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Abstract: Foreign exchange transactions are subject to a unique type of settlement risk. This risk ultimately stems from the difficulty of coordinating separate settlements in two different currencies. Settlement of foreign exchange transactions through the proposed CLS ("Continuous Linked Settlement") Bank has been discussed as a potential solution to this problem. This paper describes the CLS proposal and analyzes the incentives it places on banks engaged in foreign exchange transactions. The analysis shows that while settlement through the CLS Bank may represent an improvement over current arrangements, some important problems associated with foreign exchange settlements will remain.

JEL classification: G20, F31

Key words: foreign exchange, settlement risk

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Please address questions regarding content to Charles M. Kahn, Department of Finance, University of Illinois, Urbana, Illinois, or William Roberds, Research Department, Federal Reserve Bank of Atlanta, 104 Marietta Street, N.W., Atlanta, Georgia 30303, 404-521-8970, 404-521-8956 (fax), william.roberds@atl.frb.org.

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When foreign exchange transactions fail to settle, commercial banks can suffer major losses. While settlement failures are rare, they lead to significant disruption when they occur. Thus improvements to the system are also of interest to central banks, concerned with the size of their potential liabilities as "settlement guarantors" under the current arrangements (see Bank for International Settlements 1993, 1996, 1998).

The arrangements for settling foreign exchange transactions may undergo a major transformation in the coming year. In 1997, a group of major commercial banks established CLS Services, Limited, to develop a new centralized system (see Bank for International Settlements 1998 and CLS Services Limited 1998). Under the system, foreign exchange trades in major currencies would be settled through the CLS (Continuous Linked Settlement) Bank, a special-purpose bank chartered in the U.S.

Not only will this arrangement involve a private entity in a role heretofore taken on by central banks, it will also introduce a mechanism for settlement which is different in several important ways from current techniques.[1] Given the significance and the scale of the potential changes, it is important to understand how the arrangement will alter the risks of participation in foreign exchange markets.

In this paper, we describe the major provisions of the CLS arrangement and develop a series of simple models of bank incentives and settlement risk that can be used to analyze the CLS proposal. Unlike previous descriptions of the legal and technological

[1] It should be noted that even after CLS becomes operative, some foreign exchange transactions may continue to be settled through traditional channels, although the common expectation is that within a few years, most transactions will be settled through CLS.

aspects of the proposed arrangement, this paper focuses on the incentives the arrangement provides for the participants.

We find that, while settlement through the CLS Bank represents an improvement over current arrangements, it leaves several problems associated with foreign exchange settlement untouched. The system also leads to some complex selection effects: On the one hand, some of the advantages of the system are likely to encourage its rapid adoption, since they will prove most attractive to the strongest financial institutions. On the other hand, in comparison with current arrangements, the system discourages monitoring of counterparty quality. The analysis also points to new issues which central banks will have to address in dealing with the new system.

1. Background

The market for foreign exchange is the world's most active financial market, turning over an estimated $1.5 trillion daily. By way of comparison, the daily trading volume in the U.S. Treasury market averages about $227 billion, and the New York Stock Exchange turns over about $29 billion per day. The FX market has also grown quite rapidly in recent years, its dollar-equivalent nominal volume expanding roughly 11 percent annually since 1989.[2]

[2] FX trading volume is the daily average volume reported by Bank for International Settlements (1999) based on a global survey conducted in April, 1998. This figure is adjusted for double counting. Today most foreign exchange trades are not spot trades but "forex swaps." A forex swap combines a spot trade with a later spot trade in the opposite direction of the original trade. The risks associated with the settlement of swaps are similar to those associated with the settlement of spot trades.

The market for foreign exchange is also exceptional in other respects. Compared to most securities markets, it is loosely organized, with the bulk of trading occurring in the decentralized "interdealer" market.[3] Unlike most developed financial markets, it has no centralized mechanism for settling trades. This is at least partly due to the nature of what is being traded: A typical "spot" foreign exchange trade, for example, consists of a commitment from two parties to deliver "good funds" to each other by the end of the second business day following the trade. Thus, a typical spot FX transaction is actually an exchange of short-maturity forward commitments. Settlement of each side or "leg" of a trade is governed by the respective laws and institutions of the two nations whose currencies are involved. In practice this means that separate settlements are required in each currency.[4]

Standard FX trading agreements call for banks to "irreversibly" commit to settlement on the day following the trade (Bank for International Settlements 1996, 1998), but such commitments cannot be honored in all states of the world. Suppose for example, that on day t Bank A sells yen to Bank B in return for dollars, and that on day t+1, both A and B commit to deliver yen and dollars, respectively. If, however, Bank A fails before it delivers yen to B, then A's commitment to settle might not be honored. Nor do existing arrangements always allow Bank B to back out of its commitment to deliver dollars to A, even in cases where B knows of A's default before it has sent any dollars to A.

[3] On the organization of the foreign exchange markets, see Lyons (forthcoming).

[4] In the tradition of the international finance literature, the term "currency" refers to bank deposits denominated in a given country's currency.

An obvious question that arises is why settle FX trades in this fashion? For example, why not settle trades immediately, or at least on the same day as the trade? Clearly, if the funds are needed immediately then it useful to have them sooner rather than later. The shallow answer to such questions is that the present legal and operational infrastructure would not allow for such changes in the settlement process. Over the longer run, the necessary infrastructure could be put in place, but doing so would entail certain costs (see for example, Noël 1994). Accelerating settlement would require streamlining trade confirmation procedures and more precise management of settlement funds. Also, if certain FX settlements are seen as "too big to fail" and therefore implicitly guaranteed by central banks, accelerating settlement would effectively shorten the maturity of banks' default "option" and thereby lessen the value of these guarantees.

As a practical matter, however, the deadline by which funds are needed can likely be forecasted sufficiently far in advance that existing techniques for cash management can be used to minimize the associated risks. Thus the delay may not be a major consideration. The CLS system is focused instead on the benefits that arise from a reduction in counterparty risk, i.e., the risk that one of the parties to a trade may not settle. Counterparty risk will be a small consideration in any individual transaction, but may become significant when aggregated over a system as a whole.[5]

Situations in which settlement does not occur because a bank cannot honor its obligations fall into two categories: The first category is operational failure resulting from

[5] That is, the likelihood of any individual counterparty being unable to settle is usually quite small, but as the number of trades increases, settlement failures become more likely. The presence of a large number of interconnected trades also increases the probability that a settlement failure by one trader could result in a more costly sequence of settlement failures.

say, a natural disaster or a computer crash. The second category is bank "failure," including (more typically) closure by a regulator. From the viewpoint of the defaulting bank's counterparties, the problems associated with failures are exacerbated by the inability to cut off settlement of one leg of the transaction when the other leg does not settle.

The possibility of bank failure in the course of settlement is not simply a theoretical issue. Failures occur frequently enough for them to be a concern both to regulators and to participants. An important case of settlement problems stemming from bank failure occurred in June 1974, when bank regulators closed a German bank, Bankhaus Herstatt, at the end of the German business day (mid-morning in New York). A number of Herstatt's counterparties in foreign exchange transactions had settled their Deutschmark obligations to Herstatt, in anticipation of offsetting dollar settlements. The dollar settlements could not be made once Herstatt had been declared insolvent, resulting in a loss of principal for Herstatt's counterparties.[6]

Today, it is common to refer to the risk that foreign exchange transactions will not be settled as "Herstatt risk," although this name has sometimes given the misleading impression that settlement failures can only be caused by a bank's inability to settle. In fact, settlement failures can result when either or both counterparties are able, but simply unwilling, to settle their leg of the transaction. For example, the 1990 collapse of Drexel Burnham Lambert resulted in a severe liquidity crisis for one of its London subsidiaries,

[6] See the "Allsopp report" (Bank for International Settlements, 1996) for additional details of the Herstatt episode. In cases of bank failure, unsettled obligations may or may not be offsetting depending on the laws of the country where the failure occurs; see Bank for International Settlements (1992). As a general principle, however, it is better to be a debtor rather than a creditor of a bankrupt.

Drexel Burnham Lambert Trading (DBLT). DBLT had been active in foreign exchange markets and came under severe liquidity pressure as problems became apparent with its parent group. Fearing default by DBLT, its counterparties became less willing to honor their obligations to DBLT. At the same time, DBLT was reluctant to pay amounts due to its counterparties, for fear that the counterparties would not settle the other leg of the foreign exchange transaction, but instead offset any funds received from DBLT against outstanding debts that had been incurred by other DBL companies. Central banks feared that withholding of these settlements could have resulted in a "gridlock" scenario, in which DBLT and its counterparties (and potentially its counterparties' counterparties) might have all withheld settlements, despite the fundamental solvency of everyone involved.[7]

In the absence of a real-time or coordinated system for settling trades, settlement in foreign exchange markets has been supported by banks' belief in their mutual creditworthiness. In some cases, as in the Herstatt episode, settlement failures have occurred and losses have resulted. In other instances, central banks have intervened to prevent settlement failures, out of concern for the systemic or "knock-on" effects of a settlement failure. In the case of the DBLT, for example, a facility was set up whereby the Bank of England, in coordination with other central banks, guaranteed that neither DBLT nor its counterparties would "take the money and run." The current system for settling foreign exchange transactions thus poses difficulties both for market participants and for central banks.

[7] Again see Bank for International Settlements (1996) for more information on the DBLT episode, as well as for other examples of settlement failures or near-failures.

2. Policy Responses and the CLS Proposal

Regulatory interest in the area of FX settlement was spurred by the 1991 failure of the Bank of Credit and Commerce International (BCCI). BCCI's failure resulted in losses of principal for at least two of its FX counterparties (Bank for International Settlements 1996) and prompted interventions by several central banks (George 1994). The "Noël Report" (Bank for International Settlements 1993; see also the discussion in Noël 1994) provided the first extensive discussion of policy tradeoffs in the area of FX settlement risk. It suggested that central banks needed to find some way of coordinating settlements across currencies through the actions of a "common agent," but did not provide a detailed plan for how such an arrangement would work. At the same time, two private-sector groups, Multinet (Glass 1994) and Echo (Duncan 1994), advanced their own initiatives for controlling FX settlement risk. Both schemes involved both within-currency netting of settlement obligations and coordination of settlements across both legs of a given FX transaction.

The successor to the Noël Report, the "Allsopp Report" (Bank for International Settlements 1996), strongly endorsed the development of additional private-sector initiatives for the coordination of settlements across currencies. The Allsopp Report was widely interpreted as a regulatory warning that FX market participants should assume a more proactive role in managing settlement risk (see, e.g., Davidson 1996, Sesit 1996, or Marjanovic 2000). In response, a group of commercial banks began development of a more comprehensive system for coordinating settlements through CLS. In December 1997, Multinet and Echo were formally merged with CLS Services.

Under the CLS proposal, foreign exchange trades would be settled through a private intermediary known as the CLS Bank. Settlement through the CLS Bank will differ from today's settlement practices along a number of dimensions.[8] Below, we analyze and compare settlement risks in the present, decentralized system and in the centralized system being developed by CLS. We do this by presenting some of the issues involved in the context of stylized examples. Subsequent sections focus on the incentive effects of CLS in both bilateral and multilateral situations.

Examples and Details of the CLS Procedures

We will illustrate the key features of CLS through a series of examples. The first example focuses on the basics of the CLS system's "payment-versus-payment" feature, which is the centerpiece of the new arrangement. The second shows the main aspects of the system's overdraft facilities, and in particular how the system mitigates the risks associated with the use of overdrafts. The third example focuses on the way that the system economizes on the use of central bank funds in settlement through "quasi-netting."[9]

Example 1. On day *t*, Bank *A* needs $1 million dollars and is willing to sell yen to get it. Bank *B* needs ¥100 million and is willing to sell dollars. Suppose that the exchange

[8] Description of the CLS settlement procedure can be found in CLS Services Limited (1998) and Roscoe (1998). Some information is also available at the CLS website: www.cls-services.com. Since the scheme is not yet in operation, some details presented in this paper will undoubtedly change during implementation.

[9] In the examples below, all banks are assumed to be able to directly settle their own accounts. It should be noted that under the proposed CLS system, only the largest and most creditworthy institutions will have direct access to settlement via the CLS Bank.

rate is $1.00 = ¥100. What is the normal procedure by which *A* and *B* trade dollars for yen? Today the standard arrangement would be for a trader for Bank *A* to contact *B* with a request to buy $1 million dollars. Say *B*'s trader agrees to the trade at a price of $1.00=¥100. In effect the trade is an exchange of promises to deliver "good funds" in the appropriate currency, two business days hence.[10] The first pair of accounts in Table 1 shows the situation after the agreement is made on date *t*. At some point during day *t*+2, Bank *A* is obligated to send ¥100 million to *B* over FEYCS (the Japanese large-value payment system used to settle the yen legs of foreign exchange transactions). Likewise, Bank *B* is obligated to send $1 million to *A* over CHIPS (the corresponding large-value system for settling dollar legs) at some point during *t*+2.[11] As illustrated in Table 1, we suppose that the yen transaction happens to be executed first. In most cases, both funds transfers occur and the trade is settled. However, there is a "coordination problem," under current arrangements. For instance, if Bank *B* is closed down by regulators before its funds are sent to Bank *A*, then Bank *A* suffers a capital loss. On the other hand suppose it is Bank *A* that is shut down early on date *t+2*. Then Bank *B* is likely to suffer a capital loss even if the shut down occurs before any settlement takes place, since it is difficult or impossible for either bank to cancel its leg of transaction, should it learn of the failure of its counterparty.

<Insert Tables 1&2 about here>

[10] To ensure that no mistakes have been made there is a confirmation process the next day.

[11] CHIPS is a private system operated by the New York Clearing House Association. Some dollar settlements are also made through Fedwire, the large-value payment system operated by the Federal Reserve.

Now consider settlement of the same transaction under the system proposed by CLS. Suppose Banks *A* and *B* are both members of CLS; for illustrative purposes, assume that no other transactions take place on day *t*. Once the two banks have verified the transaction, each notifies the CLS of their intent to settle. The deadline for such notification is midnight the day before the settlement (i.e., the end of day *t*+1). On the morning of day *t*+2, each CLS member is required to make payments on its short positions. For the moment we will assume that the payments required are equal to the full value of the short position; we will consider more complicated cases later. Table 2 illustrates the process. The initial position on date *t*+1 is the same as in the previous case. Each bank begins by making a payment of its short position to CLS. These payments are made on the central bank RTGS systems. Once CLS has both currencies available to it, settlement is effected on the books of CLS, by moving funds between accounts. After that, the currencies can be sent out to the banks.

As example 1 shows, the key feature of the new arrangement is that there is never a point at which one leg is settled and the other is not. In this sense, CLS is a "payment-versus-payment" (PvP) system. Under CLS, final settlement of each side of a transaction is simultaneous and mutually conditional. Under the current arrangement there is an instant where one bank (Bank *A* in Table 1b) has paid out funds to its counterparty but not received funds in return. At this point, Bank *A* is a creditor of Bank *B* and therefore vulnerable to a failure by Bank *B*. By contrast, at no point in the process in Table 2 is either bank a net creditor of the other. Under CLS, if Bank *B* fails at any instant before settlement, the transaction does not go through, and the funds paid in by Bank *A* are

returned to Bank *A*. If Bank *B* fails at any instant after settlement, it is of no concern to Bank *A*. After settlement, Bank *A* has no remaining financial links with the failed institution, all such links having been transformed into links with the CLS Bank.

Of course at that vulnerable point Bank *A* is instead a creditor of CLS until the time when CLS sends the payments to Bank *A*. For this situation to be an improvement over current arrangements, it must be the case that the CLS bank is a better counterparty than any individual bank. But this is indeed the case. In this simple example, the CLS Bank is never the creditor of any bank and therefore is invulnerable to failures of other banks. Note the importance to the CLS arrangement of the finality of payments on RTGS systems. Since the CLS Bank's assets are simply "good funds," not "due froms," they don't disappear in the event of the disappearance of the bank paying them in.

The extreme safety of the arrangement described in example 1 stems from the fact that full pay-in by both sides occurred before settlement. In some circumstances, the CLS proposal will allow settlement to occur before all net funds have been paid in.[12] Example 2 examines the case where settlement takes place with only a small initial pay-in.

<Insert Table 3 about here>

Example 2. As before, but suppose that initially Bank *B* pays in $1 million or 10% of its due-to position in its short currency, and Bank *A* pays in a corresponding amount: ¥10 million (changes in bank balance sheets are indicated in Table 3). As before,

[12] Payment, on the other hand cannot be completed until all participants pay-in all net amounts due in each currency. (Again, care must be taken to distinguish between settlement and payment. In this context, from the point of view of a participating bank, "settlement" means substitution of the CLS Bank's "due from" for the initial counterparty's "due from." "Payment" means substituting central bank funds for the CLS Bank's "due from.")

settlement occurs by transferring the required balances between the sub-accounts of the two banks on the books of CLS: ¥100 million from Bank *A*'s yen sub-account to Bank *B*'s yen sub-account and $1 million from Bank *B*'s dollar sub-account to bank *A*'s dollar sub-account. Now, however, these transactions leave overdrafts in a sub-account for each of the banks. Once the pay-ins are completed, the situation is the same as in the earlier description, and pay-out can proceed safely. But until pay-in is completed, the system is vulnerable again to a failure by either of the banks. For example, if Bank *B* fails before completing its pay-in, CLS Bank will owe Bank *A* $1 million but will only have $100,000 in good funds.

Although CLS permits member banks to have overdrafts during the day, it places several sorts of limits on the overdrafts. A transaction will not be settled if it causes either bank to exceed its overdraft limits; instead both legs of the transaction will be held in a queue to await inflows of funds to the bank's account.

Moreover, in order to handle the possibility of a failure by a bank with an overdraft, the CLS arrangement includes a back-up provision. The CLS Bank will hold lines of credit with a set of "liquidity providers," who agree to provide the funds that CLS needs to cover settled transactions. There are two features of the CLS arrangement that should make it possible for the CLS Bank to obtain these lines of credit at small cost: First, there is an upper limit on the amount of liquidity that ever needs to be provided, namely the limit on the overdrafts permitted to the various banks. A transaction will not be settled if it causes either bank to exceed its overdraft limits; instead both legs of the transaction will be held in a queue to await inflows of funds to the bank's account.

Second, although a bank is permitted an overdraft in individual currency sub-accounts, its net position across all currencies in its account must be positive. Again, CLS Bank is never in the position of being an overall creditor to any bank. Thus the event of the failure of Bank *B* does not adversely affect the value of the CLS Bank.

These arguments demonstrate why the liquidity providers should regard the CLS Bank as carrying no credit risk. But why should the CLS Bank be satisfied with the reliability of its liquidity providers? Indeed, who are these liquidity providers? They turn out to be the owners of the CLS Bank—that is, none other than the member banks themselves. Might the protection offered by them be illusory? There are two counter arguments: first it is the group of liquidity providers as a whole that provides protection to the CLS bank against failure of any individual member. Second, the limits on overdrafts under CLS, while explicitly protecting liquidity providers, may also be there to convince any potential additional liquidity providers—including in extreme situations, central banks—of the ultimate safety of any liquidity infusion.[13] To the extent that the participating banks regard the liquidity facilities of CLS as sound, *and* to the extent that the relative value placed on currencies by the participating bank are identical to market values, participant behavior will be unaffected by early settlement.

[13] This discussion should also make it clear that the safety of the CLS Bank from the point of view of liquidity providers depends on the maintenance of several underlying regulatory principles by the relevant American regulatory bodies (recall that the CLS Bank will have a U.S. charter). First, all payments to or from CLS Bank over RTGS systems of the various central banks must be regarded as final. Second, sub-accounts at CLS of a failed bank must be treated as a single netted account. Finally, CLS can not be treated as a "source of strength" to any of the banks owning it.

The principle that a bank's net position over all currencies must be positive becomes even more important once we take into account currency fluctuations. In the absence of exchange rate fluctuations, settlement could begin before the pay-in of any funds, without violating the principle that a bank's net position at CLS must not be negative. With exchange rate fluctuations, the "out-of-the-money party" (at least) must make some pay-in before settlement can begin.[14]

Example 2, continued. Suppose that on day t+1 the value of the yen falls, so that by the close of trading on day t+1, ¥100 is now worth only \$.90, so that Bank *B*'s position vis-à-vis Bank *A* is "out of the money." CLS then calculates the day t+2 settlement schedule as follows. Bank *B* is short dollars so has a minimum initial pay-in obligation of \$1 million − (.90×\$1 million) = \$100,000 or 10% of its due-to position in its short currency.[15]

So far we have dealt with a single payment. In fact pairs of participants in CLS will make large numbers of exchanges during the day, repeatedly swapping currencies back and forth in offsetting or near-offsetting trades.[16] In such circumstances netting arrangements are used to reduce the amount of currency needed to settle the trades. The

[14] In other words, the requirement of a net positive balance plays much the same role as margin requirements under "marking-to-market" in an organized futures market. See e.g., Baer, France, and Moser, (1995), or Moser (2000).

[15] In practice, an additional amount would have to be paid in to provide a "cushion" against additional exchange rate volatility during day t+2.

[16] Such patterns are common in foreign exchange trading. See e.g., Lyons (1997, 1998).

CLS system will also economize on the use of currency through a "quasi-netting" arrangement that avoids some of the undesirable consequences of standard netting.

Example 3. Suppose that Bank *A* buys $2 million from Bank *B* for ¥200 million during the first trade of day *t*, and then buys ¥100 million from Bank *B* for $1 million during the second trade of the same day. As before, assume that the dollar rises to ¥100 = $.90 by the close of trading on day *t*+1, so that each bank's initial pay-in requirement would be the same as in example 2. That is, at the beginning of day *t+2*, Bank *B* is net short $1 million and long ¥100 million, so once again *B* would need to pay in $100,000.

When settlements now occur depends on how large an overdraft the two banks are permitted. For simplicity we will assume that the overdraft each bank is permitted is sufficient to handle each trade. Even so, settlement still cannot take place until the pay-ins are sufficient to ensure that the trade leaves each bank with a net positive balance. Since bank *B* is out of the money $200,000 on the first trade, that trade will not settle until bank B puts a further $100,000 in its account. Once it does, the first trade will settle. Although *A* is out of the money on the second trade, the settlement of the first trade leaves the net position of *A* sufficiently positive to enable the second trade to be settled as well.

Although the trades are settled, the CLS Bank still lacks the funds to make a payout. These must await the pay-in of funds by each of the banks. As those funds appear, payouts are made subject to two restrictions: 1) the CLS Bank can never

overdraw its account with any RTGS system, and 2) all settlement banks' accounts with CLS must remain net positive.

Note the ways that this arrangement is and is not like a netting arrangement. Like netting arrangements, CLS economizes on the use of central bank funds. In the example we have described, the payment process can be completed with each bank paying in only its net position in the short currency. If we had assumed the banks faced more stringent caps on their overdraft positions, the necessary pay-in could have exceeded this net amount, but typically by smaller amounts as the number of transactions engaged in by each bank becomes large.

Nonetheless, in its handling of settlements the CLS arrangement is *not* a netting arrangement. Each trade is settled or not on its own. It would be possible for one trade between the two banks to settle and (either because of subsequent bank failure, or because of operational problems with a pay-in) for another trade not to settle. Payouts on the settled trade become the responsibility of CLS Bank. On the unsettled trades, each bank is returned its initial pay-ins.

3. Payment vs. Payment and Bilateral Incentives

The remainder of this paper uses a series of simple models to explore the incentives on settlement banks induced by the proposed CLS arrangement as compared with existing or potential alternatives. This section of the paper focuses on the basic effects of a payment-versus-payment system. Appendix *A* describes the model underlying this section.

Since CLS is billed as (and is) a method of reducing certain kinds of settlement risks, there is a danger that it will be interpreted in terms of insurance. In fact, if insurance were the goal, it would easy to concoct arrangements more effective than CLS. It has become a commonplace as a criticism of certain payments arrangements that they do not in fact reduce risks, but simply shift them from one party to another. The CLS arrangement does do its share of risk shifting, but it also has interesting effects on participants' behavior. Indeed, CLS is in most respects the opposite of insurance: it reduces the risks by penalizing the undesired behaviors.

We will examine the effect of the CLS system on several types of behavior. The first, and most basic form of behavior we will examine is compliance: a bank's willingness to carry out the pay-ins of the amounts they have promised. In any payment system with a prayer of survival, compliance must be the norm. The decision to cancel a trade only occurs in extreme circumstances (financial distress, operational failures), since the consequences are severe, including possible loss of future ability to trade. But these are the sorts of circumstances that matter for the design of a system. The payments system arrangements determine how extreme the circumstances must become before the bank fails to comply. A social planner will likewise prefer that in some exceptional circumstances the trade (or possibly one leg of the trade) not go through,[17] although there may be a difference between private and public calculations of when cancellation is desirable.

[17] As a response to Herstatt risk, "Central Bankers are not generally keen on 'one strike and you're out' arrangements," according to Clementi (1999) – implying that, at least in some extreme circumstances, non-payment ought to be tolerated.

All of the models we consider have the following structure: Initially two banks agree to make an exchange of currencies. Subsequently either party can cancel (default on) the trade (what this means exactly will vary with the arrangement) but it is not possible to modify the terms in any way.[18] This seems a reasonable modeling of the situation. There are fixed costs to each act of establishing a trade and to each act of canceling a trade. Situations inducing firms to cancel their payments are rare and non-replicable and central authorities have limited time to respond. Thus, it is natural to assume that the mechanisms allow only a single message (cancel/don't cancel) from each agent and consequently only four (2x2) possible responses to their behavior.

In this framework the fundamental difference between the current arrangement and a payment-versus payment (PvP) system like CLS is this: under a PvP system, if a bank does not pay in, it cannot receive the payments from the counterparty. Under the current system, receipt of counterparty payments is independent of the pay-in decision, because it depends only on the *other* party's decision. In other words, the CLS system requires lower penalties to enforce the same degree of compliance. In the model of Appendix A, compliance under CLS is achieved with zero penalty, while the current system requires positive penalties. In more general situations, holding other penalties constant,[19] the CLS arrangement increases the cost of default and decreases the likelihood of default.

[18] Thus in terms of CLS default corresponds to a decision to cancel the trade after it becomes "irrevocable" (midnight of the day after making the arrangement).

[19] This includes any cost to reputation from a default decision. Implicitly we are holding these non-pecuniary costs constant when comparing regimes. However, this assumption may not be valid: one of the

Now there will certainly be extreme circumstances in which a social planner would prefer that trades not be carried out given some new information arriving at the intermediate period. But in general we might expect that the central planner's goal is to make parties comply more readily. If system administrators would like to increase compliance, but penalties are already as severe as possible, then the CLS arrangements offer a means to improve the situation, by increasing compliance without further increasing penalties. Similarly, if penalties are socially costly to administer, then the CLS arrangement allows the same outcomes to be enforced at lower cost.

Moreover, the model in the appendix shows that for a range of penalties, the current system is subject to coordination failure to which the CLS system is immune. In other words, there can be multiple equilibria to the current arrangement: expectations that counterparties will fail to honor their commitments can be self-fulfilling. By making payments conditional on counterparty behavior, a PvP system reduces this problem.

On the other hand, the CLS arrangement may not be superior to the current arrangements in terms of risk sharing or optimal allocation of currencies. In the case of a unilateral default,[20] under the current system the counterparty's payment goes through; under the CLS system it is stopped. Those considerations might lead a central planner to favor an arrangement that continues to send payments to banks in financial distress or under operational problems, even if those banks are unable to send payments in return.

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effects of CLS may be to make any failure of pay-in more public and thus more costly to reputation (we are grateful to seminar participants at Norges Bank for pointing this out).

[20] It should be noted that the systems also differ in the case of a mutually agreed upon rescission of a transaction: CLS permits this (CLS Services, 1998, p. 13) , but there is no way to allow for it without penalty in the current uncoordinated systems.

In the model, the relevant concern in ranking the two systems is the social costs of penalties under current arrangements, versus the ex post cost of misallocations under CLS.

Individual banks could conceivably prefer the risk sharing arrangements under the current system: True, the CLS system affords insurance against counterparty risk in sense that, if the counterparty defaults, the arrangement will not go through. But in the long run a bank could be either the counterparty of a distressed firm or the distressed firm itself. The symmetry of the situation could make it possible that the current system offers better insurance.

In fact, however, it is unlikely that banks will prefer the implicit insurance embodied in current arrangements. First, limited liability means that a firm that is already in the extreme situation of contemplating defaulting on payments is likely to behave from that point on in a risk loving, rather than a risk averse fashion. A firm is unlikely to desire what is in effect small amounts of ex ante income insurance over such extreme states. Second, even if this insurance were desired, any effects of such a system providing insurance would likely be swamped by the adverse selection characteristics of the arrangements. Once in place, a CLS like system is likely to cream skim the best risk categories, as financial institutions regarding themselves as relatively unlikely ever to choose unilateral default migrate to the system that penalizes them least in the case of a counterparty default.[21]

[21] Finally, to the extent that the participants in the system themselves bear the enforcement costs then the reduction in these costs for similar performance levels will encourage agents to switch to the new system. On the other hand, to the extent that enforcement costs in public arrangements are publicly subsidized, there will be resistance to migration.

In summary, CLS represents an improvement over the status quo because it provides a mechanism for coordinating settlement. Coordination through PvP reduces the need for penalties: it increases the penalty to the defaulting party and reduces the penalty to the party defaulted against.

Although the effects on banks' incentives to default in a crisis are the fundamental feature of the new system, it is also of considerable practical importance to understand the incentives CLS places on a bank to avoid such crises in the first place. The CLS arrangements will impose direct restrictions and requirements on its member banks for managing various sorts of risks, including operations risks. But it is also worthwhile to determine the extent to which the system itself encourages or discourages risk taking by participants.

A simple extension of the model shows that, to the extent that a PvP system puts additional penalties on a bank which does not make its pay-in, the CLS system encourages banks to reduce risks of operational problems or financial distress. On the other hand, since a PvP system reduces the costs of dealing with unreliable counterparties, it encourages banks to take on trades with other banks who would have been excluded from trading under current arrangements. In a two-trader world this is of little concern, since the bank can gauge the costs and benefits of dealing with less reliable counterparties. In a multiparty world, negative effects from the relaxation of standards may be concentrated on third parties. Appendix B outlines an extension of the basic model to illustrate this possibility.

While the design of the CLS arrangement may give its participants an incentive to relax their standards for monitoring counterparty quality, there will still be an interest in

maintaining standards for the system as a whole. In the CLS structure, the responsibility for scrutinizing the quality of counterparties falls on the CLS bank itself, which sets standards for membership. Current standards are rather stringent, e.g., a member must have Tier 1 capital in excess of $1 billion and a BBB+ or better rating of its long-term debt. The question of membership standards is a vexing one for regulators: on the one hand they too have an interest in maintaining the quality of counterparties so as to minimize the chances of settlement disruption. On the other hand the CLS bank may be interested in setting standards higher than those which an efficiency analysis will pose, since restriction of membership will (assuming CLS is successful) be a way of enhancing the profits of the members.

4. CLS and Multilateral Incentives

In this section we describe several additional multilateral examples illustrating other incentive effects of the CLS arrangement. We begin with the simplest case, where burdens of payment failure are shared between the counterparty and other uninvolved traders. The more complex case, where a failure between one pair of traders triggers a second failure, is dealt with only in a preliminary fashion.

Burden Sharing

Our examination of the sharing of burdens of counterparty failure is designed to show the differences between CLS and two possible alternatives: a true netting system and a pure gross settlement system with PvP. By "true netting" we mean a system

incorporating "netting by novation"—that is, one where original obligations are legally replaced by net obligations.[22]

So far we have emphasized how the CLS system resembles a netting system through its economizing on use of currency. It is also important to understand how it differs from a true netting system. There are at least three aspects to this difference. First, in the event of default on one leg of a transaction, the other leg ceases to be an obligation under CLS. In a true netting arrangement, the link between performance in specific pairs of obligations is lost in the new replacement arrangements. Second, CLS avoids the regulatory costs (collateralization requirements and position limits) associated with true netting under the Lamfalussy standards.[23] Finally, CLS differs from the netting arrangements found in many organized futures exchanges, where obligations originally described in terms of delivery of a variety of specific items can all be reduced to and settled for dollar equivalents. This last difference is closely related to the lack of a true spot market for foreign exchange, so we will confine the present discussion to within-currency netting arrangements. The issue of cross-currency netting is briefly addressed in the concluding section of the paper.

Suppose Bank *A* contemplates trading with a counterparty *B* with a known probability of failure. Under a pure PvP system, if the trade fails, the principal is returned. Under a true netting arrangement, all trades are aggregated, and any failure is shared among the surviving parties, through paid-in collateral. Although some arrangements put an additional penalty on the counterparty of the failed institution, in

[22] Under current arrangements netting by novation is only possible within-currency.

[23] The Lamfalussy standards are described in Bank for International Settlements (1990).

general netting arrangements will penalize the counterparty less than a pure PvP system would.

The CLS system would be in effect a pure RTGS system with PvP except for the presence of the overdraft privileges. Because of these privileges, it is possible for an institution to fail after its transaction has settled but before its payment has arrived. In this case the CLS Bank, through its liquidity providers and ultimately its members, bears the costs of the liquidity problem, thereby reducing the cost borne by the counterparty relative to the pure system.

But how do the costs to the rest of the participants under CLS compare with those costs under a pure netting system? That depends on the constraints put on activity in a netting system, but unless the constraints were infeasibly tight, costs to others will be smaller under CLS. First of all, the CLS arrangement limits the liquidity cost to the system as a whole through its limits on overdrafts. A netting arrangement could maintain an equivalent limitation only by imposing a tight limit on positions and a strict collateral requirement—in each case, probably tighter than current netting systems achieve.

To summarize, a pure PvP system encourages trading with risky counterparties more than the current system does. However, since it concentrates the cost of a settlement failure on the individual counterparties, a pure PvP system gives less encouragement than does a true netting system. The CLS system lies between PvP and true netting: the overdraft privileges speed up settlement and reduce the need for currency, but they deflect part of the burden of counterparty default to the system as a whole.

Ex Post Inefficiencies

As we have seen in the two-bank case, the CLS arrangement is more likely to lead to an ex post inferior allocation of currencies, since it stops both legs of a trade. Our next example shows that in multilateral settings this phenomenon is exacerbated, leading to a larger role for central banks in solving ex post coordination problems under CLS.

The traders decide whether to trade in period 0 and whether to default in period 1 under CLS rules. For simplicity we deal with the case of no penalties for default. The central bank does not trade with any bank initially, but may intervene (supplying liquidity ex post) in period 2 if it so wishes. The goal of the central bank is to maximize ex post social welfare, defined as the sum of traders' utilities. In the example we treat dollars as numeraire, with the same value to all holders. Other currencies ex post will can have different possible values to the bank trading them. With a probability near one they will have either a low marginal value $L<1$ or a high marginal value $H>1$ (in each case, relative to dollars). These values are known ex ante, and determine the pattern of planned trade. However with a small probability, these marginal values will be discovered at date 1 to be different, resulting in changes in the desire to trade. Specifically, we consider the consequences of individual firms facing an idiosyncratic shock to its valuations. One natural interpretation of such a shock is financial distress for the individual firm.

There are three traders *A*, *B*, & *C*. Each buys a foreign currency with U.S. dollars and sells another foreign currency for dollars, so each trader has a zero net position in dollars (not an unreasonable scenario since 80-90% of FX trades have a dollar leg). All traders have a MU of dollar consumption equal to unity. Suppose all trades are one for one.

Trader *A* buys euros from *B* and sells pounds to *C*; trader *B* buys Swiss francs from *C* and sells euros to *A*; trader *C* buys pounds from *A* and sells francs to *B*. Initially each trader believes that he will have marginal utility *H* for the bought currency and *L* for the sold currency. Suppose, however, that after the fact it turns out with small probability that any firm finds that its valuations are reversed. These probabilities are independent for each of the firms. For example if it is firm *C* that suffers from this shock, *C* has MU of *H* for francs and *L* for pounds and defaults on his dollar settlement *to A* and franc settlement to *B*. Suppose also that *A* is liquidity-constrained in dollars, so that without the dollar settlement from *C*, *A* cannot settle the trade with *B*.

Note that after the shock *to C* the original sequence of trades still has positive social value equal to $H\text{-}L = 2(H\text{-}L)\text{-}(L\text{-}H)$. Thus there is an incentive for the central bank to step in and settle *C*'s trades, by supplying francs and selling pounds. Even if the central bank places values on these currencies that are the same as *C*'s valuations (the worst possible case) and therefore suffers a loss of *H-L* on the settlement, the total benefit increases.

The basic problem here is that *C* cannot renegotiate with *A* and *B*, once he realizes that he has no incentive to complete the original trade. Since the overall gains to trade are positive, presumably *A* and *B* would be willing to give up some of their gains from trade in order to compensate *C* for his loss. Since there is no practical way of doing this, the central bank finds it optimal to step in and take the loss after the fact. Now if the reversal occurs instead for *A* or *B*, the result is the same. Since simultaneous reversals by two banks are second order small, this completes the analysis.

Note that this phenomenon requires at least three traders. Consider the analogous situation with two traders: *A* and *B*. *A* buys euros from *B* and sells pounds to *B* (if desired, each leg of this trade can be accompanied by a flow of dollars in the reverse direction). Suppose that *A*'s valuations now reverse, so that it is unwilling to complete its trades. The two banks now agree on the valuation of all currencies. If the central bank intervenes to complete the trade with *B,* and its valuations are identical as well, no welfare gain arises.[24]

In contrast, netting arrangements have an advantage in such circumstances (at least from the point of view of a central bank), since they spread the trades themselves and the costs of failed trades on a pro-rata basis, implying a diminished need for central bank intervention to complete desirable trades.

Exchange rate fluctuations

In this section we consider the effects on CLS of exchange rate fluctuations. We use the same example as the previous section, only changing the details of the small probability shock. Suppose the shock takes the following form: the value of a currency (say, pounds) to all traders falls in a proportionate fashion. Specifically, suppose the value of pounds to *C* falls from *H* to *L*, (and falls from *L* still lower for A). Note that it still remains socially desirable to have all trades consummated, since currencies then end up in the hands of traders who value them most. However, while *C* still wishes to

[24] Of course this specific description depends on the fact that the currencies can only take on two valuations. But in a more general formulation with a multiplicity of possible valuations by the traders, the difference between the two and three bank cases continues to hold if we assume the natural (conservative) valuation of currencies by the central bank.

consummate the franc/dollar trade with *B*, he wishes to cancel the pound/dollar trade with *A*.

The first case to consider is the one where bank *C* still prefers consummating both trades to consummating neither.[25] The outcome then depends on the extent to which the two trades are tied.

Under current arrangements, each currency would be transacted on a different facility. The dollar legs of the transaction, once entered into CHIPS, would be subject to netting. However, the two other currency transmissions, going on separate systems, would be subject to the coordination failures described in the earlier sections.

Complete integration would tie all transactions to each other so that they stand or fall as a group. Doing so increases the likelihood of compliance by a participant, since in the money transactions support the trader's willingness to take the out of-the-money transactions. CLS achieves this by making it impossible to selectively repudiate transactions after midnight on day 1.

But there are additional layers to the CLS arrangement which are designed to increase compliance. The pay-in requirements on the short positions are adjusted to reflect the current exchange rate, and to ensure that as the day goes on, the value of the participant's net short position is limited. If the participant values all currencies at their market values, then the CLS arrangement guarantees that the account is "in the money" so that he has no desire to default. The pay-in amounts thus provide additional protection of the system against adverse information that the participants could acquire during the course of the settlement day. The arrangement therefore represents a trade-off between

[25] The alternative assumption reduces the situation to that described in the previous section.

the benefits of economizing on pay-ins through the quasi-netting behavior of "recycling" reserves, and increasing pay-ins to ensure compliance.

5. Conclusion

A characteristic feature of modern payment systems is their capacity to economize on the use of outside money. Through the use of netting and similar techniques, banks and other financial intermediaries can, to a large degree, allow inside money to substitute for outside money in market transactions.[26] The introduction of CLS will open a new avenue to such substitution, by allowing for simultaneous, coordinated settlements in inside funds across different currencies.

Previous descriptions of CLS have tended to focus on the mechanics of the arrangements for payment and settlement. In this paper we have concentrated on a more limited set of aspects in order to focus on participants' incentives under CLS. The payment versus payment arrangement eliminates the risk of loss of principal. The CLS system is not, nor has it been advertised as, a system designed to eliminate the liquidity risk associated with settlement failure. Nonetheless we have shown how the arrangement reduces these risks by encouraging compliance by participants. We have also examined how specific provisions of the arrangement encourage its use relative to existing uncoordinated arrangements.

[26] Green (1999, 2000) has suggested that many innovations in payments systems can best be thought of as an increase in such substitution, as measured by an aggregate "netting ratio" (the ratio of gross to net transactions within an economy).

The idea that "I will give you this valuable object if and only if you give me that valuable object in return" is the essence of what we mean by a spot trade. It is this conditionality, not mere simultaneity, which is the essential feature of CLS. And it is the lack of arrangements for such spot trades in foreign exchange markets which has made them special.

A promise of dollars or pounds from any private party is a slightly different good from dollars or pounds themselves. A currency is good as long as the central bank survives. A promise of a currency from a private party is the same as the currency only in states where the private party honors its promise. Thus in the rarefied world of foreign exchange trading, where even the remote probability of a bank default is relevant to pricing and trade, it becomes important to find a way to exchange pounds for dollars, not just for the mere promise of currencies. But this poses a problem. For the only place that large denominations of a currency exist is on the books of that central bank. Thus coordination of funds transfers would require a higher degree of communication and cross-border cooperation between central banks than present arrangements provide.

We conjecture that if such a spot market existed (imagine for a moment a medieval money changer transported to a stall in present-day London, with billions of dollar, yen and euro notes piled high on his bench), then the additional innovations corresponding to CLS would be relatively minor, and could mirror instead the standard repertory of arrangements in organized futures exchanges, with the posting of margin collateral on netted positions. A similar conjecture might apply if much of today's foreign exchange trades were to be replaced with trades in "contracts for difference." A contract for difference requires one party to pay the other a payment equal to the home-currency

value of the market gain or loss that would have resulted from a foreign exchange transaction (see Bank for International Settlements 1998).

Clearly incentives are fundamental to settlement risk, and central to a regulator's evaluation of a settlement system. And the incentives associated with the decision of whether or not to pay up are clearly the most fundamental incentives that there are, which, together with their simplicity, justifies focusing upon them in this initial analysis of CLS. However, other incentives must also be considered in examining settlement risk: we have briefly considered the inducements that a system gives for risk taking behavior—in particular the extent to which they encourage or discourage increasing the magnitude of foreign exchange activity for a bank, and the degree to which they encourage or discourage monitoring of counterparty quality.

We have also considered in a preliminary fashion, the effects of the CLS arrangement on incentives in a multiparty context. We found that the CLS system lay between pure PvP and netting arrangements in its encouragement of trading with risky counterparties. Compared to netting arrangements it leaves a greater role for ex post intervention by Central Banks to complete uncompleted trades. And the ability of the arrangement to hold completion of some trades by a bank hostage to the completion of other trades also serves to increase compliance. Although these are significant implications of the new arrangement, our analysis has clearly only scratched the surface in investigating CLS in a multiparty context.

Appendix A: A Basic Two-Bank Model

At stage 0, each bank can agree to enter a proposal to make a trade. If both banks agree, then the game begins, and there are two stages to the banks' activities. At stage 1, each bank can choose to make an investment[27] at a cost k. If the investment is made, then one indivisible unit of initial asset arrives with probability $(1 - p)$. If the investment is not made, then there is zero probability of the asset's arrival. The agreement to trade mandates that each bank deliver its initial asset to the other bank, in return for its more preferred asset—i.e., the initial asset of the *other* bank.

The stage 2 decision for a bank is whether to carry out the agreement by delivering the initial asset, or to renege on the agreement by refusing to deliver. (If the asset did not in fact arrive, then delivery is impossible).

Depending on these actions, and on the rules for handling clearing, a bank can end up holding its initial asset, its preferred asset, both, or neither. The following equations define the parameters associated with each holding, $H(x,y)$, where x represents the holding of the initial asset, and y represents the holding of the preferred asset:

$$H(0,0) = 0 \quad (1)$$

$$H(1,0) = c \quad (2)$$

$$H(0,1) = b \quad (3)$$

$$H(1,1) = a \quad (4)$$

where

[27] For some applications it is more natural to consider these investments as reliance investments taken before the agreement is made. For the issues in this appendix, however, no substantive difference arises, and technicalities are avoided by reversing the order.

$$a > b > c > a - b \qquad (5)$$

A bank's total payoff is the sum of *H*, investment costs, if any, and penalties assessed by the clearing mechanism, if any.

The *current arrangements* for clearing and settlement can be described as follows: each party makes a unilateral decision to deliver. A fine is imposed on a party failing to deliver. A *PvP system* can be described as follows: each party makes a unilateral decision to deliver. If one party chooses not to deliver, then neither asset is delivered. For completeness, we include the possibility of a fine assessed for choosing not to deliver in a PvP system as well; let f_c and f_p represent the fines under current arrangements and the PvP system, respectively. Then Table 4 describes payments as a function of various consequences in the subgame after investment has already been made.

<Insert Table 4 here.>

We will assume that the social costs of a penalty are equal to the private costs, so that the social value of the arrangement is the sum of the payoffs to the two banks.[28] Thus it is ex post always socially beneficial for a bank to deliver when (and of course, only when[29]) it receives the initial asset. Also we assume

$$(1-p)\, b > k \qquad (6)$$

so that investment is socially valuable if the asset is then transferred.

[28] I.e., there is complete dissipation of penalties paid by a defaulter.

[29] Non-arrival is simply short hand for a circumstance where delivery becomes prohibitively costly, both privately and socially.

Once the two banks have entered the agreement, there are three pure strategies in the full game: 1) Invest and Deliver, 2) Invest and Renege, and 3) Don't Invest. The payoffs are therefore those given in Table 5.

<Insert Table 5 here>

Elementary calculations demonstrate:

Lemma 1: If

$$f_c \geq (1 - p)(a - b) + p\,c \tag{7}$$

and

$$f_c \geq k/(1\text{-}p) \tag{8}$$

Then there is a Nash equilibrium under current arrangements in which each party invests and delivers. Moreover, given these assumptions, the Nash equilibrium is the unique pure strategy equilibrium if and only if

$$f_c > c \tag{9}$$

Lemma 2: Under the PvP system, it is a Nash equilibrium for each party to invest and deliver for any non-negative f_p. Moreover, if $f_p > 0$ the equilibrium is unique.

Thus the PvP system can be implemented without penalties, while current arrangements require positive penalties. Moreover provided

$$c > k/(1\text{-}p) \tag{10}$$

there is in general a range of penalties over which there will be multiple equilibria under current arrangements.

If we assume instead that

$$c < k / (1-p) \tag{11}$$

then equilibrium is unique under both current arrangements and under PvP. Under this assumption it is not socially valuable to invest unless the asset will be transferred to the other party. Thus the social value of the current arrangement is

$$2(1-p)\, b - 2\, p\, f_c \tag{12}$$

while the social value of a PvP system (assuming zero penalty) is

$$2(1-p)^2\, b + 2\, p(1-p)\, c \tag{13}$$

Since the minimum feasible penalty under the current system is

$$\text{Min } \{(1-p)\,(a-b) + p\, c,\, k/(1-p)\}, \tag{14}$$

the question of which system dominates depends on parameters. As an illustration, let p approach 0. Then if $b\text{-}c > k$, the current system dominates. If the inequality is reversed a PvP system dominates. Roughly speaking, the question boils down to the issue of whether the social costs of the penalties necessary under the current system to maintain incentives are greater than or less than the social costs of the ex post misallocation of assets under PvP.

Appendix B: A Three-Bank Extension (outline)

Label the three banks *A, B,* and *C*. Banks *A* and *C* are as described in the previous appendix with the following exceptions: Bank *A* is "perfectly reliable" –that is, bank *A*'s initial asset arrives with probability 1. We will continue to use 1-*p* for the probability that bank *C*'s initial asset will arrive. However, *p* is now stochastic, with probability distribution *F*(*p*). The realization of *p* is observed by *C*, but not by *A*. For concreteness, we will call *A*'s initial asset "dollars" and *C*'s initial asset "yen."

Clearly in a two-bank world trade between *A* and *C* will frequently break down: *A* will not be willing to trade if his expectation of the value of *p* is too high. To facilitate comparison, we will assume that the fine under the current arrangements is set so that the same types of *C* are willing to trade in the bilateral case under the current arrangements as under the PvP arrangements.

Now suppose there is an intermediary bank which observes the probability *p.* This bank makes its profits by facilitating trade between the other two, but it is not wholly reliable, either. Specifically, we assume that with probability 1-*q* bank *B* receives an initial allocation of a unit of "dollars" and a unit of "yen," and with probability *q* it receives neither. These probabilities are independent of all probabilities for bank *C*. The payoffs to bank *B* based on its final holdings are:

For holding 1 unit of yen and 1 unit of dollars: *v*

For holding one unit of either: *w*

For holding two units of either: 2*w*

For holding nothing: *0.*

We will ignore the incentives for *B* to renege (while they could be included, they are not the point of this section and would only increase notational clutter). Bank *B* will receive a payoff in addition to payoffs for final holdings, from the profits *h* it collects on each consummated trade.[30]

[30] It would be feasible, but not particularly instructive, to keep this section consistent with the previous section by increasing the number of assets in the model and folding *h* into the payoff for particular asset holdings by B.

The trades that will be worth considering under any arrangement are arrangements for bank *B* to buy dollars from *A* and yen from *C*. Bank *B* will be able to carry out its side of these arrangements if it receives its initial holdings or if its counterparties do, so that it can use the proceeds of each to satisfy the other's requirements. We assume that

$$v > 2w + h \tag{15}$$

so that bank *B* prefers to enter trades only under the anticipation that each side of the trade will settle successfully.

The payoff to bank *B* is the same under the current system as it is under PvP, as long as bank *C* pays up. However, under current arrangements it is not possible for a bank to monitor whether trades have gone through before commencing its own trades. Thus exchanges will go through unilaterally as soon as the funds are available. For this reason, bank *B* faces greater chance of losses under current arrangements than under PvP. Specifically, compare the outcomes when bank *B* receives its initial assets but bank *C* does not. Under current arrangements bank *B* sends assets to bank *C* but receives nothing in return, while the trade with bank *A* is consummated. Thus the payoff to *B* under the circumstances is

$$w + h. \tag{16}$$

Under PvP, bank *B* does not send assets to bank *C* but continues to consummate the trade with bank *A*. Thus the payoff to *B* under the circumstances is

$$2w + h. \tag{17}$$

Thus the outcome is worse for bank *B* under current arrangements than under PvP.

(If both *B* and *C* fail to receive initial assets, then under both current arrangements and under PvP, bank B will end up with no assets and with no trade consummated; thus the only difference between the two will be in terms of the size of penalties assessed of *B* under the two systems. Under CLS no specific penalties would be attached to these circumstances. In any event, as long as the penalties are greater under the current system than under CLS, then bank *B* is also worse off in this case under PvP than under current arrangements and the rest of the discussion in this section is unaffected.)

In summary, bank *B* will choose to make arrangements with both bank *A* and bank *C* or with neither of them. Which it will do will depend on the quality of bank *C*. Under a PvP system, bank *B* will be willing to make arrangements when bank *C* has a higher realization of *p* than under the current arrangements. Let Ep_c and Ep_p be the expectation of *p* in the distribution *F* conditional on bank *B*'s accepting a trade under, respectively the current arrangements and a PvP system. Thus,

$$Ep_c < Ep_p \tag{18}$$

We now turn to a consideration of the values of the two arrangements from the point of view of bank *A*. If the trade is successful, A's payoff is *b-k*. If the trade fails, *A*'s payoff is *c-k* under PvP and *–k* under the current arrangements. Under either regime, the trade will fail when both *B* and *C* have no assets, so the probability of failure is

$$(Ep)\, q \tag{19}$$

and *A* will participate if

$$(b\text{-}k)[1\text{-}(Ep)\, q] \; - (Ep)\, q\, m > 0 \tag{20}$$

where

$$Ep = Ep_c \text{ or } Ep_p \tag{21}$$

and

$$m = k \text{ or } k - c \tag{22}$$

according to whether the market operates under the current arrangements or PvP respectively. Under PvP, the principal risk is smaller—that is, the amount lost when a counterparty defaults is smaller. But the liquidity risks are greater—that is, counterparties engage in trades with lower quality third parties—making shortfalls more likely.

The effect of the regime switch on A's payoff is ambiguous: Depending on parameters, bank A will be willing to participate in both regimes, in either regime or in neither.

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Table 1. Settlement of Spot FX Trade: Current System

Bank *A* Purchases $1M from Bank *B* for ¥100M

1a. After trade, before settlement:

Bank *A*

Assets	Liabilities
+ $1M due from Bank *B*	+ ¥100M due to Bank *B*

Bank *B*

Assets	Liabilities
+ ¥100M due from Bank *A*	+ $1M due to Bank *A*

1b. After settlement of one leg

Bank *A*

Assets	Liabilities
–¥100M in CB funds + $1M due from Bank *B*	

Bank *B*

Assets	Liabilities
+¥100M in CB funds	+ $1M due to Bank *A*

1c. After settlement of second leg

Bank *A*

Assets	Liabilities
+ $1M CB Funds –¥100M CB Funds	

Bank *B*

Assets	Liabilities
– $1M CB Funds +¥100M CB Funds	

Table 2. Settlement of Spot FX Trade: CLS With Full Pay-In

Bank *A* Purchases $1M from Bank *B* for ¥100M

2a. After trade, before settlement:

Bank *A*

Assets	Liabilities
+ $1M due from Bank *B*	+ ¥100M due to Bank *B*

Bank *B*

Assets	Liabilities
+ ¥100M due from Bank *A*	+ $1M due to Bank *A*

CLS Bank

Assets	Liabilities
0	*0*

2b. After pay-in

Bank *A*

Assets	Liabilities
+ $1M due from Bank *B* + ¥100M due from CLS Bank – ¥100M CB Funds	+ ¥100M due to Bank *B*

Bank *B*

Assets	Liabilities
+ ¥100M due from Bank *A* + $1M due from CLS Bank – $1M CB Funds	+ $1M due to Bank *A*

CLS Bank

Assets	Liabilities (Accounts)
+ ¥100M CB Funds + $1M CB Funds	Currency Sub Accts. ¥ $ Bank *A* ¥100M Bank *B* $1M

2c. After settlement

Bank *A*

Assets	Liabilities
+ $1M due from CLS Bank – ¥100M CB Funds	

Bank *B*

Assets	Liabilities
+ ¥100M due from CLS Bank – $1M CB Funds	

CLS Bank

Assets	Liabilities (Accounts)
+ ¥100M CB Funds + $1 M CB Funds	Currency Sub Accts. ¥ $ Bank *A* $1 M Bank *B* ¥100M

2d. After pay-out

Bank *A*

Assets	Liabilities
+ $1M CB Funds – ¥100M CB Funds	

Bank *B*

Assets	Liabilities
+ ¥100M CB Funds – $1M CB Funds	

CLS Bank

Assets	Liabilities
0	*0*

Table 3. Settlement of Spot FX Trade: CLS With Delayed Pay-In

Bank *A* Purchases $1M from Bank *B* for ¥100M

3a. After trade, before settlement:

Bank *A*

Assets	Liabilities
+ $1M due from Bank *B*	+ ¥100M due to Bank *B*

Bank *B*

Assets	Liabilities
+ ¥100M due from Bank *A*	+ $1M due to Bank *A*

CLS Bank

Assets	Liabilities
0	*0*

3b. After initial pay-in

Bank *A*

Assets	Liabilities
+ $1M due from Bank *B* + ¥10M due from CLS Bank – ¥10M CB Funds	+ ¥100M due to Bank *B*

Bank *B*

Assets	Liabilities
+ ¥100M due from Bank *A* + $0.1M due from CLS Bank – $0.1M CB Funds	+ $1M due to Bank *A*

CLS Bank

Assets	Liabilities (Accounts)		
+ ¥10M CB Funds + $0.1 M CB Funds		Currency Sub Accts.	
		¥	$
	Bank *A*	¥10M	
	Bank *B*		$0.1 M

3c. After settlement

Bank *A*

Assets	Liabilities
+ $1M due from CLS Bank – ¥10 M CB Funds	+ ¥90 M Overdraft at CLS

Bank *B*

Assets	Liabilities
+ ¥100M due from CLS Bank – $0.1M CB Funds	+ $0.9 M Overdraft at CLS

CLS Bank

Assets	Liabilities (Accounts)
+ ¥10 M CB Funds + $0.10 M CB Funds	Currency Sub Accts. ¥ $ Bank *A* – ¥90M $1M Bank *B* ¥100M – $0.9 M

3d. After final pay in

Bank *A*

Assets	Liabilities
+ $1M due from CLS Bank – ¥100M CB Funds	

Bank *B*

Assets	Liabilities
+ ¥100M due from CLS Bank – $1M CB Funds	

CLS Bank

Assets	Liabilities (Accounts)
+ ¥100M CB Funds + $1 M CB Funds	Currency Sub Accts. ¥ $ Bank *A* $1 M Bank *B* ¥100M

3e. After pay-out (same as Table 2)

Table 4: Payoffs in Settlement Subgame

4a: Subgame under current arrangements

	And My Counter Party		
If I		Delivers	Reneges or Holds No Asset
	Deliver	b	0
	Renege	$a - f_c$	$c - f_c$
	Hold No Asset	$b - f_c$	$- f_c$

4b: Subgame under PvP system

	And My Counterparty		
If I		Delivers	Reneges or Holds No asset
	Deliver	b	c
	Renege	$c - f_p$	$c - f_p$
	Hold No Asset	$- f_p$	$- f_p$

Table 5: Payoffs in the Full Game

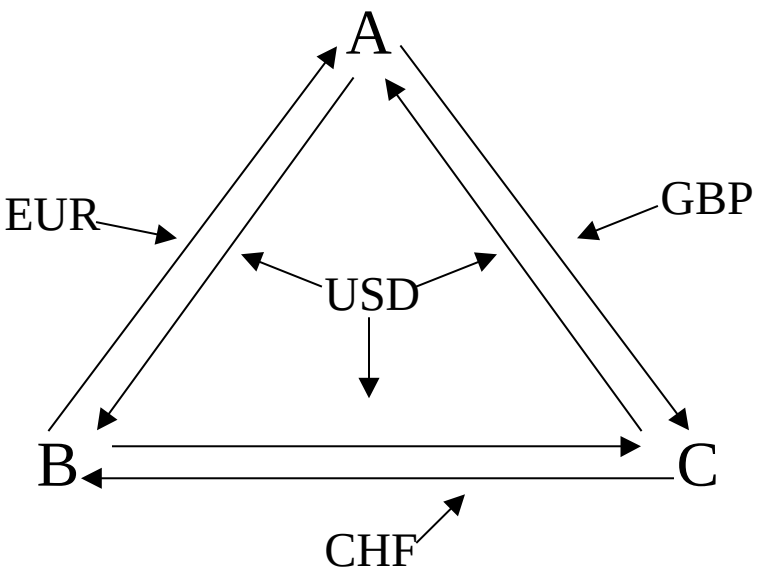
5a: Payoffs under current arrangements

		And My Counterparty		
If I		Invests and Delivers	Invests and Reneges	Doesn't Invest
	Invest and Deliver	$(1-p)\ b - p\ f_c - k$	$-p\ f_c - k$	$-p\ f_c - k$
	Invest and Renege	$(1-p)^2\ a + (1-p)\ p\ c + (1-p)\ p\ b - f_c - k$	$(1-p)\ c - f_c - k$	$(1-p)\ c - f_c - k$
	Don't Invest	$(1-p)\ b - f_c$	$-f_c$	$-f_c$

5b: Payoffs under a PvP system

		And My Counterparty		
If I		Invests and Delivers	Invests and Reneges	Doesn't Invest
	Invest and Deliver	$(1-p)^2\ b + (p - p^2)\ c - p\ f_p - k$	$(1-p)\ c - k$	$(1-p)\ c - k$
	Invest and Renege	$(1-p)\ c - f_p - k$	$(1-p)\ c - f_p - k$	$(1-p)\ c - f_p - k$
	Don't Invest	$-\ f_p$	$-\ f_p$	$-\ f_p$

Figure 1: Multilateral Settlement



Ex Post Marginal Utilities

Example 1

Trader	USD	GBP	CHF	EUR
A	1	$L<1$	—	$H>1$
B	1	—	*H*	*L*
C	1	*L*	*H*	—
CB	1	*L*	*H*	—

Example 2

Trader	USD	GBP	CHF	EUR
A	1	$L'<L$	—	*H*
B	1	—	*H*	*L*
C	1	*L*	*H*	—