How has the Liquidity Saving Mechanism reduced banks' intraday liquidity costs in CHAPS?

By Nick Davey and Daniel Gray of the Bank's Market Services Division.[1]

- Banks require intraday liquidity to settle payments in CHAPS, the United Kingdom's high-value sterling payment system.
- In April 2013, the Bank of England introduced a Liquidity Saving Mechanism (LSM) into the infrastructure used to settle CHAPS payments. The LSM has reduced CHAPS banks' intraday liquidity requirements by around 20% (or £4 billion).
- The LSM has reduced incentives for banks to adopt adverse behaviours to economise on their intraday liquidity requirements, thus enhancing the resilience and efficiency of CHAPS.

Overview

CHAPS is the United Kingdom's high-value sterling payment system. On average £280 billion of CHAPS payments are made every business day. The Bank of England provides the infrastructure used by banks to settle CHAPS payments, called the Real-Time Gross Settlement (RTGS) infrastructure. All banks that settle CHAPS payments have an account in RTGS.

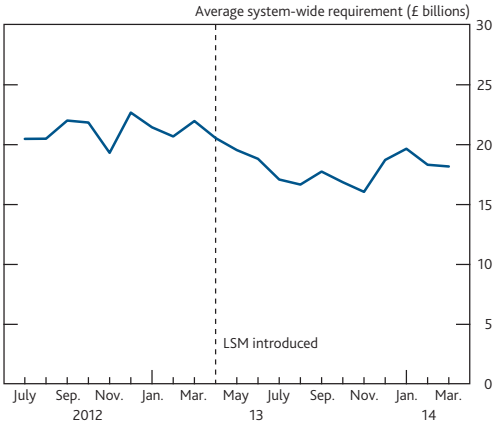
In order to settle a CHAPS payment, a bank must have sufficient funds in its RTGS account. Broadly speaking, a bank has two types of funds in its account. First, there are 'received funds' — that is, payments received from other banks throughout the day. Second, there are 'own funds' — these include sterling reserves held at the Bank, for example. A bank requires 'own funds' when, at any point during the day, it has sent more payments than it has received. This need is referred to as an 'intraday liquidity requirement'.

Following the recent financial crisis, the Financial Services Authority (the prudential banking regulator at the time) strengthened its liquidity regulations which, unavoidably, created incentives for banks to economise on their intraday liquidity requirements. Specifically, banks might have started to reduce the amount of their own funds that they used to settle CHAPS payments — relying more on received funds instead. This could have introduced additional operational and liquidity risks into CHAPS.

To minimise the likelihood of these risks materialising, the Bank sought to provide a technical means for banks to reduce their CHAPS intraday liquidity requirements. As a result, the Liquidity Saving Mechanism (LSM) was introduced into the Bank's RTGS infrastructure in April 2013.

The LSM, which uses algorithms to match up groups of broadly offsetting CHAPS payments and then settle them simultaneously, has reduced CHAPS banks' intraday liquidity requirements by around 20%, or £4 billion. This has reduced incentives for banks to adopt adverse behaviours to economise on their intraday liquidity requirements, enhancing the resilience of CHAPS. It is also now less likely that, under stressed conditions, banks will be unable to settle CHAPS payments due to liquidity shortfalls, enhancing UK financial stability.

Summary chart Average value of intraday liquidity required by CHAPS settlement banks for sterling payment systems



(1) The authors would like to thank Andrew Georgiou and Danielle Gontier for their help in producing this article.

Electronic payments are essential to the functioning of modern economies. They are used, for example, by individuals to purchase goods, by companies to pay salaries, and by the government to pay for public goods and services. For this reason, the infrastructure used to make sterling electronic payments is sometimes described as the financial plumbing that enables money to flow around the UK economy.

The Bank of England sits at the heart of this financial plumbing in the United Kingdom. As 'settlement agent' for the main sterling electronic payment systems, the Bank facilitates the transfer of electronic payments between the customers of different banks. To do so, it operates an accounting system called the Real-Time Gross Settlement (RTGS) infrastructure.

One of the electronic payment systems that uses the RTGS infrastructure is CHAPS, the United Kingdom's high-value sterling payment system. CHAPS is vital to the functioning of the UK economy: on average, £280 billion of CHAPS payments are made every business day. As part of its financial stability objective, the Bank therefore seeks to identify and mitigate any risks to the smooth functioning of CHAPS.

In 2009 and 2010, the Financial Services Authority (FSA) strengthened its liquidity regulations which, unavoidably, created incentives for banks to economise on the amount of liquid assets that they required to make CHAPS payments (referred to as their 'intraday liquidity requirement' for CHAPS).(1) This might, in turn, have incentivised banks to adopt adverse behaviours such as delaying the rate at which they settled CHAPS payments. To counter this potential risk, the Bank sought to reduce the likelihood that banks would delay their CHAPS payments by providing them with a technical means to reduce their intraday liquidity requirements. This technical means is referred to as the Liquidity Saving Mechanism (LSM). The LSM was introduced into the RTGS infrastructure in April 2013.

This article describes the motivations for introducing the LSM, its design, and its effect on banks' intraday liquidity requirements. It follows a series of publications by the Bank of England about liquidity saving mechanisms.(2)

Drawing on these previous Bank publications, the first section of this article describes CHAPS and the importance of the Bank's role in settling CHAPS payments. The second section details the rationale for providing banks with a technical means to reduce their intraday liquidity requirements for CHAPS. The article then outlines recent developments, by detailing how the Bank redesigned its RTGS infrastructure to incorporate the LSM and describing the outcomes, as of March 2014, of introducing the LSM.

The CHAPS payment system

CHAPS and the Bank of England's role

CHAPS is the electronic payment system designed for making real-time, high-value sterling payments, such as wholesale market transactions by financial institutions and corporate treasury transactions. CHAPS is also used to make other, lower-value but time-critical payments, such as house purchases.

Economic agents — such as individuals, companies, the government and financial institutions — are able to make CHAPS payments via a CHAPS settlement bank. There are currently 21 CHAPS settlement banks, which are the payment system's 'direct participants'.(3) When the customer of one settlement bank makes a CHAPS payment to the customer of another settlement bank, an interbank obligation arises as the paying bank needs to pay the receiving bank the value of that payment. In order to settle these interbank obligations, each CHAPS settlement bank has an account at the CHAPS system's settlement agent — the Bank of England. The Bank undertakes the role of settlement agent for CHAPS for financial stability reasons, as explained in Dent and Dison (2012).(4)

To fulfil its role as settlement agent, the Bank provides the RTGS infrastructure. The RTGS infrastructure allows banks and building societies to hold sterling balances, called reserves, at the Bank.(5) During the day, these reserves can be transferred between settlement banks to extinguish the interbank obligations arising from payments made by the banks and their customers. Interbank obligations arising from CHAPS payments are settled individually and in real time. Each time a CHAPS payment is settled, the paying bank's settlement account in RTGS is debited and the recipient bank's account credited immediately.

The real-time settlement of CHAPS payments means that payments are settled with finality. There is no gap between the settlement of a payment and the clearing of funds, hence no scope for credit exposures between settlement banks to build up within the settlement process. Recipient banks can

(1) The new regulatory framework was introduced by the FSA, the banking regulator at the time. Since April 2013, the microprudential regulation of deposit-takers, insurers and major investment firms has been performed by the Prudential Regulation Authority — see Murphy and Senior (2013) for more information.
(2) Norman (2010) summarises the empirical and theoretical evidence on the effectiveness of liquidity saving mechanisms. Ball *et al* (2011) describe why a change in intraday liquidity regulation in the United Kingdom may merit the introduction of an LSM. And Denbee and McLafferty (2013) present the results of a simulation study which predicted how an LSM would affect banks' intraday liquidity requirements in CHAPS.
(3) This figure is set to increase to 25 by 2015 following the Bank's 'de-tiering' initiative. See Finan, Lasaosa and Sunderland (2013).
(4) The Bank of England is also settlement agent for Bacs, Cheque & Credit Clearing (C&CC), the Faster Payments Service (FPS), LINK, Visa Europe and the interbank payments arising from securities transactions in CREST.
(5) Reserves held in RTGS are also a key component of the Sterling Monetary Framework (SMF). For an explanation of the SMF and how monetary policy is implemented, see Bank of England (2014).

credit customer accounts, or use incoming funds to pay other banks, in the knowledge that they have received the funds irrevocably and in real time.

Intraday liquidity requirements for CHAPS

While the real-time settlement of payments eliminates interbank credit risk in CHAPS, it also requires that banks have a relatively large value of funds (termed 'liquidity') on their settlement accounts. This is because when a CHAPS payment is settled, the paying bank's account is debited immediately. Therefore prior to settling a CHAPS payment, the paying bank must have sufficient funds in its account at the Bank to settle the gross value of that payment.

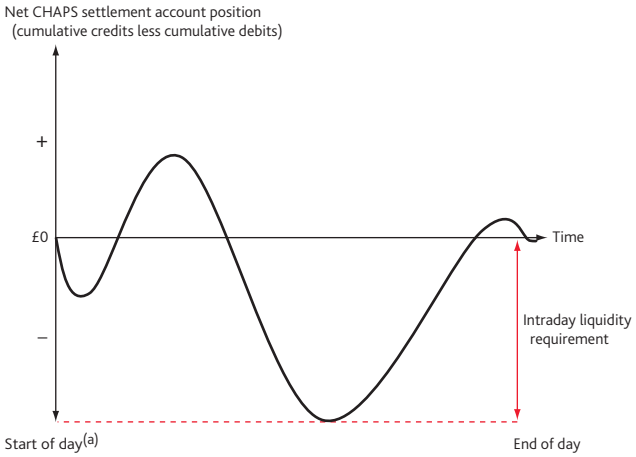
Broadly speaking, a settlement bank has two types of funds in its account which can be used to settle CHAPS payments. First, there are 'received funds'. Settlement banks receive CHAPS payments from other settlement banks throughout the day and are able to use these received payments to fund their outgoing payments. Second, there are 'own funds'. A settlement bank can supply own funds by holding reserves at the Bank, or borrowing intraday from the Bank on a secured basis.

The amount of its own funds that a settlement bank requires to settle payments is referred to as its intraday liquidity requirement. Such requirements exist because settlement banks are not always able to recycle received funds to settle outgoing payments: typically settlement banks will, at some point during the day (and possibly for only a very short period), have sent more payments than they have received. In other words, it is common for there to be a timing mismatch between a bank's debits and its credits.

A settlement bank's intraday liquidity requirement on any given day is the value by which its sent payments most exceed its received payments during that day. Or, equivalently, it is the largest net debit position the settlement bank incurs intraday — as illustrated in **Figure 1**. Prior to the introduction of the LSM in April 2013, the total daily value of intraday liquidity required by all the CHAPS settlement banks averaged £21.2 billion.

The total value of intraday liquidity that banks require is significant for two reasons. First, it is important that a settlement bank's intraday liquidity requirement does not exceed its supply of own funds, since insufficient funds would prevent it from being able to settle payments in a timely manner. This could have important financial stability implications: a lack of liquidity was one of the key elements that precipitated the collapse of Lehman Brothers on 14 September 2008 (Ball *et al* (2011)), for example. Second, the Prudential Regulation Authority (PRA) now monitors the total value of own funds that banks require for payment systems, as discussed in the next section.

Figure 1 Intraday liquidity requirements



(a) CHAPS is available on sterling business days between 06:00 and 16:20.

Regulatory changes

The new regulatory framework for liquidity risk management

In response to the recent financial crisis, the FSA — the prudential banking regulator at the time — strengthened its liquidity regulations so as to reduce the risk that banks experience liquidity shortfalls. As described in Ball *et al* (2011), the new regulations changed how the regulator considers a bank's intraday liquidity requirements for payment systems, including CHAPS, when determining the value of liquid assets that the bank is required to hold. Liquid assets include cash or assets that a bank can convert into cash in a timely manner and at little cost.(1)

A settlement bank holds a buffer of liquid assets for two purposes. First, to enable the bank to fund outflows at times of stress, ensuring balance sheet resilience. And second, to fund intraday liquidity requirements in payment systems. The minimum value of liquid assets a bank should hold is determined by the regulator and is referred to as a 'liquid asset buffer' requirement.

Under the pre-crisis regulatory framework, the only formal requirement was for banks to hold liquid assets for the first of these purposes: to ensure an adequate degree of balance sheet resilience to a stress scenario. During the day, their liquid asset buffers could be used to fund payment activity — a practice known as 'double duty'. The problem with this approach was that the same assets were charged with meeting two separate requirements: liquid asset buffer values were calibrated to fund outflows at times of stress, so may not always have been available to fund intraday payment activity.

(1) See Farag, Harland and Nixon (2013) for a description of bank liquidity.

Under the new regulatory framework banks must hold enough liquid assets to meet both prudential resilience needs *and* intraday payment requirements. This regulatory change has made intraday liquidity usage in payment systems potentially more costly. Previously, if a bank's intraday liquidity usage was less than the amount of liquid assets it was required to hold for prudential resilience needs, then intraday liquidity requirements for payments were essentially costless, since the bank could use its liquid asset buffer for intraday activity. But since the regulatory change came into force, there has been a direct opportunity cost to using liquidity in payment systems: the more liquidity a bank uses intraday to settle payments, the higher the level of liquid assets the bank will be required to hold, all else equal. The Bank fully supported the introduction of this new regulatory framework as it seeks to ensure that banks have sufficient liquid assets available to meet their intraday payment requirements, even in stressed financial circumstances.

Implications of the new regulatory framework

This regulatory change has made it less likely that banks will experience intraday liquidity shortfalls. Banks will now have a greater resilience to stressed conditions than under the pre-crisis regulatory framework. However, the regulatory change has also had the unavoidable effect of incentivising banks to economise on their intraday liquidity requirements for payment systems (so that they can reduce the size of their liquid asset buffer requirement). As discussed above, a CHAPS settlement bank uses its own funds when, at any point during the day, it has sent more payments than it has received. To reduce its liquidity requirement (that is, its need for own funds), a CHAPS settlement bank can therefore simply wait to receive payments from others *before* it sends payments. This behaviour is referred to as being 'receipt-reactive'.

However, by waiting to receive liquidity first, receipt-reactive behaviour can result in individual banks sending payments later in the day — a practice that increases that bank's vulnerability to operational problems. For example, consider a bank that suffers a system failure so that it is unable to make payments for the rest of the day. The impact of this operational issue will depend upon the value and volume of payments that are unsettled at the time of the failure, which is likely to be higher if a bank has deliberately delayed its payments. Ten unsettled house purchase payments would inevitably cause more disruption than one unsettled house purchase payment. The impact of operational stress is therefore greater if banks act receipt-reactively.

Receipt-reactive behaviour can also increase the intraday liquidity requirements of other banks. If a bank delays its payments, all the other banks will receive payments from that bank later in the day. This means it is less likely that the other banks will be able to recycle those funds, and may therefore have to use more of their own funds to settle outgoing payments.

Perhaps most importantly, however, receipt-reactive behaviour could turn out to be self-defeating. If all banks delay their payments, then no bank would receive payments early in the day (or succeed in reducing its intraday liquidity requirements). Instead, system-wide receipt-reactive behaviour might simply lead to all payments being settled significantly later in the day, increasing vulnerability to the operational risks discussed above. Commentators such as Bech (2008) have likened this scenario to the mutually adverse outcome in the 'prisoner's dilemma' game.

To discourage CHAPS settlement banks from adopting receipt-reactive behaviours, the operators of the CHAPS system, CHAPS Clearing Company Limited (CHAPS Co) enforce 'throughput' rules. These are intraday deadlines by which banks are required to send a proportion of the value of their day's payments.(1) However, recognising that regulatory change may create renewed incentives for settlement banks to reduce their intraday liquidity requirements through adopting receipt-reactive behaviours, the Bank, CHAPS Co and the settlement banks agreed to design a technical means to reduce the settlement banks' intraday liquidity requirements in CHAPS. This technical solution, referred to as the Liquidity Saving Mechanism, incentivises banks to bring forward, rather than delay, the submission of their payments. The LSM was therefore designed to operate in conjunction with the CHAPS Co throughput rules and reduce operational and liquidity risks in the CHAPS payment system.

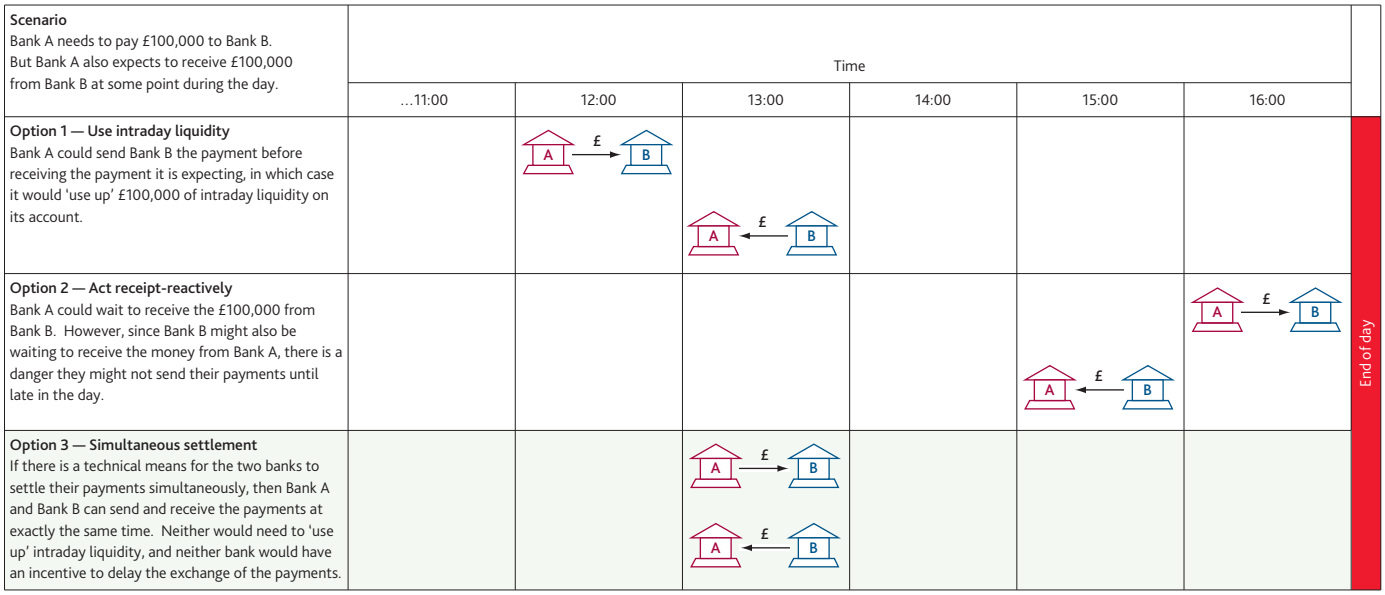
The Liquidity Saving Mechanism

The introduction of the LSM formed part of a programme of changes, led by the Bank, to increase the resilience of both the RTGS infrastructure and the payment systems that settle across it. In addition to the LSM, recent examples of risk-reduction measures include: first, the Bank's initiative to increase the number of CHAPS settlement banks, reducing the operational, credit and liquidity risks arising from a more 'tiered' payments system (Finan, Lasaosa and Sunderland (2013)). And second, the implementation of the Market Infrastructure Resiliency Service — a generic RTGS infrastructure, developed and hosted by SWIFT offsite, that would be used by the Bank should the RTGS infrastructure ever fail simultaneously at both its principal and standby sites.(2)

(1) In CHAPS, two throughput rules have been set: banks need to have settled 50% of their CHAPS payments (by value) by 12 pm and 85% (by value) by 3 pm. CHAPS banks are required to meet these targets over the course of a month. Where a settlement bank considers that there are mitigating circumstances that prevent them from meeting these criteria, it can apply for a Throughput Adjustment Waiver. If successful, the Adjustment Waiver amends the throughput target required to be met by that bank for a defined period. For more information see CHAPS Clearing Company Limited (2013).

(2) SWIFT supplies secure messaging services and interface software to wholesale financial entities.

Figure 2 Example to illustrate the advantages of simultaneous settlement



Because of its critical role in the settlement of sterling electronic payments, the Bank maintains RTGS to extremely high standards of operational reliability, service and resilience. Any business case for a change to the design of RTGS is subject to thorough analysis, where the benefits of change are weighed against the risks and the costs associated with modifying the RTGS infrastructure. In order to assess the potential benefits of introducing an LSM into the RTGS infrastructure, the Bank undertook a comparative analysis of other RTGS systems that had implemented an LSM.

Internationally, a number of different solutions have been implemented to reduce intraday liquidity requirements in high-value payment systems. Some of these solutions are set out in the box on page 185. The most common approach has been to enable payments to 'queue' temporarily in the RTGS infrastructure and introduce an algorithm that matches up groups of queued, offsetting payments and settles them simultaneously.

By identifying broadly offsetting payments from different banks and settling them simultaneously, these algorithms mean that banks no longer have to choose between using 'own funds' (by sending payments before they receive payments) or being receipt-reactive (by waiting to receive payments before sending payments). Rather, settlement banks can send and receive payments at precisely the same time.

Figure 2 demonstrates with a simple example how this can reduce a bank's intraday liquidity requirements, without introducing additional operational and liquidity risk into the settlement process. It shows that Option 3 — simultaneous settlement using offsetting algorithms — acts to reduce the intraday liquidity requirements associated with Option 1, without introducing the delay associated with acting receipt-reactively, Option 2.

Empirical research to date has concluded that introducing such measures delivers liquidity savings. For example, Norman (2010) cites estimated savings of 15% and 20% in the Japanese and Korean RTGS systems, respectively, following the introduction of offsetting algorithms.

The Bank undertook a series of simulation studies to estimate the potential liquidity savings that could be realised by introducing offsetting algorithms into CHAPS.[1] These simulation studies used a subset of CHAPS payments from the period from 12 July 2010 to 3 September 2010 and information from a survey of the CHAPS settlement banks to make assumptions about how banks would use CHAPS with an LSM. A range of different algorithms were tested and assessed based upon measures of liquidity saving and payment delay. Results suggested that, under some assumptions, offsetting algorithms could lead to aggregate liquidity savings of around 30%.

Recognising the potential benefits of offsetting payments in CHAPS, the Bank, CHAPS Co and the settlement banks agreed to redesign how CHAPS settled across the RTGS system. Input from the settlement banks was essential: they are the users of the RTGS system, and the success of offsetting algorithms would hinge on the settlement banks adopting new liquidity management techniques. The settlement banks also bear the costs that the Bank incurs by supplying the RTGS infrastructure, and so would be funding the redesign of the CHAPS settlement process.

(1) See Denbee and McLafferty (2013) for more details.

International examples of liquidity saving mechanisms

Internationally there have been various solutions employed to reduce liquidity requirements in high-value payment systems (Norman (2010)). These solutions typically seek to limit the potential differences in value between what any one bank has sent and received in the high-value payment system at any point during the day. This has been achieved, for example, by:

(a) Incentivising all participants to submit the bulk of their payments at approximately the same time. This increases the likelihood that most participants' payments and receipts will be broadly co-timed so that the potential difference between any one participant's payments and receipts is reduced. For example, SIC, the Swiss RTGS system, has a tariff structure which means that payments made early in the day incur a lower fee than those made towards the end of the day. Participants do not necessarily have to be incentivised through pricing to submit payments at roughly the same time. For example, in the Norwegian RTGS payment system, NBO, participants have agreed to submit the majority of their payments at around 13:00 (Berge and Christophersen (2012)).

(b) Splitting high-value payments so that they can be settled piecemeal over time. This minimises the potential liquidity impact of settling a large payment. For example, participants in the Swiss RTGS system are encouraged to split payments larger than CHF100 million.

(c) Introducing a technical means for participants to settle payments simultaneously. This means that banks can send and receive payments at precisely the same time, extinguishing timing mismatches between payments and receipts. This has been a particularly common solution internationally — adopted in Canada, the euro area and Japan, for instance — and is the solution that the Bank of England has implemented.

The design of the UK LSM

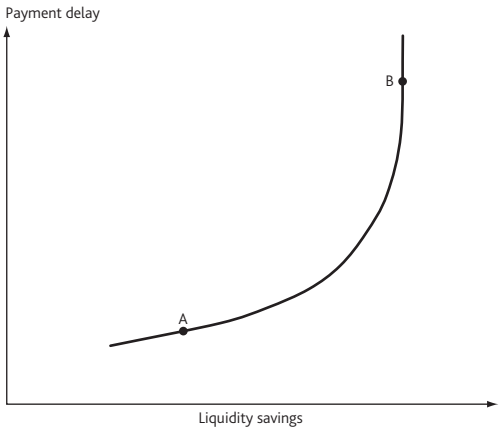
To facilitate the simultaneous settlement of CHAPS payments, using offsetting algorithms, banks are now able to submit their payments into the RTGS system without settling them immediately. Payments which have been submitted but not yet settled are referred to as 'queued'.

Once payments are queued in the RTGS system, settlement banks are able to use a queue management program, called the 'central scheduler', to control when payments are settled. Some of the features of the central scheduler are described in the box on page 186. The longer a payment queues in the central scheduler, the more time there is for another bank to submit an offsetting payment, and thus the less intraday liquidity a bank is likely to use. However, queuing a payment for longer means settling a payment later, introducing delay into the settlement process.

There is therefore a trade-off between liquidity savings and payment delay. This is illustrated in **Figure 3**: a bank that wishes to minimise the delay to its payments at the expense of liquidity savings (perhaps because it must settle certain payments by a specific intraday deadline), might be represented by point A on the curve. Conversely, a bank facing less time pressure to settle payments might choose point B, thereby achieving greater liquidity savings.

If a settlement bank wants to settle a payment immediately, it can submit the payment to RTGS as 'urgent'. Urgent payments can settle with minimal delay. This functionality is useful for banks that need to prioritise payments which must settle within a specific time frame, for example margin payments to central counterparties,(1) and pay-ins to the Continuous Linked Settlement (CLS) system.(2)

Figure 3 The trade-off between payment delay and liquidity savings(a)



(a) The shape of this trade-off curve is derived from data produced during simulation testing, see Denbee and McLafferty (2013).

RTGS is available to immediately settle CHAPS payments classified as urgent for 85% of the settlement day. For the remaining 15% of the day, RTGS briefly suspends the immediate processing of urgent payments in order to settle payments classified as 'non-urgent'. These payments are settled in 'matching cycles' that last just over 20 seconds. At the start of a matching cycle, an algorithm attempts to find

(1) For an introduction to central clearing, see Nixon and Rehlon (2013).
(2) The international CLS system settles foreign exchange transactions on a so-called 'payment versus payment' basis. See Sawyer (2004) for more details.

Tools available to the banks in the central scheduler

As part of the LSM changes, the Bank of England built a queue management program called the 'central scheduler'. The design of the central scheduler was heavily based on the design of the settlement banks' internal payment schedulers. Banks use the central scheduler to control when payments they have submitted to RTGS settle. For example, banks have tools that allow them to:

(a) Limit the amount of funds they are willing to contribute to any one matching cycle. Banks are able to use the central scheduler to cap the size of the net difference between payments sent and received in a matching cycle.

(b) Limit the value of payments they are willing to send to another CHAPS settlement bank in excess of the value they have received from that settlement bank. This enables banks to ensure that they do not use too much liquidity settling payments to any one counterparty.

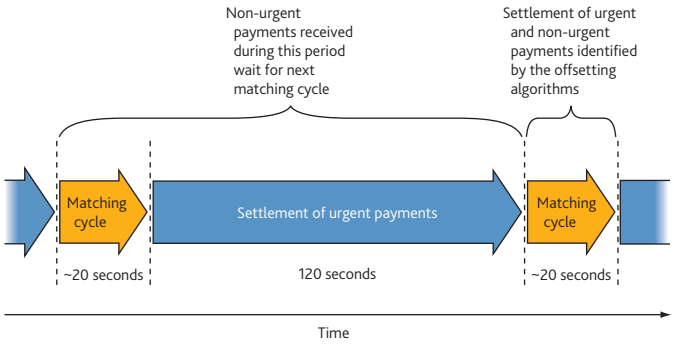
(c) Limit the value of payments they are willing to send to all other settlement banks in excess of the value they have received from all other settlement banks at any point during the day. This gives the settlement banks a means to limit the overall amount of 'own funds' they require for CHAPS on any one day.

(d) Change the priority of a payment from non-urgent to urgent after it has been submitted to RTGS. This gives banks a means to 'promote' a payment to urgent after it has been queuing for a certain length of time.

(e) Prevent a payment from settling without the bank's specific authorisation if it breaches a certain value or is destined to a particular settlement bank. This enables banks to prevent a certain type of payment from settling in the next matching cycle.

groups of broadly offsetting payments from different banks.(1) At the end of the matching cycle, all payments identified as eligible by the algorithm settle at precisely the same time. Any non-urgent payments not settled by the end of a matching cycle will remain in the queue until the start of the subsequent cycle. This settlement model is illustrated in **Figure 4**.

Figure 4 The matching cycle process



There is a two-minute period between matching cycles that enables non-urgent payments to accumulate in queues while the system is only available for the settlement of urgent payments. This has two advantages. First, it ensures that banks can, for the majority of the settlement day, settle high-priority payments immediately, if they wish to. Second, it enables non-urgent payments to queue between matching cycles, increasing the likelihood that two offsetting payments will be considered in the same matching cycle, thereby driving down settlement banks' intraday liquidity requirements.

The matching cycle process reduces settlement banks' intraday liquidity requirements in CHAPS because successfully matched payments are settled at precisely the same time. A bank therefore only needs liquidity to fund the net difference between the payments it has sent and received in that cycle. Without the matching cycle process, the bank's liquidity requirement could have been as high as the gross value of its sent payments.

Crucially, all CHAPS payments, irrespective of whether they settle inside or outside of matching cycles, still settle gross and individually. The fundamental attributes of CHAPS remain the same: the CHAPS settlement banks are able to receive money into, and send money from, their settlement accounts continuously throughout the day. In line with the set-up prior to the introduction of the LSM, all payments are debited from the banks' settlement accounts individually, hence there continues to be no credit exposures between settlement banks within the settlement process.

The results of implementing the Liquidity Saving Mechanism

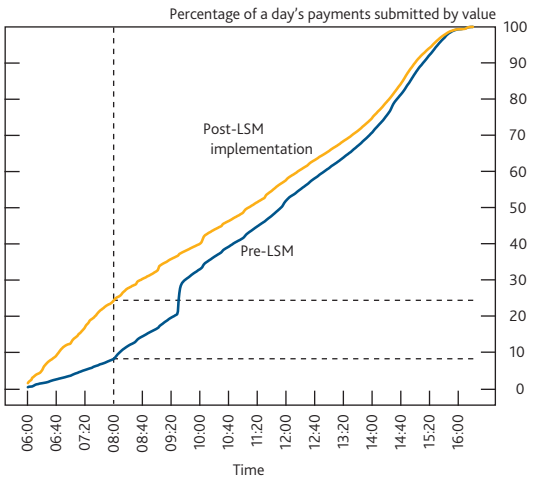
The LSM was introduced into RTGS on 15 April 2013. The Bank and the settlement banks thereafter began a six-month

(1) The LSM switches between bilateral and multilateral offsetting algorithms, and uses three different sorting modes for selecting which payments (out of those that are queuing upon entering a matching cycle) are considered in each cycle. The multilateral algorithm is able to identify 'circles' of offsetting payments between two or more settlement banks. A maximum of 500 payments for each CHAPS settlement bank are considered in each matching cycle.

'optimisation' period where queue management best practice was discussed at industry fora and in bilateral meetings. This collaboration was a fundamental driver of the liquidity savings achieved under the LSM. The optimisation period aimed to assist settlement banks in two respects: first, to establish which of their payments were likely to receive an offset within a reasonable time frame (essentially, choosing an optimal position on the savings-delay curve shown in **Figure 3**); and second, to determine how to use the central scheduler tools to manage that trade-off.

In principle, enabling payments to queue centrally and be considered by an offsetting algorithm should encourage early submission of payment instructions: if banks submit payments early, there is a greater likelihood that the algorithm will identify offsetting payments (Ball *et al* (2011)). The implementation of the LSM did indeed lead to the earlier submission of CHAPS payments into RTGS, as shown in **Chart 1**. For example, prior to the implementation of the LSM, on average only about 8% of payments (by value) had been submitted to RTGS by 08:00. Since the implementation of the LSM, about 24% of payments have been submitted by 08:00 on an average day.

Chart 1 Submission of CHAPS payments before and after the introduction of the LSM(a)

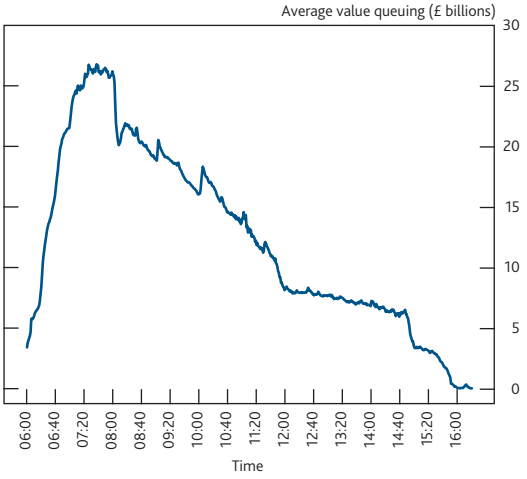


(a) Pre-LSM is defined as July 2012 to March 2013. Post-LSM is defined as July 2013 to March 2014.

As anticipated, settlement banks are using the central scheduler to queue their CHAPS payments. On average, payments queue for approximately seven and a half minutes. **Chart 2** shows the total value of payments that the banks have typically been queuing throughout the day, with around £26 billion of payments — equivalent to just under 10% of an entire day's payments — queued at 07:30.

Combined, these two developments mean that the implementation of the LSM has had a broadly neutral effect on the rate of CHAPS payment settlement, or 'throughput': the earlier submission of payments to RTGS has been broadly

Chart 2 The average value of payments queuing during the day



offset by banks queuing their payments. Consequently, the median time of settlement — or the point during the day at which half of all payments (by value) have settled — has remained broadly the same: 12:11 before the implementation of the LSM, compared with 12:00 since.

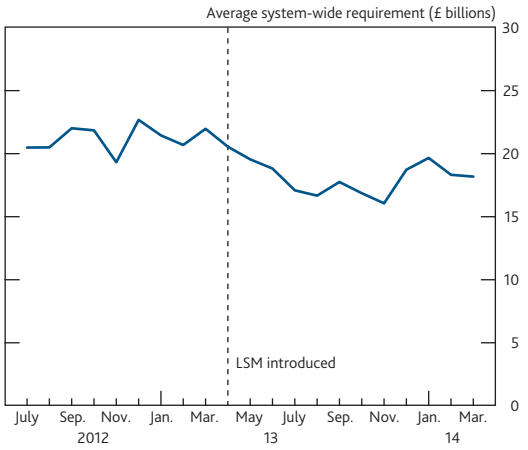
The fact that the settlement banks are queuing a significant value of payments in the central scheduler means that the offsetting algorithms, run during matching cycles, have been successful in finding broadly offsetting payments between banks. The simultaneous settlement of these payments has reduced the CHAPS settlement banks' intraday liquidity requirements. Prior to the implementation of the LSM, the combined intraday liquidity requirements of all the settlement banks averaged £21.2 billion.(1) Since the implementation of the LSM, the monthly average of combined intraday liquidity requirements has been in the range of £16 billion to £20 billion, as shown in **Chart 3**.

Regression analysis suggests that the combined intraday liquidity requirements of all the settlement banks would have remained approximately £21.2 billion between July 2013 and November 2013 if the LSM had not been introduced.(2) Given that actual intraday liquidity requirements averaged £16.9 billion during this period, this would imply aggregate intraday liquidity savings for the CHAPS banks of around £4 billion — equivalent to a 20% reduction in intraday

(1) This figure refers to the liquidity required by CHAPS settlement banks for the following payment systems between July 2012 and March 2013: Bacs, CHAPS, C&CC, FPS, LINK and Visa Europe (from 23 October 2013). All payment systems were included, even though the LSM could only make savings in CHAPS, because the liquidity requirements in CHAPS cannot easily be disentangled from liquidity requirements in the other payment systems. Bank of England has been excluded because, given its unique ability to create sterling central bank money, it has no incentive to minimise its liquidity usage via offsetting. CLS has also been excluded as it cannot manage payments to minimise intraday liquidity usage. This is consistent with the methodology used during simulation testing.

(2) The daily aggregate liquidity requirements were regressed on: (i) the daily aggregate sum of all funds that individual banks sent in excess of what they received; and (ii) the total value of payments that individual banks sent. The estimation period was October 2012 to April 2013.

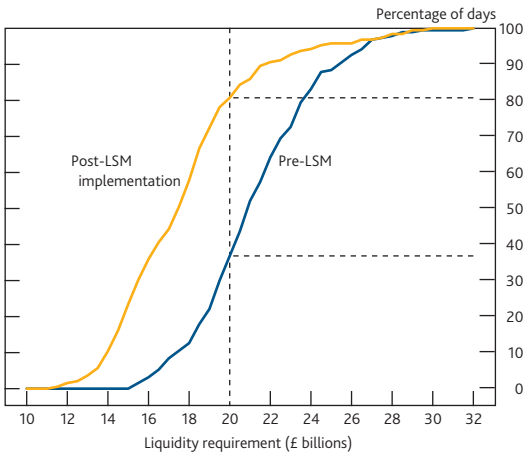
Chart 3 Average value of intraday liquidity required by CHAPS settlement banks for sterling payment systems



liquidity costs. The regression analysis also suggests that the average combined intraday liquidity requirements would have averaged around £22.5 billion between December 2013 and March 2014, partially due to a shift in some settlement banks' payment profiles. Given that actual intraday liquidity requirements averaged £18.7 billion in this period, this implies that the LSM led to aggregate intraday liquidity savings of around £4 billion in this period too.

Chart 4 provides further evidence of the liquidity savings achieved under the LSM. It shows the percentage of days on which the CHAPS banks' intraday liquidity requirements were below a given value. Before the implementation of the LSM, the banks needed less than £20 billion of intraday liquidity on approximately 35% of days; since the implementation of the LSM, this has risen to 80%.

Chart 4 The percentage of days on which CHAPS settlement banks' intraday liquidity requirements were below a given value[a]



(a) Pre-LSM is defined as July 2012 to March 2013. Post-LSM is defined as July 2013 to March 2014.

Aggregate intraday liquidity requirements have varied since the implementation of the LSM (**Chart 3**). This variation has been partly driven by changes in settlement banks' queue management practices. For example, over certain periods some settlement banks have queued particular payments for longer. This has increased the likelihood of these particular payments offsetting against incoming payments, therefore reducing the intraday liquidity required. The variation in aggregate intraday liquidity requirements has also been partly driven by changes in settlement banks' payment profiles. For example, over certain periods some settlement banks have borrowed more from the overnight sterling money markets. As settlement banks typically repay such overnight loans (that is, send a CHAPS payment) before taking out a new loan (that is, receive a CHAPS payment), borrowing from the overnight sterling money markets tends to drive up a settlement bank's intraday liquidity requirement in CHAPS.

Aggregate intraday liquidity requirements have not fallen by the 30% suggested as possible in the simulation study (discussed in the previous section of this article). This is likely to stem from the assumptions that the simulation study made about settlement bank practices, such as how they would manage their liquidity, as well as features of the CHAPS payment system. For example, the simulation study was undertaken when there were only 17 CHAPS settlement banks, whereas on implementation this figure had risen to 19 and has since risen to 21. Finan, Lasaosa and Sunderland (2013) describe some of the benefits of having a less concentrated payment system, but in the context of implementing the LSM, a less concentrated membership might reduce the potential for liquidity savings since there are likely to be proportionately fewer pairs or chains of offsetting payments present.[1]

Nevertheless, the objective of the LSM changes was to give CHAPS participants a means to reduce their liquidity requirements without slowing the rate at which they settled payments. The evidence suggests that the LSM has reduced the settlement banks' average liquidity requirements by some 20%, without reducing their throughput. This is broadly in line with the savings achieved by introducing similar mechanisms into other RTGS systems internationally.

Conclusion

This article has discussed the motivations for introducing the LSM, its design, implementation and its effect on settlement banks' intraday liquidity requirements. Close collaboration between the infrastructure provider (the Bank), the operator of the payment system (CHAPS Co) and the users of that payment system (the settlement banks) has been important for the success of the LSM.

The implementation of the LSM, and the consequent reduction of settlement banks' intraday liquidity requirements, has had two clear benefits. First, it has reduced incentives for

(1) See Norman (2010).

CHAPS settlement banks to adopt adverse behaviours to economise on their intraday liquidity requirements, thus enhancing the resilience of the CHAPS payment system. And second, it has reduced the likelihood that a bank's intraday liquidity requirement will outstrip its supply of own funds, and so it is now less likely that banks will be unable to settle payments due to liquidity shortfalls, enhancing UK financial stability.

The LSM therefore operates in conjunction with the PRA's liquidity regulations to enhance the resilience of CHAPS. The regulatory framework ensures that the settlement banks have sufficient liquid assets to support their payment system liquidity requirements, and the LSM enables CHAPS settlement banks to manage those liquidity requirements more efficiently.

Importantly, the implementation of the LSM has not compromised the ability of settlement banks to settle CHAPS payments in real time: payments classified as urgent can settle immediately. The Bank will periodically review the potential for changes or enhancements to the LSM to maintain its position as a key risk-reducing feature of the CHAPS system.

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