A Cost-benefit Analysis of Polymer Banknotes

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Abstract

Australia was the first country to issue a full series of polymer banknotes, completed over 1992–96. After 25 years, issuance of the second generation of polymer banknotes is well advanced. It seems appropriate, therefore, to revisit the financial savings resulting from the switch to polymer. Employing a cost-benefit analysis framework, we find that the switch to polymer has resulted in net savings of close to $1 billion over the past 25 years in inflation-adjusted terms. This does not take account of the benefits of reduced counterfeiting, which have also been substantial and were the original motivation for switching to polymer. We also discuss cost savings arising from outsourcing banknote distribution to the private sector, as well as seigniorage income which accrues from banknotes on issue and which ultimately flows to the Australian Government as non-tax revenue in the form of the dividend payment from the Reserve Bank.

Introduction

Australia was the first country to issue a full series of polymer banknotes, completed over 1992–96. After 25 years, issuance of the second generation of polymer banknotes is well advanced. This presents a good opportunity to revisit the financial savings resulting from the switch to polymer.

The cost of printing polymer banknotes is generally higher than for paper banknotes, since polymer substrate costs more than paper. However, polymer banknotes have a much longer lifespan than paper banknotes – which in Australia's case tended to wear out after six months to a year – potentially reducing transport, processing, destruction, and production costs over time (Graph 1; paper life shown in lighter colours on the left). So while the initial motivation for developing polymer banknotes was to enhance security, there were also durability benefits which can result in lower overall cost. This article seeks to quantify these potential benefits.[1] The issuance of banknotes – regardless of the substrate they are printed on – also usually results in seigniorage income which ultimately flows to the government. Box A explains seigniorage and provides some estimates for Australia.

Cost-benefit Analysis Framework

The cost-benefit analysis framework used in this article is based on Bouhdaoui, Bounie and Van Hove (2013). The framework has two components: the 'upgrade' or 'up-front' cost of replacing all old-series banknotes (this is the initial cost of upgrading, and it can be significant); and the ongoing annual savings in production and other costs. The break-even point is when the sum of annual savings equals the migration cost.

Old-series Australian banknotes remain legal tender in Australia and can continue to be used. However, when upgrading a series, the Bank has historically sought to remove old-series banknotes from circulation and issue new banknotes to meet demand. This is a policy choice, and we could alternatively allow multiple series to co-circulate.[2] Given this approach, the Bank also has to replace banknotes held as contingency stocks, where we assume that the contingency buffer is set as sufficient to cover one year's worth of additional banknote demand. (Given that it takes some time to print new banknotes, central banks typically hold extra stock in case demand for banknotes suddenly surges or normal production is disrupted.) For N_t representing the number of banknotes in circulation at time t; $c_p^{polymer}$ the cost to produce polymer banknotes; c_d all costs associated with processing and destroying old banknotes (which for simplicity we assume are the same irrespective of substrate); and d_t representing banknote life (so that a $1 / d_t$ share of banknotes wear out each year), banknote upgrade costs will be given by:

$$C_m = N_0 \cdot \left[c_p^{polymer}\left[1 + \frac{1}{d_0^{polymer}}\right] + c_d\left[1 + \frac{1}{d_0^{paper}}\right]\right]. \quad (1)$$

Here the first term captures the cost of printing sufficient new polymer banknotes to replace all circulating banknotes plus those held in the contingency buffer, while the second term captures the cost of destroying existing paper banknotes (both those in circulation and those held as contingency).

Next we consider annual savings. Each year: old, worn-out banknotes will need to be replaced with new banknotes; additional new banknotes will need to be printed due to growth in overall banknote demand; and banknote contingency stocks will need to be topped up to account for growth in banknote demand. Accounting for each of these, the difference in annual replacement costs of polymer versus paper t periods after transition is given by:

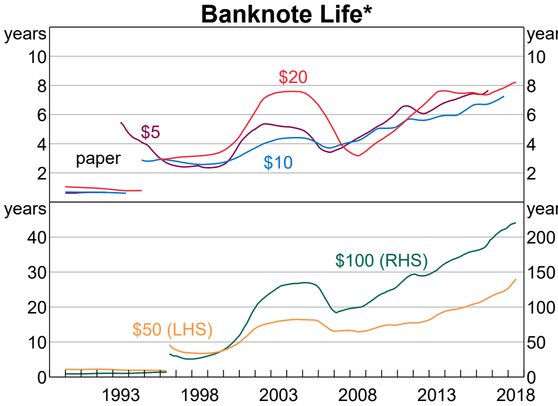
$$C_r(t) = N_{t-1}\left[\frac{c_p^{polymer} + c_d}{d_{t-1}^{polymer}} - \frac{c_p^{paper} + c_d}{d_{t-1}^{paper}}\right] + (N_t - N_{t-1}) \cdot \left(c_p^{polymer} - c_p^{paper}\right) + c_p^{polymer}\left[\frac{N_t}{d_t^{polymer}} - \frac{N_{t-1}}{d_{t-1}^{polymer}}\right] - c_p^{paper}\left[\frac{N_t}{d_t^{paper}} - \frac{N_{t-1}}{d_{t-1}^{paper}}\right]. \quad (2)$$

Here the first term represents the difference in replacement costs for existing banknotes that wear out; the second term represents the difference in the cost of printing new banknotes to meet increased net demand; and the third and fourth terms represent the difference in the cost of topping up the contingency buffer.

The total cost or gain from switching to polymer is the up-front upgrade cost as given by Equation (1), plus the sum over each period of the difference in annual replacement costs, as given by Equation (2).

Graph 1

Banknote Life*



* Five-year-ended average; initial data are paper, later data are polymer; excludes periods when issuance of new series banknotes materially affected data; banknote distribution arrangements were changed in the early 2000s, resulting in a large stock of new banknotes entering circulation and temporarily boosting estimated life

Source: RBA

Data and Modelling Results

Costs, prices and banknote life

To conduct a fair cost-benefit analysis we should compare the cost of printing polymer banknotes with the cost of printing otherwise similar paper banknotes. It has been around three decades since the Reserve Bank has ordered paper banknotes, however, and had Australia stayed with paper, then our previous paper series, first issued in 1966, would almost surely have been upgraded over that period. Reflecting this, we use publicly available banknote cost estimates from the Bank of Canada, which switched from paper banknotes to polymer banknotes over the period 2011–13, rather than out-of-date Reserve Bank figures. In particular, Bank of Canada (2018) estimates that the last paper series of Canadian banknotes cost CAD 10 cents per banknote to print (around AUD 11 cents); the first polymer series of Canadian banknotes cost CAD 23 cents per banknote to print (around AUD 25 cents); and the latest polymer series of Canadian banknotes cost roughly 20 per cent more per banknote to print at CAD 27 cents (around AUD 30 cents). In the analysis that follows we use AUD 25 cents as the assumed cost of polymer banknotes, and AUD 13 cents as the assumed cost of paper banknotes (being the final Bank of Canada paper banknote cost of AUD 11 cents, increased by 20 per cent to reflect a higher cost for a counterfactual upgraded paper banknote series). We assume that all-in unit processing and destruction costs are roughly 10 cents per banknote, irrespective of banknote substrate. (Our counterfactual paper banknote cost assumption is conservative. A more realistic approach might be to add 5 cents to the previous paper banknote cost rather than boost it by 20 per cent, since additional security features are likely to be similarly expensive for paper and polymer banknotes. Doing this would increase estimated savings by around 30 per cent.)

The longer life of polymer banknotes is what drives their reduced ongoing cost, due to lower transport, destruction, processing, and production costs over time. The average lifespan of Australia's polymer banknotes has increased since issuance, however, which at least in part is likely due to structural changes largely unrelated to the substrate (e.g. greater hoarding and less transactional use of banknotes, improved banknote distribution systems, and banknote processing machine upgrades). It seems reasonable to assume that some of this increase in banknote life would have occurred with paper banknotes also. To account for this, we grow the counterfactual paper banknote life by the average increase in polymer banknote life. It is important to note that different assumptions around the average life of the counterfactual paper banknote series will lead to different estimated cost savings, with longer assumed paper banknote life leading to fewer savings, and shorter assumed paper banknote life leading to more savings.

Results

Using a simple data-driven estimate of average banknote life through time, the cost-benefit analysis framework outlined above suggests that the introduction of polymer banknotes has led to large savings for the Bank and ultimately the Australian public. Most of these savings relate to the low denominations which tend to be used more for transactions than for store-of-value purposes ($5, $10 and $20; Graph 2). For these banknotes, upgrade costs are estimated at between $30 and $50 million, and the break-even point was achieved within four years of issuance. The relatively quick break-even time was driven by the very low banknote life of low denomination paper banknotes, being less than a year prior to polymer. For the $50 banknote, a greater outstanding volume means that estimated upgrade costs are higher at around $60 million, and the break-even point occurred after about eight years. For the $100 banknote, upgrade costs are estimated at around $30 million. Net savings remain negative for the $100, reflecting relatively long assumed paper banknote life due to more store-of-value and less transactional use. From the issuance of the first polymer series of banknotes until the recent introduction of new-series NGB banknotes, we estimate that the Bank will have saved just under $1 billion in inflation-adjusted terms.

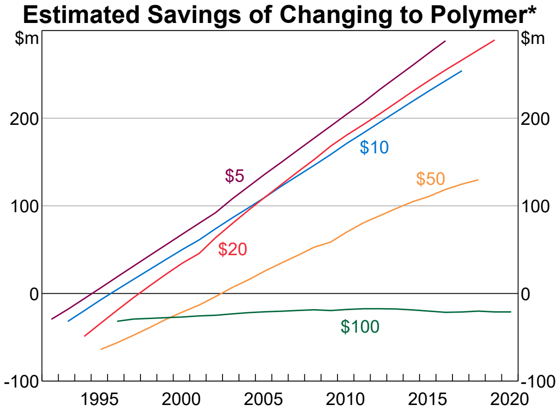
It is worth highlighting again that these estimates are sensitive to our assumptions, including those regarding banknote life (with the longer average life of polymer banknotes the driver of cost savings). If we instead use model-driven estimates of average polymer banknote life as contained in Aves (2019), estimated savings over the past 25 years are around 25 per cent higher. Conversely, if we base the assumed banknote life of the counterfactual paper series on public data on the UK's paper banknotes available from the Bank of England (instead of assuming that paper banknote life grows in line with polymer banknote life), estimated savings are still positive but are around 25 per cent lower.

Additional considerations

Although the model above is illustrative, it does exclude some important costs and benefits. The primary motivation for introducing polymer banknotes was to make counterfeiting more difficult by significantly increasing the security of Australia's currency. Counterfeiting rates did decline after the issuance of polymer and stayed low for many years. Quantifying these benefits and including them in the model would increase annual savings and reduce the time taken to reach the break-even point. However, due to the difficulty of putting a dollar value on this benefit, which includes the direct loss of inadvertently accepting a counterfeit as well as the potential for a loss of confidence in the currency more generally, we do not consider it here. Further, the longer banknote life of polymer partly contributed to the Bank changing storage and processing arrangements to a largely outsourced model (Menzies 2004). This resulted in a number of Reserve Bank branches closing and the Bank making considerable savings (see Box B for a discussion of the evolution of the Bank's banknote distribution arrangements). It is likely that some of these arrangements would eventually have occurred had the Bank continued with paper banknotes, and so we again exclude them.

Graph 2

Estimated Savings of Changing to Polymer*



* CPI-adjusted

Source: RBA

Working the other way, the Bank spent about $30 million on polymer research and development (R&D) over the period 1968–88 and approximately $2 million in public education when polymer banknotes were first introduced. Adjusting for inflation brings these costs to approximately $150 million in current prices. Moreover, the Bank has to periodically cleanse and upgrade banknotes regardless of the substrate used (for example, the Bank is currently upgrading from the first series of polymer banknotes to new-series NGB banknotes), and these costs will be higher when the substrate is polymer.

In the section below we attempt to incorporate an upgrade cycle into our model. We assume that each time a series of banknotes is upgraded, per-banknote printing costs rise by 20 per cent irrespective of substrate. Moreover, we assume set-up and R&D costs would have been equivalent under either a paper or polymer upgrade. Using the cost-benefit analysis framework and the above assumptions, we estimate that NGB upgrade costs are about $160 million higher than they would have been had the Bank continued using paper banknotes, although the figure of course depends on numerous assumptions, including the number and level of security features incorporated into the hypothetical paper banknote (Graph 3).[3]

A general setting

The length of time between the first and second generation polymer banknote series in Australia – about 25 years – was significantly longer than most central banks would expect to have between series, which is typically in the order of 10 to 15 years, which highlights how successful the move to polymer was in terms of security.

We now illustrate the trade-offs between paper and polymer in a hypothetical setting where upgrades occur every 15 years. At time zero we take the cost to produce polymer and paper banknotes to be those quoted earlier. We start circulation and banknote life where they were at the initial switch to polymer, and assume that the Bank undertakes a banknote upgrade immediately. We then apply average annual circulation growth rates. The next time the Bank has to upgrade a banknote series, we assume that the unit production cost for both paper and polymer banknotes increases by 20 per cent. Further, we let banknote life trend higher in line with past experience. Finally, for simplicity we assume that the Bank upgrades all denominations at the same time.

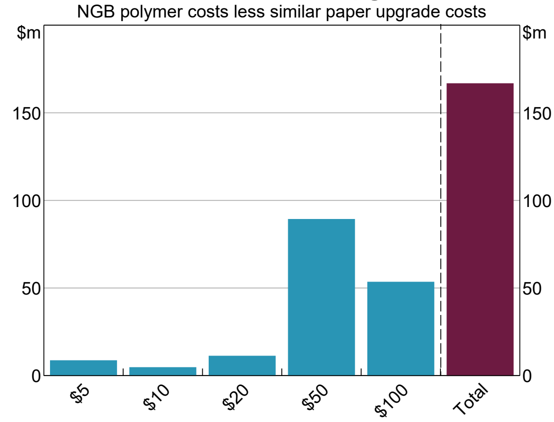
The longer lifespan of polymer banknotes again leads to the accumulation of significant savings over time (Graph 4; top panel). With the introduction of each new series, however, the Bank incurs higher upgrade costs than it would have if the upgrade was made with paper, causing drops in net savings. At a denominational level, we again see that gains from issuing polymer $5, $10 and $20 banknotes account for most of the savings (Graph 4; bottom panel). Savings from the $50 banknote are also substantial, while they are negative for $100 banknotes, due to large upgrade costs and the assumption that paper banknote life would have increased over time (after 30 years, our counterfactual $100 paper banknote life increases to 60 years, compared with an upgrade cycle of only 15 years). This highlights that with more frequent upgrades, ever-longer banknote life is not particularly useful since the counterfeit-resistance of security features becomes the binding constraint, and many banknotes will be recalled before they are physically worn out.

In summary, Australia's move to using polymer banknotes around 25 years ago has been very successful: the banknotes have proved difficult to counterfeit, which was the original aim; and they have been very durable, which has saved the Bank and, by implication, Australian taxpayers, roughly $1 billion over that period. These cost savings have been driven by those banknotes which are predominantly used for transactions – the $5, $10, $20 and to a lesser extent the $50. Conversely, the $100 banknote is to a large extent used as a store of value. This means that it does not tend to wear out, and so the extra durability of polymer over paper is less of an advantage from a cost perspective (although the added security of polymer, while not considered here, has been very beneficial). ✠

Graph 3

Estimated Difference in Upgrade Costs

NGB polymer costs less similar paper upgrade costs

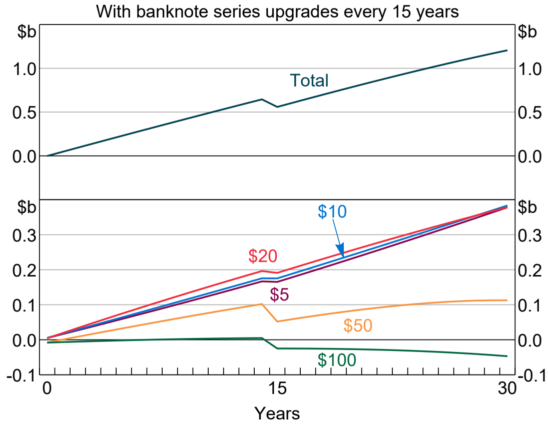


Source: RBA

Graph 4

Estimated Savings from Polymer Banknotes*

With banknote series upgrades every 15 years



* CPI-adjusted

Source: RBA

Box A: Seigniorage[4]

What is seigniorage?

Seigniorage is the financial benefit (or loss) that a government or central bank receives from issuing currency. (The term 'seigniorage' comes from earlier times when only the seignior, or lord, had the right to mint coins.) Historically, seigniorage was the difference between the face value of currency issued and the cost to produce it. That is, it was the profit (or loss) realised at the time currency entered circulation. Seigniorage from coins issued by the Royal Australian Mint is still calculated in this way. Most banknote issuing authorities, however – including the Bank – do not book a profit when banknotes are issued. Rather, since commercial banks can and do return banknotes to the central bank, the Bank treats banknotes as zero-interest liabilities. Seigniorage is then the benefit (or cost) that flows from being able to issue such liabilities and invest the proceeds in interest-bearing assets.

In particular, for banknotes to first enter circulation, commercial banks must purchase them from the Bank. To do this, they pay the Bank using their Exchange Settlement Accounts (ESAs) a sum equal to the face value of the banknotes purchased.[5] This entails a fall in ESA liquidity which, if not offset, might eventually cause the overnight cash rate to deviate from its policy target. To avoid this, the Bank typically purchases some interest-bearing asset from the private sector (either outright, under repurchase agreement, or via a foreign exchange swap), the effect of which is to return liquidity to the ESAs. When commercial banks return banknotes to the Bank, the reverse occurs. Consequently, the Bank collects seigniorage over the period for which banknotes stay in circulation.

Measuring seigniorage

As with other forms of profit, seigniorage can be calculated as the revenue obtained from issuing currency, less the costs involved.

Revenue

The most common method for measuring seigniorage revenue is as the flow of income from investments purchased with funds acquired through currency issuance.[6] As central banks (including the Reserve Bank) typically do not disaggregate asset returns by their funding source, one typically prorates total interest income by the share of liabilities accounted for by banknotes in circulation.

A drawback with this approach, however, is that it frames the gain from issuing banknotes in terms of the central bank's investment performance, when the benefit really flows from being able to issue a zero-interest liability. To illustrate this, imagine that there are two neighbouring countries that are identical except that the central bank of country A is able to achieve high investment returns whereas the central bank of country B is not (with the difference perhaps due to the respective investment mandates, investment skill, or natural variability in returns). When country A invests the funds obtained from currency issue, it makes a large return and records high seigniorage. Country B on the other hand makes a negative return on the funds obtained from issuing banknotes, resulting in a loss from seigniorage. The issue is that two separate matters are being conflated: the benefit of not having to pay interest on one's liabilities, and the return one manages to make using the funds thus obtained.

An arguably better measure of seigniorage revenue is the spread between zero-interest banknote liabilities and the cost of alternative financing. Appropriate benchmarks might include the policy interest rate set by the central bank or the yield on a longer-term government bond.

Production costs

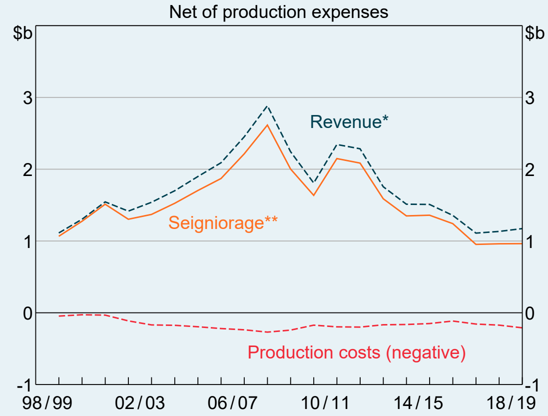
We take production costs as all expenses incurred by the Reserve Bank in relation to banknote production, distribution and policy, since the Bank would not incur these costs if it did not issue banknotes. A few of the more significant cost components are worth highlighting:

- For banknotes to be issued, they have to first be manufactured. Australia's banknotes are made by Note Printing Australia (NPA), a wholly owned subsidiary of the Bank. In 2018/19, the Bank paid NPA $108 million for the supply of new banknotes and related services (RBA 2019).
- To discourage excessive movement of banknotes, and encourage commercial banks to maintain sufficient banknote stocks to meet unexpected changes in demand, the Bank pays interest compensation on banknotes held in approved cash centres. In 2018/19 this amounted to $54 million (RBA 2019).
- To encourage effective banknote fitness sorting, the Bank operates various incentive schemes, including the Note Quality Reward Scheme, which pays (or charges) commercial banks a sum related to how well fitness sorting is conducted. In 2018/19 the Bank made roughly $15 million in incentive payments.

Seigniorage in Australia and around the world

Using the Reserve Bank's policy rate as the alternative cost of financing, we estimate annual seigniorage to have ranged between $1 billion and $3 billion over the past two decades (Graph A1); this corresponds to between 0.05 and 0.25 per cent of nominal GDP. Taking a shorter view, annual seigniorage – both in value and as a share of GDP – has declined sharply since 2008. This reflects falling interest rates over this period, somewhat offset by a rise in outstanding banknotes, with the value of banknotes in circulation as a share of nominal GDP increasing from 3½ per cent in 2014 to around 4 per cent at the end of 2018.

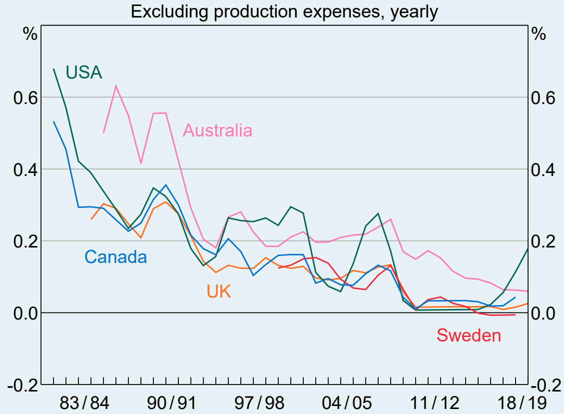
Graph A1
Seigniorage
Net of production expenses



* Revenue equals stock of outstanding banknotes multiplied by central bank policy rate
** Seigniorage equals revenue less production costs
Source: RBA

Australia's estimated seigniorage revenue as a share of nominal GDP has followed a similar trend to that of other comparable countries, although it has generally been a little higher (Graph A2). Both facts largely reflect interest rates, which tend to broadly move together across advanced economies, with Australia's prevailing level of interest rates typically a little higher than interest rates in the other countries shown.

Graph A2
Seigniorage as a Share of GDP*
Excluding production expenses, yearly



* We use each country's central bank policy rate as a proxy for the cost of alternative financing.
Sources: ABS; Central banks

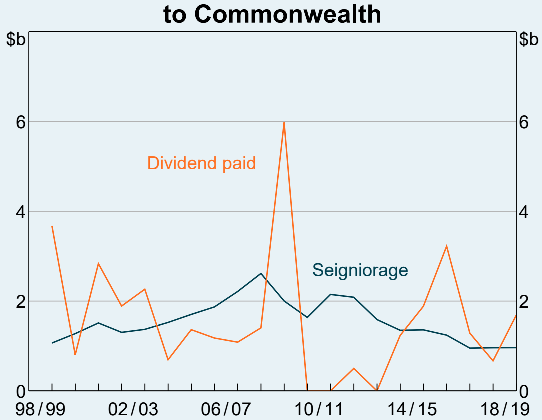
Note that our calculation of seigniorage may differ from that published by other central banks, for two reasons. First, we use our preferred revenue measure discussed above, while other central banks might not. Second, we do not deduct production costs in the international comparison due to a lack of comparable data. This is particularly evident for Sweden: our measure of Swedish seigniorage is negative, since policy rates in Sweden are negative, whereas the Riksbank records seigniorage as contributing positively, reflecting positive investment returns.

Distributing the Profits of Seigniorage

Unlike some other central banks, the Reserve Bank does not list seigniorage as a line of revenue on its financial statements. Indeed, there is no formal place for seigniorage in the accounting standards that the Bank must adhere to. Instead, the Bank records net interest income from all activities while highlighting that a large portion of this flows from its ability to issue non-interest-bearing liabilities. Net interest income then forms part of the Bank's net profit, with the Bank paying a part of its profits to the Australian Government as determined by the *Reserve Bank Act 1959* and the Treasurer. In 2018/19, the Bank recorded a net profit of $4.5 billion. Our estimates suggest that seigniorage accounted for about 20 per cent of this. In 2018/19, the dividend payable to the Commonwealth was $1.7 billion (Graph A3).

Graph A3

Seigniorage and RBA Dividend to Commonwealth



Source: RBA

Box B: Savings from Outsourcing Cash Processing

History

Prior to the introduction of polymer banknotes, the Reserve Bank ran cash-related branch operations around Australia, and was involved in banknote distribution to commercial banks. The introduction of polymer banknotes, however – which were longer-lasting, more secure, and required less processing – led to a series of decisions from the mid 1990s onwards to close branch-related services and outsource the majority of cash distribution to the private sector. This also coincided with broader Australian Government competitive neutrality reforms, which aimed to ensure that publicly owned businesses did not enjoy a competitive advantage over the private sector simply because they were publicly owned.

In particular, the Reserve Bank ceased its previous practice of providing cash directly to commercial bank branches over the late 1990s. Instead, the Reserve Bank introduced 'note pools' – banknotes owned by the Reserve Bank but located at commercial cash depots operated by cash-in-transit (CIT) companies – with CITs using these pools to service commercial bank branches. This change removed the need for the Reserve Bank to operate regional branches throughout the country, and these were closed.[7]

In the early 2000s, commercial banks assumed ownership of the note pools. The new arrangement encouraged commercial banks to trade banknotes between each other, rather than dealing with the Reserve Bank directly. This increased efficiency by reducing excessive transportation and processing of banknotes. To compensate commercial banks for interest forgone on their new holdings of physical currency, the Reserve Bank agreed to pay commercial banks interest on banknotes held in approved cash centres, provided the cash centres fitness-sorted the banknotes and were regularly audited. The interest compensation is in line with the interest that would have been earned were the commercial banks to instead hold electronic balances at the Reserve Bank in their Exchange Settlement Accounts.[8]

Benefits and savings

Outsourcing cash distribution has improved efficiency within the cash distribution system by reducing double-handling, and increasing the incentives to recycle cash locally rather than transport it back and forth between individual commercial bank branches and the Reserve Bank. While the Bank began paying interest compensation to commercial banks on part of their banknote holdings, the cost of this was offset by increased seigniorage earned on those banknotes; other resource costs related to staffing, banknote sorting equipment, buildings, and the transportation of banknotes fell. For example, in 1996/97 just before outsourcing began, banknote distribution cost the Bank around $60 million in inflation-adjusted terms, whereas in 2018/19 this had fallen to around $25 million excluding interest compensation (RBA 1997b, RBA 2019).

Footnotes

[*] The authors are from Note Issue Department and would like to thank Katie Healey and James Holloway for their input.

[1] See Ball 2019 for a discussion of banknote security features and recent trends in counterfeiting.

[2] Allowing multiple series to co-circulate can, however, cause confusion and make the passing of counterfeits easier; see Finlay and Francis (2019).

[3] This calculation assumes that the Bank upgraded all banknote denominations at the same time, which is not quite true. For reference, for each extra cent of production cost difference between the hypothetical paper and polymer banknotes, upgrade costs change by around 10 per cent relative to those shown in Graph 3, and total savings over an assumed 15-year lifecycle change by around 10 per cent relative to those shown in Graph 4.

[4] Note that the Reserve Bank accounts for income as per the relevant accounting standards, which do not include a formal definition of seigniorage, and this note is intended as a discussion of economic concepts rather than accounting principles.

[5] See https://www.rba.gov.au/payments-and-infrastructure/esa/ for more detail on Exchange Settlement Accounts, and https://www.rba.gov.au/education/resources/explainers/pdf/how-the-reserve-bank-implements-monetary-policy.pdf for a simple explanation of how the Bank trades to keep the cash rate at target.

[6] See for example RBA (1997a), as well as the Bank of England and Sveriges Riksbank annual reports.

[7] Other factors, including a decline in the Reserve Banks' provision of banking services to government, also contributed to the closure of regional branches; see RBA (2000) for more information.

[8] If the Reserve Bank did not pay interest compensation on banknote holdings, commercial banks would have a strong incentive to minimise their banknote holdings, which they would do by moving banknotes to and from the Reserve Bank more frequently. This would increase transport and environmental costs. Reduced banknote holdings by the commercial banks would also reduce seigniorage income to the Reserve Bank.

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