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Currency Demand during
the Global Financial Crisis:
Evidence from Australia

Tom Cusbert and Thomas Rohling

RDP 2013-01

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Currency Demand during the Global Financial Crisis: Evidence from Australia

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Abstract

Australian financial institutions remained healthy throughout the global financial crisis and their deposits were guaranteed by the Federal Government. Nevertheless, demand for currency increased abnormally quickly in late 2008, resulting in an additional \$5 billion (or 12 per cent) of Australian banknotes on issue by the end of that year. The rise in currency demand began in mid October 2008, around four weeks after the collapse of Lehman Brothers and concurrently with policy responses of the Reserve Bank of Australia (RBA) and the Federal Government. The surge in currency demand did not have any destabilising effect on the banking system – indeed bank deposits also rose during the period. However, the rise in currency demand did raise some issues for the RBA’s banknote distribution operations. Traditional models of currency demand suggest a role for interest rate reductions and the Federal Government stimulus payments to households in explaining the increase in currency holdings. We estimate that these factors can only account for around 20 per cent of the observed increase in currency holdings. The remainder of the rise could be due to an increase in precautionary holdings by people concerned about the liquidity or solvency of financial institutions and by financial institutions as a contingency. This is consistent with the disproportionate rise in demand for high-denomination banknotes at this time.

JEL Classification Numbers: C22, E41

Keywords: currency demand, banknote demand, financial crisis

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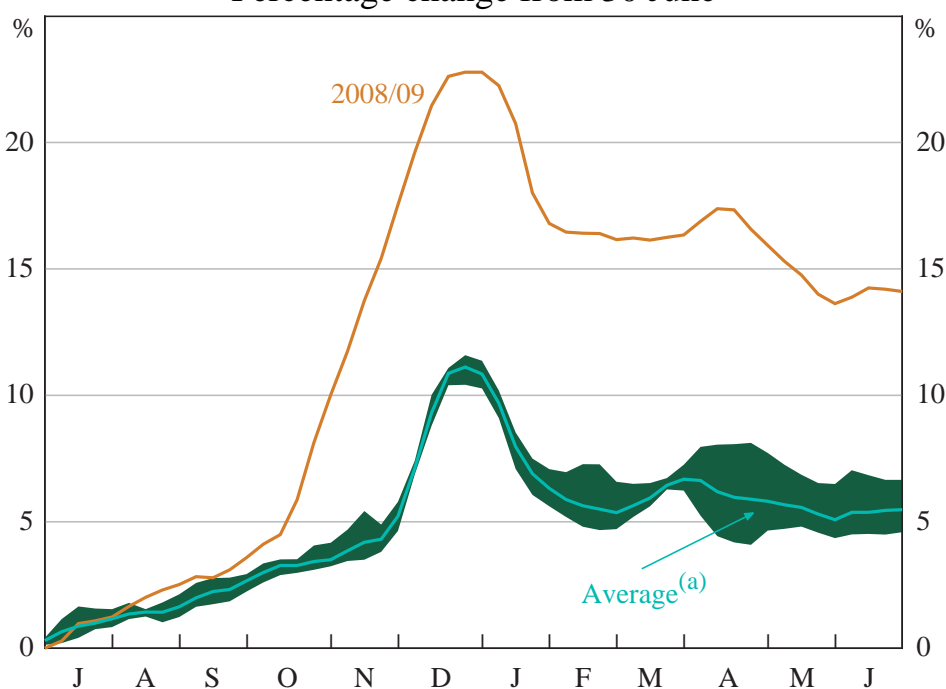
Currency Demand during the Global Financial Crisis: Evidence from Australia

Tom Cusbert and Thomas Rohling

1. Introduction

Late 2008 witnessed an intensification of turmoil in financial markets around the world. As this unfolded, there was a substantial surge in holdings of Australian currency. The increase in total banknote demand in late 2008 was 12 percentage points larger than the normal increase in demand at that time of year, amounting to an additional \$5 billion on issue (Figure 1).

Figure 1: Banknotes on Issue
Percentage change from 30 June



Note: (a) Shaded area represents the range for 2004/05-2007/08

Source: RBA

History has shown that periods of increased demand for currency can be associated with losses of confidence in financial institutions and even runs on deposits. This paper examines the recent episode of heightened currency demand to further the understanding of the behaviour of the Australian public and banks in times of

financial stress.¹ In particular, we look at what drove the surge in currency demand and whether it was of broader significance to the economy. We also consider whether high-frequency currency demand data contain useful real-time information during crises. Understanding currency demand is also important for the role of the Reserve Bank of Australia (RBA) in issuing currency, especially given that it is difficult to increase banknote production at short notice.

There were many events in late 2008 both internationally and domestically that are likely to have had an effect on currency demand. Internationally, Lehman Brothers collapsed and financial markets became increasingly turbulent, while several other major financial institutions were placed into receivership or required emergency liquidity measures. In Australia, as confidence fell and the Australian dollar depreciated, there were a number of policy responses: the RBA cut the interest rate on overnight cash sharply; the Federal Government enacted a guarantee of deposits with authorised deposit-taking institutions (ADIs); and the Federal Government announced, and distributed, stimulus payments to households equivalent to 1.7 per cent of annual GDP. At the same time, there was a sizeable increase in the demand for currency.

Traditional models of currency demand focus on interest rates and income as key explanatory variables. Lower interest rates reduce the opportunity cost of holding currency and so make it relatively more attractive. Increases in income tend to be associated with increases in the demand for currency to conduct transactions. An alternative (but not mutually exclusive) explanation for the rise in currency demand in late 2008 is that precautionary demand increased as a result of at least some depositors being concerned about the stability or liquidity of banks during the financial crisis.² Also, financial institutions may have increased their precautionary demand for currency in anticipation of rises in demand from their customers. However, bank deposits increased during the period in question, so it is clear that there was no large-scale loss of confidence in the banking sector.

1 Currency supplied by the RBA is perfectly elastic so actual quantities of currency in circulation can be thought of as demand.

2 We are using *precautionary demand* to mean demand for currency as a precaution against difficulties in accessing currency in the future due to a banking crisis. This is a different sense to Keynes' use of precautionary demand to mean a precaution against future requirements for currency to make unexpected transactions.

To investigate the relative importance of these factors we estimate traditional models of currency demand and then expand them to include new variables that may be important during financial crises. We also include transaction cost variables to avoid possible model misspecification. We find that the increase in currency holdings in late 2008 was substantially larger than can be attributed to the normal response to interest rate cuts and the fiscal stimulus payments, and so may have been due to precautionary demand.

The demand for different denominations of banknotes can help to identify the different causes of the increase in currency demand. We posit that precautionary demand for banknotes should result in a disproportionate increase in demand for high-denomination banknotes because they are more likely to be used as a store of value than low-denomination banknotes. This is consistent with the relative rises in currency holdings of different denominations observed in late 2008.

The remainder of the paper is structured as follows. Section 2 provides some background on currency demand in past financial crises, followed by a more detailed description of the Australian experience during late 2008 to early 2009. Section 3 discusses currency data in more detail. Econometric modelling to control for the effects of interest rates and income is presented in Section 4, followed by a conclusion in Section 5.

2. Financial Crises and Currency Demand

2.1 A Historical View

Financial crises can result in depositors losing confidence in financial institutions and withdrawing their money, which can then appear as increased currency in circulation. Banks and other deposit-taking institutions are vulnerable to such withdrawals because they typically retain only a fraction of their customers' deposits in liquid form, investing the remainder in loans whose terms are often longer than those of deposits. In extreme circumstances, this can result in a bank run. Expectations of a bank run can become self-fulfilling because depositors have an incentive to withdraw their deposits if they believe that other depositors will withdraw their funds (see Diamond and Dybvig (1983) for a theoretical

discussion). History has shown that bank runs can quickly turn a liquidity problem into a solvency crisis (see Reinhart and Rogoff (2009) for a review).

Australia, like many countries, has had some experience with financial crises and bank runs. An early crisis occurred in the 1890s, following a property boom associated with lowered lending standards at many financial institutions. As property prices collapsed, depositors became concerned about the solvency of some exposed banks and building societies. Some depositors transferred deposits to more conservative and well-established financial institutions and others withdrew their deposits from the banking system. As a result, the value of currency in circulation increased in 'leaps and bounds' in a short period of time (Holder 1970). Even solvent banks not exposed to the property market faced liquidity problems and became increasingly unable to redeem depositors' claims. At the height of this crisis, half of all deposits in Australia were suspended (Rohling and Tapley 1998). Most deposits were paid back between 1893 and 1901 and did not suffer direct financial losses, although there were 'considerable indirect losses via frozen deposits' (Kent 2011).

In contrast to the 1890s financial crisis, only three Australian financial institutions suspended withdrawals after runs on deposits during the Great Depression. This was because in the years leading up to the Great Depression, there was less speculation in the property market, less rapid credit growth and many financial institutions had become more conservative in their risk-taking due to less competition (Kent 2011).

In more recent history, there was a significant financial crisis in the mid 1970s. Again, the crisis followed a property boom and was precipitated by a liquidity squeeze that led to 'the failure of almost half of the largest 20 finance companies' (Bloxham, Kent and Robson 2010). The crisis was concentrated in building societies and did not involve a noticeable increase in currency on issue.

Another crisis began in 1989, after a combination of high interest rates and a softening commercial property market brought credit quality problems to light. The crisis involved a number of runs on building societies and small regional banks (Fitz-Gibbon and Gizycki 2001). Two larger banks also suffered large losses, but had, or were able to raise, sufficient capital to cover them. The crisis resulted in a

steep increase in currency demand in 1990/91. From then until late 2008, Australian financial institutions largely avoided difficulties. There were no out-of-the-ordinary increases in currency demand until the intensification of the global financial crisis in late 2008.

This historical view, as well as international experience, demonstrates that periods of financial instability and losses of confidence in financial institutions can be marked by increases in the public's demand for currency. This suggests that during financial crises, changes in currency demand may provide useful information about the degree of public confidence in the financial system.

2.2 The Global Financial Crisis

The global financial crisis was associated with a substantial increase in currency demand in Australia. While it is difficult to date the beginning of the crisis precisely, money market spreads first began to widen in August 2007 following a series of announcements of losses by financial institutions and the suspension of some bank-sponsored investment funds (Ellis 2009). In Australia, corporate bond spreads also began widening around that time (Figure 2).

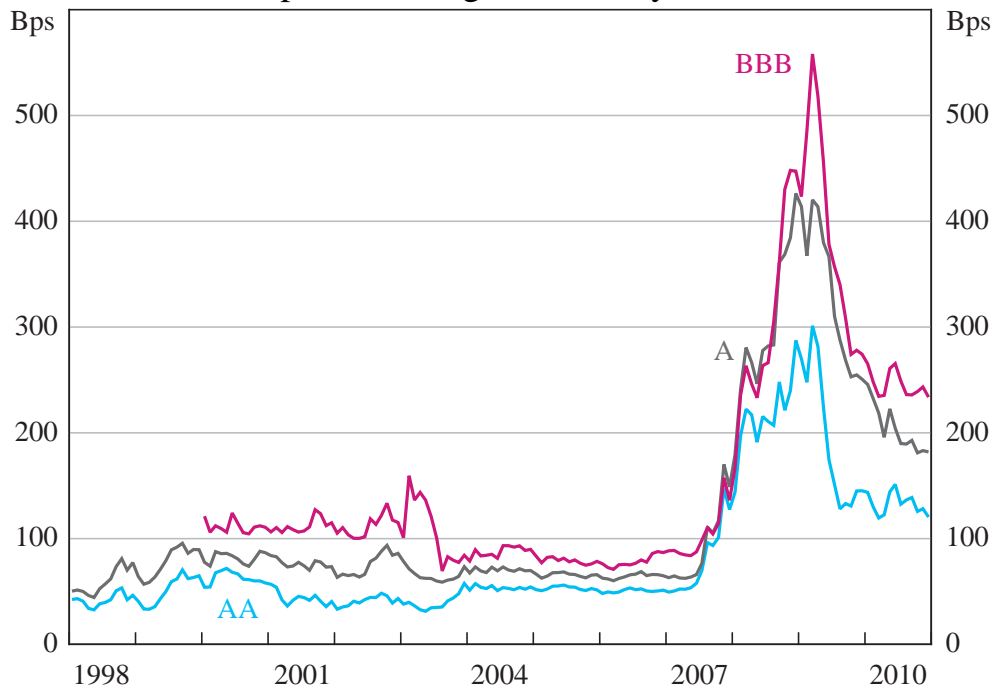
In September 2007, there was a depositor run on Northern Rock, a mortgage bank in the United Kingdom (Dodd 2007). This was the first bank run in the United Kingdom since 1866. However, it did not follow the traditional model of bank runs. Rather than occurring *prior* to official support for the bank, it occurred *after* Northern Rock sought, and received, emergency liquidity from the Bank of England (Shin 2009).

The next major disruption occurred in March 2008 when Bear Stearns suffered a sharp withdrawal of funds. This prompted an injection of liquidity by the US Federal Reserve through JPMorgan Chase, which subsequently announced its acquisition of Bear Stearns (RBA 2008).

The greatest period of disruption followed the announcement of Lehman Brothers' bankruptcy on 15 September 2008 (Edey 2009). Soon after, AIG required emergency support from the US Federal Reserve, and several large banks (e.g. Washington Mutual, Wachovia and Iceland's Landsbanki) were placed into

receivership or forced sales. During this period, confidence collapsed, equity prices fell sharply and wholesale credit markets went into a state of serious dysfunction.

Figure 2: Australian Corporate Bond Spreads
Spreads over government yields



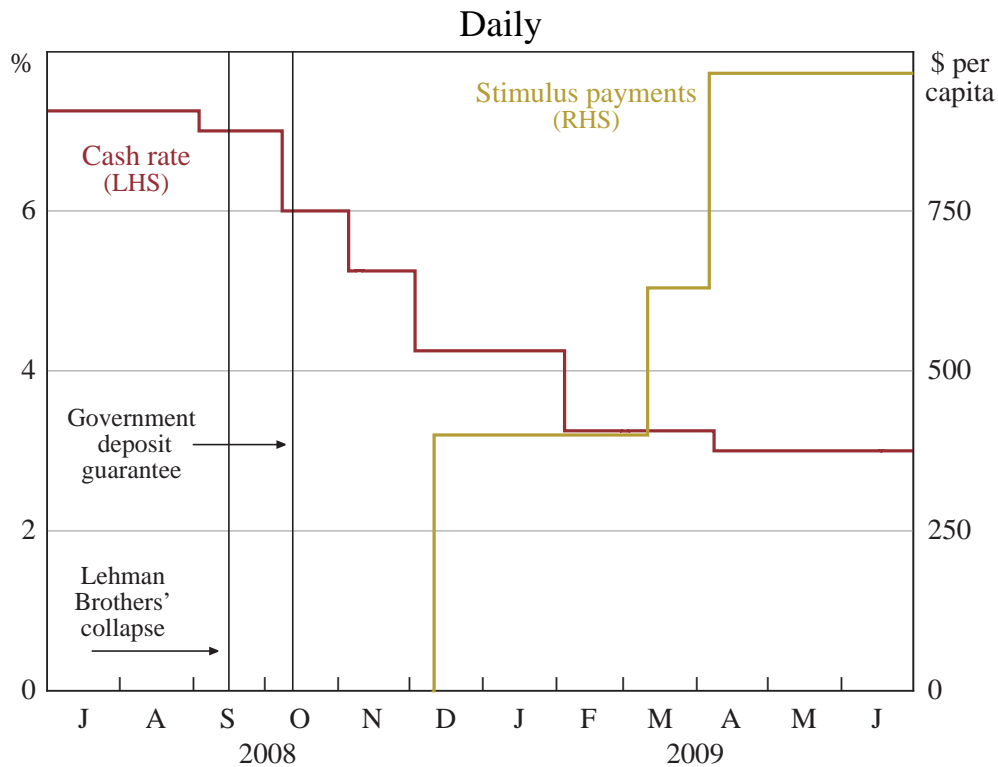
Notes: Corporate bond spreads are a weighted average of senior bonds with remaining maturities of 1 to 5 years, they include financial and non-financial corporates

Sources: Bloomberg; RBA; UBS AG, Australia Branch

The Australian policy response to the unfolding crisis was prompt. In October 2008, the RBA lowered the cash rate from 7.0 to 6.0 per cent. The easing continued until April 2009 when the cash rate was lowered to 3.0 per cent (Figure 3). As well as lowering the policy rate, the RBA undertook a range of market operations designed to provide liquidity in the Australian market (RBA 2009a). The Federal Government also announced a series of measures to bolster confidence in Australian financial institutions, including an Australian deposit guarantee scheme, which took effect on 12 October 2008 following the announcement of similar measures in other countries. A wholesale funding guarantee was announced at the same time. Soon after this, the Federal Government announced stimulus payments to be made to households in December 2008. More stimulus payments were announced early the following year (to be paid from 11 March 2009), as well as tax bonus payments that would begin

on 6 April 2009. The value of payments to households totalled approximately \$21 billion, or almost \$1 000 per capita (RBA 2009c).

Figure 3: Monetary and Fiscal Policy Events



Source: RBA

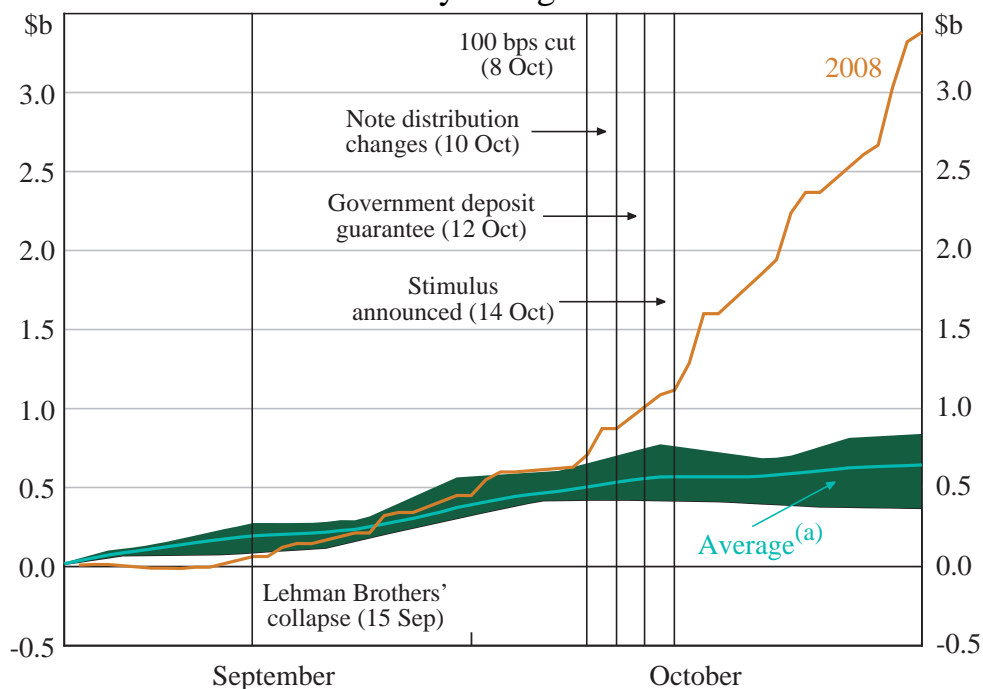
2.3 Currency Demand in Australia during the Global Financial Crisis

As the global financial crisis unfolded, the stock of banknotes on issue increased dramatically. Figure 4 shows the cumulative increase in banknotes on issue on a daily basis alongside relevant events that occurred at the time. The surge in banknote demand was not an immediate response to the intensification of the crisis around the collapse of Lehman Brothers, suggesting that the Australian public was not immediately concerned. However, the stock of banknotes on issue began rising sharply around the same time as the RBA's 100 basis point cut in the cash rate (on 8 October) and accelerated further upon the Federal Government's 14 October announcement of the upcoming cash payments to households.³

³ Single and multi-day changes in this period were 2–5 standard deviations larger than average for that time of year.

Standard explanations of currency demand posit that lower interest rates should cause increases in currency demand but the speed and magnitude of this rise suggests that this explanation is not the full story.⁴ The further increases in banknote demand following the announcement of the stimulus payments could be the result of banks stocking up on currency in anticipation of increased cash withdrawals. This might seem overly preemptive given the payments were not to be made until December, but liaison with banks at the time suggests that it was a factor.

Figure 4: Banknotes on Issue
Cumulative daily change in total value



Note: (a) Shaded area represents the range for 2004–2007

Source: RBA

The magnitude of the growth in banknotes on issue suggests a role for precautionary demand that was not immediately apparent in September 2008. Given that this demand appears to have coincided with the policy responses of the RBA and Federal Government, it is possible that there was some adverse signalling effect of these policies.⁵ However, it is also possible that the public and policymakers were both responding to the ongoing deterioration in financial

⁴ This is borne out in the modelling results in Section 4.

⁵ A similar line of argument can be found in Taylor (2008).

conditions over that period; indeed, the deposit guarantee is likely to have limited the extent of the rise in currency demand by providing added confidence in deposits.

Another factor that contributed to the rise in currency demand was a rise in demand from offshore as a result of the sharp depreciation of the Australian dollar seen in this period. Information collected at the time suggests that expatriates, tourists and families of international students studying in Australia took the opportunity to obtain Australian currency at what appeared to be a good exchange rate (RBA 2009a). Indeed, foreign banks engaged in currency exchange reported that they were barely able to keep up with the demand for Australian currency. We are unable to quantify this offshore demand, but it may have been a significant contributor to the overall rise in banknotes on issue.⁶

The daily banknotes-on-issue series shows demand in real time, which reflects changes in both household and bank behaviour. These daily data may be useful to monitor in order to inform judgements about whether financial market turmoil is spilling over to the broader economy. The close working relationship between the RBA's Note Issue Department and the commercial banks also yields information on the motivation for banknote demand.

3. Currency Demand Data

To analyse the surge in demand for Australian currency in late 2008 further, it is useful to understand how it is distributed and where it is held. Total currency on issue is made up of banknotes and coins and can be split into currency holdings of the non-bank sector and currency holdings of banks (Table 1).⁷ As an illustration, at the end of June 2012 there was \$56.9 billion worth of currency in circulation, of which \$51.0 billion was held by the non-bank sector and \$5.9 billion was held by the bank sector.

6 Previous sharp depreciations do not appear to have been associated with rises in currency on issue, and we find the exchange rate is not significant in a currency demand model (see Section 4.4.2).

7 We refer to ADIs as the *bank sector* and currency holdings outside ADIs as holdings of the *non-bank sector*. The non-bank sector includes household, corporate, government and foreign sectors.

Table 1: Currency on Issue by Type and Holder
As at 30 June 2012

	\$b	Data frequency
Banknotes	53.6	Weekly/daily ^(a)
Coins	3.4	Monthly
Total	56.9	Monthly
Non-bank sector	51.0	Monthly
Bank sector	5.9	Monthly

Note: (a) Daily data available from 15 May 2008 onwards

Sources: APRA; RBA; Royal Australian Mint

3.1 Currency Holdings of the Non-bank Sector

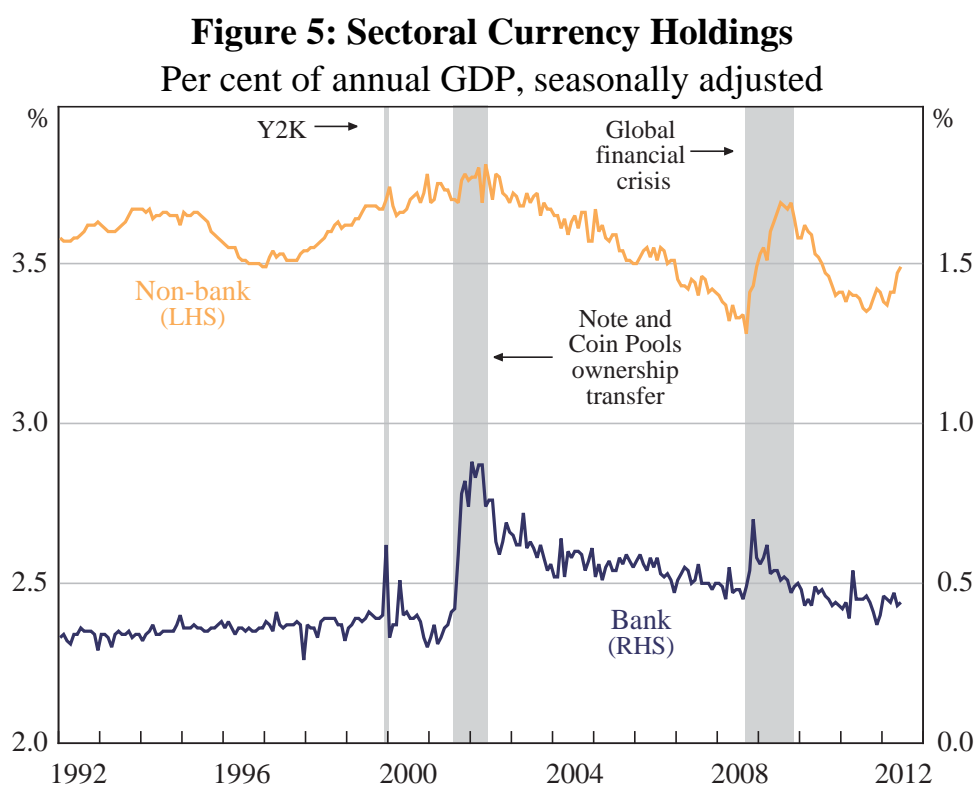
Currency held by the non-bank sector has trended steadily upward through time, roughly in line with nominal GDP. However, demand for Australian currency by the non-bank sector increased dramatically in late 2008 as the global financial crisis intensified and policymakers responded (Figure 5). Currency holdings of the non-bank sector jumped by 5 per cent in October 2008 (a rise of just over \$2 billion). In seasonally adjusted terms, that is 1¼ percentage points larger than the next biggest monthly increase in the history of the series going back to 1959.

The strong growth continued such that the increase in currency holdings over the three months to 31 December 2008 was 8 percentage points higher than the average increase over the same period in the previous four years. This is equivalent to an additional \$3¼ billion and was 8 standard deviations above average, so cannot be considered a part of normal volatility. The increase in currency holdings of the non-bank sector was pronounced, but temporary. After a few months of very rapid growth, the currency stock stabilised and returned to trend by around mid 2010.

3.2 Currency Holdings of the Bank Sector

Bank holdings of currency are usually fairly stable as a ratio to nominal GDP, although there have been three periods since the early 1990s when this was not the case (Figure 5). Understanding these periods can tell us something about bank behaviour and aids in the econometric modelling of the total currency series (see Section 4).

The first occasion was in preparation for the year-date change at the end of the millennium (that is, ‘Y2K’). Commercial banks increased their currency holdings sharply in case they experienced an increase in currency demand from their customers. In the event, the date change was virtually incident free, and the stocks that were built up were not drawn upon (RBA 2000).



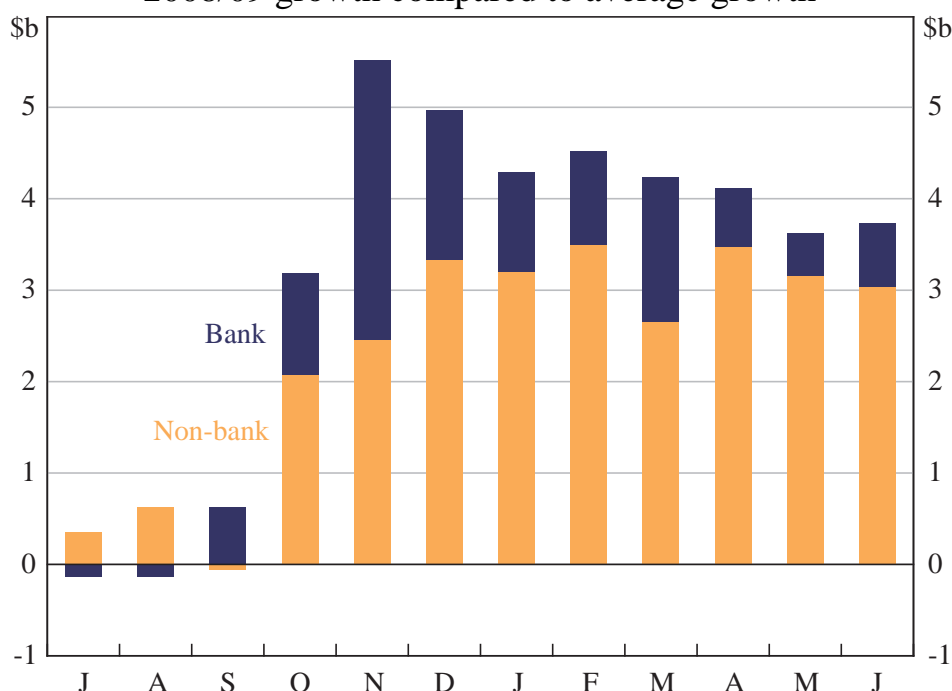
Sources: ABS; RBA

The second period began in August 2001, when the processing and storage of banknotes was outsourced from the RBA and banknote distribution arrangements were changed such that ownership of the RBA’s Note and Coin Pools was transferred to the commercial banks (Carlin 2004). In lieu of the RBA’s Note and Coin Pools, commercial banks are allowed to hold verified cash holdings (VCH), which attract interest payments from the RBA. VCH act as a buffer stock between the RBA’s contingency holdings of banknotes and the day-to-day needs of commercial banks. The overall result of this change was a step increase in the level of bank holdings, as well as a transitory spike as banks became accustomed to the new arrangements.

The third period was during the global financial crisis in late 2008. This period was different to the previous two periods in that currency demand by the non-bank

sector also increased sharply. During 2008/09 there was *additional* currency demand – that is, growth in excess of average growth in the previous four years – in both the non-bank and bank sectors (Figure 6). The peak in additional currency holdings came in November 2008, with the bank sector accounting for around \$3 billion of the \$5½ billion in total additional currency holdings.

Figure 6: Additional Currency Demand
2008/09 growth compared to average growth



Note: Calculated as the difference between the cumulative growth to date in 2008/09 and the average cumulative growth to date for 2004/05–2007/08

Source: RBA

In response to signs of increased demand for currency from the banking sector, the RBA changed operational arrangements on 10 October 2008 to allow interest to be paid on all VCH rather than only on a predetermined limit as had previously been the case. This facilitated banks building up buffers of currency beyond the increase in demand from the non-bank sector in order to be prepared for any further spikes in demand for currency.⁸ To some extent this experience echoes the build-up of cash in banks on the eve of Y2K, where banks built up a buffer of currency. However, unlike the Y2K episode, the public did demand additional currency.

⁸ There is some anecdotal evidence of large withdrawals from banks at the time (e.g. Taylor and Uren 2010), although withdrawal data show only a moderate increase (see Section 3.5).

Such precautionary build-ups of currency by banks are a sensible risk management strategy given the potential for very adverse effects if they are unable to meet the demands of their depositors.

3.3 Banknote Distribution by the RBA

The rise in currency demand in late 2008 was not large enough to have any destabilising effects on the financial system, but it did raise some concerns about the physical provision of sufficient banknotes. The RBA was able to meet the additional demand from its existing contingency holdings of banknotes, and the 2008/09 production schedule was accelerated in case the increased demand for banknotes was sustained. The RBA also temporarily suspended the destruction of unfit banknotes, but these were never used and were subsequently destroyed.

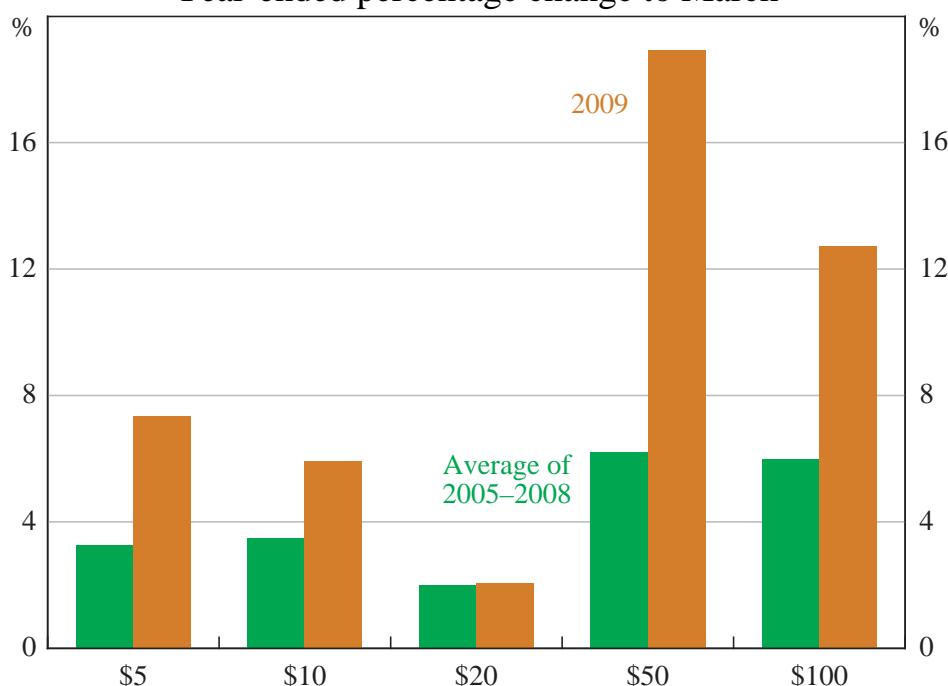
This experience demonstrated that sharp rises in banknote demand have the potential to be disruptive to normal operations. As a result, the RBA has increased its contingency holdings to reduce the likelihood of shortages in the event of a future crisis and has improved banknote distribution to alleviate any logistical problems in periods of heightened demand.

3.4 Banknotes on Issue by Denomination

The daily banknotes-on-issue data are available by denomination. The surge in banknotes on issue in late 2008 was not evenly spread across all denominations, but was most pronounced for high-value denominations (Figure 7). The value of low-denomination banknotes on issue also increased, but the extent of the increase was substantially less.

The difference in growth between low-value and high-value denominations suggests that the rapid rise in banknote demand was driven by increases in the demand for currency as a store of value, rather than increases in demand for transactions. A strong rise in transactional demand would probably have resulted in stronger demand for low-denomination banknotes as merchants would have required them to make change (although it is possible that a brief increase in transactional demand associated with the fiscal stimulus may have resulted in a faster rate of turnover of these low-denomination banknotes).

Figure 7: Banknotes on Issue by Denomination
Year-ended percentage change to March



Source: RBA

In contrast, \$50 and \$100 banknotes are more likely to be held to store value, so their demand is likely to have been more sensitive to concerns about the stability of financial institutions.⁹ The sharp rise in \$50 banknotes could be interpreted in either way as they are used in transactions as well as to store value. They are also the most common banknote withdrawn from ATMs, so the government stimulus payments probably contributed to some of the rise in \$50 banknotes on issue. Ideally, we would like to consider non-bank currency demand by denomination but data limitations mean that we can only do this for total banknotes on issue.

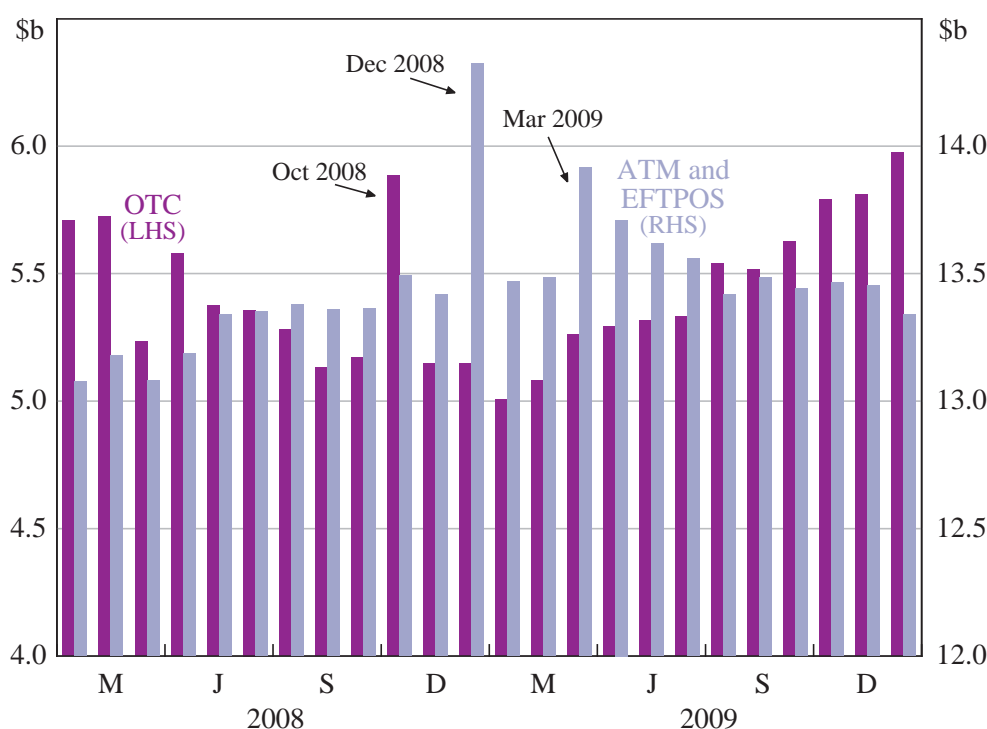
3.5 Withdrawals

Another dimension to currency demand through this period is retail cash withdrawals – that is, withdrawals either in banks over the counter (OTC), from ATMs (automated teller machines) or as cash taken out as part of EFTPOS transactions (electronic funds transfer at point of sale). OTC withdrawals picked up

⁹ Foreign demand for Australian currency, for example to satisfy retail foreign exchange demand, is mostly for \$100 banknotes as they are the least costly to transport. Some of the increase in demand for \$100 banknotes was likely to have been from offshore.

noticeably in October 2008, and were \$700 million higher than the level in adjacent months (Figure 8).¹⁰ The increase in the value of withdrawals in October was greater than the increase in the number of withdrawals, which is consistent with a small number of people making large precautionary withdrawals due to financial uncertainty. ATM withdrawals show an \$850 million spike in December and another smaller spike in March 2009.¹¹ These two spikes coincided with government stimulus payments.

Figure 8: Retail Currency Withdrawals
Seasonally adjusted



Source: RBA

Taken together, the three spikes in the withdrawals data can only account for just over half of the \$3¼ billion in additional currency holdings of the non-bank sector. However, retail withdrawals are only one way that the total stock of non-bank currency holdings can change. A lower-than-usual flow of cash deposits into banks by households and businesses in late 2008 would also have caused currency

¹⁰ The series is fairly volatile, so it is difficult to read much into this monthly movement. Nevertheless, growth in October was 5 standard deviations above average so represents some highly unusual behaviour.

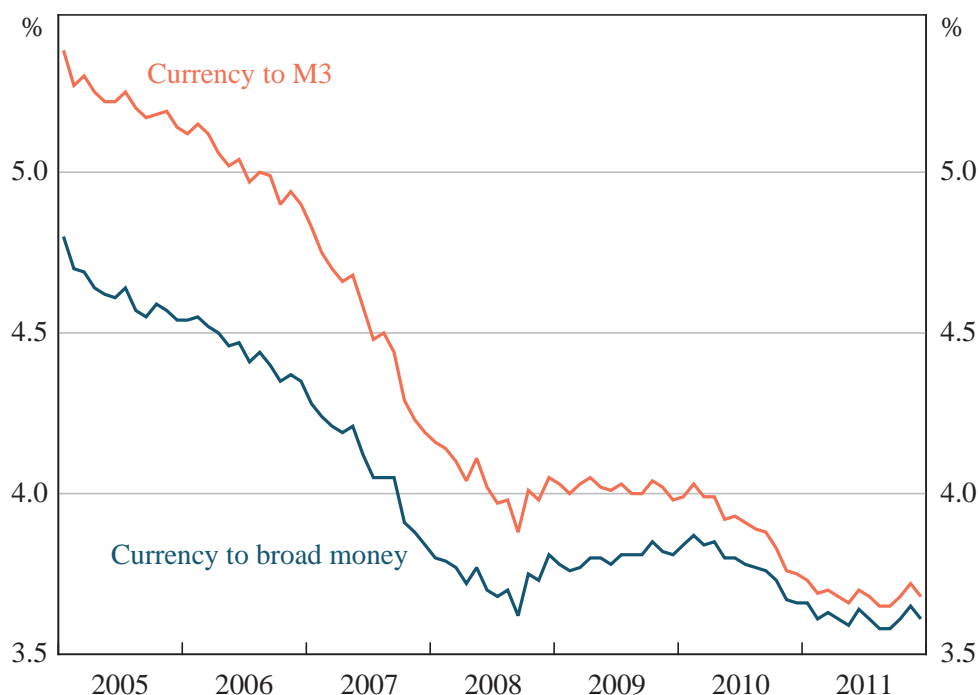
¹¹ The series is multiplicatively seasonally adjusted and December has the highest value of withdrawals, so the spike in December 2008 could be understated by about 10 per cent.

holdings of the non-bank sector to rise, all else being equal. These retail withdrawals data do not include corporate or government withdrawals and can only give a partial view of currency flows.

3.6 Deposits

The rise in currency on issue in late 2008 was quite significant relative to the stock of currency. In light of international bank failures at the time, a natural question to ask is whether this additional currency demand in Australia was part of a shift away from bank deposits. Deposits data show this was not the case. Deposits rose over late 2008 (coinciding with the announcement of the Australian Government deposit guarantee on 12 October), suggesting that any concerns that some people may have had about the banking sector were not widely held. The rise in deposits was not as sharp as the rise in non-bank currency holdings at the time, resulting in an increase in the ratio of currency to deposits between September and December 2008 (Figure 9). But the increase in deposits suggests that confidence in Australian banks remained very strong. To the extent that the rise in currency demand suggests that a minority may not have shared in the broader public's confidence in the banking system, this is somewhat surprising given the introduction of the deposit guarantee.

While there is no evidence of any substantive lack of confidence in financial institutions across the community, there were some signs of nervousness among some depositors at this time, with the largest banks gaining market share in the period preceding the guarantee announcement at the expense of some smaller institutions (RBA 2009b). The introduction of the deposit guarantee system quickly quelled whatever depositor nervousness there had been, and deposits grew strongly thereafter.

Figure 9: Ratios of Non-bank Currency Holdings to Deposits

Note: Deposits are calculated as M3 and broad money less currency holdings of the non-bank sector

Source: RBA

4. Modelling Currency Demand in Australia

In this section, we estimate how much of the increase in currency demand in late 2008 can be explained by traditional factors (i.e. interest rates and income movements). A large unexplained rise in currency holdings in this period would be consistent with an increase in precautionary demand. We consider banknote demand split by denomination, as well as total currency on issue, to help identify transactional demand compared to store-of-value or precautionary demand. To achieve these aims, we draw upon three strands of the literature: traditional models, transaction cost models and financial crisis models.

4.1 Traditional Models

Most money demand models include income and interest rates as explanatory variables. Income is positively related to money demand because demand for transaction balances increases in line with income. Interest rates are negatively related to money demand because a higher interest rate increases the opportunity

cost of holding money. Early Australian money demand models following this literature include Cohen and Norton (1969) and Stevens, Thorp and Anderson (1987).

de Brouwer, Ng and Subbaraman (1993) explore the sensitivity of Australian money demand relationships to specification changes across various definitions of monetary aggregates, economic activity and interest rates. They find the real long-run demand for currency to be a function of real income and an opportunity cost variable. However, they find the existence of cointegrating relationships to be highly dependent on the definitions of variables.

Lim (1995) establishes a cointegrating relationship between M1, income, the rate of return on money and the rate of return on other assets using an error correction model estimated on Australian data.¹² In contrast, Felmingham and Zhang (2001) only find a cointegrating relationship between a broad definition of Australian money, GDP, interest rate spreads and inflation.

In our model, we use currency holdings of the non-bank sector to represent currency demand, as this series captures the behaviour of the public.¹³ We also consider total banknotes on issue because these data allow for separate modelling of demand for different denominations.¹⁴ The changes to banknote distribution in 2001 discussed in Section 3.2 mean that there is a level shift in the total banknotes-on-issue series. We control for this shift using a dummy variable. The changes to distribution arrangements also resulted in a transitory spike in banknote holdings for the three quarters after the change, so we include temporary dummy variables in the affected quarters.

To capture the opportunity cost of holding currency, we include a composite interest rate for retail deposits. This rate is a weighted average of at-call savings

¹² In Australia, M1 is the sum of currency plus bank current deposits of the private non-bank sector.

¹³ Full details of all data series and sources are given in Appendix A.

¹⁴ Analysing currency on issue, which includes banknotes and coins, makes no difference to the results.

deposit rates and term deposit rates.¹⁵ We use nominal GDP as our income variable, although the results are robust to other measures.

4.2 Transaction Cost Models

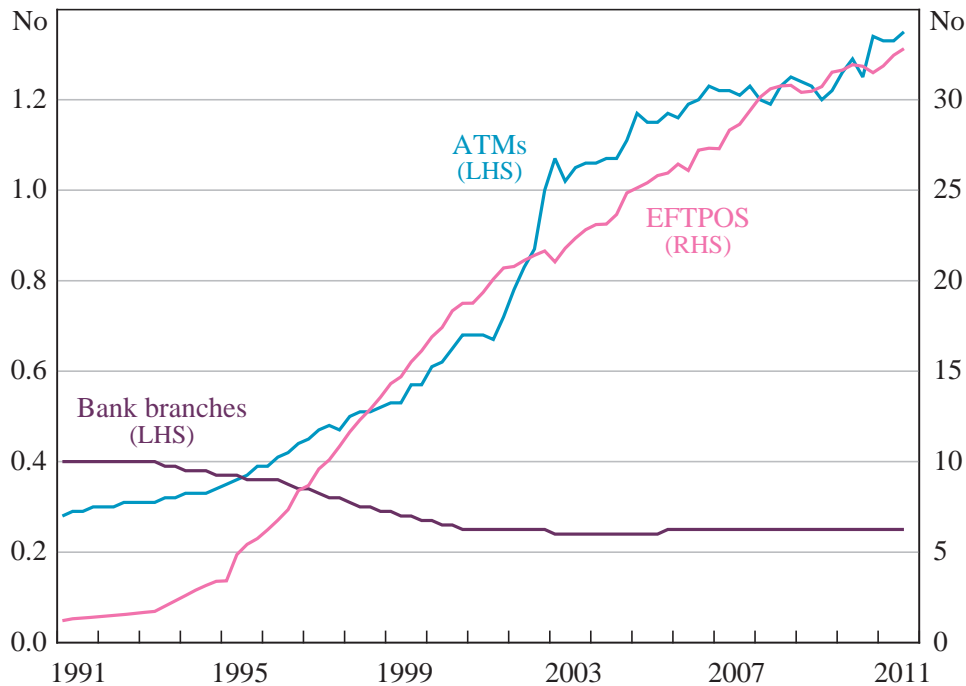
We also consider models that explicitly include transaction costs. Models that omit these influences may be misspecified and thus have biased estimates of the effect of interest rates on currency holdings. This method is particularly useful when modelling the determinants of high- and low-denomination currency demand separately because the effects of transaction costs on demand are likely to be different for different denominations.

Baumol (1952) and Tobin (1956) develop inventory models of the demand for currency, in which consumers take into account the cost incurred per withdrawal (including the opportunity cost of time and effort). If withdrawing currency becomes less costly, consumers will withdraw less currency more often and thus hold less cash on average. This idea has been incorporated into empirical models by including the number of ATMs and EFTPOS terminals into money demand models (Drehmann, Goodhart and Krueger 2002; Amromin and Chakrovorti 2009). They find a weak relationship between these transaction cost variables and currency demand.

To capture transaction cost effects, we include the number of ATMs, the number of EFTPOS terminals and the number of bank branches per capita. Over the past two decades, ATM and EFTPOS terminal numbers have increased substantially while bank branches per capita have declined (Figure 10). More of these currency access points make it easier to obtain currency, which would tend to decrease the average holdings of currency by the public. EFTPOS terminals also allow substitution from cash to debit cards. Working in the other direction, however, ATM providers demand more banknotes to stock the extra machines.

¹⁵ The weighted average deposit rate is highly correlated with the cash rate, especially in the pre-GFC sample. Using the cash rate instead has little effect on most of the modelling results.

Figure 10: Points of Currency Access
Per 1 000 residents



Sources: ABS; Australian Payments Clearing Association

Judson and Porter (2004) find a positive relationship between the share of small businesses and banknote demand across all denominations. Amromin and Chakrovorti (2009) include the ratio of self-employment to total employment in the economy to measure the number of small businesses and they find it to be positively related to demand. They suggest two reasons for this relationship. First, small businesses are less likely to have EFTPOS terminals. Second, small businesses are more likely to undertake the quick low-value transactions that are the most likely to be conducted using cash (see also Emery, West and Massey 2007). We include the ratio of self-employment to total employment to capture this effect.

4.3 Financial Crisis Models

There is some literature on currency demand during financial crises. Bjørnland (2003) finds that currency demand increased substantially during the Venezuelan banking crisis of the mid 1990s, but returned to trend in the long run. Miyagawa and Morita (2009) find a cointegrating relationship between money demand, interest rates, GDP and a ‘financial anxiety’ variable that holds through the financial crises in Finland and Japan during the early 1990s. The financial

anxiety variable – derived from business survey data – accounts for a strong rise in money demand, which the authors attribute to a rise in precautionary balances in those countries during these crises. Khamis and Leone (1999) use Mexican data to find a stable cointegrating relationship between real currency balances, real private consumption expenditure and an interest rate, even during the financial crisis in the 1990s.

Few papers have examined the stability of money demand over the most recent financial crisis. Beyer (2009) uses euro area data and finds a stable cointegrating relationship within a vector error correction model that includes M3 over a sample that includes the financial crisis. The inclusion of a wealth variable is crucial to this stability.

We attempt to capture the effects of the global financial crisis (GFC) on currency demand in three ways. First, we add dummy variables for the three quarters from December 2008 to June 2009 to the baseline model. Second, we introduce confidence, financial market and wealth variables to our model. Finally, we examine whether these wealth variables retain any explanatory power in the presence of dummy variables. We would expect rises in the stock of currency to be associated with declines in confidence and wealth variables, and rises in financial volatility variables. In particular, we look at the NAB business confidence survey, the Westpac-Melbourne Institute consumer sentiment survey, stock market volatility and household wealth. These variables were all affected in a highly correlated fashion during the global financial crisis, but none can be considered to directly measure households' confidence in the banking system. As a result, at best we can only proxy for the precautionary demand motive.

4.4 Estimating Error Correction Models

Following de Brouwer *et al* (1993) we model currency demand in an error correction framework to exploit the possible cointegration between currency holdings, GDP and interest rates. We also include ATMs, EFTPOS terminals, bank branches per capita and the ratio of self-employment to total employment in the long-run relationship to form a general error correction model:¹⁶

¹⁶ The financial crisis variables are omitted at this stage, but are included in Section 4.4.2.

$$\Delta c_t = \lambda(c_{t-1} - \beta X_{t-1} - \beta_0) + \sum_{i=1}^m \delta_i \Delta c_{t-i} + \sum_{j=0}^n \gamma_j \Delta X_{t-j} + \varepsilon_t \quad (1)$$

$$X_t = \left[GDP_t \quad DepositRate_t \quad \frac{ATM_t}{Pop_t} \quad \frac{EFTPOS_t}{Pop_t} \quad \frac{BankBranch_t}{Pop_t} \quad \frac{SelfEmp_t}{Emp_t} \right]$$

where c_t is the currency stock in period t , β is a vector of long-run parameters, X_t is a vector of variables including nominal GDP, the deposit interest rate, ATMs per capita, EFTPOS terminals per capita, bank branches per capita, the ratio of self-employment to total employment and β_0 is a constant. All variables except the interest rate are in logarithms. The speed of adjustment parameter is λ , and the parameters for the dynamic terms are δ_i and γ_j . The residual is ε_t . We estimate the model using quarterly data from March 1993.

4.4.1 Non-bank sector currency holdings results

We start with currency holdings of the non-bank sector as the dependent variable. All variables from the cointegrating vector in Equation (1) are significant so were retained, except the self-employment variable because its sign was negative (which goes against its theoretical rationale).¹⁷ Among the dynamic terms, only the first lag of changes in the currency stock is significant so it is the only dynamic term retained.

Focusing initially on the pre-GFC sample, the coefficients on GDP and the interest rate are significant and have the expected signs (Table 2). The elasticity on GDP is not significantly different from unity, suggesting that GDP growth is met with commensurate growth in the currency stock in the long run. The semi-elasticity of the currency stock with respect to the deposit rate is -1.3 per cent. This implies that a permanent 100 basis point decrease in the deposit rate is associated with a \$520 million long-run increase in the currency stock, based on the level in mid 2008. The magnitude of the semi-elasticity is broadly consistent with that estimated in de Brouwer *et al* (1993).

¹⁷ Excluding the self-employment variable has no major bearing on other coefficients.

Table 2: Non-bank Currency Holdings – Error Correction Model

	1993:Q1–2008:Q2	1993:Q1–2011:Q4	
		Without GFC dummies	With GFC dummies
Speed of adjustment (λ)	–0.23***	–0.26***	–0.23***
GDP_{t-1} (β_1)	1.07***	1.02***	1.00***
$DepositRate_{t-1}$ (β_2)	–0.013*	–0.005	–0.011***
ATM_{t-1} (β_3)	–0.16**	–0.12***	–0.12***
$EFTPOS_{t-1}$ (β_4)	–0.06***	–0.04***	–0.06***
$BankBranches_{t-1}$ (β_5)	–0.59***	–0.50***	–0.55***
Constant (β_0)	4.93**	6.52***	6.39***
Δc_{t-1} (δ_1)	–0.30**	0.15	–0.17
Dummy variables			
GFC (2008:Q4)			0.044***
GFC (2009:Q1)			0.026***
GFC (2009:Q2)			0.015**
Adjusted R ²	0.41	0.31	0.63
Standard error	0.0046	0.0070	0.0048
LM(5) test ^(a)	0.20	0.31	0.23
Chow test (mid sample) ^(a)	0.04	0.26	0.30

Notes: ***, ** and * indicate significance at the 1, 5 and 10 per cent level, respectively

(a) p-value of F-statistic reported

The negative coefficients on ATMs, EFTPOS terminals and bank branches are in keeping with theory. That is, by making it easier to access cash (or pay without cash), these variables are inversely related to currency demand. To give some scale to the magnitudes of the coefficients of these variables, a 10 per cent increase in ATMs and EFTPOS terminals per capita is estimated to reduce currency demand by 1.6 and 0.6 per cent respectively. A 1 per cent reduction in bank branches per capita is estimated to increase currency holdings by 0.59 per cent.¹⁸

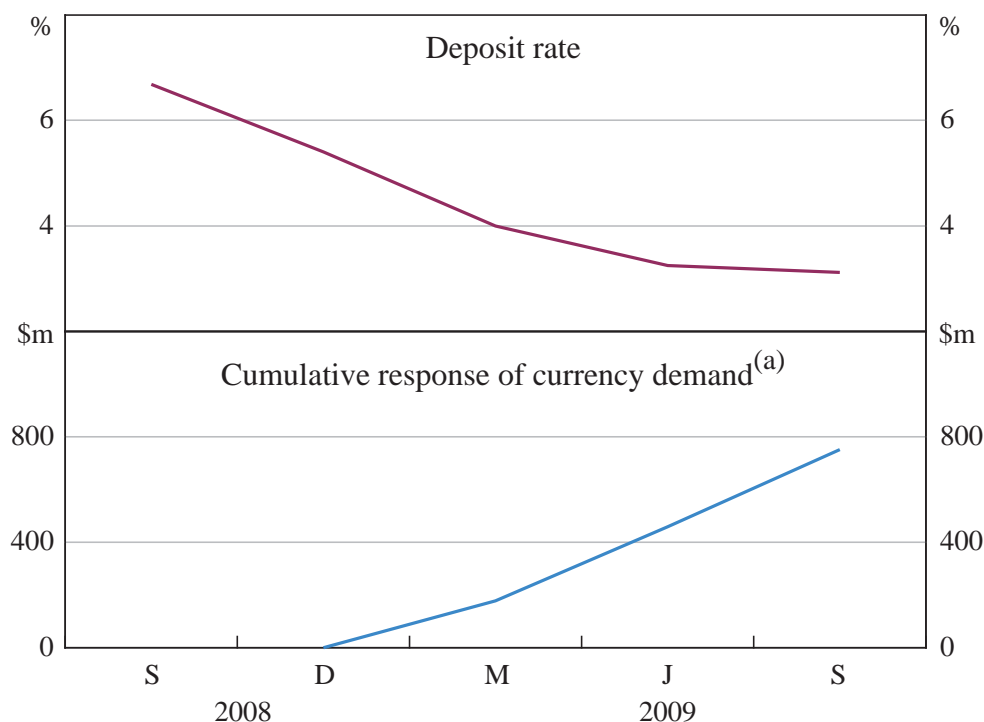
Overall, non-bank currency holdings grew by 6 per cent per year on average over the period. Nominal GDP was the main driver, accounting for around 7 per cent

¹⁸ ATMs and ETPOS terminals per capita increased on average by 9 and 21 per cent per year respectively between 1993 and 2008. Bank branches per capita have decreased by an average of 3 per cent per year over the same period.

average annual growth. The net effect of trends in ATMs, EFTPOS terminals and bank branches was negative and in the order of an average reduction of 1 per cent per year in currency holdings.

Extending the sample to include the surge in currency during the global financial crisis (but with no dummy variables) leads to some changes in the coefficients. In particular, the interest rate becomes insignificant and the lagged dependent variable changes sign and becomes insignificant. With the inclusion of GFC dummy variables, the coefficient on the deposit rate estimated over the full sample is not significantly different to the pre-GFC sample estimation. The coefficient on lagged currency changes switches back to its original sign, but remains insignificant. No other coefficient estimates are significantly different in the two samples. A Chow breakpoint test at December 2008 rejects the null hypothesis of parameter stability, which is consistent with unusual currency demand behaviour from that point.

We can use the coefficients estimated in the pre-GFC sample to generate estimates of the effects of the changes in interest rates on currency demand. The fall in the deposit rate between the September quarter 2008 and the June quarter 2009 of 343 basis points implies a long-run increase of \$1.8 billion in currency demand. However, the short-run effects are much smaller. The estimated response of currency demand to the changing deposit rate in the late 2008–early 2009 period is around \$500 million, only a small fraction of the overall rise (Figure 11).

Figure 11: Estimated Response of Currency Demand to Deposit Rates

Note: (a) The response is calculated based on coefficients estimated in the error correction model using the 1993:Q1–2008:Q2 sample

Sources: RBA; authors' calculations

The model is less well-suited to generating estimates of the effect of the fiscal stimulus payments on currency demand, although this effect will be captured to some extent through the GDP variable.¹⁹ Overall, the dummy variables suggest that 4.4 percentage points of the 6.5 per cent rise in the December quarter 2008 can be attributed to factors other than interest rates and nominal GDP, and that almost all of the further rises in the March and June quarters of 2009 were unexplained by the model (Table 3).

¹⁹ The stimulus payments totalled around 1.7 per cent of annual GDP, but this cannot be directly translated to an increase in transactional demand because the payments were temporary and households could choose to save or spend them.

Table 3: GFC Dummy Variables in the Error Correction Model

	Δ Non-bank currency	Attributed to dummy
	%	ppts
December 2008	6.5	4.4 (0.6)
March 2009	2.7	2.6 (0.8)
June 2009	1.8	1.5 (0.6)
Total	11.0	8.5 (1.3)

Note: Standard errors of estimated coefficients are in parentheses

Around 80 per cent of the rise in currency holdings during the global financial crisis, therefore, cannot be explained by the standard explanatory variables, which is consistent with it being an unusual increase in precautionary demand for currency.²⁰

4.4.2 *Financial crisis models*

We now examine whether confidence and financial variables add explanatory power to the baseline error correction model, and compare them to the GFC dummy variables. The results shown in Table 4 show that a number of these variables, when included individually, improve the explanatory power of the model overall. However, they do not improve the explanatory power of the models in the pre-GFC sample, and the explanatory power of the variables disappears in the presence of the GFC dummy variables.

²⁰ Given that bank deposits also rose, this could be interpreted as a general increase in demand for less risky assets. However, in estimations of a similar model with household deposits as the dependent variable, GFC dummy variables are not significant (compared with the highly significant dummies for non-bank currency holdings in Table 2). This suggests that the rise in currency holdings in late 2008–early 2009 was more unusual than the rise in deposits.

Table 4: Financial Crisis Variables in the Error Correction Model
1993:Q1–2011:Q4

Financial crisis variables ^(a)	Sign	Additional R ²	
			GFC dummies included
GFC dummy variables	+	0.31	
TWI	–	0.23	0.01
VIX	+	0.14	0.00
ASX volatility	+	0.12	0.00
Business confidence	–	0.09	0.00
Household wealth ^(b)	–	0.05	0.00
ASX 200 ^(b)	–	0.04	0.01
Consumer confidence	–	0.00	0.00

Notes: (a) Each included separately in the baseline model shown in column 2 of Table 2

(b) Variables expressed in logarithms

4.4.3 Estimation of banknotes on issue by denomination

Separate models of currency demand for different denominations allow us to test whether low-denomination banknotes are less sensitive to interest rates, which would be the case if the demand for these banknotes is driven more by transaction needs. We can also examine whether demand for high-denomination banknotes was more sensitive to the concerns that drove precautionary holdings of cash during the global financial crisis. We estimate separate models using low-denomination banknotes (the sum of five and ten dollar banknotes), fifty dollar banknotes and one hundred dollar banknotes.²¹ The denomination splits are available only for all banknotes on issue, not just non-bank holdings as above, so we estimate a model of total banknotes on issue as well for comparison.

Table 5 shows the regression results. We removed insignificant variables, leaving us with slightly different models for each independent variable.²² The specification using total banknotes on issue is similar to the non-bank currency holdings

²¹ Twenty dollar banknotes are omitted due to their changing role over time. In regressions with twenty dollar banknotes, all explanatory variables except EFTPOS terminals are insignificant.

²² The coefficient on the dummy variable for Y2K in the December quarter 1999 is insignificant because the effect is muted by averaging across the quarter.

specification in Table 2. The insignificant ATM coefficient could be because the extra currency used by the bank sector to stock ATMs offsets the negative effect of ATMs on non-bank sector currency holdings (as in Table 2). Also, the coefficient on the lagged changes in total banknotes is insignificant.

Table 5: Banknotes on Issue by Denomination – Error Correction Models
1993:Q1–2011:Q4

	Total	Low- denomination	\$50	\$100
Speed of adjustment (λ)	-0.28***	-0.35***	-0.36***	-0.10***
GDP_{t-1} (β_1)	0.88***	0.57***	0.82***	1.14***
$DepositRate_{t-1}$ (β_2)	-0.011***	-0.010**	-0.017***	-0.019*
ATM_{t-1} (β_3)	–	–	0.10*	–
$EFTPOS_{t-1}$ (β_4)	-0.04**	-0.02**	0.08***	-0.22***
$BankBranches_{t-1}$ (β_5)	-0.42***	–	–	-1.05***
Constant (β_0)	9.87***	13.87***	14.45***	–
Δc_{t-1} (δ_1)	–	–	–	0.56***
Dummy variables				
VCH (2003:Q3 onwards)	0.03**	0.11***	0.06**	-0.13***
VCH (2001:Q4)	0.08***	0.12***	0.10***	0.04***
VCH (2002:Q1)	0.04***	0.03***	0.06***	–
GFC (2008:Q4)	0.07***	–	0.12***	0.03***
GFC (2009:Q1)	0.02**	–	0.03**	–
GFC (2009:Q2)	–	–	–	–
Adjusted R ^{2(a)}	0.50	0.37	0.49	0.68
Standard error	0.0076	0.0094	0.012	0.0064
LM(5) test ^(b)	0.12	0.03	0.58	0.13
Chow test (midpoint) ^(b)	0.95	0.17	0.94	0.54

Notes: ***, ** and * indicate significance at the 1, 5 and 10 per cent level, respectively; ‘–’ indicates the variable was not significant and removed from estimation

(a) Not including single quarter dummy variables

(b) p-value of F-statistic reported

The estimated interest rate coefficients are broadly consistent with the theory that demand for larger denominations should be relatively more sensitive to deposit rates. The insignificance of the GFC dummy variables in the low-denomination regression confirms that only larger denominations were behaving unusually in this period. The larger coefficients on the GFC dummies for the \$50 banknote regression compared to the \$100 banknote regression mirrors the larger rise in \$50 banknotes seen at the time.

The rise in high denominations (particularly the \$100 banknotes) is consistent with some individuals converting their deposits into currency for precautionary purposes as the events of the global financial crisis made them more apprehensive about holding deposits. The rise in deposits overall, however, seems to suggest that others may have increased their holdings of deposits by substituting out of relatively more risky assets such as trusts or mortgaged-backed securities.

5. Conclusion

The global financial crisis resulted in the failure or near-failure of a number of large financial institutions in many countries, putting financial markets around the world under considerable stress. Although the solvency of Australian banks was not in jeopardy, there was a substantial policy response in Australia due to the potential economic and financial consequences of the global financial crisis for the domestic economy. The Australian policy response included large interest rate cuts, substantial fiscal stimulus packages and the introduction of a comprehensive deposit guarantee scheme. Coinciding with these measures, Australian currency demand rose at an unprecedented pace, resulting in an additional \$3¼ billion in currency holdings of the non-bank sector.

Around 20 per cent of this rise can be attributed to the normal response of currency holdings to the lowering of interest rates and the increase in incomes from the government stimulus. The remaining 80 per cent of the rise may be due to an increase in precautionary holdings in response to uncertainty in the financial sector, which is consistent with the larger increases in demand for high-denomination banknotes. In addition to the rise in currency holdings of the non-bank sector, the banking sector also built up a larger-than-usual buffer of currency

holdings to guard against spikes in customer demand. This meant that there was an additional \$5 billion of currency on issue in total at the end of 2008.

The rise in currency demand was not large enough to cause any financial system instability. Indeed, bank deposits rose over the period in question. This suggests a degree of robustness in the Australian financial system that was lacking in some other advanced economies. However, the surge did raise some issues for the RBA's banknote distribution operations. The RBA's contingency holdings were tested, suggesting a prudent increase in these holdings as a precaution against any future crises.

It is somewhat surprising that the rise in currency demand occurred around the time that the Federal Government implemented a deposit guarantee. This may reflect the public reacting to the same news as policymakers, but the public may also have had concerns about short-term liquidity even with the deposit guarantee in place.

Data on banknotes on issue are available on a daily basis. Their value as a leading indicator has not been fully established, but they may give a real-time sense of household and bank behaviour in a crisis, especially when buttressed by information from banks about the source of banknote demand and the motivation behind it. The data may also give a sense of whether financial market turmoil is spilling over into the broader economy.

Appendix A: Data

ASX 200 refers to the S&P/ASX 200 stock market index, from Bloomberg.

ASX volatility refers to the intraday range of the ASX 200 (expressed as a percentage of the midpoint), from Bloomberg.

ATM data are from the Australian Payments Clearance Association (APCA) website. Quarterly data are only available from June 1994 before which only annual data are available. Quarterly estimates are obtained by straight-line interpolation.

Banknotes on issue by denomination refer to the value of issued banknotes outside the RBA. These data are from internal RBA sources and seasonally adjusted by the authors, but are also available from the statistical tables on the RBA website, A6 Banknotes on Issue by Denomination.

Broad money data are from the statistical tables on the RBA website, D3 Monetary Aggregates, series mnemonic DMABMS.

Business confidence refers to the NAB business confidence index available from the statistical tables on the RBA website, G8 Indicators of Spending and Confidence, series mnemonic GICNBC.

Consumer confidence refers to the Westpac-Melbourne Institute consumer sentiment series available from the statistical tables on the RBA website, G8 Indicators of Spending and Confidence, series mnemonic GICWMICS.

Currency holdings of the non-bank sector data are from the statistical tables on the RBA website, D3 Monetary Aggregates, series mnemonics DMACN and DMACS.

Currency on issue refers to the sum of banknotes on issue and coins on issue. Coins on issue data are from the Royal Australian Mint.

Deposit rate data for at-call savings and term deposits are from the statistical tables on the RBA website, F4 Retail Deposit and Investment Rates.

EFTPOS terminals data are from the APCA website.

GDP is seasonally adjusted current price GDP from Australian Bureau of Statistics (ABS) Cat No 5206.0 'Australian National Accounts: National Income, Expenditure and Product', series ID A2304418T.

Household wealth data are available from the statistical tables on the RBA website, B20 Selected Assets and Liabilities of the Private Non-financial Sectors, series mnemonic BSPNSHUFAT.

Population data are from ABS Cat No 3101.0 'Australian Demographic Statistics', series ID A2060842F.

M3 data are from the statistical tables on the RBA website, D3 Monetary Aggregates, series mnemonic DMAM3S.

Retail currency withdrawals data are from internal sources and seasonally adjusted by the authors.

Self-employment is the ratio of self-employment to total employment. It was created and seasonally adjusted by the authors using ABS Cat No 6291.0.55.001 'Labour Force, Australia, Detailed - Electronic Delivery', Table 08. Specifying series ID, the formula to create the series is: $(A53534F+A53537L)/A53543J$.

RBA cash rate refers to the target cash rate series from the statistical tables on the RBA website, F1 Interest Rates and Yields – Money Market - daily, series mnemonic FIRMMCRTD.

TWI refers to the quarterly average of the daily trade-weighted exchange rate from the statistical tables on the RBA website.

VIX refers to the Chicago Board Options Exchange SPX Volatility Index, from Bloomberg.

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