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ATM Fees, Pricing and Consumer Behaviour: An Analysis of ATM Network Reform in Australia

Clare Noone

RDP 2012-03

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Abstract

Automated teller machine (ATM) networks are a key component of payments systems. A number of competing theoretical models have been developed to examine fees associated with ATM transactions. A common feature of these models is that they imply that the elimination of interchange fees will cause a *one-for-one* increase in direct fees and a *one-for-one* fall in foreign fees, leaving the price of foreign ATM transactions unchanged in the short run. This prediction is not entirely consistent with recent experience in Australia. Following reform of the Australian ATM network in March 2009 that eliminated interchange fees, the total price of foreign ATM transactions was unchanged but the adjustment in foreign and direct fees was almost twice as large as the eliminated interchange fee. This paper addresses this discrepancy by developing a model of ATM fees that can explain this feature of the Australian experience and also explicitly models various ATM usage costs often ignored in the literature. However, this approach to modelling ATM fees, and the approach taken in the existing literature, cannot explain a striking feature of the Australian experience – the shift in consumer behaviour away from foreign ATM use – and two potential explanations for the observed behaviour are proposed.

JEL Classification Numbers: L11, L13, L84
Keywords: ATM fees, network pricing, circular city model, strategic behaviour

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Clare Noone

1. Introduction

For many countries, automated teller machines (ATMs) have become the main channel through which consumers withdraw cash from banks. In 2007, two out of every three cash withdrawals in Australia were made via ATMs (Emery, West and Massey 2008). Almost half of the ATM transactions made that year occurred at machines that were not owned by the cardholder's bank, that is, at so-called foreign ATMs.[1] A number of fees can be associated with a single transaction at a foreign ATM: an interchange fee (that the cardholder's bank pays to the ATM owner); a foreign fee (that the cardholder pays to his own bank); and a direct fee (that the cardholder pays directly to the ATM owner).[2] In Australia, interchange fees were prohibited in March 2009 by the Reserve Bank of Australia (RBA). This was part of an industry-led reform that also included a move to a direct-fee model for ATM pricing and other measures designed to increase competition and efficiency in the ATM system (RBA 2009a).

A number of theoretical models have been developed to examine banks' profit-maximising choices about how to structure ATM fees. A common feature of these models is that the elimination of interchange fees will cause a *one-for-one* increase in direct fees and a *one-for-one* fall in foreign fees, leaving the price faced by consumers for foreign ATM transactions unchanged in the short run. However, while the total price of foreign ATM transactions was unchanged in Australia following the 2009 reform, the adjustment of foreign and direct fees was almost twice as large as the reduction in the interchange fee.

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1 In 2010, ATMs were still the primary channel through which individuals accessed cash, though their use relative to other cash withdrawal methods had diminished (see Bagnall, Chong and Smith 2011). This shift may reflect the March 2009 ATM reforms discussed in Sections 2 and 5. Data on ATM cash withdrawals can be found in Reserve Bank of Australia Statistical Table 'C4 ATM Cash Withdrawals'.

2 The direct fee is also known as the direct usage fee, the direct charge or the ATM surcharge in the literature.

This paper addresses this discrepancy by developing a model of ATM fees that can explain this feature of the Australian experience. Specifically, it extends an existing model of ATM fees (Croft and Spencer 2004) by relaxing a number of assumptions regarding the division and identification of costs and the number of banks in the market. Equilibrium fee strategies are solved for explicitly, and it is shown that when there are three banks in the market, the model still predicts that the total price of a foreign ATM transaction will be unchanged, but that the change in foreign and direct fees need not equal the eliminated interchange fee. The extensions to the model regarding costs also allow a direct assessment of whether certain costs of providing ATM services map directly into certain fees. However, the approach taken in this paper to modelling ATM fees, and the approach taken in the existing literature, cannot explain a striking feature of the Australian experience – the shift in consumer behaviour away from foreign ATM use. Two potential explanations for this are proposed.

The paper proceeds as follows. Section 2 describes the Australian ATM market pre- and post-reform. Section 3 surveys the literature on ATM fee determination and discusses theoretical and empirical findings, while Section 4 develops a model of ATM fees based on Croft and Spencer's (2004) approach and derives predictions for ATM fees following the removal of interchange fees. These results are then shown to be consistent with the Australian experience. The response of the consumer is examined in Section 5 and potential explanations for observed behaviour are put forward. Section 6 concludes.

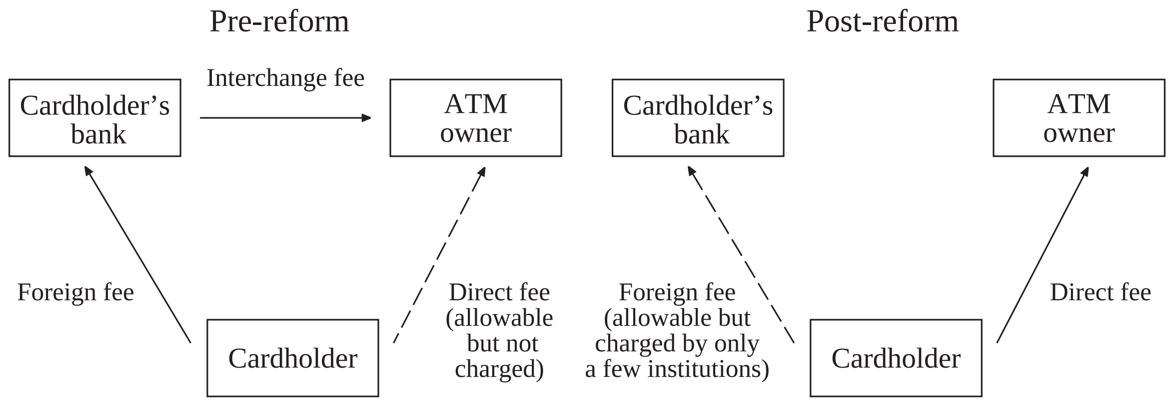
2. The ATM Market in Australia

At the beginning of 2009 there were around 27 000 ATMs in Australia. Each of these machines provided cash withdrawal services and could be used by cardholders of all Australian banks, credit unions and building societies (hereafter generally referred to as banks). Deposit customers were typically not charged for using ATMs owned by their bank ('own-bank' ATMs).[3] In contrast, until

3 Many Australian banks – particularly the larger banks by market share – offer accounts with unlimited free own-bank ATM transactions, while some institutions limit customers to around six free transactions per month (RBA (2004) and bank websites). As the average number of ATM withdrawals made by an individual in a month is around four (Emery *et al* 2008; Bagnall *et al* 2011), it is unlikely that a material number of consumers paid own-bank ATM fees.

March 2009, the use of a foreign ATM may have led to the levying of interchange fees, foreign fees and direct fees, although ATM owners chose not to impose direct fees (Figure 1).

Figure 1: Allowable Fees for a Foreign ATM Transaction



2.1 Reform

In March 2009, the payments industry and the RBA introduced major reforms to Australia's ATM system. These reforms involved the elimination of interchange fees and a move to direct fees, reflecting concerns regarding efficiency, deployment of ATMs, the transparency of fees and the sufficiency of competition.[4] As the reform altered the fee regime, it prompted an adjustment in ATM fees. Post-reform, an ATM owner's only recourse to recovering the cost of providing ATM services from non-deposit customers is to charge directly for ATM services (see Figure 1).[5] In addition to the formal elimination of interchange fees, the RBA also discouraged the use of foreign fees, although foreign fees were not formally banned (Lowe 2009; RBA 2009c). These aspects of the reform were aimed at increasing the transparency of ATM fees: as part of the reform, direct fees must be displayed prior to a transaction being finalised, at which point the customer can cancel the transaction at no cost.

At the time of the reform, banks claimed that discouraging foreign fees was inappropriate because a foreign fee was needed to recover the costs incurred when their deposit account customers used foreign ATMs (ABA 2009; Westpac 2009).

4 See RBA (2009a) for details on the reform package.

5 *Non-deposit customers* refers to the potential users of a bank's ATMs that are not the bank's deposit account customers.

These costs no longer included interchange fees but still included managing disputed transactions and customer complaints, settling the transactions and costs associated with maintaining ATM network connections. These are hereafter collectively referred to as the *own-bank processing cost* which was estimated to be $0.12 on average in 2007, which was 14 per cent of the total cost of an ATM withdrawal to financial institutions (Table 1).

Table 1: Average Cost of an ATM Withdrawal
Weighted average cost in 2007

	Cost per withdrawal	**Share of total cost**
	Dollars	Per cent
Cardholder's bank[(a)]	**0.12**	**14**
ATM operator	**0.74**	**86**
Of which:		
Cash handling and storage	0.14	16
Interest foregone on cash	0.11	13
Authorisation and transaction processing	0.05	6
Fraud, theft, insurance	0.01	1
Equipment	0.18	21
Rent	0.12	14
Other	0.13	15
Total cost	**0.86**	**100**

Notes: Weighted average of nine financial institutions (including ATM operators); weights are the number of transactions for each respondent; excludes interchange fees
(a) That is, the own-bank processing cost incurred by the cardholder's bank (or more generally the card issuer) that primarily reflects costs of ATM withdrawals made using a debit card. Schwartz *et al* (2008) make an allowance for the issuer costs of credit card advances, which reflect the cost of the payment function for these transactions. If the costs of credit functions are included, the weighted-average card issuer cost is $0.04 higher.
Source: Schwartz *et al* (2008)

ATM operators also incur costs when a withdrawal takes place at one of their machines. In 2007 the average cost to an ATM operator was $0.74. Similarly, more recent survey data suggest the industry average cost per transaction was $0.70 for ATM operators in 2010 (Edgar, Dunn & Company 2010), although there is considerable variation in the average cost across types of ATM operators and ATM locations. For a foreign ATM transaction, the ATM operator and the cardholder's bank are separate institutions; in own-bank transactions they are the same entity.

2.2 Empirical Features of the Reform

Prior to the reform, interchange fees were around $1.00 per transaction and foreign fees were around $2.00 per transaction. Post-reform, when interchange fees were prohibited, almost all institutions increased their direct fees from zero to $2.00 (for a cash withdrawal; Table 2). A year on from the reform, direct fees had largely stayed at this level (Filipovski and Flood 2010).[6] Foreign fees adjusted in the opposite direction, by around twice the change in interchange fees. Many Australian financial institutions immediately dropped their fees to between $0.00 and $0.50 on the day the reform was implemented (RBA 2009b) and over the month that followed virtually all financial institutions reduced this fee to zero, where they have remained (Table 2).[7] Following the reforms, cardholders continue to be able to use own-bank ATMs without charge. For a sample distribution of fees charged by financial institutions and independent ATM operators before and after the reform see Appendix A.

Given the offsetting movements in foreign and direct fees, the price paid by consumers for using a foreign ATM remained broadly unchanged at around $2.00. However, as the price is now comprised entirely of the direct fee, customers see the total price of a foreign ATM transaction directly before deciding whether to proceed.[8]

6 Of the institutions that were not charging a direct fee of $2.00 a year on from the reform, most were charging a direct fee of $1.50 with the remainder generally charging more than $2.00.

7 Well after the reform, only a very small fraction of Australia's deposit-taking institutions charge a non-zero foreign fee. These foreign-fee charging institutions are all small credit unions or building societies, and some foreign fees only apply after a certain number of transactions have been made.

8 As opposed to seeing the price on their bank statement, which was the case when the price of a foreign ATM transaction was composed entirely of the foreign fee.

Table 2: ATM Fees for Cash Withdrawal

Median (mode); Australian dollars, current prices

	Pre-reform	Immediately post-reform[(a)]	Three months post-reform	One year post-reform
	2 March 2009		June 2009	May 2010
Fees for foreign ATM use				
Interchange fee	~$1.00	$0.00	$0.00	$0.00
	(~$1.00)	($0.00)	($0.00)	($0.00)
Foreign fee	$2.000	$0.10	$0.00	$0.00
	($2.00)	($0.00)	($0.00)	($0.00)
Direct fee	$0.00	$2.00	$2.00	$2.00
	($0.00)	($2.00)	($2.00)	($2.00)
Fees for own-bank	$0.00	$0.00	$0.00	$0.00
ATM use[(b)]	($0.00)	($0.00)	($0.00)	($0.00)

Notes: Sample for foreign fee comprises 11 financial institutions that accounted for around 85 per cent of the ATMs in Australia owned by banks, credit unions and building societies in 2009; sample for direct fee comprises 12 ATM operators (financial institutions and independent operators) that together owned over 80 per cent of the ATMs in Australia in 2009

(a) Direct fee data as at 8 April 2009; all other fee data in this column as at 3 March 2009

(b) Effective fee levied

Sources: Australian Competition and Consumer Commission; Filipovski and Flood (2010); RBA (2009a); bank, credit union and building society websites

As well as affecting prices, the reform appears to have brought about an acceleration in the pace of ATM deployment. The number of ATMs grew at an annual rate of 5½ per cent over the two years following the reform, compared with average annual growth of 3¼ per cent over the four years to March 2009 (calculated using Australian Payments Clearing Association (APCA) data). With the move to charging direct fees, ATM operators were better able to set fees that reflected costs; deploying ATMs in low-volume or high-cost locations became more viable and it was easier for non-bank operators to participate in the ATM market (Treasury and RBA 2011).

3. Theoretical Models of ATM Fees and Empirical Findings

The literature on ATM networks explores a number of inter-related aspects of banks' profits, including decisions over pricing, the number and location of ATMs, the linking of networks, and strategies in closely related markets such as retail deposits and general banking services. Current theoretical research is focused on generating testable predictions regarding equilibrium outcomes in ATM markets. Empirical work has been more limited, in large measure due to data availability (McAndrews 2003). Empirical support for the most recent theoretical work has generally relied on qualitative results.

Two of the earliest papers to examine the profit and welfare implications of different ATM fee regimes were Salop (1990) and Gilbert (1991). Gilbert asserts that a regime that only allows jointly determined interchange fees will yield a more efficient outcome than a regime where banks are also independently allowed to set foreign and direct fees. He argues that because banks sell complementary products – ATM services and general deposit banking services – independent fee setting will lead to higher prices than in either the joint profit-maximising setting or the social welfare-maximising setting. This is because, when setting fees, each bank will not consider the decline in demand for the complementary products offered by other banks. In contrast, Salop reasons that as operating costs and consumers' utility from ATMs vary by location, regimes that only allow interchange fees are unlikely to yield an optimal allocation of ATM services. He also argues that if banks are allowed to charge both foreign and direct fees for ATM use, the price faced by consumers will be unaffected by whether an interchange fee is charged or not. Salop informally shows this interchange fee neutrality by demonstrating that any transfers between a cardholder, his bank and the ATM owner brought about by a given set of interchange, foreign and direct fees can be replicated by the combination of just a foreign fee and a direct fee.[9] Salop does not, however, formally examine banks' equilibrium strategies in setting fees or the determinants of the equilibrium level of fees.

With the widespread introduction of direct fees across the United States in 1996, theoretical models began examining the use of direct fees as a strategic tool to attract deposit customers. Massoud and Bernhardt (2002) show that banks have an incentive to charge a high direct fee to non-deposit customers, as this induces more consumers to open deposit accounts with them, in order to avoid the fee.[10]

9 This result is shown more formally in a number of later papers with varying market set-ups including Croft and Spencer (2004). This result is also demonstrated in this paper.

10 This strategy has become known as the depositor-stealing motive for direct fees. It is employed by banks because fixed account-keeping fees lend themselves to rent extraction more readily than per transaction direct fees.

Massoud and Bernhardt (2004) endogenise the ATM deployment decision and find that when direct fees are charged, banks have an incentive to over-provide ATMs. All else equal, this raises the likelihood that consumers will open an account with a bank deploying many ATMs in order to avoid high direct fees.

The introduction of direct fees in the United States also provided a 'natural experiment' to test model inferences empirically. Massoud, Saunders and Scholnick (2006) find evidence that in the presence of direct fees, deposit customers will switch from banks with smaller ATM networks to those with larger networks. In addition, they find evidence that banks with smaller networks can increase their market share by deploying more ATMs. In contrast, Prager (2001) finds no evidence that the introduction of direct fees affects the market share of small banks.

A significant drawback of Massoud and Bernhardt's (2002, 2004) approach is that they exclude interchange fees and foreign fees from their analysis. As shown in a number of more recent papers, the presence of these fees critically influences banks' strategic behaviour.[11]

Croft and Spencer (2004) incorporate interchange fees as well as endogenously determined foreign fees. Different degrees of customer lock-in are also allowed (where lock-in captures the ability of customers to switch their deposit account to a different bank). Although Croft and Spencer do not solve for the explicit profit-maximising level of fees, they show that the total price faced by consumers for foreign ATM withdrawals is higher when direct fees are charged. In addition, they also prove the intuitive result that banks' foreign fees will be higher when customers are locked-in at the time (non-interchange) ATM fees are set, because deposit customers are not able to move to banks offering lower foreign fees. They also show that joint-profits are lower when banks use direct fees, providing an explanation for why US ATM network operators had previously tried to ban direct fees.

Donze and Dubec (2008) use a model where only interchange fees are charged to make predictions regarding the adjustment of the ATM market in the United Kingdom when an interchange fee-only regime was implemented in 2000.

11 See, for example, Croft and Spencer (2004), Donze and Dubec (2006, 2008, 2009).

They predict a decrease in ATM deployment by banks, but an increase in deployment by non-bank ATM providers, which retained the option to charge direct fees. They then show that this prediction is qualitatively consistent with the UK experience to date.

Donze and Dubec (2009) also analyse the effect the Australian ATM reforms may have had on the entry of non-bank ATM providers. They predict that the elimination of interchange fees will lead to more non-bank ATM providers entering the market and a fall in banks' share of ATMs. There is some tentative evidence of this occurring following the Australian reforms, with the share of ATMs owned by independent operators (that is, those not owned by banks, credit unions or building societies) rising to 51 per cent in 2010 from 48 per cent in 2008 (Edgar, Dunn & Company 2010).

A drawback of existing models is their failure to accurately reflect the costs faced by banks and ATM owners. The common assumption is that banks bear the same marginal cost of a transaction irrespective of who uses their ATM, and that banks bear no costs when their customers use a foreign ATM. In reality, banks face an own-bank processing cost each time their deposit account customers use an ATM, irrespective of whether the ATM is owned by the bank or is 'foreign'. This processing cost is significant, and is estimated to be 14 per cent of the average total cost of an ATM transaction (to banks; Table 1). It may, therefore, affect the incentives of banks and modify equilibrium fee strategies and outcomes.

More generally, the usually innocuous practice of normalising costs to zero to simplify the analysis – which occurs to some extent in most recent models of ATM fees – might be undesirable in a market where multiple costs and fees are present. A normalisation of costs to zero in this setting precludes analysis of the relationship between each of the fees charged by banks and each of the costs incurred. It also prevents prediction of the equilibrium level of fees in absolute terms, and the comparison of the relative magnitude of each of the fees. This paper addresses these issues by explicitly including marginal ATM usage costs, including the own-bank processing cost, in the model.

4. The Model and Implications

This paper develops a model that captures the salient features of the Australian ATM market as described in Section 2. The aim is to model the short-run effect that eliminating interchange fees has on foreign, direct and account-keeping fees, and ultimately on the price consumers pay for foreign ATM transactions. The potential effects on optimal ATM deployment decisions, and other long-run decisions, are ignored in order to focus on short-run pricing dynamics.

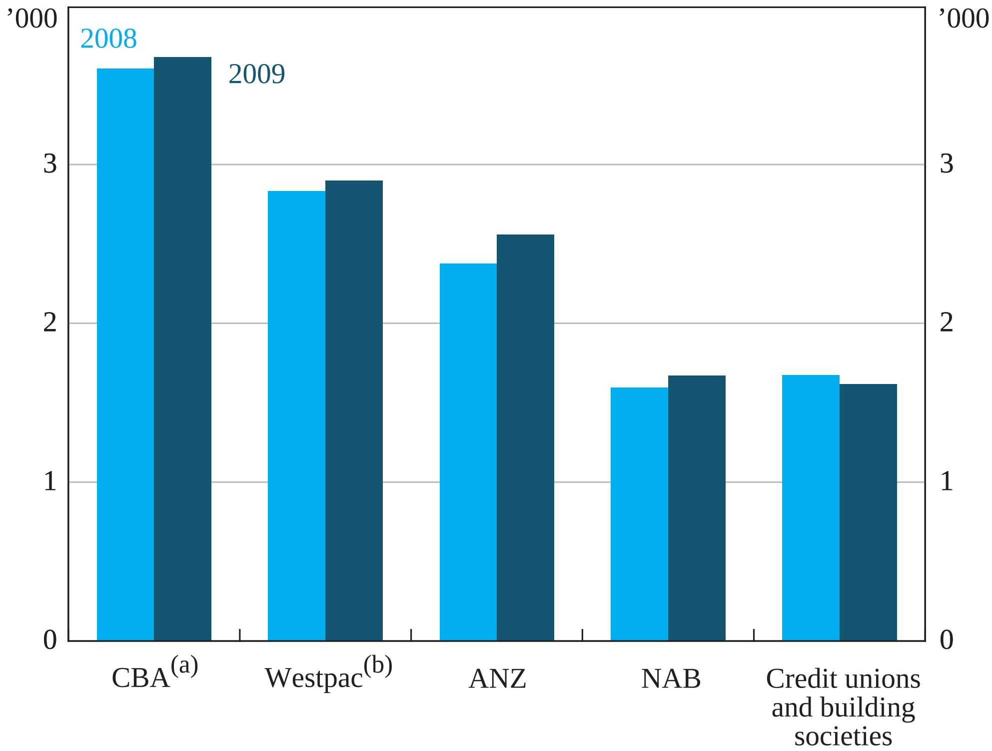
The model is based on Croft and Spencer's (2004) model of ATM networks. As the model is intended to focus on ATM pricing behaviour, bank branches are removed from the Croft and Spencer model, as are fees charged on own-bank ATM transactions since they are generally not levied in Australia.[12]

The assumption that each bank has the same number of ATMs is retained, as this is a close approximation to reality in Australia prior to the reform (see Figure 2),[13] though as in Croft and Spencer (2004) we abstract from the presence of non-bank (that is, independent) ATM operators. Given the evidence of switching costs in the market for deposit accounts (Zephirin 1994; Sharpe 1997), the model explores two different scenarios based on the extent to which deposit account customers are locked in to their existing bank – full lock-in and no lock-in – noting that the degree of depositor lock-in in the Australian market lies somewhere between these two extremes. A two-bank version of the model is solved first, before considering a three-bank version.

12 Croft and Spencer assume that own-bank ATM fees are set at marginal cost. This is limiting in the Australian case as banks do not typically charge for own-ATM withdrawals. Using this assumption, the model cannot capture the incentive banks may have to discourage own-ATM use (because the fee charged – zero – is below marginal cost) and/or subsidise foreign ATM use, which happens in some cases, for example Bankwest (2010) and ING Direct (2010).

13 The shared ATM network of the credit unions and building societies was also of a comparable size to the networks of the large Australian banks.

Figure 2: Major Banks, Credit Unions and Building Societies – Number of ATMs



Notes: (a) Includes Bankwest

(b) Includes St. George Bank and BankSA

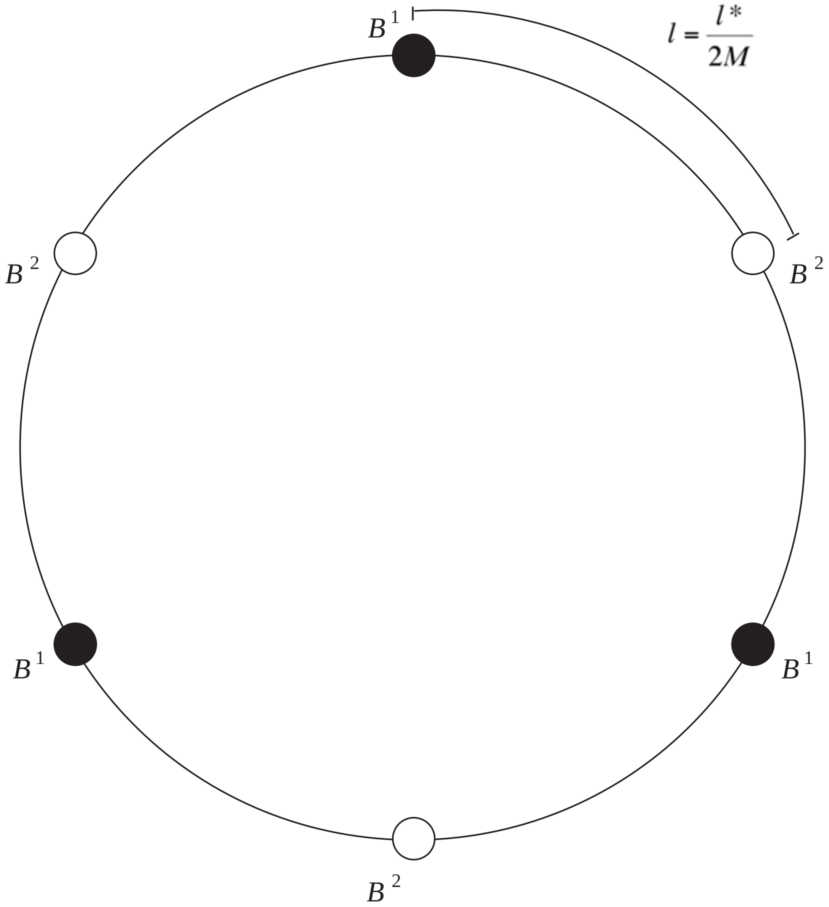
Source: APRA

In addition to developing a model that captures the key features of the Australian reform, this paper makes a number of novel contributions to the literature. First, explicit solutions are obtained for banks' profit-maximising level of fees. Second, the own-bank processing cost is taken into account and the relationship between this cost and ATM fees is shown; this is useful in understanding why virtually all foreign fees were ultimately eliminated after the reform even though Australian banks had earlier cited own-processing costs as a reason for keeping foreign fees above zero. Finally, the three-bank model is believed to be the first to consider the determination of ATM fees where there are more than two banks. This final contribution is important as banking markets are more likely to be characterised as oligopolistic, or even competitive, rather than duopolistic.[14]

4.1 Model Set-up (Two Banks)

Our model initially consists of two banks, B^1 and B^2, which each deploy M ATMs symmetrically spaced and interleaved around a circular city. The city has circumference l^* so the distance between ATMs is $l = l^*/2M$ (Figure 3). There are N consumers distributed uniformly around the city who each have a deposit account at one bank and make one ATM transaction.

Figure 3: The Two-bank ATM Market Place



14 Donze and Dubec (2006, 2008) do consider an ATM market with more than two banks, but only in the scenario where banks do not charge consumers fees for ATM transactions (that is, foreign fees, direct fees and own-bank ATM usage fees are not considered).

Two versions of this model are considered – one where customers are locked-in, and one where they are not. In the locked-in model timing is as follows: (i) the interchange fee is set (this fee is taken as given by both banks and customers); (ii) banks set their account-keeping fee; (iii) customers choose a bank to open a deposit account with; (iv) banks set their other ATM-related fees; (v) consumers are randomly located around the circular city and make ATM withdrawals. In the model without lock-in: (i) the interchange fee is set; (ii) *all* bank fees are set; (iii) consumers choose a bank to open a deposit account with; (iv) consumers are randomly located around the city and make their withdrawals. The consumers' problem of choosing which ATM to use, given all fees, is common to our two models. This is solved first. Then the consumers' bank-choice problem and the banks' profit maximisation problem to determine fees are solved.

Bank i, for $i = 1, 2$, charges consumers three types of fees: an account-keeping fee F_i to each deposit account customer (hereafter, customer); a foreign fee f_i for any transaction carried out by a customer of bank i at a foreign ATM; and a direct fee σ_i for any transaction carried out by a non-customer using one of bank i's ATMs. A customer receives utility x for making an ATM withdrawal as well as disutility equal to the distance travelled to the ATM plus any fee incurred.[15] A list of definitions is found in Appendix B.

4.2 The Consumer's ATM Problem (Two Banks)

Consider a customer of bank i and let the distance to an own-bank ATM be d_i. The utility from making an own-bank withdrawal is $u^O = x - d_i$. The utility from making a foreign withdrawal is:

$$u^F = x - (l - d_i) - (f_i + \sigma_j), j = 1, 2, j \neq i.$$

Where the distance to the foreign ATM is $l - d_i$ and the cost consists of the own-bank foreign fee f_i plus the foreign bank's direct fee σ_j. The customer is indifferent between the own and foreign ATM if $u^F = u^O$, which occurs at:

15 Travel costs are captured by the parameter l (which depends on l^* and M). For a given number of ATMs, the average travel cost to withdraw cash increases with the circumference of the circular city.

$$d_i^* \equiv d_i = \frac{l + \left(f_i + \sigma_j\right)}{2} \tag{1}$$

That is, bank i customers will use own-bank ATMs up to a distance of d_i^* away, after which they will use a foreign ATM. An immediate implication is that $f_i + \sigma_j < l$ is needed if customers are not going to always use own-bank ATMs.

Prior to the final stage, consumers do not know where in the circular city they will be located, but do know that they will be randomly and uniformly distributed around the city. Consequently, prior to the final stage, consumers make decisions based on the *expected* utility from making ATM withdrawals.

Since consumers are distributed uniformly around the circular city in the final stage, on average a proportion d_i^*/l of bank i customers will travel a distance $d_i \leq d_i^*$ to use an own-bank ATM; the remaining proportion of bank i customers $(1 - d_i^*/l)$ will travel a distance $(l - d_i^*) \geq d_i$ to use a bank j ATM. Correspondingly, a customer of bank i that uses a bank i ATM (to undertake an own-bank ATM transaction) will, on average, travel $d_i^*/2$ and achieve expected utility $E(u^O) = x - d_1^*/2 = x - l/4 - (f_i + \sigma_j)/4$ from that transaction. A customer of bank i that uses a bank j ATM (to make a 'foreign' ATM withdrawal) will, on average, travel $(l - d_i^*)/2$ and receive expected utility $E(u^F) = x - (l - d_i^*)/2 - (f_i + \sigma_j) = x - l/4 - 3(f_i + \sigma_j)/4$ from that transaction.

Without knowing his final stage location, a customer of bank i anticipates total expected utility from ATM services, u_i, of:[16]

$$u_i = \frac{d_i^*}{l} E\left(u^O\right) + \left(1 - \frac{d_i^*}{l}\right) E\left(u^F\right) = x - \frac{l}{2} + \frac{\left(l - \left(f_i + \sigma_j\right)\right)^2}{4l}. \tag{2}$$

4.3 The Consumer's Bank-choice Problem (Two Banks)

Along with ATM services, it is assumed that banks provide other general services that consumers value such as internet banking, automated transfers and teller

16 For any given x there exists an l small enough (or M large enough) to ensure that expected utility is positive. If the number of ATMs is too small the network will not be viable.

service. In this model, consumers' tastes with regard to these services are uniformly distributed on a unit circle and bank 1 and 2's offerings (denoted s_1 and s_2) are situated at opposite sides of this circle. It is assumed that a consumer with distance in taste e_i from bank i gains gross utility (that is, before fees are paid) of $s_i - e_i$ from an account with bank i, and gross utility of $s_j - (1/2 - e_i)$ from an account with bank j, where $1/2 - e_i$ is the distance to s_j.

Given the above, a consumer with taste parameter e_1 gains total expected utility (that is, the utility from general banking services and ATM use net of fees) of $U_1(e_1) = s_1 - e_1 + u_1 - F_1$ from an account with bank 1 and $U_2(e_1) = s_2 - (1/2 - e_1) + u_2 - F_2$ from an account with bank 2.[17] For a given level of fees, the marginal consumer has taste e_1* satisfying:

$$U_1(e_1*) = U_2(e_1*) = \frac{(s_1 + s_2) - \frac{1}{2} + u_1 - F_1 + u_2 - F_2}{2}. \tag{3}$$

As consumers' tastes are uniformly distributed around a unit circle, the total expected utility of the marginal consumer depends on the total quantity of general banking services offered, $s_1 + s_2$, rather than the relative amount of general services provided by each bank. Given this, for computational simplicity, and following Croft and Spencer (2004), the total quantity of general services offered is normalised such that $s_i + s_j = 1/2$. This simplifies the marginal consumer's total expected utility to:

$$U_1(e_1*) = U_2(e_1*) = \frac{u_1 - F_1 + u_2 - F_2}{2}. \tag{4}$$

This quantity must be positive to ensure that all consumers open accounts.[18]

Finally, since tastes are uniformly distributed, there are $N_1 = 2e_1*N$ consumers with $e_1 \leq e_1*$ who choose bank 1, and $N_2 = N - N_1$ consumers with $e_1 > e_1*$ who choose

17 Recall that u_1 and u_2 are functions of f_i and σ_i, i =1, 2. In the non locked-in case the consumer will know the (fixed) values of f_i and σ_i explicitly and hence know u_1 and u_2; in the locked-in case the consumer will know, given a set of other model variables, how the banks will choose f_i and σ_i, although they may not know the explicit values chosen.

18 This constraint can be thought of as a universal service obligation imposed by the regulator.

bank 2. Since $U_1(e_1*) = s_1 - e_1* + u_1 - F_1$, e_1*can be found and it can be shown that:

$$N_1 = 2N\left(s_1 - U_1\left(e_1*\right) + u_1 - F_1\right) = N\left(2s_1 + u_1 - u_2 - F_1 + F_2\right). \tag{5}$$

This is an intuitive result. It implies that the number of deposit account customers bank i attracts, N_i, is decreasing in the account-keeping fee it charges and increasing in the quantity of general services it provides. The number of bank i customers is also increasing in both the account-keeping fee charged by its rival (bank j) and the difference in utility that its customers would derive from using an own ATM over a 'foreign' ATM.

4.4 The Bank's Problem (Two Banks)

Banks derive revenue from fees charged to customers and (in the pre-reform regime) the interchange fee charged to the other bank. For each foreign customer who uses one of bank i's ATMs, bank i receives the interchange fee, denoted τ, from the foreign customer's bank. In our model this fee is exogenous and reflects either an amount previously agreed upon between banks (the Australian case pre-reform), or an amount set by the regulator (the Australian case post-reform). Banks also face three costs: the interchange fee, τ, that must be paid each time one of their deposit account customers uses a foreign ATM; the common ATM usage cost c incurred when an ATM they own is used, either by their own deposit account customer or a foreign customer; and an own-bank processing cost m incurred when a deposit customer of theirs withdraws cash from either an own-bank or foreign ATM.[19]

Given these fees and costs, bank i's profit is given by:

$$\pi_i = N_i\left(F_i + \left(f_i - \tau\right)\rho_{ij} - c\rho_{ii} - m\right) + N_j\left(\sigma_i + \tau - c\right)\rho_{ji} \tag{6}$$

where $\rho_{ii} = d_i*/l$ is the proportion of bank i customers who use a bank i ATM, and $\rho_{ij} = 1 - d_i*/l$ is the proportion of bank i customers who use a bank j ATM. That is, bank i profits from its N_i customers from an account-keeping fee F_i, as well as its

19 The ATM usage cost c reflects ATM maintenance costs such as cash refilling for example.

foreign fee (less the interchange fee) in proportion to own customers using foreign ATMs, $(f_i - \tau)\rho_{ij}$. Own customers cost the bank the ATM usage cost in proportion to their use of own-bank ATMs, $c\rho_{ii}$, as well as the own-bank processing cost, m. Bank i also profits from the N_j bank j customers by its direct fee plus the interchange fee it earns, less the ATM usage cost, all in proportion to bank j's customer's use of foreign (bank i) ATMs, $(\sigma_i + \tau - c)\rho_{ji}$.

4.5 Solving the Non Locked-in Model (Two Banks)

To solve the banks' problem and determine the Nash equilibrium for F_i, f_i and σ_i, π_i is maximised, for i = 1, 2, subject to the constraints that $u_i - F_i \geq 0$ and $u_j - F_j \geq 0$ which, from Equation (4), ensures that all consumers open bank accounts. In the symmetric case $s_1 = s_2 = 1/4$, where each bank provides the same level of general banking services[20] and charges the same fees, all bank fees can be explicitly calculated as functions of the model's parameters. These explicit forms for bank fees are a new result of this paper, and are given below (see Appendix C for derivations):

$$f = \tau - c \tag{7}$$

$$\sigma = \frac{2l}{3} - \tau + c \tag{8}$$

$$F = \frac{1}{2} + c + m + \frac{l}{9}. \tag{9}$$

Because customers choose banks after all fees have been set in this case, banks have an incentive to set ATM fees to attract customers and earn the account-keeping fee. Each bank does this by charging (or subsidising) own customers for foreign ATM use so as to just cover the marginal cost of the transaction, $\tau - c$, as shown in Equation (7).[21] Conversely, Equation (8) shows that foreign customers are charged $2l/3$ more than marginal cost to use an

20 But not necessarily the same type of banking services.

21 The customer's bank must pay the interchange fee τ when a customer uses a foreign ATM. Conversely, a customer who makes a foreign ATM withdrawal does *not* make an own-bank withdrawal, saving the customer's bank the ATM usage cost c.

ATM.[22] These fee strategies (of only charging deposit customers the marginal cost for making foreign withdrawals, while charging foreign customers a direct fee that is greater than the marginal cost) increase the attractiveness of being a customer of the bank.

Equations (7) and (8) imply that when interchange fees are not permitted (that is, when the regulator sets $\tau = 0$), the foreign fee will fall by the amount of the interchange fee while the direct fee will rise by this amount, leaving the total price of foreign ATM withdrawals unchanged at $2l/3$.

Equation (9) gives the account-keeping fee, F, which allows the cost of ATM use, c, the own-bank processing cost, m, as well as part of the consumer surplus to be recovered.[23] Equations (6) and (8) show that, at least in this model, contrary to the claim of some Australian banks, profit-maximising banks will recover the own-bank processing costs of ATM transactions through account-keeping fees rather than the foreign fee, since this cost is incurred irrespective of whether customers use own or foreign ATMs.[24] It therefore follows that the presence of own-bank processing costs need not necessarily imply foreign fees that are strictly positive.

In the more general case, where $s_1 \neq s_2 \neq 1/4$ so that the level of banks' general services differ, an explicit form solution can only be obtained for the foreign fee.

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22 Heuristically, in Equation (8) the term $2l$ is divided by three due to the common direct fee, σ, appearing three times in the lagrangian that describes bank i's constrained optimisation problem; once in the profit function (as the bank derives revenue from charging a direct fee) and once in each of the two constraints that ensure consumers open bank accounts (as these constraints essentially state that the ATM fees, σ and f, must not be so large that accounts are not opened). For the same reason, in Equation (9) the term l is divided by $9 = 3^2$. For the precise derivation, see Appendix C.

23 Note that banks subsidise deposit customers' use of foreign ATMs by c.

24 More specifically, as each bank incurs the own-bank processing cost, m, each time their deposit customers use *either* a foreign ATM *or* an own-bank ATM, and as the number of transactions each customer makes is known to the banks when the account-keeping fee is set, this cost is most profitably recovered through the account-keeping fee. Heuristically, if m was recovered in the foreign fee, and not in any other fee, the banks would only recoup the own-bank processing costs incurred from their customers' use of foreign ATMs but not the own-bank processing costs incurred by their customers' use of own ATMs.

In this case, the foreign fee is identical to the symmetric case and is given by $f_i = \tau - c$ for $i = 1, 2$.[25]

4.6 Solving the Locked-in Model (Two Banks)

The locked-in model can also be solved and an explicit solution is derived in Appendix C for the general model where banks need not provide a symmetric level of general services. This explicit solution, a novel result of this paper, is given by:

$$f_1 = f_2 = \frac{l}{3} + \tau - c \tag{10}$$

$$\sigma_1 = \sigma_2 = \frac{l}{3} - \tau + c \tag{11}$$

$$F_i = \frac{1}{3} + \frac{2s_i}{3} + c + m, i = 1, 2. \tag{12}$$

Equations (10), (11) and (12) are similar to Equations (7), (8) and (9), although there are a few differences. As deposit customers are locked-in at the point of ATM fee determination, banks no longer have an incentive to set ATM fees strategically to attract (or retain) deposit customers. Hence, they increase their foreign fee relative to the non locked-in case, raising the per transaction ATM revenues from their deposit customers. In the non locked-in case, increasing foreign fees drives deposit customers away and so gains in per customer ATM revenue come at the cost of losing revenue from the account-keeping fee. At the same time, the direct fee, which penalises customers of the other bank, is reduced. Overall though, the total price of a foreign transaction is the same as in the non locked-in case and interchange fee neutrality continues to hold, as does the implication that foreign and direct fees will shift by an amount equal to the interchange fee when the interchange fee is banned.

It is also interesting to note that both banks choose the same level of fees, even in the non-symmetric case. This is because, while banks are asymmetric in the level

25 Although the result cannot be proved explicitly, solving the non-symmetric model numerically for a range of model parameters also resulted in neutrality of the interchange fee.

of general services they offer (and as a result attract different numbers of customers), once customers are locked-in, the two banks' profit maximisation problems are essentially the same, except for a scale factor (compare Equations (C8) and (C9)).

In the symmetric case, the account-keeping fee is also lower in the locked-in model. This reflects the fact that in the locked-in case, banks compete more aggressively in setting account-keeping fees, knowing that the deposit customers they secure cannot subsequently switch banks in response to foreign or direct fees.[26]

4.7 The Three-bank Case

The intuition behind the three-bank case is similar to the two-bank case and so the model development is left to Appendix C. The main difference is the existence of a discontinuity in the profit function when there are three banks.[27]

In this model, the cost to the consumer of walking from a foreign ATM to an own-bank ATM is l (Figure 4).[28] As a result, if the total cost to the consumer of using a foreign ATM is less than or equal to l then at least 1/3 of customers will use foreign ATMs; this is because 1/3 of consumers will be located between two foreign ATMs and, with the total cost less than or equal to l, they will not find it

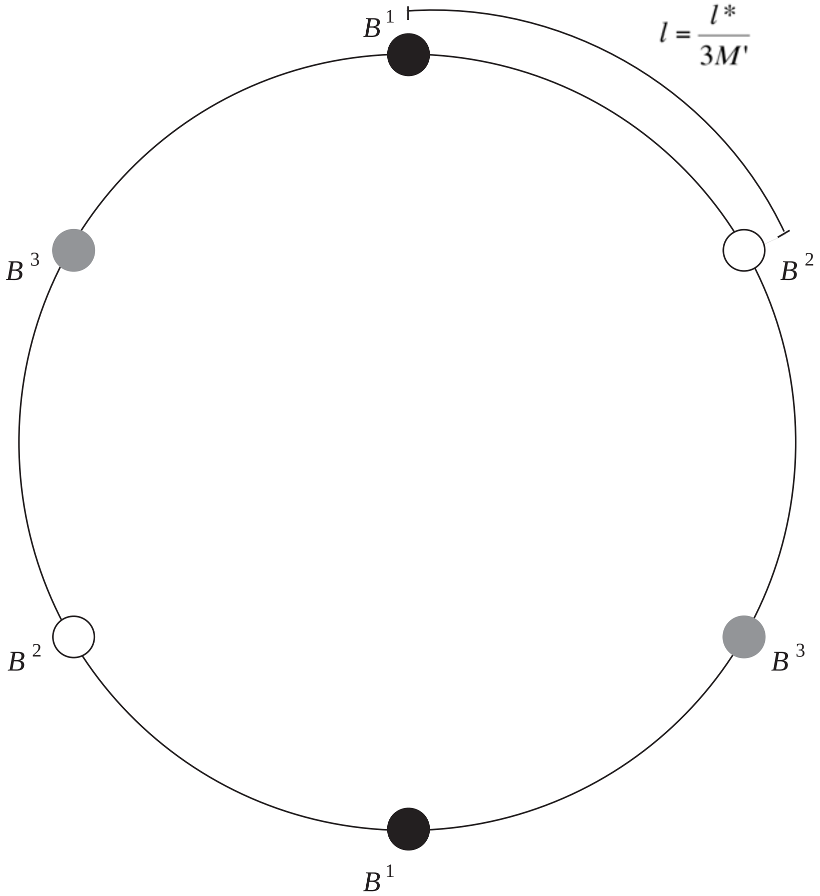
26 We can also solve a version of the Croft and Spencer (2004) model with no bank branches and compare results to those of our model. In the symmetric non locked-in case we find that $f = \tau$, $\sigma = 2l/3 - \tau + c$, $F = 1/2 + l/9$, while in the general locked-in case we find that $f_1 = f_2 = l/3 + \tau$, $\sigma_1 = \sigma_2 = l/3 - \tau + c$, $F_i = 1/3 + 2s_i/3$. By assumption, banks charge their customers the marginal cost c for own-bank ATM transactions in the Croft and Spencer model, so there is no incentive to subsidise customers to make foreign transactions and the total price of a foreign ATM transaction is higher by c than in our model. The account-keeping fee in the Croft and Spencer model is also lower by $c + m$ since the foreign fee is now not subsidised by c and the processing fee m is not considered. We omit proofs as they are similar to those of our model given in Appendix C.

27 The discontinuity arises because some customers are located between two foreign ATMs in the final stage. This occurs when banks' ATMs are distributed symmetrically and there are three or more banks. The discontinuity could also arise with just two banks if the banks' ATMs are not symmetrically distributed and interleaved; specifically, a bank would need to locate two or more of its ATMs adjacent to each other.

28 A customer that is indifferent between own and foreign ATM use is assumed to use the foreign ATM. This assumption is only for notational convenience and does not change the results.

worthwhile to walk past either foreign ATM to use an own-bank ATM. Conversely, when the total cost is greater than l, no consumers will use foreign ATMs as even those located between two foreign ATMs will find it worthwhile to walk past the foreign ATMs to use an own-bank ATM.

Figure 4: The Three-bank ATM Market Place



In the symmetric non locked-in case, the discontinuity noted above does not affect the solution, which is given by:[29]

$$f = \tau - c \tag{13}$$

29 Heuristically, in Equation (14) the term $6l$ is divided by 7 due to the common direct fee, σ, appearing seven times in bank i's total profit function; twice directly, as direct fee revenue is gained when the deposit account customers of the other two banks use bank i's ATMs, and five times indirectly through the ρ terms that describe the proportion of a given bank's customers that use a particular ATM network. For the same reason, in Equation (15) the term l is divided by $49 = 7^2$. For the precise derivation, see Appendix C.

$$\sigma = \frac{6l}{7} - \tau + c \tag{14}$$

$$F = \frac{1}{3} + c + m + \frac{8l}{49} \tag{15}$$

As with the two-bank case, banks strategically set foreign fees and direct fees to attract customers. As the density of ATMs has been kept unchanged from the two-bank set-up (so that the distance between ATMs is still l, and each bank owns M' ATMs), own-bank ATMs are now further apart, so banks are also able to raise their overall level of ATM fees relative to the two-bank model.

In the locked-in case, the profit function discontinuity is important. In this case there is a continuum of Nash equilibria characterised by the parameter χ, which lies between 0 and $l/2$ (see Appendix C for proof):

$$f_i = l + \tau - c - \chi \tag{16}$$

$$\sigma_i = \chi - \tau + c \tag{17}$$

$$F_i = \frac{2}{15} + \frac{3s_i}{5} + c + m - \frac{l}{3} + \frac{\chi}{2}, i = 1,2,3 \tag{18}$$

Each of these equilibria results in the consumer paying the same total price, $f_i + \sigma_j = l$, for a foreign ATM transaction, and implies interchange fee neutrality.[30] Importantly though, the presence of a spectrum of equilibria means that foreign and direct fees need not adjust in lock-step with the interchange fee. Rather, the possibility of an exogenous shift to another equilibrium point on the continuum (that is, a change in χ), allows foreign and direct fees to move independently of the interchange fee.

The range of values χ can take describes the suite of stable equilibria that can exist in the market. The actual value χ takes can be thought of as capturing the historic context of the market. A change in χ reflects a shift in the status quo. In the

30 In fact, a total price l for foreign ATM transactions corresponds to the joint profit-maximising level of ATM fees.

Australian case, it is plausible that public pressure from the Reserve Bank for foreign fees to be set at or near zero post-reform triggered such a shift (see Section 2.1).

This model, therefore, provides a mechanism to explain the post-reform changes observed in ATM fees in Australia. In this case, interchange fees of around $1.00 were eliminated, but foreign fees fell from $2.00 to zero and direct fees rose from zero to around $2.00. That is, foreign and direct fees adjusted by twice as much as the change in the interchange fee. In this model, such a change could be explained by a move to a new point along the spectrum of equilibria (via an increase in χ). Specifically, the change in fees observed in Australia is generated by the three-bank model when an interchange fee of $\tau = 1$ is prohibited, χ shifts from 0 to 1, and the cost of providing ATM services and distance between ATMs are given by $c = 1$ and $l = 2$.

5. Consumer Behaviour Post-reform

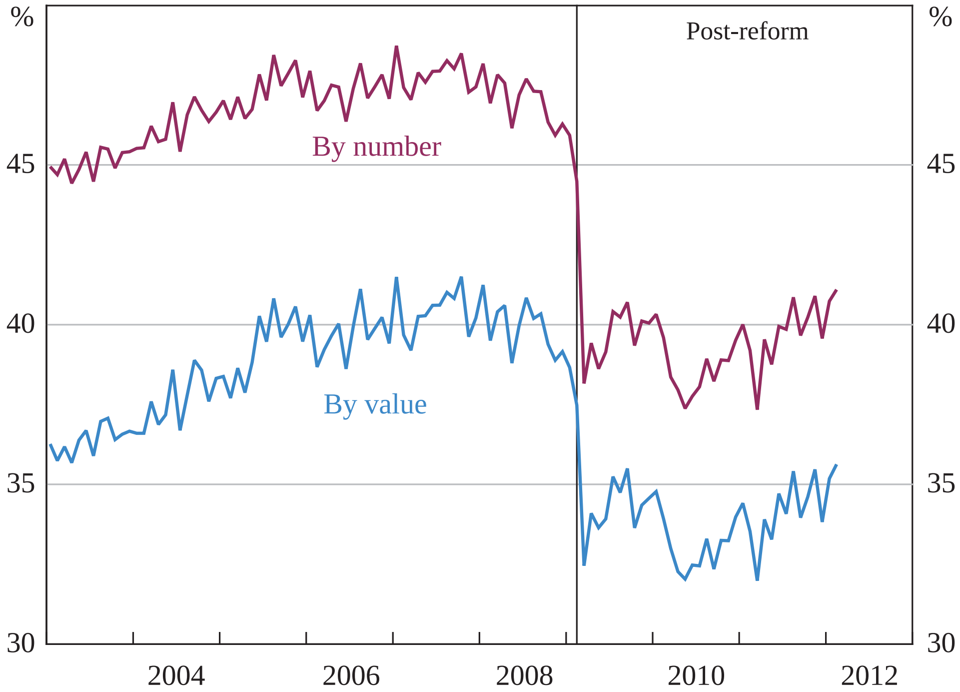
A key feature of the Australian ATM market post-reform has been consumers' sharp and sustained shift away from using foreign ATMs (Figures 5 and 6). Transactions at foreign ATMs accounted for almost half of all ATM withdrawals in the four years prior to reform, but fell to around 40 per cent post-reform despite there being no change in price.[31, 32] This behaviour cannot be accounted for by the model of ATM fees presented in this or any other existing paper on ATM fees. There are at least two possible explanations of this change in behaviour.

31 As the price of an own-bank ATM transaction was also unchanged, this shift in ATM usage cannot be explained by a change in relative prices (Table 2). A shift in the composition of ATM ownership and/or rates of deployment are other possible explanations for decreased foreign ATM use, but given that these are generally slow moving factors and that the shift in consumer behaviour was abrupt, they are unlikely to explain this episode.

32 There was also a modest decline in the foreign ATM share over the five months prior to the reform; this may have reflected public awareness campaigns ahead of the reforms.

Figure 5: ATM Transactions at Foreign Machines

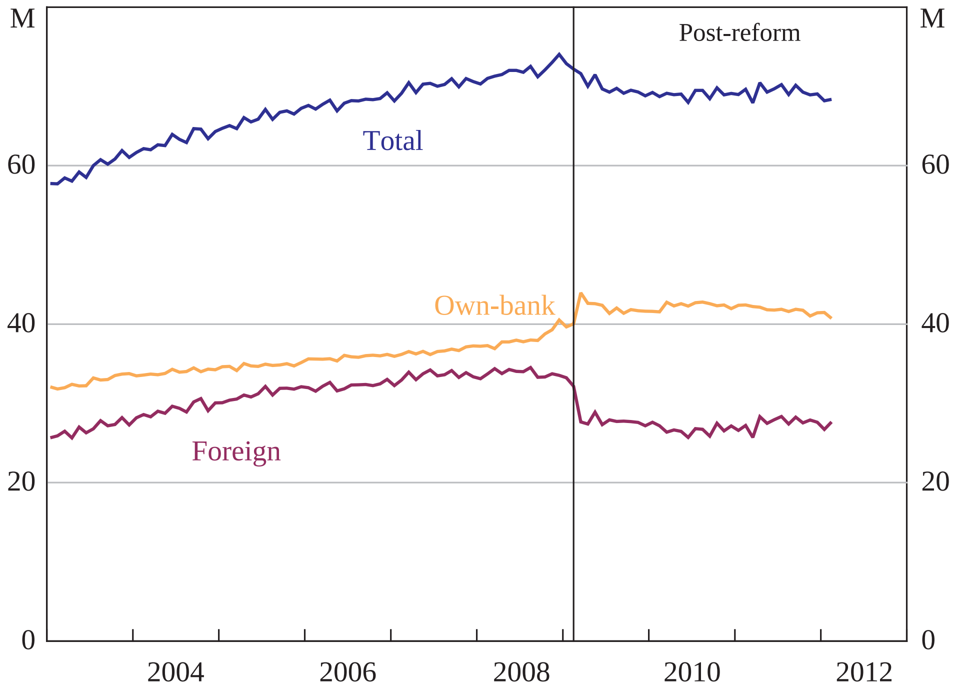
Share of total ATM transactions



Source: RBA

Figure 6: ATM Transactions

By number, seasonally adjusted



Source: RBA

The first explanation comes from the literature on prompting and suggestive selling that shows consumers' decisions can be influenced by point-of-sale promotions (see DiClemente and Hantula (2003) for a review of relevant studies). In particular, Wansink, Kent and Hoch (1998) show that, consistent with a simple anchoring and adjustment model of consumer behaviour, point-of-sale promotions that convey no new information can change a consumer's purchase decision.

This is relevant for the Australian ATM market as reform saw the introduction of a new point-of-sale prompt for foreign ATM transactions. Since the reforms, the following message has been displayed prior to the completion of a foreign ATM transaction:

> If you continue with this transaction you will be charged [amount of direct fee]. To continue press here. To cancel press here. (APCA 2009)

That is, consumers are now prompted to consider cancelling foreign ATM transactions. Given the results of Wansink *et al* (1998), this could contribute to a reduction in foreign ATM use.

A second, complementary, explanation for the decline in foreign ATM use when the price of foreign transactions was unchanged is incomplete information. This explanation rests on the observations that in Australia after the reforms: (i) the price of foreign ATM transactions shifted from being entirely comprised of the foreign fee to being entirely comprised of the direct fee; and (ii) foreign and direct fees differ in how and when they are disclosed to consumers. If charged, direct fees are displayed on the ATM screen prior to a transaction being completed, whereas foreign fees are disclosed to bank customers on regular bank statements or on request.

To the extent that consumers did not know the exact price of a foreign transaction when making the decision to travel to a foreign or own-bank ATM, the information available post-reform is news to the consumer.[33] Moreover, once the consumer travels to a foreign ATM and learns the price, he can now choose to either

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33 Anecdotal evidence suggest that some customers were unaware that a fee for foreign ATM use was applied at all (particularly in the case of non-cash ATM services such as balance inquiries).

complete the transaction if the cost is deemed acceptable, or cancel the transaction and travel to an own-bank ATM or look for a cheaper foreign ATM.

To explore this possibility, it is assumed that consumers know with certainty the price of own-bank ATM transactions but assign a probability distribution to the price of foreign transactions.[34] It is shown that if consumers have incomplete information over fees pre-reform, the additional disclosure post-reform can lead to decreased foreign ATM use, even if the expected price of foreign ATM transactions remains unchanged.[35]

Within this framework, the consumer's ATM problem from Section 4.2 can be adapted to have the price of a foreign ATM transaction defined as a random variable, Φ, instead of a fixed number.[36]

Pre-reform, as no new information on price is gained from visiting a foreign ATM, consumers only make one choice: do they travel from their initial location to a foreign ATM or do they travel to an own-bank ATM? The consumer at distance d_1 from an own-bank ATM makes this decision by comparing the utility he would receive from using an own-bank ATM, $u^O = x - d_1$, and the utility he expects to receive from using the foreign ATM, $E(u^F) = x - (l - d_1) - E(\Phi)$. The proportion of customers using own-bank ATMs in this set-up is given by:

34 These assumptions are reasonable. It is widely known that own-bank ATM transactions are, in most cases, free in Australia. Conversely, direct fees can vary by ATM and, prior to the reforms, consumers may not have always known the exact level of foreign fees (foreign fee information is available on bank statements, but it may not be rational to keep track of this information if the costs of doing so exceed the expected benefits). Given the publicity surrounding the reform and widespread scrapping of foreign fees by banks, consumers are likely to have become aware of the fact that foreign fees were permanently set to zero after the 2009 reform.

35 In the more general case, where direct fees are charged pre-reform and foreign fees are charged post-reform, the argument is still valid. So long as the direct fee constitutes a greater proportion of the total price of foreign transactions post-reform, then visits to a foreign ATM will reveal more information and so potentially lead to greater own-ATM use.

36 Recall the price of a foreign ATM transaction is composed of f_i and σ_j ($\Phi = f_i + \sigma_j$). In this extension, pre-reform the foreign fee, f_i, is a random variable and the direct fee, σ_j, is a fixed number (set at zero, as it was widely known that banks did not charge direct fees at this time). Post-reform, f_i is a fixed variable (set at zero, as banks no longer charge foreign fees) and σ_j is a random variable.

$$\frac{1}{2}+\frac{E(\Phi)}{2l}. \tag{19}$$

Post-reform, as new information on price is gained from visiting a foreign ATM, consumers that travel to a foreign ATM now face a second choice: do they stay and use the foreign machine or do they travel back to an own-bank ATM? For simplicity and consistency with the model set-up in Section 4.2, the possibility of looking for a cheaper foreign ATM nearby is ignored.[37] Consumers stay and use the foreign ATM if they learn $\Phi \leq l$, but travel back to an own-bank ATM if $\Phi > l$.[38] The expected utility from initially travelling to a foreign ATM is therefore

$$u^F = \Pr(\Phi \leq l)E\left(x-(l-d_1)-\Phi \middle| \Phi \leq l\right)+\Pr(\Phi > l)E\left(x-2l+d_1\right). \tag{20}$$

The first term in Equation (20) is the expected utility of using the foreign ATM *conditional* on Φ being less than or equal to l, since the consumer only uses the foreign ATM if this is the case. The second term is the expected utility of returning to an own-bank ATM taking into account that by travelling back to the own-bank ATM the consumer avoids the cost of the foreign ATM but travels an extra distance l. Equating the utility derived from initially travelling to an own-bank ATM, $u^O = x - d_1$, and the utility derived from initially travelling to a foreign-bank ATM, u^F, and solving, the marginal consumer is located at

$$d_1{}^* = \frac{1}{2}\left(l+\Pr(\Phi \leq l)E\left(\Phi \middle| \Phi \leq l\right)+l\Pr(\Phi > l)\right). \tag{21}$$

The proportion of consumers using own-bank ATMs now consists of those that travel to an own-bank ATM first, $d_1{}^*/l$, plus those that travel to a foreign ATM but decide not to use it and return to an own-bank ATM, $(1 - d_1{}^*/l)\Pr(\Phi > l)$. The proportion of consumers using own-bank ATMs is therefore

37 In the model set-up described in Section 4.2, if the consumer is already located at a foreign ATM he will not choose to look for a cheaper foreign ATM. This is because the consumer knows that an own-bank ATM (offering free transactions) is located at least as close as the nearest alternative foreign ATM.

38 In our two-bank model, the disutility of travelling from a foreign to an own-bank ATM is l, so consumers will only do this if the price of the foreign transaction is greater than l.

$$\begin{aligned}&\frac{1}{2}\left(1+\frac{\Pr(\Phi\le l)E(\Phi|\Phi\le l)}{l}+\Pr(\Phi>l)\right)\\&\quad+\frac{1}{2}\Pr(\Phi>l)\left(1-\frac{\Pr(\Phi\le l)E(\Phi|\Phi\le l)}{l}-\Pr(\Phi>l)\right).\end{aligned} \tag{22}$$

There will be a rise in own-bank ATM use post-reform if the difference between 'Equations' (22) and (19) is positive. That is

$$\begin{aligned}&\frac{1}{2}\left(1+\frac{\Pr(\Phi\le l)E(\Phi|\Phi\le l)}{l}+\Pr(\Phi>l)\right)\\&+\frac{1}{2}\Pr(\Phi>l)\left(1-\frac{\Pr(\Phi\le l)E(\Phi|\Phi\le l)}{l}-\Pr(\Phi>l)\right)-\frac{1}{2}-\frac{E(\Phi)}{2l}>0.\end{aligned} \tag{23}$$

This will hold under a variety of specifications for Φ. A simple example is when the random variable Φ takes values $\varphi^* - 1 < l$ and $\varphi^* + 1 > l$, both with probability 1/2. In this case, the increase in customers using own-bank ATMs post-reform is given by:

$$\frac{3}{8}\left(1-\frac{\varphi^*}{l}\right)-\frac{1}{8l}$$

which is positive if $l > \varphi^* + 1/3$.

Therefore, under incomplete information, foreign ATM use may fall relative to own-bank ATM use post-reform even if there is no change in the expected price.

6. Conclusion

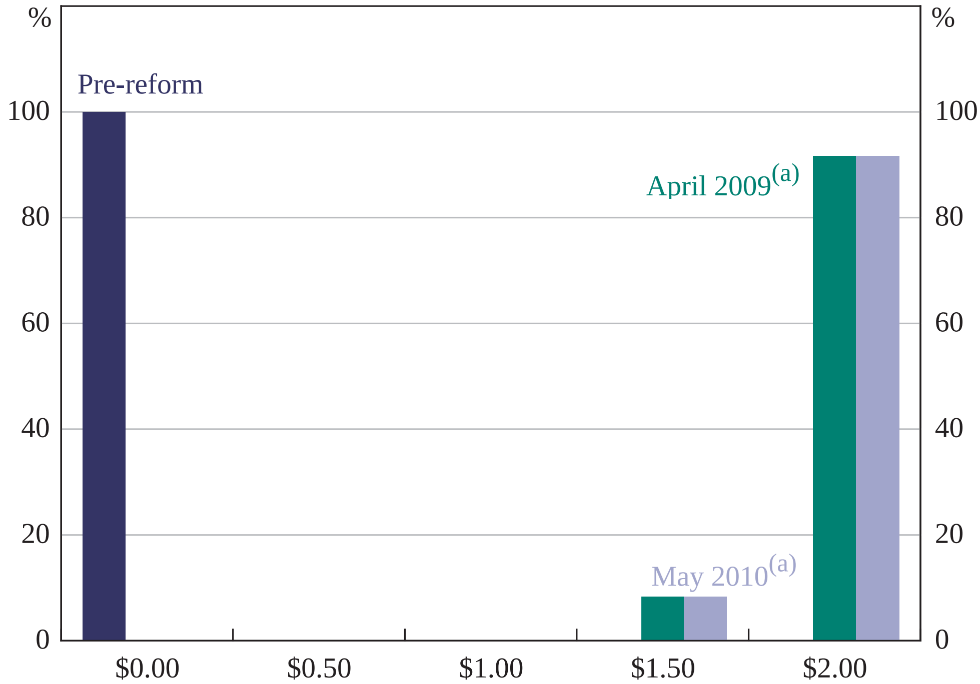
This paper develops a model of ATM fees that captures the salient features of the Australian ATM market. In particular, various ATM usage costs, often ignored in the literature, are explicitly incorporated into existing models and the number of banks modelled is increased to three from the usual two. These contributions are important for a number of reasons. First, including ATM usage costs in the model provides the complexity required to understand why, despite claims by the industry that maintaining foreign fees was required to cover own-bank processing costs, foreign fees have mostly been eliminated since the 2009 ATM reforms. Second, having three banks makes the model more realistic and provides a mechanism whereby interchange fee neutrality is maintained but foreign and direct fees no longer need to move in lock-step with changes in the interchange fee, matching the Australian experience.

The consumer response to ATM reform in Australia is a key feature of the data not explained by the model in this or any other paper on ATM fees. However, this paper demonstrates that in the presence of incomplete information, the shift towards direct charging may have contributed to this change in behaviour, even if the price of foreign transactions remained unchanged. In a similar vein, prompting – in this case, a question asking customers if they wish to cancel their foreign ATM transaction – may also have driven the observed consumer behaviour. Future work to incorporate incomplete information into a model of ATM fees would be a potentially useful contribution to the literature.

Appendix A: Distribution of Fees

Figure A1: Distribution of Direct Fees

Share of sampled financial institutions and independent operators



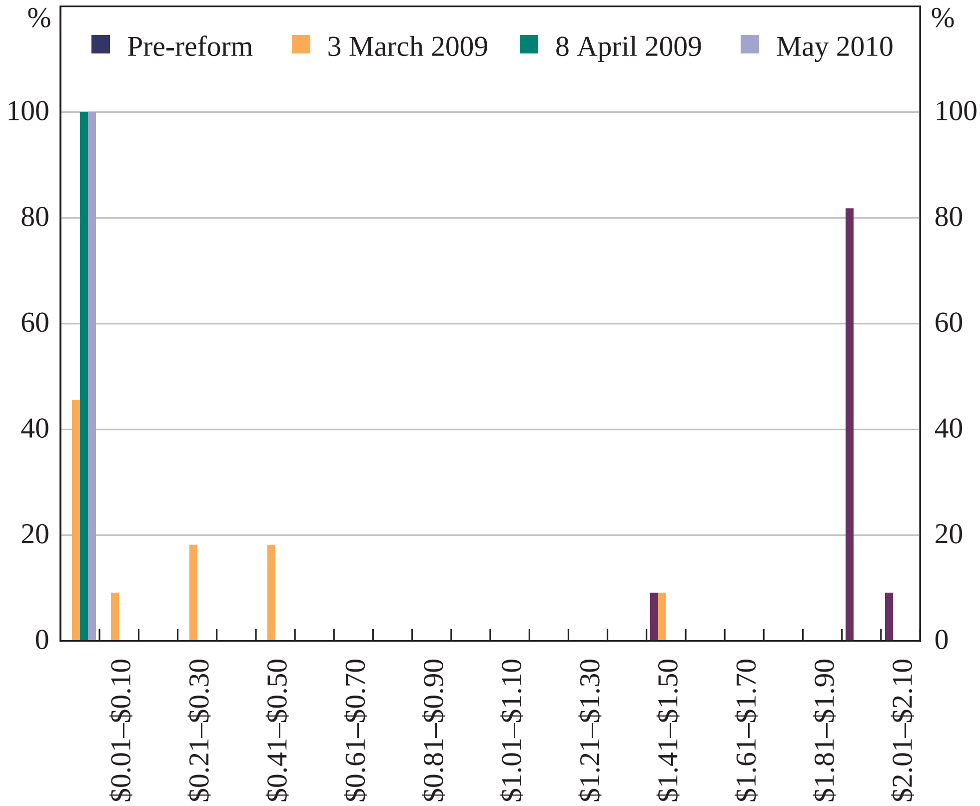
Notes: Sample covers a set of banks, credit unions, building societies and independent operators that owned around two-thirds of the ATMs in Australia in 2009

(a) In some cases networks charged a range of direct fees; where this occurred we used the fees predominately charged, except in the case of RediATM where the network's cap on direct fees is used

Sources: APCA; Filipovski and Flood (2010); RBA (2009b)

Figure A2: Distribution of Foreign Fees

Share of sampled financial institutions



Note: Sample covers a set of financial institutions that owned around 85 per cent of the ATMs owned by banks, credit unions and building societies in Australia in 2009

Sources: APRA; Filipovski and Flood (2010); RBA (2009b); bank, credit union and building society websites

Appendix B: Definitions

l^*	Circumference of city
l	Distance between ATMs
M	Number of ATMs deployed by each bank in the two-bank case
M'	Numbers of ATMs deployed by each bank in the three-bank case
N	Number of consumers
N_i	Number of consumers with deposit accounts at bank i
F_i	Account-keeping fee charged by bank i
τ	Interchange fee
σ_i	Direct fee charged by bank i
f_i	Foreign fee charged by bank i
d_i	Distance a customer of bank i is from an own-bank ATM
x	Customer's gross utility from making an ATM withdrawal
u^O	Customer's utility from making an own-bank ATM withdrawal net of travelling costs
u^F	Customer's utility from making a foreign ATM withdrawal net of travelling costs
e_i	Consumer's distance in taste from bank i offering of general services
s_i	Quantity of general services offered by bank i

$U_i(e_j)$	Total expected utility of a customer with taste parameter e_j from having an account with bank i
c	Common ATM usage cost
m	Own-bank processing cost
ρ_{ij}	Proportion of bank i customers who use a bank j ATM
π_i	Profit of bank i

Appendix C: Derivation of Results

Results are derived for the two- and three-bank models, both when consumers are locked-in to the bank they choose for deposit account services and when they are not. All models are solved by backwards induction, maximising either the consumer's or bank's objective functions in turn.

The same general approach to optimisation is used to solve each model; first order conditions are found, and the solution is checked to verify that it satisfies second order conditions for a maximum. The exact technique used varies depending on the specification of the initial optimisation problem.

C.1 The Two-bank Non Locked-in Model

First note that from Equations (2) and (5) for i = 1, 2 and j = 2, 1, we have the number of consumers with bank accounts at bank i:

$$N_i = N\left(2s_i + \frac{\left(l-\left(f_i+\sigma_j\right)\right)^2}{4l} - \frac{\left(l-\left(f_j+\sigma_i\right)\right)^2}{4l} - F_i + F_j\right)$$

so that:

$$\frac{\partial N_i}{\partial f_i} = N\left(\frac{f_i+\sigma_j}{2l} - \frac{1}{2}\right), \qquad \frac{\partial N_i}{\partial f_j} = N\left(\frac{1}{2} - \frac{f_j+\sigma_i}{2l}\right),$$

$$\frac{\partial N_i}{\partial \sigma_i} = N\left(\frac{1}{2} - \frac{f_j+\sigma_i}{2l}\right), \qquad \frac{\partial N_i}{\partial \sigma_j} = N\left(\frac{f_i+\sigma_j}{2l} - \frac{1}{2}\right),$$

$$\frac{\partial N_i}{\partial F_i} = -N, \qquad \frac{\partial N_i}{\partial F_j} = N.$$

Similarly, using Equation(1), $\rho_{ii} = d_i^*/l = 1/2 + (f_i + \sigma_j)/(2l)$ and $\rho_{ij} = 1 - d_i^*/l = 1/2 - (f_i + \sigma_j)/(2l)$ we have:

$$\frac{\partial\rho_{ii}}{\partial f_i}=\frac{1}{2l},\qquad \frac{\partial\rho_{ii}}{\partial f_j}=0,\qquad \frac{\partial\rho_{ii}}{\partial\sigma_i}=0,$$
$$\frac{\partial\rho_{ii}}{\partial\sigma_j}=\frac{1}{2l},\qquad \frac{\partial\rho_{ii}}{\partial F_i}=0,\qquad \frac{\partial\rho_{ii}}{\partial F_j}=0,$$
$$\frac{\partial\rho_{ij}}{\partial f_i}=\frac{-1}{2l},\qquad \frac{\partial\rho_{ij}}{\partial f_j}=0,\qquad \frac{\partial\rho_{ij}}{\partial\sigma_i}=0,$$
$$\frac{\partial\rho_{ij}}{\partial\sigma_j}=\frac{-1}{2l},\qquad \frac{\partial\rho_{ij}}{\partial F_i}=0,\qquad \frac{\partial\rho_{ij}}{\partial F_j}=0.$$

Now using Equations (2) and (6), for i = 1, 2 and j = 2, 1, bank i's problem is to maximise profits with respect to F_i, f_i, and σ_i, subject to the constraints that customers of bank i have a total expected utility of using an ATM that is greater than bank i's account-keeping fee, and similarly that customers of bank j have a total expected utility of using an ATM that is greater than bank j's account-keeping fee. These constraints are necessary to ensure customers open bank accounts when the account-keeping fee is non-negative. This is summarised as:

$$\begin{aligned}L_i&=\pi_i+\lambda_i\left(u_i-F_i\right)+\lambda_j\left(u_j-F_j\right)\\&=N_i\left(F_i+\left(f_i-\tau\right)\rho_{ij}-c\rho_{ii}-m\right)+N_j\left(\sigma_i+\tau-c\right)\rho_{ji}\\&+\lambda_i\left(x-\frac{l}{2}+\frac{\left(l-\left(f_i+\sigma_j\right)\right)^2}{4l}-F_i\right)+\lambda_j\left(x-\frac{l}{2}+\frac{\left(l-\left(f_j+\sigma_i\right)\right)^2}{4l}-F_j\right).\end{aligned}$$

Taking the model parameters and F_j, f_j, and σ_j as given, and requiring $\lambda_i > 0$, $\lambda_j > 0$, $u_i - F_i > 0$, $u_i - F_i > 0$, $\lambda_i(u_i - F_i) = 0$, $\lambda_j(u_j - F_j) = 0$, the first order conditions for this problem are given by:

$$\begin{aligned}\frac{\partial L_i}{\partial f_i}&=N_i\left(\rho_{ij}-\frac{f_i-\tau+c}{2l}\right)-N\rho_{ij}\left(F_i+\left(f_i-\tau\right)\rho_{ij}-c\rho_{ii}-m\right)\\&+N\rho_{ij}\rho_{ji}\left(\sigma_i+\tau-c\right)-\lambda_i\rho_{ij}=0\end{aligned}\tag{C1}$$

$$\frac{\partial L_i}{\partial \sigma_i} = N\rho_{ji}\left(F_i + \left(f_i - \tau\right)\rho_{ii} - c\rho_{ii} - m\right) - N\left(\rho_{ji}\right)^2\left(\sigma_i + \tau - c\right) + N_j\left(\rho_{ji} - \frac{\sigma_i + \tau - c}{2l}\right) - \lambda_j\rho_{ji} = 0 \tag{C2}$$

$$\frac{\partial L_i}{\partial F_i} = N_i - N\left(F_i + \left(f_i - \tau\right)\rho_{ij} - c\rho_{ii} - m\right) + N\rho_{ji}\left(\sigma_i + \tau - c\right) - \lambda_i = 0. \tag{C3}$$

Multiplying Equation (C3) by ρ_{ij} and subtracting it from Equation (C1), we get that $N_i\,(f_i - \tau + c)/(2l) = 0$. Since $N_i \neq 0$ and $l \neq 0$ this implies that $f_i = \tau - c$. That is, $f_1 = f_2 = \tau - c$. The general case cannot be progressed further.

In the symmetric case, $s_1 = s_2 = 1/4$, further insights can be derived. In this case $f_1 = f_2 = \tau - c$ which implies $N_1 = N_2 = N/2$, $\sigma_1 = \sigma_2 = \sigma$, $F_1 = F_2 = F$, $\rho_{12} = \rho_{21} = \rho^{\mathrm{F}}$, and $\rho_{11} = \rho_{22} = \rho^{\mathrm{O}}$. Setting λ_1 and λ_2 to zero, ignoring the $u_1 - F_1 \geq 0$ and $u_2 - F_2 \geq 0$ constraints for the moment, since we can verify that they hold later on, this further implies $\rho^{\mathrm{F}} + \rho^{\mathrm{O}} = 1$ and Equations (C2) and (C3) become:

$$\frac{\partial L}{\partial \sigma} = N\rho^{\mathrm{F}}\left(\frac{1}{2} + F - c - m - \rho^{\mathrm{F}}\left(\sigma + \tau - c\right)\right) - \frac{\frac{1}{2}N\left(\sigma + \tau - c\right)}{2l} = 0 \tag{C4}$$

$$\frac{\partial L}{\partial F} = N\left(\frac{1}{2} - F + c + m + \rho^{\mathrm{F}}\left(\sigma + \tau - c\right)\right) = 0. \tag{C5}$$

Since $\rho^{\mathrm{O}} = 1/2 + (\sigma + \tau - c)/(2l)$ and $\rho^{\mathrm{F}} = 1/2 - (\sigma + \tau - c)/(2l)$, from Equations (C4) and (C5) we have $1/2 - 3(\sigma + \tau - c)/(4l) = 0$. And from this follows

$$\sigma_1 = \sigma_2 = \sigma = \frac{2l}{3} - \tau + c \tag{C6}$$

$$F_1 = F_2 = F = \frac{1}{2} + c + m + \frac{l}{9} \tag{C7}$$

By construction Equations (C6) and (C7), together with $f_1 = f_2 = f = \tau - c$ and taking $\lambda_1 = \lambda_2 = 0$, satisfy Equations (C1) to (C3), and so constitute a Nash equilibrium, although this is not a proof that the equilibrium is unique.

The associated Hessian matrix (H) evaluated at $f_i = \tau - c$, $F_i = 1/2 + c + m + l/9$, $\sigma_i = 2l/3 - \tau + c$ is negative definite and the second order conditions are satisfied when $l < 27/2$. In particular the Hessian matrix is given by

$$H = \begin{pmatrix} -N\left(\dfrac{9+2l}{36l}\right) & \dfrac{-N}{3} & 0 \\ \dfrac{-N}{3} & -2N & 0 \\ 0 & 0 & -N\left(\dfrac{27-2l}{36l}\right) \end{pmatrix}$$

and

$$Det\left(H_{11}\right) = \frac{-N\left(9+2l\right)}{36l} < 0$$

$$Det\left(H_{22}\right) = \frac{N^2}{2l} > 0$$

$$Det\left(H\right) = \frac{-N^3\left(\dfrac{27}{2} - l\right)}{36l^2} < 0.$$

In addition, the solution satisfies all imposed constraints: $f + \sigma = 2l/3$ is between 0 and l as required; and, $u - F = x - l/2 + (l - (f + \sigma))^2/(4l) - F = x - 1/2 - c - m - 7l/12$, so that the solution is valid so long as the utility from an ATM withdrawal satisfies $x \geq 1/2 + c + m + 7l/12$. Bank profit can also be shown to equal $N(1/4 + l/9)$.

C.2 The Two-bank Locked-in Model

Taking all fees as given, the consumer's ATM choice is the same as given in Section 4.2. That is, $\rho_{ii} = 1/2 + (f_i + \sigma_j)/(2l)$ and $\rho_{ij} = 1/2 - (f_i + \sigma_j)/(2l)$.

Banks maximise profit from ATM transactions through their choice of f_i and σ_i for i = 1, 2. Banks anticipate consumers' ATM choice and take as given account-keeping fees, N_1 and N_2.[39] The profit from ATM transactions for bank i is given by

$$\begin{aligned}\pi_i^{\mathrm{A}} &= N_i\left(\left(f_i-\tau\right)\rho_{ij}-c\rho_{ii}-m\right)+N_j\left(\sigma_i+\tau-c\right)\rho_{ji} \\ &= N_i\left(\left(f_i-\tau\right)\left(\frac{1}{2}-\frac{f_i+\sigma_j}{2l}\right)-c\left(\frac{1}{2}+\frac{f_i+\sigma_j}{2l}\right)-m\right) \\ &+N_j\left(\sigma_i+\tau-c\right)\left(\frac{1}{2}-\frac{f_j+\sigma_i}{2l}\right).\end{aligned}$$

The first order conditions for this problem are given by, for i = 1, 2 and j = 2, 1:

$$\frac{\partial\pi_i^{\mathrm{A}}}{\partial f_i}=N_i\left(\frac{1}{2}-\frac{f_i+\sigma_j}{2l}-\frac{f_i-\tau}{2l}-\frac{c}{2l}\right)=0 \tag{C8}$$

$$\frac{\partial\pi_i^{\mathrm{A}}}{\partial \sigma_i}=N_j\left(\frac{1}{2}-\frac{f_j+\sigma_i}{2l}-\frac{\sigma_i+\tau-c}{2l}\right)=0. \tag{C9}$$

Taking Equation (C8) for $i = 1, j = 2$ and Equation (C9) for $i = 2, j = 1$, we find that $f_1 = l/3 + \tau - c$ and $\sigma_2 = l/3 - \tau + c$. Similar calculations show that $f_2 = l/3 + \tau - c$ and $\sigma_1 = l/3 - \tau + c$, so that even in the non-symmetric case both banks choose the same foreign fee and direct fee. (The Hessian matrix of second derivatives of π_i^{A} is diagonal with entries $-N_i/l$ and $-N_j/l$, and so is negative definite. Hence our solution is a maximum.)

N_1 and N_2 can now be found, taking account-keeping fees as given and ATM fees and choices as the endogenous functions previously determined. Similar to Section 4.3, we find the marginal consumer by equating $U_1(e_1*)$ and $U_2(e_1*)$ from Equation (4), but now we take account-keeping fees as fixed and f_i and σ_i for i = 1, 2 as determined above. In this case, from Equation (2), $u_1 = u_2$ so that from Equation (5) $N_i = N(2s_i - F_i + F_j)$.

39 At this stage, banks maximise profits from ATM transactions (as opposed to total profits) since the profit from account-keeping fees has already been determined in the locked-in case.

Finally, the account-keeping fees can be found by maximising total bank profit, taking all other fees and choices as the endogenous functions previously determined. Noting that, $f_1 + \sigma_2 = f_2 + \sigma_1 = 2l/3$ such that $\rho_{ii} = 5/6$ and $\rho_{ij} = 1/6$, the total profit for bank i is given by:

$$\begin{aligned}\pi_i &= N_i\left(F_i + \left(f_i - \tau\right)\rho_{ij} - c\rho_{ii} - m\right) + N_j\left(\sigma_i + \tau - c\right)\rho_{ji} \\ &= N\left\{\left(2s_i - F_i + F_j\right)\left(F_i + \frac{l}{18} - c - m\right) + \left(2s_j - F_j + F_i\right)\left(\frac{l}{18}\right)\right\}.\end{aligned}$$

The first order conditions for this problem are given by $\partial\pi_i/\partial F_i = N(2s_i - 2F_i + F_j + c + m) = 0$, which, since $s_1 + s_2 = 1/2$ and $\partial^2\pi_i/\partial F^2_i = -2N < 0$, leads to the profit-maximising solution $F_i = (1/3) + 2s_i/3 + c + m$.

The solution is shown to satisfy all imposed constraints: $f + \sigma = 2l/3$ is between 0 and l; and, as $u_1 - F_1 + u_2 - F_2 = 2(x - 1/2 - c - m - 17l/36)$, the remaining constraints hold so long as the utility from an ATM withdrawal satisfies $x \geq 1/2 + c + m + 17l/18$. Bank i's total profit can be shown to equal $N(l + 2(1 + 2s_i)^2)/18$ which reduces to $N(1/4 + l/18)$ in the symmetric case.

C.3 The Three-bank Non Locked-in Model

First the consumer's ATM choice. Let ρ_{ij} be the proportion of bank i customers using bank j ATMs and $P_{ij} = f_i + \sigma_j$ be the price they pay, where $i, j, k \in \{1, 2, 3\}$, each distinct. Then so long as the total price of any foreign ATM transaction is less than or equal to l we have:

$$\rho_{ij} = \frac{1}{3} + \frac{P_{ik}}{6l} - \frac{2P_{ij}}{6l}, \text{ and } \quad \rho_{ii} = \frac{1}{3} + \frac{P_{ik}}{6l} + \frac{P_{ij}}{6l}. \tag{C10}$$

Further, assuming that the total cost of any foreign ATM transaction is less than or equal to l, utility from ATM services for customers of bank i, u_i, is given by:

$$u_i = \frac{1}{3l}\int_0^{3l} \left\{ \begin{aligned} & (x-d_i)1_{\left\{0\le d_i \le \frac{l+P_{ij}}{2}\right\}} + \left(x-(l-d_i)-P_{ij}\right)1_{\left\{\frac{l+P_{ij}}{2}\le d_i \le l\right\}} \\ & +\left(x-(d_i-l)-P_{ij}\right)1_{\left\{l\le d_i \le \frac{3l+P_{ik}-P_{ij}}{2}\right\}} \\ & +\left(x-(2l-d_i)-P_{ik}\right)1_{\left\{\frac{3l+P_{ik}-P_{ij}}{2}\le d_i \le 2l\right\}} \\ & +\left(x-(d_i-2l)-P_{ik}\right)1_{\left\{2l\le d_i \le \frac{5l-P_{ik}}{2}\right\}} + \left(x-(3l-d_i)\right)1_{\left\{\frac{5l-P_{ik}}{2}\le d_i \le 3l\right\}} \end{aligned} \right\} dd_i \tag{C11}$$

$$= x - \frac{l}{4} - \frac{P_{ij}}{3} + \frac{P_{ij}^2}{6l} - \frac{P_{ij}P_{ik}}{6l} - \frac{P_{ik}}{3} + \frac{P_{ik}^2}{6l}.$$

Where 1_A is an indicator function, taking the value 1 when A is true and 0 when A is false.[40]

Next the consumer's bank choice. As in the two-bank case, consumers value general bank services and their tastes with respect to these services are uniformly distributed around a unit circle. We assume that banks' general service offerings, s_i, are evenly spaced around this circle, each 1/3 units apart, and $s_1 + s_2 + s_3 = 1$. In this case, the marginal consumer (between bank i and bank j) is at $1/2(s_i - s_j + 1/3 + (u_i - F_i) - (u_j - F_j))$. From this it follows that the number of customers choosing bank i is given by:

$$N_i = \frac{1}{2}N\left(3s_i - \frac{1}{3} + 2(u_i - F_i) - (u_j - F_j) - (u_k - F_k)\right). \tag{C12}$$

As verified later, the solution gives positive marginal utility and N_i so long as each s_i is greater than 2/9.

Total profit of bank i is then given by:

$$\pi_i = N_i\left(F_i + (f_i - \tau)(\rho_{ij} + \rho_{ik}) - c\rho_{ii} - m\right) + N_j(\sigma_i + \tau - c)\rho_{ji} + N_k(\sigma_i + \tau - c)\rho_{ki}$$

40 The argument partitions the circular city into regions of different ATM use and utility, and integrates over all regions by the (uniform) distribution of consumer location.

where ρ_{ij}, N_i, and u_i are as defined above. As in the two-bank case, partially differentiating π_i by f_i, σ_i and F_i, imposing fee symmetry, setting the partial derivatives to zero, and solving, yields the formulae given in Section 4.7. In this case the total price for foreign ATM transactions is $6l/7 < l$; and $u_i = u_j$ and $F_i = F_j$ so the marginal customer will open a bank account and each N_i will be positive so long as each s_i is greater than 2/9. The Hessian evaluated at the solution is negative definite, and so satisfies the second order conditions for a maximum, so long as $l < 13.611$. In particular, $Det(H_{11}) = -N(49 + 128l)/(441l) < 0$, $Det(H_{22}) = 2N^2/(9l) > 0$ and $Det(H) = -N^3(10/(81l^2) - 4/(441l)) < 0$ for $l < 245/18 = 13.611$.

C.4 The Three-bank Locked-in Model

As in the two-bank case we solve the model backwards. First, taking all fees as given, the consumer's ATM choice is as given by Equation (C10).

Next consider banks' choice of f_i and σ_i. Profit from ATM transactions for bank i is given by $\pi_i^{\mathrm{A}} = N_i((f_i - \tau)(\rho_{ij} + \rho_{ik}) - c\rho_{ii} - m) + N_j(\sigma_i + \tau - c)\rho_{ji} + N_k(\sigma_i + \tau - c)\rho_{ki}$. Then, the first order conditions are given by:

$$\frac{\partial \pi_i^{\mathrm{A}}}{\partial f_i} = N_i\left(\frac{2}{3} - \frac{P_{ij} + P_{ik}}{6l} - \frac{f_i + c - \tau}{3l}\right)$$
$$\frac{\partial \pi_i^{\mathrm{A}}}{\partial \sigma_i} = N_j\left(\frac{1}{3} + \frac{P_{jk} - 2P_{ji}}{6l} - \frac{\sigma_i - c + \tau}{3l}\right) + N_k\left(\frac{1}{3} + \frac{P_{kj} - 2P_{ki}}{6l} - \frac{\sigma_i - c + \tau}{3l}\right).$$

Assuming that the total prices of foreign ATM transactions, that is, P_{ij}, P_{ik}, and P_{jk}, each equal l, $\partial\pi_i^{\mathrm{A}}/\partial f_i = N_i(1/3 - (f_i + c - \tau)/(3l)) \geq 0$ for $f_i \leq \tau - c + l$. Conversely if f_i is increased so that P_{ij}, $P_{ik} > l$, then all foreign fee income is lost and profit falls. Hence if the total price of foreign ATM transactions is l, banks will maintain any foreign fee between $\tau - c$ and $\tau - c + l$.[41] Similarly:

$$\frac{\partial \pi_i^{\mathrm{A}}}{\partial \sigma_i} = \left(N_j + N_k\right)\left(\frac{1}{6} - \frac{\sigma_i - c + \tau}{3l}\right) \geq 0 \quad \text{for} \quad \sigma_i \leq c - \tau + \frac{l}{2}.$$

41 $\tau - c$ is a lower bound since foreign fees below this level cost the bank more than c per transaction, whereas by raising the foreign fee so as to make P_{ij}, $P_{ik} > l$, the bank can induce all its customers to use own-bank ATMs, for a total cost to the bank of c.

Again if σ_i is increased so that P_{ji}, $P_{ki} > l$, then all direct fee income is lost and profit falls, so banks will maintain any direct fee between $c - \tau$ and $c - \tau + l/2$.[42]

Given the above two results, $f_i = l + \tau - c - \chi$ and $\sigma_i = \chi - \tau + c$ for any χ between 0 and $l/2$ constitutes a Nash equilibrium – banks have no incentive to reduce fees (to do so would reduce profit), and if they increase fees then their profit will step-down to a lower level. A total price for foreign ATM use of l, as in the equilibria above, corresponds to the level of fees that maximises joint ATM profits.[43]

Next since all $P_{ij} = l$, $u_1 = u_2 = u_3$ and $N_i = 1/2N(3s_i - 1/3 - 2F_i + F_j + F_k)$. Finally, given the above results, total profit for bank i is given by $\pi_i = N_i\,(F_i + (l - \chi)/3 - c - m) + \chi(N_j + N_k)/6$ for $N_i = (1/2)N(3s_i - 1/3 - 2F_i + F_j + F_k)$. Setting $\partial\pi_i/\partial F_i = 0$ for each i and solving yields the formulae given by Equation (18). Further, the second order condition for a maximum is met as $\partial^2\pi_i/\partial F^2_i = -2N < 0$.

In the lock-in case, marginal consumer utility from opening a bank account is given by $(1/2)(2s_i/5 - 2s_j/5 + 1/3) \geq 0$ so long as each s_i is greater than 1/18. Further, $N_i = N(3s_i/5 + 2/15) \geq 0$ for all $s_i \geq 0$.

42 $c - \tau$ is a lower bound since direct fees below this level cost the bank money, whereas by raising the direct fee so as to make P_{ji}, $P_{ki} > l$, the bank can induce all foreign customers to use their own-bank ATMs, thus avoiding any cost.

43 Joint ATM profit can be written as $N_1(P_{12}\rho_{12} + P_{13}\rho_{13}) + N_2(P_{21}\rho_{21} + P_{23}\rho_{23}) + N_3(P_{31}\rho_{31} + P_{32}\rho_{32}) - N(c + m)$. Jointly, the banks can set each P_{ij}, $i, j \in \{1, 2, 3\}$, $i \neq j$ independently so it is only necessary to consider how to maximise $J = P_{ij}\rho_{ij} + P_{ik}\rho_{ik}$, say, since by Equation (C10), ρ_{ij} and ρ_{ik} are functions of P_{ij} and P_{ik} only. Talking the partial derivative of J with respect to P_{ij} and P_{ik}, setting to zero and solving yields $P_{ik} = P_{ik} = l$, which is a maximum (as the associated Hessian has negative eigenvalues $(-1/l, -1/3l)$).

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