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An Introduction to Multilateral Foreign Exchange Netting

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ABSTRACT

This paper examines some of the key issues that arise in the design of a multilateral foreign exchange netting facility. First, it presents a brief overview of the primary risks that exist in the foreign exchange market. Bilateral netting, close-out and multilateral netting are also introduced. Then three aspects that are central to the design of a multilateral netting facility are considered: management of credit risks; provision of settlement and liquidity arrangements; and membership criteria of the clearinghouse.

To ensure that risks are in fact reduced, and not exacerbated, by multilateral netting, efficient mechanisms must be established to manage credit risks (both forward replacement risk and settlement risk) arising in the clearinghouse and to manage the liquidity needs of the clearinghouse. Accordingly, a highly reliable loss allocation procedure is fundamental. Ensuring the reliability of loss allocation suggests a central role for collateral, and this collateral would also underpin any needed liquidity arrangements.

This paper also suggests examples of specific risk management procedures that would limit the risk that members can present to the clearinghouse. Such procedures would also ensure that the clearinghouse could promptly arrange the needed liquidity and recover any loss in the case of the default of any single member. Having these procedures in place would in turn require the establishment of a real-time data-processing and communications system.

RÉSUMÉ

Dans la présente étude, l'auteur examine plusieurs questions importantes que soulève la conception d'un mécanisme de compensation multilatérale des opérations sur devises. Dans un premier temps, il passe rapidement en revue les principaux risques inhérents au marché des changes; il examine aussi la problématique de la compensation bilatérale et multilatérale et de la déchéance du terme. Dans un deuxième temps, l'auteur aborde trois aspects centraux de la conception d'un mécanisme de compensation multilatérale, à savoir la gestion des risques de crédit, la mise en place d'un dispositif de règlement des opérations et de gestion des liquidités et l'établissement de critères d'adhésion à la chambre de compensation.

Pour que la compensation multilatérale entraîne une réduction plutôt qu'une aggravation des risques, il faut établir des mécanismes permettant à la chambre de compensation de gérer efficacement les risques (risque de remplacement d'un contrat à terme et risque de règlement) auxquels elle s'expose ainsi que ses besoins en liquidités. Il est notamment essentiel que soit mis en place un mécanisme très sûr de répartition des pertes. Le nantissement d'avoirs pourrait jouer un rôle central à cet égard en plus d'étayer tout dispositif de gestion des liquidités.

L'auteur donne également des exemples de procédures précises qui pourraient servir à limiter les risques auxquels les membres de la chambre de compensation peuvent exposer celle-ci. La chambre de compensation devrait aussi être dotée de moyens lui permettant de mobiliser promptement les liquidités nécessaires et de combler toute perte en cas de défaillance d'un membre. La mise en place de ces procédures exigerait à son tour l'implantation d'un système de communication et de traitement des données en temps réel.

1. INTRODUCTION

In the last several years, a group of North American banks and a group of European banks have been working independently to develop arrangements to net their foreign exchange transactions on a multilateral basis.[1] This paper examines some of the central issues that arise in the design of a multilateral netting facility. As background, the next section presents a brief overview of the primary risks that exist in the foreign exchange market. Bilateral netting, close-out and multilateral netting are then introduced.[2] The rest of the paper then focusses on three central aspects that arise in designing a multilateral netting facility: management of credit risk; provision of settlement and liquidity arrangements; and membership or access issues. (A series of supporting appendices is attached.)

The discussion is cast explicitly in terms of a foreign exchange netting facility. However, all multilateral netting arrangements appear to have fundamental similarities. Accordingly, the analysis might also be relevant to the design of other types of clearinghouses intended to net transactions among many participants, such as a large value transfer system for Canadian dollar payments or a securities transactions netting arrangement.

2. RISKS IN THE FOREIGN EXCHANGE MARKET

The last comprehensive survey of the global foreign exchange market, conducted by the BIS in April 1989, estimated that daily trading in spot, forward and derivative instruments was about U.S.$650 billion.[3] Participants are mainly large North American, European and Japanese banks acting on behalf of clients or as principals. The market is concentrated in a few currencies, notably the U.S. dollar, Deutsche mark, yen and pound sterling, and in a few centres, New York, London and Tokyo.

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[1] See, for example, the North American Foreign Exchange Multilateral Netting Project, *Status Report*, mimeo (February 1992); and the Exchange Clearing House Organisation, *ECHO Netting -- Multilateral Netting for the Global FX Market*, mimeo (December 1991).

This paper is not a critique of these or any other ongoing efforts to develop multilateral netting facilities. The analysis of this paper addresses generic, theoretical aspects raised by multilateral netting.

[2] For additional introductions to foreign exchange netting, see: Brian J. Cody, "Reducing the Costs and Risks of Trading Foreign Exchange," *Business Review*, (Federal Reserve Bank of Philadelphia, November/December 1990); George R. Juncker, Bruce J. Summers and Florence M. Young, "A Primer on the Settlement of Payments in the United States," *Federal Reserve Bulletin*, (November 1991); and R. Alton Gilbert, "Implications of Netting Arrangements for Bank Risk in Foreign Exchange Transactions," *Review*, (Federal Reserve Bank of St. Louis, January/February 1992).

[3] Bank for International Settlements, *Survey of Foreign Exchange Market Activity*, (BIS, February 1990).

The major risks that banks currently face in their foreign exchange business are settlement risk, liquidity risk and forward replacement risk. As shown below, both settlement risk and forward replacement risk are forms of credit risk. In addition, banks are concerned about liquidators of failed institutions engaging in *cherry picking*.[4]

(i) Settlement Risk

All foreign exchange transactions involve an exchange of funds between two counterparties, and obtaining finality requires that foreign currency payments be made in the country that issues the currency. If the hours of operation of the national payment systems for the currencies specified in the contract do not overlap, then one of the counterparties must inevitably pay out one currency prior to receiving payment in the other. Even if the hours of operation overlap, no linked mechanisms are available to ensure the simultaneous settlement of both currency legs of a transaction.[5] During the interval between these two payments, the bank that has made the first payment is at risk of losing the full value of the second payment if its counterparty fails after the first payment is made, but before the counterparty makes its payment to complete the transaction.

Since this risk arises because payments are not contemporaneous, it is also referred to as *temporal risk*. Alternatively, it is referred to as *Herstatt risk*, after the bank whose failure in 1974 resulted in significant settlement losses for some of its counterparties.

(ii) Liquidity Risk

Both parties to the contract are also exposed to liquidity risk on the settlement date. If the anticipated delivery of a currency fails to occur, the bank expecting to receive the payment generally would have to borrow or liquidate assets in that currency to offset the shortfall. Even if the failure to pay were detected before the bank paid out according to the terms of the contract, liquidity risk would still exist. In this case, the deficit in the currency receivable would be offset by a surplus in the currency payable, but a same-day foreign exchange transaction would be required to use this surplus to fund

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[4] The description of risks that follows draws on Bank for International Settlements, *Report of the Committee on Interbank Netting Schemes of the Central Banks of the Group of Ten Countries* (the Lamfalussy Report), (BIS, November 1990).

[5] Moreover, payment orders are not irrevocable in some national payments systems, for example, in the Canadian payments system.

the deficit. Such a transaction may be difficult to complete if, for example, the transaction is attempted late in the business day in the domestic market of a foreign currency. Moreover, the amount subject to liquidity risk is always the full principal amount of the payment to be received.

(iii) Forward Replacement Risk

The preceding two risks both arise on the settlement date, the date at which the contract is executed and currencies are exchanged. The third type of exposure, forward replacement risk, is a credit risk that results from the bankruptcy of a counterparty before the settlement date, which renders the counterparty unable to honour its future obligation. Since banks typically have multiple contracts with any given counterparty, the failure of a counterparty would leave the surviving bank with one side of a portfolio of contracts to replace.

At the time that a foreign exchange contract is entered into, it could be replaced at little cost, because the exchange rate specified in the contract is probably very close to that prevailing in the market. As time passes and rates change, however, the market values of the currency receivable and the currency payable under the contract are likely to deviate from the values that prevailed at the time that the contract was entered into. As a result, for example, from the perspective of one of the counterparties, the market value of the cash flow that it is to receive may have appreciated relative to the market value of the cash flow that it is to pay. Therefore, in the event of the failure of its counterparty before the settlement date, the surviving bank would incur a loss when replacing the needed cash flow in the market. This is referred to as a *forward replacement loss*. (Note that in this example the failing counterparty necessarily makes a forward replacement gain.)

More generally, the net present value of the cash flows specified in a portfolio of contracts between two counterparties, at current market rates, is referred to as *forward replacement value*. The risk associated with changes in forward replacement value depends on the volatilities of the relevant exchange rates and the discount rate used to calculate present values.

(iv) Cherry Picking

In the event of the failure of a counterparty, some of the outstanding contracts would probably imply a claim by the surviving bank on the failed counterparty. For example, if the default occurred on the settlement date, the surviving bank might have made a payment but not received one in return. If the default occurred before the settlement date, the surviving bank might incur a loss when replacing some of the contracts. On the other hand, some contracts could imply a claim by the failed counterparty on the surviving bank. From the surviving bank's perspective, if the default occurred on the settlement date, the surviving bank might have received a payment but not made one in return, or if the default was before the settlement date, the surviving bank might have made a gain when replacing some of the contracts.

In some jurisdictions, the liquidator of the failed counterparty might seek to enforce only those claims arising from the latter contracts -- those that benefit the failed counterparty -- but avoid counterclaims arising from the former contracts -- those that reduce the net assets of the failed counterparty. This is referred to as *cherry picking*. If a liquidator could successfully cherry pick, the surviving bank's exposure would be the sum of the gross credit exposures on the contracts on which it had a claim on the failed counterparty, rather than the net difference between the total claims on and obligations owing to the defaulting counterparty. The risk of cherry picking, that is, enforcing only those contracts that benefit the failed counterparty, and repudiating those that do not, is a principal motivation for netting.[6]

3. NETTING

(i) The Basic Idea: Bilateral Netting

Bilateral netting is a contractual technique by which claims and obligations, in a given currency and for a given value date, which arise from multiple foreign exchange contracts between two counterparties, can be set off against one another in a legally binding way, resulting in a net claim or obligation in that currency for that value date. This also achieves *payments netting*, whereby gross payments flows in a given currency and for a given value date are set off against one another, resulting in operating

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[6] In some countries, statutory *rights of set-off* or similar common law rights might provide a means of setting off mutual debts or obligations by one party to another. In this case, if a failed bank's liquidator attempted to cherry pick, a successful assertion of a right of set-off by the surviving counterparty would limit its exposure to the net balance of any outstanding settlement obligations plus any gains and losses on forward contracts.

economies. Market participants have indicated that bilateral netting can lead to important savings arising from a reduction in transactions volumes.[7]

In addition, the bilateral netting arrangement can be designed to place a series of such transactions under a single contract. Therefore, all of the net claims and obligations under the netting arrangement would be binding on a liquidator in the event of the bankruptcy of one of the counterparties. That is, where the netting is legally effective, a liquidator could only claim or reject performance of the entire book of covered transactions, as a single contract. As a result, the risk of cherry picking is eliminated and credit risk is reduced.[8]

(ii) Acceleration or Close-Out

As noted above, bilateral netting can be established under a single contract governing a series of transactions, thus eliminating the risk of cherry picking. An acceleration or close-out clause in the netting contract goes one step further and provides for the explicit determination of the net present value of all covered transactions, given the occurrence of some specified event, such as the bankruptcy of one of the counterparties. In other words, a legally valid close-out clause provides for the binding determination of the replacement value of the portfolio, that is, the present value, converted to a single currency, of the balance of all covered obligations.

(iii) An Illustration of Bilateral Netting and Close-Out

As an example of what a bilaterally netted book might look like, consider the following book of bilateral foreign exchange positions in four currencies -- dollars, Deutsche marks, yen and pounds sterling as at June 27.

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[7] See, for example, the Lamfalussy Report (p. 11) and Peter Bartko, "Foreign Exchange and Netting by Novation," *Payment Systems Worldwide*, (Spring 1990).

[8] Foreign exchange netting (and close-out provisions -- see below) raise difficult legal questions because the contracts can cover transactions in several currencies between the counterparties who may be from different countries. As a result, the netting contract can implicate several different legal jurisdictions, leading to choice-of-law and conflict-of-law questions that might not be easily resolved. Ensuring that netting schemes have a well-founded legal basis is one of the minimum standards for netting schemes advanced by the Lamfalussy Report. Appendix I presents the Lamfalussy minimum standards.

Value dates	*$*	*DM*	*¥*	*£*
July 6	n_{11}	n_{12}	n_{13}	n_{14}
July 17	n_{21}	n_{22}	n_{23}	n_{24}
July 22	n_{31}	n_{32}	n_{33}	n_{34}
August 2	n_{41}	n_{42}	n_{43}	n_{44}

Each cell in the matrix represents a legally binding *net* position, that is, gross claims are set off or netted against gross obligations by currency and by value date. For example, the net payment in yen due on July 17 is n_{23}. Moreover, since the netting contract covers the entire matrix of transactions, a liquidator could only claim or reject performance of the entire book of transactions. With a close-out provision in the netting contract, the entire matrix also can be expressed as a single, present value claim or obligation (given exchange and discount rates), which has legal effect.

This single figure is the forward replacement value of the book of netted contracts and it is an expression of the value of a legally binding foreign exchange position. In comparison, without netting, the credit exposure of this book of contracts would be the sum of the present values of the gross receivables. There would be no offset for the gross payables. As a result, netted books have much smaller credit and liquidity exposures than non-netted books.

In sum, bilateral netting can be designed to economize on payments flows and to eliminate cherry picking by a liquidator of multiple contracts with a single counterparty, thereby reducing credit and liquidity risks. This is achieved in practice most commonly by the legal technique of *novation* or by *master agreement*.

(iv) Multilateral Netting

Multilateral netting is designed to extend the benefits of netting to cover contracts which originate with any of a *group* of counterparties that participate in the netting arrangement, instead of with just a single counterparty, as in bilateral netting. In the absence of multilateral netting, if a market participant were to fail, some surviving banks might have a bilateral net claim on the failed counterparty, while it, in turn, might have a bilateral net claim on other surviving banks. Multilateral netting is intended to reduce

exposures of surviving banks that have a claim on the failed party. This is achieved by, in effect, setting off the bilateral net claims of surviving banks on the failed party against the bilateral net claims of the failed party on other surviving banks.

This can be achieved in practice by netting all transactions that originate bilaterally through a central counterparty -- a clearinghouse. For each contract submitted by a pair of members to the clearinghouse, the clearinghouse would be inserted as the counterparty to each member, and any obligations between the members arising from the original contract would be discharged. The clearinghouse would maintain a running, legally binding net position for each member in each currency and each value date eligible for netting. Thus, for each member of the clearinghouse, multiple transactions with *many* counterparties can be amalgamated or netted.

According to market participants involved in the development of a foreign exchange clearinghouse in North America, simulations suggest that multilateral netting would reduce forward replacement exposures by about 80 to 85 per cent for a given set of transactions conducted in the absence of netting.[9] Multilateral netting can also significantly reduce settlement and liquidity risks. In a multilateral netting arrangement, all original obligations to pay or to receive a given currency on a given value date are discharged by making a single, netted payment to, or receiving a single, netted payment from the clearinghouse. Such payments would be no larger, and generally would be considerably smaller, than the sum of the gross payments that would result in the absence of netting. As a result, operating economies would be achieved, and the problems arising from the failure to receive payments would be greatly diminished in each currency accepted for netting, thereby reducing settlement and liquidity risks. Again, simulations suggest that multilateral netting would reduce settlement flows by about 75 per cent, compared with the payments that would be needed to settle the corresponding gross obligations.[10]

In designing a multilateral netting facility, there are at least three general considerations that must be addressed: the management of credit risk, that is, forward replacement risk and settlement risk; the provision of settlement arrangements and the

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[9] Estimates of the benefits of multilateral netting can vary somewhat depending on the specific aspects of the simulations, such as the nature of the transactions netted and the number of clearinghouse members. Herbert L. Baer and Douglas D. Evanoff, *Payments System Risk Issues in a Global Economy*, Working Paper 90-12, Federal Reserve Bank of Chicago, August 1990) pp. 7-8, suggest credit risk reductions and operational gains that are somewhat different from those noted above.

[10] See the North American Foreign Exchange Multilateral Netting Project, op. cit., p. 12.

management of liquidity risk; and membership or access criteria of the clearinghouse.[11]

4. CREDIT RISK MANAGEMENT AND LOSS ALLOCATION

(i) Introduction

There are two specific types of exposures with which the clearinghouse must be concerned: forward replacement loss and settlement loss.[12] Forward replacement loss can arise in the event of a member's failure before settlement begins. In this event, the clearinghouse would replace the currency flows which the defaulter's portfolio of foreign exchange contracts would have produced. It would also establish immediately how much it should pay to, or claim from, the liquidator of the failed member, which would be the replacement value of the member's portfolio. In the event of a claim on the defaulter, that is, in the event of a forward replacement loss, the clearinghouse would have to go to its members to recover the shortfall, since it would have very limited resources of its own.

Settlement loss can arise if a member defaults after settlement begins. If the clearinghouse makes its payments but does not receive the funds owed to it by the defaulter, then it may have to bear the full settlement loss, which would also have to be recovered from the membership.

How are losses in these cases to be recovered from the membership? Under multilateral netting, for each contract submitted by a pair of members to the clearinghouse, the clearinghouse would be inserted as the legal counterparty to each member, and any direct obligation between the originating members would be discharged. Although the clearinghouse would be the legal counterparty for all participants, losses resulting from the default of a member would have to be allocated to members according to a predetermined allocation rule.

In a *defaulter-pays* clearinghouse, each member is obliged to post collateral equal to its own net debit with the clearinghouse. In the event of a member's default, the clearinghouse would seize the defaulting member's collateral to cover the amount in default. In a *survivors-pay* clearinghouse, the loss allocation rule applies to the non-

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[11] In addition to these considerations, the clearinghouse must be concerned about the legal validity and enforceability of the underlying netting contracts (see footnote 8) and about the efficiency of its information processing and transmission systems. The minimum standards for netting schemes suggested by the Lamfalussy Report (see Appendix I) indicate that "all netting schemes should ensure the operational reliability of technical systems and the availability of back-up facilities capable of completing daily processing requirements."

[12] The failure of a settlement agent can also expose the clearinghouse to loss. Managing settlement agent risk is discussed below.

defaulting, surviving members. For example, losses could be allocated in proportion to a measure of the surviving members' bilateral relationship to the defaulting member, such as bilateral credit limits provided to the defaulter. Alternatively, losses could be allocated in proportion to survivors' *notional* bilateral exposures to the defaulting member.[13] This is referred to as *primary loss allocation*. If any surviving member defaulted on this loss allocation, it could be allocated to the remaining survivors, again, in proportion to their dealings with the (original) defaulting member. This is referred to as *secondary loss allocation*.

However, as a practical matter, it would be misleading to make a strong distinction between the survivors-pay and the defaulter-pays models. As argued below, some collateralization appears to be necessary to ensure the reliability of the loss allocation procedure and to underpin liquidity arrangements. Indeed, in a hybrid of the survivors-pay and defaulter-pays models, all members would stand ready to reimburse the clearinghouse for losses, and they would post collateral to secure these obligations. But losses to be allocated to survivors would be reduced in the first instance by collateral posted by the defaulting member. The rest of this paper focusses on survivors-pay netting and hybrid variants, which underpin current efforts to develop multilateral foreign exchange netting.

(ii) The Importance of a Highly Reliable Loss Allocation Procedure

Perhaps the central concern in a clearinghouse is the reliability of the expectation that members will contribute their share to cover any defaults to the clearinghouse and thereby enable settlement to occur. Several considerations suggest that the clearinghouse should be designed to ensure a highly reliable loss allocation procedure given the implications for the clearinghouse's ability to meet its obligations on any given day.

Through multilateral netting and loss sharing, a clearinghouse concentrates risk in one place, and a well-designed clearinghouse should stop a chain of defaults (*a domino effect*) from developing within the membership in the concerned markets. Defaults on primary loss allocations (secondary defaults) could result in greater shares of the original default being allocated to remaining members. Therefore, the probability of additional

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[13] Notional bilateral exposures arise from the bilateral transactions that counterparties submit to the clearinghouse for netting, and represent the bilateral positions that would have resulted in the absence of netting. They are notional (and have no legal standing), since once the transaction is accepted for netting by the clearinghouse, it is inserted as the legal counterparty to each member. The clearinghouse could keep track of these positions, which are a measure of the exposure brought into the clearinghouse by a member.

defaults of loss allocations could rise with such defaults. Moreover, this process could motivate additional primary defaults to the clearinghouse. Through such domino or chain reaction effects, bank defaults, which could otherwise be regarded as largely independent events, would become dependent events. To reduce the probability of such a result, the loss allocation procedure must be highly reliable.

Also, clearinghouse membership would include some of the largest banks in North America (and Europe). These banks may believe that they operate with an implicit guarantee from their regulators, that they are *too big to fail*, with consequent effects on incentives. That is, clearinghouse members may rely on regulators to ensure the survival of the clearinghouse, and this would bias their risk management with respect to the clearinghouse and lead to excessive risk-taking, which in turn would raise the risk of failures.[14] To discourage such moral hazard, the loss allocation procedure must be highly reliable.

A highly reliable loss allocation procedure is fundamental to a well-designed clearinghouse: it provides incentives for clearinghouse members to establish appropriate practices and procedures in the management of the clearinghouse and in their own activities;[15] it reduces the risk that (otherwise independent) bank defaults would become dependent events, by reducing the magnitude and risk of a domino or chain reaction effect running through the clearinghouse; and it ensures that the clearinghouse will settle its obligations, reducing the risk of spillovers of problems (of a liquidity or a solvency nature) from the clearinghouse to other payments mechanisms and market participants. These benefits in turn reduce the likelihood that the public sector would be asked to bail out the clearinghouse or individual market participants.

(iii) A Simple Survivors-Pay Loss Allocation Rule

As noted in subsection (i) above, losses could be allocated in proportion to members' bilateral relationship to the defaulter. In a survivors-pay clearinghouse, without collateral

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[14] Both this factor and the prospect of domino effects raise the possibility that the public sector might be asked to bail out the clearinghouse or its members.

[15] The minimum standards for netting schemes suggested by the Lamfalussy Report (see Appendix I) indicate that the credit and liquidity risk management procedures of multilateral netting facilities should "ensure that all parties have both the incentives and the capabilities to manage and contain each of the risks they bear."

or rights of set-off,[16] the loss to bank j from the default of bank i can be summarized by the following equation:

$$(1) \qquad L^i_j = [E^i_j/(\sum_{x=1}^{b} E^i_x)]D_i + \sum_{y=1}^{s} [E^i_j/(\sum_{x=s+1}^{b} E^i_x)]L^i_y$$

where L^i_j = the loss to bank j from the default of bank i to the clearinghouse;

E^i_x = the bilateral exposure of bank x to bank i;

D_i = the obligation of bank i (in default) to the clearinghouse;

L^i_y = the loss allocation of bank y in default; that is, bank y is a secondary defaulter and the amount of its secondary default with respect to the original default (D_i) is L^i_y;

b = the number of members with bilateral exposures to defaulter i;

s = the number of secondary defaulters.

Also, let n = the number of clearinghouse members so that $s \leq b < n$. (The maximum value for b is n-1.)

Thus, the total possible loss to bank j is the sum of loss allocations to it resulting from the defaults of members to which it has bilateral exposures, that is,

$$(2) \qquad L^t_j = \sum_{i=1}^{p} L^i_j$$

$$= \sum_{i=1}^{p} [E^i_j/(\sum_{x=1}^{b} E^i_x)]D_i + \sum_{i=1}^{p} \{\sum_{y=1}^{s} [E^i_j/(\sum_{x=s+1}^{b} E^i_x)]L^i_y\}$$

where p = the number of primary defaulters to which bank j has a bilateral exposure; $p < n$.

(iv) How Large Can Loss Allocations Get Under This Survivors-Pay Rule?

Here we examine how large a member's loss allocations can possibly be under the survivors-pay loss allocation rule noted above. The cases considered, that is, multiple defaults of clearinghouse members, may be unlikely, and the extremes considered here

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[16] Set-off in this context refers to a legally effective clearinghouse rule that stipulates that the clearinghouse could recover a member's loss allocation by setting it off against that member's net credits in the clearinghouse.

might suggest catastrophic circumstances in the financial markets. Nevertheless, consideration of these cases is instructive with respect to an understanding of the analytics of loss allocation. Moreover, poorly designed loss allocation procedures raise the probability of moving from the simplest case of one primary default toward cases of multiple secondary and primary defaults.

Again, suppose that losses resulting from the default of a member would be allocated to surviving members according to a predetermined rule, in proportion to the surviving members' bilateral relationship to the defaulting member. If any surviving member defaulted on this primary loss allocation, it would be allocated to the remaining survivors, again, in proportion to their dealings with the (original) defaulting member (secondary loss allocation).

Appendix II shows that with this loss allocation rule, the maximum loss allocation to a member is the sum of the net debits with the clearinghouse of all primary defaulters to which the member has a bilateral exposure. It follows that a member's maximum loss allocation in the event of multiple primary and secondary defaults can exceed the sum of its own bilateral exposures to the primary defaulters.

The reasons for these results are straightforward. Defaults of members in a net debit position with the clearinghouse generate losses to the clearinghouse which must be shared among the surviving members. However, secondary defaults also reduce the pool of surviving members that share in the primary defaults, and thereby shift loss allocations to a smaller group of surviving members. In the extreme, where there is only one survivor of a loss sharing group, all of the loss allocations are shifted to that sole surviving member, which must equal the sum of the primary defaults.

Note that with the type of loss allocation rule analyzed here, loss allocations always remain within that group of members that have bilateral exposures to the primary defaulters. If *all* members with bilateral exposures to a primary defaulter were to default on their loss allocations, there could remain unallocated losses. In general, loss allocation procedures that (arbitrarily) limit loss allocations appear to have the potential to leave losses unallocated in the clearinghouse (which may cause its insolvency and liquidation). A more generalized loss allocation, to include members that did not have bilateral exposures to the primary defaulter, could avoid this result. However, it would also imply that members could be allocated losses from the primary defaults of members with which they did not deal. Therefore, in the extreme, all of the loss allocations would be shifted to the sole surviving member, and must equal the sum of *all* primary defaults to the

clearinghouse, that is, the sum of *all* net debits.

(v) A More Sophisticated Loss Allocation Rule: The Roles of Net Debit Caps, Collateral and Set-Offs

Now suppose that each member were obliged to post collateral to the clearinghouse to secure loss allocations (and liquidity needs -- see below), and that the clearinghouse rules stipulate that the clearinghouse would recover, to the extent possible, defaults on any member's loss allocations by setting them off against the member's net credit position with the clearinghouse. (Of course, for any given member, there may not be a net credit position to use as a set-off.) Equation (2) then becomes:

$$(3) \qquad L^i_j = \sum_{i=1}^{p} [E^i_j/(\sum_{x=1}^{b} E^i_x)](D_i - K_i) + \sum_{i=1}^{p} \{\sum_{y=1}^{s} [E^i_j/(\sum_{x=s+1}^{b} E^i_x)](L^i_y - M_y - K_y)\}$$

where K_i = the collateral posted by primary defaulter bank i;
M_y = the multilateral net credit position of secondary defaulter bank y;
K_y = the collateral posted by secondary defaulter bank y.

Equation (3) shows that exposures (L^i_j) can be managed by constraining bilateral exposures (E^i_j), multilateral net debits (D_i) and loss shares (L^i_y); posting collateral (K); and using set-offs (M_y). While this loss allocation rule is conceptually a survivors-pay rule, it also incorporates defaulter-pays characteristics. That is, it is a hybrid model: loss allocations are reduced in the first instance by the collateral posted by the defaulting member (K_i).

Since a clearinghouse member's potential loss (L^i_j) is directly related to the bilateral exposures (E^i_j) that it undertakes in the course of arranging foreign exchange transactions, members themselves can be expected to limit their bilateral exposures. In addition, to help establish the reliability of the loss allocation procedure, the clearinghouse would limit the aggregate obligation that a member could present to the clearinghouse; that is, its net debit position (D_i). In other words, each member would be subject to a net debit cap.[17]

Secondary defaults (the second term of equation 3) arise only if loss allocations

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[17] The minimum standards for netting schemes suggested by the Lamfalussy Report (see Appendix I) indicate that the credit and liquidity risk management procedures of multilateral netting facilities should ensure "that limits are placed on the maximum level of credit exposure that can be produced by each participant."

are in default and if the amount in default minus posted collateral and amounts available to the clearinghouse under set-off is greater than zero, (that is, $L^i_y - M_y - K_y > 0$ in equation 3). Ensuring the reliability of the loss sharing procedure implies that this value should be minimized, indicating a central role for collateral and set-offs in a survivors-pay clearinghouse.[18]

(vi) Allocating Future Cash Flows to Allocate Forward Replacement Losses

The preceding implies that, in the event that a member's forward position is closed out, the clearinghouse would sell (forward) the set of cash flows that it would have sent to the defaulting, closed-out member to replace the set of cash flows that were due from this member. However, if there was a replacement loss on the closed-out position, simply selling these cash flows would not allow the clearinghouse to fully replace the set of needed cash flows. Thus, the surviving members must provide resources according to the loss allocation rule sufficient to ensure that the clearinghouse can replace the needed set of cash flows. The possibility of default on loss allocations leads to the possibility of loss allocations rising for members in the manner described above.

As an alternative approach to allocating forward replacement losses, the clearinghouse could allocate the replacement of the closed-out member's portfolio of cash flows directly to surviving members on a pro rata basis, according to notional bilateral exposures. In other words, the clearinghouse would allocate pro rata shares of each currency and value date cash flow, due to and due from the closed-out member, to each surviving member with a notional bilateral exposure to the closed-out member. (These replacement cash flows would be novated into these members' existing positions.) For example, if a surviving bank's notional bilateral exposure was 25 per cent of the sum of all bilateral exposures to the closed-out member, it would be assigned 25 per cent of each cash flow receivable of the closed-out member and 25 per cent of each cash flow payable of this member. Since the net present value of this portfolio of cash flows is negative from the perspective of the loss sharing members (the portfolio is *out-of-the-money*), the assignment of the cash flows automatically allocates the loss on the closed-out position.

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[18] This loss allocation procedure does not distinguish between settlement losses and forward replacement losses, so that collateral is pledged to secure the reliability of the loss allocation procedure with respect to both settlement losses and forward losses -- and therefore secures the ultimate settlement of these forward positions. The next subsection considers a loss allocation procedure that distinguishes between settlement and forward losses.

Put differently, this procedure assigns the notional bilateral losses and gains of the closed-out member to the loss sharers. The notional bilateral losses of the closed-out member are absorbed, in effect, by the loss sharers' notional bilateral gains (exposures) vis-à-vis this member.[19] However, the effect of these losses on the loss sharers is partially offset by any notional bilateral gains that the closed-out member had, which are also transferred to the loss sharers. Therefore, each member's loss allocation would be less than (or equal to) its notional bilateral exposure to the closed-out member.

At this stage, analysis suggests some additional implications. For example, as a result of this procedure, the value of a loss sharing member's multilateral net forward position would decline, and a loss sharer could, conceivably, be pushed above a net debit cap. Also, the allocation of replacement cash flows can alter the pattern of subsequent settlements.[20] In addition, since a loss sharer would be allocated (a share of) the notional bilateral gains of the closed-out members, it would be assigned a new set of notional bilateral exposures -- possibly unwanted. Nevertheless, this member would still be better off than it would have been without multilateral netting -- the transfer of the notional bilateral gains has reduced its loss.

If one of the loss sharers was subsequently closed out, and if there was a net replacement loss on the position, this loss -- which would include the original loss allocation -- would be allocated to another group of members with notional bilateral exposures to the closed-out member. However, again, the notional bilateral gains of the closed-out member would also be transferred to these loss sharers, and this would again partially offset the effect of absorbing the notional bilateral losses of the closed-out member. Thus, again, each member's loss allocation would be less than (or equal to) its notional bilateral exposure to the closed-out member. In the event of multiple defaults on forward positions, this process would be repeated, and it follows that, even in the extreme, a member's loss allocations could not exceed the sum of its notional bilateral exposures.

Finally, if such an approach were used to allocate forward losses, then the analysis of subsections (iii), (iv) and (v) above, and related sections below, would continue to apply to settlement losses.

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[19] The sum of the notional bilateral losses of the closed-out member always equals the sum of the notional bilateral gains vis-à-vis the closed-out member.

[20] The consequences of these considerations for risk management deserve further analysis.

(vii) How Much Collateral is Enough?

In general, the greater the collateral requirement relative to a member's obligations, the more secure the operations of the clearinghouse. Given the opportunity cost of collateral, however, collateralization raises the cost of the netting facility to the members. Following are four examples of collateralized survivors-pay clearinghouses, differentiated by the amount of collateral that they hold.[21]

(a) Protecting Against All Possible Primary Defaults: Each member of the clearinghouse could post collateral equal to its potential obligations to the clearinghouse arising through the loss allocation procedure. This would have the effect of protecting the clearinghouse against *all* possible primary defaults occurring simultaneously. (Note that the amount of collateral held by the clearinghouse in this case would equal the collateral posted in a defaulter-pays clearinghouse.)

(b) Protecting Against the Single Largest Possible Primary Default -- Based on Bilateral Credit Limits: On the premise that bank failures are independent events, one might argue that the members should protect the clearinghouse against the *single largest* possible failure, instead of securing all possible primary losses to the clearinghouse. (This would therefore cover several smaller defaults.)[22] If each member posted collateral equal to its largest bilateral credit limit, the clearinghouse would hold sufficient collateral to cover the single largest possible default. It follows that *any* single possible primary default to the clearinghouse also would be covered.

(c) Protecting Against the Single Largest Possible Primary Default -- Based on Scaled-Down Bilateral Credit Limits: The preceding two approaches both could involve substantial collateral requirements. Therefore, one could consider a less collateral-intensive possibility, whereby each member would be required to collateralize some fraction, say θ per cent, of the largest bilateral credit limit that it offered to any member of the clearinghouse.

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[21] Appendix III presents formally the intuitive arguments and results discussed in this subsection. For simplicity, the analysis here refers to a survivors-pay clearinghouse. In a hybrid model which blends survivors-pay and defaulter-pays features, the amount of collateral posted by each member could reflect the fact that a loss allocation would be reduced by the collateral posted by the defaulting member.

[22] The minimum standards for netting schemes suggested by the Lamfalussy Report (see Appendix I) indicate that "multilateral netting systems should, at a minimum, be capable of ensuring the timely completion of daily settlements in the event of an inability to settle by the participant with the largest single net-debit position."

Each member would in turn face a net debit cap equal to θ per cent of the sum of the bilateral credit lines offered to it. Again, the collateral posted by the membership would be greater than or equal to any loss to the clearinghouse caused by the failure of any *single* participant.[23]

In effect, this approach lowers net debit caps (and therefore collateral requirements) towards the net debit positions that would actually tend to prevail under the multilateral netting of a given set of bilateral exposures, thus reducing "excess" collateralization inherent in an approach like (b) above. That is, collateralizing simply the single largest *possible* default under approach (b) would tend to result in collateral pledges considerably in excess of loss allocations that would *actually* arise.

(d) Protecting Against the Single Largest Possible Primary Default -- Based on Notional Bilateral Exposures: Provided that the clearinghouse and its members had the operational capabilities, each member could be required to post collateral equal to its largest single potential loss allocation arising from notional bilateral exposures (instead of credit limits) to members in net debit positions with the clearinghouse. However, given that loss allocation exposures could be very volatile, this approach could introduce considerable volatility into the collateral pledges, complicating collateral management for the clearinghouse and its members. Thus, while basing the loss allocation rule on notional bilateral exposures might provide members with the greatest scope to manage their loss allocation exposures, operational considerations may lead to a preference for collateral requirements based on scaled-down bilateral credit limits, as in approach (c) above.

(viii) The Role of Capital Adequacy

Limiting exposures to a fraction of capital could also enhance the reliability of loss allocation rules and therefore ultimate settlement in a clearinghouse. Could this be a substitute for a loss allocation procedure secured by collateral? From the clearinghouse's perspective, a requirement for members to post collateral to secure their obligations has four advantages relative to capital. (i) Collateral is immediately available to the clearinghouse, unlike bank capital. (ii) Collateral can also be used to secure liquidity drawings for the clearinghouse -- see below. (iii) Collateral is marked to market -- in

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[23] The Clearing House Interbank Payments System (CHIPS) in the United States uses such a rule, where θ equals .05, because of concerns about the reliability of loss allocation and settlement.

contrast to capital adequacy standards which are at book value -- and thus provides a more accurate measure of the security of the clearinghouse. Finally, (iv) given that collateral is, in effect, an ex-ante payment against exposures, it provides stronger incentives for clearinghouse members to establish appropriate practices and procedures in the management of the clearinghouse and in their own activities. This is particularly relevant since many of these members may hold the view that they are immune to failure.

However, this does not imply that capital adequacy has no role to play. For instance, as noted below, collateral cannot guarantee that clearinghouse members will not fail, which suggests that exposures should be limited to some fraction of capital.

(ix) What Collateral Cannot Do

A collateralized loss allocation rule will ensure, up to some point, that loss allocations are honoured and that the netting system will settle. However, it cannot guarantee that clearinghouse members will not fail: if a member pledges collateral up to or in excess of its capital, then a loss allocation up to that amount would render that member insolvent. Also, while collateralized loss allocation could ensure that the system would settle, the impact of the loss itself on members could impair the ability of the system to operate subsequently. For example, if losses are large enough, some members may fail capital-based membership requirements, or more generally, losses could impair their ability to function. If the loss allocation rule were collateralized, then a loss allocation could leave a member with insufficient collateral to be able to operate in the clearinghouse the next day. In sum, a large loss allocation, collateralized or not, would damage the member banks. This underscores the need to provide incentives to members to undertake manageable exposures in the clearinghouse.

5. SETTLEMENT AND LIQUIDITY ARRANGEMENTS

(i) Settlement Arrangements and Settlement Risk

The clearinghouse would need to establish transfer accounts with settlement agents in each country whose currency is eligible for netting,[24] and it would require that each member make arrangements that allow it to make payments to, and accept payments from these transfer accounts.

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[24] Achievement of finality requires that payments be made in the country that issues the currency.

To help manage settlement risk, the clearinghouse could stipulate that all, or a small subset of very large, settlement payments would be made in advance of their value dates. For example, all payments could be made to the clearinghouse (or its agents) a day or two before their settlement dates. Alternatively, pre-paying settlements might be restricted to infrequently occurring settlement dates on which unusually large settlement payments would be made.[25] Provision for early payment would provide the clearinghouse with ample warning to arrange liquidity cover for any failed payments, and the payments due to the defaulter, which would be withheld, would be used to help secure any needed liquidity borrowing to cover payments due to other members that would otherwise be in default.[26]

To minimize the cost of this approach, which arises from pre-funding settlement balances, pre-paid balances could be invested on behalf of the paying member, so that the member's cost of pre-paying would be related to only the spread between the bid and ask rates. However, it must be stressed that this shifts the default risk from the member that is pre-paying its settlement to the assets in which the pre-paid balance is invested. That is, this approach requires the clearinghouse and its members to bear the risk associated with the investment of the settlement balances, which could be minimized by choosing government treasury bills or a diversified portfolio of high quality investments.

(ii) Liquidity Arrangements and Liquidity Risk

There are three main approaches to providing liquidity for clearinghouse operations.

(a) Arranging standby lines of credit or overdraft facilities in the currencies of operation: Lines of credit or overdraft facilities probably would be provided by settlement agents. The clearinghouse could arrange lines with more than one highly rated bank per currency to

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[25] Such unusually large settlement obligations could be those that, for example, would otherwise lead to violations of net debit caps. If collateral requirements were based on scaled-down bilateral credit limits (as discussed above), pre-paying unusually large settlements would lower collateral requirements that would otherwise prevail, since these settlement exposures would not arise.

[26] Alternatively, the clearinghouse could stipulate that receipts to members in earlier time zones would be withheld until any payments due from these members on that value date in later time zones were made; or, payments due in later time zones on a given value date would have to be pre-paid by members that had receipts in earlier time zones on that value date. In a *regular-way settlement* of a foreign currency option transaction, the Options Clearing Corporation (OCC) requires an option holder to pre-pay U.S. dollar amounts owed to the OCC two days before the settlement date. See Federal Reserve Bank of New York, *An Overview of the Operations of the Options Clearing Corporation*, (FRBNY, April 1989).

I am indebted to Patrick M. Parkinson of the U.S. Federal Reserve Board for suggesting the potential contribution of pre-paying settlements.

avoid relying on a single bank to provide liquidity services for a given currency.

(b) Requiring each member to provide a committed line of credit to the clearinghouse: Such lines could be provided on an equal basis or in proportion to a member's potential or actual business with the clearinghouse.

Reliance on credit lines, either (a) or (b), raises questions about the conditions under which the funds would be available and the speed with which they would be made available for settlement.

(c) Establishing a pool of assets (or one for each relevant currency): These assets would be provided by members, and the clearinghouse could draw on the pool for collateral to support borrowing or it could sell the assets to raise cash. It is very likely that collateral would be needed to support approaches (a) or (b) above. Thus, collateral would both underpin the loss allocation procedure (as discussed above) and support the liquidity needs of the clearinghouse.

In the event of a default, collateral might not be sold immediately to raise cash. In the event of a settlement default, collateral probably would be used initially to support borrowing to ensure timely settlement, since selling collateral might be less efficient than drawing on a collateralized line of credit at short notice in some circumstances. In this case, assuming that the settlement failure is the result of a member's insolvency instead of a temporary payment delay, collateral subsequently would be sold to repay the lender of the funds. Otherwise, the late payment from the member would be used to repay the lender. If the failure occurred before settlement, so that the exposure is a forward replacement loss, it is more likely that collateral would be sold in the first instance (depending on the expected exchange rate and discount rate movements), since the urgency associated with ensuring settlement would not be present. As a practical matter, however, a member's default could readily involve both settlement and forward replacement losses.

(iii) Settlement Agent Risk

The failure of a settlement agent could expose the clearinghouse to losses if it occurred after clearinghouse members with net debits had irrevocably paid the settlement agent but before the settlement agent had irrevocably paid members with net credits in the currency. Since losses to the clearinghouse must be recovered from the membership,

a loss arising from the failure of a settlement agent would also need to be allocated to members according to a predetermined loss allocation rule.[27]

To lower settlement agent risk, settlement agents could be commercial banks with high credit ratings, and more than one agent could be employed in a given country. Also, a settlement agent could operate through an escrow account so that the failure of a settlement agent would not necessarily lead to losses. Alternatively, settlement agents could be the central banks of the relevant countries, obviating the risk of settlement agent failure.

6. MEMBERSHIP OR ACCESS CRITERIA

Since losses from the default of any member would be allocated to surviving members, a great deal of attention would need to be paid to the creditworthiness of prospective members. As a result, a survivors-pay clearinghouse can be expected to have more demanding membership standards than a defaulter-pays clearinghouse in which members fully collateralize their own net debits with the clearinghouse so that there is relatively little risk of liability for non-defaulting members. A hybrid model, which blends survivors-pay and defaulter-pays features, can provide greater access than a survivors-pay clearinghouse, but it may restrict a member's activity more than a defaulter-pays clearinghouse.[28] Finally, membership standards could be more demanding to the extent that the clearinghouse relies on allocating replacement cash flows to allocate forward losses, since this procedure can alter the distribution of notional bilateral exposures within the clearinghouse (as discussed above).

At the same time, if membership in a multilateral netting facility is seen to be highly valuable to the conduct of foreign exchange business (and the associated increase in payments efficiency and decreases in credit and liquidity risks suggest that this might be the case), then unduly restrictive or opaque access requirements could conceivably be challenged on fair trade grounds by excluded parties. This might be most likely where the economies of scale of clearinghouse operations would result in only a few such

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[27] In some cases, the settlement agent may also be a clearinghouse member and a provider of liquidity, which raises additional risk management complexities.

[28] Note also that access to the clearinghouse and its benefits may be direct, that is, through membership, or indirect, that is, a non-member may hire a member to act as an agent to conduct foreign exchange transactions.

facilities globally (as seems plausible).[29]

7. CONCLUDING REMARKS

Multilateral netting is a contractual technique through which transactions among numerous counterparties are set off against one another according to currency and value date. As a result, gross credit exposures can be reduced in a way which is legally binding not only on the parties to the contract, but also on liquidators in the event of the failure of one of the originating counterparties. In this way, the risk of liquidators cherry picking beneficial contracts and repudiating costly contracts is eliminated from foreign exchange transactions. It follows that the legal effectiveness of the underlying netting arrangements is of primary importance to the success of any multilateral netting facility.

Simulations suggest that multilateral netting would reduce forward replacement exposures by about 80 to 85 per cent for a given set of transactions conducted in the absence of netting. Multilateral netting can also significantly reduce settlement and liquidity risks. Again, simulations suggest that multilateral netting would reduce settlement flows by about 75 per cent, compared with the payments that would be needed to settle the corresponding gross obligations. Multilateral netting also would reduce the aggregate losses to participants from a failure of a settlement agent, because it would reduce considerably the amounts to be settled.

However, to ensure that risks are in fact reduced, and not exacerbated, by multilateral netting, efficient mechanisms must be established to manage credit risks arising in the clearinghouse -- both forward replacement risk and settlement risk -- and to manage the liquidity needs of the clearinghouse in the event of a temporary shortfall of payments to the clearinghouse. Thus, a highly reliable loss allocation procedure is fundamental to a well-designed clearinghouse. Ensuring the reliability of loss allocation suggests a central role for collateral, and this collateral would also underpin any needed liquidity arrangements.[30]

This paper also stresses the establishment of net debit caps to limit the risk that

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[29] The minimum standards for netting schemes suggested by the Lamfalussy Report (see Appendix I) indicate that "multilateral netting systems should have objective and publicly disclosed criteria for admission which permit fair and open access."

[30] Currently, multilateral netting facilities are in existence or under development for Canadian dollar payments, securities and foreign exchange that depend on reliable loss allocation procedures and thus include a role for collateral. It follows that policymakers must also begin to consider the aggregate implications of pledging collateral to different systems and the possible relationships between them.

members can present to the clearinghouse, and risk management procedures that ensure that the clearinghouse can promptly arrange the needed liquidity and recover any loss associated with, at a minimum, the default of the member with the largest net debit position. These features can be achieved by requiring each member to collateralize some fraction, say θ per cent, of the largest bilateral credit limit that it offered to any member of the clearinghouse. This could be complemented by pre-paying unusually large settlements to the clearinghouse, which would invest the pre-paid balances in a diversified set of high quality assets until the settlement date.

Finally, it follows that to enable members to manage their loss allocation exposures and to monitor compliance with respect to net debit caps, a real-time data-processing and communications system is required.

APPENDIX I
MINIMUM STANDARDS FOR NETTING SCHEMES[31]

1. Netting schemes should have a well-founded legal basis under all relevant jurisdictions.

2. Netting scheme participants should have a clear understanding of the impact of the particular scheme on each of the financial risks affected by the netting process.

3. Multilateral netting systems should have clearly defined procedures for the management of credit risks and liquidity risks which specify the respective responsibilities of the netting provider and the participants. These procedures should also ensure that all parties have both the incentives and the capabilities to manage and contain each of the risks they bear and that limits are placed on the maximum level of credit exposure that can be produced by each participant.

4. Multilateral netting systems should, at a minimum, be capable of ensuring the timely completion of daily settlements in the event of an inability to settle by the participant with the largest single net-debit position.

5. Multilateral netting systems should have objective and publicly disclosed criteria for admission which permit fair and open access.

6. All netting schemes should ensure the operational reliability of technical systems and the availability of back-up facilities capable of completing daily processing requirements.

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[31] Bank for International Settlements, *Report of the Committee on Interbank Netting Schemes of the Central Banks of the Group of Ten Countries* (the Lamfalussy Report), (BIS, November 1990).

APPENDIX II
HOW LARGE CAN LOSS ALLOCATIONS GET IN A PROCEDURE WITHOUT COLLATERAL OR SET-OFFS?

In a survivors-pay multilateral clearinghouse, without collateral or rights of set-off, the loss to bank j from the default of bank i can be summarized by the following equation:

$$(1) \qquad L^i_j = [E^i_j/(\sum_{x=1}^{b} E^i_x)]D_i + \sum_{y=1}^{s} [E^i_j/(\sum_{x=s+1}^{b} E^i_x)]L^i_y$$

where L^i_j = the loss to bank j from the default of bank i to the clearinghouse;

E^i_x = the bilateral exposure of bank x to bank i;

D_i = the obligation of bank i (in default) to the clearinghouse;

L^i_y = the loss allocation of bank y in default; that is, bank y is a secondary defaulter and the amount of its secondary default with respect to the original default (D_i) is L^i_y;

b = the number of members with bilateral exposures to defaulter i;

s = the number of secondary defaulters.

Also, let n = the number of clearinghouse members so that $s \leq b < n$. (The maximum value for b is n-1.)

Thus, the total possible loss to bank j is the sum of loss allocations to it resulting from the defaults of members to which it has bilateral exposures, that is,

$$(2) \qquad L^i_j = \sum_{i=1}^{p} L^i_j.$$

$$= \sum_{i=1}^{p} [E^i_j/(\sum_{x=1}^{b} E^i_x)]D_i + \sum_{i=1}^{p} \{\sum_{y=1}^{s} [E^i_j/(\sum_{x=s+1}^{b} E^i_x)]L^i_y\}$$

where p = the number of primary defaulters to which bank j has a bilateral exposure;

$p < n$.

Also, note that

$$(3) \qquad D_i \leq \sum_{x=1}^{b} E^i_x.$$

That is, the multilateral net debit of member i is no greater than the sum of all bilateral exposures to that member. (However, clearinghouse rules could cap net debits at any level lower than the sum of the bilateral exposures. Thus the rules of the clearinghouse could determine the maximum D_i for each member i.)

Case (a): In the simple case of one primary default (D_i) without any secondary defaults (that is, all survivors honour their loss allocations), the loss to member j from the primary default of member i is

$$L^i_j = [E^i_j/(\sum_{x=1}^{b} E^i_x)]D_i.$$

Member j's loss is its pro rata share (scaled by bilateral exposures) of the primary default.

Case (b): Suppose that there is only one multilateral default (D_i), but there are multiple secondary defaults (that is, defaults on loss allocations), leaving only member j as a loss sharer; that is, s = (b-1).[32] Thus, in the extreme:

$$L^i_j = [E^i_j/(\sum_{x=1}^{b} E^i_x)]D_i + \sum_{y=1}^{b-1} [E^i_j/(\sum_{x=b}^{b} E^i_x)]L^i_y$$

$$= [E^i_j/(\sum_{x=1}^{b} E^i_x)]D_i + \sum_{y=1}^{b-1} L^i_y.$$

Substituting for L^i_y yields

$$L^i_j = [E^i_j/(\sum_{x=1}^{b} E^i_x)]D_i + \sum_{y=1}^{b-1} [E^i_y/(\sum_{x=1}^{b} E^i_x)]D_i.$$

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[32] It should be noted that cases (b) and (c) considered in this appendix, that is, multiple defaults of clearinghouse members, may be unlikely, and the extremes considered here might suggest catastrophic circumstances in the financial markets. Nevertheless, consideration of these cases is instructive with respect to an understanding of the analytics of loss allocation. Moreover, poorly designed loss allocation procedures raise the probability of moving from the simplest case (a) of one primary default toward cases (b) and (c) of multiple secondary and primary defaults.

Thus, $L^i_j = D_i[(E^i_j + \sum_{y=1}^{b-1} E^i_y) / \sum_{x=1}^{b} E^i_x]$.

However, $(E^i_j + \sum_{y=1}^{b-1} E^i_y) = \sum_{y=1}^{b} E^i_y$

= the sum of all bilateral exposures to defaulter i of members 1 through b.

Therefore,

$$(E^i_j + \sum_{y=1}^{b-1} E^i_y) = \sum_{x=1}^{b} E^i_x.$$

Thus, $L^i_j = D_i$.

In this case, a member's loss allocation can be as high as the primary default to the clearinghouse, which, in turn, can be as high as the sum of *all* bilateral exposures to the defaulting member (equation 3).

Case (c): If there are multiple primary defaulters (that is, $p > 1$), along with multiple secondary defaults, then the total possible loss allocation to member j is

$$(4) \qquad L^t_j = \sum_{i=1}^{p} L^i_j = \sum_{i=1}^{p} D_i.$$

And from equation (3):

$$(5) \qquad \sum_{i=1}^{p} D_i \le \sum_{i=1}^{p} \sum_{x=1}^{b} E^i_x = \sum_{i=1}^{p} \sum_{x=1}^{b-1} E^i_x + \sum_{i=1}^{p} E^i_j.$$

Thus, the maximum loss allocation to a member is the sum of the net debits of all primary defaulters to which the member has a bilateral exposure (equation 4). It follows that a member's maximum loss allocation in the event of multiple primary and secondary defaults can exceed the sum of its own bilateral exposures to the primary defaulters ($\sum_{i=1}^{p} E^i_j$ in equation 5).

APPENDIX III
HOW MUCH COLLATERAL IS ENOUGH?

In general, the greater the collateral requirement relative to a member's obligations, the more secure the operations of the clearinghouse. Given the opportunity cost of collateral, however, collateralization raises the cost of the netting facility to the members. The following underpins the views expressed in the text concerning the four examples of collateralized survivors-pay clearinghouses, differentiated by the amount of collateral that they hold.

To begin, consider again the basic loss allocation rule:

$$(1) \qquad L^i_j = [E^i_j/(\sum_{x=1}^{b} E^i_x)]D_i + \sum_{y=1}^{s} [E^i_j/(\sum_{x=s+1}^{b} E^i_x)]L^i_y$$

where all variables are as previously defined (see, for example, Appendix II), but D_i now is the maximum net debit possible for each member i, a ceiling set by the clearinghouse.

(a) Protecting Against All Possible Primary Defaults: Each member of a survivors-pay clearinghouse could post collateral equal to its potential obligations to the clearinghouse arising through the loss allocation procedure. In the context of the preceding equation, this could imply that each member j posts collateral equal to L^i_j, that is,

$$\sum_{i=1}^{p} [E^i_j/(\sum_{x=1}^{b} E^i_x)]D_i.$$

This would have the effect of protecting the clearinghouse against *all* possible primary defaults occurring simultaneously. Note that the amount of collateral held by the clearinghouse in this case would necessarily equal the collateral posted in a defaulter-pays clearinghouse for a given volume of transactions, that is,

$$\sum_{x=1}^{n} L^i_x = \sum_{i=1}^{n} D_i.$$

(b) Protecting Against the Single Largest Possible Primary Default -- Based on Bilateral Credit Limits: On the premise that bank failures are independent events, one might argue that the members should protect the clearinghouse against the *single largest* possible

failure, instead of securing all possible primary losses to the clearinghouse. (This would therefore cover several smaller defaults.)[33] Suppose that bank L was the bank that received the largest bilateral credit limit from each member of the clearinghouse, and assume that bank L reached all of its bilateral credit limits from the other members. (As a result, bank L's multilateral debit position would be the largest possible in the clearinghouse). The clearinghouse's maximum possible exposure to this bank would be

$$(2) \qquad D_L = \sum_{x=1}^{n-1} E^L_x.$$

Therefore, under these circumstances (and assuming that there are no secondary defaults), the maximum primary loss to bank j from the failure of bank L would be, from equation (1),

$$L^L_j = [E^L_j/(\sum_{x=1}^{n-1} E^L_x)]D_L$$

$$= [E^L_j/(\sum_{x=1}^{n-1} E^L_x)]\sum_{x=1}^{n-1} E^L_x$$

$$= E^L_j.$$

If the collateral posted by bank j were equal to this loss, then

$$(3) \qquad K^L_j = E^L_j$$

The total collateral posted by all banks to the clearinghouse would be

$$K^L = \sum_{x=1}^{n-1} K^L_x$$

$$= \sum_{x=1}^{n-1} E^L_x \text{ from equation (3).}$$

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[33] The Lamfalussy standards also indicate that "multilateral netting systems should, at a minimum, be capable of ensuring the timely completion of daily settlements in the event of an inability to settle by the participant with the largest single net-debit position."

Therefore,

$K^L = D_L$, from equation (2).

Thus, if each member posted collateral equal to its largest bilateral credit limit, the clearinghouse would hold sufficient collateral to cover the single largest possible default (D_L). It follows that *any* single possible primary default to the clearinghouse also would be covered: For any bank i, the maximum default that it can impose on the clearinghouse is $D_i = \sum_{x=1}^{b} E^i_x \leq \sum_{x=1}^{n-1} E^L_x = K^L$.

(c) Protecting Against the Single Largest Possible Primary Default -- Based on Scaled-Down Bilateral Credit Limits: The preceding two approaches both could involve substantial collateral requirements. Therefore, as a less collateral-intensive possibility, each member could be required to collateralize θ per cent of the largest bilateral credit limit that it offered to any member of the clearinghouse. Each member would in turn face a net debit cap equal to θ per cent of the sum of the bilateral credit lines offered to it. Again, the collateral posted by the membership would be greater than or equal to the loss to the clearinghouse from the failure of any *single* participant.

In effect, this approach lowers debit caps (and therefore collateral requirements) toward the debit positions that would actually tend to prevail under the multilateral netting of a given set of bilateral exposures, thus reducing "excess" collateralization inherent in an approach like (b) above. That is, collateralizing simply the single largest *possible* default (as in [b] above) would tend to result in collateral pledges considerably in excess of loss allocations that would *actually* arise.

Collateralizing the largest single possible primary default, based on scaled-down credit limits, would imply that the largest net debit possible is

$$D_L = \theta \sum_{x=1}^{n-1} E^L_x.$$

Each member's collateral pledge would be

$$K^L_x = \theta E^L_x.$$

Total collateral would be

$$K^t = \sum_{x=1}^{n-1} K^L_x$$

$$= \theta \sum_{x=1}^{n-1} E^L_x,$$

Therefore,

$$D_L = K^t.$$

The key is that the net debit cap (D_L for bank L), would be closer to the actual net debit positions that would tend to prevail under the multilateral netting of bilateral exposures than would be

$$D_L = \sum_{x=1}^{n-1} E^L_x,$$

which is the debit cap for bank L that emerges under approach (b) above. As a result, collateral pledges could be lowered without significantly affecting the net debit positions that members would need under the multilateral netting of a given set of bilateral exposures.

(d) Protecting Against the Single Largest Possible Primary Default -- Based on Notional Bilateral Exposures: Provided that the clearinghouse and its members had the operational capabilities, each member could be required to post collateral equal to its largest single potential loss allocation arising from notional bilateral exposures (instead of credit limits) to members in net debit positions with the clearinghouse. However, given that loss allocation exposures could be very volatile, this approach could introduce considerable volatility into the collateral pledges, complicating collateral management for the clearinghouse and its members.

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