

Optimal settlement rules for payment systems

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Abstract

We construct a model with which we study the optimality of two alternative payment systems: a deferred net settlement (DNS) and a real-time gross settlement (RTGS) payment system. Our model provides a plausible explanation for why many countries have moved from traditional DNS systems to less risky RTGS systems. In particular, we posit that historically the transfer of funds from one institution to another was very costly, and so a DNS system was the most efficient and potentially the only feasible payment system. However, as these costs have been reduced with advances in technology, while risks posed by settlement failures have simultaneously grown, we argue that RTGS systems have become feasible and even welfare superior. Given this, we argue that there could be a public policy case for a central bank to coordinate the adoption of real-time gross settlement in its country's large-value payment system.

1 Introduction

Payments are transfers of value between agents. For all payments that are not made in cash, finalisation of payment occurs separately to the exchange of goods and will involve a payment system: a specification for when and how the actual funds are delivered consisting of a settlement asset, credit arrangements, infrastructure and rules. Indeed, Zhou (2000) defines a payment system as a “contractual and operational arrangement that banks and other financial institutions use to transfer funds to each other”. Such systems support a vast amount of economic activity. For example, on an average day CHAPS Sterling, the United Kingdom’s large-value payment system, processes about 110,000 transactions with a total value of around £200 billion, about 20% of the United Kingdom’s annual gross domestic product. Given this, problems in a payment system could affect the functioning of the financial system and in turn the wider economy. As part of their role in ensuring the stability of their financial systems, central banks ‘oversee’ a number of payment systems with the goal of assessing and, if necessary, reducing the amount of risk that they bring to the financial system.⁽¹⁾

Historically, interbank payments have been settled via end-of-day deferred net settlement (DNS) systems. As the volume and value of interbank payments passing through such systems increased rapidly in the 1980s and 1990s, central banks became increasingly concerned about the risk that stemmed from such systems. In particular, where payments are credited to customer accounts before being finally settled, credit exposures can build up and a failure of one participant in the system can then lead to the failure of other participants in the system. At the same time as these exposures were becoming larger, advances in IT meant that it became increasingly technologically feasible to settle payments gross and in real time (Fry *et al*, 1999). Since doing this eliminates credit risk from a payment system, central banks increasingly favoured real-time gross settlement (RTGS) as the settlement rule within their countries’ large-value payment systems. In particular, in 1995 Switzerland and the United States were the only major countries relying on RTGS systems for their large-value payments. The Bank of Japan, which had offered both DNS and RTGS systems, switched to only offering RTGS in the late 1990s; in the United Kingdom, CHAPS switched to settling payments on an RTGS basis in 1996; and EU central-bank-administered, wholesale, systems have operated as RTGS systems since 1997.

But, RTGS systems can be more costly than DNS systems. In addition, to the higher (albeit relatively low these days) IT costs involved in setting up and running such systems, RTGS systems are ‘liquidity hungry’ relative to DNS systems. That is, participant banks require more liquidity to settle their payments in an RTGS system than in a DNS system. In turn, this liquidity is costly as when banks do not have it to hand, they will need to borrow. To a degree, central banks can mitigate

⁽¹⁾ For more on the Bank of England’s roles and responsibilities in the area of payment systems, see Bank of England (2005).

this cost by providing intraday liquidity at low cost – typically free so long as it is collateralised – but, even then, this liquidity will still carry an opportunity cost. So, it is not at all clear that moving from a DNS to an RTGS payment system is necessarily welfare improving. Indeed, in a comparison of the costs of secured net settlement on CHIPS – at the time a DNS system – to those of an otherwise equivalent RTGS system Schoenmaker (1995) concludes that “the estimated extra cost of RTGS exceeds the estimated reduction in settlement risk”.⁽²⁾

Furthermore, Selgin (2004) argues that the ‘credit risk’ between banks in DNS systems used as a justification for imposing RTGS does not exist. He argues that this is because a bank is only exposed to the risk of another bank failing to meet a net obligation in a DNS system if it credits customer accounts before settlement occurs, something it does not actually have to do. In addition, such customer credits can typically be reversed in the event of settlement not taking place. Therefore, Selgin argues, all agents involved face the right incentives to manage these risks and there is no market failure in payment systems. As a result, he suggests that the imposition of RTGS, where the market had settled on a DNS system, must be welfare reducing.

The purpose of this paper is to construct a model within which we can examine the trade-off between cost and risk in payment systems. While the current model is too stylised to be carefully parameterised, we hope to identify the crucial parameters of an economy that will determine both when these systems are feasible and which system is socially optimal.

To that end, we consider a banking economy in the spirit of He, Huang and Wright (2005), ignoring theft as a motive for banking and instead focussing on the case of interest-bearing deposits. Moreover, we introduce into the He, Huang and Wright model two possible payment systems, and endogenise the choice of payment system for both buyers and sellers. Incorporating this creates a framework within which we can analyse the given payment system as an equilibrium outcome of the economy. In particular, in our model the end recipients of payments placed through a DNS system are exposed directly to the possibility of default by the banks of the payees. Interestingly, this is where Selgin (2004) suggests the credit risk in DNS systems lies. Unlike Selgin, we argue that because of the existence of multiple equilibria the economy would not necessarily settle on the social optimum or, in other words, there may be a case for government intervention to move the economy’s equilibrium from one with a DNS payment system to one with an RTGS payment system.

We start by considering an economy in which a DNS equilibrium exists and first show that if the costs of using an RTGS system are too high, then there will not be an equilibrium in which agents use an RTGS system. We think of this economy as representative of a time when IT had not developed to the extent to allow RTGS to occur at an economical price. We also show that if these costs become low enough an RTGS equilibrium will exist, in addition to the DNS equilibrium. We

⁽²⁾ The Clearing House Interbank Payment System (CHIPS) is a private payment system operated by the New York Clearing House. At the time of Schoenmaker’s work it was a DNS system; as of 2001 settlement happens almost continuously.

think of this economy as representative of developed economies in the early 1990s. Finally, we show that if the costs of RTGS are low enough relative to the costs of DNS, the equilibrium in which all agents use the RTGS system generates a higher value of social welfare than that in which all agents use a DNS system.⁽³⁾

Since our model cannot handle dynamics and, in particular, the endogenous decision to move from one equilibrium to another, we cannot handle the question of which equilibrium – RTGS or DNS – will be selected by agents in the economy. We would argue that historically, DNS was the only system that could be used in equilibrium and that we have now moved to a situation in which either a DNS or an RTGS system could be used in equilibrium. Further, we would argue that we have moved to a position in which the RTGS system is welfare dominating. If this intuition is correct, then there would be a role for a public authority – such as a central bank – to act as a co-ordinator ensuring that agents selected the welfare-superior RTGS equilibrium, just as they did in the early to late 1990s in many countries.

The paper is structured as follows. Section 2 outlines the model we use and section 3 discusses equilibria within the model. Section 4 compares welfare over regions of the parameter space within which both DNS and RTGS equilibria exist showing that we can find a critical value for the costs of the RTGS system below which the RTGS equilibrium welfare dominates the DNS equilibrium. Section 5 offers conclusions and suggestions for future work.

2 The model

We begin by describing a simple random matching model of money that we use as a platform for our analysis. In the economy there is a unit continuum of infinitely-lived agents. A proportion $M \in [0,1]$ of agents are each endowed with one indivisible unit of fiat money. Agents produce and consume indivisible goods. In each period, agents are randomly and anonymously matched with one another. In any pair-wise meeting, a double coincidence of wants occurs with zero probability. Single coincidence meetings, where one agent wants the other's good but not vice versa, occur with probability x . Given the absence of any double coincidence of wants, the only feasible trades involve the exchange of one unit of money for one good. In any single coincidence meeting, the buyer receives utility u while the seller incurs cost of production c .

2.1 Banks

We build on this simple random matching model of money by allowing agents either to hold money in the form of cash or to deposit it in a bank. Banks are modelled in the same way as in He, Huang and Wright (2005) and, in particular, are perfectly competitive. An agent deposits his money at a bank with probability θ and pays a fee ϕ , which is derived from the setup of the banking sector.

⁽³⁾ While in this paper, we assume the existence of a cost-risk trade-off between RTGS and DNS, this is derived from first principles in Lester (2005).

Banks face a fixed cost, a , for managing each account. Banks also make loans, L , to agents without money but must retain a fraction α of deposits (D) as reserves. We denote the measure of agents holding their money as cash as M_0 and the measure of agents holding either cash or having a bank account as M_1 (total money supply). So $L + M = M_1$ and $D + M_0 = M$. Banks charge an upfront fee, ρ , for loans. This fee can be interpreted as a coupon payment, $r\rho$, each period.

2.2 Settlement

Whether an agent chooses to hold his money in the form of cash or a bank deposit has implications for when money is transferred between buyers and sellers. To capture this we assume that each period is divided up into two sub-periods. Trade between agents takes place during the first sub-period, which we refer to as the morning. If a buyer uses cash, money is transferred between the buyer and the seller in the morning since cash changes hand at the point of sale. If a buyer makes a payment to a seller from his bank account, the money has to be transferred via an inter-bank payment system.⁽⁴⁾ When inter-bank payments are received depends on the rule in place governing how payments are settled. Payments are settled in the morning if they are made through a real-time gross settlement (RTGS) payment system and are settled in the afternoon if they are made through a deferred net settlement (DNS) payment system.

The timing of the settlement process would be irrelevant if there is perfect commitment among banks, as there is in He, Huang and Wright (2005). Agents would simply choose the cheaper of the two settlement rules as money is transferred from the buyer's bank to the seller's bank before the next trading sub-period with certainty. However, the timing of the settlement process is crucial if there is a possibility of bank insolvency between when trading occurs and when the transfers of money are completed. Sellers may fail to receive funds altogether or receive them only at a cost if a bank becomes insolvent before the settlement of payment occurs. We introduce the possibility of bank default into the model by assuming that there is an exogenous risk that each bank could become insolvent and consequently default on any outstanding payment obligations it may have. Banks can become insolvent between the morning and the afternoon in every period. We assume that there is full deposit insurance implying that depositors face no costs as a result of bank default. In the following morning, their money is transferred to accounts at new banks that replace the insolvent institutions. Any default situation is resolved and sellers receive their money but only at a cost. The expected per payment cost incurred by a seller is ω . This cost represents a deadweight loss to the economy.

Sellers are not exposed to default risk when they receive an RTGS payment because they receive a payment before a buyers' banks can become insolvent. But reducing the lag between trade and settlement comes at a cost. First, there exist bureaucratic costs to settling every transaction more

⁽⁴⁾ We assume that although a seller may not already have a bank account when a buyer offers to make a payment from his bank account, he will open an account if he agrees to receive money in this way. The seller pays a fee for holding a bank account in the following period when he is buyer.

promptly. Moreover, a higher frequency of settlements requires banks to hold larger amounts of idle reserves, thereby decreasing the revenue earned per unit of money deposited. Finally, some banks will also be forced to borrow from the monetary authority or enter the inter-bank market in order to obtain sufficient reserves to complete settlement of all of their customers' transactions. These additional costs will result in customers facing higher fees in a perfectly competitive banking sector. The cost of making RTGS payments is captured by a cost κ that is levied on all bank accounts in proportion to the amount of RTGS payments made.

In a single coincidence meeting, the buyer proposes how he wishes to pay for the seller's good. The seller then chooses between accepting a payment through these means and not trading. Trade does not take place if they cannot agree. Trade always occurs when a buyer offers to pay in cash because a seller incurs no cost and is exposed to no risk when receiving cash. If a buyer offers to make a payment from his bank account, he offers to make an RTGS payment with probability $1 - \beta$. As with cash, a seller accepts an RTGS payment with probability one since there is no cost or risk to him from receiving a payment this way. A buyer offers to make a DNS payment with probability β . A seller accepts a DNS payment with probability σ . Therefore, trade takes place in a single coincidence meeting, when the buyer wishes to make a payment from his bank account, with probability

$$P(\beta, \sigma) = (1 - \beta) + \beta\sigma \quad (1)$$

It also follows that the ex ante expected cost to a bank of providing payment services is

$$K(\beta) = (1 - \beta)\kappa \quad (2)$$

This implies that the per-period fee that each (perfectly competitive) bank charges a customer for providing deposit services is

$$\phi(\beta) = a - (1 - \alpha)rp + (1 - \beta)\kappa \quad (3)$$

2.3 Bellman equations

We can now derive the Bellman equations for the value of being a buyer holding cash, V_m , the value of being a buyer who has a bank deposit, V_d , and the value of being a seller, V_0 . These are shown in equations (4)-(6).

$$rV_0 = (M_0x + (M_1 - M_0)xP(\beta, \sigma))(V_1 - V_0 - c) - (M_1 - M_0)x\beta\sigma\omega \quad (4)$$

$$rV_m = (1 - M_1)x(u + V_0 - V_1) + V_1 - V_m \quad (5)$$

$$rV_d = (1 - M_1)xP(\beta, \sigma)(u + V_0 - V_1) + V_1 - V_d - (1 + r)\phi(\beta) \quad (6)$$

where $V_1 = \max\{V_m, V_d\}$ is the value of being a buyer prior to the decision of whether or not to deposit his money in the bank.

The first component of equation (4) is the gains from trade enjoyed by a seller multiplied by the probability of meeting someone to trade with in any given period. The second component is the expected cost of failing to receive a DNS payment times the probability of accepting a DNS payment. The first part of equation (5) is the gains from trade enjoyed by a buyer times the probability of trading in a given period when he offers to make payments in cash. The first component of equation (6) is the same except that it represents the gains from trade times the probability of trading when a buyer deposits his money in a bank and makes payments from his account. The second component of equation (6) is the fee paid by a buyer for depositing his money in the bank.

3 Equilibrium analysis

In this section we examine equilibria in our model in which all money is deposited in banks; i.e. $V_1 = V_d$, $M_0 = 0$ and $M_1 = M / \alpha$. Therefore, a buyer's Bellman equation is

$$rV_1 = (1 - M_1) \alpha P(\beta, \sigma)(u + V_0 - V_1) - (1 + r)\phi(\beta) \quad (7)$$

We restrict attention to pure strategy equilibria where either DNS payments are always accepted or RTGS payments are always accepted. We then compare the conditions under which each type of equilibrium exists.

There is a (pure-strategy) equilibrium if the following conditions hold:

Individual rationality; the value of being a seller or a buyer is at least as good as leaving the market and living in autarky:

$$V_0 \geq 0 \quad (8)$$

$$V_1 \geq 0 \quad (9)$$

Incentive Compatibility; A seller has an incentive to produce his good in exchange for one unit of money and a buyer has an incentive to trade his unit of money for one unit of the good:

$$V_1 - V_0 \geq c + \beta\sigma\omega \quad (10)$$

$$u \geq V_1 - V_0 \quad (11)$$

Banking constraint: Agents choose to deposit money in a bank.⁽⁵⁾

$$\phi(\beta) \leq 0 \quad (12)$$

The buyer's individual rationality constraint holds if the seller's individual rationality constraint and the buyer's incentive compatibility constraints are both satisfied. Thus, we only need to derive the conditions under which equations (8) and (10)-(12) hold.

From equations (4) and (7), and the fact that $\rho = V_1 - V_0$ in equilibrium,⁽⁶⁾ we can derive the following expressions for the values of being a buyer and of being a seller, respectively:

$$rV_0 = \frac{M_1 x P(\beta, \sigma) [(1 - M_1) x P(\beta, \sigma) u - (1 + r)(a + (1 - \beta)\kappa)]}{r(\alpha(1 + r) - r) + xP(\beta, \sigma)} \quad (13)$$

$$- \frac{M_1 x [(1 - M_1) x P(\beta, \sigma) + r(\alpha(1 + r) - r)] [P(\beta, \sigma)c + \beta\sigma\omega]}{r(\alpha(1 + r) - r) + xP(\beta, \sigma)}$$

$$rV_1 = \frac{[r + M_1 x P(\beta, \sigma)] [(1 - M_1) x P(\beta, \sigma) u - (1 + r)(a + (1 - \beta)\kappa)]}{r(\alpha(1 + r) - r) + xP(\beta, \sigma)} \quad (14)$$

$$- \frac{M_1 x [(1 - M_1) x P(\beta, \sigma) - r(1 + r)(1 - \alpha)] [P(\beta, \sigma)c + \beta\sigma\omega]}{r(\alpha(1 + r) - r) + xP(\beta, \sigma)}$$

We use equations (13) and (14) to derive ranges of parameter values for which there exists an equilibrium in which there is trade and all payments are made via DNS ($\beta = \sigma = 1$) and there is an equilibrium with trade when all payments are made via RTGS ($\beta = 0$). The ranges of values of x and a for which there exist such equilibria are illustrated in Charts 1-4. In each chart, the dashed line represents the seller's individual rationality and incentive compatibility conditions. These conditions hold for values of x that are sufficiently high relative to the value of a that (x, a) lies to the right of the dashed line. This is because the value of being a seller is increasing in the probability of meeting an agent to trade with (x) but decreasing in the cost of operating a banking account (a). The dashed line is upward sloping since when a rises, sellers must be compensated by an increase in x for their individual rationality and incentive compatibility conditions to still hold. The solid line represents

⁽⁵⁾ The probability that trade occurs equals one in any single coincidence meeting when we restrict attention to pure-strategy equilibria. Thus, the only difference between holding money as cash and depositing it in the bank is the banking fee. Buyers have incentives to deposit money in banks as long as they receive a return from doing so; i.e. the banking fee is negative. This is why equation (12) is the necessary and sufficient for agents to choose to deposit money.

⁽⁶⁾ It is not feasible for all agents without money to borrow from a bank because then there would be no sellers. So in equilibrium, the loan market clears at a rate at which sellers are indifferent between remaining a seller and borrowing. They are indifferent when the cost of borrowing ρ is equal to the difference between the value of being a buyer and the value of being a seller, $V_1 - V_0$ (He *et al*, 2005).

the banking constraint. This condition is met for values of x that are sufficiently high relative to the value of a because the banking fee is only negative if the cost of operating an account (a) is low enough compared to loan market rate (ρ). The loan market rate is increasing in the gain from moving from being a seller to a buyer, which is obviously increasing in the probability of trading (x). It follows that the solid line is upward sloping.⁽⁷⁾ The grey, highlighted, areas show possible equilibria.

Chart 1 shows the DNS equilibrium. RTGS equilibria are shown in Charts 2-4. The charts show that the range of parameter values for which there exists an RTGS equilibrium grows smaller the more costly is RTGS (i.e., the higher is κ). When κ is high enough there does not exist an RTGS equilibrium (see Chart 4).

Historically, κ was very high and hence, trade was only possible if payments settled on a deferred net basis (Chart 4). It is likely that the value of κ has fallen over time (say, with improvements in information technology). This means that an equilibrium in which payments settle on an RTGS basis is possible in addition to one in which they settle on a DNS basis (Charts 2 and 3). Further reductions in κ would expand the range of parameter values for which there exist both RTGS and DNS equilibria. However, when there exist both DNS and RTGS equilibria, social welfare may be higher in one than in the other. We discuss the welfare properties of the two settlement rules in the next section.

Chart 1: DNS equilibrium

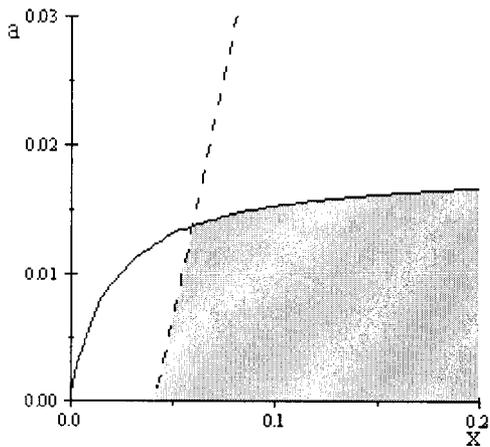
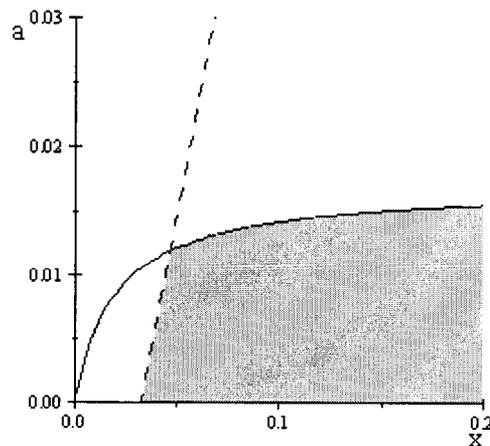


Chart 2: RTGS equilibrium ($\kappa = 0$)



⁽⁷⁾ For the parameter values we use, the buyer's incentive compatibility condition holds for all values of x and a .

Chart 3: RTGS equilibrium ($\kappa = 0.005$)

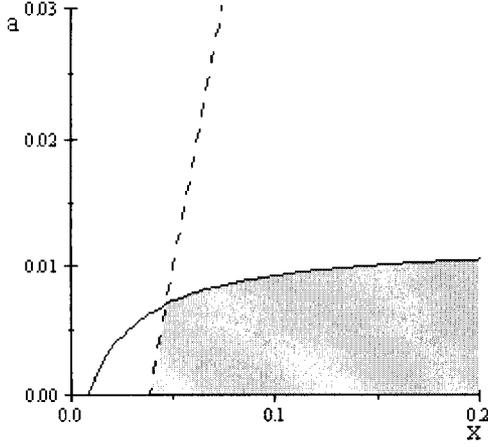
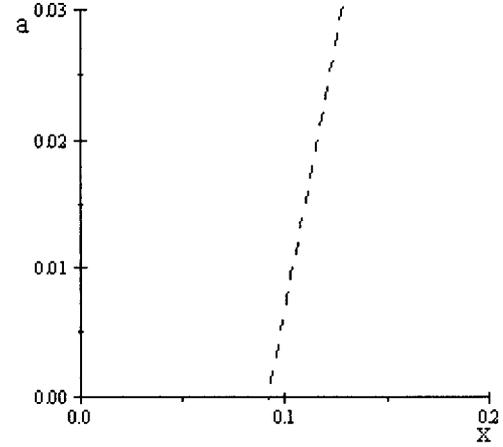


Chart 4: RTGS equilibrium ($\kappa = 0.05$)



Note: The charts are drawn for $M = 0.5$, $\alpha = 0.7$, $u = 5$, $c = 2$, $\omega = 0.003$, $r = 0.02$.

4 Welfare

In this section we will analyse the level of social welfare under the two settlement rules. We will identify the (positive) values of κ and ω under which one of the settlement rules has superior welfare properties. Social welfare, W , is defined as the average of the value of being a buyer and the value of being a seller:

$$W = M_1 V_1 + (1 - M_1) V_0 \quad (15)$$

The social planner chooses whether payments settle on a DNS or RTGS basis to maximise W subject to agents' individual rationality constraints, incentive compatibility constraints and banking constraint.

In terms of values of κ and ω , there exists a DNS equilibrium if $\omega \in [\omega_1, \omega_2]$, where $\omega \geq \omega_1$ ensures that the banking constraint holds and $\omega \leq \omega_2$ ensures that the seller's individual rationality and incentive compatibility conditions hold. The values of ω_1 and ω_2 are

$$\omega_1 = \frac{(r+x)a - rx(1-\alpha)[(1-M_1)u + M_1c]}{rM_1x(1-\alpha)}$$

$$\omega_2 = \frac{(1-M_1)xu - (1+r)a}{(1-M_1)x + r(\alpha(1+r) - r)} - c$$

There exists an RTGS equilibrium if $\kappa \leq \min\{\kappa_1, \kappa_2\}$, where $\kappa \leq \kappa_1$ ensures that the banking constraint holds and $\kappa \leq \kappa_2$ ensures that the seller's individual rationality and incentive compatibility conditions hold. The values of κ_1 and κ_2 are

$$\kappa_1 = \frac{rx(1-\alpha)[(1-M_1)u + M_1c]}{r+x} - a$$

$$\kappa_2 = \frac{(1-M_1)xu - [(1-M_1)x + r(\alpha(1+r) - r)]c}{1+r} - a$$

It is straightforward to show that

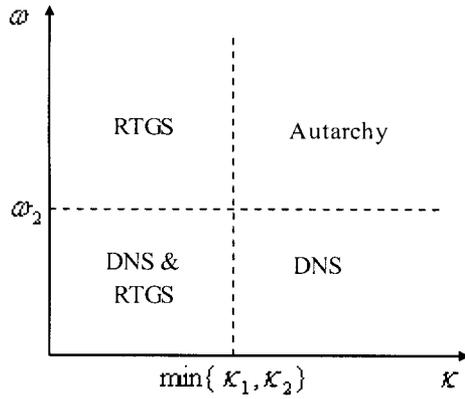
$$\kappa_1 \geq (<) \kappa_2 \quad \text{if} \quad \frac{(1-M_1)x}{r+(1-M_1)x} u \leq (>) c$$

When c is relatively low, the relevant constraint on κ is the banking constraint; the cost of settlement must be sufficiently small so that banks can continue to pay interest on deposits. Alternatively, when c is relatively high, the relevant constraint are the seller's incentive constraints because κ must be sufficiently small that a seller finds its profitable to produce and trade.

Before comparing welfare levels under either settlement rule, note that we can ignore the constraint $\omega \geq \omega_1$ because of the fact that $\kappa_1 \geq 0$ implies $\omega_1 \leq 0$. In other words, if the banking constraint can be satisfied under RTGS for a positive value of κ it will definitely be satisfied (not bind) under DNS. The banking constraint is satisfied under RTGS as long as the gains from trade enjoyed by a seller are sufficiently high relative to the cost of RTGS. Under DNS, there is no cost from the using this settlement rule and there is also an additional benefit to the seller of not facing the cost ω in the following period. It follows that if the banking constraint can be satisfied under RTGS the banking constraint will not bind under DNS.

Chart 5 depicts the different equilibria that can occur for different values of κ and ω . Both the DNS and the RTGS equilibria are possible when the costs of default and the costs of making payments on an RTGS basis are low enough that $\omega \leq \omega_2$ and $\kappa \leq \min\{\kappa_1, \kappa_2\}$. When ω exceeds ω_2 , but $\kappa \leq \min\{\kappa_1, \kappa_2\}$, there exists an RTGS equilibrium but no DNS equilibrium. There is a DNS equilibrium but no RTGS equilibrium when $\omega \leq \omega_2$ and $\kappa > \min\{\kappa_1, \kappa_2\}$. Finally, if both costs are sufficiently high, there is neither a DNS nor an RTGS equilibrium.

Chart 5: Existence of DNS and RTGS equilibria



When a DNS equilibrium and an RTGS equilibrium both exist, welfare is not unambiguously higher under one of the settlement rules than under the other, so it is possible that a welfare-inferior equilibrium arises.

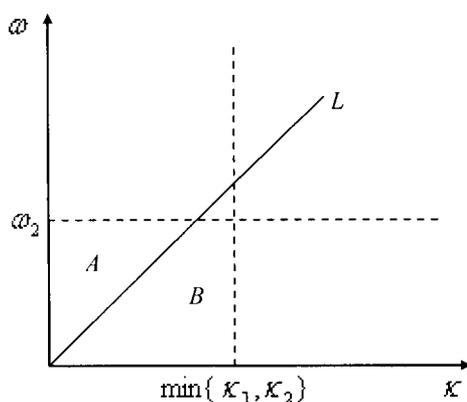
Welfare is the same under either settlement rule if the expression in equation (17) holds.

$$\omega = \frac{(1+r)(r+x)}{x[r(\alpha(1+r)-r)+(1-M_1)x-rM_1]} \kappa \quad (17)$$

When $\kappa = 0$ (that is, RTGS is costless) welfare is the same under both settlement rules only if DNS is also cost free ($\omega = 0$). Thus, the locus of values of κ and ω for which welfare is the same under either settlement rule passes through the origin and divides the area in which both a DNS and an RTGS equilibrium exist into two.⁽⁸⁾ Welfare is higher under RTGS above the locus (region *A*) and is higher under DNS below the locus (region *B*). The locus is depicted in Chart 6.

⁽⁸⁾ The locus is upward sloping because the value of being a buyer (V_1) is decreasing in the production cost (c) and the cost of default (ω).

Chart 6: Welfare



This result shows that when both settlement rules can occur in equilibrium, agents may choose to use DNS when RTGS is socially optimal or they may choose to use RTGS when DNS is socially optimal. However, as we argued in the previous section, over time the value of κ is likely to decrease; eventually, it is likely to become sufficiently small that welfare is higher under RTGS. Indeed, we would argue that we have moved to just such a position. If this intuition is correct, then there would be a role for a public authority – such as a central bank – to act as a co-ordinator ensuring that agents selected the welfare-superior RTGS equilibrium, just as they did in the early to late 1990s in many countries.

In summary, when trade can occur under either of the two settlement rules there may be a case for public policy in replacing one settlement rule with the other.

6 Conclusions and future work

In this paper we have constructed a model for examining the trade-off between cost and risk in DNS and RTGS payment systems. The model showed that when the costs of settling payments on an RTGS basis are high, only a DNS equilibrium can exist. The opposite is true when the costs of default are high: only an RTGS equilibrium can exist. Either settlement rule may hold in equilibrium for intermediate values of costs. We argue that historically, DNS was the only system that could be used in equilibrium and that we have now moved to a situation in which either a DNS or an RTGS system could be used in equilibrium. We suggest that there could be a role for public policy in helping agents coordinate upon the RTGS equilibrium if it produces higher social welfare.

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