Central Bank intraday collateral policy and implications for tiering in RTGS payment systems
Central Bank intraday collateral policy and implications for tiering in RTGS payment systems

John P. Jackson and Mark J. Manning*

* This Working Paper has been presented at the 9th Annual DNB Research Conference on ‘Recent Developments in Payment Economies’. Views expressed are those of the individual authors and do not necessarily reflect official positions of De Nederlandsche Bank.
Central bank intraday collateral policy and implications for tiering in RTGS payment systems

(DRAFT – October 2006)

John P Jackson*
and
Mark J Manning**

e-mail: john.jackson@bankofengland.co.uk

e-mail: mark.manning@bankofengland.co.uk

The views expressed in this paper are those of the authors, and not necessarily those of the Bank of England. We would like to thank the following for helpful comments during the preparation of this work: Victoria Saporta, Steve Millard, Matthew Willison, Ana Lasaosa, Jochen Schanz and Will Roberds.
1 Introduction

In this paper we present a model of a Real-Time Gross Settlement (RTGS) payment system with tiered membership where settlement is facilitated by intraday credit extensions from the central bank. RTGS systems process and settle payment instructions individually in real time, ensuring intraday finality. Furthermore, central banks typically provide the settlement accounts across which payments are processed; hence, settlement is typically effected in central bank money, thereby eliminating counterparty risks between members once settlement has taken place. The model allows us to examine the key factors that influence both an agent’s decision over whether to participate directly in an RTGS payment system, and a central bank’s decision as to whether to require collateralisation of intraday credit extensions to payment system participants.

The design of all payment arrangements must reflect a trade-off between cost and risk. As noted in BIS (2005), “if a system was so costly or burdensome that no one used it, the system would have no effect on risks no matter how extensive its risk controls.” This applies as much to RTGS systems as to any other system design, for while addressing the counterparty credit risks associated with deferred net settlement (DNS) systems, real-time gross settlement of payments can be a significant, and costly, drain on a bank’s liquidity (Kahn and Roberds (2001)).

To alleviate this burden, central banks also typically offer intraday credit to payment system participants. In the absence of such credit, users would have to pre-fund their settlement accounts at the central bank, thereby incurring a substantial opportunity cost of holding liquidity.1 Chakravorti (2000), Kahn and Roberds (2001), Bech and Garratt (2003) and Bech et al in this volume all highlight the behavioural implications of costly liquidity needs. They note that system participants might then seek to reduce these costs by delaying the submission of payments, with potentially adverse consequences for liquidity recycling in the system, operational risk, and, to the extent that obligations are not settled as expected, ultimately social welfare.

Central bank provision of intraday credit to payment system participants entails a potential credit exposure. Several risk-mitigating measures might be taken, but these impose costs on payment system participants, and potentially also on society. Many central banks, including the Bank of England, require full collateralisation of intraday credit exposures; this greatly reduces credit risk, but imposes an opportunity cost of posting collateral. By contrast, the US Federal Reserve does not require collateralisation, but instead charges an interest rate on all intraday overdrafts and imposes

---

1 For example, in September 2005, participants of the CHAPS and CREST systems used an average of £65 billion of intraday liquidity at the Bank of England to facilitate settlement. This includes more than £50bn generated by self-collateralising repos in CREST.
credit limits on agents’ usage of intraday credit. Costly intraday credit can have similar behavioural consequences to pre-funding requirements: prompting banks to economise on their usage of liquidity in the system by delaying payments.

The trade-off faced by central banks, between assuming greater credit exposure and imposing costs on participants, has been subject to considerable scrutiny in recent years. Furfine and Stehm (1998), for instance, highlight the deadweight welfare losses associated with costly collateral requirements. They conclude that, from a social welfare perspective, a policy of free liquidity provision would be preferred to full collateralisation unless the opportunity cost of collateral tended to zero. However, more recent work by Mills (2004) suggests that models of this type may not have adequately accounted for the credit risks faced by the central bank under zero collateralisation.

A related strand of literature focuses on how central banks, if they do require that intraday credit be collateralised, can reduce the opportunity costs incurred by system participants in posting such collateral. Manning and Willison (2005) show that allowing cross-border usage of collateral enables agents to economise on their total collateral holdings, while Green in this volume suggests that central banks could accept less liquid (and hence lower cost) collateral than might other secured lenders. Alternatively, Willison (2005) considers recourse to more liquidity-efficient payment system designs, so-called hybrid systems, to reduce the amount of intraday credit needed to settle a given set of payments.2

Where significant costs of obtaining intraday credit remain, agents might choose not to participate directly in an RTGS system at all. Rochet in this volume argues that to the extent that an agent chooses to by-pass an RTGS system, by entering into bilateral agreements with other agents or by shifting flows to a competing deferred-net-settlement (DNS) system, systemic risk may be increased. Such alternative arrangements typically include recourse to a correspondent bank, who processes payments on behalf of indirect system participants. This phenomenon, known as ‘tiering’, is a commonly observed feature in many RTGS systems internationally. CHAPS Sterling, with only 13 out of around 350 commercial deposit-taking banks operating in the United Kingdom participating directly, is particularly highly tiered (Harrison et al (2005)). In this paper we explore the implications tiering can have on the welfare costs associated with risk mitigation in payment arrangements.

Our starting point is an insight from Kahn and Roberds (2006), who identify delegated monitoring as an alternative enforcement device to collateralisation. They show that, in the presence of private information about the reliability of agents, delegated monitoring can economise on the need for
agents to post collateral to guarantee repayment of intraday credit. This monitoring is achieved through a tiered structure, whereby a direct participant of a payment system absorbs the risk associated with credit extensions to its customer banks, hence maintaining good incentives to monitor.

When default states occur only a fraction of the time, a full collateralisation policy can achieve only a second-best outcome; any collateral posted to the central bank in non-default states is a deadweight loss to society, arising as a result of the central bank’s imperfect information about settlement banks’ credit quality and their wish to minimise their own credit losses (and hence costs to the taxpayer). Under such a scenario, if monitoring is sufficiently accurate, and monitoring costs sufficiently low, delegated monitoring can achieve a smaller deviation from the first-best.

In this paper we highlight two additional channels by which tiering in payment systems might lead to a reduction in the deadweight social costs associated with full collateralisation of intraday credit extensions by the central bank.

First, we consider internalisation of payments. This refers to a situation where payments made between customers of the same correspondent bank are settled internally across the correspondent’s books, without being processed through the payment system. Internalisation allows payments to be made without recourse to intraday credit from the central bank, thereby avoiding any costs associated with collateral posting requirements. Therefore, to the extent that tiering facilitates the internalisation of payments, it can reduce the costs imposed by a central bank’s full collateralisation policy. Furthermore, to the extent that payment flows from a correspondent’s customers to other first-tier participants are likely to be spread out through the day, there may be a diversification, or ‘collateral-pooling’ benefit. That is, unless customers’ payment flows are perfectly correlated, the total pool of collateral required to generate intraday credit on behalf of several customer banks, will be smaller than that required were each customer’s collateral needs served from segregated pools of collateral.

Where payments made by second-tier participants are not internalised, but rather are effected by the correspondent over central bank settlement accounts, any collateral-posting requirements at the central bank would apply. But here too, tiering may reduce the deadweight social costs of collateral if agents with high opportunity costs of posting collateral are able to take advantage of lower collateral-posting costs enjoyed by their correspondent. The opportunity cost of posting collateral may be proxied by the reverse-repo spread (i.e., the spread between secured and unsecured borrowing costs). This may vary across agents, according to differences in credit-worthiness which

---

2 See also BIS (2005) for a discussion of alternative hybrid system designs.
affect the unsecured cost of borrowing. Also, market imperfections and regulatory policy may influence agents’ relative opportunity cost of collateral. For example, in the United Kingdom, banks subject to the Stock Liquidity Requirement (SLR), a prudential liquidity regime, are able to meet intraday collateral requirements using assets that they have to hold, in any case, to meet their prudential requirement at the end of the day; hence they have a very low opportunity cost of posting collateral intraday.3

The foregoing discussion highlights the potential benefits of tiering. However, tiering can also introduce additional risks to the system.

First, a correspondent bank might not have sufficient incentive to monitor because it does not fully internalise the potential systemic consequences of a customer’s default which triggers liquidity or solvency problems of its own. Even if sufficient incentives were to exist, monitoring of second-tier agents by a correspondent might not be accurate, causing the correspondent to incur credit and liquidity exposures that might in turn lead to wider contagion. Harrison et al (2005) analyse the credit risk implications of the highly tiered structure of the UK large value payment system, concluding that this channel might not impose significant risks on the system as a whole, except in extreme circumstances. However, other risks exist. For instance, internalized payments might be subject to greater legal risks as they are not likely to be covered by provisions providing protection against bankruptcy law (such as the Settlement Finality Directive in the European Union). And tiering increases the risk that operational or financial problems at a settlement bank lead to disruption of payments in a large part of the system. Another important concern is that, in response to liquidity problems among second-tier banks, settlement banks might decide to cut or restrict intraday credit, further exacerbating these liquidity problems.

In this paper, we apply a simple model of an RTGS payment system, in which agents rely on the central bank to provide intraday credit to facilitate settlement of a single payment obligation. We allow the paying agent to choose whether to be a direct participant of the payment system, or to settle its obligation via an existing direct participant. With complete information as to the determinants of the agent’s choice, the central bank chooses whether or not intraday credit should be fully collateralised.4

---

3 In some securities settlement systems where the cash leg is settled gross (equally relevant to the issues considered in this paper), the cost of generating cash liquidity is significantly reduced via the implementation of self- or auto-collateralisation techniques. CREST and Euroclear France, for instance, apply such procedures, allowing the immediate pledge/repo of (eligible) securities to the central bank to generate liquidity to fund their own purchase.

4 Other possible central bank policies, such as restricting access or imposing quantity limits, are not considered in this paper.
Using this framework, we are able to show that, when the central bank requires full collateralisation, it may be optimal for an agent to become an indirect participant, so as to take advantage of cost-efficiency benefits arising from monitoring as a substitute for collateralisation. These benefits are increased to the extent that payments can be internalised and that agents can take advantage of their correspondent’s lower collateral posting costs. Furthermore, in the absence of spillover risks from tiering, private and social costs are aligned when the central bank opts for full collateralisation. Therefore, any private cost-efficiency benefit derived translates directly into a social welfare improvement.

We do show, however, that a wedge between social and private costs is likely to exist under zero collateralisation and that, although welfare might be maximised if the central bank requested zero collateral and the agent chose to access the system indirectly, this outcome is not achievable: it will always be in the agent’s interest to access directly under zero collateralisation. Unless the probability of default is very low, this will rarely be optimal for the central bank.

With imperfect monitoring and the potential for systemic spillovers from tiering, a wedge will also emerge between social and private costs when the central bank opts for full collateralisation, with this wedge increasing in the degree of monitoring imperfection, the value of payments to be settled and the degree of spillover per unit of exposure. In this case, policy intervention might be desirable to address the risks introduced.

The paper is organised, as follows. Section 2 outlines our analytical framework. Section 3 applies this framework to analyse agents’ decisions under alternative scenarios for the quality of monitoring and the existence of tiering externalities. Section 4 concludes.

2 Analytical Framework

In this section, we present a simple model of payment arrangements to explore two key decisions: a bank’s decision as to whether to access an RTGS payment system directly, or via a correspondent banking arrangement and a central bank’s decision as to whether to collateralise intraday credit extensions. Our analysis draws on the framework presented in Kahn and Roberds (2006), but applies this in a much-simplified, stylised and reduced-form fashion. In Section 2.1 we provide an overview of the model set-up, going on to describe in greater detail the actions taken and costs incurred under each alternative arrangement.

---

5 Our model cannot capture the potential effects of collateral pooling because we only consider the decision of a single agent.
6 Specifically we use the framework in arrangements 4 and 5 of the paper, which deal with payments settling across central bank accounts.
2.1 The model set-up and timeline for actions

The essence of the model is a game of complete information, with actions taken sequentially by two players: the central bank; and a commercial bank, C. There are two further agents in the game, banks A and B, both of whom are direct settlement members of the payment system, with A also a potential provider of correspondent banking services to C. Bank B never provides payment services. All agents are assumed to be risk-neutral. Neither bank A nor bank B take any direct actions in the game, although we do establish the terms on which A provides correspondent banking services if called upon to do so, ensuring that it would be rational for A to offer such services. Bank C makes a single payment, of value unity.\(^7\) No other payments are made.

Time consists of a single day, divided into four periods. In period 0 the central bank sets its collateral policy with respect to bank C, choosing actions from the set \(\{F, Z\}\), where \(F = \) full collateralisation; and \(Z = \) zero collateralisation, so as to minimise expected social costs.\(^8\)

In period 1, observing (with certainty) the central bank’s policy choice, C minimises its expected costs with respect to its decision as to whether to fulfil a single payment obligation directly in the RTGS payment system, or via correspondent banking services provided by direct payment system participant, A. Its set of potential actions is then \(\{D, I\}\), where \(D = \) direct participation; and \(I = \) indirect. We assume that, if indifferent, C will always choose to participate directly.

The state of the world is characterised by \(\{e, \delta\}\). Parameter \(e \in [0,1]\) describes the possible orientation of payment flows in the system; with probability \((1-e)\), C is obliged to make a payment to A, whereas with probability \(e\), C has an obligation to B. As will be discussed below, the orientation of payment flows has implications for the degree of internalisation possible when C’s payments are settled indirectly via A. The orientation of payment flows is realised by a draw from nature in period 2 and revealed immediately to the agents. Parameter \(\delta \in [0,1]\) is the probability that C suffers an exogenous default shock which prevents it from repaying intraday credit extended by either A or the central bank.\(^9\) The incidence of a default shock is also realised by a draw from nature in period 2. The outcome is not revealed to agents until period 3, although a signal as to whether or not a shock has occurred can be obtained by monitoring in period 2.

\(^7\) We later generalise the value of the payment.

\(^8\) It is assumed that C is eligible to participate directly in the system, but that the central bank’s preferences over direct versus indirect participation by C, from the perspective of social cost, will be reflected in the collateral policy chosen.

\(^9\) We assume that only C faces the possibility of an exogenous default shock in this model. A more complete framework might allow A to suffer such a shock also. We note in our discussion the potential implications for our results of this simplification.
Settlement of C’s payment obligation occurs in the payment system in period 2. It is assumed that C has no endowment of the settlement asset at the start of the period and hence always requires an intraday credit extension, either from the central bank or from A, before settlement can be effected. Equally, we assume that A requires intraday credit from the central bank before it can make a payment on C’s behalf. All intraday credit extended in period 2 is to be repaid by the end of period 3, by which time C expects to have received a sufficient quantity of the settlement asset (from a maturing investment). Parameter $\delta$ may be interpreted as the probability that this investment fails and returns nothing.

If settling directly in the system under full collateralisation, C also posts collateral in period 2 to support its request for intraday liquidity. C then settles its obligation with finality in central bank money.\(^{10}\)

If bank A is settling on behalf of C, A first obtains intraday credit from the central bank. Any cost to A of posting collateral to the central bank is passed on directly to C.\(^{11}\) This collateral requirement in respect of C’s payments under an indirect arrangement can, however, be reduced by internalisation. When C has a payment obligation to A, this can be settled directly on A’s books. Only if C has to make a payment to B will settlement occur in central bank money. This is shown in Chart 1 below.

**Chart 1: Payment flows when C accesses the system via bank A**

Whether settling C’s obligation in central bank money, or internalising across its own books, A settles C’s payment obligation in advance of the receipt of funds from C; that is, A extends intraday

\(^{10}\) With only a single payment here, we rule out the possibility of strategic behaviour among settlement banks. In particular, we abstract from the possibility that banks delay outgoing payments until incoming payments have arrived so as to economise on collateral costs. This behaviour is well documented in the literature, e.g. Bech and Garratt (2003) and Bech et al in this volume.

\(^{11}\) We assume that the central bank’s collateral policy is applied to all direct members. However as A and B take no decisions and make no payments on their own behalf in this model, it is not necessary that the central bank considers the implications of its collateral policy on these agents’ behaviour.
credit to C. A can potentially economise on collateral sought from C in respect of such a credit extension by carrying out monitoring. More specifically, A monitors to obtain a signal as to whether C has suffered a default shock in period 2. If monitoring reveals that a default shock has occurred, collateral will be sought from C in respect of intraday credit granted; otherwise A will not require payments to be collateralised. Any monitoring costs incurred by A are passed on to C.

If no default shock arises in period 3, all intraday credit is repaid. Otherwise, C defaults on the repayment of its intraday credit. Unless sufficient collateral has been posted, this will impose default costs upon agents in the system. These costs will be described in Section 3.2, below. The timeline of the model is shown in Chart 2.

**Chart 2: A time-line for actions**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period 0</td>
<td>The central bank sets its collateral policy with respect to intraday credit extensions to C.</td>
</tr>
<tr>
<td>Period 1</td>
<td>C decides whether to fulfil its payment obligation directly in the payment system; or indirectly via A.</td>
</tr>
<tr>
<td>Period 2</td>
<td>Nature determines the recipient of C’s payment obligation and C’s default shock is realised (but not revealed to agents). If settling for C, A monitors to obtain a signal as to whether C has suffered a default shock. Intraday credit is granted and C posts collateral if required to do so. Settlement occurs.</td>
</tr>
<tr>
<td>Period 3</td>
<td>C’s default shock is revealed to agents. Intraday credit repaid if no shock has occurred.</td>
</tr>
</tbody>
</table>

### 2.2 Agents’ actions and costs

#### 2.2.1 Characterisation of bank C’s costs

Bank C’s costs are characterised by: $E[C^C] = f(M, \lambda^C, \lambda^A)$, where $M$ is A’s cost of monitoring C, which, to the extent incurred, will be passed on to C; $\lambda^C$ is C’s private opportunity cost of posting collateral either to A or the central bank; and $\lambda^A$ is A’s private opportunity cost of posting collateral to the central bank, which again will be passed onto C. We consider each in turn.

---

12 Consistent with empirical observation, we assume that the central bank either does not have the capacity, or finds it excessively costly, to monitor.

13 In practice, these costs are often not passed on explicitly. Given that there is a clear economic rationale for full pass-through, it is likely that these costs are fully reflected in the price for a bundle of services provided by correspondent banks, which includes monitoring costs. Furthermore, explicit charging for intraday liquidity may become increasingly
As noted above, by incurring a monitoring cost, $M$, A can obtain a signal as to whether C has suffered a default shock and hence will be unable to repay an intraday credit extension. It is initially assumed that the signal obtained by monitoring is perfectly correlated with the shock; we later relax this assumption and allow for Type I and Type II errors. Private monitoring costs might be expected to be relatively low to the extent that the normal-course interconnection between financial institutions ensures a steady flow of information between them. Indeed, this implies that larger banks with diversified activities and a wide network of clients in non-payments-related businesses, will have access to more private information, and hence be better monitors. Furthermore, there are likely to be economies of scale in monitoring activity.

Turning to collateral costs, it is worth noting that where the costs faced by a correspondent bank are lower than those faced by its customer banks, indirect participation may allow agents with high collateral costs to take advantage of lower costs enjoyed by other agents. Recall that in the model, any costs incurred by A in respect of settlements effected on behalf of C will be passed on in full; but the lower are these costs relative to C’s own direct collateral costs, the more efficient indirect participation will be relative to direct membership.

Should C suffer a shock in period 3 and consequently fail to repay its intraday loan, additional private costs of default might be incurred. For simplicity such costs are normalised to zero. To further simplify the exposition, we also normalise to zero any fixed costs (technological and fees) associated with linking directly to the payment system or indirectly through A.

2.2.1.1 Bank C’s costs under alternative collateral policy/participation combinations

When settling directly, C faces a collateral cost of $\lambda^C$ if the central bank requires full collateralisation.

Bank C’s costs under indirect participation depend on the relative costs of monitoring and collateralisation, and the potential for internalisation. We assume that A prices its correspondent services competitively, subject to a full cost-recovery constraint, and offers two alternative correspondent banking services: one involving monitoring; and another involving full collateralisation. Bank C chooses the service that offers the lowest expected cost. We assume that C has no private information about its likelihood of experiencing a default shock, and that this is common knowledge. As the full collateralisation service offered by A can never be cheaper than settling directly at the central bank (C faces cost, $\lambda^C$, in both cases), and under the assumption that, common in future, as payments become more time-critical intraday. Alternatively, it may be that the providers of these services simply face very low opportunity costs to posting collateral.
where the costs of direct \((D)\) and indirect participation \((I)\) are equal, \(C\) will choose \(D\), it is clear that \(C\) will never choose \(A\)’s full collateralisation service. Hence, indirect participation will always be associated with monitoring.

Where \(A\) does monitor \(C\), and the signal obtained is perfectly correlated with the incidence of default, it will only be optimal for \(A\) to request collateral in default states (at a cost of \(\delta\lambda^C\) to \(C\)), but not otherwise. Bank \(C\) will, however, still have to compensate bank \(A\) for any additional collateral it may be required to post to the central bank, implying an extra cost above the direct cost of posting collateral to \(A\) of \(\epsilon(1-\delta)\lambda^A\). This assumes that \(\delta\) of the time \(A\) will simply use collateral posted by \(C\) to cover any requirement at the central bank. The expected cost to \(C\) is then:

\[
E[C^C] = M + \delta \lambda^C + \epsilon(1-\delta)\lambda^A \quad \text{under } (F,I)
\]

\[
E[C^C] = M + \delta \lambda^C \quad \text{under } (Z,I)
\]

### 2.2.2 Central bank’s costs

We assume that the central bank makes decisions in order to minimise expected social costs. These costs are characterised by \(E[C^{CB}] = f(M, \lambda^C, \lambda^A, S)\), where the first three cost parameters are private costs, as in Section 2.2.1 above, and \(S\) is the social cost of default by \(C\) when intraday credit is not fully collateralised. Monitoring and collateral costs are included here as these are deadweight costs to society arising from informational asymmetries and limited enforcement.

A social cost \(S \geq 1\) arises when \(C\) cannot repay an uncollateralised intraday loan at the central bank and hence the central bank is forced to cover the resulting loss via taxation of unmodelled agents. The extent to which \(S\) exceeds 1 reflects any distortion imposed by the tax.

If, on the other hand, default occurs and collateral has been pledged, the defaulting agent’s creditor (either the central bank, or bank \(A\) under a tiered arrangement) may attach the defaulter’s collateral up to the amount of the pledge. For simplicity, we assume no market risk to the value of collateral posted.\(^{14}\)

### 3 Agents’ decisions

In this section, we apply the framework described above to establish equilibrium outcomes for central bank collateral policy and the degree of direct participation in payment systems. We consider

\(^{14}\) It is worth noting that the linearity of all components of social cost implies that a central bank policy of partial collateralisation will never be a dominant strategy.
three alternative cases: (i) perfect monitoring; (ii) imperfect monitoring; and (iii) imperfect monitoring with tiering spillovers.

3.1 Case 1: Perfect monitoring and agent-specific collateral costs

In this case, we assume that monitoring reveals default states with certainty, and allow for banks A and C to face different opportunity costs of posting collateral.

We solve the model by backwards induction, applying subgame-perfection as an equilibrium concept. Accordingly, we begin with C’s decision. Consistent with the discussion in Section 2.2.1.1, C faces the expected private costs detailed in (1). To establish expected costs, states of the world are weighted by the probabilities $\varepsilon$ and $\delta$.

\[ (Z, D) : 0 \quad (F, D) : \lambda^C \]
\[ (Z, I) : \min[ M + \delta \lambda^C, \lambda^C ] \quad (F, I) : \min[ M + \delta \lambda^C + e(1-\delta)\lambda^A, \lambda^C ] \]

Comparison of C’s expected costs in (1) immediately reveals that it will always be optimal for C to access the payment system directly if the central bank adopts a policy of zero collateralisation ($\min[ M + \delta \lambda^C, \lambda^C ] > 0$).

In the event that the central bank chooses $F$, we see that $\lambda^C$ constitutes an upper bound for costs under indirect participation. Hence, in this case, C will certainly opt for indirect participation if the inequality in (2) below holds.

\[ \lambda^C > M + \delta \lambda^C + e(1-\delta)\lambda^A \iff \lambda^C > \frac{M}{(1-\delta)} + e\lambda^A \quad (2) \]

If this inequality does not hold, expected costs under $(F,I)$ will equal $\lambda^C$, leaving C indifferent. Again, we assume that, if indifferent, bank C will settle directly.\(^{15}\) It is clear from (2) that C’s choice under full collateralisation will depend on several parameters. In particular, (2) is more likely to hold, and hence C is more likely to participate indirectly, the higher is $\lambda^C$ and the lower are $\delta, M, e$ and $\lambda^A$. Inequality (2) illustrates that, with $\lambda^A < \lambda^C$, C can take advantage of A’s lower collateral costs by choosing to be an indirect member. With $\lambda^A = \lambda^C = \lambda$, this potential efficiency is no longer available and (2) reduces to (3) below, which is less likely to hold.

\(^{15}\) This might be justified if technological costs and the profit component of costs under indirect participation, which are normalised to zero here, exceeded the fixed costs of joining and accessing the payment system directly.
In period 0, the central bank chooses its actions, anticipating the choices C will make in response in period 1. The central bank’s expected (social) costs are given by:

\[
\begin{align*}
(Z, D) : & \quad \delta S \\
(Z, I) : & \quad \min[M + \delta \lambda^C, \lambda^C] \\
(F, D) : & \quad \lambda^C \\
(F, I) : & \quad \min[M + \delta \lambda^C + e(1 - \delta)\lambda^A, \lambda^C]
\end{align*}
\]

It is important to note that social and private costs are equivalent in all cases with the exception of when uncollateralised exposure is retained (and hence there is some probability that social default costs are suffered) – i.e., the case with \((Z,D)\). No externality exists under \((Z,I)\) as A fully absorbs the shock of any default by C. This assumption will be relaxed later. Given that C will choose to participate directly if the central bank chooses Z, the central bank will compare expected social costs under \((Z,D)\) with those under C’s optimal response to a policy of full collateralisation. If (2) holds, the relevant comparison is with expected costs under \((F,I)\); if (2) does not hold, the relevant comparison is with expected costs under \((F,D)\).

Depending on whether (2) holds, the central bank will choose zero collateralisation if either \(\delta S < \lambda^C\) or \(\delta S < M + \delta \lambda^C + e(1 - \delta)\lambda^A\) (whichever is relevant, given parameter values); and full collateralisation otherwise.\(^{16}\) Intuitively, then, ceteris paribus, zero collateralisation and direct participation by C is more likely, the lower the probability that C defaults and the social costs associated with default; the higher the opportunity cost of posting collateral for either (or both) A and C; the lower the cost of monitoring; and the lower the probability of internalisation.

### 3.1.1 A graphical illustration

It is instructive to illustrate agents’ choices graphically, so as to draw out their important determinants and identify potential sources of divergence of public and private interests. Charts 3 and 4, below, trace private and social costs with varying \(M\), for given values of \(\lambda^A, \lambda^C, S, \delta\) and \(e\).

Chart 3 presents a case with a high degree of internalisation (a 90% probability that payments will be internalised). It is clear that, with zero collateralisation, C will choose direct participation; and, with full collateralisation, C will prefer indirect participation for all values of \(M\) up to the threshold \(X\) shown in the chart. Thereafter, direct participation will be chosen. Given these responses, the

\(^{16}\) It is worth noting that, under full collateralisation, the central bank’s and C’s expected costs are the same.
central bank will choose full collateralisation: it is clear that the social cost of the combination \((Z,D)\) is higher than that associated with C’s optimal choices under full collateralisation, for all \(M\).

However, this is not the socially optimal outcome. It is clear from the chart that \((Z,I)\) would maximise social welfare for all values of \(M\) shown. However, this first-best outcome is unachievable because C makes its choice after the central bank, and \((Z,D)\) offers lower private costs for all \(M\). Hence, under such a scenario, there is a wide interval of monitoring costs within which it seems that policy intervention might be justified to steer the market towards the socially optimal outcome of indirect participation when the central bank chooses not to require that credit extensions be collateralised. However, it should be recognised that this initial scenario has perfect monitoring and no tiering risks/spillovers, which, as we will show, will leave \((Z,I)\) socially preferred for a narrower range of monitoring costs, if preferred at all. Also, we have assumed that A faces no risk of an exogenous default shock and hence the central bank’s credit extension to A is, in this scenario, riskless.

**Chart 3: High degree of internalisation**

\[ \lambda^C = \lambda^A = 0.0015; S = 1.1; \delta = 0.0015; e = 0.1 \]

Chart 4 presents a scenario with a low default probability. Here, the lowest expected private cost for C is again associated with the combination \((Z,D)\). Under full collateralisation, C would prefer indirect participation for values of monitoring cost up to threshold value \(X\); above these values direct participation would be optimal. Given C’s responses, and the low default probability in this scenario, the central bank would choose full collateralisation for values of monitoring cost up to
threshold value $W$. Beyond this point, the central bank would favour zero collateralisation. Interestingly, social and private preferences are aligned beyond $Y$ in this case, reflecting $C$’s low default probability and hence the relatively low social costs associated with outcome $(Z,D)$. Below $Y$, however, the first-best outcome $(Z,I)$ is again unachievable, although the caveats noted above remain relevant in this regard.

**Chart 4: Low default probability**

\[
\lambda^C = \lambda^A = 0.0015; S = 1.1; \delta = 0.00075; e = 0.5
\]

3.1.2 The profile of payment system participation in the UK

The UK experience is consistent with the broad predictions of the model as stated above. The key stylised facts in the UK are that the Bank of England requires full collateralisation of intraday credit extensions\(^{17}\); and a sub-set of banks (the UK-owned banks) face very low opportunity costs of collateral due to the fact that assets held to meet prudential regulatory requirements can be used to back intraday liquidity needs. Furthermore, correspondent banking is extremely highly concentrated, and becoming more so, with just three banks providing the bulk of these services. Thus, a high degree of internalisation takes place.\(^{18}\)

These correspondent banks are all UK-owned, and hence all benefit from, and offer, a low opportunity cost of collateral. Foreign-owned banks therefore have a strong incentive to participate

\(^{17}\) Such an intraday credit policy is adopted by most G10 central banks, although some notable exceptions do exist, in particular the Federal Reserve who charge an explicit fee on intraday overdrafts.

\(^{18}\) It is thought that upwards of 20% of sterling large-value payments are internalised across the accounts of correspondent banks.
indirectly, taking advantage of a high $\lambda^C - \lambda^A$ and a low $e$ (i.e., a high degree of internalisation).

The trend towards concentration in correspondent banking is thus largely self-fulfilling, particularly to the extent that economies of scale exist in monitoring. And, with the three large correspondent banks in the UK all major banks with diversified businesses, it is likely that they also have better access to their customer banks’ private information through other business lines than would smaller banks, and hence can offer a ‘cheaper’ correspondent service. Thus, despite the UK’s role as an international financial centre and a high foreign presence in sterling markets, just 15% of daily value flowing through the large-value payment system is represented by the three foreign-owned direct participants.  

3.2 Case 2: Imperfect monitoring and agent-specific collateral costs

The assumption of perfect monitoring in case 1 is perhaps a strong one. In this sub-section, we relax this assumption to allow for Type I and Type II errors in monitoring. That is, with some probability, $\gamma$, bank A fails to ask for collateral and a default occurs (a Type I error); and with some probability, $\phi$, bank A mistakenly identifies a state as a default state, and hence requests collateral unnecessarily (a Type II error). As bank A fails to obtain collateral in some default states, some uncollateralised exposure will be retained in the system under indirect participation. More specifically, when A monitors under full collateralisation and indirect participation, C’s expected private costs are augmented by:

$$\gamma \lambda^C + \gamma \lambda^A$$

The first term in (5) captures the direct collateral cost incurred by C, adjusted for the correspondingly smaller pass-through of A’s collateral costs vis-à-vis the central bank. The second term captures costs imposed upon A, $\gamma$, in the event that C defaults and A is uncollateralised. Under the assumption that A is aware that it will retain uncollateralised exposure $\gamma$ of the time, these costs would be passed on to bank C.

---

19 It is worth noting that in many comparable economies, large value payment arrangements are far less highly tiered. For example in the US the Fedwire system has over 7,000 member banks, and the Japanese large-value payment system BOJ-NET has over 300 members, compared to 15 members of the UK’s CHAPS system and 14 members of the Canadian LVTS system. Several factors might help to explain the structural differences that can be observed between countries. In some jurisdictions authorities have made greater efforts to encourage wider membership of large value payment systems, either through imposing a specific regulatory requirement, applying moral suasion, or subsidising the cost of such payment arrangements. In addition the impact of prudential liquidity requirements in encouraging concentration is not relevant in a number of jurisdictions. Finally, some countries have historically always had highly concentrated banking systems (this is true of the UK) while in others highly fragmented banking arrangements are observed.
But, of course, with (5) strictly positive when $\lambda^C > \lambda^A$, it is less likely that A’s correspondent service with monitoring will entail a lower cost to C than direct participation with full collateralisation; that is, it is less likely that (6) below will hold.

$$\lambda^C > M + (\phi + \delta - \gamma)\lambda^C + e(1 - (\phi + \delta - \gamma))\lambda^A + \gamma$$

Imperfect monitoring therefore has significant implications for both private and social costs under each of the policy/participation states involving indirect participation. As it has the effect of increasing costs, indirect participation is less likely than in case 1.

More formally, bank C’s expected costs under the four possible strategy pairs become:

$$(Z, D): 0$$

$$(F, D): \lambda^C$$

$$(Z, I): \min[ M + (\phi + \delta - \gamma)\lambda^C + \gamma, \lambda^C ]$$

$$(F, I): \min[ M + (\phi + \delta - \gamma)\lambda^C + e(1 - (\phi + \delta - \gamma))\lambda^A + \gamma, \lambda^C ]$$

It remains the case that, under zero collateralisation, C will choose direct participation. With the imperfection in monitoring, however, it becomes less likely that indirect participation with monitoring will be a low-cost outcome and hence more likely that C’s costs under $(F, I)$ will be equivalent to those under $(F, D)$. Hence, given that, if indifferent, C will participate directly, $(F, D)$ is more likely to be favoured.

The central bank faces the following expected social costs:

$$(Z, D): \delta S$$

$$(F, D): \lambda^C$$

$$(Z, I): \min[ M + (\phi + \delta - \gamma)\lambda^C + \gamma, \lambda^C ]$$

$$(F, I): \min[ M + (\phi + \delta - \gamma)\lambda^C + e(1 - (\phi + \delta - \gamma))\lambda^A + \gamma, \lambda^C ]$$

As before, it is known that C will choose to participate directly if Z is chosen and with $(F, D)$ now more likely to be favoured by bank C in the event that the central bank chooses strategy $F$, the most relevant comparison may well be between expected social costs under $(Z, D)$ and $(F, D)$. Also, given that the costs associated with indirect participation and monitoring are higher in this scenario, the (unachievable) $(Z, I)$ outcome is likely to be the socially preferred outcome for a much smaller interval of values for $M$ (if, indeed, socially preferred at all).
The foregoing has an interesting and important implication. In particular, given that A is more likely to resort to costly full collateralisation when monitoring is imperfect and there is a risk of retaining uncollateralised exposure, the potential efficiency benefits associated with delegated monitoring are lost. Hence, it would appear that welfare could be improved if the banks accessing the system directly and providing correspondent banking services were ‘better monitors’ - i.e., they had better skills or better information in this regard, which ensured that both $\phi$ and $\gamma$ (and particularly the latter) were low. To the extent that monitoring quality is improved when banks are large and diversified and hence have better access to private information, this implies that such banks should be encouraged to participate directly and to provide correspondent banking services.

Chart 5 illustrates that imperfect monitoring creates a smaller range of monitoring costs for which C will choose to be an indirect participant (the threshold value of M moves from Y to X) and shows that the effect of better monitoring would be to narrow the horizontal distance between the perfect and imperfect monitoring thresholds. Case 3, however, offers a qualification to this conclusion where tiering imposes a spillover.

**Chart 5: The impact of imperfect monitoring**

$$\lambda^C = \lambda^I = 0.0015; S = 1.1; \delta = 0.0015; e = 0.5; \phi = 0.00075; \gamma = 0.0005$$

3.3 **Case 3: Imperfect monitoring and spillovers under indirect participation**

In the model, as presented in cases 1 and 2, indirect participation introduces no spillover risk to the payment system, or to the wider economy. Indirect participation is an equilibrium choice for C only when the central bank adopts a strategy of full collateralisation; thus, even if C were to default with A uncollateralised, there would be no disruption to payments in the system and no spillovers.
We do, however, allow for the possibility in (7), under \((F,I)\), that C’s default could impose costs on A, with an expected value of \(\gamma\). While A seeks compensation from C for these expected losses (by passing through the expected cost), an actual loss of 1 unit would be suffered in those states of the world in which default occurred. This could cause liquidity, or even solvency, problems at A which might spill over into the system more widely.

While we do not explicitly model the channels by which losses might be transmitted under such a scenario, we can attempt to capture possible spillovers by introducing an additional ‘tiering risk’ term, \(T\), to expected social costs under indirect participation. By definition, \(T\) is an externality, and hence will not be internalised by C or A. It might be interpreted as reflecting the potential that A fails to fully internalise the risk that a failure of C will trigger A to suffer liquidity or solvency problems that could have knock-on effects on the financial system. In addition it might capture the potential that A fails to internalise the risk that operational problems to itself would disrupt C’s payments.

Expected social costs under \((Z,I)\) and \((F,I)\) in (8) thus become:

\[
(Z, I): \text{If } \lambda^C > M + (\phi + \delta - \gamma)\lambda^C + \gamma, \text{ then } M + (\phi + \delta - \gamma)\lambda^C + \gamma T \quad (9)
\]

\[
(F, I): \text{If (6) holds, } M + (\phi + \delta - \gamma)\lambda^C + e(1 - (\phi + \delta - \gamma))\lambda^A + \gamma T; \text{ otherwise, } \lambda^C
\]

Allowing for this tiering externality, a wedge is introduced between social and private costs under full collateralisation and indirect participation (illustrated in Chart 6). Specifically, there exists a range of monitoring costs, between X and Y in the diagram, in which \((F,I)\) is preferred to \((F,D)\) for C, but \((F,D)\) is preferred to \((F,I)\) for the central bank. That is:

\[
\Sigma + \gamma T > \lambda^C > \Sigma + \gamma \quad \text{where } \Sigma = M + (\phi + \delta - \gamma)\lambda^C + e(1 - (\phi + \delta - \gamma))\lambda^A \quad (10)
\]

The range of monitoring costs for which (10) holds is increasing in \(T\). However, we know from (6) that, for C, \((F,I)\) is only likely to be preferred to \((F,D)\) for low values of \(\gamma\). For larger values, the costs associated with indirect participation and monitoring would exceed those associated with full collateralisation. Hence, it would never be optimal for indirect participation to be chosen by C. This limits the potential incidence of tiering externalities, and hence the potential impact of \(T\).

Nevertheless, the existence of this wedge indicates that there might be a role for additional policy intervention to mitigate tiering externalities.
Indeed, up until now we have worked with the value of C’s payment obligation normalised to unity. Generalising this, by allowing C’s payment to take the value, $P$, we can capture the policy implications associated with payment system participants of different ‘sizes’. In particular, we find that the interval of monitoring costs over which social and private incentives under full collateralisation are misaligned is increasing in the value of payments. That is, for a given error in monitoring, $\gamma$, and a given degree of spillover, $T$, higher payment values lead to higher potential uncollateralised exposures and hence potentially greater social losses.

More formally, bank C’s and the central bank’s expected costs under full collateralisation are given by equations (11) and (12), respectively. In these expressions, we assume that monitoring costs are invariant with respect to $P$, but recognise that total collateral costs and spillover costs will, ceteris paribus, be increasing in step with the value of payments. Hence, as $P$ increases, the expected cost schedules shift upwards.

**Bank C:**

$$(F,D): P \lambda^C$$

$$(F,I): \min \{M + P[(\phi + \delta - \gamma)\lambda^C + e(1 - (\phi + \delta - \gamma))\lambda^A + \gamma], P\lambda^C \}$$

---

20 This assumption seems reasonable, although one could argue that a bank’s monitoring intensity might increase when the size of its potential exposures was greater.
Central Bank:

\[(F, D) : p \lambda^C \]

\[(F, I) : \text{If } M + P[(\phi + \delta - \gamma)\lambda^C + e(1 - (\phi + \delta - \gamma))\lambda^A + \gamma] < P\lambda^C, \text{ then } M + P[(\phi + \delta - \gamma)\lambda^C + e(1 - (\phi + \delta - \gamma))\lambda^A + \gamma T]; \text{ otherwise, } P\lambda^C \]

Chart 7, drawn in an analogous fashion to Chart 6, illustrates the implication of increasing payment values, or increasing size of payment system participants. Note the difference in the scales of the two Charts, reflecting the fact that, with a ‘high P’, expected costs are scaled up significantly. The important observation from Chart 7 is that the interval X-Y covers a much wider range of monitoring costs and hence tiering spillovers may be a much more significant policy concern when ‘large’ payment system participants settle indirectly.

**Chart 7: The impact of tiering risk with high payment value**

\[\lambda^C = \lambda^A = 0.0015; \delta = 1.1; e = 0.5; \phi = 0.00075; \gamma = 0.0005; T = 1.4; P = 5 \]

3.3.1 Policy alternatives

As a result, policymakers may wish to consider policy options that either reduce the size of the wedge, or encourage large payment system participants to settle directly. A number of policy options might be considered in this regard.
First, banking supervisors might consider more stringent ex ante capital and/or liquidity regulation to encourage correspondent banks to internalise the externalities associated with intraday credit extensions to indirect payment system participants.

Second, steps might be taken to ensure the quality of monitoring carried out by correspondent banks, perhaps via improved accounting and disclosure standards for financial institutions.

Third, direct participation might be encouraged by efforts to reduce either the quantum of liquidity required to effect payments in the system; or the opportunity cost of collateral faced by prospective direct members. The liquidity burden might be addressed by introducing a more liquidity-efficient payment system design; e.g., introducing queuing or netting algorithms, or allowing certain payments to be settled on a deferred net basis. And collateral costs might be lowered by broadening the eligible collateral list to include less liquid assets; or allowing greater fungibility of collateral across borders or across systems.21 Were such measures to be successful in encouraging direct participation of large and diversified banks that enjoyed superior access to private information and were such banks to then offer correspondent banking services, this might also ultimately achieve an improvement in monitoring quality.

4 Conclusions

The model developed in this paper can be used to examine the key factors influencing both an agent’s decision over whether to participate directly in a payment system and a central bank’s decision as to whether to require collateralisation of intraday credit extensions to payment system participants.

Consistent with the existing literature in this area, we show that a central bank will be more likely to require full collateralisation of intraday credit when participants have high default probabilities, or face low collateral costs. However, a contribution of this paper is to show that, for full collateralisation to be a rational policy choice for the central bank, it is only necessary that a subset of agents have low collateral and monitoring costs; other agents can take advantage of these low costs if they become indirect participants.

We also find that internalisation is likely to make indirect participation more attractive under full collateralisation. This suggests that economies of scale exist in correspondent banking and implies

21 A more extreme policy option might be to simply compel certain payment system participants to settle directly. However, even if these banks were required to open settlement accounts with the central bank, could they be compelled to actually use them?
that significant concentration is likely to be observed in the provision of correspondent banking services (particularly where a subset of agents faces particularly low collateral posting costs). And to the extent that economies of scale also exist in monitoring, one would expect a gravitation towards the larger, cheaper service-providers. Collateral pooling benefits, which we do not model here, are also likely to support such concentration.

The model’s predictions are, prima facie, consistent with UK experience, with full collateralisation, a high degree of indirect participation, and significant concentration in correspondent banking all key features of the UK landscape. Although the model does not capture legal and operational risks, and hence the full implications of internalisation, our model can go some way towards offering some policy guidance as to whether such a profile of participation is desirable.

Given that the agent’s and central bank’s decisions are taken sequentially, we show that, under certain circumstances, the first-best outcome might not be achievable. In particular, we find that zero collateralisation and indirect participation might be optimal for a range of monitoring costs, but that, if the central bank chooses zero collateralisation, the agent will always find it privately optimal to access directly. We do show, however, that zero collateralisation and indirect participation is likely to be socially optimal for a smaller range of monitoring costs as monitoring becomes less perfect.

When we allow for both imperfect monitoring and tiering spillovers, a wedge also emerges between private and social choices under full collateralisation. In particular, we show that there will exist a range of monitoring costs in which the bank will prefer to participate indirectly under full collateralisation, while the central bank would prefer direct participation. While we do not model the precise channels by which such spillovers arise, we can draw some broad policy conclusions in this regard.

In particular, we show that the key determinants of the size of this wedge will be: the error in monitoring; the magnitude of any spillover, reflecting both the size of exposures arising through correspondent banking and the spillover per unit of exposure; and the cost of collateral if participating directly. This implies that policy to reduce the size of the wedge should be directed towards: (i) ensuring the capacity of correspondent banks to absorb either capital losses or liquidity shocks arising from the failure of a customer bank, perhaps via enhanced ex ante solvency and/or prudential regulation; (ii) encouraging correspondent banks to improve monitoring quality; and (iii) facilitating a low opportunity cost of posting collateral for all prospective payment system members.

Our analysis could be improved by a more complete and sophisticated treatment of the interaction between payment system participants and the provision of payments services. For example, with just one agent making choices and a single payment made, we cannot address the implications of factors...
such as collateral pooling, or the intraday liquidity management game. And, with the direct members A and B playing only a passive role in this model, we cannot assess the risk they bring to the system, and hence cannot perform a complete welfare analysis. Finally, a more detailed analysis of tiering spillovers would be useful, in order to refine our policy conclusion that such spillovers should be addressed in regulatory design.
References


Green, E, ‘The Role of the Central Bank in Payment Systems’, *this volume*.


Previous DNB Working Papers in 2007

No. 124 Andrew Hughes, Rasmus Kattai and John Lewis, Early Warning of Just Wise After the Event? The Problem of Using Cyclically Adjusted Budget Deficits for Fiscal Surveillance

No. 125 Kerstin Bernoth, Juergen von Hagen and Casper de Vries, The Forward Premium Puzzle: new Evidence from Futures Contracts

No. 126 Alexandra Lai, Nikil Chande and Sean O’Connor, Credit in a Tiered Payments System

No. 127 Jean-Charles Rochet and Jean Tirole, Must-Take Cards and the Tourist Test

No. 128 James McAndrews and Zhu Wang, Microfoundations of Two-sided Markets: The Payment Card Example