any further increase in the no/low deposit spread (from a cash rate reduction) may outweigh the offsetting net provisioning effect. At which point, pass-through may fall beyond the level identified since 2007, banks' desire for risk may increase, and/or their profitability may fall.

References

ACCC (2018), ‘Residential mortgage price inquiry - interim report’. Available at <https://www.accc.gov.au/about-us/inquiries/residential-mortgage-products-price-inquiry/interim-report>.

Alessandri P and BD Nelson (2015), ‘Simple Banking: Profitability and the Yield Curve’, *Journal of Money, Credit and Banking*, 47(1).

Altavilla C, M Boucinha and J-L Peydró (2017), ‘Monetary policy and bank profitability in a low interest rate environment’, *ECB Working Paper Series*.

Andreasen MM, M Ferman and P Zabczyk (2013), ‘The business cycle implications of banks’ maturity transformation’, *Review of Economic Dynamics*, 16(4), pp 581–600.

Andries N and S Billon (2016), ‘Retail bank interest rate pass-through in the euro area: An empirical survey’, *Economic Systems*, 40, pp 170–194.

Angeloni I and M Ehrmann (2003), ‘Monetary Transmission Evidence’, *Economic Policy*, 18(37), pp 469–501.

Apergis N and A Cooray (2015), ‘Asymmetric interest rate pass-through in the U.S., the U.K. and Australia: New evidence from selected individual banks’, *Journal of Macroeconomics*, 45, pp 155–172.

APRA (2018a), ‘Quarterly ADI Property Exposures statistics’. Available at <http://www.apra.gov.au/adi/Publications/Pages/Quarterly-ADI-Property-Exposures-statistics.aspx>.

APRA (2018b), ‘ARF_320_0: Statement of Financial Position (Domestic Books)’. Available at <http://www.apra.gov.au/sbr-pet/ARF/ARF_320_0-D2A2.html>.

Aristei D and M Gallo (2014), ‘Interest rate pass-through in the Euro area during the financial crisis: A multivariate regime-switching approach’, *Journal of Policy Modeling*, 36, pp 273–295.

Atkin T and G La Cava (2017), ‘The Transmission of Monetary Policy: How Does It Work?’, *RBA Bulletin*, September.

Baker A and D Jacobs (2010), ‘Domestic Market Operations and Liquidity Forecasting’, *RBA Bulletin*, December.

Bech ML and A Malkhozov (2016), ‘How have central banks implemented negative policy rates?’, *BIS Quarterly Review*, March.

Begenau J, M Piazzesi and M Schneider (2015), ‘Banks’ Risk Exposures’, *NBER Working Paper Series*, 21334.

Berkelmans L and A Duong (2014), ‘Developments in Banks’ Funding Costs and Lending Rates’, RBA *Bulletin*, March, pp 69–75.

BIS (2017), ‘Debt Securities Statistics’. Available at <https://www.bis.org/statistics/secstats.htm>.

Black S, A Brassil and M Hack (2010), ‘Recent Trends in Australian Banks’ Bond Issuance’, *RBA Bulletin*, March.

Borio C, L Gambacorta and B Hofmann (2015), ‘The Influence of Monetary Policy on Bank Profitability’, *BIS Working Papers*.

Borio CEV and W Fritz (1995), ‘The Response of Short-term Bank Lending Rates to Policy Rates: A Cross-country Perspective’, *BIS Working Paper*, 27.

Brown A, M Davies, D Fabbro and T Hanrick (2010), ‘Recent Developments in Banks’ Funding Costs and Lending Rates’, *RBA Bulletin*, March.

Brunnermeier MK and Y Koby (2017), ‘The “Reversal Interest Rate”: An Effective Lower Bound on Monetary Policy’, *mimeo*.

Cheung B (2017), ‘Developments in Banks’ Funding Costs and Lending Rates’, RBA *Bulletin*, March, pp 45–50.

Claessens S, N Coleman and MS Donnelly (2017), ‘"Low-For-Long" Interest Rates and Banks’ Interest Margins and Profitability: Cross-Country Evidence’, *Board of Governors of the Federal Reserve System - International Finance Discussion Papers*, 1197.

Cœuré B (2012), ‘Central banks and the challenges of the zero lower bound - Speech at University of Chicago Booth School of Business’. Available at <http://www.ecb.europa.eu/press/key/date/2012/html/sp120219.en.html>.

Cook B and D Steenkamp (2018), ‘Funding cost pass-through to mortgage rates’, *Reserve Bank of New Zealand Analytical Note Series*, AN2018/02.

Darracq Paries M, DN Moccero, E Krylova and C Marchini (2014), ‘The retail bank interest rate pass-through: the case of the euro area during the financial and sovereign debt crisis’, *ECB Occasional Paper Series*, 155.

Davies M, C Naughtin and A Wong (2009), 'The Impact of the Capital Market Turbulence on Banks' Funding Markets', *RBA Bulletin*, June.

Davis K (2012), 'Bakning Profitability, Bank Capital and Competition', *Australian Centre for Financial Studies Financial Regulation Discussion Paper*, FRDP 2012-1.

de Bondt GJ (2005), 'Interest Rate Pass-Through: Empirical Results for the Euro Area', *German Economic Review*, 6(1), pp 37–78.

Debelle G (2012), 'Address to the Australian DCM Summit 2012 - Bank Funding'. Available at <https://www.rba.gov.au/speeches/2012/sp-ag-220312.html>.

Dell'Ariccia G, L Laeven and R Marquez (2014), 'Real interest rates, leverage, and bank risk-taking', *Journal of Economic Theory*, 149, pp 65–99.

Deloitte Access Economics (2014), 'Competition in Retail Banking'. Available at <https://www2.deloitte.com/content/dam/Deloitte/au/Documents/Economics/deloitte-au-economics-retail-banking-competition-010314.pdf>.

Eggertsson GB, RE Juelsrud and EG Wold (2017), 'Are Negative Nominal Interest Rates Expansionary?', *NBER Working Paper Series*, 24039.

Fabbro D and M Hack (2011), 'The Effects of Funding Costs and Risk on Banks' Lending Rates', *RBA Bulletin*, March.

Finlay R and M Chambers (2008), 'A Term Structure Decomposition of the Australian Yield Curve', *RBA Research Discussion Paper*.

Fitzpatrick R and G White (2017), 'Banking Fees in Australia', RBA *Bulletin*, June, pp 35–40.

Gambacorta L (2008), 'How do banks set interest rates?', *European Economic Review*, 52, pp 792–819.

Gerali A, S Neri, L Sessa and FM Signoretti (2010), 'Credit and Banking in a DSGE Model of the Euro Area', *Journal of Money, Credit and Banking*, 42.

Gishkariany M, D Norman and T Rosewall (2017), 'Shadow Bank Lending to the Residential Property Market', *RBA Bulletin*, September.

Gizycki M and B Gray (1994), 'Default Risk and Derivatives: An Empirical Analysis of Bilateral Netting', *RBA Research Discussion Paper*, 9409.

Hoffmann P, S Langfield and F Pierobon (2017), 'Who bears interest rate risk?', *mimeo*.

Horvath R, J Kotlebova and M Siranova (2018), 'Interest rate pass-through in the euro area: Financial fragmentation, balance sheet policies and negative rates', *Journal of Financial Stability*, 36, pp 12–21.

Hristov N, O Hülsewig and T Wollmershäuser (2014), 'The interest rate pass-through in the Euro area during the global financial crisis', *Journal of Banking & Finance*, 48, pp 104–119.

La Cava G, H Hughson and G Kaplan (2016), 'The Household Cash Flow Channel of Monetary Policy', RBA Research Discussion Paper No 2016-12.

Lowe P (1995), 'The Link Between the Cash Rate and Market Interest Rates', *RBA Research Discussion Paper*.

Lowe P (2012), 'Remarks to the 41st Australian Conference of Economists - Bank Regulation and the Future of Banking'. Available at <https://www.rba.gov.au/speeches/2012/sp-dg-110712.html>.

Maddala GS and I-M Kim (1998), *Unit roots, cointegration and structural change*, Cambridge University Press.

McCririck R and D Rees (2017), 'The Neutral Interest Rate', *RBA Bulletin*, September.

McKinnon T (2018), 'Developments in Banks' Funding Costs and Lending Rates', *RBA Bulletin*, March.

Norman D (2017), 'Return on Equity, Cost of Equity and the Implications for Banks', RBA *Bulletin*, March, pp 51–58.

RBA (2009a), 'Box A: Banks' Provisioning', *Financial Stability Review*, pp 39–41.

RBA (2009b), 'Box B: An International Comparison of Pass-through of Policy Rate Changes to Housing Loan Rates', *Statement of Monetary Policy*, February.

RBA (2014), ‘Box B: Australian Major Banks’ Cost-to-income Ratios’, *Financial Stability Review*, September, pp 35–38.

RBA (2014), ‘Submission to the Financial System Inquiry’. Available at <https://www.rba.gov.au/publications/submissions/financial-sector/financial-system-inquiry-2014-03/>.

RBA (2016a), ‘Financial Stability Review - April’. Available at <https://www.rba.gov.au/publications/fsr/2016/apr/>.

RBA (2016b), ‘Box C: Recent Developments in Australian Banks’ Capital Position and Return on Equity’, *Financial Stability Review*, October, pp 40–43.

Rodgers D (2015), ‘Credit Losses at Australian Banks: 1980–2013’, RBA Research Discussion Paper No 2015-06.

Rogoff K (2017), ‘Dealing with Monetary Paralysis at the Zero Bound’, *Journal of Economic Perspectives*, 31(3), pp 47–66.

Simon J (2015), ‘Low Interest Rate Environments and Risk’, Paul Woolley Centre for the Study of Capital Market Dysfunctionality Conference, Sydney, 8 October.

Van den Heuvel SJ (2007), ‘The Bank Capital Channel of Monetary Policy’, *mimeo*.

von Borstel J, S Eickmeier and L Krippner (2016), ‘The interest rate pass-through in the euro area during the sovereign debt crisis’, *Journal of International Money and Finance*, 68, pp 386–402.

Wang JC (2017), ‘Banks’s Search for Yield in the Low Interest Rate Enviroment: A Tale of Regulatory Adaptation’, *Federal Reserve Bank of Boston Working Paper*, 17-3.

Wheelock DC (2011), ‘Banking Industry Consolidation and Market Structure: Impact of the Financial Crisis and Recession’, *Federal Reserve Bank of St. Louis Review*, November/December.

World Bank (2017), ‘Global Financial Development Database ’. Available at <http://www.worldbank.org/en/publication/gfdr/data/global-financial-development-database>.

Appendix A – The Impact of Hedging on the Model

This appendix explains why, for any hedged interest rate risk or for assets and liabilities with the same repricing term, we can replace the spreads to cash rate with spreads to the relevant reference rates and the Equation (2) equality will still hold.

Re-producing Equation (2) without the non-interest incomes/expenses or provisions (as these are not hedged), gives:

$$(r_E - r_C)\left(1 - \sum_j \alpha_j\right) = \sum_i (r_{A,i} - r_C)\beta_i - \sum_j (r_{L,j} - r_C)\alpha_j$$

Now suppose we group the assets and liabilities into their various repricing terms (where S_t is the set of assets and liabilities with pre-hedging repricing term t) and re-write the right-hand-side as spreads of the bank interest rates to the reference rates for each repricing term (r_t):

$$(r_E - r_C)\left(1 - \sum_j \alpha_j\right) = \sum_t \left\{ \sum_{i \in S_t} (r_{A,i} - r_t)\beta_i - \sum_{j \in S_t} (r_{L,j} - r_t)\alpha_j + \sum_{i \in S_t} (r_t - r_C)\beta_i - \sum_{j \in S_t} (r_t - r_C)\alpha_j \right\} \quad \text{(A1)}$$

Now suppose the bank enters into derivative contracts for some assets and liabilities such that their interest rates are hedged to some other term (term s). For each asset in Equation (A1), we need to add a derivative that pays r_t and receives r_s; and for each liability, we need to add a derivative that pays r_s and receives r_t. Let the subset of each S_t that is hedged into term s be $S_{t,s}$ (assets and liabilities that are not hedged belong to the subset $S_{t,t}$), then with the derivatives Equation (A1) becomes:

$$\begin{aligned}(r_E - r_C)\left(1 - \sum_j \alpha_j\right) \\ = \sum_t \Bigg\{ & \sum_{i \in S_t} (r_{A,i} - r_t)\beta_i - \sum_{j \in S_t} (r_{L,j} - r_t)\alpha_j + \sum_{i \in S_t} (r_t - r_C)\beta_i - \sum_{j \in S_t} (r_t - r_C)\alpha_j \\ & + \sum_s \left\{ \sum_{i \in S_{t,s}} (r_s - r_t)\beta_i + \sum_{j \in S_{t,s}} (r_t - r_s)\alpha_j \right\} \Bigg\}\end{aligned}$$

The above equation can be simplified by re-grouping the last four sums into their post-hedging terms:

$$(r_E - r_C)\left(1 - \sum_j \alpha_j\right) = \sum_t \left\{ \sum_{i \in S_t} (r_{A,i} - r_t)\beta_i - \sum_{j \in S_t} (r_{L,j} - r_t)\alpha_j + (r_t - r_C) \sum_s \left\{ \sum_{i \in S_{s,t}} \beta_i - \sum_{j \in S_{s,t}} \alpha_j \right\} \right\} \quad \text{(A2)}$$

Equation A2 produces our results. Assets and liabilities with the same post-hedging repricing term (t) will belong to one of the $S_{s,t}$ subsets. Therefore, the sum $\sum_s \{\sum_{i \in S_{s,t}} \beta_i - \sum_{j \in S_{s,t}} \alpha_j\}$ measures the extent of hedging. If interest rate risk for repricing term t is completely hedged (i.e. the value of assets with post-hedging repricing term of t equals the value of liabilities with the same post-hedging repricing term), then $\sum_s \{\sum_{i \in S_{s,t}} \beta_i - \sum_{j \in S_{s,t}} \alpha_j\} = 0$. **Therefore, for hedged assets and liabilities, we can replace the spreads to cash rate with spreads to the relevant reference rates and the Equation (2) equality will still hold.**

Since the value of assets is greater than the value of liabilities, there will be some assets with post-hedging repricing terms that are not offset by liabilities. Therefore, even if all liabilities are hedged (as is shown in Graph 2), replacing the spreads to cash of all assets and liabilities in Equation (2) with spreads to reference rates will introduce a new term into Equation (2). This new term will equal:

$$\sum_t \left\{ (r_t - r_C) \sum_s \left\{ \sum_{i \in S_{s,t}} \beta_i - \sum_{j \in S_{s,t}} \alpha_j \right\} \right\}$$

With all liabilities hedged, $\sum_s\{\sum_{i\in S_{s,t}}\beta_i - \sum_{j\in S_{s,t}}\alpha_j\} > 0$ for all t. Moreover, $\sum_t\sum_s\{\sum_{i\in S_{s,t}}\beta_i - \sum_{j\in S_{s,t}}\alpha_j\} = 1 - \sum_j \alpha_j$. So, if we divide this new term by $\left(1-\sum_j \alpha_j\right)$, it becomes a weighted average of spreads between reference rates (r_t) and the cash rate (r_C), with weights equal to the post-hedging net position of each term. If we let the proportional post-hedging net position of each repricing term be represented by $V_t \equiv \frac{\sum_s\{\sum_{i\in S_{s,t}}\beta_i - \sum_{j\in S_{s,t}}\alpha_j\}}{1-\sum_j \alpha_j}$, then Equation (2) becomes (we have excluded non-interest incomes/expenses and provisions for simplicity):

$$\left(r_E - \sum_t r_t V_t\right)\left(1-\sum_j \alpha_j\right) = \sum_t \left\{\sum_{i\in S_t}(r_{A,i}-r_t)\beta_i - \sum_{j\in S_t}(r_{L,j}-r_t)\alpha_j\right\}$$

Therefore, our analysis of the return on equity spread should not look at the spread to cash, but should look at the return on equity spread to a weighted average of reference rates (with the weights determined by the post-hedging repricing term structure of the major banks' balance sheets). This replacement is not necessary in this paper since we add an additional margin to all spreads to convert them into hedged spreads to current/expected cash rates, and we only evaluate the long-run relationship between the return on equity and the cash rate (so different repricing terms do not matter).

Appendix B – Principal Component Analysis

Table A1: Principal Component Variable List and Sources

Quarterly

Variable	Detail	Source
Real GDP	Annual, year-ended growth	RBA Statistical Table H1
Real GDP Forecast	One-year ahead, annual, year-ended growth	RBA Forecast
CPI Inflation	Year-ended	RBA Statistical Table G1
CPI Inflation Forecast	One-year ahead, year-ended	RBA Forecast
Unemployment Rate	End of quarter	RBA Statistical Table H5
Unemployment Rate Forecast	One-year ahead	RBA Forecast
Business Credit	Nominal, year-ended growth	RBA Statistical Table D1
Housing Credit	Nominal, year-ended growth	RBA Statistical Table D1
Personal Credit	Nominal, year-ended growth	RBA Statistical Table D1
Business Profits[(a)]	Nominal, year-ended growth	ABS
Household Disposable Income[(b)]	Real, annual, year-ended growth	ABS/RBA
Established House Price Index	Year-ended growth	ABS
Terms of Trade	Year-ended growth	RBA Statistical Table H1
ASX 200 Option-implied Volatility[(c)]	Quarter average	Thomson Reuters

Notes: (a) Gross operating surplus and gross mixed income.
(b) Excluding unincorporated businesses, after tax and before deductions for interest payments.
(c) Implied volatility from at-the-money ASX SPI call options used before 2008. ASXVIX data used after 2008.

To parsimoniously incorporate information from a large number of variables, we use a common dimensionality reduction technique known as principal components analysis. In short, out of all possible linear combinations of the variables, the first principal component (PC) is the linear combination with the largest variance.[32] The second PC then has the largest variance conditional on the linear combination being orthogonal to the first linear combination. And so on. Ideally, as a result of this process we can construct a small number of variables that contain the majority of the explanatory power contained within the array of original variables. We find that the first two PCs contain 57 per cent of the variation contained within our collection of variables.

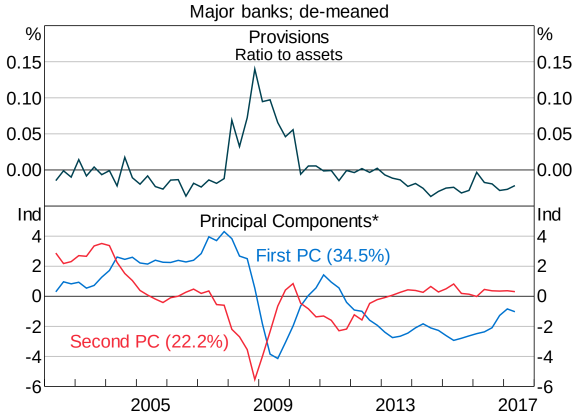
Graph B1 shows the time series of the first two PCs (also known as the 'scores'). From our regression results, after controlling for the cash rate and the yield curve, both PCs have a negative relationship with provisions. Graph B2 shows each underlying variable's 'loading' with respect to each PC (to construct each principal component, each underlying variable is multiplied by a *loading*, these products are then summed). In this graph, the scores are normalised such that the loadings are the correlations between the underlying variables and each PC.

The unemployment rate and its forecast have a strong negative correlation with the first PC, while the credit and income variables have a strong positive correlation.[33] Therefore, the negative relationship between the first PC and provisions is expected. The second PC has a strong negative relationship with the equity volatility index and a strong positive relationship with house prices and household credit, consistent with the second PC's estimated negative relationship with provisions. However, the positive relationship between unemployment and the second PC, and the negative relationship between inflation forecasts and the second PC, are difficult to explain.

Graph B1

Provisions and Principal Components

Major banks; de-meaned



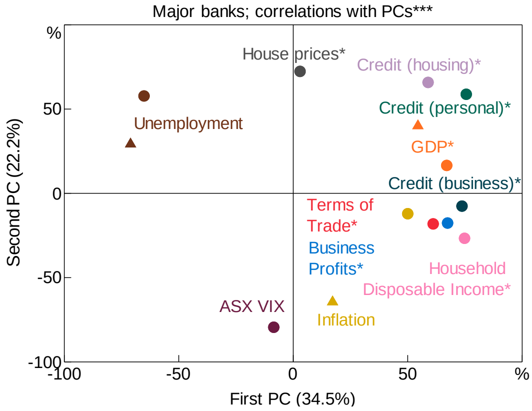
* First two principal components of macro variables (GDP growth, inflation, unemployment, RBA forecasts, credit growth, house price growth, business profits, household disposable income, terms of trade, ASX VIX). Constructed from correlation matrix of macro variables and with loadings normalised to have unit length. Numbers in parentheses are the proportions of variation explained by each principal component.

Sources: ABS; APRA; authors' calculations; RBA

Graph B2

Principal Component Loadings**

Major banks; correlations with PCs***



* Year-ended growth.

** Circles are outcomes, triangles are forecasts.

*** First two principal components (PCs) constructed from correlation matrix. Scores are normalised to have unit length, so loadings equal the correlation between each variable and the relevant PC. Numbers in parentheses are the proportions of variation explained by each PC.

Sources: ABS; APRA; authors' calculations; RBA

One potential problem with using PCs in a regression with other variables (the cash rate and yield curve in our case) is that these other variables could be correlated with the excluded PCs (we only include the first two, out of 14 PCs), in which case the estimated relationship between the cash rate and provisions may be picking up the relationship between the excluded PCs and provisions rather than the true relationship between the cash rate and provisions (i.e. there may be omitted variable bias).

32 More accurately, our method normalises each variable by its standard deviation before conducting the PCA. So the first principal component maximises the normalised variance.

33 The interpretation here is that falling credit growth signals poor macroeconomic conditions and/or a reduced ability of borrowers to refinance, which then causes provisions to rise. Alternatively, higher credit growth could reduce provisions to the extent that new borrowers are of higher credit quality than the existing stock of loans (Borio, Gambacorta and Hofmann 2015). However, another possibility is that higher provisions reduce profitability, causing banks to pull back on lending (i.e. reverse causality).

To evaluate the potential extent of this problem, we regress the cash rate on all excluded PCs. By construction, no other linear combination could reduce the unexplained portion of the cash rate (i.e. the squared residuals are minimised). Therefore, the R^2 from this regression can be interpreted as the maximum possible (squared) correlation between the cash rate and the information omitted by only using the first two PCs. We find an R^2 of 0.16 and that it is insignificantly different from zero. So we conclude that the estimated relationship between the cash rate and provisions is not just picking up the relationship between provisions and the omitted macro variables.

Appendix C – The Envelope Theorem as it relates to Cost of Funding

Suppose each bank is subject to a cost function $f(\boldsymbol{x}, \boldsymbol{a})$, where the vector $\boldsymbol{x}$ contains the bank's discretionary variables and the vector $\boldsymbol{a}$ contains the banks non-discretionary variables. And that each bank, as a profit maximiser, wants to minimise this cost function subject to a vector of constraints $\boldsymbol{g}(\boldsymbol{x}, \boldsymbol{a}) \geq 0$.

Let the constrained optimum values of $\boldsymbol{x}$ be $\boldsymbol{x}^*(\boldsymbol{a})$ (i.e. the optimum values are a function of the non-discretionary variables) and let the Lagrange multipliers at the optimum point be $\boldsymbol{\lambda}^*(\boldsymbol{a})$. And suppose we put these optimum values back into the cost function to get the constrained optimum value of the cost function: $f(\boldsymbol{x}^*(\boldsymbol{a}), \boldsymbol{a})$.

The Envelope Theorem states that, assuming the cost function and constraints are continuously differentiable, then the total derivative of the optimised cost function with respect to the non-discretionary variables ($\boldsymbol{a}$) is equal to the partial derivatives of the Lagrangian with respect to $\boldsymbol{a}$. In other words, to a first-order approximation, we can ignore the effect changes in $\boldsymbol{a}$ have on $\boldsymbol{x}^*(\boldsymbol{a})$ and $\boldsymbol{\lambda}^*(\boldsymbol{a})$, and just evaluate the effect the change has on the cost function and any binding constraints.

The intuition behind this result is as follows. From the chain rule, the total derivative of the optimised Lagrangian with respect to $\boldsymbol{a}$ will include $\frac{\partial \mathcal{L}}{\partial \boldsymbol{x}} \cdot \frac{d\boldsymbol{x}^*(\boldsymbol{a})}{d\boldsymbol{a}}$ terms and $\frac{\partial \mathcal{L}}{\partial \boldsymbol{\lambda}} \cdot \frac{d\boldsymbol{\lambda}^*(\boldsymbol{a})}{d\boldsymbol{a}}$ terms.[34] However, at the optimum, the derivative of the Lagrangian with respect to the components of $\boldsymbol{x}$ and the Lagrange multipliers must be zero (i.e. the first order conditions), so all these terms will equal zero. All that remains of the total derivative are the partial derivatives of the cost function with respect to $\boldsymbol{a}$ (i.e. $\frac{\partial f(\boldsymbol{x},\boldsymbol{a})}{\partial \boldsymbol{a}}$), and the partial derivatives of the constraints with respect to $\boldsymbol{a}$ multiplied by the Lagrange multipliers (i.e. $\boldsymbol{\lambda}^*(\boldsymbol{a}) \cdot \frac{\partial g(\boldsymbol{x},\boldsymbol{a})}{\partial \boldsymbol{a}}$).

So what does this mean for our analysis? Take the following simplified summary of a bank's cost minimisation problem:

$$\min_{r_H, x, y} \{r_D x + r_H y + r_W(1 - x - y) + D(y)\}$$

Subject to:

$$x = s_x(r_H, r_D, r_W)$$

$$y = s_y(r_H, r_D, r_W)$$

Where r_D is the spread on no/low interest deposits, x is the share of no/low deposits, r_H is the discretionary spread on the bank's other deposit accounts (e.g. high interest and term deposits) and y is the share of these deposits, and r_W is the cost of wholesale funding and equity. $D(y)$ is some demand function for discretionary deposits (e.g. demand for stable funding).

The two constraints are the supply functions of no/low deposits and other deposits, respectively; they are a non-negative function of their own spread and a non-positive function of the spreads on substitutes. There is no supply curve for wholesale funding as the bank is assumed to be a price-taker in the wholesale market.

---

34 The complementary slackness condition from the Karush–Kuhn–Tucker theorem means that $f(\boldsymbol{x}^*(\boldsymbol{a}), \boldsymbol{a})$ and the Lagrangian at $\boldsymbol{x}^*(\boldsymbol{a})$ and $\boldsymbol{\lambda}^*(\boldsymbol{a})$ are identical.

When minimising the cost function subject to the constraints, the Lagrange multipliers associated with the no/low deposit supply curve and the other deposit supply curve are, respectively, $\lambda_x = r_D - r_W$ and $\lambda_y = r_H - r_W + D'(y)$; these are the shadow prices of the constraints.

From the first order condition for r_H:

$$y + (r_D - r_W)\frac{\partial s_x}{\partial r_H} + [r_H - r_W + D'(y)]\frac{\partial s_y}{\partial r_H} = 0$$

Assuming $r_D < r_W$ and that $\frac{\partial s_y}{\partial r_H} > 0$ (both realistic assumptions from the data), the above equality requires $r_H - r_W + D'(y) < 0$. That is, both shadow prices are negative.

Then, from the Envelope Theorem, the change in the cost function following an exogenous increase in r_D (i.e. a decrease in the cash rate) equals:

$$\left[x + (r_D - r_W)\frac{\partial s_x}{\partial r_D} + [r_H - r_W + D'(y)]\frac{\partial s_y}{\partial r_D}\right] dr_D$$

Suppose we further assume that: $r_H > r_D$ (a realistic assumption from the data); $\frac{\partial s_x}{\partial r_D} \geq -\frac{\partial s_y}{\partial r_D}$ (i.e. a change in r_D cannot have a bigger effect (in absolute value) on the supply of substitute deposits than it has on no/low deposits); and the demand for discretionary deposits is not so inelastic that it causes an increase in r_H so large that it completely offsets the cost reduction from substituting into the cheaper deposits. Then:

$$(r_D - r_W)\frac{\partial s_x}{\partial r_D} + (r_H - r_W)\frac{\partial s_y}{\partial r_D} + D'(y)\frac{\partial s_y}{\partial r_D} < 0 \qquad \text{(C1)}$$

The first two terms in Equation C1 are captured in the 'Funding Mix' part of Graph 9, the third term could be partially captured in the funding mix part and would cause an endogenous increase in r_H. Since we know the change in r_H will be ≥ 0, the funding mix component must be negative. Moreover, it must be larger in absolute value than any endogenous increase in r_H. Therefore, the absolute value of the funding mix component is an upper bound on the total size of the combined indirect effects from changes in the constraints. The counter-factual exercise we run in Section 4.2.5 estimates the size of this upper bound.

Importantly, if the supply curve for no/low deposits was vertical, both s_x and s_y would not directly be affected by r_D. Therefore, the total change in funding costs resulting from an increase in r_D would be the direct effect $(x \times dr_D)$.

Appendix D – Accuracy of the Lending Spreads part of the Model

The shares of each asset component – the β_i parameters in Equation (2) – are calibrated using APRA data reported by the major banks and other balance sheet data obtained by the RBA. The spreads are estimated from major bank interest rate data collected by the RBA.

The loan asset classes are: housing loans (split into the various combinations of owner-occupier/investor, principal and interest/interest only, variable/fixed), home equity loans, unsecured personal loans (variable/fixed), credit cards, margin loans, and business loans (small/large, variable/bank bills/fixed). The RBA collects interest rate data on each of these asset classes (including average discounts on the advertised rates offered by the major banks), and we use information on the repricing maturity of these loans to convert these interest rates into spreads to reference rates. The offset accounts of home loans are assigned an interest rate of zero.

This appendix evaluates how well the loan assets part of our model lines up with more aggregated data reported to APRA. While the reported data may be more accurate than our model estimates, they likely also contain measurement error and do not provide a sufficiently rich breakdown for our purposes. For example, we need to know the repricing terms of the various loan types, the shares of each loan type, and the spreads to reference rates of the loans. None of the data used for comparison in this section was used to calibrate our model, so this is a true external validation exercise.

Graph D1 compares quarterly average outstanding loan rates estimated from our model, to quarterly average lending rates reported to APRA by the banks. Our model provides a close approximation to the reported rates. Moreover, it is not just the broad trends that are matched, but the shape of the interest rate curves. These results give us confidence in the accuracy of our assumptions and calibration.

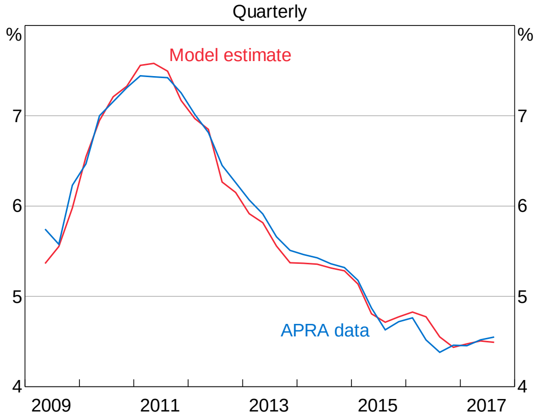
While the quarterly average rates reported by APRA provide the best comparison, we only have data from 2009. For a longer time series, we approximate quarterly average lending rates from the major banks' quarterly interest income data reported to APRA. The APRA data in Graph D2 is constructed by taking the quarterly loan interest income, dividing it by the average loan balance during the quarter, and annualising.

Graph D2 is constructed on a 'licensed authorised deposit-taking institution (ADI)' basis, while our model and Graph D1 is based on the 'domestic book of the licensed ADI'; so we do not expect our model to align as closely in Graph D2 as it does in Graph D1. That said, our model closely approximates these licensed ADI estimates over the entire sample, providing further validation of our assumptions and calibration.

Graph D1

Average Outstanding Lending Rates

Quarterly

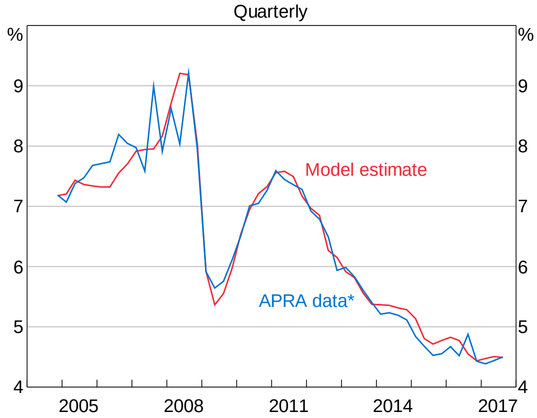


Sources: APRA; authors' calculations; RBA

Graph D2

Average Outstanding Lending Rates

Quarterly



* Licensed ADI; from ARF 330.1.L

Sources: APRA; authors' calculations; RBA

Appendix E – Further Details about the Construction of Debt Funding Spreads

- The long-term debt spreads at issuance are estimated from a combination of primary and secondary market data.
- We use BBSW rates as the measure of domestic short-term funding costs. For foreign-currency debt, we add the cost of foreign-currency hedging to get an estimate of the hedged foreign-currency cost.
- For term deposits, we first group the available terms into short, medium, and long. Within each group, the proportion choosing each term depends on the advertised 'special' rates at each point in time, and is assumed to be inversely proportional to the length of the term. For example, if 12 and 24 month term deposits currently have special offers, and these are the only available offers within the 'long' group, we assume new 'long' term deposits (including rollovers) will be for either 12 or 24 months. Two-thirds of people will choose 12 months, and one-third will choose 24 months (because a 24 month term is twice as long as a 12 month term). From this, we construct a weighted-average spread of the outstanding term deposits in each group. Each group is then given a weight to produce an estimate for the weighted-average spread on all outstanding term deposits.
- The RBA has data on the total volume of the major banks' at-call high interest accounts (such as online savings accounts, bonus saver accounts, and cash management accounts). However, while these data

align with the interest rate data collected by the RBA, they do not perfectly align with the balance sheet shares produced by the APRA data (i.e. these accounts potentially span several of the APRA data categories). Therefore, to consolidate the high interest account data with the APRA data, we assume all non-transaction non-term deposits (from the APRA data) are at-call high interest accounts, and apportion the excess at-call high interest accounts across the household and non-household transaction accounts based on the volumes of deposits in these transaction accounts.