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Liquidity saving in real-time gross settlement systems — an overview

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Contents

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During the past two decades, Large Value Payment Systems (LVPSs) in many countries have been redesigned so that the payments they process are settled on a 'Real-Time Gross Settlement' (RTGS) basis. Such systems eliminate interbank credit risk in the payment system — which, from the perspective of the Bank of England, is a key feature of the United Kingdom's LVPS, CHAPS, and one which cannot be compromised by any future design changes. But such RTGS systems can require relatively large amounts of liquidity to be available. So some of the more recent RTGS system designs — for instance, TARGET2 (for euro payments); or Japan's BOJ-Net — have incorporated sophisticated 'liquidity saving mechanisms'. These mechanisms have allowed participants in the payment system to save on liquidity needs without reintroducing interbank credit risk. To support discussions among participants in CHAPS on possible liquidity saving mechanisms, this article sets out a conceptual framework for thinking about the drivers of liquidity needs in RTGS systems. It then discusses a number of practical liquidity saving measures, which can meet the good of greater liquidity efficiency without reintroducing credit risk.

Introduction

A payment is a transfer of value. A payment system can be defined as any organised arrangement for transferring value between its participants. In 2003, the value passing through the main payment systems in the United Kingdom, including the United Kingdom's Large Value Payment System (LVPS) CHAPS, was around £130 trillion. By 2008, this figure had risen to approximately £200 trillion. This is equivalent to around a half of the United Kingdom's annual gross domestic product flowing through the country's payment systems every business day. These payments support a wide variety of transactions in goods, services and financial assets. The same sort of stylised facts apply too in other countries. So payment systems are fundamental to the well functioning of market economies.(1)

Since the start of the 1990s, many LVPSs around the world have been (re)designed so that the payments they process are settled with immediate finality, one-by-one.(2) The LVPS design previously in vogue — deferred net settlement (DNS) — had created significant interbank credit risk. Specifically, in a DNS system, payment messages are exchanged among payment system participants (settlement banks, hereafter referred to simply as 'banks') during the day, before the obligations that these payments create are netted off and settled with finality (usually) at the end of each day. A default by one bank in a DNS system after its payments have been made during the day, but prior to the finality of settlement at the end of the day, could create losses for other banks that would be expecting the settlement of the incoming funds from the failed bank. If these losses were sufficiently large, they could set off a domino effect of failures across the system and potentially beyond. By settling each payment individually with finality and in real time, so-called 'real-time gross settlement' (RTGS) systems do not create this credit risk in the first place.

RTGS systems almost always settle in central bank money,(3) and central banks require banks in these systems to have funds on their accounts before each of their payments is settled. To

(1) Bank of England (2005) and Bank of England (2009).
(2) For more background, see (among others): Committee on Payment and Settlement Systems (CPSS) (1997); Bech, Preisig and Soramäki (2008); Manning, Nier and Schanz (Eds) (2009), Chapter 3 in particular.
(3) An exception to this comes in the shape of some foreign currency RTGS systems — specifically, in Hong Kong (US$, € and Renminbi) and China (US$, HK$, ¥, €, AUS$, CA$, £ and SFr), where a commercial bank performs the role of settlement agent — see www.info.gov.hk/hkma/eng/infra/index.htm and www.pbc.gov.cn/english//detail.asp? col=6400&ID=1128&keyword=paymentsystem respectively.

help banks in RTGS systems to meet this cash in advance constraint, banks may use the reserves that they hold with the central bank. In addition, most central banks provide a facility whereby the banks that are direct members of the payment system can repo or pledge collateral in order to obtain liquidity on their accounts.(1) Given that the collateral accepted by central banks is generally only of a high quality (such as government debt), banks in the payment system can face an opportunity cost. This arises to the extent that these banks, in the absence of this requirement for high quality collateral, would aim instead to achieve a higher return by holding a greater proportion of (usually higher-yielding) assets in their portfolios that were not eligible as collateral at the central bank.

Various ways of economising on the liquidity needs of banks have increasingly been applied in RTGS systems in the past decade or so, which do not undermine the original objective of moving to RTGS, namely the elimination of interbank credit risk.(2) To date, CHAPS banks have not moved in the direction of introducing so-called 'liquidity saving mechanisms'. However, the prominence of this issue has been raised since the United Kingdom's Financial Services Authority recently consulted on its plans to reform liquidity regulation.(3) Among other things, these reforms are likely, in due course, to increase the opportunity costs that banks face when providing collateral to the Bank of England to obtain intraday liquidity in CHAPS. In turn, this could create incentives to delay payments so as to economise on liquidity, which could raise operational and other risks.

In analysing possible ways to reduce liquidity needs while not introducing other risks, it is helpful first to understand conceptually what drives the liquidity needs in an RTGS system. This article then also sets out more practically how a number of liquidity saving mechanisms can help to reduce these liquidity needs.

How can (and do) banks economise on their liquidity needs in the payment system?

Box 1 describes the key drivers of liquidity needs in an RTGS system. These are:

- the need to have cash in order to make a payment;
- the timing and urgency of the payments that need to be made;
- the size of individual payments; and
- the aggregate balance of payments received and payments made over the course of a day, and its predictability.

In practice, there are many more payments flowing between banks (and, for that matter, more than two banks) than are shown in the stylised examples in Box 1. In real life, there is also much greater uncertainty regarding the timing of both when banks receive payment instructions (from customers) and when payments themselves will settle (from other banks in the payment systems). Nevertheless, with larger volumes of payments, a natural ebb and flow of payments can occur between banks, which of itself begins to economise on liquidity. For example, where a bank has to make some urgent payments and some non-urgent payments, it will often obtain liquidity for its urgent payments and settle those first, and then await incoming funds for making a number of its non-urgent payments. In such a case, by providing liquidity to their recipient banks, urgent payments can trigger virtuous payment cascades.(4)

But there are currently few genuinely urgent payments (when defining as 'urgent' those payments that need to settle by a particular time during the day). As currently written, commercial contracts tend to require most payments simply to be settled at some point before the close of business on a particular business day, without specifying the time during the day when such settlement is required. Examples of payments where there is a contractual requirement to settle explicitly by a specific intraday deadline include margin payments to central counterparty clearing houses, and pay-ins to the Continuous Linked Settlement (CLS) system.(5)

So, in order to manage their liquidity needs in an RTGS system like CHAPS, a number of banks also adopt a loose 'carrot and stick' approach of monitoring their bilateral flows, and putting in place bilateral limits that restrict the balance of payments that a bank makes to, less the payments it receives from, each of the other banks in the payment system. Under this decentralised monitoring and limits approach, banks can reward/punish (respectively) those banks that are/are not making payments to them, by reciprocating: in other words, either they make payments back in the opposite direction, or if they are not receiving payments from a particular counterparty then they hold off from making payments back to that counterparty. This approach is more likely to be effective in payment systems, such as CHAPS, either which have a relatively small membership or in which a large proportion of payments is concentrated among relatively few of the members.(6)

(1) One exception to this is the US Fedwire system, whose participants are permitted to make payments using (limited) unsecured overdrafts provided by the Federal Reserve, for which an overdraft fee is charged. See www.federalreserve.gov/newsevents/press/other/20081219a.htm.
(2) For more background, see (among others): McAndrews and Trundle (2001); CPSS (2005); Bech, Preisig and Soramäki (2008); Manning, Nier and Schanz (Eds) (2009), Chapter 4 in particular.
(3) Financial Services Authority (2009).
(4) Cascades of payments are (artificially) simulated in Beyeler, Glass, Bech and Soramäki (2007). For a practical analysis of urgent payments that trigger payment cascades, as well as bilateral limits and throughput guidelines (liquidity saving features that are described later in this article), see Becher, Galbiati and Tudela (2008).
(5) See, for example, the discussion on (intraday) pay-ins to LCH.Clearnet Ltd and (briefly) CLS in Bank of England (2009).
(6) The reason why the size/concentration of a payment system matters for the effectiveness of bilateral limits can be understood when considering the counterfactual of bilateral relationships in diffuse payment systems with many counterparties. In those systems, the fact that another bank is not sending payments to a particular bank may more plausibly be because it does not have any payment instructions to make to that bank — in which case, punishing it by refusing to send payments in the other direction is ineffective. This issue is discussed in Manning, Nier and Schanz (2009), section 4.1.2.

Box 1
What drives liquidity needs in an RTGS system?

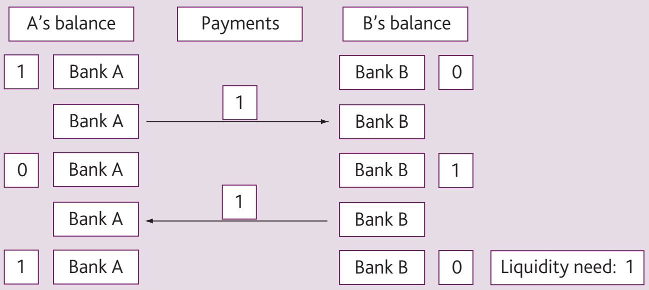
The main drivers of liquidity needs in an RTGS system are:

(i) the need to have cash in order to make a payment;
(ii) the timing and urgency of the payments that need to be made;
(iii) the size of individual payments; and
(iv) the aggregate balance of payments received and payments made over the course of a day, and its predictability.

The following stylised examples illustrate each of these liquidity drivers in turn.

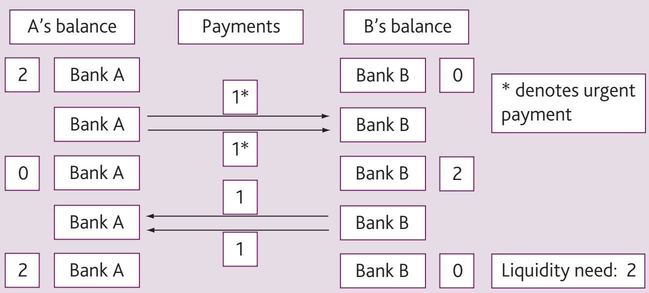
(i) The need to have cash (in advance) in order to make a payment

Example: say, there are two banks (A and B), each needing to make a payment of 1 to the other. In an RTGS system, one of the banks would need to pay first (and usually the other bank would use the incoming funds to make its payment). The RTGS liquidity need in the system as a whole is 1.



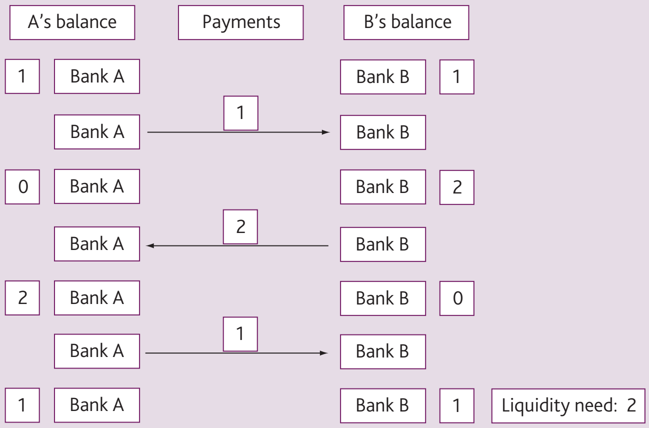
(ii) The timing and urgency of payments

Example: say, there are two banks (A and B), with A needing to make two urgent payments of 1 to B as soon as the payment system opens; and B finding at some point later in the day that it needs to make two non-urgent payments of 1 back to A. As in the first example, B can rely on receiving funds from A to make its payments. But because of the urgency of its payments, A cannot wait to receive funds from even one of the payments back from B. So the RTGS liquidity need, which is met entirely by A, is 2.



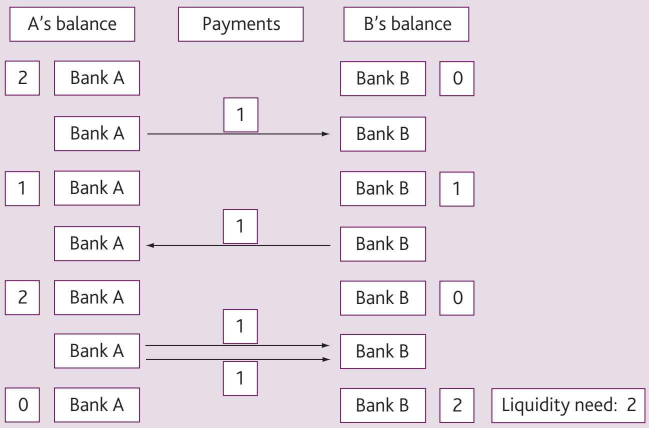
(iii) The size of individual payments

Example: say, there are two banks (A and B), with A needing to make two payments of 1 to B, and B needing to make one payment of 2 to A. Whatever order these payments are made in, the liquidity requirement in an RTGS system will be 2, because of the size of B's payment to A.



(iv) The aggregate balance of payments received and payments made, and its predictability

Example: say, there are two banks (A and B), with A needing to make three payments of 1, and B needing to make just one payment of 1 back that day. In this case, the liquidity need of 2 is driven by the difference in the value of payments that A has made to (3) and received from (1) B. Whatever the sequencing and urgency of the payments, A will always need to provide liquidity of at least 2, given that this is the scale of the imbalance of payments over the course of the day.



If A had known at the outset that it would end up sending 3 and receiving 1, then it could have limited its liquidity need to 2. But if it had been uncertain about the size of the net flow of payments with B, and if it had feared that this might be greater than 2, then its (precautionary) liquidity need could have been still greater.

Without this sort of monitoring and limits, banks in RTGS systems might always wait for incoming payments before making their payments, thereby recycling the funds received.(1) On its own, such an approach can lead to delays in the settlement of payments, which could lead ultimately to gridlock, where payments remain unsettled because each bank is waiting for another to pay first. Even where gridlock does not occur, a delay in making payments that leads to a concentration of payments settling later in the day is undesirable, as it increases the impact of, for example, operational risks such as a major intraday IT problem in the payment system that prevented settlement of payments from being effected until the following day.(2) Furthermore, delays in making — and hence also in receiving — payments can make liquidity management for banks less predictable. This unpredictability may lead banks to hold higher precautionary balances of intraday liquidity than would otherwise be necessary. Were this to occur, it would represent an inefficient outcome.(3)

Allowing a bank to submit its payments to queue centrally (ie alongside other banks' central queues of payments) and to reserve liquidity for its urgent payments can encourage earlier submission of payments and hence improve liquidity recycling.(4) In this context, a formal strategy of making payments on receipt of other payments is sometimes referred to as balance-reactive gross settlement (BRGS) or receipt-reactive gross settlement (RRGS):

- Under BRGS, a bank sets a threshold balance for its account. If the balance falls to this threshold, then it reserves that liquidity for making urgent payments; any non-urgent payments it wishes to make are queued until the balance is back above the threshold (normally as a result of incoming payments).

- Under RRGS, a bank maintains a buffer of liquidity with which to make its urgent payments; and it makes non-urgent payments using funds it receives in by way of payments from other banks. All non-urgent payments are queued, unless there are payments in the opposite direction that offset (at which point they then settle).

BRGS and RRGS can be implemented on either a decentralised or a centralised basis. In other words, individual banks are at liberty to make their payments according to the BRGS/RRGS 'rules'; alternatively some systems provide central queuing and liquidity reservation functionality for all participants to make use of. An example of a BRGS system is TARGET2, through which euro payments are made. It is worth noting that payments made under a BRGS or RRGS strategy could be to any recipient, unless bilateral positions are also monitored and limited (as discussed above) to guard against counterparties that may be 'free riding' on the liquidity in the system. A simulation study of payment flows, where banks adopt an RRGS strategy (with no bilateral limits) for a significant proportion of their payments, has found that, with postings of liquidity sufficient not to create payments gridlock, liquidity savings can be significant compared to a pure RTGS arrangement — in the order of, on average, 20%–30% (though with some banks standing to make greater liquidity savings, and others achieving savings below this average).(5)

Even a combination of bilateral limits and/or BRGS/RRGS may not be a sufficient mechanism to ensure that banks make their payments in a manner that combines timeliness with liquidity efficiency. Moreover, they do not prevent banks from setting limits/thresholds that are too tight, given the values of payments that need to be effected during the course of a day.

To supplement these methods, a number of (further) centralised approaches are also possible. One such method is to impose so called 'throughput guidelines'.(6) A throughput guideline creates artificial intraday deadlines by which banks are required to effect a proportion of their payments (by value). The expectation is that, by meeting these deadlines, banks receive a non-trivial proportion of payments in a timely fashion, and they can recycle the resulting liquidity to make their own payments (which, in turn, virtuously creates further cascades of payments). In CHAPS, two throughput guidelines have been set: 50% by noon and 75% by 2.30pm. CHAPS banks need to meet these targets on average over the course of a month. Failure to do so results in a requirement for the bank in question to explain its payments behaviour to its peers (in what is referred to as the CHAPS 'Star Chamber').(7) In the United Kingdom, throughput guidelines have encouraged the flow of payments during the day, although their effect is partly to create small peaks of payments activity shortly prior to the throughput deadlines.(8) Furthermore, the guidelines have not always been adhered to, for example at the height of the recent financial crisis, because the Star Chamber process does not create sufficient disincentives for CHAPS members always to meet them.(9) One specific limitation of the throughput guideline approach is that it can be difficult to distinguish between banks that receive instructions (from their customers) only late in the day and then make these payments, and those banks that deliberately hold back making payments in order to free ride on liquidity from incoming payments.

(1) Such a strategic incentive to delay is modelled formally in Bech and Garratt (2003).
(2) For discussion of the costs of such outages, see the annex of Norman *et al* (2009).
(3) Angelini (1998) discusses banks' need for higher precautionary intraday liquidity balances in the context of payment delays.
(4) Glaser and Haene (2008) point out another advantage of central queuing, namely that it potentially reduces the systemic impact of operational risks that affect only a bank's internal payments function — sometimes referred to as a 'liquidity sink'.
(5) Ercevik and Jackson (2010).
(6) Buckle and Campbell (2003).
(7) Historically, the Star Chamber was an English court of law, whose jurisdiction (until it was abolished in 1641) covered mainly public disorder, such as riots! For real Star Chamber cases see (for example) Elton (1958).
(8) Becher, Galbiati and Tudela (2008).
(9) See Bank of England (2009).

An alternative centralised approach, which can create natural incentives for banks to submit payments early, is for the central bank (as settlement agent) to set banks a tariff for settling payments that becomes more expensive during the course of the day.(1) Currently, a tariff is set in most RTGS systems, in order to recoup the costs of their development. Such tariffs have been set in most countries (for simplicity) on a flat-rate basis. A notable exception to this is the graduated approach to intraday pricing for payments submitted and settled in the Swiss RTGS system, SIC, in which payments made early in the day attract a tariff that is a fraction of the cost of settling towards the end of the day.(2) Since introducing this tariff, the Swiss experience has been positive: banks in SIC have brought forward the time at which they submit their payments for settlement. As with throughput guidelines, this encourages liquidity saving by creating the opportunities early on in the payments day for payments between banks that broadly offset to be settled with relatively little liquidity.

An algorithm that matches up individual (broadly) offsetting payments, whether bilaterally or multilaterally, and settles them simultaneously has, to date, been by far the most widely adopted centralised approach to liquidity saving in RTGS systems internationally. In this case the liquidity requirement becomes the net difference between the values of the payments that have been matched. In many cases, these payments still settle legally gross, but the economic effect is to net the liquidity requirement. The liquidity effectiveness of such an offsetting algorithm is demonstrated by way of a stylised numerical example in Box 2.

While it is not exhaustive in its scope, **Table 1** sets out how prevalent offsetting algorithms have become internationally, and also sets out where some other liquidity saving approaches discussed in this article have been implemented.

Table 1 Examples of liquidity saving approaches in selected countries

Offsetting algorithm	Time-varying tariff	Payment splitting
RITS (Australia)	STR (Brazil)	CLS (global)
LVTS (Canada)(1)	SIC (Switzerland)	BOJ-Net (Japan)(2)
TARGET2 (Euro area)		SIC (Switzerland)(2)
CHATS (Hong Kong)		
BOJ-Net (Japan)		
ESAS (New Zealand)		
BOK-Wire+ (South Korea)		
SIC (Switzerland)		
CHIPS (United States)		

(1) The Canadian LVTS uses an offsetting algorithm only for efficient settlement of large value — so-called 'jumbo' — payments.
(2) Payment splitting in the Japanese and Swiss systems is not a technical system feature; rather it is a non-mandatory guideline/rule that encourages participants in the system to split payments greater than a certain value (in the case of Japan, in relation to the cash leg of Japanese Government Bond transactions).

The liquidity efficiency of offsetting algorithms has been modelled theoretically(3) and empirically,(4) and the studies find that liquidity savings can be achieved in collateralised RTGS systems, such as CHAPS, provided that banks are willing to make their payments available for offsetting.(5) Liquidity savings have also been observed in practice in those RTGS systems where offsetting algorithms have been introduced — often in combination with other features discussed above, such as central queuing and liquidity reservation. For example, among recent converts to bilateral and multilateral offsetting algorithms:

- the launch of the Bank of Korea's BOK-Wire+ payment system is estimated to have achieved liquidity savings in the order of 20% within a month of its launch, when compared to previous liquidity requirements in the BOK-Wire RTGS system;(6) and

- a liquidity saving of nearly 15% has been estimated for banks in the Japanese RTGS system, BOJ-Net. The Bank of Japan suggest that liquidity savings in the system arising from offsetting would be greater, once market conditions return to normal following the global financial crisis.(7)

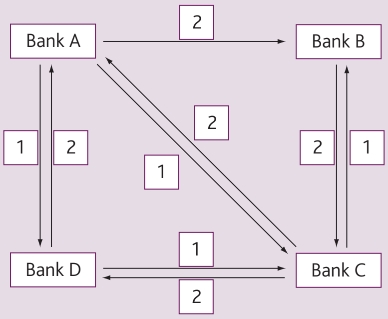
Further quantitative evidence of the liquidity efficiency of offsetting algorithms is available when looking at the 'turnover ratio' for an RTGS system. This is the ratio of the total value of payments made in the system to the total value of liquidity that is used for settlement. The introduction of a multilateral offsetting algorithm in Hong Kong's HK$ CHATS system in January 2006 resulted in an increase in that system's turnover ratio from (approximately) eight (pre-2006) to ten (in 2006) and still further to twelve (in 2007).(8) In the United States' CHIPS system, the turnover ratio has been estimated at between 500 and 600, which is above all due to a sophisticated bilateral and multilateral netting process, as well as a bespoke weekly calculation of each CHIPS bank's liquidity needs.(9)

(1) Ota (2010).
(2) See SIX Interbank Clearing website for details of SIC Pricing. The main Brazilian payment system, the Sistema de Transferência de Reservas, also encourages early submission of payments by way of a simple variable intraday tariff, charging half price for payments made before 9.00am (local time) — see Central Bank of Brazil (2008).
(3) For instance, Willison (2005); Jurgilas and Martin (2010). Willison also considers whether queue transparency — ie the ability of prospective recipient banks to see that payments to them are queuing at a sending bank — improves the liquidity efficiency of an RTGS system with offsetting algorithms, but finds that transparency either does not change the use of the queue or could even reduce its use.
(4) For instance, Galbiati and Soramäki (2009).
(5) For RTGS systems where an overdraft fee is charged instead of requiring collateral, ie Fedwire in the United States, the results of introducing an offsetting algorithm are not clear-cut: Martin and McAndrews (2008) find that an offsetting algorithm is not necessarily welfare improving.
(6) Bank of Korea (2009).
(7) Bank of Japan (2009).
(8) Lee and Yip (2008).
(9) See www.chips.org/financials/033779.php. The bespoke weekly calculation of CHIPS banks' liquidity needs reduces the denominator in the turnover ratio. CHIPS (2009) describes how CHIPS banks can also provide so-called 'supplemental' funding, with which to settle priority payments. This is similar in effect to the liquidity reservation functionality described earlier in this article. Strictly speaking, Fedwire is the RTGS system in the United States. From a liquidity efficiency perspective, CHIPS operates like an RTGS system with bilateral and multilateral offsetting functionality — so the data presented here are broadly comparable.

Box 2
The liquidity efficiency of an offsetting algorithm

Example: say, there are four banks (A, B, C and D), and, amidst the many payments they need to make each day, the following nine payments are effected simultaneously — ie without relying on incoming payments to fund them:

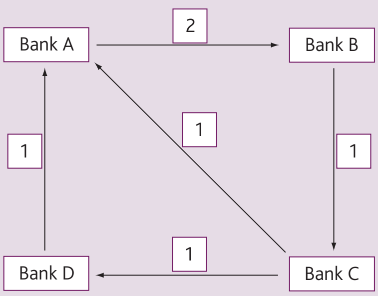
A to B: 2	B to C: 2	C to D: 2
A to C: 1	C to A: 2	D to A: 2
A to D: 1	C to B: 1	D to C: 1



The individual banks' liquidity requirements for this sub-set of payments would be:

A: 2 + 1 + 1 = 4
B: 2
C: 2 + 1 + 2 = 5
D: 2 + 1 = 3

An offsetting algorithm is effectively a co-ordination device that could reduce these liquidity needs. With *bilateral* offsetting, an algorithm could match up each pair of these banks' payments, and replace them with bilateral obligations as follows:



The banks' liquidity needs would now be:

A: 2
B: 1
C: 1 + 1 = 2
D: 1

An algorithm that offsets all the payments *multilaterally* would be even more liquidity efficient — indeed, optimally so. It would match up the chains of:

- four payments for value 2 (A to B, B to C, C to D and D to A) and settle these simultaneously without the need for any liquidity; and
- the four remaining payments between A, C and D, which also offset perfectly, and so also require no liquidity to settle, and leave one remaining payment for value 1 from C to B.

The banks' liquidity needs would now be:

A: 0
B: 0
C: 1
D: 0

In summary, the liquidity needs for each of the banks in this example under the RTGS, bilateral and multilateral offsetting options are set out in **Table A**.

Table A Summary of how liquidity needs in stylised example fall as bilateral and multilateral offsetting algorithms are applied to the RTGS system

Bank	RTGS	Bilateral offset	Multilateral offset
A	4	2	0
B	2	1	0
C	5	2	1
D	3	1	0

In each of these real-life examples, the number of participants in the payment system is greater than in CHAPS. Specifically, in each of CHIPS and BOK-Wire+, there are several dozen participants; in both CHATS and BOJ-Net the number of participants is in three figures, whereas CHAPS currently has fifteen members. With a more concentrated membership, such as in CHAPS, the effectiveness of offsetting algorithms could be expected to be even greater, since proportionately more pairs/chains of offsetting payments would be likely to be present. On the other hand, more concentrated payment systems may already be more liquidity efficient, because their close-knit nature makes monitoring and co-ordination of payments easier, in which case the incremental effect of introducing liquidity-saving mechanisms may not be as powerful.

Discussion

The attractiveness of bilateral and multilateral offsetting algorithms, as demonstrated by the example in Box 2, is that they have the potential to reduce the 'type (i)' cash in advance liquidity driver directly, by coordinating the settlement of payments that (broadly) offset each other.(1) On the other hand, neither offsetting algorithms nor other liquidity saving approaches, which encourage early submission of payments for settlement, can guarantee liquidity savings for all payments. In the case of 'type (ii)' liquidity drivers (ie urgent payments for which there are no immediately available offsetting payments), banks still need to have liquidity available to make their payments in a sufficiently timely fashion. For this reason, in LVPSs that have adopted offsetting algorithms it is generally the case that their participant banks still have the option to reserve liquidity in order to make 'normal' RTGS payments (sometimes in parallel payment queues) — often referred to as 'hybrid' systems.

In the case of 'type (iii)' liquidity drivers (ie large individual payments), offsetting algorithms may again not achieve liquidity savings, especially where particularly large individual payments need to be made, even if these are not urgent, for the simple reason that it could take too long to accumulate a set of smaller payments in the opposite direction that would offset the large payment. In this case, a complementary liquidity-saving mechanism could be to allow banks to split such large payments, and settle them piecemeal as the required liquidity becomes available. Payment splitting is an approach that is used in CLS, and has also been adopted as a convention in Japan and Switzerland for payments that are related to Japanese government bond transfers (exceeding ¥5 billion) as well as for payments in SIC (exceeding SFr 100 million) respectively. An empirical simulation of the effect of payment splitting in CHAPS finds that introducing such a facility could reduce banks' liquidity needs by 5%–10%, although again these savings were unevenly distributed among the banks.(2) The applicability of splitting is potentially strongest in the case of transfers that are extinguishing exposures, such as the repayment of unsecured (overnight) interbank loans. To the extent that payment splitting would encourage the partial repayment of such loans sooner (intraday) than currently occurs, then it could also help to reduce what, in the United Kingdom, remains a significant credit risk outside the payment system.(3)

As for 'type (iv)' liquidity drivers, the net balance of payments received and payments made during the course of a day is itself rarely an additional liquidity driver in practice, given the relatively large value in aggregate of gross payments that get made compared to the net balance of payments made and received during the course of a day. Furthermore, where a bank is paying out more than it is receiving in, such imbalances reflect a structural liquidity need — ie they represent the minimum funds that that bank requires to settle its payments in the system on a particular day, and so there are no liquidity savings mechanisms that can reduce such imbalances. On the other hand, again, to the extent that liquidity saving mechanisms incentivise banks to submit their payments for settlement earlier in the day, and that this in turn reduces the uncertainty regarding the aggregate end of day balance that they will need to meet, then liquidity saving mechanisms also have the potential to reduce banks' precautionary liquidity needs arising from type (iv) drivers.

Table 2 summarises how various liquidity saving approaches discussed in this paper help to limit the liquidity needed to meet each of the four intraday liquidity drivers identified. An especially striking feature of this summary is how only offsetting algorithms can cut the need for cash in advance for settling individual payments. This may explain the prevalence of such algorithms internationally.

Conclusions

Payment systems that settle on an RTGS basis place liquidity demands on their participant banks. These liquidity demands arise above all from the requirement for these banks to have cash on their accounts for settling each of the payments they make, and the timing and urgency of payment instructions. Various liquidity saving approaches — notably offsetting algorithms — have the potential to reduce these liquidity demands, especially where they allow the settlement of (non-urgent) payments to be better co-ordinated. The earlier that non-urgent payment instructions are submitted for

(1) One further efficiency consideration regarding offsetting algorithms is that, by their design, they create a short delay in settlement, ie while one (or more) payments are identified to create the offset. In practice, such a delay is typically short: in the most efficient RTGS systems that have such offsetting algorithms, it can be a matter of (split) seconds. And the existence of such offsetting algorithms is likely to encourage participants to submit their payment instructions earlier than they would do under the natural ebb and flow approach that banks tend to adopt in an RTGS system with no such liquidity-saving mechanisms.
(2) Denbee and Norman (2010).
(3) Millard and Polenghi (2004).

Table 2 Summary of how approaches to liquidity saving can help to limit liquidity requirements of identified intraday liquidity drivers

	Liquidity Drivers			
Approaches to Liquidity Saving(1)	The need for cash in advance	Timing/urgency of payments	Size of payments	Aggregate balance at end-of-day (and its predictability)
(Bilateral) limits/reciprocal payments strategy	n/a	All approaches to liquidity saving described here could potentially lead to (non-urgent) payments being submitted/ settled earlier than would otherwise be the case, thereby increasing the scope for co-ordination with (urgent) payments in the opposite direction, thereby helping to reduce liquidity need.	n/a	The liquidity need driven by the aggregate end-of-day balance cannot be reduced. But any liquidity saving approach that leads to earlier submission/ settlement than would otherwise be the case may improve the predictability of the end-of-day balance thereby reducing precautionary liquidity need.
Central queuing/liquidity reservation	n/a		n/a	
Throughput guidelines	n/a		n/a	
Graduated intraday tariff	n/a		n/a	
Offsetting algorithm	Liquidity need falls to net difference of offsetting payments.		n/a	
Payment splitting	n/a		Liquidity need falls to size of splitting threshold.	

n/a = not applicable.

(1) A combination of some or all of (bilateral) limits, a reciprocal payments strategy, central queuing and liquidity reservation can result in the balance-reactive and receipt-reactive gross settlement (BRGS, RRGS) strategies described earlier in this paper.

settlement, the greater the potential that offsetting algorithms in particular have to make liquidity savings by acting as a co-ordination device. Other incentive mechanisms, such as a time-varying tariff, are potentially helpful in this regard. And for some individual payments that, despite being non urgent, are too large to be offset by the algorithms in a timely fashion, liquidity savings may nevertheless be achieved by introducing the ability for banks to split some of their payments.

The experience, in particular during the past decade, gained from many countries that have introduced liquidity saving mechanisms to their RTGS systems — notably offsetting algorithms — has been positive, both from a system participant perspective (who reap the liquidity savings) and from the perspective of the authorities (whose priority is risk reduction). The continued elimination of credit risk in CHAPS is, for the Bank of England, non-negotiable. And the available evidence points clearly to banks being able to reduce their RTGS liquidity needs without re-introducing credit risks that had been such an undesirable feature pre-RTGS.

Changes to liquidity regulation in the United Kingdom may increase the opportunity costs of obtaining intraday liquidity and (therefore) the incentives to delay payments, with the potential risks that could give rise to. So now is a natural time for CHAPS banks to consider whether liquidity-saving mechanisms could usefully be introduced here as well. This article has summarised observed, empirical and theoretical evidence on the effectiveness of liquidity saving mechanisms, and thereby provides a common knowledge base to support discussions on this issue among the CHAPS banks and other stakeholders. It has also identified further avenues that CHAPS banks may wish to explore during these discussions. Among other things, can the intuition that offsetting algorithms are more effective in RTGS systems whose membership is concentrated (such as CHAPS) be demonstrated rigorously? Can further analysis shed more light on the way in which the savings from introducing liquidity saving mechanisms would be likely to be distributed among CHAPS banks? And what procedural changes would the CHAPS banks need to make in order to gain the greatest liquidity savings? These — and other — questions remain to be considered in due course.

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