Bulletin

SEPTEMBER 2019

RESERVE BANK OF AUSTRALIA

Bulletin

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Contents

The *Bulletin* is published under the direction of the Bulletin Editorial Committee: Luci Ellis (Chair), Andrea Brischetto, Ellis Connolly, Darren Flood, Judy Hitchen, Carl Schwartz and Paula Drew (Secretary).

The *Bulletin* is published quarterly in March, June, September and December and is available at www.rba.gov.au. The next *Bulletin* is due for release on 12 December 2019.

The graphs in this publication were generated using Mathematica.

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ISSN 1837–7211 (Online)

The Committed Liquidity Facility

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Photo: Daniel Grill – Getty Images

Abstract

The Reserve Bank provides the Committed Liquidity Facility (CLF) as part of the global framework to improve the resilience of the banking system to periods of liquidity stress. The CLF is required due to the low level of government debt in Australia. This limits the amount of high-quality liquid assets that financial institutions can reasonably hold as a buffer against periods of liquidity stress. Under the CLF, the Reserve Bank commits to providing a set amount of liquidity to institutions, subject to them satisfying several conditions. These include having paid a fee on the committed amount. No financial institution has needed to draw upon the CLF in response to a period of financial stress.

The Reserve Bank provides the Committed Liquidity Facility (CLF) as part of Australia's implementation of the Basel III liquidity standard.[1] This framework has been designed to improve the banking system's resilience to periods of liquidity stress. In particular, the liquidity coverage ratio (LCR) requires authorised deposit-taking institutions (ADIs) to have enough high-quality liquid assets (HQLA) to cover their net cash outflows in a 30-day liquidity stress scenario. Under the Basel liquidity standard, jurisdictions with a clear shortage of domestic currency HQLA can use alternative approaches to enable financial institutions to satisfy the LCR. These include the central bank offering a CLF. This is a commitment by the central bank to provide funds secured by high-quality collateral through the period of liquidity stress. This commitment can then be counted by the ADI towards meeting its LCR requirement given the scarcity of HQLA. The Australian Prudential Regulation Authority (APRA) has implemented the LCR in Australia, incorporating a CLF provided by the Reserve Bank.[2]

The CLF Is Required Due to the Low Level of Government Debt in Australia

The Australian dollar securities that have been assessed by APRA to be HQLA are Australian Government Securities (AGS) and securities issued by the central borrowing authorities of the states and territories (semis). All other forms of HQLA available in Australian dollars are liabilities of the Reserve Bank, namely banknotes and Exchange Settlement Account (ESA) balances. For securities to be considered HQLA, the Basel liquidity standard requires that they have a low risk profile and be traded in an active and sizeable market. AGS and semis satisfy these requirements since they are issued by governments in Australia and are actively traded in financial markets. In contrast, there is relatively little trading in other key types of Australian dollar securities, such as those issued by supranationals and foreign governments (supras), covered bonds, ADI-issued paper and asset-backed securities (Graph 1). Given this, these securities are not classified as HQLA.

The supply of AGS and semis is not sufficient to meet the liquidity needs of the Australian banking system. This reflects the relatively low levels of government debt in Australia (Graph 2). When the CLF was first introduced in 2015, ADIs would have needed to hold around two-thirds of the stock of HQLA securities to be able to cover their LCR requirements. Such a high share of ownership by the ADIs would have reduced the liquidity of these securities, defeating the purpose of them being counted on as HQLA.

Jurisdictions with low government debt have used a range of approaches to address the resulting shortage of domestic currency HQLA. Australia is one of three countries that have put in place a CLF, along with Russia and South Africa. Some other jurisdictions have allowed financial institutions to hold HQLA in foreign currencies to cover their liquidity needs in domestic currency. The main downsides of the latter approach is that it relies on foreign exchange markets to be functioning smoothly in a time of stress and increases the foreign currency exposures in the banking system. Some jurisdictions have classified a broader range of domestic currency securities as HQLA. However, this approach has not been taken in Australia due to the low liquidity of Australian dollar securities other than AGS and semis.

The Conditions for Accessing the CLF

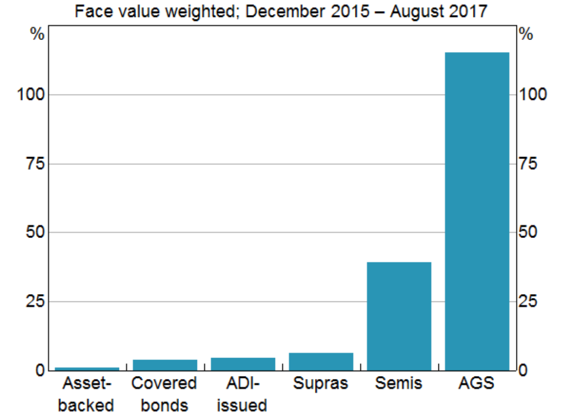
APRA determines which ADIs can establish a CLF with the Reserve Bank. Access is limited to those ADIs domiciled in Australia that are subject to the LCR requirement.[3] Before establishing a CLF, these ADIs must apply to APRA for approval. In these applications, the ADIs have to demonstrate that they are making every reasonable effort to manage their liquidity risk independently rather than relying on the CLF. APRA also sets the size of the CLF, both in aggregate and for each ADI.

The Reserve Bank makes a commitment under the CLF to provide a set amount of liquidity against eligible securities as collateral, subject to the ADI having satisfied several conditions.[4] The ADI is required to pay a CLF fee to the Reserve Bank that is charged on the entire committed amount (not just

Graph 1

Monthly Turnover Ratio for AUD Bonds*

Face value weighted; December 2015 – August 2017



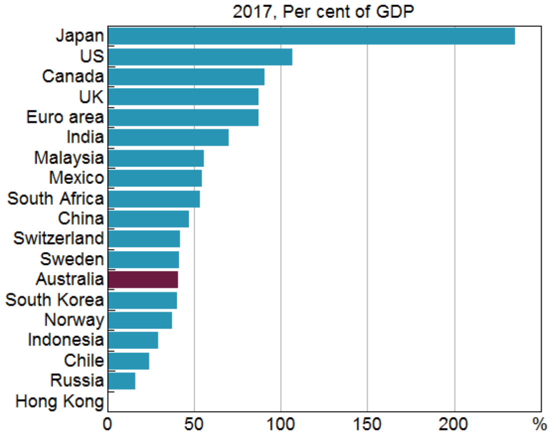
* Includes non-RBA repos and an estimate of bonds that did not trade in the period

Sources: Austraclear; RBA

Graph 2

Gross Government Debt

2017, Per cent of GDP



Source: IMF

Table 1: CLF ADIs' Reasonable Holdings of HQLA Securities and LCR Requirements

$ billion

	RBA projection of HQLA securities outstanding[(a)]	RBA assessment of CLF ADIs' reasonable holdings of HQLA Securities	CLF ADIs' projected LCR requirements[(b)]	Aggregate CLF amount
2015	700	175	449	274
2016	780	195	441	246
2017	880	220	437	217
2018	905	226	474	248
2019	898	225	468	243
2020	934	243		

(a) As an input to APRA's assessment of the aggregate CLF amount for the following calendar year, the RBA publishes its projection of the market value of HQLA securities that will be outstanding at the end of that year; this is based on information available from the Australian Government and state government borrowing authorities.

(b) 'LCR requirements' refers to APRA's assessment of the aggregate Australian dollar net cash outflows for the CLF ADIs at the end of the calendar year, including an allowance for the ADIs to have buffers over the minimum LCR requirement of 100 per cent; it also takes into account ADIs' projected holdings of banknotes and ESA balances.

Sources: APRA; RBA

the amount drawn). To access liquidity through the CLF, an ADI must make a formal request to the Reserve Bank that includes an attestation from its CEO that the institution has positive net worth. The ADI must also have positive net worth in the opinion of the Reserve Bank.

Under the CLF, the Reserve Bank will provide an ADI with liquidity via repurchase agreements (repos). In a repo, funds are exchanged for high-quality securities as collateral until the funds are repaid. These securities must meet criteria set by the Reserve Bank. The types of securities that the ADIs can hold for the CLF include self-securitised residential mortgage backed securities (RMBS), ADI-issued securities, supras, and other asset-backed securities. To protect against a decline in the value of these securities should an ADI not meet its obligation to repay, the Reserve Bank requires the value of the securities to exceed the amount of liquidity provided by a certain margin. These margins are set by the Reserve Bank to manage the risks associated with holding these securities.[5] If the CLF is drawn upon, the ADI must also pay interest to the Reserve Bank for the term of the repo at a rate set 25 basis points above the cash rate.

The First Five Years of the CLF

Since the CLF was introduced in 2015, the number of ADIs that have applied to APRA to have a facility has risen from 13 to 15.[6] Each year, APRA sets the total size of the CLF by taking the difference between the Australian dollar liquidity requirements of the ADIs and the amount of HQLA securities that the Reserve Bank assesses can be reasonably held by these ADIs (the CLF ADIs) without unduly affecting market functioning.

For 2015-19, the Reserve Bank assessed that the CLF ADIs could reasonably hold 25 per cent of the stock of HQLA securities. In determining this, the Reserve Bank took into account the impact of the CLF ADIs' holdings on the liquidity of HQLA securities in secondary markets, along with the holdings of other market participants. The volume of HQLA securities that the CLF ADIs could reasonably hold increased from $175 billion in 2015 to $225 billion in 2019, reflecting growth in the stock of HQLA securities (Table 1). Over the period, the CLF ADIs held a significantly higher share of the stock of HQLA securities than in the years leading up to the introduction of the LCR (Graph 3). The CLF ADIs have been holding a larger share of the stock of semis compared to AGS.

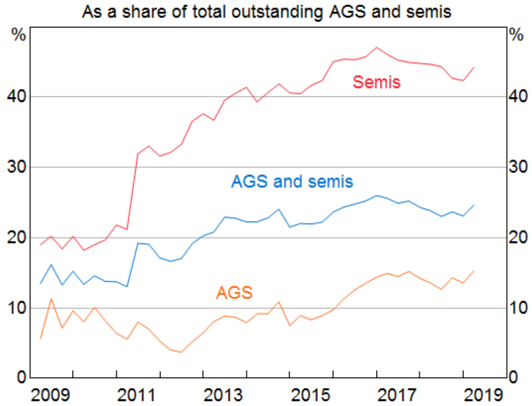
The CLF ADIs' projected LCR requirements, which were used in calculating the CLF, increased modestly in aggregate from $449 billion in 2015 to $468 billion in 2019. This increase can be entirely explained by the CLF ADIs seeking to raise their liquidity buffers over time to be well above the minimum LCR requirement of 100. Reflecting this, the aggregate LCR for these ADIs increased from around 120 per cent in 2015 to around 130 per cent in 2019; this was the case for their Australian dollar liquidity requirements as well as for their requirements across all currencies (Graph 4).[7]

The aggregate CLF amount is the CLF ADIs' projected LCR requirements less the RBA's assessment of their reasonable holdings of HQLA securities. APRA reduced the aggregate size of the CLF from $274 billion in 2015 to $243 billion in 2019. This reflected that the volume of HQLA securities that the CLF ADIs could reasonably hold increased by more than their projected liquidity requirements over this period.

Graph 3

CLF ADIs' Holdings of AUD HQLA Securities

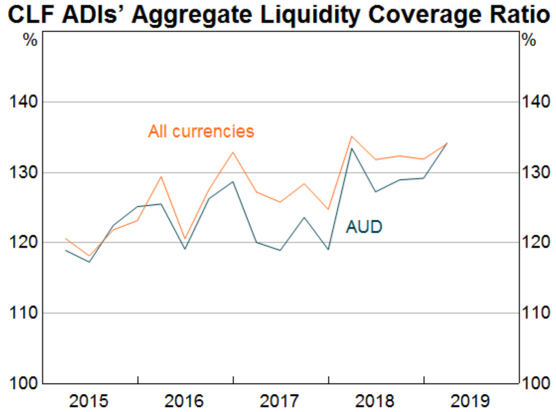
As a share of total outstanding AGS and semis



Sources: ABS; AOFM; APRA; RBA

Graph 4

CLF ADIs' Aggregate Liquidity Coverage Ratio



Sources: APRA; RBA

From 2015 to 2019, the Reserve Bank charged a CLF fee of 15 basis points per annum on the commitment to each ADI. The fee is set so that ADIs face similar financial incentives to meet their liquidity requirements through the CLF or by holding HQLA. The amount of CLF fee paid by the CLF ADIs to the Reserve Bank declined from $413 million in 2015 to $365 million in 2019, which is in line with the reduction in the size of the CLF. Since the CLF was established, no ADI has drawn on the facility in response to a period of financial stress.[8]

Assessing ADIs' Reasonable Holdings of HQLA Securities

When assessing the volume of HQLA securities that the CLF ADIs can reasonably hold, the Reserve Bank seeks to ensure that these holdings are not so large that they impair market functioning or liquidity. For the period from 2015 to 2019, the Reserve Bank assessed that the CLF ADIs could reasonably hold 25 per cent of HQLA securities without materially reducing their liquidity. This was informed by the fact that a large proportion of HQLA securities were owned by 'buy and hold' investors. These investors were price inelastic and generally did not lend these securities back to the market, reducing the free float of HQLA securities. Many of these investors were non-residents (such as sovereign wealth funds), which were holding nearly 60 per cent of the stock of HQLA securities earlier in the decade (Graph 5). So overall, the Reserve Bank concluded that these bond holdings were not contributing significantly to liquidity in the market.

Over recent years, the volume of HQLA securities has risen and they have become more readily available in bond and repo markets (Table 1). The Australian repo market has grown considerably, driven by more HQLA securities being sold under repo. Since 2015, non-residents have emerged as significant lenders of AGS and semis (and borrowers of cash) in the domestic market (Graph 6). Over the same period, repo rates at the Reserve Bank's open market operations have risen relative to unsecured funding rates (Graph 7). This is consistent with market participants financing a larger volume of HQLA securities on a short-term basis through the repo market. For this assessment, the increased availability of HQLA securities in the market suggests that the CLF ADIs should be able to hold a higher share of these securities without impairing market functioning.

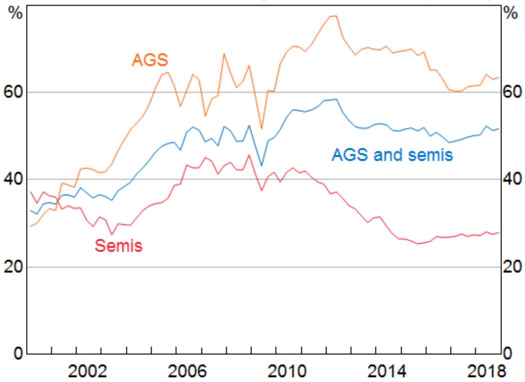
Analysis of transactions in the bond and repo markets using data from 2015–17 suggests that most HQLA securities were being actively traded.[9] Monthly turnover ratios for AGS bond lines were well above zero, and much higher than turnover ratios for other Australian dollar securities such as asset-backed securities, covered bonds, ADI-issued paper and supras (Graph 1). Although semis bond lines were traded less frequently than AGS, relatively few semis had low turnover ratios (Graph 8). As such, some increase in ADIs' holdings of AGS and semis would appear unlikely to jeopardise liquidity in these markets.

Earlier in the decade, a 'scarcity premium' had emerged in the pricing of HQLA securities. Australia's relatively strong economic performance and AAA sovereign rating have been of considerable appeal to investors with a preference for highly rated securities. Higher yields compared to other AAA-rated sovereigns also contributed to strong demand from foreign investors, particularly for AGS. The scarcity premium was most prominent before 2015, when the yield on 3-year AGS was well below the expected cash rate over the equivalent horizon (as measured by overnight indexed swaps (OIS); Graph 9). However, the scarcity premium has dissipated alongside an increase in the stock of AGS

Graph 5

Non-resident holdings of HQLA Securities*

As a share of total outstanding AGS and semis respectively



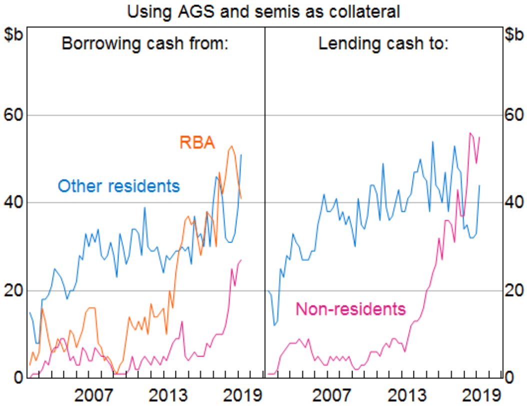
* Holdings are adjusted for AGS and semis held under repurchase agreements from 2009 onwards

Sources: ABS; AOFM; APRA; RBA

Graph 6

Repurchase Agreements*

Using AGS and semis as collateral



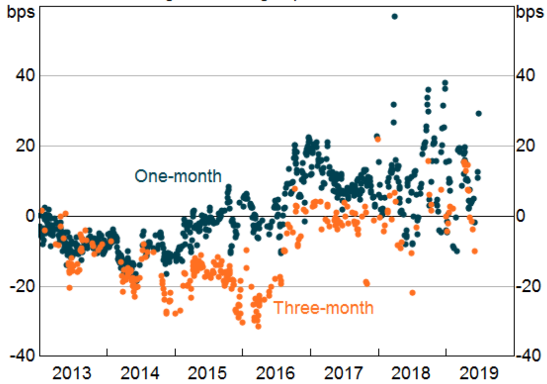
* Entered into by banks and registered financial corporations

Sources: APRA; RBA

Graph 7

Repo Rates at Open Market Operations*

Weighted-average spread to BBSW



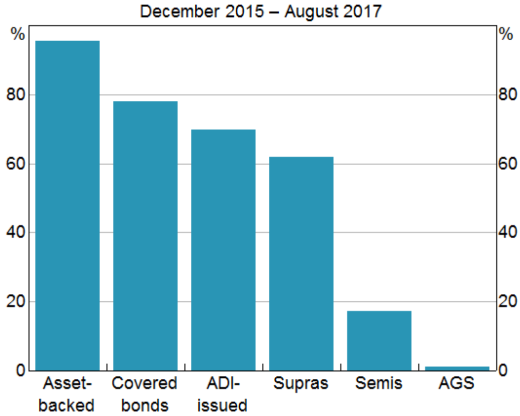
* One-month (Three-month) refers to repo terms between 23 and 37 (75 and 105) days

Sources: ASX; RBA; Tullet Prebon (Australia) Pty Ltd

Graph 8

Bonds with Low Turnover Ratios*

December 2015 – August 2017



* Share of AUD bond lines with monthly turnover ratio less than 5 per cent

Sources: Austraclear; RBA

Table 2: Yields on CLF ADIs' Portfolios of CLF Collateral and HQLA Securities

March quarter 2019

	Share[a] Per cent of CLF collateral or HQLA securities respectively	Yield Per cent
CLF collateral held by CLF ADIs	**100**	**2.9**
Marketed securities	29	2.6
– Supras	2	2.2
– ADI-issued securities	18	2.4
– Bonds	*11*	*2.6*
– Bills	*8*	*2.1*
– Asset-backed securities	8	3.0
Self-securitised RMBS	71	3.0
HQLA securities held by CLF ADIs	**100**	**2.0**
AGS	39	1.9
Semis	61	2.1
Spread of CLF collateral to HQLA securities		**0.9**

(a) CLF ADIs' holdings of collateral as at December 2018.

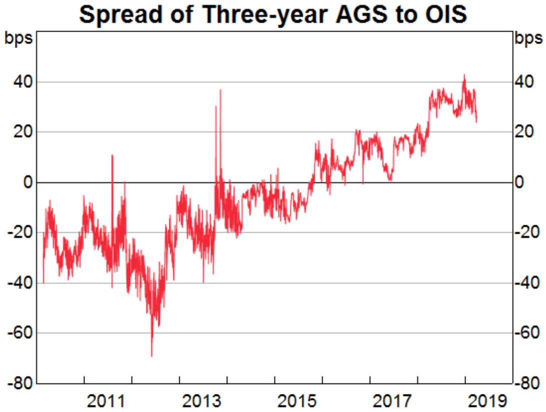
Sources: ABS; APRA; Bloomberg; ICE; RBA; Thomson Reuters

on issue. This suggests that there is scope for the CLF ADIs to hold more HQLA securities without impairing market functioning.

Given these developments, the Reserve Bank has assessed that the CLF ADIs should be able to increase their holdings to 30 per cent of the stock of HQLA securities.[10] To ensure a smooth transition and thereby minimise the effect on market functioning, the increase in the CLF ADIs' reasonable holdings of HQLA securities will occur at a pace of 1 percentage point per year until 2024, commencing with an increase to 26 per cent in 2020.

Graph 9

Spread of Three-year AGS to OIS



Sources: Bloomberg; RBA

The CLF Fee

The Reserve Bank sets the level of the CLF fee such that ADIs face similar financial incentives when holding additional HQLA securities or applying for a higher CLF in order to satisfy their liquidity requirements. A useful starting point to assess the appropriate CLF fee is to compare the yields on the CLF collateral and the HQLA securities held by the relevant ADIs.[11] The Reserve Bank estimated that the weighted average yield differential between the CLF collateral and the HQLA securities was around 90 basis points in the March quarter 2019 (Table 2). This includes the compensation required by ADIs to account for the higher credit risk associated with holding CLF collateral rather than HQLA securities, which would be a sizeable share of the spread. However, it is only the additional liquidity risk associated with holding CLF collateral that should be reflected in the CLF fee. In practice, adjusting the spread between CLF collateral and HQLA securities to remove the credit risk component is not straightforward.

When the Reserve Bank set the CLF fee earlier this decade, it looked at repo rates on some CLF-eligible securities to gauge how much a one-month liquidity premium might be worth. Before late 2013,

Table 3: CLF ADIs' Net Cash Outflows in LCR Scenario and Holdings of HQLA Securities
$ billion

	CLF ADIs' Net Cash Outflows in LCR Scenario			CLF ADIs' Holdings of HQLA Securities		
	Projection used for CLF	Actual[(a)]	Difference	RBA's assessment of reasonable holdings	Actual	Difference
2015	410	360	–50	175	170	–5
2016	402	353	–49	195	201	+6
2017	394	357	–37	220	202	–18
2018	387	355	–32	226	201	–25

(a) CLF ADIs' final estimates of net cash outflows under the LCR stress scenario using actual balance sheet data at the end of the relevant year.

Sources: APRA; RBA

it was possible to separately identify repo rates on government securities (AGS and semis) and private securities (such as ADI-issued securities) in the Reserve Bank's market operations. Based on these data, it was estimated that the one-month liquidity premium for private securities was less than 10 basis points in normal circumstances. However, given that part of the purpose of the liquidity reforms was to recognise that the market had under-priced liquidity in the past, it was judged to have been appropriate to set the fee at 15 basis points.

It has since become more difficult to gauge a liquidity premium by using repo rates. In particular, in late 2013 the Reserve Bank ceased to charge different repo rates for government and private securities. Instead, the Bank revised its margin schedule to manage the credit risk on different types of collateral accepted under repo. Moreover, most of the collateral now being purchased by the Reserve Bank under repo is HQLA securities. This suggests that repo rates mostly reflect the price for converting HQLA securities into ESA balances, rather than CLF collateral into HQLA.

At the same time, it is now possible to take into account how the CLF ADIs have responded to the existing framework when setting the future CLF fee. Since the CLF was introduced, the CLF ADIs (in aggregate) have consistently overestimated their liquidity requirements (Table 3). This has resulted in the CLF ADIs being granted larger CLF amounts, which they have mainly used to hold larger buffers above the minimum required LCR of 100 (Graph 4).[12] In recent years, the CLF ADIs have also been holding fewer HQLA securities than the Reserve Bank had judged could be reasonably held without impairing the market for HQLA securities. Taken together, these two observations suggest that the CLF fee should be set at a higher level in future.

However, there is uncertainty about the exact level of the fee that would make ADIs indifferent between holding more HQLA or applying for a larger CLF. If the CLF fee is set too high, this could trigger a disruptive shift away from using the facility and distort the markets that use HQLA. This has potential implications for the implementation of monetary policy, since the market that underpins the cash rate involves the trading of ESA balances, which are also HQLA.[13] The remuneration on ESA balances is purposefully set at a rate of 25 basis points below the cash rate target in order to encourage ADIs to recycle their surplus ESA balances rather than holding them. There are scenarios where holding ESA balances could be a cheaper way to satisfy the LCR than holding HQLA securities. For instance, earlier in the decade, the yield on AGS was at or below the expected return from holding ESA balances (Graph 9). In this context, the CLF fee should be set such that ADIs would not have an incentive to meet their LCR requirements by holding excessive ESA balances.

As a result of these considerations, the RBA has concluded that the CLF fee should be increased moderately. This should ensure that ADIs have strong incentives to manage their liquidity risk appropriately, without generating unwarranted distortions in the markets that use HQLA. To ensure a smooth transition by minimising the effect on market functioning, the increase will occur in two steps, with the CLF fee rising to 17 basis points on 1 January 2020 and to 20 basis points on 1 January 2021.[14]

Conclusion

The CLF has been in operation for five years and continues to be required given the still relatively low level of government debt in Australia. However, because the volume of HQLA securities has increased over recent years and they appear to have become more available for trading in secondary and repo markets, the Reserve Bank has assessed that the CLF ADIs should be able to raise their holdings to 30 per cent of the stock of HQLA securities. This increase will occur at a pace of 1 percentage point each year, commencing with an increase to 26 per cent in 2020. Taking into account how the CLF ADIs have responded to the framework between 2015 and 2019, the Reserve Bank has also concluded that the CLF fee should be increased from 15 basis points to 20 basis points by 2021; this is to proceed in two steps, with the fee rising to 17 basis points on 1 January 2020 and to 20 basis point on 1 January 2021.

Footnotes

[*] The authors completed this article while in Domestic Markets Department. The authors would also like to thank Julie Guo, Dmitry Titkov and Zhan Zhang for their contribution to this work.

[1] See BCBS (2013); for more information about the introduction of the CLF, see Debelle (2011).

[2] See APRA (2018)

[3] ADIs that are branches of foreign banks are required by APRA to maintain an LCR of only 40 per cent, and therefore do not need access to the CLF.

[4] The legal documentation for the CLF is published on the Reserve Bank's website at https://www.rba.gov.au/mkt-operations/resources/tech-notes/pdf/clf-terms-and-conditions.pdf and https://www.rba.gov.au/mkt-operations/resources/tech-notes/clf-operational-notes.html.

[5] For more information about the Reserve Bank's collateral framework, see Naghiloo and Olivan (2017).

[6] APRA publishes the list of ADIs domiciled in Australia that are subject to the LCR at: <https://www.apra.gov.au/frequently-asked-questions-faqs-liquidity>. These banks are AMP Bank Ltd, Australia and New Zealand Banking Group Limited, Bank of China (Australia) Limited, Bank of Queensland Limited, Bendigo and Adelaide Bank Limited, Citigroup Pty Limited, Commonwealth Bank of Australia, HSBC Bank Australia Limited, ING Bank (Australia) Limited, Macquarie Bank Limited, Members Equity Bank Limited, National Australia Bank Limited, Rabobank Australia Limited, Suncorp-Metway Limited and Westpac Banking Corporation.

[7] The CLF is only designed to address the shortage of Australian dollar HQLA, so that the ADIs can meet their Australian dollar liquidity needs as measured by an Australian dollar LCR; the ADIs are also required to meet their liquidity needs in other currencies as measured by an 'all currencies' LCR. For more information on how the ADIs responded to the introduction of the LCR, see Debelle (2015) and Atkin and Cheung (2017).

[8] Some ADIs have technically been drawing upon the CLF, since any usage of the Reserve Bank's standing facilities by a CLF ADI is considered to be a drawing on their CLF. In particular, some ADIs maintain 'open repos' with the Reserve Bank to support the smooth functioning of the payments system. The funds obtained via these open repos are held in the ADIs' ESAs for use in meeting their payment obligations after normal banking hours, such as from transactions through the New Payments Platform. These open repos have averaged around $25 billion over the past five years, and account for virtually all of the usage of the CLF over this period. The remaining usage of the CLF has been for small test transactions.

[9] The data analysed were on a settlement basis. Trades between counterparties with the same Austraclear custodian account are not recorded. RBA repo transactions have been excluded, while repo transactions between non-RBA accounts are recorded twice (the initial transaction and the unwinding of the repo).

[10] This was announced by the Reserve Bank in a media release on 7 June 2019: https://www.rba.gov.au/media-releases/2019/mr-19-16.html

[11] Around 70 per cent of CLF collateral has been self-securitised RMBS, with the remainder largely consisting of ADI-issued securities and marketed asset-backed securities. The CLF ADIs' holdings of HQLA Securities have been around 60 per cent semis and 40 per cent AGS.

[12] Each year, as part of their CLF applications, the CLF ADIs provide APRA with projections of their net cash outflows for the following year, which APRA uses (along with the RBA's projection of reasonable holdings of HQLA Securities) to set the aggregate size of the CLF.

[13] For more information about monetary policy implementation, see RBA (2019).

[14] Other jurisdictions that have implemented a CLF have also increased the fee on the facility. The Central Bank of Russia introduced a CLF in 2016 with a fee of 15 basis points, and has recently increased the fee to 50 basis points. The South African Reserve Bank (SARB) put in place a CLF in 2015, with a fee scale that increased depending on the extent to which financial institutions used the facility. The maximum weighted average fee for the facility was 30 basis points in 2015. Since 2017, the SARB has charged a flat fee of 58 basis points.

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A Brief History of Currency Counterfeiting

Richard Finlay and Anny Francis[*]

Photo: *The Sunday Telegraph*

Abstract

The crime of counterfeiting is as old as money itself, and can be targeted at both low- and high-value denominations. In most cases, counterfeiting is motivated by personal gain but, at times, it has also been used as a political weapon to destabilise rival countries. This article gives a brief history of counterfeiting, with a particular focus on Australia, highlighting selected incidents through time and the policy responses to them. For source material on Australia, we draw on Reserve Bank archives dating back to the early 1900s.

Introduction

Historical evidence suggests that, for as long as physical money has existed, it has been counterfeited.[1] The reason to counterfeit – in the distant past and today – is usually fairly straightforward: the possibility of money for (almost) nothing, offset of course against the likelihood of getting caught and punished. However, the means of counterfeiting has changed, with rapid technological advances making counterfeiting arguably easier and reducing the amount of time that a currency remains resilient to counterfeiting. As a result, currency issuers have tended to release new currencies in shortening timespans in order to stay ahead of counterfeiters.

Early Counterfeiting

Counterfeiting predates the most common forms of physical currency used today, namely coins and banknotes. While it is difficult to pinpoint the very earliest form of money used, cowrie shells are a contender, having been used as currency as far back as 3300–2000 BC; they were also imitated using ivory, bone, clam shell and stone, and later bronze (Figure 1; Davies 1994; Peng & Zhu 1995).

Moving to more familiar forms of money, early coins were subject to counterfeiting via a range of different methods. Around 400 BC for instance, Greek coins were commonly counterfeited by covering a less valuable metal with a layer of precious metal (Markowitz 2018). Another method was to make a mould from a relatively low-value genuine copper coin, which was then filled with molten metal to form a counterfeit. The widespread practice of counterfeiting coins led to the rise of official coin testers, who were employed to weigh and cut coins to check the metal at the core.

Coin 'shaving' or 'clipping' was another commonly observed method of early coin fraud, whereby the edges of silver coins were gradually shaved off and melted down. In 17th century England, for example, the weight of properly minted money had fallen to half the legal standard, while one in 10 British coins was counterfeit (Levenson 2010). To remedy the situation, by mid 1690 all British coins had been recalled and reminted, and Sir Isaac Newton – the warden of the Royal Mint as well as the person who formulated the laws of motion and gravity – was tasked with stopping the situation re-emerging. By the end of 1699 he had successfully identified the lead counterfeiter as William Chaloner, who had produced counterfeits with a face value of £30,000 (worth around A$10 million today). He was ultimately hanged for his crimes.

Early paper banknotes were also counterfeited. Some of the first banknotes to be issued appeared in the Song Dynasty in China towards the end of the 10th century, and were known as 'jiaozi' (Von Glahn 2005). Initially jiaozi were issued privately by all manner of entities but, in 1005, the right to issue jiaozi was restricted by the authorities to 16 merchant houses. Complex designs, special colours, signatures, seals and stamps on specially made paper were used to discourage counterfeiters. Those caught counterfeiting faced the death penalty. Despite this, counterfeiting increased over time. This, along with an oversupply of jiaozi, led to inflation and in 1024 the right to print and issue currency was restricted to the government. The officially issued notes 'expired' after two years, after which they were redeemed, for a 3 per cent fee. This policy – perhaps the first 'clean note' policy in history – was in part aimed at preventing circulating currency from becoming too worn and tattered; having a higher quality of notes should make it easier to distinguish counterfeits from the genuine article. Some aspects of the evolution of the Song Dynasty's approach to note issue – such as moving from multiple issuers to just the government, having increasingly complex banknote designs and implementing a clean note policy – can be seen in modern banknote policy evolution 1,000 years later, including in Australia as discussed below.

Figure 1: Cowrie Shells

Photo: Getty Images

The Pre-decimal Era in Australia

The earliest forms of paper money used in Australia were not fixed denomination banknotes as we know them today, but were more akin to promissory notes or personal IOUs. They were redeemable in coin and issued either by government authorities in exchange for produce, or by private individuals, with the latter often just handwritten on pieces of paper. The lack of any serious security features on these notes predictably led to forgeries. On 1 October 1800, the Governor of the Colony of New South Wales, Captain Philip King, noted that '[due to] the indiscriminate manner in which every description of persons in the colony have circulated their promissory notes … numerous forgeries have been committed, for which some have suffered, and others remain under the sentence of death'. While Governor King passed orders designed to regularise issuance, privately issued, hand-written notes continued to circulate, and be forged, in the years that followed (Vort-Ronald 1979).[2]

Banknotes proper were first issued in Australia in 1817 by the Bank of New South Wales, the forerunner of today's Westpac. Banknotes continued to be issued by various private banks (and the State of Queensland) throughout the 1800s. The proliferation of different notes made it difficult for the public to keep track of what was what, however, and counterfeiters made use of this by 'converting' low-value or worthless notes into what appeared to be relatively high-value notes (Vort-Ronald 1979). Eventually the authorities decided to standardise Australian banknotes. In 1910, the *Australian Notes Act 1910* barred Australian states from issuing banknotes, with this responsibility transferred to the Commonwealth Treasury. Under the *Bank Notes Tax Act 1910*, commercial banks were strongly incentivised not to issue banknotes by means of a 10 per cent tax levied on their outstanding issue. In 1920, the sole responsibility for note issue was taken over by the government-owned Commonwealth Bank, the Reserve Bank's forerunner.[3]

Reserve Bank archives relating to banknotes begin around 1910 and already by 1921 a major counterfeiting event had been recorded. It was discovered that, in 1921, almost £3,000 (around $250,000 in current prices) in counterfeit £1 and £5 notes were circulating, corresponding to an estimated counterfeiting rate for those denominations in the order of hundreds of parts per million (compared with around 10 parts per million currently). Thomas S Harrison, the Australian Note and Stamp Printer, was apparently unsurprised, noting 'the forgery … is of very poor workmanship and in my opinion has been manufactured by a criminal of a rather low type … a cleaner issue would minimise largely forged notes of this description being accepted … I cannot too strongly recommend the adoption of an engraved portrait in the design of Australian notes … I would reiterate my oft expressed opinion that the existing issue of Australian Notes, so far as design and character of work are concerned, are nothing more than what might be termed glorified jam labels' (letter to the Secretary of the Commonwealth Treasury, 18 August 1921).

Newspaper reports at the time record one Ernst Dawe, a goldminer from Kalgoorlie, charged in relation to the counterfeits: Dawe was 'alleged to have introduced two Jugo-Slavs to a man who went under the name Jacobson … the accused was present when the man known as Jacobson paid the Slavs in forged bank notes for a large quantity of gold' ('Gold Dealing', *West Australian*, 4 March 1922, p 7). The connection to the counterfeits was not proven, however, and Dawe was found not guilty.

The authorities appear to have taken on board a number of lessons flowing from this and earlier counterfeiting incidents. The Commonwealth Bank ceased its practice 'of paying £4 to the Public and £3 to the Banks in respect of forged £5 Notes' (letter from HT Armitage, Secretary, dated 15 June 1921), which had provided an incentive to counterfeit. To make counterfeiting more difficult, future banknote series typically contained at least one portrait.[4]

It is not uncommon for counterfeit manufacturers, once caught, to claim that the counterfeits they made were for promotional or other innocent purposes, and not made to be passed off as genuine. Even if true, manufacturing such copies is against the law, in part because no matter the original intended purpose, the counterfeits can still end up being passed off as genuine money and deceiving people. A case from 1927 illustrates this. Lance Skelton, John Gillian, and Roy Ostberg were tried for printing £12,500 worth of counterfeits (around $1 million in current prices). They claimed that 'the notes were crudely printed on one side. It was intended to use the other side for advertising purposes' ('Note conspiracy charges', *The Argus*, 26 March 1927, p 35). The first two men were nonetheless convicted and sentenced to four years in prison with hard labour, while Mr Ostberg was acquitted.

Another interesting episode concerns not so much counterfeits, as the law criminalising them. Section 60T of the *Commonwealth Bank Act 1920* stated that it was an offence to possess counterfeit money. In 1927 Albert Wignall pleaded guilty to possessing 21 forged £5 notes but maintained that he had found them and had not known that they were counterfeits. This is despite earlier telling police 'cut my head off if I tell you [who gave them to me]' (statement by police officer John James Keogh, 15 February 1927). The judge hearing the case described the relevant law as 'ridiculous' since 'as the charge is framed, anyone who handled the notes in court is liable to be arrested and charged', and ruled that one could not be convicted unless one had 'guilty knowledge' ('Ridiculous Act Has Dangerous Side', *The Evening News*, 29 April 1927, p 8). The current version of the relevant law, as contained in the *Crimes (Currency) Act 1981*, states that 'a person shall not have in his or her possession counterfeit money … [this] *does not apply if the person has a reasonable excuse*'. A related prohibition against possessing equipment that could be used to make counterfeits, which as originally drafted in law would have captured all printing presses in the country and today could conceivably capture anyone who owns a desktop printer, has similarly been amended.

A loss of confidence in banknotes can have serious economic and social implications; this was especially true in the past when people were poorer (and so the loss flowing from unknowingly accepting a counterfeit was higher), the real value of banknotes was higher (the purchasing power of £5 in 1940 is around $400 in today's money), and there were no alternative payment methods to fall back on. This was demonstrated in 1940 when counterfeit £5 notes again became a major problem. A spate of hotels was defrauded and a large number of individuals were charged and convicted of passing forgeries. The police described it as 'a determined gigantic attempt to defraud the public' ('Forged notes', *Sydney Morning Herald*, 14 February 1940, p 8), and many workers and businesses refused to accept the £5 denomination (Figure 2).[5] While a number of individuals with many tens of notes – and who were therefore likely close acquaintances of the manufacturers – were caught and convicted, it appears that the manufacturers themselves were not caught. A police officer noted at that time that 'The plant that produced them is probably at the bottom of the harbour by now' ('Many forged £5 notes still out', *The Daily Telegraph*, 25 February 1940, p 5).

Australian Counterfeiting in the Decimal Era

The mid 1950s saw another spike in counterfeit £5 notes but, in 1966, Australia switched from pounds, shillings and pence to decimal currency. With this change, a new series of what were then state-of-the-art banknotes was introduced. The security features used on the new banknotes – including raised intaglio print and a metallic security thread embedded within the banknote substrate – were believed at the time to make them very hard to counterfeit, and so it came as a shock when one of the largest historical counterfeiting episodes in Australia followed less than a year later. In late 1966, forgeries of the new $10 note from what appeared to be a single counterfeiting syndicate began to appear in large numbers. It became known as the 'Times Bakery' counterfeiting incident, as the horizontal lines on the Times Bakery building on the counterfeits were not flush with the vertical edge of the building, as they should have been (Figure 3). These forgeries became a major issue, with police estimating at the time that $1 million worth – around $12.5 million in current prices, and equivalent to a counterfeiting rate of several thousand parts per million – were put into circulation, and numerous newspaper articles were written on the case ('Police fear $1m in fake $10 notes', *The Sun*, 26 December 1966, p 3).[6] In 1967, 10 defendants, five of whom came from the same family, were arrested and charged with manufacturing and distributing the fake notes in what was at the time a sensational case.[7] Seven of the accused were eventually found guilty and jailed,

Figure 2: How to spot a counterfeit £5 note

Source: 'Huge counterfeit banknote coup', *The Sunday Telegraph*, 28 January 1940, p 1 although their counterfeit notes appear to have still been turning up 11 years later ('More dud notes turn up in shops', *The Daily Telegraph*, 5 August 1977, p 9). One of the leading counterfeiters, Jeffery Mutton, wrote a manuscript while in prison, which was later unearthed and written about in the press (Shand, 2012). In the manuscript, Mutton revealed that he had been undone when Mutton's sister-in-law unknowingly used one of the counterfeits at her local corner store; the shop assistant suspected the notes weren't genuine, took down the sister-in-law's number plates, and alerted police. In his manuscript, Mutton wrote that his 10-year jail sentence was 'small compared to the heartbreak, degradation and insecurity I have brought on my family'.

The Times Bakery incident prompted the Reserve Bank to offer a $10,000 reward for information leading to the apprehension and conviction of future counterfeiters (Commonwealth Treasury Press Release N. 941, 11 December 1967; Figure 4), while the lack of a well-coordinated police response led to public calls for the federal police to take over primary responsibility for the investigation of counterfeits from state police forces (Kennedy 1967). On 8 December 1967, the Attorney-General announced that Commonwealth Police Officers (the forerunner of today's Australian Federal Police (AFP)) would be assigned to combat counterfeiting on a full-time basis, with technical assistance from the Reserve Bank; this arrangement is still in place today. This counterfeiting incident also ultimately led to Reserve Bank-sponsored research by the CSIRO into how to make banknotes more secure, which, in turn, resulted in Australia's polymer banknote technology.[8]

Figure 3: A 'Times Bakery' Counterfeit

Source: https://museum.rba.gov.au/displays/polymer-banknotes/

Selected International Episodes from Modern Times

Counterfeiters with access to a criminal network have, on occasion, made large profits producing high volumes of counterfeits, at least initially. Stephen Jory, an infamous British criminal who produced £300 million worth of fake perfume in the 1970s, is a prime example. After enhancing his criminal connections in prison, Jory and others set up an operation which manufactured counterfeit £20 banknotes in the garage of a house in Essex. Between 1994 and 1998, two-thirds of Britain's counterfeit money was produced by the gang – some £50 million in £20 banknotes. The counterfeits were of sufficiently high quality that in some cases they were redistributed through the banking system (Willis 2006; Woodward 1999). Jory and associates were nonetheless eventually caught and convicted.

Counterfeiters do not need to target high denominations of a currency to make a sizeable profit. The United Kingdom has experienced a significant issue with counterfeit £1 coins over the past two decades, with counterfeiting rates in the range of 2–3 per cent, even though the marginal profit from counterfeiting these coins is small.[9] In March 2017, in response to continuously high volumes of detections, the round £1 coin was replaced with a 12-sided £1 coin with new security features and, in October 2017, legal tender status was removed from the old coin. This example highlights that counterfeiters are willing to

Figure 4: Historical Reserve Bank Reward

RESERVE BANK OF AUSTRALIA

REWARD

FORGED NOTES

SUBSTANTIAL REWARDS of up to **$10,000** will be paid by the RESERVE BANK OF AUSTRALIA for information leading to the apprehension and conviction of persons responsible for the forging of Australian notes or the uttering or the unlawful possession of forged Australian notes. Rewards of smaller amounts will be paid to persons who supply information which assists in the investigation.

ANY PERSON with this information should communicate immediately with the Police.

J. G. PHILLIPS
GOVERNOR
RESERVE BANK OF AUSTRALIA

Source: Reserve Bank of Australia, N-75-661 counterfeit low-value denominations if large-scale production and distribution is possible, forcing currency issuers to invest more in security features.

Counterfeiting can also have significant economic and political impacts, especially when counterfeits are indistinguishable from genuine banknotes. Portuguese counterfeiter Arthur Alves Reis was a case in point. In the 1920s, Reis forged a banknote printing contract and supporting letters purportedly from the Governor of the Bank of Portugal. He used these to deceive a London-based banknote printer, Waterlow & Sons, who held official Bank of Portugal printing plates. Waterlow & Sons used the official plates to print additional banknotes for Reis, which were collected in suitcases by an associate and transported by train to Portugal (Bloom 1966; Hawtrey 1932). Reis used Portugal's then-reputation for corruption, and the banknote printer's desire to secure new business, to convince the printer that the unusual arrangements were authorised by the central bank Governor. He ultimately convinced the printer to produce 580,000 500 escudo banknotes, worth almost 1 per cent of Portugal's nominal GDP at the time. Reis founded a commercial bank in Portugal using the proceeds, and made investments including mines in Angola and purchases of Bank of Portugal shares (the aim of these share purchases was to gain control of the privately owned central bank and then retrospectively regularise the print run). The apparent easy success of Reis's bank raised envy and suspicion, which ultimately led to Reis's arrest (Kisch 1932). The uncovering of the plot (rather than the counterfeits themselves necessarily) contributed to the collapse of the government and the installation of the Salazar dictatorship (Wigan 2004).

Another interesting example of counterfeiting occurred in Somalia. Somalia descended into civil war in 1991 and, for the next two decades, had no government. The population still needed a means of exchange, however, and this was provided for by an influx of counterfeits which, despite being easy to differentiate from 'official' currency, were accepted at face value (although the value of the currency fell to the marginal cost of printing a counterfeit, being a few cents). The stock of Somali shillings currently consists of a mix of official and counterfeit banknotes accumulated over the years, with 95 per cent of the local currency in circulation being counterfeit (IMF 2016; Koning 2013; Koning 2019).[10]

Counterfeiting as a Political Weapon

While counterfeiting is often motivated by financial gain, the ability of counterfeiting to have significant economic consequences has led to it being used as a political weapon. One example of this, although by no means the first, occurred during the American War of Independence from 1775 to 1783, when the British manufactured counterfeits of Continental currency on a boat anchored in New York harbour (Rhodes 2012).[11] These counterfeits were distributed through the colonies by those supportive of the British cause, which contributed to the devaluation of the currency by generating uncertainty about whether banknotes were genuine and by increasing the money supply.

During the Second World War, roles were reversed and Britain was the target of two secret counterfeiting operations, Operation Andreas and Operation Bernhard (NBB 2011). In particular, the German Government first planned to drop counterfeit pounds on the British Isles to create hyperinflation, but later changed plans to use the counterfeits to purchase supplies and further the German war effort. The Germans were quite successful in replicating the currency and using the forgeries, but the British authorities were alerted and ceased to issue denominations greater than five pounds as a precautionary measure. Most of the forged notes appear to have been destroyed by the defeated Germans at the end of the war. Nonetheless, it was not until 1970 that the £20 note was reissued by the Bank of England.

However, counterfeits manufactured overseas are not always an attack on sovereignty. For example, the 2011 United States Department of State Money Laundering and Financial Crimes Report (USDoS 2011) noted that India faced an increasing inflow of high-quality counterfeit currency from Pakistan. The report made clear that this activity was undertaken by criminal networks rather than any government, and was done for financial gain, but still noted the potential threat to the Indian economy.

New Challenges in Counterfeit Deterrence

Currency issuers and counterfeiters have always been locked in a battle of innovation, where issuers develop new security features and banknote series to make counterfeiting more difficult – with Australia's new Next Generation Banknote upgrade program an example of this – while criminals look for new techniques to help them counterfeit. The advance of modern technology is making counterfeit manufacturing more accessible, however, and law enforcement agencies such as Europol have noted a reduction in counterfeiters' need for 'years of skilled apprenticeship and access to expensive professional printing equipment' as they have moved from traditional to digital production methods (Europol 2014). This has shortened the timeframe over which currency issuers must respond.

The rise of the internet and the darknet has also allowed for new counterfeit distribution strategies, with counterfeit manufacturers sometimes selling their wares online. This allows the manufacturer to remain separate from distribution activities. It also means that multiple active distributers of the same counterfeit type may have no apparent link. One example of such an operation was uncovered in China in 2016 (Wei 2016). Partially manufactured counterfeit yuan were sold online by wholesalers. Those purchasing the counterfeits would finish the manufacturing process and then attempt to pass the counterfeits, although often unsuccessfully, with police making a number of arrests and seizing over CNY4 million (worth around A$1 million) in counterfeits and over 600kg of paper for future counterfeit production in this particular case (capable of making an estimated CNY100 million).

Responding to Counterfeit Attacks

Law enforcement response

Law enforcement agencies play a key role in responding to counterfeiting, and many have it explicitly included in their remit. The United States Secret Service (USSS) was originally founded in 1865 for the purposes of combating high levels of counterfeiting following the American Civil War (USSS 2018). Similarly, for international law enforcement agencies such as Europol and Interpol, counterfeiting remains a common crime area. In Interpol's case, uncovering counterfeiting was also part of its original mandate. These agencies provide their member countries with a range of services, including access to counterfeit data and counterfeit detection training.

National law enforcement agencies also routinely engage in joint operations to combat cross-border counterfeit crime. For example, in March 2014, Europol, the USSS, and the Spanish and Colombian police raided seven premises in Bogota, Colombia. They arrested six criminals and seized counterfeiting equipment and large volumes of counterfeit euros, US dollars and Colombian pesos valued at over 1.6 million euros (Europol 2014). Australia has benefited from such operations in the past. In 2006, a joint investigation between the USSS, the AFP and Colombian authorities disrupted a counterfeiting operation that had begun manufacturing Australian dollar counterfeits on polymer ('Counterfeit Aust notes seized in Colombian raid', *ABC*, 24 May 2006; RBA 2006). The raids uncovered sufficient material to produce counterfeits with a face value of up to A$5 million.

Focusing on just Australia, the AFP and state police forces regularly investigate and shut down local counterfeiting operations and prosecute those involved; see Ball (2019) for a discussion of recent trends in counterfeiting in Australia and the role of law enforcement in combating counterfeiting.

Central bank responses

In response to rising counterfeit threats, most central banks regularly update their banknotes to include improved security features that are harder to counterfeit. De La Rue, one of the world's largest banknote manufacturers, notes on its website that it produces new banknote designs for around 40 countries each year.[12] Many central banks also invest in counterfeit deterrence activities, including in research and development of new security features, and in counterfeit analysis centres to analyse and identify counterfeits. Central banks also work together where it makes sense to do so.[13]

Central banks also work with other stakeholders, such as manufacturers of banknote processing equipment, to combat counterfeiting. Many central banks – including the Reserve Bank – make counterfeits available to these manufacturers to allow them to check that their machines can accurately authenticate banknotes. Some central banks, such as the European Central Bank (ECB), go further, publishing the results of testing on their website and regulating the types of machines that can be used for processing banknotes (ECB 2010).

Conclusion

Counterfeiting has a rich and varied history going back to the very earliest forms of money. It has been pursued for personal gain – although at the significant risk of jail time, or, in the past, death – as well as for economic and political destabilisation by hostile countries. Both high- and low-value denominations are liable to be attacked. Currency issuers and counterfeiters are, and always have been, locked in a battle of innovation, with government authorities adapting and innovating in order to deter counterfeiting. Acceleration in the rate of technological development, however, seems to have shortened the timeframe over which each new security feature remains counterfeit-resistant and, in response, currency issuers are having to upgrade their banknotes and coins more frequently to ensure that counterfeiting remains low.

Regarding Australia, government and Reserve Bank policies concerning banknote issuance have evolved over time, with past counterfeiting episodes playing a major role in this change. Early banknotes were issued by multiple banks, contained few security features and were often worn and tatty, making the passing of counterfeits relatively easy. Today the Reserve Bank is the sole banknote issuer and has in place a system of incentives that serve to ensure that dirty and worn banknotes are removed from circulation. Australian banknotes are among the most secure in the world; and absent banknote upgrades (as are currently taking place), there is typically only a single series of banknotes circulating. Past policies of paying for counterfeits served to encourage their manufacture, whereas now counterfeits are recognised as worthless. And on the law enforcement side, badly drafted laws, which potentially could criminalise every printer in the country, have been amended. It has also been recognised that federal oversight of counterfeit policing can be beneficial; this resulted in the establishment of a team within the AFP dedicated to counterfeit deterrence.

Footnotes

[*] The authors are from Note Issue Department and would like to thank Andrea Brischetto, Sani Muke and James Holloway for helpful comments and suggestions, as well as the Bank's Archives staff for help with historical documents.

[1] In fact, counterfeits may have been around before money: in early agricultural societies, records of exchanges were kept. These records were often sealed up inside an envelope of clay on which the information was duplicated. This extra precaution suggests that fake records also circulated (we thank Professor Bill Maurer for pointing this out).

[2] Given that the Colony of New South Wales was founded as a penal colony, and that a significant number of convicts transported to the colony were indeed forgers – including most famously Francis Greenway – it should perhaps come as no surprise that counterfeiting was an issue for the authorities.

[3] The *Reserve Bank Act 1959* separated the central banking function of the Commonwealth Bank into the new Reserve Bank of Australia, while the commercial banking function became the responsibility of the Commonwealth Banking Corporation, known today as the Commonwealth Bank.

[4] Although even in 1937 a representative of the National Bank of Australasia wrote to the Commonwealth Bank seeking reimbursement for a counterfeit and noting that 'when this bank was issuing its own notes, any such forgery was promptly considered a liability of the bank, and the presenter was reimbursed with the amount'. Letter dated 9 October 1937.

[5] For example, the assistant secretary to the Royal Agricultural Society, a Mr AW Skidmore, stated that £5 notes would not be accepted at the Royal Easter Show, and ' … in view of recent events, I advise people with £5 notes to change them before they go to the Show.'

('Won't take £5 notes at Show', *The Daily Telegraph*, 28 February 1940, p 7). Workers also objected to being paid in £5 notes ('Object to £5 notes in pay', *The Daily Telegraph*, 31 January 1940, p 1).

[6] In hindsight, it appears that the $1,000,000 estimate was too pessimistic, with $119,720 worth of $10 counterfeits having been detected and removed from circulation by 1974.

[7] The case involved allegations of police brutality ('a 20-year-old girl was slapped in the face and her fiancé, 19, was handcuffed to a chair and kicked in the shins during police questioning'; 'Assaults alleged in fake $10 case', *The Herald* (Melbourne), 10 March 1967, p 2) and a 'how-to' manual for passing counterfeits ('Hints list issued with $10 fakes', *The Age*, 10 March 1967, p 3).

[8] See <https://csiropedia.csiro.au/polymer-banknotes/> for a brief history of this research.

[9] That is, the counterfeiting rate was 20,000 to 30,000 parts per million (ppm), compared with a current Australian counterfeiting rate of around 10 ppm; Royal Mint 2016.

[10] An interesting side point to the Somali case is the light it sheds on what makes fiat currency valuable: in this case it can't have been government dictate to pay taxes in that money, as the currency continued to be used despite there being no government for two decades.

[11] See also Cooley (2008) for further discussion.

[12] Although this may also include numismatic products such as commemorative banknotes; see <https://www.delarue.com/markets-and-solutions/state-manufacturing-and-direct-sales>.

[13] For example the Central Bank Counterfeit Deterrence Group is a group of 32 central banks and note printing authorities which investigates the common emerging threats to the security of banknotes and proposes solutions for implementation by issuing authorities; see <https://rulesforuse.org/en>.

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Education Choices and Labour Supply During the Mining Boom

James Bishop[*]

Photo: shotbydave – Getty Images

Abstract

The mining boom led to large increases in wages for many lower-skilled jobs in mining regions. This raised the opportunity cost of remaining in school, TAFE or university for many students, particularly those in mining areas. I show that this led fewer people in those areas to pursue tertiary study. These educational responses were an important source of labour market adjustment during the boom. It accommodated most of the strong rise in the labour force participation rate of 15–24 year olds in the resource-rich states, and 5–10 per cent of the total additional labour supply needed in those states.

Introduction

The world price of Australia's mining exports more than tripled over the 10 years to 2012, while investment spending by the mining sector increased from 2 per cent of GDP to 9 per cent. This 'mining boom' led to a substantial increase in the demand for labour in the resource-rich states of Western Australia and Queensland. This resulted in strong wages growth and very low rates of unemployment in these states relative to the rest of the country (Graph 1). This was true both for highly skilled labour, such as engineers, and for less skilled labour, such as machinery operators and labourers.

The high wages paid for low-skilled jobs increased the opportunity cost of remaining in school, TAFE or university for many students. This was particularly true in the resource-rich states, given the geographically concentrated nature of the mining boom.[1] The higher opportunity cost of studying led some students to undertake less education than they would have had the boom not occurred. In particular, many younger people responded to the boom by abandoning or deferring their plans to attend TAFE or university, choosing instead to pursue the high-paying employment on offer.

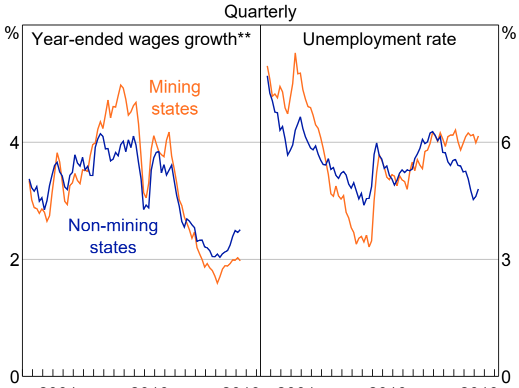
These education responses shed light on an important source of labour market adjustment to economic shocks. Previous work suggests that when economic conditions improve, more people enter the labour force, and particularly younger people (Benati 2001; Evans, Moore and Rees 2018). The mining boom episode highlights that decisions about whether to remain in study or not play a key part in this.[2] Indeed, changes in the study plans of younger people accommodated most of the strong rise in the labour force participation rate of 15–24 year olds in the resource-rich states and, on some simple estimates, 5–10 per cent of the total additional labour supply needed in those states. The importance of this adjustment mechanism has often been under-appreciated in previous analysis and discussion of the Australian mining boom. However, similar findings have been made for other countries (see, for example, Black, McKinnish and Sanders 2005; Emery, Ferrer and Green 2012; Cascio and Narayan 2015).

To the extent that the boom permanently altered the education decisions of younger people, the reduction in human capital accumulation during this period could also have longer-run consequences for the productive capacity of the economy. This is another potential negative side effect of the mining boom aside from 'Dutch Disease', where a higher exchange rate leaves the manufacturing sector uncompetitive and industrial capacity is hollowed out (Gregory 1976; Corden and Neary 1982).[3] However, some of those whose study decisions were influenced by the mining boom may still pursue further study later in their lives.

Graph 1

Labour Market Outcomes by State*

Quarterly



* 'Mining states' are Western Australia and Queensland; 'Non-mining states' are all other states and territories

** Wage Price Index excluding bonuses and commissions

Sources: ABS; RBA

Approach

The goal of this article is to estimate the counterfactual; that is, what would education attendance rates have done in the absence of the mining boom? My approach is to examine the change in education attendance in the 'mining states' during the boom relative to their pre-boom levels. I compare these changes to those of a control group – a set of regions whose students' decisions were not affected (or less affected) by the mining boom. While it is impossible to find a perfect control group, the 'non-mining states' are likely to provide a reasonable control. I define the mining states to be the resource-rich states of Western Australia and Queensland and the non-mining states to be the other states and territories of Australia. If the boom also had an influence on students' education decisions in the non-mining states, this approach would lead me to underestimate the effect of the boom on education decisions.

Until recently, the Labour Force Survey (LFS) collected data only on education attendance for *15–24 year olds studying full time*. It did not collect similar data for older age groups or for students in part-time study. As such, I begin by examining the full-time study decisions of 15–24 year olds. This group accounts for 80 per cent of all working-age people in full-time study. In a later section I examine the study decisions of older age groups and part-time students using some alternative data sources.

The Boom Had a Large Impact on Full-time Study

In the decades leading up to the mining boom, the share of young people in full-time study followed remarkably similar trends in mining and non-mining states; both tended to rise over time in line with the expansion of the higher education system (Graph 2). However, after the onset of the boom in the early 2000s, the full-time study rate continued to rise in the non-mining states but stopped rising in the mining states. The gap between the mining and non-mining states' full-time study rates widened by 6 percentage points between 2001 and 2012. This divergence is statistically significant and large; taken at face value, it suggests that 6 per cent of all 15–24 year olds in the mining states did not pursue full-time study (or postponed their study) as a result of the boom. However, part of this gap – around 1¾ percentage points – reflects the high rates of migration into mining states from overseas and interstate (see Appendix A for details).

This response of full-time education mainly reflected lower participation in tertiary study (e.g. TAFE and university), rather than a change in the high school dropout rate (Graph 3). We can get further insight into this effect on tertiary study using data from the Census, which provides more detailed (but less frequent) data than the LFS on the types of education institutions students attend. A comparison of the 2001 and 2011 Census data suggests that the response of full-time tertiary study to the boom was driven by a decline in university attendance, rather than TAFE. That is, fewer people enrolled in full-time university than would have been the case had the boom not occurred.[4] The number of younger people studying at TAFE also declined due to the boom, but this had a smaller effect on the aggregate share in tertiary study (right-hand panel of Graph 3) given that TAFE students account for less than 20 per cent of all students in full-time tertiary study.[5]

The effects of the mining boom on full-time study rates were similar for males and females (Graph 4). This is surprising given that mining and its associated activities (e.g. engineering and construction) tend to be male dominated. The surge in labour demand during the boom may have meant that firms hired more females than usual; indeed, the share of females in mining employment rose from 12 per cent in the early 2000s to more than 16 per cent in 2012. The response in the full-time study rate of females may also reflect that it was not only mining-related wages that increased, as other firms in resource-rich areas also had to pay higher wages to compete with mining for labour. The minimum wage in Western Australia was also increased at a faster rate than other states during the mining boom, in part reflecting strong economic conditions.

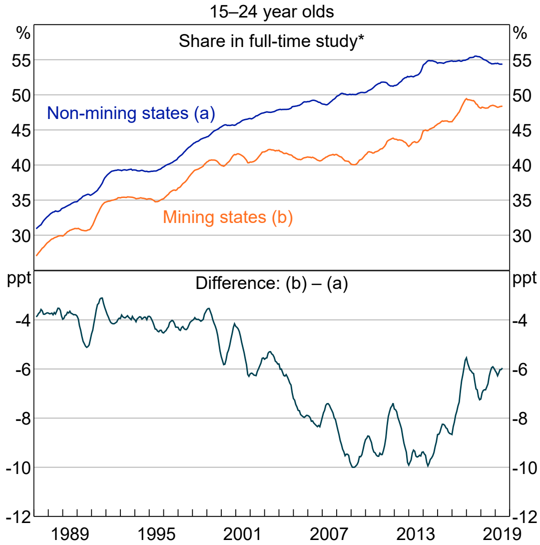
Some Students Downgraded to Part-time Study

Until recently, the regular LFS did not provide data on part-time study attendance. However, we can gain some insights on part-time study from the ABS Survey of Education and Work, which is included as a supplement to the LFS every May. These data suggest that part-time study rates declined in both mining and non-mining states during the boom, though the falls were relatively larger in the latter

Graph 2

Full-time Study and the Mining Boom

15–24 year olds



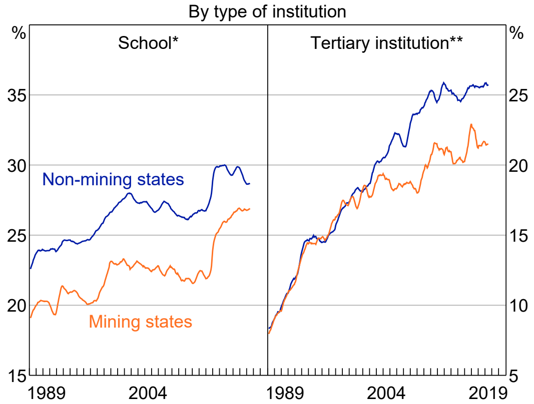
* Attending school or tertiary institution; smoothed using 12-month-trailing average

Sources: ABS; RBA

Graph 3

Share of 15–24 Year Olds in Full-time Study

By type of institution



* 15–19 year olds only

** Includes TAFE, university or other higher educational institution

Sources: ABS; RBA

(Graph 5). Since we are using the non-mining states as a control group (i.e. a guide to what would have occurred in mining states in the absence of the boom), this suggests that the boom contributed to a *rise* in the share of young people undertaking part-time study in the mining states. This was largely driven by a rise in the likelihood of undertaking part-time study at TAFE, although part-time university attendance also rose. One interpretation of this finding is that some of the students that abandoned (or deferred) full-time study went into part-time study instead. For example, in response to high wages for low-skilled jobs, some full-time students may have dropped their study load to part time and increased their hours of work. Nonetheless, the rise in part-time study did not completely offset the decline in full-time study, at least at university. The effect of the mining boom on the share of young people in study was both statistically and economically significant.

There Was Also an Effect on Older Students

The Survey of Education and Work also lets us examine the education choices of persons over the age of 25 years. I find that the boom lowered the education attendance rate of 25–34 year olds in mining states, relative to non-mining states (Graph 6). The peak impact on attendance rates for this age group occurs in 2012, and is quite large (around 2 percentage points) considering that only around 15 per cent of people in this age group are usually engaged in study. DEEWR (2008) has also linked the decline in university applications from mature age students in Western Australia during the mining boom to strong labour market conditions. I find no discernible effect on 35–64 year olds, which is unsurprising given that only 6 per cent of people in this age range are usually engaged in any kind of study.

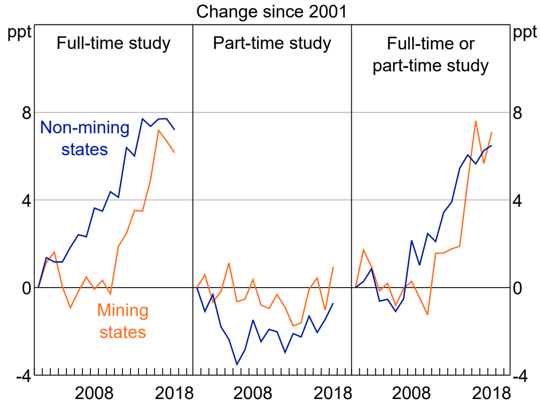
What Role Did Education Attendance Play in Labour Market Adjustment?

Interstate and overseas migration clearly played a key role in the labour markets' adjustment to the mining boom. But previous Bank analysis also highlights the important role played by the increase in labour supply from *within* the mining states, through a combination of higher participation rates and lower unemployment rates. These within-state factors accounted for more than a third of the

Graph 5

Share of 15–24 Year Olds in Study

Change since 2001

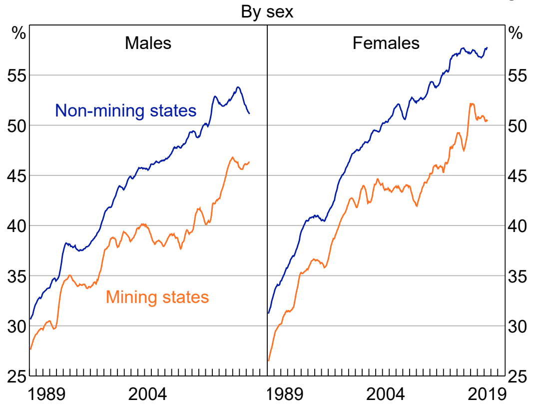


Sources: ABS Survey of Education and Work; RBA

Graph 4

Share of 15–24 Year Olds in Full-time Study

By sex

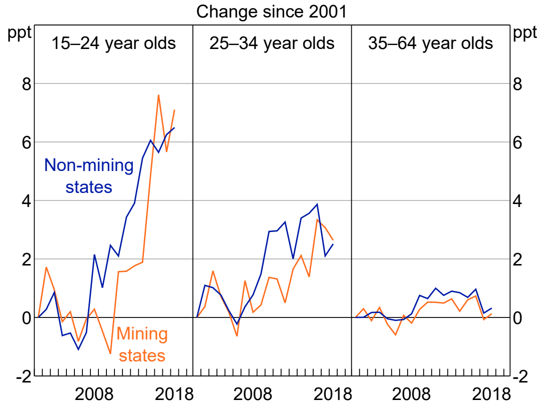


Sources: ABS; RBA

Graph 6

Share of Population in Full-time or Part-time Study

Change since 2001



Sources: ABS Survey of Education and Work; RBA overall increase in labour supply in the mining states (Graph 7, reproduced from D'Arcy *et al* (2012)). The cyclical adjustment of the participation rate accounted for around 40 per cent of the total within-state adjustment, in line with standard rules of thumb (Evans, Moore and Rees 2018).

What is less well understood is that the vast majority of the participation rate adjustment within the mining states came from a surge in participation amongst 15–24 year olds (Graph 8). This was made possible by fewer young people undertaking full-time study. Indeed, the response of full-time study attendance accounted for more than half of the overall increase in labour force participation of younger people in mining states relative to non-mining states during the mining boom.[6] A further rough calculation suggests that this response of full-time study to the mining boom helped meet around 5–10 per cent of the overall increase in labour demand in mining states. The positive participation rate response of 25–34 year olds can also largely be accounted for by the decline in study rates.

Longer-run Consequences

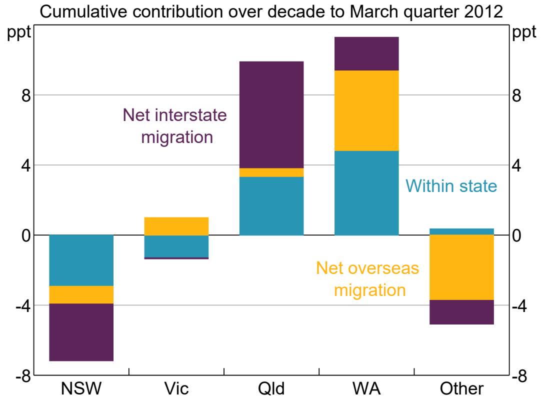
In theory, even a temporary mining boom could have a permanent effect on long-run growth. During the mining boom some commentators were concerned that the economy would suffer from 'Dutch Disease'. The RBA has previously argued that the Dutch Disease effects of this episode appear to have been small (Downes, Hanslow and Tulip 2014; Ellis 2017). Education choices are another mechanism through which mining booms could have permanent effects. This ultimately depends on whether the impact on study rates was large enough to put a dent in the economy's stock of human capital, which, in turn, depends on the number of people whose decisions were affected, and whether they abandoned study or simply deferred it.[7]

Although it is difficult to be precise, a rough estimate suggests that the number of individuals with a Bachelor's degree in Australia would currently be around ½ per cent higher had the boom not occurred. On the other hand, the effect of the mining boom on the number of individuals with a TAFE qualification was trivial. It is worth noting that those students who made the decision to defer or abandon their studies as a result of the mining boom may be those who would have benefited the least from university anyway. If so, the private and social returns to those 'marginal' students obtaining a degree would be lower than those students who did not leave their studies as a result of the mining boom. Relatedly, people who worked rather than studied may not have attained a formal post-school education, but still benefited from on-the-job training while working. At a minimum, those choosing work and earning income through that period would have been likely to start the post-mining boom period in a stronger financial position than those studying throughout the period and incurring study expenses.

Graph 7

Sources of Relative Employment Growth*

Cumulative contribution over decade to March quarter 2012



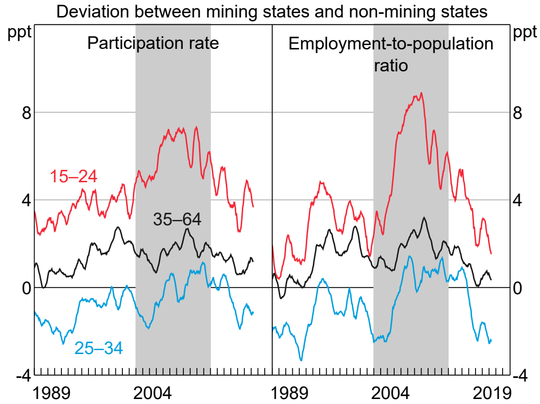
* Excludes a small residual

Sources: ABS; RBA

Graph 8

Participation and Employment by Age*

Deviation between mining states and non-mining states



* Mining boom period shaded, 2002 to 2012

Sources: ABS; RBA

Table A1: Share of 15–24 Year Olds in Full-time Study[(a)]
By migration status, 2011

Change in location since five years ago	Mining state %	Non-mining state %
Same location	45	52
Moved from interstate[(b)]	36	39
Moved from overseas	56	66

(a) Data are a 1 per cent sample of individuals from the 2011 Census; individuals' location five years ago is based on recollection; excludes overseas visitors intending to stay for less than one year.

(b) Interstate moves only include movements between mining and non-mining states and vice versa

Sources: ABS; RBA

Conclusion

The high wages paid to low-skilled labour during the mining boom led to a decline in full-time study rates in the resource-rich states relative to the other states and territories. This played a key role in the adjustment of the labour market to the boom, as it allowed for a sharp rise in labour force participation of young people in the booming areas.

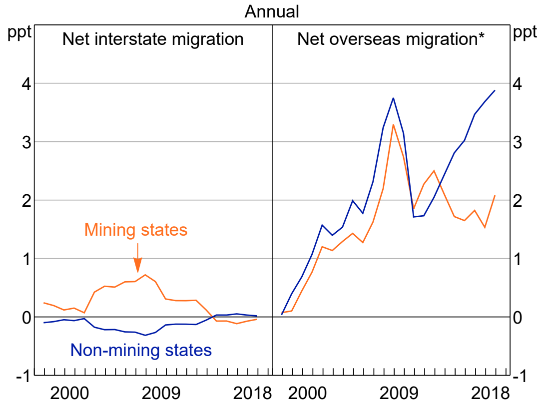
Appendix A: Overseas and Interstate Migration

During the mining boom, the populations of younger people in the mining states were boosted by migration from other states and overseas (Graph A1). Some of these people were relocating in search of job opportunities rather than to study. As such, we may be concerned that the apparent decline in the education attendance rates in the mining states relative to non-mining states reflects migration, rather than an impact of the boom on education decisions per se.

Considering the impact of interstate migration first, Table A1 confirms that younger people who migrated from a non-mining state to a mining state during the boom did indeed have a lower propensity to study full time than those who did not migrate. All else being equal, this means that interstate migration reduced the full-time study share in the mining states relative to the non-mining states via a composition effect. Overall however, these migration flows only explain part of the decrease in full-time study rates in the mining states during the boom. Over the decade to 2012, net interstate migration boosted the population of 15–24 year olds in the mining states by less than 20,000 people (less than 2 per cent of the total number of 15–24 year olds living in those states in 2012). Given the difference in study rates of interstate migrants relative to existing residents in the mining states (Table A1), these flows can account for less than ¼ percentage point of the overall decline in the share of 15–24 year olds in full-time study in the mining states.[8],[9]

Net overseas migration made a strong contribution to growth in the number of 15–24 year olds in both the mining and non-mining states during the mining boom (Graph A1). Higher immigration in this age group reflected strong growth in foreign student numbers (particularly from China and India) and increasing use of foreign labour to meet skills shortages. To some extent, the composition of these migrants differed depending on where they settled; a larger share of younger migrants who settled in the non-mining states studied full time compared to those who settled in the mining states

Graph A1
Contribution to Growth in 15–24 Year Olds
Annual



* Calculated as a residual contribution prior to 2004
Sources: ABS; RBA

(Table A1). Notwithstanding this, more than half of all younger people who migrated to mining states from overseas did so to study, rather than to work. A simple calculation suggests that differences in the amount and type of migration between mining and non-mining states can explain around 1½ percentage points of the overall increase in full-time study rates of younger people in mining states vis-à-vis the non-mining states.[10],[11]

Taken together, interstate and overseas migration contributed less than 1¾ percentage points of the roughly 6 percentage point decrease in the share of young people in full-time study in mining states relative to non-mining states during the boom. This gives us confidence that the results in this article are not being driven by migration and that the mining boom had a genuine effect on the educational decisions of young people who grew up in mining states.

Footnotes

[*] The author is from Economic Research Department

[1] Almost all iron ore mining in Australia occurs in Western Australia (mostly in the Pilbara region in the north-west of the state). Two-thirds of coal mining is in Queensland. In the case of natural gas, the bulk of production is from Western Australia and Queensland.

[2] Other studies for Australia have found evidence of a negative correlation between demand for university places and job opportunities during downturns. For example, DEEWR (2011) found that the share of individuals applying to university rose sharply during the early 1990s recession, although in part this reflected structural changes to the university education system.

[3] Any longer-run impact on the economy's productive capacity would of course depend on the role of higher education in driving productivity growth. It is generally accepted that university study confers a private benefit to individuals in terms of higher wages. However, the social returns may be higher than the private returns if there are positive spillovers of an education on other workers, or lower if a university education is merely a signal of underlying ability.

[4] Prior to 2010 the number of university places funded by the Australian Government was capped; each university received an allocation of funding, determined largely according to history. If these funding allocations had not kept pace with population growth in the mining states, any resulting shortage in university places could have contributed to the decline in their education attendance rates relative to the other states. However, there is no evidence that 'unmet demand' for university places (i.e. the share of applicants who were not offered a place at university) rose in the mining states relative to the non-mining states during the boom (see DEEWR (2011), section 6). Moreover, when the funding caps were removed after 2010, there was little evidence of a rise in enrolments in the mining states relative to the rest of Australia, suggesting little pent-up demand.

[5] The Census data suggest that the response of university attendance rates accounts for around three-quarters of the overall effect of the boom on full-time tertiary study, while attendance at TAFE and other institutions accounts for the remainder.

[6] Many of the people who would have undertaken full-time study had the boom not occurred would have participated in the labour force anyway. For example, they may have otherwise decided to study full time and work part time, or vice versa. I assume that half of all students who did not pursue full-time study as a result of the boom would have participated in the labour force regardless. This is based on the labour force participation rate of 15–24 year olds that studied full time in 2011. I also adjust for compositional effects stemming from higher rates of migration into mining states from overseas and interstate (see Appendix A). These compositional effects can account for less than half of the increase in participation rates of 15–24 year olds in mining states relative to non-mining states during the mining boom, although it is difficult to be precise.

[7] In their study of the 1973–81 oil boom in Alberta, Emery *et al* (2012), find that many of those students who dropped out of school during the boom re-enrolled later in their lives.

[8] This calculation assumes that younger people who migrated out of the non-mining states had a similar propensity to study to those who remained in those states. If the likelihood of studying was lower amongst those who migrated, this compositional effect would have increased the share of younger people in full-time study in the non-mining states. However, this assumption makes little difference to our overall conclusions about the effect of the mining boom on education decisions.

[9] In the Census, a person's 'usual residence' is the dwelling they live in most of the time. As such, some 'fly-in-fly-out' (FIFO) workers are included in the usual resident population of their FIFO community, while others are included in the population of their home town. In the LFS, a usual residence is the dwelling the person perceives to be their 'home', irrespective of how much time they spend there. To the extent that FIFO workers are more likely to be classified as a resident of their FIFO community in the

Census than in the LFS means that, if anything, our calculations overstate the contribution of net interstate migration on study rates during the boom.

[10] Overseas migrants (including foreign students) are in scope of the LFS provided they have been (or expect to be) residing in Australia for 12 months or more in a 16-month period.

[11] Net overseas migration of 15–24 year olds in the decade to 2012 contributed 10.9 per cent and 11.5 per cent of the 2012 populations of 15–24 year olds in the mining and non-mining states, respectively. This accounts for the fact that many of those who migrated as 15–24 year olds in the mid to late 2000s had moved into a higher age bracket by 2012. Combined with the data in Table A1, this suggests overseas migration made a mechanical contribution of 1.5 percentage points to the overall 6 percentage point increase in the share of young people in full-time study in mining states relative to non-mining states during the boom.

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The Changing Global Market for Australian Coal

Michelle Cunningham, Luke Van Uffelen and Mark Chambers[*]

Photo: CUHRIG – Getty Images

Abstract

Coal is one of Australia's largest exports, and has accounted for around one-quarter of Australia's resource exports by value over the past decade. However, demand in the global market for coal has been evolving in recent years, which is creating some uncertainties for the longer-term outlook for coal exports. Looking forward, demand will be shaped by the speed of the transition towards renewable energy sources, changing steel production technologies, and the pace of global economic growth. Over the next few years, Australian coal production and exports are expected to grow fairly modestly.

Introduction

Australia is one of the world's largest producers and exporters of coal. Total domestic production has more than doubled since the early 1990s and export volumes have grown strongly. Australia produced around 510 million tonnes (Mt) of coal in 2017/18, of which around 75 per cent (380 Mt) was exported, up from 55 per cent in 1990/91 (Graph 1).

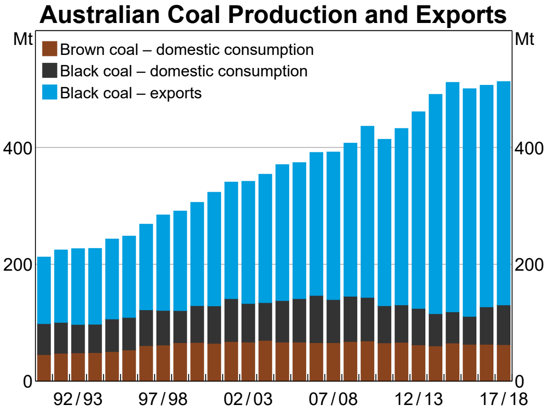
For most of the past decade, coal has been Australia's second largest resource export, after iron ore, and since 2015 has averaged around one-quarter of annual resource export values and 14 per cent of total export values (Graph 2). In 2018, the value of coal exports was $67 billion, equivalent to 3½ per cent of nominal GDP. Australia's coal exports consist of different grades of black coal: metallurgical coal, which has a relatively high energy content and is used for industrial purposes (primarily steel making); and lower-energy content thermal coal used for electricity generation.

Until the mid 2000s, growth in Australian coal exports was primarily driven by steadily expanding exports to Japan and other developed Asian economies. In the late 2000s there was a period of more rapid growth as exports to China and India in particular expanded, and there was significant investment to expand capacity. Investment in the sector slowed from 2012 because falling prices led to a number of projects being delayed or cancelled (Saunders 2015). Investment has remained subdued since, as firms in Australia have focused on investments to sustain production rather than significantly expand output.

Unlike the strong growth in exports, domestic consumption of coal has been declining over the past 10 years or so. Domestic consumption is primarily for electricity generation – both black and brown coal are used.[1] Annual domestic coal consumption since 2015 has averaged around 122 Mt, but has declined by around 11 per cent since the mid 2000s. Although other forms of energy generation (mainly natural gas and renewables) have increased, coal still accounts for a relatively high share of energy generation in Australia – around 60 per cent in 2018.

Graph 1

Australian Coal Production and Exports

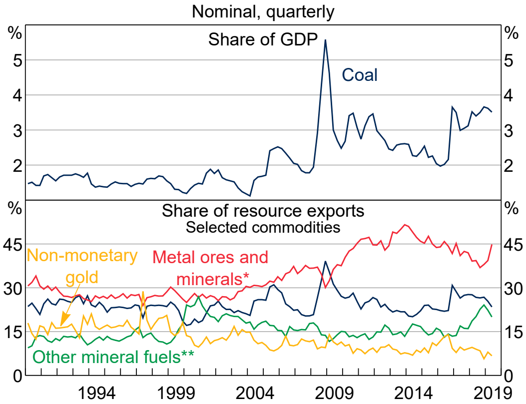


Sources: ABS; DOIIS; RBA

Graph 2

Australian Resource Exports

Nominal, quarterly



* Includes iron ore

** Includes liquefied natural gas

Sources: ABS; RBA

Given the size of Australia's coal exports, changes in export volumes and prices can have a significant effect on Australia's GDP and terms of trade. The rest of this article discusses some of the international developments shaping the global market for Australian coal exports, and how these are informing the Bank's forecasts.

Global Coal Demand over Recent Decades

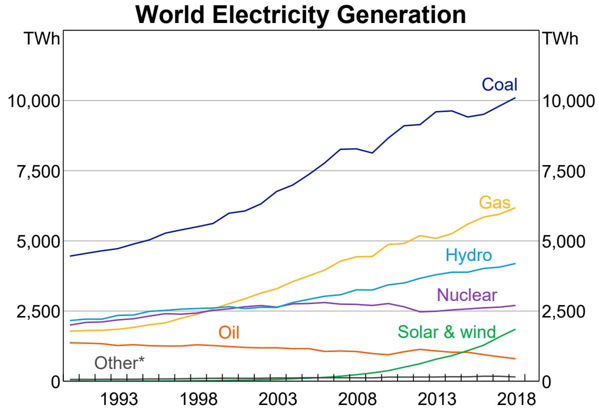
Coal has two main uses: electricity generation and steel production.[2] Thermal coal is primarily used for electricity generation and accounts for around three-quarters of global coal consumption. Metallurgical coal is typically used in the steelmaking process and accounts for 13 per cent of global coal consumption; metallurgical coal generally attracts a price premium over other coal types because of its higher energy content.[3]

Thermal coal and electricity generation

Globally, coal is the largest source of electricity generation, reflecting both its reliability as a base-load energy source and its relatively low cost. Of the estimated total global electricity generation of 26,600 terawatt hours (TWh) in 2018, around 10,000 TWh was generated using coal (Graph 3). Total coal-powered electricity generation has more than doubled since 1990, driven by sustained growth in developing economies and the related increase in energy demand.

Graph 3

World Electricity Generation



* Includes pumped hydro, non-renewable waste and statistical discrepancies

Sources: BP (2019a); RBA

Global thermal coal demand increased sharply from the early 2000s, mainly due to rapid growth in the Chinese economy over that period. China is the largest global consumer of thermal coal, consuming around 3,200 Mt in 2018, a little over half of the global total, and around triple what it was consuming in 1990 (Graph 4). Sustained economic growth over recent decades in India and other Asian economies has also contributed to increased global thermal coal consumption.

In recent years, however, coal's share of global electricity generation has been declining – down from a peak in 2007 of a little over 41 per cent, to 38 per cent in 2018. A key driver of this decline has been increased global competition from less carbon-intensive energy sources, supported by lower gas prices and falling renewable energy costs. The investment in, and adoption of, these alternative energy sources has in part been because of changes to environmental and energy policies globally, as well as the private sector anticipating the transition to a lower carbon economy.

There have been some more pronounced trends for individual countries (Graph 5). Coal's share of electricity generation has declined more in advanced economies and China. This has been supported by government policies that have encouraged a shift away from coal, as well as an increase in gas-powered generation in the United States. Meanwhile, in India and other Asian countries, coal's share of electricity generation has increased alongside rising energy demand in these countries.

Steel production and metallurgical coal

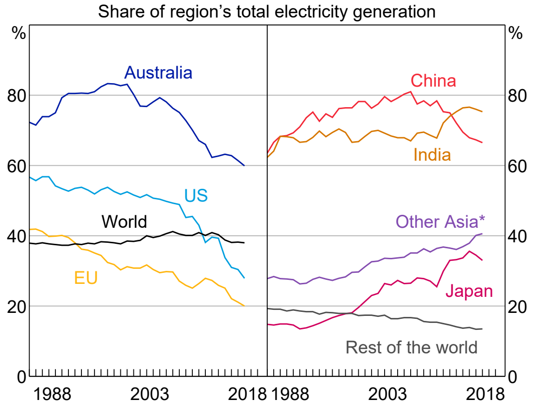
Demand for metallurgical coal has also increased strongly since the early 2000s, driven by the rapid increase in steel production in China, which became the world's largest steel producer in the early 2000s (Graph 6). China's demand for steel increased as rapid industrialisation and urbanisation drove high levels of investment in infrastructure and construction. Steel demand was also supported by rapid growth in Chinese manufacturing exports. Indian demand for metallurgical coal has also increased strongly since the mid 2000s alongside rapid growth in its domestic steel industry; because India has limited domestic reserves of metallurgical coal, demand has been met by imports.

Chinese steel production is more coal intensive than production in other economies, because it mostly uses blast furnace technology which

Graph 5

Coal-fired Electricity Generation

Share of region's total electricity generation

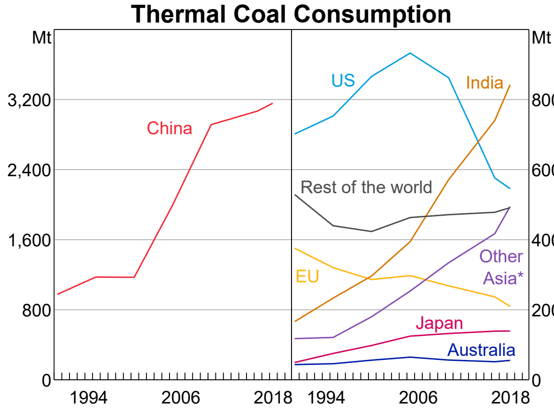


* Asia excluding China and India

Sources: BP (2019a); RBA

Graph 4

Thermal Coal Consumption

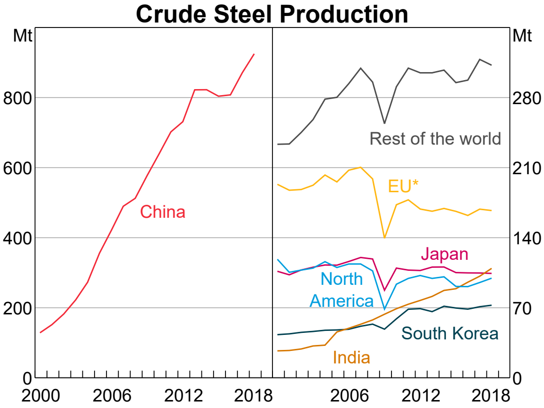


* Asia excluding China and India

Sources: IEA (2019); RBA

Graph 6

Crude Steel Production



* 2018 is an estimate

Sources: RBA; World Steel Association (worldsteel) consumes metallurgical coal and iron ore as raw inputs. The main alternative mode of steel production – electric arc furnaces – allows steelmakers to melt down and reuse scrap steel, and hence does not directly rely on metallurgical coal as a raw input (although thermal coal may be used to generate the electricity). However, scrap utilisation rates are still relatively low in China because steel collection and recycling infrastructure remains undeveloped. Reflecting this, around 90 per cent of steel in China is manufactured using blast furnaces, compared to around 55 per cent in the rest of the world (Graph 7).

Global Coal Supply and Australia's Exports

Reflecting the large structural increases in global coal demand, global coal production has increased significantly over recent decades. Global production has averaged around 8,000 Mt a year since 2010, nearly double the amount produced in the early 1990s. China is by far the largest producer of coal, accounting for nearly half of annual global production, and driving most of the growth in production in recent decades (Graph 8).

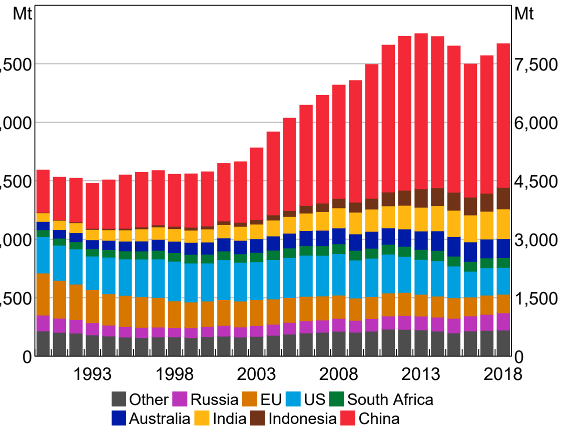
Other major producers include the United States and Europe. However, production in these economies has declined since the 2000s, as steel production has declined and other forms of electricity generation have displaced coal-powered generation. Other major producers that have grown over time include Indonesia, India, Russia and South Africa, as well as Australia. In most of these economies, apart from China and India, domestic consumption of coal is small relative to production, making them important players in the export market.

The two largest exporters of coal are Australia and Indonesia, each accounting for close to 30 per cent of total coal export volumes in 2018 (Graph 9). Australia exports slightly more thermal coal than metallurgical coal. But because the market for international trade in coal, known as the seaborne market, is smaller for metallurgical coal, Australian exports account for around half of this market, compared with around 20 per cent of global thermal coal exports.

Competition has increased in the seaborne market for both thermal and metallurgical coal, as lower-cost supply has entered the market and production

Graph 8

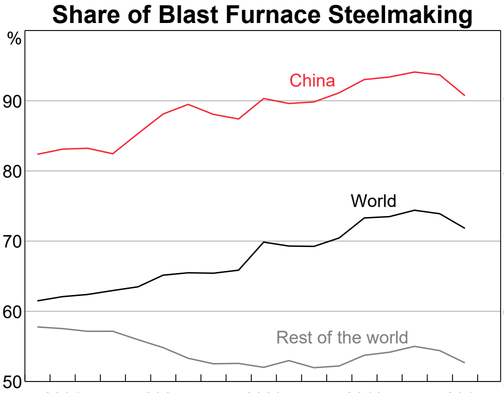
Global Coal Production



Sources: BP (2019a); RBA

Graph 7

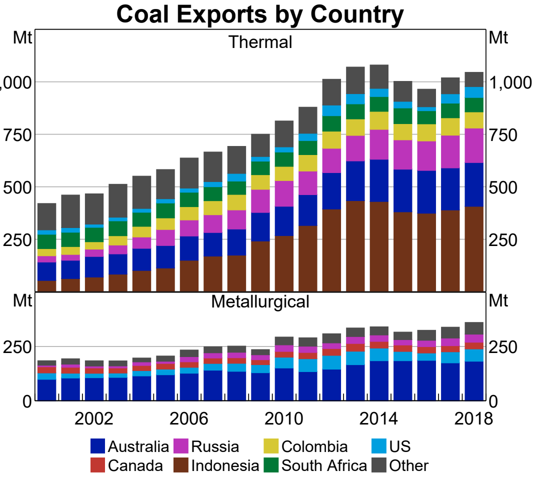
Share of Blast Furnace Steelmaking



Sources: RBA; World Steel Association (worldsteel)

Graph 9

Coal Exports by Country



Sources: AME; RBA

costs at existing mines have declined. Reflecting this, global production cost curves have moved outwards and become flatter over the past decade (Graph 10). At present, spot and contract prices exceed average variable production costs for most Australian thermal coal operations. However, Australian production costs span a fairly wide range, and some higher-cost operations may experience margin pressures if thermal coal prices were to move lower on a sustained basis. In the metallurgical coal market, in contrast, margins are currently strong, with average variable production costs for most Australian and other global operations below prevailing spot and contract prices.

Australia's coal export destinations have evolved over the past decade as market demand has shifted. Japan remains Australia's largest destination for thermal coal exports, accounting for around 40 per cent in 2018, although its share has declined from around half of thermal coal exports a decade ago (Graph 11). Thermal coal exports to China have increased rapidly over the past decade, from less than 2 per cent of Australian thermal coal exports in 2008, to around one-quarter currently.[4] In recent years exports to economies in South-East Asia have been growing strongly, albeit from fairly low levels, reflecting the increase in thermal coal electricity generation in these countries.

Australia's major markets for metallurgical coal are India, China and Japan, which collectively account for around two-thirds of exports. Metallurgical coal exports to China and India have increased strongly over the past decade, in line with their expanding steel sectors, while the relative importance of Japan and Europe as export destinations has declined.

The Changing Global Landscape and Recent Coal Price Movements

The changing landscape for coal production and demand has driven some large movements in prices over recent years. Both thermal and metallurgical coal prices increased strongly over most of the 2000s as the increase in global demand outpaced additional supply coming on line. But by 2012, production capacity had increased globally, and a larger amount of coal was available through export markets – particularly from Australia, Indonesia and Russia. Prices subsequently declined, and reached a trough in early 2016 (Graph 12).

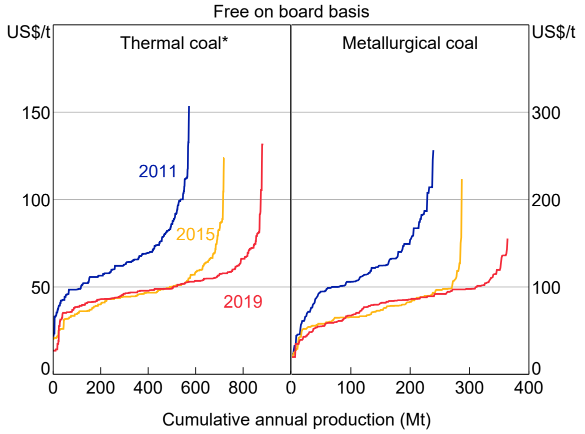
Prices for both thermal and metallurgical coal have increased since then, reflecting a range of factors including:

- changes in Chinese Government policies that have influenced global supply and demand dynamics
- limited supply growth in the seaborne market
- supply disruptions
- some changes in demand for coal with different quality characteristics.

Graph 10

Seaborne Coal Production Costs

Free on board basis

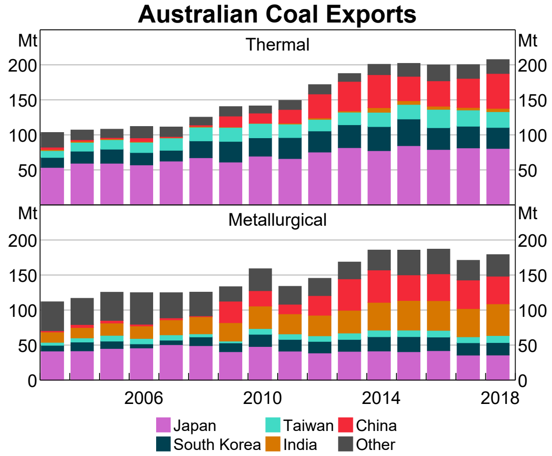


* Costs are quality adjusted

Sources: AME Group; RBA

Graph 11

Australian Coal Exports



Sources: ABS; RBA

Tightening of global supply–demand balance

One of the main drivers of stronger prices for seaborne coal since early 2016 was the rationalisation of domestic coal production in China around that time. Measures were implemented to reduce outdated capacity and to improve profitability in China's domestic coal industry, and working days in Chinese coal mines were reduced from 330 to 276 days per year (although this policy was reversed in late 2016).[5] The reduction in Chinese coal production occurred alongside a recovery in Chinese coal demand for use in both steel production and electricity generation. As a result, there was increased demand for seaborne coal, which had a large impact on coal prices (Graph 13). Thermal coal prices more than doubled from the start of 2016 to their peak in late 2016, while coking coal prices quadrupled over the same period (some supply disruptions also contributed to higher prices over this period).

Metallurgical coal prices have also been supported by continued growth in steel production in China and, to a lesser extent, India. Over the past few years, expansionary fiscal policies and accommodative financial conditions in China have supported property construction and infrastructure investment, which have boosted demand for steel production. Increased uncertainty over 2019 regarding the outlook for the Chinese economy has weighed on metallurgical coal prices in recent months, but prices are still well above the early 2016 trough. Indian steel production has also grown strongly, at an average annual rate of around 6 per cent over the past few years, although this is from a low base.

The increase in coal prices from their 2016 trough was also supported by fairly limited increases in supply, including from Australia. The earlier large declines in coal prices over 2011 to 2015 resulted in some global producers scaling back production to reduce costs, while some higher-cost mines were closed. Consequently, when demand picked up in 2016 and prices rebounded from their trough, there was reduced capacity for supply to respond.

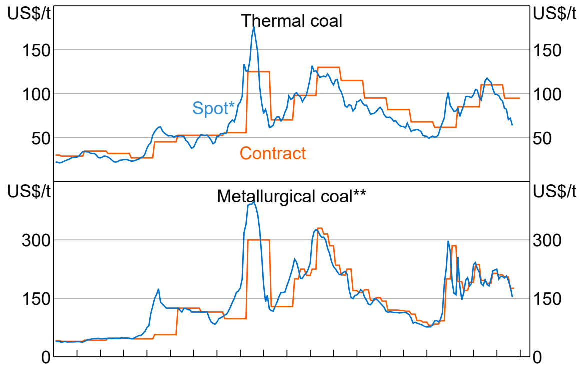
Supply disruptions

There have been a number of temporary disruptions to seaborne supply of coal over the past few years, particularly for metallurgical coal. Because Australia accounts for over half of the metallurgical coal seaborne market, and production is concentrated in the Bowen Basin region in Queensland, any disruptions to Australian coal supply tend to have a large impact on the seaborne market for metallurgical coal. In April 2017, Australian metallurgical coal exports declined by around 50 per cent, after Tropical Cyclone Debbie damaged key rail infrastructure servicing the Bowen Basin region (Graph 14). The reduction in Australian exports had a significant impact on global supply and prices rose sharply as a result. Prices continued to be supported over the rest of 2017 by ongoing operational issues and port delays in Australia which reduced metallurgical coal exports.

Graph 12

Australian Coal Prices

Free on board basis



* Monthly average

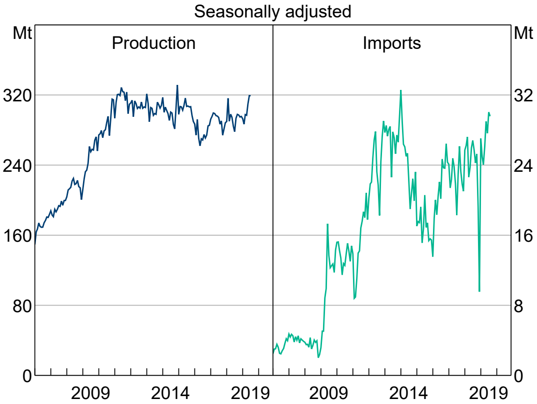
** Price index is Premium Hard Coking Coal

Sources: DOIIS; IHS Markit; RBA

Graph 13

Chinese Coal Production and Imports

Seasonally adjusted



Sources: CEIC Data; RBA; WIND Information

There have also been temporary disruptions to supply from key thermal coal exporting countries. However, because the seaborne thermal coal market is larger and less geographically concentrated, any disruptions in one exporting country tend to have a smaller impact on global supply and prices.

Changing demand for different coal qualities

Demand for higher-quality metallurgical coal has increased following reforms in China's steel industry, including the closure of inefficient steel mills (that typically used lower-quality inputs) and stricter environmental standards. Improved steel margins have also supported demand for higher-quality inputs in recent years, which has contributed to a price premium for higher-grade coking coal (Graph 15).

In the case of thermal coal, the price premium for higher-quality coal widened over recent years, in part because of more countries pursuing more stringent environmental targets (DOIIS 2018). This contributed to the premium for Newcastle high-quality coal (6,000 kcal/kg) over lower-grade Newcastle coal (5,500 kcal/kg) widening to over US$50/t in mid 2018, compared with its long-run average of around US$17/t. Meanwhile, there had also been fairly limited growth in global supply of higher-quality coal, whereas supply of lower-quality coal had been increasing at a faster pace (IEA 2018a). Over the past year, however, the premium for higher-quality thermal coal has decreased. In part this is because some countries have substituted towards cheaper natural gas and because of an increase in renewable generation. Looking ahead, rising demand from South-East Asia is likely to be concentrated in mid-quality thermal coal.

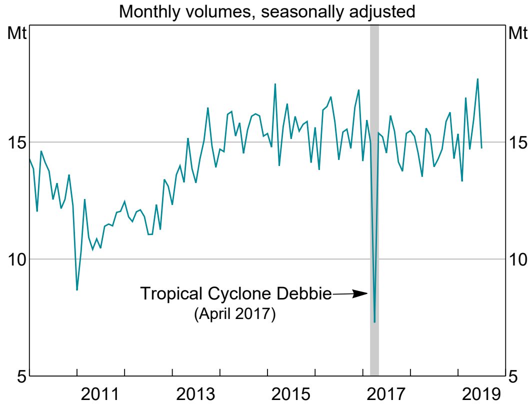
Information from the Bank's liaison program suggests that the changing outlook for prices for metallurgical and thermal coal has been a factor weighing on producers' investment decisions to expand capacity. There is a considerable lag between the decision to undertake new investment and the start of production, so investment decisions are based on long-run price expectations (which have been lower than prices observed over recent years).

A number of other factors have been cited by coal producers as weighing on coal investment. Coal producers have become more targeted with their investment decisions in recent years, due to their experience during declines in coal prices prior to 2016. The few large projects that are likely to go ahead have high-quality coal and low expected production costs. Other factors cited as weighing on investment decisions include lengthy planning and approval processes for coal projects. Funding availability has also been noted as a constraint on investment, as banks are increasingly reluctant to finance coal developments; most new finance is being secured from consortiums of lenders, which can be more complicated to arrange.

Graph 14

Australian Metallurgical Coal Exports

Monthly volumes, seasonally adjusted

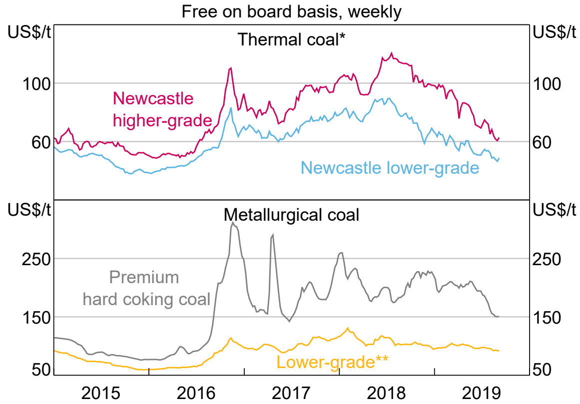


Sources: ABS; RBA

Graph 15

Australian Coal Prices

Free on board basis, weekly



* Newcastle premium energy content is 6,000 kcal/kg; Newcastle lower-grade energy content is 5,500 kcal/kg

** Australian low volatile pulverised coal injection

Sources: IHS Markit; RBA

More broadly, as discussed below, growing competition from alternative sources of energy generation, including natural gas and renewables, as well as policy measures to support less carbon-intensive energy generation, has added considerable uncertainty to investment decisions for thermal coal.

The Outlook for Global Coal Demand and Supply

To assess the outlook for coal, we consider the medium- to long-term forces shaping demand and supply for both thermal and metallurgical coal. The outlook for thermal coal demand will largely depend on how energy generation evolves and, in particular, how fast renewable and alternative electricity generation displaces coal-powered generation. Meanwhile, global metallurgical coal demand will largely be driven by global growth in steel production and changes in steelmaking technologies.

In the long run, there is considerable uncertainty around the outlook for coal consumption. Demand will depend on many factors that are difficult to forecast, including the pace of economic growth in developing economies, changes in the cost and capabilities of different technologies (particularly for renewable energy and steel production), and changes to government policies.

Changes in electricity generation

In the near term, demand for thermal coal is expected to remain supported by increases in coal-powered electricity generation in India and South-East Asia as well as continued growth in these economies. The longer-run outlook will strongly depend on the speed of transition to less carbon-intensive electricity generation relative to the pace at which aggregate electricity demand grows.

Over the next five years or so, some continued increase in coal demand, particularly from India and economies in South-East Asia, may partly offset a more general decline in demand as global electricity generation transitions away from coal to other energy sources. Over the longer term, however, the balance of risks for demand appear to be to the downside, as the transition from coal to other energy sources in advanced economies continues – including in Europe, the United States, South Korea and Japan. Over the next 20 years, the increase in global energy demand is expected to be largely met by renewable energy sources, and by 2040 renewables are expected to account for a larger share of electricity generation than coal (BP 2019b). The increasing uptake of renewables is expected to be supported by changes in technologies that make renewable electricity generation more viable, such as battery storage and upgraded electricity grid networks. Policies in many regions are also likely to be directed at reducing the carbon intensity of electricity generation, including through an increase in the share of renewables generation.[6]

The International Energy Agency's (IEA) *World Energy Outlook 2018* report presents long-term projections of thermal coal demand under different electricity generation scenarios (Graph 16). Under the IEA's scenario framed around government policies currently in place ('current policies'), global thermal coal demand is expected to increase moderately over the next 20 years, but still comprise a declining share of global electricity generation. An alternative IEA scenario ('new policies'), where a range of policies currently under consideration are implemented (which the IEA suggests moves countries towards meeting their Paris Agreement obligations), would see coal-powered generation broadly unchanged over coming decades.[7]

To date, the decline in renewable energy costs has been faster than expected. Should this trend continue, the substitution away from thermal coal and towards renewable energy sources would also be faster. In addition, if countries increase their commitments to reducing emissions, there would be an even faster transition. In the IEA's 'Sustainable Development' scenario (in which countries implement policies that the IEA suggests are comparatively more aligned with the Paris Agreement), coal's share in the electricity generation mix would decline from around 40 per cent currently to around 5 per cent in 2040.[8]

Developments in steel production

Chinese annual steel production appears to be broadly around its peak and production is expected to gradually decline, although there is considerable uncertainty around the outlook. Steel demand is expected to moderate largely because population growth and the rate of urbanisation are expected to slow. This would reduce the demand for residential housing and infrastructure, such as rail, highways and public buildings.[9] The ongoing transition towards a more services-orientated economy may also weigh on China's future steel demand.

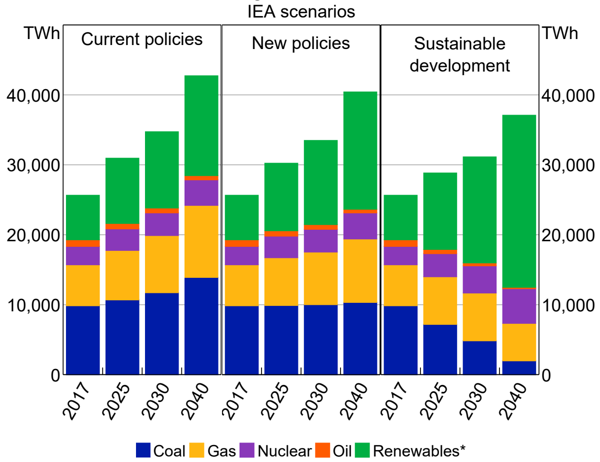
Further weighing on the outlook for Chinese metallurgical coal demand is an expected increase in the use of electric arc furnace technology. As more infrastructure assets, machinery and vehicles enter the replacement phase of their cycle, and scrap metal collection and recycling mechanisms become more widespread, scrap availability is expected to increase.[10] The Chinese Government has a target of increasing the share of scrap steel used in steel production to 30 per cent by 2025 (RBA 2017). Nonetheless, there is considerable uncertainty around how fast and how much Chinese steel production might shift towards more electric arc furnace technology.

In contrast to an expected moderation in Chinese steel production, Indian steel production has been growing strongly, and this is expected to continue over the next decade. Growth in Indian steel production is supported by an ambitious government target to triple output capacity to around 300 million tonnes by 2030, as well as plans to expand its manufacturing sector (DOIIS 2019b). The increase in India's steelmaking capacity will be primarily driven by an increase in blast furnace capacity. Rising demand for metallurgical coal will continue to be met by imports because of limited domestic availability, and India is forecast to become the world's largest importer of metallurgical coal by 2020 (DOIIS 2019a). In addition, growing steel production capacity in Vietnam, Malaysia and Indonesia is also expected to support demand for seaborne metallurgical coal.

Graph 16

Electricity Generation Mix

IEA scenarios



* Includes solar, hydropower, wind, bioenergy, geothermal, concentrated solar power and marine

Sources: IEA (2018b); RBA

Global supply[11]

Global supply of thermal coal is not expected to increase significantly in the next few years. Although there may be some scope for incremental increases in production at existing operations, there is relatively little additional capacity likely to be added to the seaborne market, given current indications of global investment plans and the long lead times for expanding capacity. In the absence of much additional global supply, it is possible that there may be episodes of tightness in the global supply–demand balance, which could support prices. This would particularly be the case if some exporting countries, such as Indonesia, were to direct more supply to their domestic market, or if global demand was stronger than expected for a period.

In contrast, the global metallurgical coal seaborne market is expected to expand over the medium term, as Australia and some other major exporting countries are expected to increase production, partly in response to recently higher prices as well as a more positive medium-term outlook for demand (DOIIS 2019b).

The Outlook for Australian Coal Exports

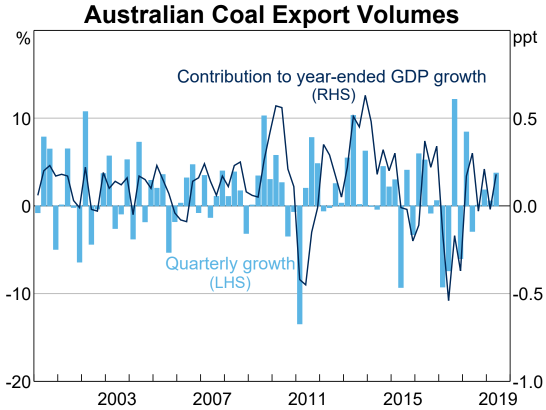
Over the next few years, Australian coal production and exports are expected to grow fairly slowly, driven by productivity improvements, the restart of some existing mines and completion of investment projects. However, mining companies generally maintain a cautious approach to any expansionary investment. In part, this is related to longer and more challenging approval processes and tighter financing conditions. The uncertain outlook for longer-term demand is also a key challenge for investment decisions. Low exploration expenditure is likely to limit future supply growth, particularly for thermal coal, despite a long pipeline of potential projects in Australia (DOIIS 2019b). The Bank's outlook therefore assumes there will be only moderate growth in coal export volumes and investment over coming years, particularly compared to the growth rates seen over the past 15 years.

Within this central outlook, it is possible that forecasts will need to be adjusted if there are any temporary supply or demand shocks. These can have large short-run volume and price effects, which, in turn, can materially affect economic aggregates. The effect of Tropical Cyclone Debbie in 2017, discussed above, is an example of this. The sharp decline in coal export volumes in April caused by this event subtracted around ½ a percentage point from GDP growth in the year to June quarter 2017 (Graph 17). As coal production and exports resumed over the latter half of 2017, there was then a period in which coal exports were making a relatively large positive contribution to GDP growth. Similarly, weather-related disruptions caused large declines in coal exports in early 2011 and mid 2015.

Beyond the next few years, the outlook for coal prices and demand is increasingly uncertain,

Graph 17

Australian Coal Export Volumes



Sources: ABS; RBA

particularly for thermal coal. The global seaborne market for thermal coal has grown significantly over the past 15 years, and Australian thermal coal exports are competing with plentiful supply from a number of other large low-cost producers. Many of Australia's key thermal coal export destinations, including China, Japan and South Korea, are transitioning away from coal-powered electricity generation. A continuation of this trend would be likely to weigh on coal export volumes and prices. On the other hand, demand is expected to grow in other economies in the Asian region, at least for a period. In particular, India and South-East Asia are likely to become increasingly important destinations for Australian coal exports over the next few decades as demand for energy grows and new coal-powered projects are added in these economies. It is difficult to forecast whether continued growth in exports to these markets might for a period outpace the global transition to less carbon-intensive electricity generation.

For metallurgical coal exports, the moderation in Chinese steel production, as well as a rising share of scrap in production, may weigh on demand over the next few years. More generally, Chinese policies could have a large impact on Australian coal demand, given that China accounts for close to a quarter of Australian metallurgical coal exports. These policies might include fiscal stimulus aimed at boosting infrastructure spending, environmental measures or changes to coal import policies. However, even if Chinese demand were to slow, this is likely to be somewhat offset by stronger demand from other destinations. India, which is already Australia's largest destination for metallurgical coal exports, should remain a key source of demand given expected growth in its steel sector. Reflecting this, Australian metallurgical coal exports are likely to remain a large part of the global seaborne market.

Overall, Australia is expected to remain a key global supplier of coal exports over coming years. This outlook is supported by Australia's proximity to key export markets, as well as the relatively more favourable characteristics of Australian coal.

Footnotes

[*] Michelle Cunningham, Luke Van Uffelen and Mark Chambers are from Economic Analysis Department. Trent Saunders also contributed to this work while in Economic Analysis Department.

[1] Although brown coal is used for some domestic electricity generation in Australia, brown coal is typically not exported. Globally the use of brown coal is less common due to its lower energy content and higher levels of carbon emissions.

[2] A small share of coal is also used for cement production and other industrial uses.

[3] Metallurgical coal includes both coking coal and pulverised coal injection (PCI) coal.

[4] Around 44 per cent of Chinese metallurgical coal imports in 2018 were sourced from Australia, compared with 24 per cent for thermal coal (DOIIS 2019a).

[5] For more information on these policies, see Boulter (2018).

[6] For example, the shift towards renewable energy sources in Europe will be supported by policies to end coal-based generation by 2030 (or earlier) in a number of countries, including Denmark, France, Ireland, Italy, Netherlands, Portugal and Spain. See, also, Debelle (2019).

[7] The 'New Policies Scenario' is based on energy policies that have been announced as at August 2018, and incorporated the commitments made in the Nationally Determined Contributions under the Paris Agreement. Where commitments are aspirational, the IEA makes a judgement as to the likelihood of those commitments being met in full. Under the New Policies Scenario, the IEA forecasts that coal's share of electricity generation will fall from 37 per cent in 2017, to around 30 per cent by 2030 and 26 per cent by 2040.

[8] The IEA's 'Sustainable Development Scenario' is based on achieving the main energy-related components of the United Nations Sustainable Development Goals, agreed in 2015. See United Nations (2015) for more information.

[9] See RBA (2017) for more information on the Chinese steel market and demand for bulk commodities.

[10] Worldsteel estimates that scrap availability in China will increase by around 50 per cent by 2030 from current levels (Çiftçi, 2018), supported by policies aimed at improving scrap metal collection and recycling, as well as higher scrap prices (DOIIS 2019b).

[11] For more discussion of the near term outlook for global coal exports, see DOIIS (2019a) and DOIIS (2019b).

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Liberalisation of China's Portfolio Flows and the Renminbi

Bobby Lien and David Sunner[*]

Photo: Somyot Techapuwapat / EyeEm and Xia Yuan – Getty Images

Abstract

China's equity and bond markets have grown rapidly to be among the largest in the world, yet, until recently, participation by foreign investors has been limited. Over recent decades, the Chinese authorities have relaxed investment restrictions to allow greater foreign access to these capital markets. This has enabled greater foreign investment and for global equity and bond index providers to increase the weight of Chinese securities in their indices, which are tracked by a range of global investment funds. These developments have contributed to an increase in gross foreign capital flows into China and they are likely to continue to support inflows in the period ahead. At the same time, an increase in Chinese resident portfolio outflows is also likely as domestic investors seek to diversify by investing abroad. The opening of China's financial markets entails benefits associated with deeper global financial integration, but may also contribute to greater variability in the renminbi.

Introduction

Over the past two decades, capital has flowed more freely across China's borders (Graph 1). The Chinese authorities have promoted increased cross-border capital flows as greater access to global financial markets offers potential benefits. For instance, increased gross foreign capital inflows can improve the efficiency of investment and also enhance liquidity in China's financial markets (thus lowering financing costs for Chinese borrowers). Increased outbound investment in foreign assets can enable Chinese residents to access a wider range of investment opportunities and to diversify risk.

The process of opening China's capital account has been deliberately gradual and controlled (McCowage 2018). This reflects the lessons learned from other developing countries that quickly opened their capital accounts to foreign investors. For instance, in the lead-up to the east Asian financial crisis, many emerging market economies relied on short-term US dollar-denominated funding from foreign investors, had large current account deficits, fixed exchange rates and low foreign currency reserves. These factors, together with insufficient corporate governance and regulatory frameworks which enabled excessive risk-taking, contributed to a severe financial crisis in several east Asian economies when foreign banks and investors rapidly withdrew financing (IMF 2012).

In the early stages of opening China's capital account, Chinese authorities prioritised foreign capital inflows that were channelled toward direct ownership stakes in firms or projects, known as foreign direct investment (FDI) (Graph 2). This was intended to minimise the risk of a sudden reversal of capital flows and a large movement in the exchange rate, as FDI tends to be a longer-term investment and therefore more stable than investment in financial market securities such as equities and bonds. Foreign purchases of securities tend to be more susceptible to rapid reversals in a time of stress as foreign investors can more readily sell and repatriate their investments back to their home country (IMF 2016).

As part of the internationalisation of the Chinese renminbi (RMB), the authorities have eased restrictions on banking-related flows since 2007 (Hatzvi, Meredith and Nixon 2015, and McCowage 2018).[1] These flows have proved to be volatile. From late 2014, market conditions changed markedly and expectations of an easing of monetary policy and depreciation of the Chinese renminbi (RMB) triggered flows (mostly channelled through the domestic banking system) out of China. To mitigate the large outflows conducted via domestic banks, the authorities implemented new capital controls and enforced existing controls more stringently, while also attempting to smooth volatility in the exchange rate. At the same time, the authorities continued to encourage foreign capital inflows.

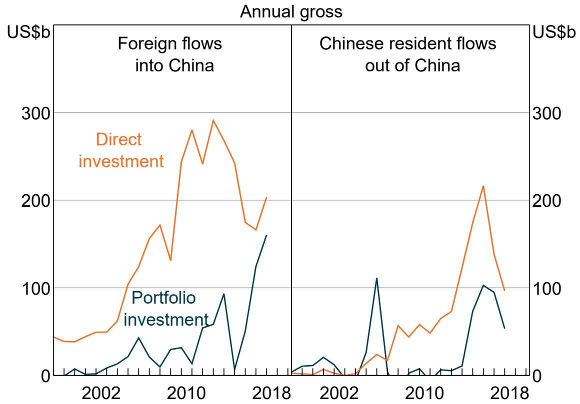
Since then, the authorities' focus has turned to progressing the liberalisation of the capital account by easing restrictions on foreign investment in China's onshore equity and debt securities markets, known as portfolio flows. This has led to a number of global equity and bond index providers recently announcing an increase in the weight of Chinese securities in their indices, which are tracked by a range of global investment funds. Running parallel with these developments have been efforts by the authorities to allow variability in the RMB to reflect fundamental market and economic forces.

The remainder of this article focuses on the liberalisation of portfolio flows and has two parts: first, it describes the progress of China's capital account liberalisation over time, particularly foreign access to China's onshore equity and bond markets.

Graph 1

China – Investment Flows

Annual gross

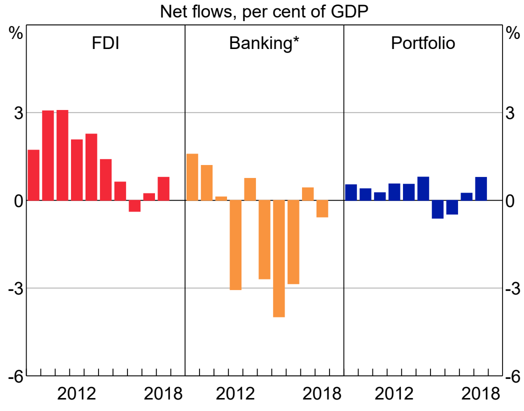


Sources: CEIC Data; RBA

Graph 2

China – Capital Flows

Net flows, per cent of GDP



* Banking and other financial flows

Sources: CEIC Data; RBA

Second, it discusses how the authorities have managed the liberalisation of these capital flows in conjunction with efforts to promote a greater role for market-based pricing in setting the value of the RMB.

Foreign Participation in China's Capital Markets

China's capital markets have grown rapidly over the past decade. Currently, China's onshore equity and debt securities markets are the second and third largest in the world by value, each accounting for about 10 per cent of the global market (Graph 3).[2] China's onshore capital markets have attracted attention from global investors seeking to gain more exposure to China's growing economy – the aggregate exposure of international investors to China's capital markets is far smaller than China's weight in the global economy. Currently, only around 4 per cent of onshore equities and 2 per cent of onshore debt securities are owned by foreign investors. This is low by international standards (Graph 4). Investing in Chinese securities has also allowed investors to diversify their risk as Chinese securities appear to have low (albeit increasing) correlation with other global financial market assets. In addition, Chinese Government bonds offer higher real yields than those of developed and some developing countries.

The market for Chinese Government Securities is where foreign participation has increased most notably in recent years, with the foreign ownership share currently around 8 per cent (Graph 5). The bulk of foreign holdings of Chinese Central Government bonds are held by foreign official institutions – and around one-third of foreign holdings is estimated to be held by the Central Bank of Russia (CBR) alone.[3]

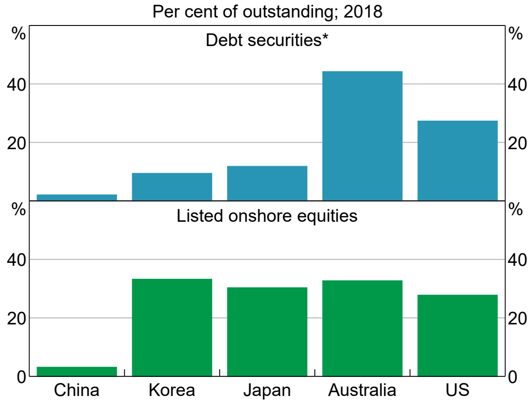
Gradual Liberalisation of China's Portfolio Flows

Chinese authorities have introduced a sequence of investment schemes to facilitate foreign access to China's onshore equity and bond markets (Table 1). These schemes were designed to balance the benefits of greater foreign participation against the risks of increasing portfolio flows too rapidly. Over time, authorities have gradually relaxed the restrictive nature of these schemes, eventually leading to Chinese onshore assets being included in

Graph 4

Foreign Holdings of Debt Securities and Equities

Per cent of outstanding; 2018

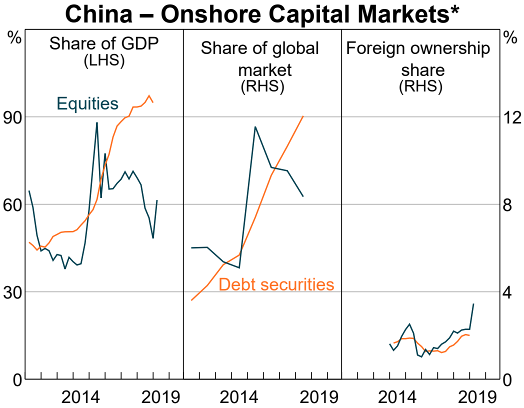


* Includes government and corporate securities

Sources: ABS; Bank of Japan; Bank of Korea; Bloomberg; CEIC Data; Federal Reserve; IMF; RBA; WIND Information

Graph 3

China – Onshore Capital Markets*

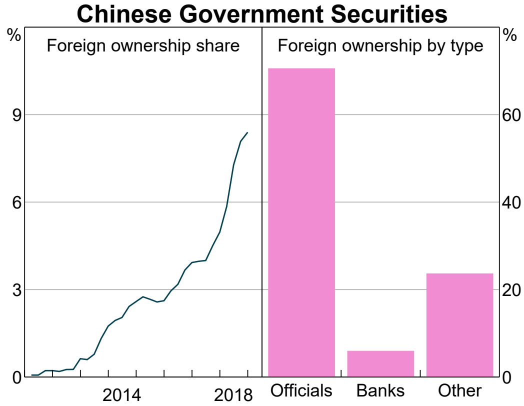


* Listed equities measured by market capitlisation; debt securities measured by face value

Sources: BIS; Bloomberg; CEIC Data; IMF; RBA; WIND Information

Graph 5

Chinese Government Securities



Sources: IMF; RBA

Table 1: Investment Schemes for Foreign Investor to Access China's Capital Markets

	QFII/RQFII	CIBM Direct	Stock Connect	Bond Connect
Date introduced	2002/2011	2015	2014	2017
Eligible securities	Onshore equities and bonds	Bonds	Onshore equities	Bonds
Investor types[(a)]	Institutional	Institutional	Institutional and individuals	Institutional
Aggregate quota	Yes	No	No[(c)]	No
Approval process	Difficult	Difficult	Simple	Simple
Clearing and settlement	Onshore	Onshore	Offshore	Offshore
Foreign exchange hedging	Yes[(b)]	Yes	Yes	Yes

(a) Subject to eligibility criteria

(b) RQFII does not allow for onshore hedging

(c) There is a daily net purchase quota in northbound flows

Sources: PBC; Stock Connect; Bond Connect; IMF; RBA

global benchmark indices. Achieving index inclusion is part of a broader agenda for China to open up its capital markets and internationalise the RMB.

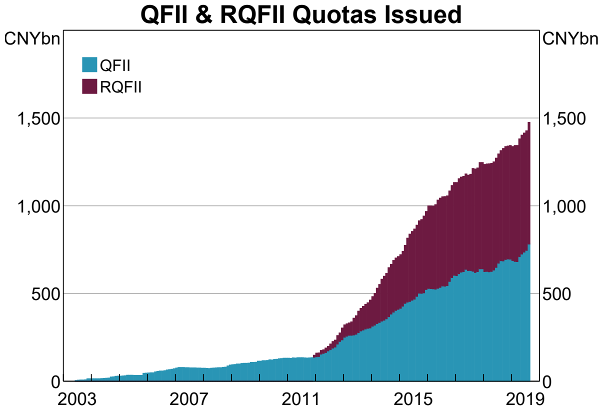
A first step in the opening of China's capital markets was the introduction of the Qualified Foreign Institutional Investor (QFII) scheme in 2002, which allowed foreign investment up to a given quota (Graph 6). This scheme was further expanded in 2011 by introducing the Renminbi QFII (RQFII) scheme, which allowed institutional investors to use offshore RMB – RMB held in accounts outside of mainland China – to access China's capital markets.[4] Promoting the use of the offshore RMB market through RQFII was a means of further developing and increasing the depth of the offshore RMB market.

These schemes provided highly regulated access to financial markets in China as they involved comprehensive investment and approval processes, lock-up periods to repatriate investment principal, and limited quotas (currently the aggregate quota is only around 1 per cent of the size of China's onshore equity and debt markets). To complement the QFII schemes, foreign central banks, sovereign wealth funds and select institutional investors were granted priority access by the authorities to China's interbank bond market (CIBM Direct). However, foreign participation remained low because the scheme was generally considered too tightly controlled.

Over time, Chinese authorities have relaxed restrictions and introduced new schemes – particularly Stock Connect and Bond Connect – to encourage greater portfolio investment (Table 1). The 'Connect' programs are two-way programs that link financial infrastructures between mainland China and Hong Kong, allowing trades to be settled using international trading platforms and offshore settlement agents in Hong Kong. In addition, there are no aggregate quotas imposed and the approval process is relatively streamlined. The attractiveness of the Connect programs is reflected by the increase in the share of foreign holdings held

Graph 6

QFII & RQFII Quotas Issued



Sources: CEIC Data; PBC; RBA

through these schemes, and has been one of the main reasons that led to benchmark index inclusion (Graph 7).

Index Inclusion Following the Creation of Stock and Bond Connect

In the past, index providers had been reluctant to allocate a large weight to Chinese securities in their benchmark indices because of concerns that capital flow restrictions would make it difficult for investors to replicate or closely track the index. The relaxation of foreign investment rules in recent years; the expansion of some onshore hedging instruments available to foreign investors; and the creation of the Bond Connect and Stock Connect schemes have collectively reduced some of these concerns. Ongoing capital account liberalisation would be supportive of a further increase in gross portfolio flows to China.

In early 2018, in anticipation of increased portfolio inflows and expectations that index providers would increase their weight of Chinese securities in their benchmark indices, the authorities substantially increased the daily Stock Connect quota of foreign investment into China (often called 'northbound' investment). The quota was increased to a daily net purchase of around CNY100 billion, or around 0.2 per cent of the market capitalisation of Chinese onshore equities (Graph 8). Given that index providers have only gradually phased Chinese securities into their indices, which has given investors time to adjust their portfolio allocations, the daily quota has not been a constraint to further inward portfolio investment.

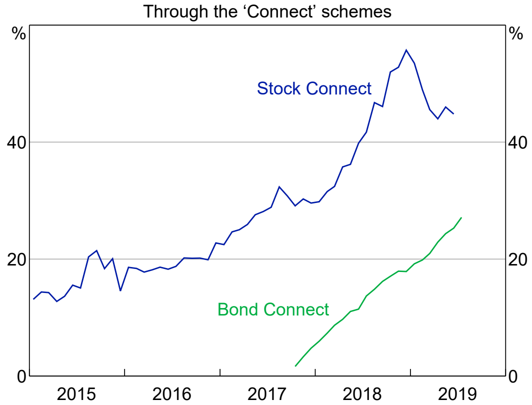
That said, there are a number of reasons why the weight of Chinese assets in global benchmark indices is likely to increase only gradually over time, and therefore remain below China's weight in the global economy. In fixed income markets, Chinese corporate bonds and local government bonds are still relatively illiquid and the credit rating system used for Chinese domestic securities is not consistent with international ratings.[5] Similarly, future increases in the weighting of Chinese onshore equities in global benchmarks is likely to be gradual, reflecting ongoing impediments to foreign investors' ability to freely trade in these securities. These include the limited active shares, as around 60 per cent of the onshore market is estimated to be not tradeable (Gatley, 2019), and Chinese authorities imposing a 30 per cent limit on foreign ownership of individual stocks.

Simple calculations suggest that index inclusion could generate large portfolio inflows. For example, it is estimated to generate a cumulative gross portfolio inflow of almost USD400bn over the next few years, or around 3 per cent of Chinese GDP (Figure 1).[6] For bonds, if realised, this additional flow should bring the share of foreign holdings of general government debt securities to around 25 per cent, above those of developed Asian countries such as Japan and Korea (at around 15 per cent). For equities, if realised, the additional flow represents only around 1 per cent of the

Graph 7

Share of Foreign Holdings

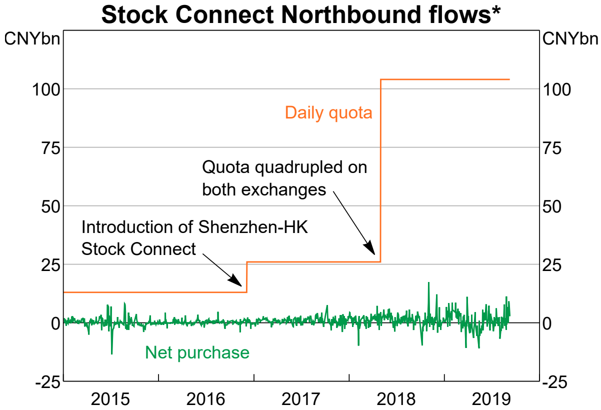
Through the 'Connect' schemes



Sources: Bond Connect; CEIC Data; RBA; WIND Information

Graph 8

Stock Connect Northbound flows*

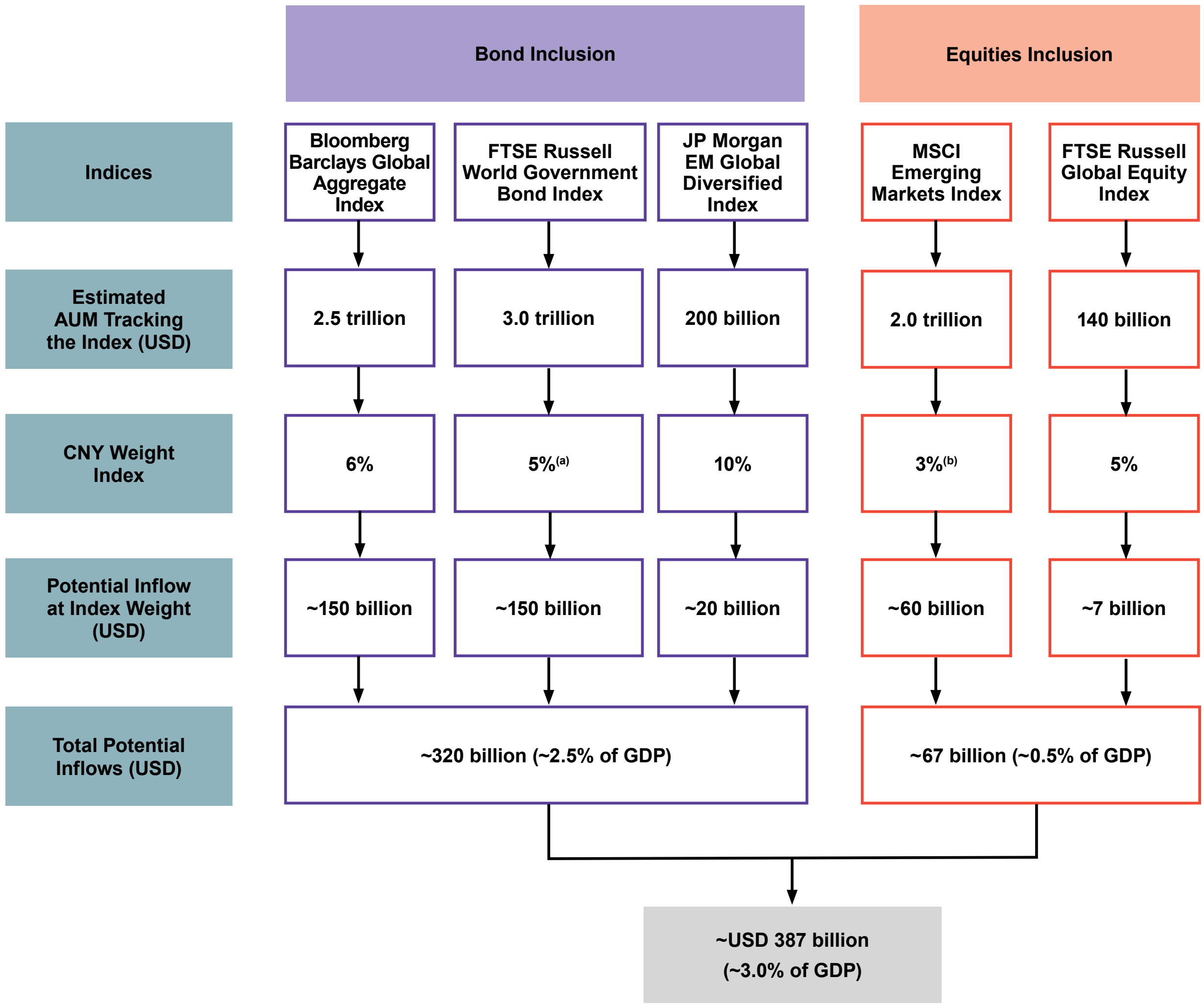


* Includes both Shanghai and Shenzhen Stock Connect programs

Sources: CEIC Data; RBA

Figure 1

Potential Chinese Onshore Portfolio Inflows from Index Inclusion (Indicative figures)



(a) Estimation as FTSE Russell has yet to announce the expected weight.
(b) Reflects the increase in weighting announced in 2019.
Sources: Bloomberg; FTSE; JP Morgan; Nomura; Queensland Investment Corporation; RBA; Reuters

onshore equity market capitalisation, which would bring the foreign investor share to around 5 per cent, well below the foreign holdings of equities in other developed countries (Graph 5). That said, these estimates are very uncertain.

Implications for the RMB

Further opening of China's financial markets to international investors (including through, but not limited to, global benchmarks) has potentially significant implications for the RMB. Increased gross portfolio investment into China will increase the demand for RMB, putting upward pressure on the exchange rate, while increased gross portfolio investment abroad by Chinese residents will work in the other direction. The net directional effect on the value of the exchange rate at any point will depend on which of these gross flows are larger, but both will unambiguously increase traded volumes (and thus liquidity) in the RMB.

Alongside increased trading volumes in the RMB, a greater tolerance for exchange rate flexibility is likely to be necessary as the capital account becomes more open. If the exchange rate is not permitted to adjust to market forces, the authorities may need to intervene in foreign exchange markets to counter depreciation (or appreciation) pressures associated with capital flows. If intent on leaning against market forces (such as portfolio flows) affecting the exchange rate via monetary policy, the authorities may also have to relinquish their ability to set domestic monetary conditions to best suit prevailing domestic economic conditions (Obstfeld and Taylor, 1997).

The Chinese authorities have allowed the RMB to become more flexible over time alongside efforts to partially liberalise China's capital account. Each morning, the authorities set the daily fixing rate based on the previous business day's spot close and overnight market movements, and permit the RMB to trade within a fixed band around the fixing rate (Halperin and Windsor 2018). The continuing use of the daily fixing rate has allowed the authorities to retain a degree of influence over the exchange rate. However, over time, the trading band has been widened from ±0.3 to ±2.0 per cent. This has allowed a modest increase in RMB volatility as the exchange rate has become more responsive to market developments (Graph 9). This increased flexibility has also seen the frequency and size of foreign currency intervention diminish over time. However, volatility of the RMB still remains low relative to free-floating currencies of advanced economies, and compared to the currencies of other emerging economies following liberalisation of their capital accounts.

Greater capital flows as a result of the ongoing liberalisation of China's capital account may result in a further increase in volatility in the exchange rate. Increased exchange rate volatility and volumes of gross portfolio flows (in and out of China) are likely to necessitate further development of Chinese derivative markets, in order to allow investors to better manage exchange rate risks. As large fluctuations in the exchange rate have been rare in China, this is likely to have contributed to the slow development of China's foreign exchange derivative markets (Garner 2017).

To the extent that gross portfolio outflows continue to increase and the RMB becomes more market determined, it will also lead to a shift in the nature of China's participation in global financial markets. More resident portfolio investment abroad, coupled with a reduced need for China's central bank to hold foreign exchange reserves, could see the role of the Chinese private sector become more consequential in global financial markets. This, in turn, may result in a shift in the global asset allocations of Chinese investors, as the private sector is likely to hold more diversified portfolios relative to the official sector, which has been primarily invested in the government bonds of advanced economies.

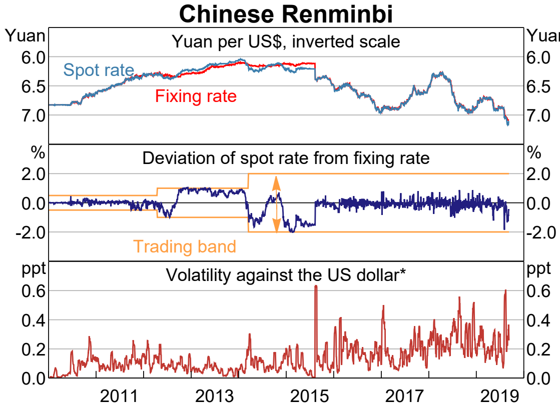
China's increased integration in the global financial system may also lead to Chinese financial conditions exerting a larger impact on global financial conditions, and vice versa.

Conclusion

China has recently taken steps to improve foreign access to its onshore equity and bond markets. This marks further progress in capital account liberalisation. Countries that have previously liberalised their capital accounts have generally mitigated the risks of doing so by developing hedging markets and other financial market infrastructure. Greater flexibility in the RMB also offers the potential benefit of increased monetary policy independence in China. ✠

Graph 9

Chinese Renminbi



* 10-day rolling standard deviation

Sources: Bloomberg; China Foreign Exchange Trade System; RBA

Footnotes

[*] The authors are from International Department and would like to thank Jarkko Jaaskela, Dana Lawson and David Lancaster for their comments and suggestions.

[1] Banking-related flows mostly constitute loans, currency & deposits and trade credit & advances. Banking-related outflows increased significantly between 2014 and 2016. Official statistics also indicate large discrepancies during this period, suggesting outflows could be larger than those shown in Graph 3.

[2] These figures excludes securities of Chinese companies that are listed offshore and denominated in either a foreign currency or offshore RMB (CNH). Offshore-listed equities account for around 35 per cent of the market capitalisation of all Chinese listed stocks. Debt securities issued offshore account for around 5 per cent of all Chinese bonds outstanding.

[3] The large share of holdings from the CBR reflects a transition away from holding US dollars over the past few years following sanctions imposed by the United States on Russia.

[4] To internationalise the RMB and promote its use in international trade, without having to fully open its capital account, China created an offshore RMB market in 2009.

[5] Domestic credit agencies apply looser standards when rating onshore debt securities than those used in other international markets. This makes it more difficult for debt investors to assess the riskiness of Chinese bonds. For example, a BBB- or below credit rating by international credit ratings agencies is considered non-investment grade. In contrast, in China a AA- or below credit rating by domestic rating agencies is considered non-investment grade – that is, a company with a AA-credit rating in China is considered riskier than a company with a AA-rating in other markets.

[6] The cumulative portfolio flow is calculated by taking the value of assets under management that track key benchmark indices that have (or will likely) include Chinese securities into their indices, then multiplying by the expected increase in the weight of Chinese securities in these indices.

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Bank Balance Sheet Constraints and Money Market Divergence

Belinda Cheung and Sebastien Printant[*]

Photo: Chuanchai Pundej / EyeEm – Getty Images

Abstract

The spread between key Australian money market interest rates has widened and become more volatile in recent years. While this might seem to imply scope to profit from arbitrage – by borrowing at a low rate to invest at a higher one – banks have additional balance sheet considerations that need to be taken into account. We find that money market trades have generally not been profitable for the four major banks since the financial crisis. This is partly because debt funding costs have fallen by less than money market returns. In addition, equity funding, which is more expensive than debt, has increased. Consequently, the incentive for banks to arbitrage between money market interest rates has fallen. We also note that banks tend to prefer more profitable lines of business, such as lending for residential housing, over the narrow margins implied by money market arbitrage.

Divergence in Money Market Rates

In recent years interest rates (or gross returns) in Australian money markets have significantly and persistently deviated from each other, and from the overnight cash rate (Graph 1).[1] Notable examples have been the swapping of Australian dollars into Japanese yen to earn the premium embedded in the forward foreign exchange swap rate and, to a lesser extent, the domestic repo rate (Becker and Rickards 2017). Deviations in interest rates that are large and persistent typically represent a profit opportunity and should not occur. Theoretically, market participants exploit such opportunities by borrowing in the market where interest rates are lowest to invest in a market where interest rates are higher, until it is no longer profitable to do so.[2] However, since at least 2014, this does not appear to have happened to the extent that might be expected.[3]

This article examines whether the major banks have scope to 'arbitrage' away divergences between Australian dollar-denominated money market interest rates. To do so, we estimate the funding cost associated with each money market asset using data since 2008. A key finding is that overall balance sheet considerations have raised asset-specific funding costs relative to gross returns. Hence, until 2018, arbitrage trading has generally not been profitable. We show how much the constraints on the use of leverage affect funding costs. Money market trading tends to be a narrow-margin business. As a result, the major banks limit trading activities and structure their balance sheets towards higher return assets such as mortgage lending. However, banks continue to actively manage their own positions in money markets and act as 'market makers' for customers.

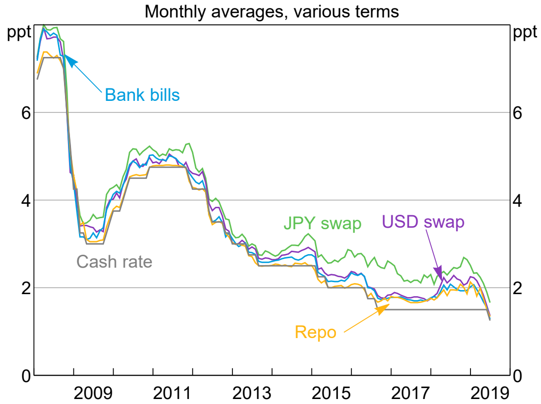
Methodology

To determine the profitability of money market trades we calculate the net return banks can earn by arbitraging between money markets. We apply the methodology put forward in Cheung and Printant (2019), which accounts for the total balance sheet considerations that major banks face. This methodology explicitly accounts for differences in funding costs due to the characteristics of specific money market assets. This is important because prudential standards generally require supervised institutions (like banks) to fund riskier assets with a larger share of equity capital, which is typically more expensive than debt. The funding structure of a bank is determined by the asset composition of its balance sheet and prudential regulation. While the debt funding cost we derive is independent of the investment decision, both the gross return on, and riskiness of, any specific investment have a material bearing on the net return that can be earned.

Graph 1

Gross Returns on Money Market Trades

Monthly averages, various terms



Sources: Bloomberg; RBA

The net return NR_{it} that a bank earns on a position in an asset i at time t is calculated as the gross return GR_{it} on the asset net of the total cost of funding the position TC_{it}:

$$NR_{it} = GR_{it} - TC_{it} \tag{1}$$

We can rewrite TC_{it} as a weighted average of the institution's overall debt funding rate (DFR_t) and equity funding rate (EFR_t):

$$NR_{it} = GR_{it} - \left[\tau_{it}{*}EFR_t + \left[1 - \tau_{it}\right]{*}DFR_t\right] \tag{2}$$

where τ_{it} is the share of equity funding notionally allocated to asset i such that $\tau_{it} = \frac{\text{Equity}_{it}}{\text{Value of asset}_{it}}$, and the remainder $(1 - \tau_{it})$ of asset i is funded with debt. While τ_{it} is not directly observable, we estimate the minimum amount of equity funding required to satisfy current prudential standards for each asset i. [4]

Assessing the Profitability of Money Market Arbitrage

Using the methodology above, we calculate the net returns for each money market asset and assess whether the investment is profitable after accounting for asset-specific funding costs. During the first half of 2008, net returns for bank bills or foreign exchange swaps were around 110 basis points, but around 60 basis points for repo (Graph 2).[5] The profitability of these trades declined during the financial crisis and net returns generally remained negative prior to 2018.

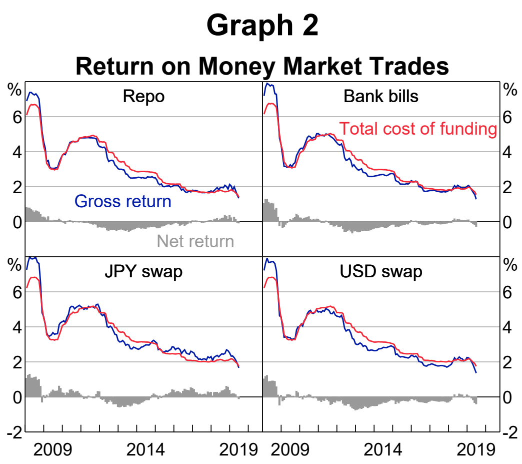
Since 2008, the total cost of funding declined in absolute terms as monetary policy became more accommodative. However, this decline in the cost of funding was less pronounced than the fall in gross money market returns. The main driver of the erosion in net returns has been the narrowing in the spread between gross returns and the debt funding costs (Graph 3). Most of this relative increase in debt funding costs is explained by the repricing of risk in retail deposits and longer-term debt, as well as intensified competition for stable funding following the financial crisis (Atkin and Cheung 2017).

The decline in net returns is also attributable to an increase in both the cost of equity and the proportion of equity funding used. While it became profitable in 2018 for major banks to pay the debt funding rate to lend into the relatively safe repo market, the additional cost of equity associated with riskier investments in bank bills and foreign exchange swaps reduced the returns from arbitrage in these markets. Equity now accounts for around 20 per cent of the cost of funding these trades (up from around 5 per cent) which reflects the increase in capital buffers since 2008.

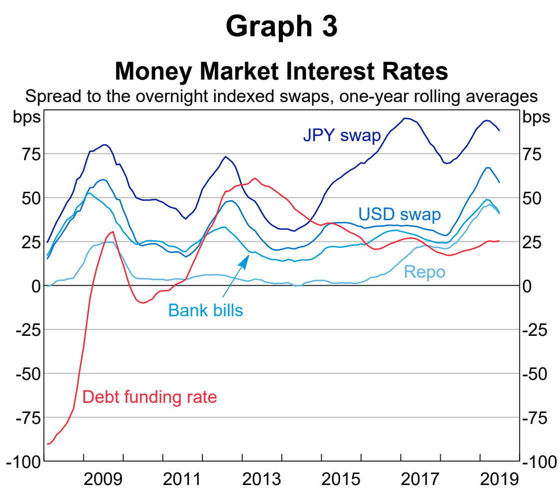
We extend our methodology to other assets on bank balance sheets to determine the opportunity cost associated with allocating funding to money market trading, and find that residential mortgages are always significantly more profitable than money market trades over the sample period (Graph 4). This suggests that there has been a substantial opportunity cost associated with diverting equity funding away from mortgages and towards lower-margin activities such as money market trading (Bajaj *et al* (2018)). This is consistent with the balance sheets of the major banks being weighted towards mortgages and away from trading investments (Roengpitya, Tarashev and Tsatsaronis 2014).

The methodology we outlined above assumes all investment activity is centrally funded at the aggregate balance sheet level. Subject to prudential regulations, this reflects the optimised allocation of capital to individual business units across the bank (Bajaj *et al* (2018)).[6] However, in practice, trading activities contracted by money market desks are at least partly 'self-funded' from a range of sources. For example, bond traders might choose to borrow in the repo market in order to invest in securities. This differs from broader funding of the institution through accepting deposits or raising offshore debt.

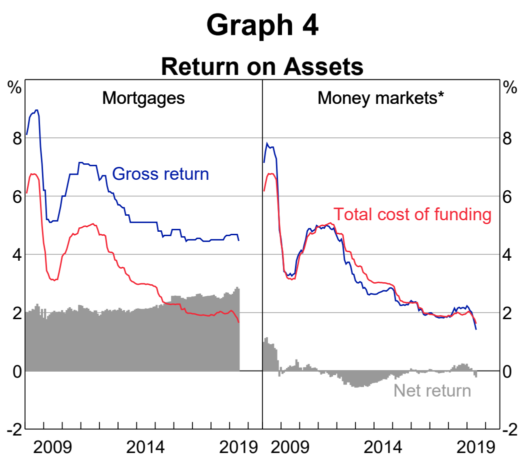
A more realistic approach might therefore be to replace the debt funding rate in our framework with the repo rate – typically the lowest money market rate over the sample period. This yields broadly similar results to our initial methodology. If banks were to borrow cash under repo to invest in bank bills, net returns would have been negative since 2016. Similarly, borrowing in the repo market to lend cash into US dollar-denominated foreign exchange swaps does not appear to have been a profitable investment for the major banks since



Sources: APRA; Bloomberg; RBA



Sources: Bloomberg; RBA



* Average of estimates for bank bills, repos and swaps into JPY and USD
Sources: APRA; Bloomberg; RBA

2009. The only market where spreads were sufficiently wide to yield a positive net return when funded by repo are those observed in the Japanese yen foreign exchange swap market. The net return for major banks borrowing under repo to lend into the Japanese yen foreign exchange swap market peaked at around 60 basis points in 2016, before narrowing to around 15 basis points for most of 2017–18.

Our approach does not measure how much arbitrage is already reflected in observed money market rates. That is, it may be possible arbitrage activity has already led to some convergence between funding and investment rates, thereby exhausting profitable trading opportunities.[7] However, the methodology is a useful framework to explain why complete convergence between market rates has not occurred.

Profitability and Leverage of Money Market Participants

Our results in the previous section can be used to define a relationship between the profitability and funding structure of an investment. We do this by estimating the point at which investors just cover their costs. The 'break-even spread' is the minimum number of basis points between the gross return on an investment and the debt funding rate that generates zero net returns.

Intuitively, if investments were to become funded by a larger share of relatively expensive equity, the return required to break even would rise. If an investment is funded with a larger share of debt, the minimum required return declines because borrowing is less expensive.[8]

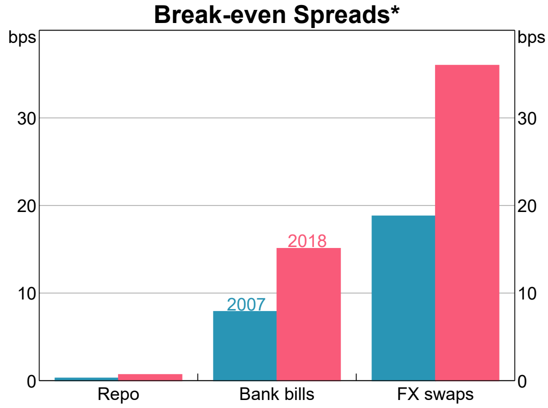
Before the crisis, banks were important providers of liquidity in money markets. These positions were funded by a relatively large share of debt, and break-even spreads were relatively low. The minimum break-even spread for repo investments funded at the aggregate debt funding rate was around one basis point (Graph 5). Reflecting the higher share of equity funding, the minimum break-even spread for bank bills and foreign exchange swaps was around 10 and 20 basis points, respectively. Following a period of repricing of risk, break-even spreads doubled by 2018. This reflects two developments. First, the relative cost of equity rose over the period so that for any given degree of leverage, the implied minimum break-even spread is higher. Second, the share of equity funding for any money market investment has almost doubled over the period. This has had few consequences for investing in the repo market as the low risk (arising from the collateralisation of the trade) means little equity funding is required. However, by 2018, the break-even spread had risen to around 15 basis points for bank bills, and to around 35 basis points for foreign exchange swaps. Effectively, the hurdle for banks to achieve profitable arbitrage rose substantially and helps to explain a significant increase in the degree of dispersion in money market rates.

However, this is a stylised representation of bank activities. There are other sources of revenue which are not explicitly taken into account, such as fees, charges and the revenue earned from market making activities. Some costs are also omitted, such as staffing, maintenance of a branch network and systems.

While major banks have a diminished incentive to arbitrage across money market rates post-crisis, this may not be true for other market participants. In the domestic repo market, around half the cash lent by dealers is borrowed by non-residents who are likely to be non-bank entities. Non-bank entities may be better able to take advantage of arbitrage opportunities across money markets, as they are

Graph 5

Break-even Spreads*



* Minimum required spread between the gross return on the investment and the debt funding rate

Sources: APRA; Authors' calculations; RBA typically less constrained by prudential requirements.

However, constraints on the balance sheets of the regulated banking sector may spill over to non-bank market participants and limit their arbitrage activities. Banks are an important source of funding for non-banks through the provision of credit lines. To the extent that this source of funds is curtailed, non-banks may be affected by regulation in the banking sector. In the United States, Boyarchenko *et al* (2018) suggest regulatory requirements that apply to broker-dealers have spilled over to non-regulated entities because regulated broker-dealers are less willing to extend credit. Consequently, this has limited the ability of non-regulated entities to pursue arbitrage opportunities. It is difficult to assess the extent to which funding to non-bank participants may have been constrained in the Australian context. Notwithstanding this, it is likely that bank lending volumes to non-bank participants in the domestic repo market are too small to close persistent money market arbitrage opportunities (Becker and Rickards 2017).

Conclusion

The incentive for banks to completely arbitrage away the divergences between money market rates has fallen since 2008. We find that developments in broadly defined funding costs can help to explain this divergence. Consequently, some dispersion in money market rates may occur unless arbitrage becomes more profitable for banks or non-bank participants emerge as the principal arbitrageurs.

Footnotes

[*] The authors are from Domestic Markets Department. This article summarises a recently released Research Discussion Paper, and interested readers should refer to Cheung and Printant (2019) for further detail.

[1] Money markets primarily consist of trading in Australian dollars in the unsecured cash market or via short-term investments, such as repurchase agreements (repos), bank bills and foreign exchange swaps. Interest rates across these different markets should generally be similar as the same product – Australian dollar cash – is traded in all these markets.

[2] In this paper, we do not adhere to the typical definition of arbitrage where all aspects of the transaction are contracted to eliminate all risk.

[3] Covered Interest Parity, whereby the expected interest rate to borrow Australian dollars in the domestic money market should be equal to the rate of borrowing Australian dollars in another currency while covering this foreign exchange exposure (using a foreign exchange swap or forward contract), appears to have been violated significantly and persistently.

[4] For the full derivation, see Cheung and Printant (2019).

[5] In 2008, the gross return associated with swapping Australian dollars into Japanese yen was around 120 basis points higher than the debt funding rate. Notwithstanding that gross returns have increased due to the widening in the cross-currency foreign exchange swap basis associated with this trade, the net return we derive is substantially lower at around 30 basis points in 2018.

[6] Wakeling and Wilson (2010) note that business units can source funding internally from the institution's treasury but are typically charged a transfer price that reflects the broader cost structure of the bank. As a result, the internal cost of funding is likely to be higher than the cost of debt described in the baseline model.

[7] Indeed, we note that money market rates have become significantly more correlated in recent years. This could be interpreted as an indication of a higher degree of market integration and trading activity.

[8] Refer to Cheung and Printant (2019) for a detailed explanation of the relationship between the composition of funding (debt or equity) with required returns.

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Survival Analysis and the Life of Australian Banknotes

Shane Aves[*]

Photo: BlackJack3D – Getty Images

Abstract

The Reserve Bank is in the process of replacing Australia's first full series of polymer banknotes – the 'New Note Series' – with the upgraded 'Next Generation Banknote' series. This presents a good opportunity to review our experience with polymer banknotes, and in particular, examine how they have worn in practice. To do so, I extend an existing survival modelling approach to estimate how long a given polymer banknote from the 'New Note Series' might be expected to last when in use by the general public. I find that $5 and $10 banknotes have tended to last for around 5 years on average, while $20 and $50 banknotes have lasted for 10 and 15 years on average, respectively. I have not modelled $100 banknotes as they are overwhelmingly used for store-of-value purposes and so do not tend to wear out.

Introduction

In this article I estimate how long a typical Australian polymer banknote from the 'New Note Series' (NNS) lasts. In particular, I estimate a survival model of banknote life based on Rush (2015) which incorporates factors that can affect the life of a banknote, including significant economic events and changes to the Reserve Bank's policies around banknotes. Given certain modelling assumptions, the output of this model gives a complete description of the lifecycle of a banknote, including the distribution of outcomes. I briefly compare the results with alternative and simpler, turnover-based ways to estimate banknote life.

The survival function

The life and death of a banknote is analogous to the life and death of a biological organism. From the day it is issued, a banknote is subject to a set of random mechanical hazards. Banknotes presenting with staples, stains, holes or tears, to name a few, will be deemed unfit and destroyed by the Bank. But those that evade the many mechanical hazards that exist in circulation may have a long life. For these banknotes, the end of their useful life can occur either through an accumulation of inkwear, or because the series they belong to is eventually retired.

Survival models are often used by medical researchers, biologists and engineers to describe the probability of some event, like death or a product failure, occurring after a point in time. In banknote life, the event of interest is the destruction of an unfit banknote, which occurs when the banknote is returned to the Bank as unfit. For T the time of destruction, the *survival function* as a function of t is defined as:

$$S(t) = P(T > t). \tag{1}$$

A related concept is the death function, or the *lifetime distribution function* as it is known in the survival literature. The lifetime distribution function represents the probability a banknote will be destroyed by time t, and in fact is simply the cumulative distribution function (CDF) from statistics:

$$L(t) = P(T \leq t) = 1 - S(t). \tag{2}$$

Differentiating L(t) with respect to t gives the instantaneous destruction rate (the probability density function or PDF from statistics), which is also known as the *Event Density function* :

$$\text{Destructionrate}(t) = l(t) = \frac{dL(t)}{dt}. \tag{3}$$

Scaling the destruction rate by the proportion of surviving banknotes gives the hazard rate. The hazard rate represents the proportion of banknotes that are expected to be destroyed at time t, conditional on their survival up to that point:

$$\text{Hazardrate}(t) = \frac{l(t)}{S(t)}. \tag{4}$$

Graph 1 shows the predicted survival curve and its associated destruction rate and hazard rate for a single issuance of $5 banknotes, based on historical issuance and destruction data. Half of the issued banknotes are expected to be destroyed within about 6 years, with the destruction rate reaching its peak shortly thereafter. The flattening of the tail of the survival curve beyond this point indicates that a relatively small number of banknotes will last longer, although a sharp increase in the hazard rate shows that the probability of death increases rapidly from here, perhaps reflecting accumulated inkwear for the few surviving banknotes.

The Joint Survival Function

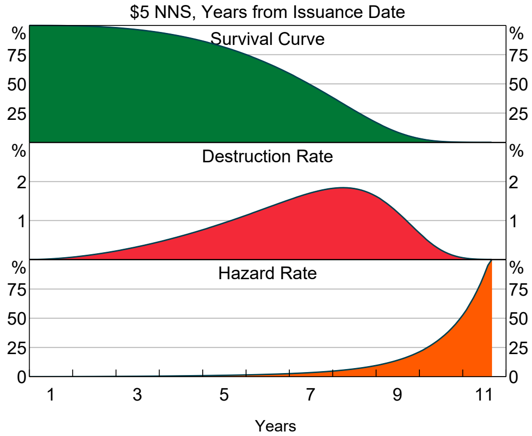
In survival modelling, researchers typically have the ability to observe the life and death of individual subjects, as well as their individual characteristics, and can use these data in estimating a survival function that describes the population. Unfortunately, no such individual-level data exists for Australian banknotes at the moment, although this may change in the future as serial number tracking in banknote processing machines becomes more widespread.

To overcome this, Rush (2015) proposed constructing a joint survival function that relies on aggregate issuance and destructions data, where the total quantity of surviving banknotes in existence is modelled as the sum of surviving banknotes from each issuance. Rush took advantage of the fact that every banknote is printed using the same method on the same materials, and assumed that each of the individual banknote survival functions were identical. Only the age of each issuance and the prevailing economic conditions change. This means that a single set of

Graph 1

Survival Curve, Destruction and Hazard Rate

$5 NNS, Years from Issuance Date



parameters are sufficient to describe the life-cycle of every banknote, regardless of when it was issued. Graph 2 illustrates the concept, where each of the grey lines represents a single issuance and its decay over time. The blue line is the sum of the survival functions, which is also the expected quantity of outstanding banknotes in existence, measured in millions of pieces.

Because issuances vary in size, the expected total quantity of outstanding banknotes, $E(O_t \mid \boldsymbol{\alpha})$, is equal to the sum of each issuances' survival function, $S(t_n; \boldsymbol{\alpha})$, multiplied by the quantity of such banknotes issued, I_n. Here $\boldsymbol{\alpha}$ is a vector of common parameters that must be estimated and t_n is the age of the *n*th issuance at time t:

$$E(O_t \mid \boldsymbol{\alpha}) = \sum_{n=1}^{t} S(t_n; \boldsymbol{\alpha}) I_n. \tag{5}$$

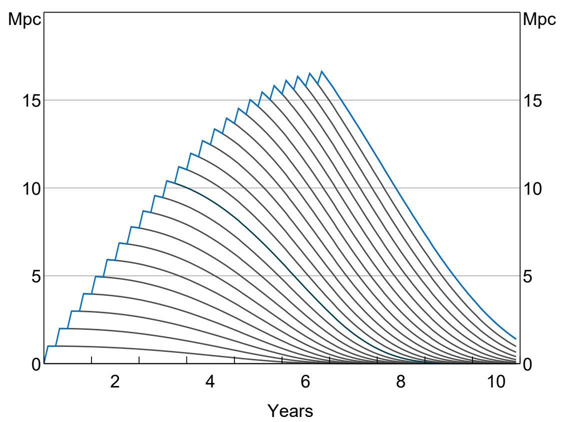
Abstracting from lost banknotes, the actual quantity of outstanding banknotes, O_t, can be calculated from the Bank's aggregate data as the sum of total issuances *less* total destructions:

$$O_t = \sum_{n=1}^{t} (I_n - D_n). \tag{6}$$

To estimate a joint survival function that best captures the actual life of banknotes, the objective is then to estimate parameters that minimise the difference between the expectation and the observed quantity of outstanding banknotes:

Graph 2

Joint Survival Curve



$$\arg\min_{\boldsymbol{\alpha}} \left(\sum_{n=1}^{N} \left(E(O_n \mid \boldsymbol{\alpha}) - O_n \right)^2 \right). \tag{7}$$

Activity Time

In the natural world, lifetimes are measured in years. This is also typically how most people view the age of a banknote. But banknotes do not age per se, they wear. Both mechanical and inkwear hazards are a function of the number of transactions a banknote undergoes throughout its life. This means, for example, that banknotes used primarily as a store of value will last many years longer than those that are transacted often.

We deviate from Rush's methodology by replacing chronological time with *activity time* – a quasi-time dimension that speeds up or slows down in response to macroeconomic conditions or changes in the currency issuer's banknote processing policy. The idea that time can run fast or slow is not new, and there is a large literature on asset pricing based on activity time and 'subordinator' models.[1] We use an additive method to construct the activity time, which ensures that time cannot run backwards and so constrains the survival function to be monotonically decreasing. Besides ensuring internal consistency, the method also adds 'memory' to the model, in the sense that if time 'ran slowly' for a period of a banknote's life, it is not forced to jump-back into line with chronological time once that period passes.

To be precise, for *t* representing activity time, $\boldsymbol{X}$ a matrix of explanatory variables (such as the velocity of cash, and control variables for Y2K and the GFC; see Appendix A for a complete list), and $\boldsymbol{\beta}$ is a vector of parameters estimated within the model, we define activity time as:

$$t_n = e^{\mathbf{x}_n' \boldsymbol{\beta}} + t_{n-1}. \tag{8}$$

Choosing a Distribution

A survival function can in principal take almost any shape as long as it starts at one and is non-increasing. Banknotes are exposed to two types of hazards: the first is mechanical damage which occurs randomly; and the second is inkwear, which accumulates with use. If mechanical hazards were the only cause of death, then one might expect the hazard rate to be constant, since the chance of a banknote becoming unfit would be the same no matter how old a banknote was. If inkwear were the primary cause, then one might expect banknotes to have similar lives and 'die' once they had been used in their allotted number of transactions. Lost, hoarded, or relatively unused banknotes further complicate the analysis. Rush takes a novel approach by separating out such banknotes from circulation. They are then locked away safely until the end of the study period. We allow for the probability that individual banknotes can change states. That is, banknotes can be temporarily hoarded before re-entering the cash economy at a later date. Nonetheless, lost, hoarded, or less frequently used banknotes are accommodated by allowing for a fat-tailed survival distribution.

The above considerations suggest that any candidate distribution will require a significant degree of flexibility to allow for the full range of possibilities. We use the Generalised Gamma (GG) distribution, which is the general form of a family of distributions that include the Exponential, Weibull, Log Normal and Gamma.[2] More importantly, the GG includes all four of the most common types of hazard function used in survival modelling: monotonically increasing and decreasing, as well as 'U' and arc-shaped hazards (Cox *et al* 2007).

Results

Graph 3 shows the model's overall fit for the $5 to $50 NNS denominations. Because relatively few $100 NNS banknotes have been returned to the Bank for processing, their expected life-span far exceeds the available data. For this reason, $100 banknotes have been excluded from the analysis.

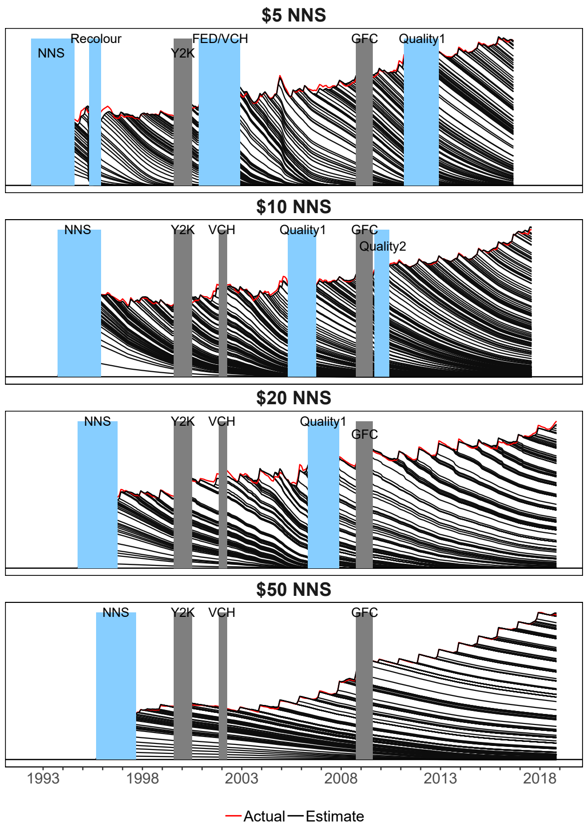
The blue shading on Graph 3 highlights targeted banknote quality programs and other denomination specific factors, while grey shading indicates significant events that are expected to affect all denominations to some extent, like the GFC (see Appendix A for more information). Most highlighted episodes are associated with some increase in the public's demand for banknotes and/or a policy change from the Bank that tends to increase banknote life. For example, demand for banknotes significantly increased ahead of Y2K, which resulted in each individual banknote being used less and so higher banknote life, despite an overall increase in transaction demand.

The fit of the survival model improves with time, particularly post 2006 when there were fewer banknote cleansing programs and other such distortions. The model performs particularly well on the $50 denomination. Australian $50 banknotes are thought to be primarily used as a store of value, while lower denominations are used more for transactions.[3] High levels of hoarding will tend to smooth out the effect of economic events on banknote life, given that the relatively low share of banknotes that are actively circulating are the only ones affected. The accumulated effects of transitory

Graph 3

Expected Quantity of Surviving Banknotes

Generalised Gamma with Activity Time



* NNS represents the introduction of NNS banknotes; Recolour is a change in colour to the $5 banknotes; FED represents the issuance of a special edition 'Federation $5' banknote; VCH relates to a change in distribution policy; Quality 1 and Quality 2 are various banknote cleansing programs. See Appendix A for more detail.

Table 1: Generalised Gamma Parameter Estimates; first issuance to 2018

	$5		$10		$20		$50	
Variable	Estimate	Sig.	Estimate	Sig.	Estimate	Sig.	Estimate	Sig.
Survival curve parameters								
μ (location)	5.00	***	4.83	***	5.23	***	6.61	***
σ (scale)	0.19	***	0.60	***	0.06	***	0.07	***
Q (shape)	1.89	***	1.47	***	19.55	***	11.87	***
Activity time parameters – environmental								
Velocity	13.29	***	11.32	***	15.64	***	55.77	***
Velocity * t	−0.04	***	−0.03	***	−0.06	***	−0.12	***
Y2K	−2.19	***	−1.65	***	−2.03	***	−1.19	***
GFC	−0.03		−0.15	*	−0.63	***	0.18	***
Surplus Fit Holdings	10.82	***	−7.33	***	−8.97	***	−1.55	***
Activity time parameters – banknote policy changes								
NNS	0.65	***	0.38	***	0.56	***	0.72	***
Federation $5	−1.14	***						
Recolour $5	1.81	***						
Quality program	0.19	***	0.40	***	0.73	***		
Quality program 2			−0.49	***	0.32	***		
VCH Distribution policy	−0.96	**	−0.37		−1.59	***	0.43	**
NGB	0.82	***	1.43	***				
MAPE (per cent)	*2.3*		*1.7*		*2.0*		*0.8*	
RMSE (million pieces)	*3.1*		*2.0*		*3.5*		*3.1*	
Degrees of freedom	*303*		*288*		*277*		*268*	

***, **, and * denote statistical significance at the 1, 5, and 10 per cent levels, respectively.

events are also less relevant to high-value banknotes that have a long life-span, since a smaller proportion of their life is affected. This, and the fact there were no cleansing programs aimed at the $50, probably explains why that denomination is the easiest to model.

Parameter estimates are presented in Table 1. The first three parameters, μ, σ and Q, determine the fit of the underlying GG survival function, while the remaining parameters define the activity time process, where positive values serve to speed up time and so reduce banknote life, and negative values slow time and so extend life. It's worth noting that the model is non-linear and subject to a scaling parameter (σ), so the coefficients cannot be compared directly between denominations. A description of each variable can be found in Appendix A.

The signs of the coefficients for variables related to the prevailing economic environment are broadly in line with what one might expect. Banknotes age more quickly when their velocity throughout the cash economy increases, but this effect has decreased over time. Y2K and the GFC are generally thought to have led to temporary increases in precautionary banknote demand, increasing banknote life. Banknote life also tends to increase with the Bank's 'surplus fit holdings' (these are used but still-fit banknotes that are stored in the Bank's vaults) as one would expect, since banknotes held in storage do not really wear.[4]

The appropriate signs for the variables related to changes in banknote policies are less obvious though. Banknote quality programs, for example, which seek to replace a significant share of outstanding worn banknotes with freshly printed ones, initially slow the destruction rate as new banknotes are issued in preparation for the program. The effect is then reversed once commercial banks start returning their stock of old banknotes for processing.

While the overall fit is encouraging, the model needs to capture the entire distribution if it is to provide valid information beyond just simple measures of central tendency. One way to check whether this is the case is to compare the model's predictions to data observed by the Bank in the course of its operations. Graphs 4 and 5 compare predictions of the average age of fit banknotes in circulation and unfit banknotes returned for processing to information taken from the Bank's commercial cash sampling (CCS) program.

In particular, the Bank records the year of manufacture of around 10,000 banknotes that are deposited by retailers each year and then sent on to the Bank for analysis. It is important to note, however, that the year of manufacture says little about when a banknote was actually issued to the public, and so to use these data to estimate how long a particular banknote has been in circulation I need to make assumptions around the timing of issuances.[5]

Overall, Graphs 4 and 5 suggest that the banknote life estimates, while close, are slightly upwardly biased overall. For unfit banknotes, the apparent bias can be explained when we recognise that the model predicts the age of unfit banknotes at the time of processing, whereas the sample data are for banknotes still in circulation which would otherwise have lived longer before they were returned to the Bank. It is less clear why the models appear to be slightly biased in regards to fit banknotes – either the models are somewhat misspecified or the assumptions used to calculate the age of banknotes from the CCS data are somewhat inaccurate. Most likely, both are true to some extent.

Graph 6 shows the average survival curve for each denomination, taken from the time they were first issued until the end of 2018. The dashed line at 50 per cent intersects with the *median* life for all banknotes in that denomination. Given that our data are largely silent on the destruction date of long-living, high-value denominations, the tail of the $50 distribution in particular, should probably be ignored.[6]

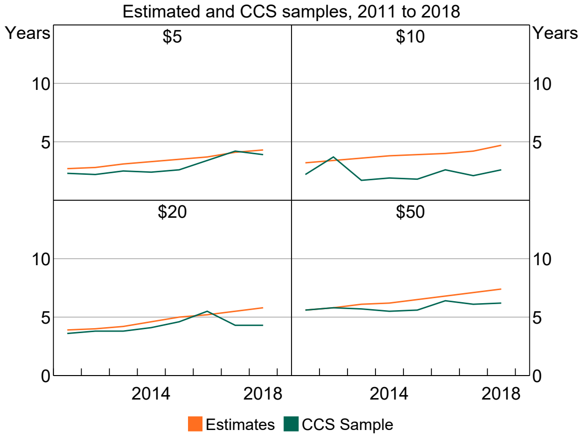
Comparison with Alternative Model Estimates

There are alternative ways to estimate banknote life. The most common method is based purely on the turnover of banknotes, and is simply the number of outstanding banknotes divided by the number of banknotes destroyed in a year. This method provides an estimate of central tendency but says nothing about the distribution of banknote life. The method is also sensitive to various idiosyncratic factors such as banknote demand shocks and

Graph 4

Age of Fit banknotes in Circulation

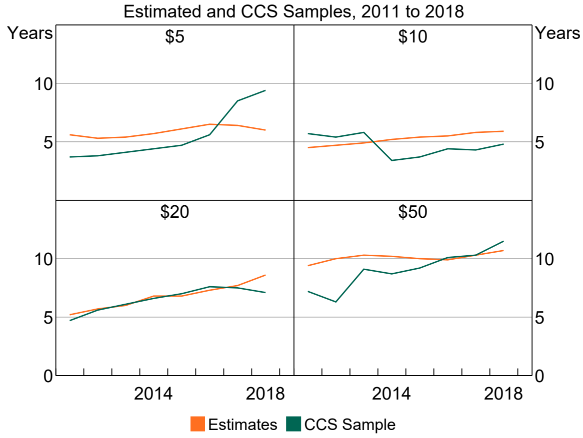
Estimated and CCS samples, 2011 to 2018



Graph 5

Age of Unfit banknotes

Estimated and CCS Samples, 2011 to 2018



changes in banknote processing policies. A slightly more sophisticated method, again based on turnover, is detailed in Feige (1989) and calculated as the average number of outstanding banknotes divided by the average of old banknotes destroyed and new banknotes issued each year (hereafter the 'Feige' method). Again, it says nothing about the distribution of banknote life and is still sensitive to various idiosyncratic factors, albeit less so.[7]

These turnover-based methods estimate banknote life using a cross-section of data taken at a particular point in time. In doing so, they implicitly assume that whatever was happening at the time will continue to happen into the future. That is, the prevailing conditions, or the *state*, are assumed to remain unchanged, and so these methods are referred to as *steady-state* methods.

Graph 7 compares some steady-state estimates of average banknote life with those from the model. As can be seen, one issue with steady-state methods is that they can be highly volatile. This stems from the fact that the steady-state methods are generally estimated based on a window of a single year of data. The effects from temporary factors are magnified because they are assumed to remain in place for the entire life of the series. Such factors usually have little to do with the structural integrity of the banknote, but are more often the result of the currency issuer's own policies. For example, in 1999 the Bank ceased destroying unfit banknotes to build a contingency stock for Y2K. The effect was to increase the steady-state estimates of banknote life at the time, and then reverse this once the contingency event had passed. In contrast, the policy change had little effect on our estimates of banknote life. More recently, the Bank limited its processing of the remaining stock of $20 NNS banknotes. This was an operational decision to ensure that the current stock of $20s would last until the new NGB series are issued in late 2019. This doubled the estimates of banknote life using the simple turnover-based measure, but had almost no effect on the model-based survival estimates which use all of the available data.

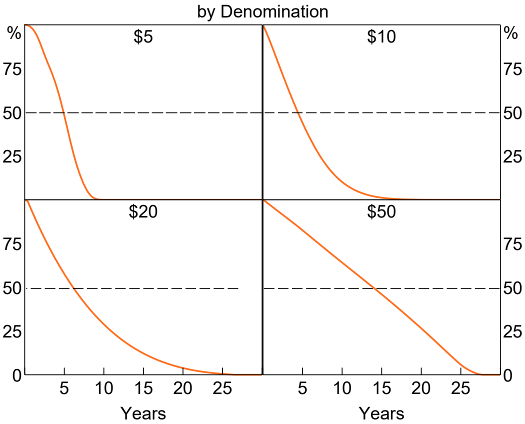
Conclusion

In late 2016, 2017 and 2018 respectively, the Bank released upgraded $5, $10 and $50 NGB banknotes, and the existing stock of old NNS series polymer banknotes were deemed unfit; the new $20 NGB is due to be released in late 2019. This banknote upgrade program, after roughly 25 years using the previous polymer banknote series, provides a good opportunity to evaluate how our banknotes have worn in use. Overall, I find that over their period of use, the average life of old-series polymer banknotes increases as the denomination gets higher: a little over 5 years for the $5 and $10; a little over 10 years for the $20; and around 15 years for the $50. This is consistent with lower-denomination banknotes incurring higher wear through greater use for transactions. ✠

Graph 6

Estimated Survival Curves*

by Denomination

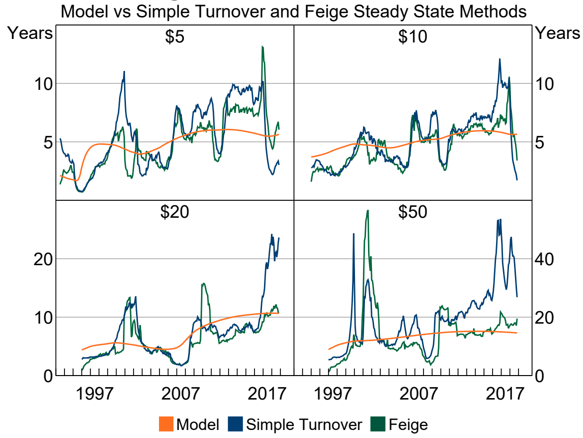


* Average survival curves, from first issuance to November 2018

Graph 7

Average Banknote Life Estimates

Model vs Simple Turnover and Feige Steady State Methods



Appendix A

Table 2: Explanatory Variables

Variable	Description
Velocity	The ratio of monthly ATM withdrawals, by value, to circulating banknotes, by denomination, is used as a proxy for the velocity of cash.
Velocity * t	The velocity variable times a time trend.
Y2K	An indicator variable is included for each denomination to allow for the RBA's precautionary measures and the possibility that public demand for banknotes increased around Y2K. The variable is equal to one between August 1999 and July 2000.
GFC	The GFC may have led to precautionary demand for banknotes or changes in use patterns. An indicator variable equal to one between October 2008 and August 2009 is included for each denomination.
Surplus Fit Holdings	Banknotes in excess of public demand are sometimes returned to the RBA where they are stored until they are re-issued at a later date. A variable is included that captures the proportion of surviving banknotes that are held at the RBA as surplus fit holdings.
NNS	An indicator variable is included for each denomination to allow for the possibility that hazard rates can differ when a banknote series is first issued. For the $5, $20 and $50 denominations the indicator variable is equal to one for the first two years. This is extended to 3.5 years for the $10 banknote since there were some minor changes to the ink used.
Federation $5	A commemorative $5 banknote celebrating the Centenary of Federation was issued in 2001 and withdrawn the next year. An indicator variable has been included and is equal to one from January 2001 to September 2002.
Recolour $5	The first $5 polymer banknotes released in 1992 were considered too pale. A brighter coloured version was subsequently released in 1995. An indicator variable has been included to allow for the possibility that hazard rates were affected during the period from May to December 1995.
Quality Programs	Indicator variables are used to capture the effect of targeted cleansing programs designed to improve the quality of banknotes in circulation. These were implemented for the $5 denomination in 2011, $10 in 2005 and 2009, and for the $20 banknote in 2006 and 2007.
VCH Distribution Policy	The RBA changed its cash management practises in 2001, transferring banknote holdings from the RBA to commercial banks. An indicator variable equal to one between November 2001 and April 2002 is included for each denomination to allow for the policy change.
NGB	Next Generation Banknote series were issued to the public in late 2016, 2017 and 2018 for the $5, $10 and $50 denominations respectively, and the old NNS series declared unfit. An indicator variable equal to one is included from two months prior to NGB's release until the end of the series for each of these denominations. The additional two months allows for the time taken to stock the commercial banks prior to the public release date.

Footnotes

[*] The author is from Note Issue Department and would like to thank Richard Finlay, Alexandra Rush, Luci Ellis, Tony Richards, Carl Schwartz and Sandra Wilkinson for their help.

[1] See for example Heyde (1999) and Finlay and Seneta (2006) for early examples that seek to model activity time in a realistic way.

[2] The GG distribution has density function:

$$f(x \mid \mu, \sigma, Q) = \frac{|Q|\left(Q^{-2}\right)^{Q^{-2}}}{\sigma x \Gamma\left(Q^{-2}\right)} \cdot exp(Q^{-2}(Qw - exp(Qw))); \; w = (log\,(x) - \mu)/\sigma$$

[3] Finlay, Staib and Wakefield (2018) discuss the drivers of banknote demand in more detail.

[4] The exception here is the $5 denomination, where the relationship inverts. On closer inspection, this particular coefficient probably suffers from omitted variable bias: the Bank generally only holds a small quantity of surplus fit $5 banknotes for around two months each year, immediately after the Christmas period, which is the time when cash demand is at its peak.

[5] Each banknote has its own unique serial number, and in principle this information could also be used to provide a wealth of information about banknote life. While this is likely to become the case in future, it has not been the case in the past: historically, serial numbers have not generally been recorded at the time of banknote issuance, and until recently the technology to capture them at the time of processing was also very expensive or unavailable.

[6] This is also why $100 banknotes were excluded from the analysis; steady state methods suggest that $100 NNS banknotes last around 200 years on average.

[7] See Rush 2015 for more information on these turnover methods.

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