# Large-Value Payment System Design and Risk Management

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## Abstract

This article considers how wholesale (also often called large-value) payment systems can be organised, how they have evolved over recent decades and what are the forces currently at play in shaping settlement mechanisms. The various risks that arise in large-value payment systems are identified and the two basic models of organising settlement – deferred net settlement and gross settlement – are explained. There has been a move away from the former type of settlement to the latter over time. Queuing and liquidity-saving mechanisms are also now being used in system design so as to reduce risk and further improve efficiency in payments.

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## 1. Introduction

In discussing payments and payment systems, a distinction is usually made between retail and wholesale payments with the principal differences between the two relating to transaction size – with the former involving relatively small value amounts and the latter relatively large value transfers – and the parties involved – typically non-banks making retail payments and banks engaging in wholesale payments. Both types of payment also bring with them a distinct set of issues that dominate discussion and policy formulation in that area. In wholesale payments, a key concern is the form in which settlement of payments takes place.

The purpose of this article is to examine how wholesale (also often called large-value) payment systems are organised, how they have evolved over recent decades and what are the forces currently at play in shaping settlement mechanisms. Most initiatives and innovations in payments are aimed at improving efficiency. In large-value payments, there is a particular emphasis on using them to reduce risks or to manage them better. Different forms of risk can arise in large-value payment systems but for the purpose of this article three key types of risk are highlighted.

The first is credit (or counterparty) risk, which is the risk that a counterparty to a payment will not settle an obligation for full value, either when due or at any time thereafter. The term credit risk ties in, or is associated, with risk types such as market or price risk (the risk of losses arising from movements in market prices), replacement risk (the risk that, owing to a counterparty to a transaction failing to meet its obligation on the settlement date, the other party may have to replace, at current market prices, the original transaction) and principal risk (the risk that the seller of a financial asset, such as currency, will deliver that asset but not receive payment, or that the buyer will pay but not take delivery).[1] Credit risk has a temporal quality to it – some difficulty arises during the time between when a payment is agreed and when it falls due to be settled so that settlement does not take place as intended and may not occur in the future either.

A particular issue in foreign exchange systems is that the separate settlement legs of a foreign exchange transaction need to be synchronised in order to avoid the risk that a counterparty will fail before all payments are completed. It is particularly relevant when the exchanging banks operate in different time zones and when their trading hours may not overlap with one another. This form of risk is often termed "Herstatt risk" after a German bank which, in 1974, was closed down without it forwarding an amount of US dollars it had agreed to deliver against a quantity of Deutsche marks it had already received as part of that foreign exchange transaction.

The second risk type is liquidity risk. This shares with credit risk the characteristic that it is a risk that a counterparty will not settle an obligation in full when due. It differs from credit risk in that the counterparty intends to meet its obligations and can do so at some future time but cannot carry them out at the originally agreed time because it does not have sufficient funds (or liquidity) to hand.

Credit risk and liquidity risk pertain to the bilateral relationship that arises in settling a particular payment, i.e., between the payer and payee to that transaction.[2] The third risk type, systemic risk, addresses how those bilateral party-based risks, if realised, can impact other payment system participants and the good functioning of the payment system as a whole. Systemic risk, then, is the risk that the inability of a participant to meet its obligations in a payment system will cause other participants to be unable to meet their obligations when due. It includes situations in which credit or liquidity problems for one or more participants create similar difficulties for other participants in the payment system and it also refers to the possibility of a chain reaction in an interlinked payment or settlement system (Emmons, 1997). Systemic risk, therefore, can be understood as encompassing both the possibility of system failures and of other events which have an adverse, if not calamitous, impact on payment systems' performance.

**1** These and other risk definitions of risk draw on the glossary in European Central Bank (2007).

**2** The term "settlement risk" is used to designate the risk that settlement of a payment will not take place as expected and embraces both credit and liquidity risks.

Historically, deferred net settlement was the norm in large-value payments systems. In recent decades, however, new settlement procedures have been adopted with the purpose, inter alia, of addressing the type of risks mentioned above. During the 1990s, gross settlement in real-time came to be adopted as the predominant settlement mode in large-value payments. Payments systems which combine elements of both gross and net settlement – so-called hybrid systems – are now feasible. In section 2, the concepts and basic models of deferred net settlement (DNS) and real-time gross settlement (RTGS) are outlined. Recent developments in payment systems, including variants on the basic settlement models, are considered in section 3. Section 4 concludes.

## 2. Settlement options in large-value payment systems

### *2.1 Methods of settlement in payments*

Large-value, or wholesale, payments can be seen as involving two elements. One is the transfer of payment information between the payer and payee banks – termed "processing" – and the other is settlement – that is the actual transfer of funds between the banks. Central banks act, in effect, as the settlement agents between commercial banks in most payment systems. Discussions of large-value payment systems tend to focus on the settlement aspect of payments as real-time processing of payment messages is a feature of both DNS and RTGS. Large-value payments are usually settled by the transfer of deposits held at the central bank from one commercial bank to another. Banks face a choice as to when and how settlement occurs. DNS and RTGS represent two of the options available.

DNS recognises that commercial banks are able to reduce the amount of central bank deposits they need to settle payments if they agree to defer settling those payments between themselves for a period of time. Payment inflows and outflows can then be offset ("netted") against one another over a period of time, such as the business day, and at a specified time, usually the end of each day, the net amount owed between any two banks is settled by a transfer of central bank deposits from the account of the net payer to the other bank. The phrase "deferred net settlement" then captures the essence of this settlement method: payments are settled on a deferred basis and the amount to be exchanged between any two banks is arrived at by netting off payments against one another, establishing an outstanding balance to be paid from one bank to the other. A simple example would be where Bank A has to make one payment to Bank B on a particular day with a value of €100 million while Bank B also happens to have one payment to make to Bank A, with a value of €70 million. In DNS, rather than Banks A and B making two separate settlements during the day, the payments are deferred for settlement until end-day when the two payments are netted, or offset, against one another with a single settlement then occurring with Bank A forwarding funds to Bank B equal to the difference between the two payment amounts, i.e., €30 million. This principle can be extended to deal with many payments and can also be applied on a multilateral (i.e., multi-bank) basis.

This basic description of DNS highlights a fundamental tension or trade-off at work in settling large-value payments. In allowing settlement to be deferred until end-day, netting of payments against one another can be employed. This will, generally, reduce the amount of central bank money required to settle the daily volume of payments. Against that, in allowing a delay to occur between a payment obligation arising and its settlement, a credit risk arises as it is possible that payees will not receive the amounts owed to them.

This credit risk can be avoided by requiring individual payment obligations to be settled instantaneously as they arise, what is termed "real-time gross settlement" (the aforementioned RTGS). Under this method, each payment is settled on an individual basis, in which case there is no netting of payments against one another. By not allowing netting, payment by this method takes place in a gross settlement format and on a bilateral basis. While eliminating credit risk, the downside of this settlement method is that it does not permit the economisation on the use of settlement balances that netting can achieve.

DNS and RTGS can be seen as the basic, generic forms of settlement in large-value payment systems.[3] In the remainder of this section, the basic models of DNS and RTGS are each considered more closely.

3 It is worth emphasising again that the focus is on the form of settlement of payment. The transmission, processing and clearing of payments need not necessarily differ between the two types of system or any intermediate configuration.

### 2.2 Deferred net settlement

In DNS systems, settlement occurs at a discrete lag to the receipt of payment instructions. Banks do not exchange the total value of settlement amounts owed to one another but rather the net amount due between them, with the net debtor settling that amount by transferring deposits to the net creditor.

Payment messages are transmitted in real-time so that a participating bank's net position can be calculated on a bilateral or multilateral basis during the business day. At a specified time, usually at the end of the business day, the net amount owed between the parties at that time is exchanged. Net settlement systems then involve a record of financial obligations developing over a pre-specified period of time at the end of which the net amounts of funds due to, or from, participants are transferred as appropriate.

The principal benefit of net settlement is that it allows banks to economise on their holdings of settlement balances, or at least reduce the immediate need for liquidity until the end of the business day when final settlement is made. To follow up on the earlier example involving payments between Bank A and Bank B, when the two payments are netted against each other, Bank A is only required to transfer €30 million in settlement balances to Bank B. If netting of these payments was not allowed, Bank A would have to access €100 million from its central bank settlement account, as opposed to the €30 million it needs at end-day under the netting scheme. Bank B would also have to access €70 million of settlement balances to meet its payment to Bank A. Such an economisation on the amount of settlement balances required to meet payment obligations is typical of DNS and is one of its advantages. The fact that net settlement of transactions typically occurs at the end of the business day also means that there are no intraday calls on banks' holding of settlement balances with the central bank. That settlement occurs at a specified time in the day can also aid banks' funds management.

The downside to DNS is that the total value of payment commitments remaining outstanding at any time during the day can be quite large. In agreeing to wait until end-day to settle the net amount outstanding, Bank B, in the example above, is incurring the risk that the €30 million net amount owed to it will not be received. If individual payments were settled as they arose, this credit risk would not occur. In DNS, individual institutions are thus exposing themselves to the possibility of default on net amounts owing to them. This is the main weakness of DNS systems: credit risk arises in them. It also means that the system of payments is potentially under threat as a failure of, say, Bank A to pay Bank B the net amount owed to it can impair Bank B's ability to meet its own net debts with respect to other banks.[4]

A number of measures can be introduced in DNS systems to manage credit risk. It is possible, for example, to put a quantitative limit on the net debit and/or net credit positions of banks. Such "caps" place a limit on the credit exposure which participants can run vis-a-vis each other. A payment will not enter the system when a cap could be breached by doing so. Loss-sharing rules, which indicate how losses arising from the default of a participant in the system are to be shared among the affected parties, are another means of addressing credit risk in DNS.

### 2.3 Real-time gross settlement

In contrast to DNS, RTGS involves final settlement of each individual payment being made at the same time as it is processed, that is at the time the instructions of the payer are transmitted to the central bank, so that the transaction can be considered to be settled in "real time". In principle at least, RTGS systems see final settlement of interbank funds transfers occurring on a continuous, transaction-by-transaction basis throughout the processing day. This form of settlement ensures that no credit risk arises.

RTGS, however, at least in its purest form, can place substantial liquidity demands on banks as they cannot reduce settlement amounts through netting. Referring again to the earlier example, under RTGS Bank A would have to draw down, or access, €100 million at the time of the day that Bank B forwarded its payment for settlement. Likewise, Bank B would have to provide €70 million when its payment to Bank B fell due. Under DNS, in contrast, Bank A alone would have to provide settlement balances (of €30 million) at end-day.

4 Emmons (1997) points out that the primary benefits and costs of netting often move in parallel to one another. For instance, the longer final settlement is deferred the greater the potential exposure of individual recipient banks to the possibility of payer banks defaulting. At the same time, the longer the period before settlement occurs the greater the reduction in settlement obligations that can likely be achieved through netting.

As a general rule, the greater the number of two-way payment flows between agents and the more those payment flows balance each other out the greater do the benefits of netting outweigh its costs.

Gridlock is a situation that can arise in RTGS systems. It occurs when a substantial number of payments in the system cannot be settled owing to one or more payers being unable to make outgoing payments. Those payers may be unable to settle those payments due to settlement rules or to a lack of funds or liquidity on their part. This, in turn, can have further effect on the payments system as their payees may have been dependent on the receipts from those payments to fund their own outgoing payments, and so on. In this way, an impediment to settling some payments can lead to a broadly-based or system-wide disruption to payments being settled. A number of variants on the basic RTGS model can help address gridlock; they are discussed in the next section.

Gross settlement procedures can be applied in foreign exchange. Such systems are often referred to as payment-versus-payment (PVP) systems.[5] They involve a pair of financial transfers being made simultaneously in separate national RTGS systems and, therefore, being settled on a gross basis and with finality. Such a mechanism is a means of avoiding Herstatt risk as the final transfer of a payment in one currency takes place at the same time that the final transfer of a payment in another currency occurs.

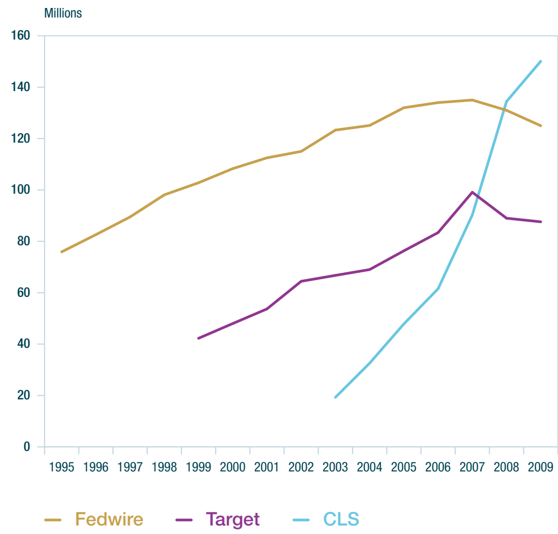
## 3. How modern large-value payment systems operate

### *3.1 The move to RTGS*

The Bank for International Settlements (BIS) (2005) identifies the 1990s as a period of major transformation in the design of large-value payment systems, with a move away from employing DNS systems to a widespread adoption of RTGS systems. The context in which this switch occurred involved a substantial rise in the volume of large-value payments, including a pickup in international payments flows.

This is illustrated in Charts 1 to 3, which focus on three major large-value payment systems. The US Fedwire system is the longest-lived of these. It saw payment volume rise by close to two-thirds between 1995 and 2009 (Chart 1), while payment value nearly tripled, in nominal terms, in the same period (Chart 2). TARGET is an interbank payment system for the real-time processing of cross-border transfers within the European Union. Data are available from 1999 for this system and Charts 1 and 2 show large pickups in the volume and value of payments in TARGET over time. Payment value has increased as a proportion of GDP in both the Fedwire and TARGET payment systems since 2000 (Chart 3). CLS (Continuous Linked Settlement) is the third payment system whose payment volumes and values are shown in the charts. It permits foreign exchange settlement between major banks. It has been in operation since 2002 and, as can be seen from Charts 1 and 2, has seen substantial growth in both payment volume and value in its short history.

**Chart 1:** Total payment volumes in major large-value payment systems




(Data for charts sourced from BIS payment statistics website, December 2010).

5 Gross settlement can also be applied in securities settlement systems, in a form known as delivery-versus-payment (DVP). This involves the title to the security and payment being exchanged simultaneously.

**Chart 2:** Total payment values in major large-value payment systems

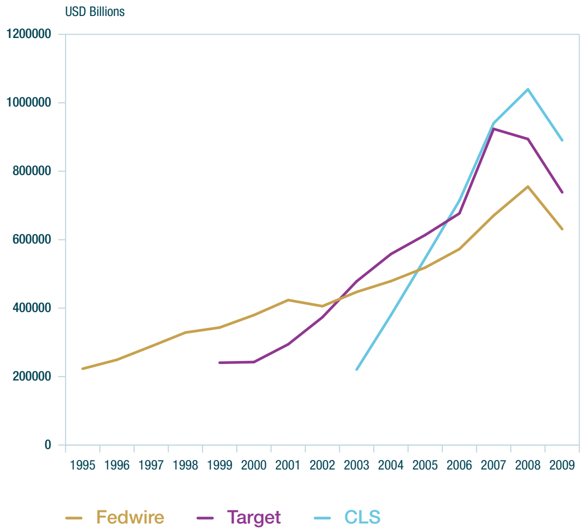



**Chart 3:** Total payment values as a proportion of GDP


Nowadays, wholesale payment systems are open longer hours and, as Bech, Preisig and Soramaki (2008) point out, they process a considerable amount of relatively low-value payments. This has resulted in a greater volume and aggregate value of payments being settled in wholesale payment systems, as illustrated in Charts 1-3.

These developments in themselves render multilateral netting procedures, on which DNS systems depend, more difficult to operate and help explain the move to RTGS. The latter settlement type addresses specific risks that arise in large-value payment systems. The most important of these is systemic risk. RTGS's appeal in reducing this type of risk was set out in a study by the Bank for International Settlements (1997): it removes the possibility of an unwinding of payments, which can be a source of systemic risk in net settlement systems, and it allows banks to process and settle payments throughout the day, which reduces the possibility of settlement pressures arising at particular points in time, such as at end-day. Adopting RTGS into payment systems, as occurred in the 1990s, then can be seen as an appropriate response to the need for sensible risk management in large-value payments systems, offering, as it does, a mechanism for limiting certain risks in the settlement process by effecting final settlement of payments on a real-time basis.

Central bank policies and some innovations in the area of large-value payments have aided RTGS's viability and adoption. Leinonen and Soramaki (2005) indicate that a wide variety of system configurations can now be achieved to address specific types of transaction flows. These include many of the risk and liquidity management techniques used in RTGS systems (outlined below).

Central banks are heavily involved in the design and operation of payment systems. There are a number of reasons for why this is the case. As the Bank for International Settlements (2003) notes, most, if not all, interbank payment systems use the central bank as the settlement institution and central bank money as the settlement asset. These choices reflect the status of the central bank as a default-free settlement institution; the use of its settlement asset in itself helping to reduce systemic risk and liquidity needs through banks having to hold only one form of settlement asset; and the flexibility that the central bank has to determine the amount of that asset available for settlement purposes. Central banks are also likely to be cognizant of the social benefits of a smooth-functioning payment system and for this reason will most usually be proactive in endeavouring to minimise systemic disruptions.

The BIS study acknowledges that while central banks have long played an important role in payment systems, the widespread adoption of RTGS has required them to play a more proactive and leading role in payments. RTGS necessitates more central bank money being supplied for settlement purposes than DNS, as netting of payments does not occur. The willingness and ability of central banks to support RTGS has allowed that settlement form come to the fore in large-value payment systems.

In the following two subsections, a number of RTGS-based settlement mechanisms employed in modern payment systems and the rationale behind them are discussed.

### *3.2 RTGS with intraday/daylight credit*

Intraday credit (also termed daylight credit) is often provided by the central bank to system participants in RTGS systems. In a RTGS system with intraday credit, a payer bank might not have sufficient deposits at the central bank to meet a settlement obligation but payment can still take place by that bank drawing on an intraday credit facility at the central bank to meet any shortfall. Settlement then is achieved but a credit risk remains insofar as a liability arises between the payer bank and the central bank equal to the amount of intraday credit received. This might not represent a difficulty if payment flows throughout the day largely "even" each other out so that the intraday position of the banks is never too large, thus leaving them in a position to settle their outstanding positions with the central bank at a specified time towards the end of the day. There is, however, always the possibility that the intraday credit positions of banks may become quite large. This can be addressed by requiring banks availing of the intraday credit facility to post collateral or by placing a cap on the amount of daylight credit that they can receive.

Dhumale (2002) indicates that central banks provide intraday credit so as to avoid the effects of a liquidity shortage emerging in large-value payment systems. In granting intraday credit to banks, central banks are also aware of the credit risk they face but accept it on the basis of the impact that an insufficient amount of liquidity in the payment system could have on activity. In any case, central banks dictate the terms upon which intraday credit is provided to banks and this can reduce the credit risks they face. While an intraday credit facility could be provided at a zero charge, it is often priced (the US Federal Reserve, for example, charges a fee for intraday overdrafts) or credit might only be granted if collateralised by the borrower (as is the practice in the Eurosystem). Providing interest-free, uncollateralised intraday credit to commercial banks is not really an option for central banks as it would likely lead banks to manage their intraday flows of liquidity less effectively and possibly create a moral hazard problem whereby banks assume the central bank would bail them out if liquidity difficulties arise.

Cross-border collateral can be used by banks that operate in a number of national payment systems to secure intraday credit from central banks. Manning and Willison (2006) demonstrate that the amount of collateral that banks require in total can be reduced if they are allowed to use their collateral stock on a cross-national basis, provided liquidity needs are imperfectly correlated across the banking group.[6]

An alternative to collateralisation is to impose a charge on credit given to system participants. The main argument in favour of charging for intraday credit, as opposed to providing it without charge, is that it would encourage banks not to utilise that credit anymore than was necessary. Charging for intraday credit, however, can also have some less desirable effects. Manning and Willison (2006) point out that the actual cost of intraday credit may be an important consideration in determining whether a bank decides to participate directly or not in a RTGS system. Rochet (2005) shows that if a bank chooses to use bilateral agreements with other banks or makes payment flows through a competing DNS system in response to the pricing of daylight credit, the effective bypassing of the RTGS system may increase systemic risk.

Quantitative limits, or caps, on the amount of intraday credit granted can also be imposed by central banks. Kahn and Roberds (1999) put forward two reasons why caps on the amount of intraday credit extended to banks are desirable. Firstly, caps lower the incidence of default and, as a result, help reduce certain costs associated with default, such as legal costs. Secondly, imposing caps discourages excessive risk-taking on the part of payment system participants. Kahn and Roberds stress that it is important to set caps at the right level to ensure intraday credit is used as efficiently as possible.

6 The Correspondent Central Banking Model (CCBM) exists within the Eurosystem to allow the cross-border use of collateral to support Eurosystem credit operations or to obtain liquidity in TARGET, the Eurosystem's large-value payment system.

### 3.3 *Queuing and liquidity-saving systems*

A queued gross settlement procedure is another variant on the basic RTGS model that can help tackle liquidity issues. Should the payer bank not have sufficient funds with the central bank with which to settle a transaction as it arises then the payment is placed in a queue for settlement and only released and completed when the bank accumulates enough funds to permit settlement to be made. As McAndrews and Trundle (2001) point out, one beneficial effect of queuing then is that it does not give rise to settlement risk.

Centrally-located queuing arrangements can operate on a first-in, first-out (FIFO) rule. Alternative queuing arrangements are possible too. The queue of payments, for example, could be re-ordered to allow a "bypassing" of some payments by others to occur, perhaps in response to sending banks close to the front of the queue not having sufficient funds available to hand with which to settle particular payments while banks further down the queue are in a position to settle immediately. Contributing to the viability of queuing systems is that not all payments require instantaneous settlement, thus allowing banks some flexibility as to when payments are released for settlement and allowing them to be queued until sufficient liquid balances arise.

The concept of queuing has lent itself to the development of certain settlement procedures that can reduce the liquidity burden on banks in settling payments. Martin and McAndrews (2008) term those procedures "liquidity-saving mechanisms" (LSMs). They rely primarily on various queuing mechanisms for settling payments that condition the release of queued outgoing payments on the arrival of offsetting incoming payments. Liquidity is saved, or economised, in the following way. A payment is placed in a queue and only released for settlement when an incoming payment arrives. The two payments may be netted off against one another with the net balance outstanding settled immediately with a transfer of central bank money. This netting off of payments reduces the amount of liquidity required for settlement compared to an uncoordinated gross settlement procedure and in that way is "liquidity saving".[7]

In practice, LSMs depend on computer algorithms searching payment queues to find offsetting payments. Those algorithms are capable of searching payment queues to find the largest subset of pending payments that can be settled and can do so while acknowledging and respecting banks' views that specific payments must be settled first. Another example of how new information technology can be used to address settlement needs is where a transaction is "split" to reflect the amount of liquidity available for settlement being less than the full amount of the transaction. In this case, a portion of the transaction equating to the amount of available liquidity is settled with the benefit that the liquidity inflow to the recipient bank can be used to settle its own payment commitments.

Just as queuing can be used at system level to reduce liquidity needs, queuing within a bank can also take place. It involves banks sequencing their own incoming and outgoing transfers. This allows them to control intraday payment flows by arranging the timing of outgoing payments according to the amount of liquidity received from incoming payments. This scheduling can also be used to determine the preferred level of intraday liquidity held by the bank (as well as respecting any formal reserve requirements imposed on them) and its use of intraday/daylight credit. In principle, a successful sequencing of payment flows can reduce substantially the amount of liquidity required for payments for the bank in question.

It is, nevertheless, possible that what may prove beneficial for one bank could involve delaying settlement of some payment outflows and have a negative impact on liquidity management in payee banks. For such reasons, modern payment systems often put in place policies that encourage the processing and settlement of a certain proportion of a day's payments by specified times. Faster settlement could also be achieved by a transaction pricing policy that makes earlier payments cheaper to execute. Throughput guidelines set by the payment system operator, requiring that a given fraction of the value of payments should be settled by a given time during the operating day, can also ensure early settlement and, according to Buckle and Campbell (2003), are a means of reducing aggregate liquidity requirements within the payment system.

7 Another settlement mechanism that can be used is where small-value and less urgent payments are settled on a net basis on several occasions during the day while large-value and urgent payments are settled on a RTGS basis (O'Brien, 2004).

## 4. Conclusion

Up to the 1990s, DNS was the prevailing settlement option in large-value payment systems. In the meantime, there has been a move away from this settlement method to RTGS. It is now becoming increasingly feasible to merge features of both DNS and RTGS in hybrid payment systems. This article has sought to review the means by which each of these settlement methods can address the various risks and other issues that arise in large-value payment activity.

The review emphasises that the main advantage RTGS has over DNS is that it effectively eliminates the credit risk that can be incurred in the payment process and, therefore, removes that particular risk as a threat to the good functioning of the payment system. Against that, a liquidity risk arises in RTGS – the potential that a commercial institution will be unable to meet its payment obligations as they come due because of an inability to liquidate assets or obtain adequate funding. Central banks are often required to take a role here by providing intraday credit to such institutions to enable them to settle payments. This, in principle at least, exposes central banks to credit risk. Different policy options, however, exist to help central banks minimise that risk and to affect payment activity more generally. Central banks can require, for example, that any intraday credit provided by them is collateralised by the recipient bank. Innovations are also helping to reduce the amount of liquidity needed in large-value payment systems. Leinonen and Soramaki (2005, p. 22) point out that while most large-value payment systems currently operated by central banks are RTGS systems, they tend to be acquiring an increasing number of liquidity-saving features over time.

It will be interesting to see how technology will interact with policy in the coming years in moulding large-value payment mechanisms. The distinction between large-value and small-value payments may become redundant over time. A recent study by the World Bank (2008) indicates that some RTGS systems are already being designed to handle both payment sizes. It also argues that more national payment systems will use technological improvements to allow all payments, whether large or small, to be made on a RTGS basis. In itself, this could reduce considerably the quantity of large-value payments that need to be processed and settled as they are replaced by a greater number of smaller value payments. This could have positive consequences in reducing the risks inherent in payment activity and could influence policy. At the very least, it suggests that the future of payments will prove stimulating for all parties concerned.

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