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The Impact of Payment System Design on Tiering Incentives

Robert Arculus, Jennifer Hancock and Greg Moran

RDP 2012-06

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ISSN 1320-7229 (Print)

ISSN 1448-5109 (Online)

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October 2012

Payments Policy Department
Reserve Bank of Australia

We are grateful to Mark Manning, Andrea Brischetto, Christopher Kent, other colleagues at the Reserve Bank of Australia, and participants at the Bank of Finland's 2009 Payment and Settlement System Simulation Seminar for their helpful comments. We would also like to thank Rod Phillips, Sammy Yousef and Bank of Finland staff for their technical advice. The views expressed in this paper are those of the authors and do not necessarily reflect the views of the Reserve Bank of Australia. The authors are solely responsible for any remaining errors.

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Abstract

Tiering occurs when an institution does not participate directly in the central payment system but instead settles its payments through an agent. A high level of tiering can be a significant issue for payment system regulators because of the increased credit and concentration risk. This paper explores the impact of payment system design on institutions' incentives to tier using simulation analysis. Some evidence is found to support the hypothesis that the liquidity-saving mechanisms in Australia's real-time gross settlement (RTGS) system – the Reserve Bank Information and Transfer System (RITS) – reduce the liquidity cost of direct participation. This may have contributed to the low level of tiering in RITS relative to RTGS systems in other countries. We find no clear relationship between system design and the size of the substantial two-way exposures tiering creates between clients and their settlement banks. Our data suggest that more tiering would result in only small increases to the level of concentration in RITS.

JEL Classification Numbers: E42, E58, G21

Keywords: large-value payment systems, tiering, liquidity, simulation

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1. Introduction

Most high-value payment systems settle payments on a real-time gross settlement (RTGS) basis. This prevents the build-up of large interbank exposures, which would otherwise occur if high-value payments were settled on a deferred net basis. However, RTGS systems require participants to hold substantial liquidity in order to make payments. Central banks generally make liquidity available to RTGS participants on a collateralised basis, in which case participants incur an opportunity cost in obtaining liquidity because the securities posted as collateral cannot be used for other purposes.

Tiering – where an institution does not participate directly in the central payment system but settles its payments indirectly through an agent that does – is a significant issue for payment system regulators. On the one hand, tiering can reduce system liquidity needs because:

- payments between a tiered participant (client) and its settlement bank are settled across the settlement bank's books rather than sent to the central system; and

- combining the payment flows of the client(s) with those of the settlement bank may allow the settlement bank to fund more payments from receipts rather than from liquidity provided by the central bank.

On the other hand, tiering can increase both credit and concentration risk. Credit risk arises because the settlement bank and its client(s) are exposed to the failure of each other. Tiering, by definition, increases concentration in the RTGS system as more payment activity occurs through a smaller number of direct participants.

The degree of tiering varies across payment systems. The Clearing House Automated Payment System (CHAPS) system in the United Kingdom, for instance, is relatively highly tiered, with only 17 direct participants (not including the Bank of England) making payments on behalf of several hundred other institutions (CPSS 2012). In contrast, the US Fedwire system has a fairly flat payments structure, with several thousand direct participants. Australia's RTGS system, the Reserve Bank Information and Transfer System (RITS), also has a low level of tiering. While in the early days of RITS this was due to restrictions on tiering, these restrictions were relaxed in 2003 to allow institutions whose RTGS payments are less than 0.25 per cent of the total value of RTGS payments to settle through an agent.[1] Since then, however, very few institutions have opted to settle indirectly. In 2008, around half of RITS's 67 participants were below the 0.25 per cent threshold and therefore eligible to settle indirectly, yet only 6 chose to do so. Given that the vast majority of eligible participants joined RITS prior to the relaxation of tiering restrictions, this may be because the fixed costs associated with becoming a direct participant have already been paid, or simple organisational inertia. However, the low level of tiering does raise the question of what drives participants' incentives to tier and whether aspects of system design reduce the incentive to tier in RITS.

This paper uses simulation analysis to explore the impact of payment system design on institutions' incentives to tier. Specifically, it tests the hypothesis that including liquidity-saving mechanisms in the design of an RTGS system reduces the incentives to use tiering to save liquidity. It also attempts to quantify the increases in credit and concentration risk that would occur if there were an increase in tiering in RITS from current low levels, and the effect of system design on credit risk. Finally, it discusses the relevant considerations in weighing-up estimates of the benefits and costs of tiering. This analysis is intended to shed light on the present level of tiering in RITS, as well as inform policymakers in regard to rules that restrict tiering.

The remainder of the paper is structured as follows. Section 2 briefly reviews the literature on the costs and benefits of tiering in payment systems. Section 3 provides an overview of RITS and Section 4 outlines the simulation methodology. Based on these simulations, Section 5 presents estimates of liquidity savings from tiering under different system designs. Section 6 presents estimates of the increases in credit and concentration risk that would occur if there was to be an increase in

1 See Australian Prudential Regulation Authority and Reserve Bank of Australia (2003) for more information. Tiering has always been allowed for low-value payments that are settled on a deferred net basis.

tiering. Section 7 discusses how the benefits and costs of tiering might be weighed. Section 8 concludes.

2. The Benefits and Costs of Tiering

2.1 Benefits

Systems that operate on an RTGS basis require participants to hold substantial liquidity in order to cover payments as they arise. In RITS, intraday liquidity is provided through *interest-free* repurchase agreements ('repos') with the Reserve Bank of Australia (RBA), but participants incur an opportunity cost as collateral posted to access this facility is unavailable for alternative uses.[2] As discussed in Jackson and Manning (2007), Lasaosa and Tudela (2008) and Adams, Galbiati and Giansante (2010), tiering can reduce the liquidity needs of an RTGS system because:

- Combining payment flows allows more payments to be funded from receipts (liquidity pooling). Unless the client's and the settlement bank's peak intraday liquidity requirements occur simultaneously, tiering requires less liquidity than the sum of their individual peak requirements since payments received by one can be used to fund payments by the other.

- Payments between the client and the settlement bank are settled across the settlement bank's books, rather than being sent to the RTGS system (payments internalisation).

While saving on liquidity is the potential benefit of tiering in which we are primarily interested in this paper, several other benefits are identified in the literature. Jackson and Manning (2007) and Adams *et al* (2010), for instance, explore the idea that tiering can benefit a system if some participants have lower costs of direct participation than others or if there are fixed costs of direct

2 A repo is an agreement between two parties under which one party sells a security to the other, with a commitment to buy back the security at a specified time for a specified price. In the case of an interest-free intraday repo, the two transactions occur on the same day at the same price, providing the original seller with liquidity to facilitate payments during the day.

participation. Also, Chapman, Chiu and Molico (2008) and Kahn and Roberds (2009) suggest that tiering encourages inter-agent monitoring of creditworthiness.

2.2 Potential Impact on Risk

While there are potential benefits from tiering in payment systems, there can also be costs. In particular, tiering can increase a number of types of risk in a payment system. Perhaps the most significant of these is credit risk. Just as moving to an RTGS system decreases credit risk at the expense of increased liquidity costs (Kahn and Roberds 2009), tiering represents the reintroduction of some credit risk. Note that this credit risk is two-way. Both the settlement bank and its client are exposed to the failure of the other; the former because it may offer its client intraday credit and the latter due to the settlement bank's role as holder of the relevant accounts. As the default of a settlement bank would affect all its clients simultaneously, the default of a large settlement bank in a highly tiered system could have a systemic impact.

Harrison, Lasaosa and Tudela (2005) attempt to quantify the credit exposure of settlement banks in CHAPS, finding that the risk is not substantial under normal operating conditions, but has the potential to rise considerably in extreme circumstances. To manage this change in credit risk, settlement banks may well react by reducing the credit they extend to their clients in times of stress. This 'liquidity dependence' may have a significant effect on the indirect participant as it no longer has direct access to central bank liquidity.

Tiering can also increase concentration risk. The more liquidity is concentrated among fewer participants, the more likely it is that an operational problem at one participant has a significant effect on the payments system as a whole. On the other hand, as a tiered network depends less on the central infrastructure, it may allow some payments to still go ahead in the event of a failure of the central system. The net effect is ambiguous, but tiering has the potential to significantly alter the effects of system disruptions and participant failures.

While the focus in this paper is on credit and concentration risk, other risks that can arise from tiering include:

- the legal risk that the finality of payments settled across the books of a commercial bank is not protected in the same way as the finality of payments settled in the RTGS system;[3]

- the business risk that the exit of a settlement bank from the market may cause more disruption to the payments system than would result were tiering not present; and

- the competitive risk involved in a settlement bank also being a competitor with its clients in the market for retail payment services (Lai, Chande and O'Connor 2006).

3. Australia's RTGS System

RITS has operated as an RTGS system since 1998.[4] The central queue in RITS operates on a 'bypass first-in first-out (FIFO) basis'.[5] If the transaction being tested for settlement cannot be settled individually, the bilateral-offset algorithm searches for up to 10 offsetting transactions (adding them based on the order of submission), which it attempts to settle simultaneously.[6] RITS incorporates other queue management features, which allow participants to manage their payments and reserve liquidity for 'priority' payments. To assist in this process, RITS participants have access to real-time information, including their settled and queued payments and receipts. The liquidity-reservation feature in RITS allows participants to set a 'sub-limit', where balances below this limit are reserved for the settlement of payments flagged as having 'priority' status. Payments flagged as

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3 For instance, under the 'zero hour' rule, a court may date the bankruptcy of an institution from the midnight before the bankruptcy order is made, in which case payments made on the day of default are reversed. In Australia, the *Payments Systems and Netting Act 1998* allows the RBA to protect payments that occur in RITS from the application of this rule, but payments settled across the books of a settlement bank do not have the same protection.

4 For more information on RTGS in Australia see Gallagher, Gauntlett and Sunner (2010).

5 Payments are tested for settlement in the order of submission, but rather than stopping if the first payment cannot be settled immediately, the system moves on to test the next payment in the queue for settlement, and so on, looping back to the first payment when it reaches the end of the queue.

6 In July 2009, the RBA added a targeted bilateral-offset algorithm, which allows participants to select specific payments for bilateral offset.

having 'active' status are tested for settlement against balances in excess of the sub-limit, while payments flagged as 'deferred' are not tested for settlement until the sending participant changes the status of the payment to either active or priority. Participants can amend the status of payments at any time prior to settlement.

Connection to RITS occurs via either the internet, infrastructure shared with the Australian debt securities depository and settlement system, Austraclear, or the Society for Worldwide Interbank Financial Telecommunication (SWIFT). The RBA does not charge for internet connections to RITS. Thus, non-liquidity costs of direct participation are those associated with equipment, office space, staff training and salaries, internet service provision, Austraclear and SWIFT. In general, these costs are likely to vary considerably across institutions and are difficult to estimate accurately.

Initially, direct access to RITS was only available to banks, and all banks were required to settle their RTGS payments using their own settlement account at the RBA.[7] In 1999, following the recommendations of the Wallis Inquiry into Australia's financial system, access was broadened to allow third-party payment providers and non-bank authorised deposit-taking institutions (ADIs) to hold a settlement account with the RBA to allow them to participate directly in RITS.[8] The Wallis Inquiry also led to the creation of the Australian Prudential Regulation Authority (APRA), which regulates all ADIs – banks, building societies, credit unions and special third-party providers of payments services. While all ADIs can now become direct participants in RITS, only banks are *required* to hold a RITS settlement account.

Notwithstanding the broad scope of participation, payments through RITS are highly concentrated, with the major domestic banks accounting for almost 60 per

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7 Special Service Provider accounts were set up for the building society and credit union industry associations, to allow building societies and credit unions to settle indirectly through these associations.

8 RITS is the means by which settlement accounts are accessed. See 'Exchange Settlement Account Policy' (found at http://www.rba.gov.au/payments-system/esa/index.html) for more information on eligibility for these accounts.

cent of the value of all payments made.[9] Indeed, payments just between the four major domestic banks account for around a third of all payments. Also, the direction of payment flows tends to be skewed. For example, most RITS participants make more than half of their payments, by value, to just a few other participants.

4. Methodology

4.1 The Simulator

The Bank of Finland has developed a versatile Payment and Settlement System Simulator (BoF-PSS2) for modelling the complex interactions that occur in payment and settlement systems. Simulations can be used for analysing the implications for liquidity and risk of changes in system functionality, market structure (such as increased tiering), and settlement rules or conventions, as well as the effect of specific events. Broadly speaking, the Bank of Finland simulator mimics the functionality of RTGS systems; it requires the user to input transaction, liquidity and other data, which are then processed according to specified algorithms that simulate the workings of an actual RTGS system. The simulations generate a wide range of transaction-level and aggregated data, such as the settlement profile of payments and measures of the liquidity used by participants in the system.

4.2 Simulating Tiering

Our methodology is adapted from Lasaosa and Tudela (2008), who study the benefits and costs of tiering in CHAPS using the Bank of Finland's payment system simulator. Lasaosa and Tudela create tiering scenarios for simulation by amending raw transaction data from CHAPS. For example, to model Bank A settling indirectly through Bank B, they create an amended transaction dataset in which payments originally to or from Bank A become payments to or from Bank B. Payments originally between Bank A and Bank B are deleted from the data, as these are now settled across Bank B's books rather than submitted to the

9 This is not unexpected given the Australian banking sector is highly concentrated, with the four major domestic banks accounting for around 70 per cent of ADI total deposits.

system. These 'internalised' payments are an immediate source of liquidity savings.

We create tiering scenarios by amending transaction data from RITS in the same way. The sample period is the month of January 2008, covering 21 business days over which 623 860 individual transactions took place with a total value of around $4.04 trillion. Excluding a number of participants for which indirect settlement would be unrealistic (such as the 4 largest participants, CLS Bank and the RBA), there are 49 participants altogether that are considered candidates for tiering in this experiment. Note that only the smallest 25 of these 49 candidates were under the 0.25 per cent threshold in 2008 and therefore eligible to tier.[10] Notwithstanding this, we model both the cumulative effect of all participants below a given size settling indirectly (the 'cumulative scenarios'), and each of the 49 candidates individually electing to tier (the 'individual scenarios'), resulting in 97 unique sets of transaction data representing 97 unique tiering scenarios.[11]

As Lasaosa and Tudela are primarily interested in the effect of a decrease in tiering in a highly tiered system, they used the results of their simulations to forecast this effect. Given the high level of direct participation in RITS, such forecasting was unnecessary in the context of this paper.

It should be noted that the analysis here is necessarily limited by the fact that it ignores the potential for payments behaviour of participants to change in response to different tiering arrangements. Because the transaction and credit limit inputs to the simulator specify, *inter alia*, payment submission times, payment status (e.g. priority or active) and maximum liquidity accessible, none of these can be altered in response to different levels of tiering.

10 The 28 direct participants eligible for tiering over the whole of 2008 include 1 participant not considered for tiering in our simulations (as it only settles low-value payments on a deferred net basis) and 2 participants that joined RITS after January 2008.

11 In the cumulative scenarios in which the fifth-largest institution is tiered, the 49 smallest institutions are all settling indirectly via the 4 largest participants. As only 1 institution is tiered in the first cumulative scenario, it is identical to the first individual scenario.

4.3 Tiering Order

Although there are a number of ways to select client institutions and their respective settlement banks (see Lasaosa and Tudela (2008) for examples), we allocate institutions based on the value of payments sent and received. In the cumulative scenarios, the 49 candidates are tiered from smallest to largest in order of their share of all payments. Our reasoning is that larger institutions will generally have a lower opportunity cost of collateral as their banking operations naturally result in their holding more eligible securities on their balance sheet, which in turn gives them a competitive advantage in the market for providing payment services. This approach is also consistent with the current formulation of RBA policy, whereby only participants whose share of RTGS payments comprise less than 0.25 per cent of the total value of RTGS transactions are eligible to tier for RTGS transactions.

The settlement bank for each individual tiering candidate is chosen as the institution with which the candidate conducts the largest share of its payments. This approach is likely to maximise the value of payments that are internalised, although this is not a mathematical certainty.[12]

In practice, decisions about tiering would be interdependent. That is, each institution's choice of settlement bank could change depending on the choices of other institutions and the subsequent sizes of different tiered networks (Adams *et al* (2010) provide an interesting model of participant tiering choice). However, preliminary work suggested that attempting to account for this would have minimal effect; for instance, when each client institution was assigned to its largest payments partner and the choices of all smaller institutions were taken as given, the choice of settlement bank differed only in four cases.

4.4 System Design

To test the hypothesis that the liquidity-saving features of RITS decrease participants' incentives to tier, we simulate tiering under four RTGS system

12 A further scenario, based on the order of the share of total volumes, was not materially different to the one based on values, and so it was not pursued further.

designs (Table 1). Details of how the bilateral-offset and sub-limit features of RITS have been incorporated in the simulations are contained in Appendix A.

Table 1: RTGS System Designs

	Central queue	Bilateral offset	Sub-limits
Pure RTGS	–	–	–
RTGS with central queue only	✓	–	–
RTGS with bilateral offset	✓	✓	–
RITS replica	✓	✓	✓

Regardless of our tiering-order methodology, we expect liquidity use to fall as we increase the number of liquidity-saving mechanisms in the system. That is, we expect liquidity use to be the greatest under the pure RTGS system, followed by the central-queue-only system, then the bilateral-offset system.[13] The RITS replica is expected to require the lowest level of liquidity.

4.5 Liquidity

The liquidity available to participants is modelled in the simulations using limits on credit extended by the system operator to each direct participant. Each participant begins each simulated day with an account balance of zero and, as payments settle, is able to accrue a negative account balance up to that participant's credit limit. Credit limits are set exogenously and may vary throughout the day. In general, the credit limit profile for each participant on each simulated day is modelled on the actual liquidity that was available to that participant at each point in time on the corresponding day of our sample period. This actual liquidity is measured as the sum of the participant's opening settlement account balance and the value of intraday repos it had outstanding at each point in time during the day.[14]

An exception is made for our simulation of the pure RTGS system. To prevent payments that do not settle immediately from being rejected and remaining

13 For the purposes of this paper the term 'pure' RTGS system is used to refer to an RTGS system that does not have a central queue.

14 In our simulations, the RBA, CLS Bank and the settlement accounts of the equity and futures clearing and settlement systems are provided with unlimited credit in all system designs.

unsettled at the end of the day, all participants are assumed to have access to unlimited liquidity. In addition, to ensure that all payments settle in our simulations, we give all participants unlimited access to liquidity under all system designs at the end of each day.[15]

In the tiering scenarios, we reason that a settlement bank does not have access to collateral on its clients' balance sheets and it will not necessarily commit more of its own collateral to access additional liquidity. Alternatively, we could have assumed that the settlement bank increases the liquidity it accesses (e.g. by the value of the liquidity accessed by its clients when they were direct participants). Indeed, preliminary simulations were run where the credit limits of the settlement bank and its clients were summed, but this resulted in quite substantial and unrealistic increases in liquidity usage under tiering. Therefore, our preference has been to remain with fixed, non-additive access to liquidity.

We measure system liquidity usage as the sum of individual participants' peak intraday liquidity requirements. For an individual participant, this peak intraday liquidity requirement is equal to the absolute value of the participant's minimum account balance. While this liquidity may only have been used for a very brief period during the day, this measure is consistent with the view that the main driver of the cost of liquidity is the maximum value of collateral used, rather than the length of time during the day that the securities are used.

5. The Impact of Tiering on Liquidity Usage

5.1 Estimates of Liquidity Savings

We present simulation results for the changes in liquidity use due to increased tiering in the four system designs. Our hypothesis is that the liquidity benefits from tiering decrease as more liquidity-saving features are added to the RTGS system. A

15 In the absence of this we find that the simulations result in a small proportion (less than 1 per cent) of payments remaining unsettled at the end of most days. This failure to settle all payments occurs because settlement times differ across the different RTGS systems, while available liquidity is set exogenously.

decomposition of liquidity savings into the two sources identified in the literature, namely liquidity pooling and payments internalisation, is contained in Appendix B.

5.1.1 Cumulative tiering

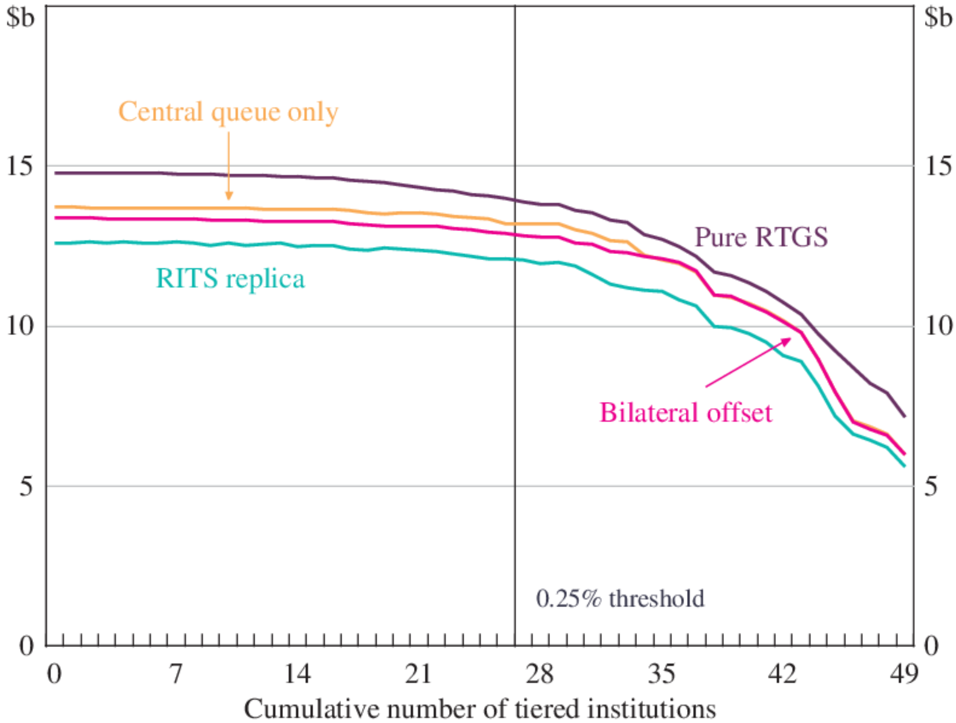
We first look at the case where individual institutions are tiered cumulatively, from smallest to largest, according to their share of the total value of payments. Figure 1 shows liquidity usage over the range from no tiering to tiering all candidate institutions. For all scenarios in this case, the pure RTGS system is the most liquidity intensive and the RITS replica the least intensive. Of the two other system designs, the bilateral-offset system clearly uses less liquidity for the first 33 tiering scenarios. For subsequent scenarios, however, the presence of bilateral offset has almost no effect. This may be due to the increasing concentration of the system; Ercevik and Jackson (2009) report the intuitive finding that liquidity recycling increases with system concentration, thus the need for bilateral offset decreases. The share of the total value of payments settled by bilateral offset falls from 28 per cent when there is no tiering to 13 per cent when all candidate institutions are tiered.

In line with our hypothesis, liquidity-saving mechanisms typically reduce the liquidity benefits from tiering. Average daily liquidity usage falls by $7.0 billion when all candidates are tiered in the RITS replica system, compared with larger decreases of: $7.4 billion in the system with bilateral offset; $7.6 billion in the pure RTGS system; and $7.7 billion in the system with a central queue only. However, there is some variance in the results, with this ranking not holding at all increments of the cumulative tiering.[16]

16 For the systems with credit limits, we find that the marginal change in liquidity usage from tiering an additional institution is often not significantly different from zero at the 10 per cent level for approximately the smallest 30 institutions.

Figure 1: System Liquidity Usage

Daily average



5.1.2 Tiering individual participants

We now look at the case where individual participants are tiered in isolation. Again, the pure RTGS system is the most liquidity intensive and the RITS replica the least intensive for all scenarios. Average daily system liquidity usage falls by $137 million on average when a single institution is tiered in the RITS replica system, compared with larger decreases of: $143 million in the system with a central queue only; $151 million in the pure RTGS system; and $155 million in the system with bilateral offset. While liquidity savings are lowest in the RITS replica system as expected under our hypothesis, the fact that savings are highest in the bilateral-offset system is not consistent with our hypothesis. Again, there is variance in the results, with this ranking not necessarily holding for each individual institution tiered.

5.1.3 Network effects

It is possible that the low level of tiering observed currently in RITS might be because the benefits of tiering are dependent on the size of the tiered network. For instance, the proportion of payments that can be internalised for a given tiering candidate will tend to increase the larger is the tiered network being joined. If these network effects are large, then multiple equilibria including both high and low degrees of tiering would be conceivable (with the latter a result of very few institutions considering it worthwhile to tier as long as very few other institutions are already tiered).

By comparing the liquidity savings in the cumulative and individual tiering scenarios, we find some evidence for this possibility. When the smallest 30 institutions are tiered in the RITS replica system, average daily liquidity usage declines by around $721 million; whereas when each of the smallest 30 institutions are tiered individually, the summed marginal changes imply a decrease in average daily liquidity usage of around $485 million. That is, the network effect leads to an additional $236 million in total liquidity savings. However, this estimate of the size of the network effects varies; if we considered tiering 35 institutions, for instance, then network effects would appear to imply only $171 million of total liquidity savings. In addition, on average an institution in the smallest 30 sends and receives just 8 per cent of the total value of its payments to and from other institutions in the smallest 30, suggesting that the scope for network effects in this group is limited.

6. The Impact of Tiering on Risk

The benefits of tiering can come at a cost of increased credit and concentration risk. This section estimates the changes in credit and concentration risk in RITS due to increased tiering. The effect of system design on credit risk is also examined.

6.1 Credit Risk

Tiering creates a two-way exposure between a client and its settlement bank because payments are settled across the settlement bank's books, rather than directly in RITS (for which there is no credit risk). Furthermore, these payments – unlike those in RITS – may be subject to the 'zero hour' rule, which means that in the event of a bankruptcy, their finality can be challenged. In this section we present measures of this two-way exposure for the two system designs at either end of the liquidity-usage spectrum: the pure RTGS system and the RITS replica system.

6.1.1 Settlement bank exposures

A settlement bank's maximum intraday exposure to a client can be measured as the client's maximum intraday cumulative net *payment* (as opposed to receipt) position when the client settles directly in the RTGS system. This measure of settlement bank exposure should be regarded as an upper bound because a settlement bank can vary the timing of sending its clients' payments to minimise its exposure, and require clients to pre-fund settlement obligations.[17]

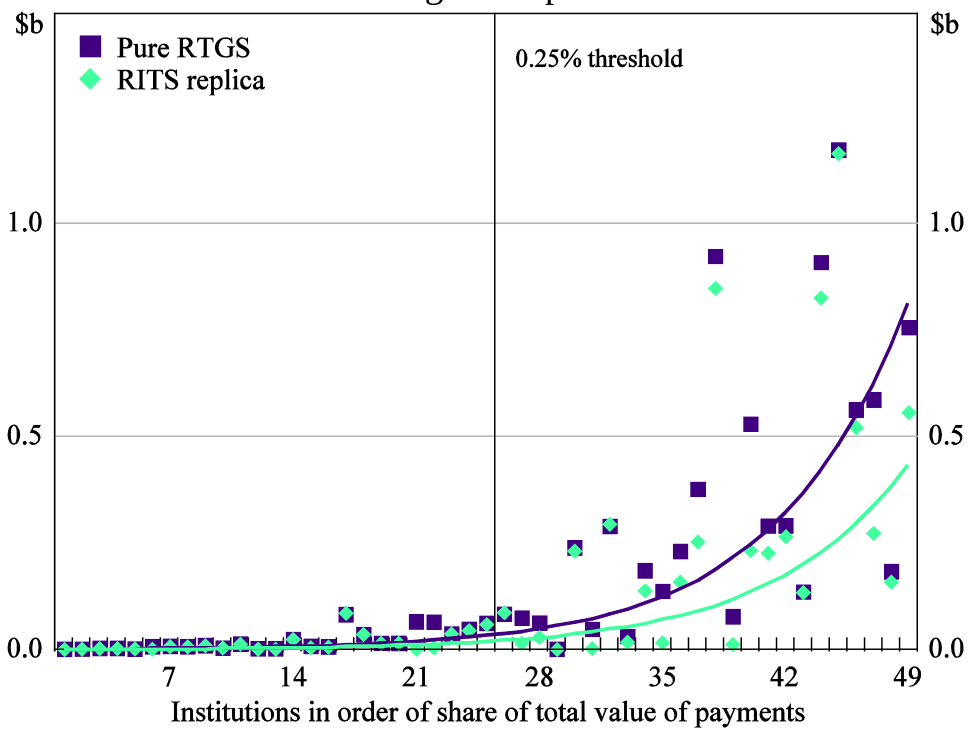
We find that a settlement bank's *average* maximum intraday exposure to any one of the smallest 29 tiering candidates over the sample period is less than $100 million (Figure 2). While the *largest* maximum intraday exposure over the month is roughly three times the size of the average maximum intraday exposure, this is still quite low for the smallest 29 tiering candidates (Figure 3). Unsurprisingly, maximum intraday exposures are typically much higher among the largest 20 tiering candidates. We are unable to determine the size of the exposures that the settlement banks in our simulations would be willing to accept, as these are likely to be functions of the capitalisation and risk preferences of the individual institutions. However, we note that while the largest maximum intraday exposure of around $2 billion is sizeable, it is considerably smaller than the tier 1 capital held by each of the four largest settlement banks (over $20 billion in 2008).

Because our measure of settlement bank exposure (a client's maximum intraday cumulative net payment position) is equal to our measure of the client's liquidity usage when it participates directly in the RTGS system we expect higher settlement bank exposures in the more liquidity-intensive pure RTGS system. The difference in exposure between the two system designs varies considerably with the institution being tiered. For the median institution in the tiering group (in terms of this exposure), the average maximum intraday exposure of the settlement bank to one of its clients is 8 per cent higher in the pure RTGS system.

17 Note that the timing of settlement in the tiered simulations may also vary depending on the liquidity available to the settlement bank.

Figure 2: Settlement Banks' Maximum Intraday Exposures

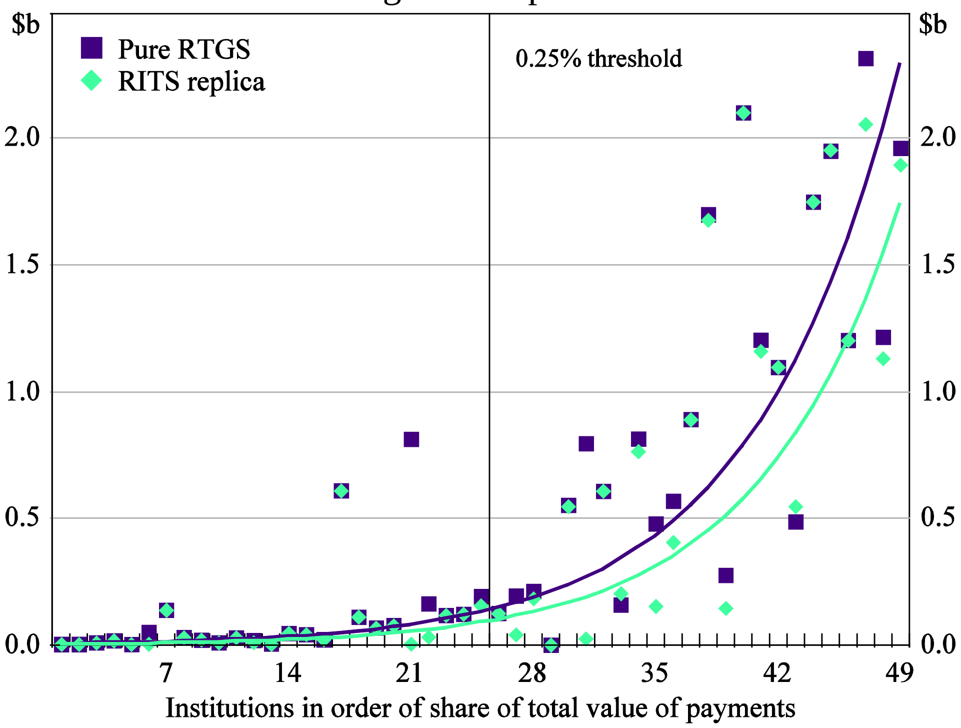
Average over period



Note: Exponential trend lines have been fitted, although the functional form is unclear

Figure 3: Settlement Banks' Maximum Intraday Exposures

Largest over period



Note: Exponential trend lines have been fitted, although the functional form is unclear

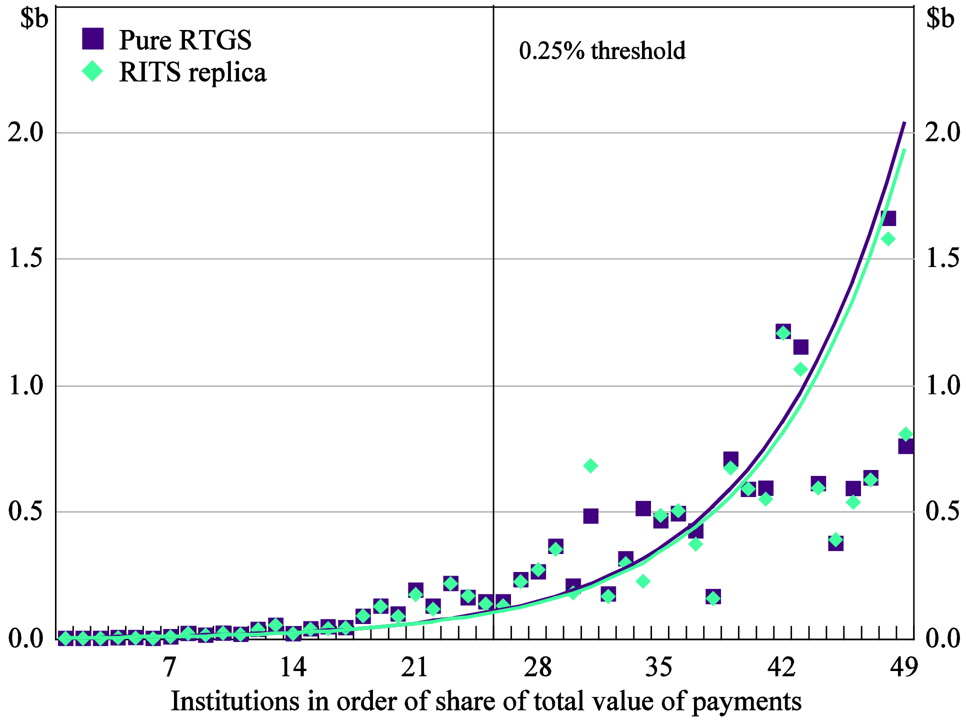
6.1.2 Individual client exposures

A client's maximum intraday exposure to its settlement bank can be measured using that client's maximum intraday cumulative net *receipt* (as opposed to payment) position when it settles directly in the RTGS system. Because a settlement bank has discretion over the timing of payments, and because it may require pre-funding from its client, these estimates should be viewed as a lower bound.

Clients' average maximum intraday exposures are typically less than $1 billion (Figure 4). The largest maximum intraday exposures are still less than $1 billion for smaller institutions, but are as high as $3.5 billion for the largest clients (Figure 5). Given that the largest clients are typically (though not always) branches of global banks, their largest exposures are still small relative to their group tier 1 capital.

Figure 4: Clients' Maximum Intraday Exposures

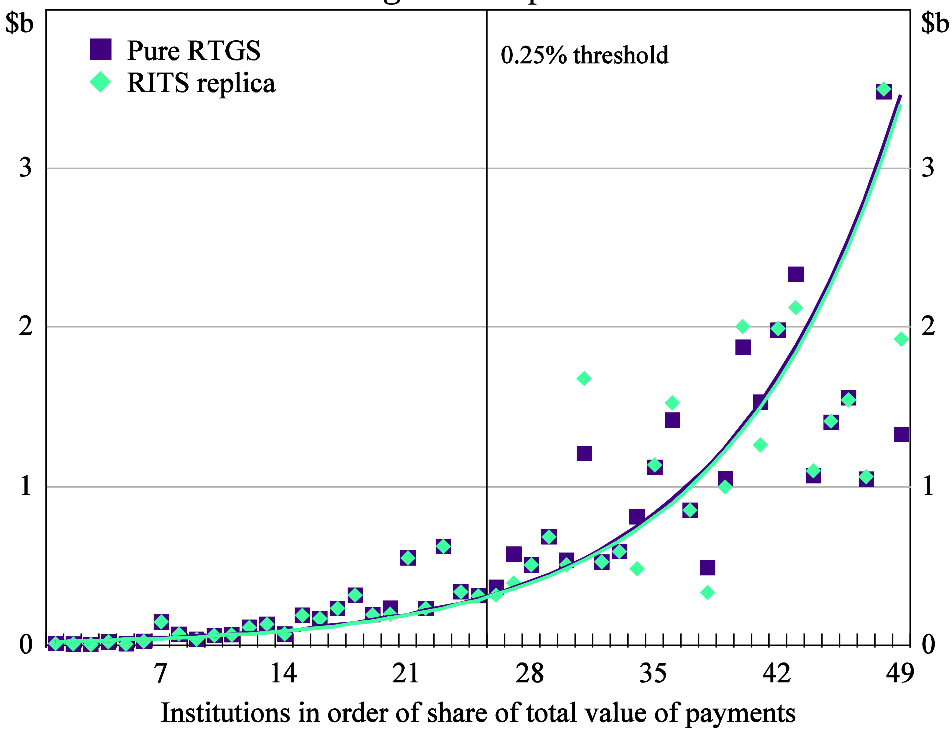
Average over period



Note: Exponential trend lines have been fitted, although the functional form is unclear

Figure 5: Clients' Maximum Intraday Exposures

Largest over period



Note: Exponential trend lines have been fitted, although the functional form is unclear

Clients' exposures in the pure RTGS system are similar to those in the RITS replica system. Again, the difference in exposure between the two system designs varies considerably with the institution being tiered. For the median institution (in terms of this exposure), the average maximum intraday exposure is 2 per cent higher in the pure RTGS system.

6.1.3 Total client exposures

While a settlement bank is unlikely to face the simultaneous default of all of its clients, if a settlement bank defaults, all of its clients are exposed. To estimate the maximum total client exposure to a particular settlement bank we can sum the minute-by-minute exposures, measured using each client's cumulative net receipt position when it settled directly.[18] As noted above, these estimates of client exposures should be viewed as lower bounds.

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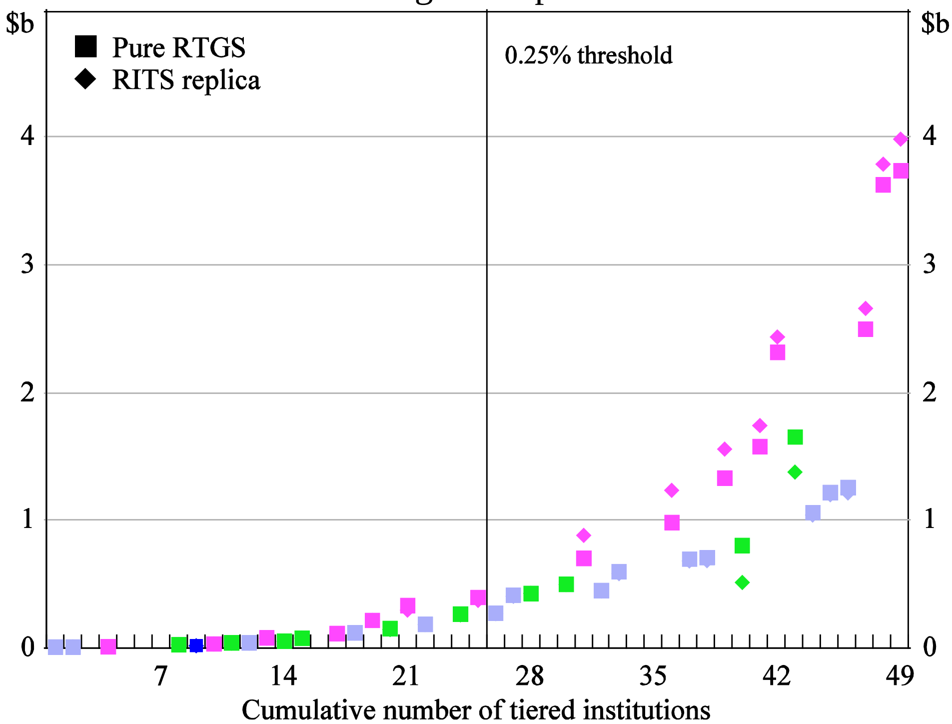
18 Note that exposures are not netted multilaterally. Therefore, if a client has negative exposure (that is, it owes the settlement bank), that exposure is excluded from the calculation.

Each observation in Figures 6 and 7 represents the maximum aggregate loss that could occur if the settlement bank to which the n^{th} smallest institution tiers defaults on its obligations, and it defaults on all its obligations to any smaller institutions that also use it as a settlement bank. For example, when the 49th institution is tiered in Figure 6, the average maximum intraday exposure in total for that institution and other clients using the same settlement bank as an agent is around $4 billion in the RITS replica system. Each colour in the figure represents one of the 4 largest settlement banks.

With the exception of larger institutions that tier to the settlement bank depicted in pink, total client exposures are typically at least as high in the pure RTGS system as they are in the RITS replica system. For the median case, the average maximum intraday exposure is around 1 per cent higher in the pure RTGS system compared with the RITS replica system.

Figure 6: Total Client Maximum Intraday Exposures

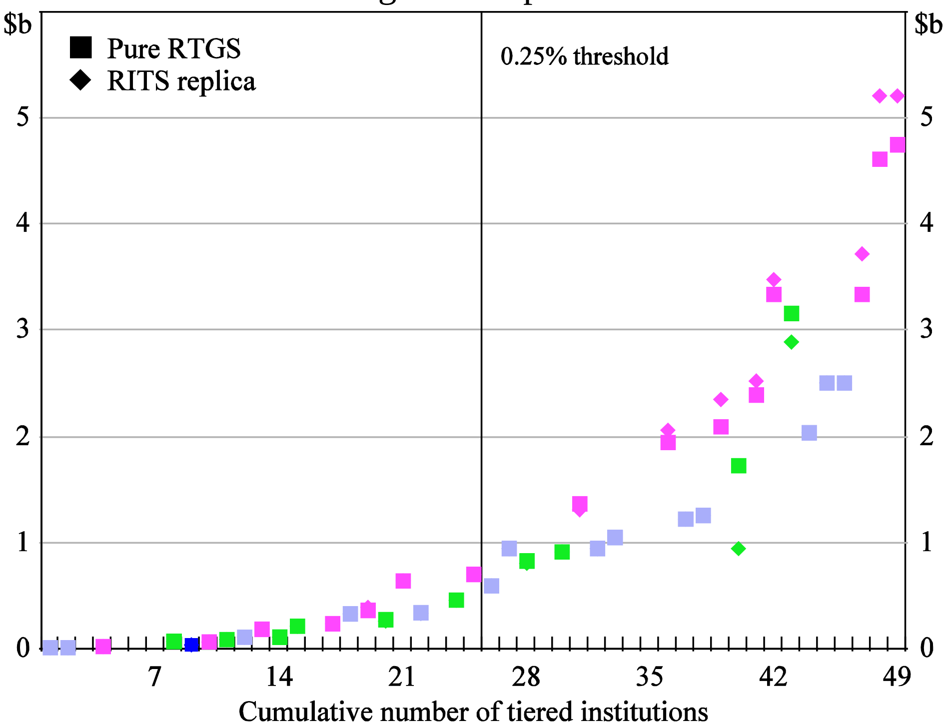
Average over period



Note: Each colour represents one of the 4 largest settlement banks. While some tiering candidates initially settle through other institutions, as the simulated level of tiering increases all 49 tiered institutions eventually settle through one of the 4 largest settlement banks.

Figure 7: Total Client Maximum Intraday Exposures

Largest over period



Note: Each colour represents one of the 4 largest settlement banks. While some tiering candidates initially settle through other institutions, as the simulated level of tiering increases all 49 tiered institutions eventually settle through one of the 4 largest settlement banks.

6.2 Concentration Risk

Indirect participants in a payments network send payment instructions to their settlement bank, which then acts on their behalf. Consequently, in choosing to tier the client becomes operationally dependent on its settlement bank. One might argue that larger institutions are better equipped to minimise the probability of an operational problem. However, by concentrating payment flows, tiering amplifies the consequences of an operational incident at the settlement bank – in particular, the size of the potential liquidity sink increases.

A general measure of this type of operational risk is the level of concentration in the system: the increase in settlement banks' share of payments as the level of tiering increases. Note that our measure of concentration is the share of payments sent, rather than sent and received, as generally even when a participant suffers an operational incident they can still receive payments. While a more accurate way to model the impact of tiering on the consequences of an operational incident is to simulate operational incidents in a tiered network, this is beyond the scope of this paper.

We find that our cumulative tiering scenarios result in only a modest increase in the concentration of payments being sent to RITS by the 4 largest participants. In the absence of tiering, the 4 largest participants account for around 57 per cent of all payments sent to RITS by value. If all of our 49 tiering candidates were to settle indirectly, the combined share of the 4 largest participants would rise by around 10 percentage points. Since it is unlikely that an operational incident would occur at all 4 of the largest participants simultaneously, it is more noteworthy that the largest increase for an individual settlement bank is only 4 percentage points.

An alternative measure of concentration is the value of payments that the four largest participants are collectively responsible for; that is, the value of payments sent by them to the central system plus the value of payments settled across their own books. By this measure the rise in concentration is more substantial, at just over 24 percentage points. In addition, the largest increase in share for an individual settlement bank rises by around 13 percentage points. Thus, the extent to which concentration risk is an issue depends on the relative likelihood of different types of operational outages; that is, whether outages are more likely to simply affect the ability of an institution to access the central system, or whether they are more likely to disrupt the processing of payments entirely. We do not pursue this issue further here.

7. Weighing the Benefits and Costs of Tiering

The liquidity savings from tiering come at the cost of increased credit and concentration risk. It follows that, in theory at least, these benefits and costs identified in Sections 5 and 6 can be weighed against each other in order to find a socially optimal level of tiering. This section briefly outlines the considerations and challenges involved in such an exercise. To do this precisely would require an expression of benefits and costs that are comparable on a dollar-for-dollar basis, which is beyond the scope of this paper.

One measure of the benefit of liquidity savings is the opportunity cost of the collateral used to obtain liquidity. For the United Kingdom, James and Willison (2004) suggest that this is equal to the value of the collateral used, multiplied by the spread between the (unsecured) London Interbank Offered Rate (LIBOR) and the secured-lending repo rate. The intuition behind this calculation is that an institution in possession of collateral-eligible securities could use those securities to obtain funds in the secured lending market, and then lend those funds out at LIBOR.

In the Australian context, however, there is evidence to suggest that the opportunity cost of collateral is low. The range of collateral accepted by the RBA for intraday repos is significantly broader than that used in secured market trades. Moreover, Commonwealth Government securities (CGS) are the most commonly used collateral in intraday repos, and many participants already hold CGS under prudential regulatory requirements. Instead, RBA liaison with RITS participants suggests that the benefit of liquidity savings might be more closely associated with savings in the operational costs (both direct and indirect) of accessing the repo facility. Placing a dollar value on these savings is difficult given that they are likely to vary across institutions.

Risk in this context relates to losses that might be realised if a particular event occurs, such as the default of, or an operational disruption at, a settlement bank. Estimating the expected loss due to credit exposures is, in theory, relatively easy. Section 6.1 provides estimates of the loss that a settlement bank faces if a particular client fails, and vice versa. Multiplying this potential loss by the relevant probability of failure would yield a measure of expected loss, comparable on a dollar-for-dollar basis with the benefit of liquidity savings. While probabilities of failure can be inferred roughly from credit ratings, this approach is subject to a number of caveats. Moreover, account should also be taken of the potential second-round effects of the default of the settlement bank's clients or the clients' inability to access the RTGS system, which could affect other participants in a tiered system.

Placing a dollar value on the loss resulting from an operational disruption at a direct participant is also quite difficult. For example, the incremental social cost of an operational disruption at a settlement bank in a tiered system should take into account the delay and operational costs incurred by:

- the settlement bank itself;
- clients of the settlement bank;
- other participants in the system; and
- the operator of the payments system.

8. Conclusions

Australia’s RTGS system, RITS, has a low level of tiering relative to many RTGS systems elsewhere. The results of the simulations conducted in this paper provide some evidence to support the hypothesis that the design of RITS (that is, an RTGS system with a central queue, a bilateral-offset algorithm and a liquidity-reservation feature) reduces the incentive to save liquidity by tiering.

While tiering can reduce liquidity needs, it can also increase risk in the system. In terms of credit risk, the simulations provide some evidence to suggest that settlement banks’ exposures to clients might be higher in systems more liquidity-intensive than RITS, although this result is not conclusive. Also, if there were to be an increase in tiering from current low levels, this would result in only small increases to the already high level of concentration in RITS, though it could potentially lead to substantial increases in the share of total payments that individual institutions are responsible for processing.

Fully quantifying the benefits and costs of tiering to find the socially optimal level of tiering is left to future consideration. Nevertheless, the results suggest that for institutions below the 0.25 per cent threshold, settling indirectly provides only modest liquidity savings, but it does so without substantially increasing credit or concentration risk. On the other hand, the results suggest that both liquidity savings and risks would increase significantly if institutions above the 0.25 per cent threshold were allowed to tier.

Appendix A: Sub-limits and Bilateral Offsetting

We use bilateral limits in the simulator to replicate RITS's sub-limits feature. This involves modifying the simulator's entry and queuing sub-algorithms so that they conduct the appropriate settlement tests (e.g. test priority payments against a participant's entire settlement account balance, and test active payments against a participant's account balance in excess of its sub-limits). However, data limitations mean that we are unable to pinpoint when a queued payment's status is changed by the sending participant; we only know the status of the payment upon submission to the RITS queue, and the status of the payment when it is settled in RITS. Input to the simulator requires payments to have a single status, which remains unchanged during queuing, thus we need to modify our underlying transaction data. Table A1 summarises the approach.

Table A1: Payment Status and Submission Times

Status when submitted to RITS	Status when settled in RITS	Status when submitted to the simulator	Time when submitted to the simulator
Deferred	Active	Active	Settlement time in RITS
	Priority	Priority	Settlement time in RITS
Active	Active	Active	Submission time to RITS
	Priority	Priority	Settlement time in RITS
Priority	Active	Priority	Submission time to RITS
	Priority	Priority	Submission time to RITS

Note: In the pure RTGS system design with unlimited liquidity all payments are submitted to the simulator at the time they were settled in RITS and payment statuses are irrelevant.

Payments that were submitted to RITS as deferred are submitted to the simulator at the time that they were settled in RITS. This change is based on the assumption that the sender of a deferred payment did not intend for the payment to settle upon its submission, but rather intended to change the status of the payment at a later time. (We assume that the actual settlement time in RITS is a better approximation of this time than the time of submission.) Payments that were submitted as active but later settled as priority also have their submission time to the simulator changed to their actual settlement time in RITS. A number of participants in RITS have been observed to manage liquidity by setting very high sub-limits, submitting payments to the queue as active, and subsequently changing a payment's status to priority when they want it to be settled. Therefore, again we assume in these cases that actual settlement time in RITS is a better approximation of the time at which the sending participant wished settlement to occur.

We also design a bilateral-offset sub-algorithm for the simulator that seeks to replicate RITS's own bilateral-offset algorithm. In RITS, payments which are queued for over a minute are tested for bilateral offset with up to 10 payments due from the receiving participant on a next-down looping basis.[19] By contrast, the BOBASIC bilateral-offset sub-algorithm provided with the simulator only tries to offset all queued payments between the counterparties to the *first* queued transaction, iteratively removing the last queued transaction between these counterparties to find a combination of offsetting transactions that it can settle simultaneously.

19 We have not incorporated the minute delay feature of RITS's bilateral-offset feature into our sub-algorithm, and this is not expected to affect our results significantly.

Appendix B: Decomposing Liquidity Savings

To decompose liquidity savings into the two sources identified in the literature, namely liquidity pooling and payments internalisation, we follow Lasaosa and Tudela (2008) and run two additional sets of simulations. For this exercise, we examine the cumulative tiering scenarios.

To isolate the impact of liquidity pooling, we run the tiered simulations including the internalised payments that were previously omitted. This involves transforming payments to and from the client into payments to and from the settlement bank, but continuing to settle payments between the settlement bank and its clients in the RTGS system. Since these internalised payments are still being sent through the system, all the liquidity savings from tiering can be attributed to liquidity pooling.

Conversely, to measure liquidity saved due to payments internalisation we omit payments between the client and the settlement bank but otherwise leave the client as a direct participant. Any reduction in liquidity usage in this case will be due to transactions between the client and the settlement bank being settled outside the RTGS system. Note that as multiple clients enter the same tiering network, all payments between them must also be omitted. For example, consider initially that participant B acts as settlement bank for participant A. To measure the internalisation effect when participant B also settles for participant C, payments among participants C, B *and* A must all be omitted.

Since liquidity pooling and payments internalisation are the only sources of liquidity savings, comparing liquidity savings in the original simulations with those in the additional simulations result in two sets of estimates for the relative importance of the sources of the liquidity savings. Note that these values should be thought of as alternative estimates, not as the upper and lower bound on a range.

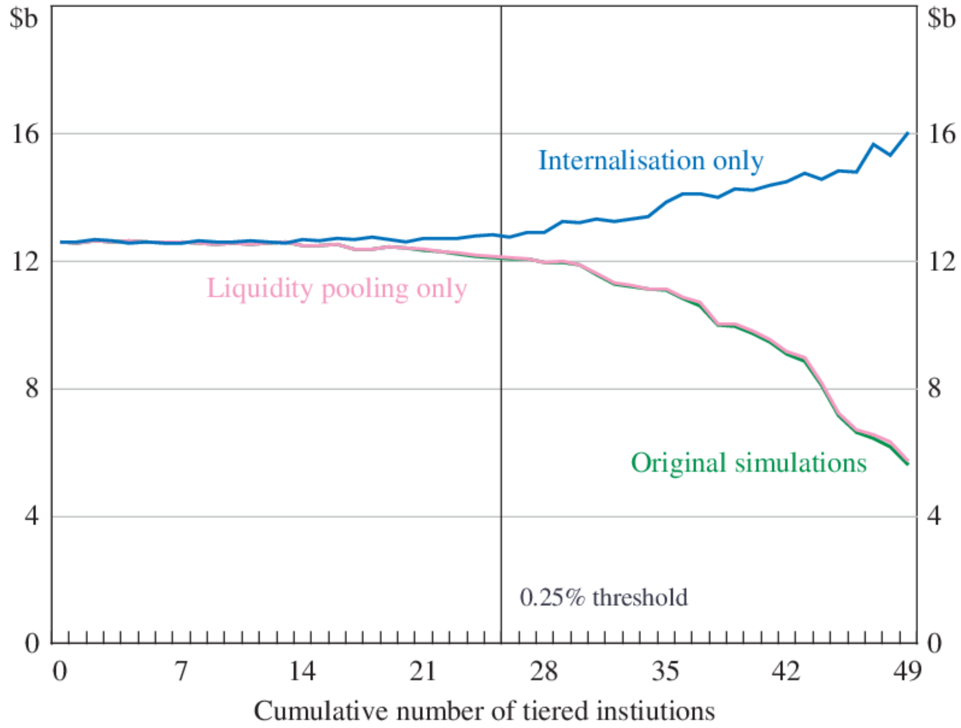
There are two reasons for differences in the two sets of estimates for the relative contribution of liquidity pooling and payments internalisation to liquidity savings. First, the complexities of the liquidity recycling process mean that a small change in transaction data can have a substantial effect on the settlement and liquidity profiles. Second, our additional simulations do not perfectly separate out the liquidity-saving effects of tiering. Because the client still participates in the system in the internalisation simulations, the fact that it no longer receives funds from – or pays funds to – the settlement bank creates an artificial and ambiguous effect on its liquidity needs. Note that this effect on liquidity does not exist in the original tiering simulations because in that case the client is completely removed from the system. Hence, this effect could cause the liquidity savings yielded by the internalisation simulations to be materially over- or under-stated.

Figure B1 shows daily average liquidity used in the RITS replica system for different levels of tiering in the original and additional simulations.[20] Note that the green line in this figure is the same as the green RITS replica line in Figure 1. Comparing liquidity use in the original simulations to that in the liquidity-pooling-only simulations suggests that almost all of the liquidity savings from tiering are due to liquidity pooling. In contrast, comparing liquidity use in the original simulations to that in the internalisation-only simulations suggests that the internalisation effect actually *increases* liquidity needs. However, as discussed above, the simulations designed to capture internalisation effects involve an artificial effect that appears to be putting upward pressure on liquidity needs and thus under-stating the liquidity-saving effect of internalisation.

20 Liquidity savings in the other three system designs exhibit a similar pattern.

Figure B1: Liquidity Usage Decomposition – RITS Replica

Daily average



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