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3/96

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14.2.1996

Systemic Risk in the Finnish Payment System: an Empirical Investigation

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Abstract

The volume of large-value funds transfers in the money, foreign exchange and securities markets has increased manifold during the last decade. This development has increased interbank debt positions and extensions of intraday credit resulting from payment transactions in the payment-intermediation sector. Systemic risk in these arrangements refers to the risk that one clearing system participant's failure to settle will cause one or more other participants to default. The danger of systemic failure exists in a clearing system in which payment messages are exchanged during the day but funds are transferred only at the end of the day. In this study, simulation with empirical data is used to measure the probability, extent and resulting effects of a systemic crisis in the Finnish payment system.

The major finding of the study is that one participant's failure to settle in the Finnish payment system can cause serious problems for other participants but the danger of systemic failure is relatively small. On average the banks' largest counterparty risks are low and amount to less than 10 per cent of their own funds. However, on some days counterparty risk can amount to over 50 per cent of banks' own funds and thus constitute a systemic risk. Large counterparty risks however do not form long interbank chains that could lead to a domino effect. Even should a payment system participant suddenly be unable to settle, the other participants would probably manage to avoid serious problems.

Although the simulation results indicate that presently the probability of systemic crisis in Finland is quite small, it is still important that payment system risk control be further developed. The environment in which the payment system operates is developing very rapidly, and risks are growing as volumes increase. As the system opens up to foreign credit institutions, Finnish payment system participants also find themselves dealing with more and more counterparties about whom they have no prior knowledge. System entry and risk control can no longer be based solely on trust; clear game rules are needed. As part of its task of overseeing payment systems, the central bank will need to closely monitor system developments, promote risk awareness in the markets and payment systems, and prevent the creation of systems in which it is possible for settlement failures to spread. This work should be done in cooperation with international organizations and the EU.

Keyword: systemic risk, clearing, settlement, Finland

Tiivistelmä

Rahamarkkina-, valuutta- ja arvopaperikauppaan liittyvien suurten maksujen volyymi on moninkertaistunut viimeisen vuosikymmenen kuluessa. Kehitys on johtanut aikaisempaa suurempiin maksuliikenteestä aiheutuviin pankkien välisiin velka-positioihin ja päivänsisäisten luottojen syntymiseen maksujenvälityssektorissa. Systeimiriskillä tarkoitetaan riskiä, että yhden maksujärjestelmän osapuolen maksuhäiriö johtaa yhden tai useamman muun osapuolen maksuhäiriöön. Maksujärjestelmissä systeimiriskin toteutumisen vaara on olemassa selvitysjärjestelmissä, joissa maksusanomia vaihdetaan päivän aikana, mutta maksujen katteet siirretään vasta päivän päätteeksi. Tässä selvityksessä pyritään empiiristä tietoa käyttävien simulointien avulla arvioimaan systeimiriskin toteutumisen todennäköisyyttä, laajuutta ja seurannaisvaikutuksia Suomen maksujärjestelmässä.

Selvityksen keskeinen tulos on, että yhden osapuolen kyvyttömyys selviytyä katevelvollisuudestaan voi aiheuttaa muille osapuolille vakavia häiriöitä, mutta systeimiriskin vaara on suhteellisen pieni. Pankkien suurimmat päivittäiset vastapuoliriskit ovat keskimäärin alle kymmenen prosenttia pankkien omista pääomista. Huippupäivinä vastapuoliriskit voivat kuitenkin olla yli 50 % pankin omasta pääomasta ja voivat siten myös laukaista systeimiriskin. Suuret vastapuoliriskit eivät kuitenkaan kertaudu ja muodosta pitkiä pankkien välisiä ketjuja, joissa domino-efekti pääsisi toteutumaan. Vaikka jokin maksujärjestelmän osapuoli joutuisi yllättäen vakavaan maksuhäiriöön, niin muut osapuolet todennäköisesti selviytyisivät siitä joutumatta itse vakavaan kriisiin.

Vaikka suoritettujen simulointien perusteella systeimiriskin todennäköisyys on Suomessa tällä hetkellä melko vähäinen, tulee maksujärjestelmien riskienhallintaa edelleen kehittää. Maksujärjestelmäympäristö kehittyy varsin nopeasti ja maksujen volyymien kasvun myötä myös riskit kasvavat. Järjestelmien avautuessa ulkomaisille luottolaitoksille suomalaisetkin maksujärjestelmäosapuolet joutuvat tekemisiin yhä useampien, aikaisemmin tuntemattomien osapuolten kanssa. Pääsy järjestelmiin ja järjestelmien riskienhallinta ei voi enää perustua pelkkään luottamukseen, vaan on oltava olemassa selkeät pelisäännöt. Keskuspankin tulee osana maksujärjestelmien valvontatehtäväänsä seurata järjestelmien kehitystä tiiviisti, edistää markkinoiden ja maksujärjestelmien riskitietoisuuden lisääntymistä sekä pyrkiä ennalta ehkäisemään sellaisten järjestelmien syntymistä, joissa maksuhäiriöiden leviäminen on mahdollista. Tätä työtä on tehtävä yhteistyössä kansainvälisten järjestöjen ja EU:n kanssa.

Avainsanat: systeimiriski, maksujärjestelmät, selvitysjärjestelmät, Suomi

Foreword

Internationally, there has been relatively little empirical research on payment systems and related risks. This study, which uses empirical data on Finnish payment systems, is one initiative to add to this area of research and increase our knowledge of systemic risks in payment systems. It was inspired by the Italian and U.S. studies on the same topic and especially by the visit and lectures of the author of the Italian study, Mr. Paolo Angelini, to the Bank of Finland in November 1994.

Veikko Saarinen
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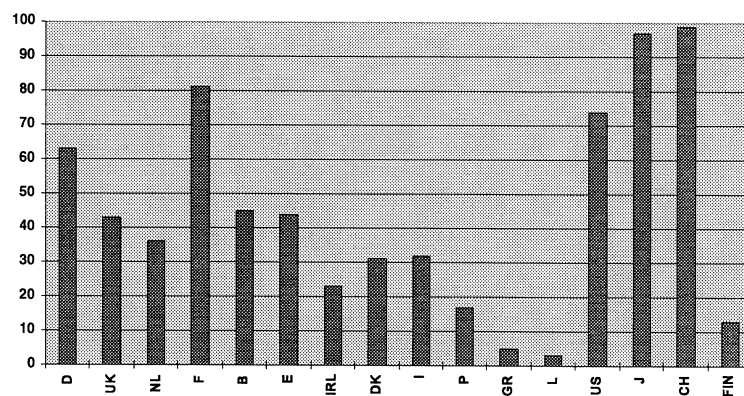
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1 Introduction

During the past decade, integration and turnover growth in the financial markets, the creation of new financial instruments and rapid technological development have led to a manifold increase in the total value of payment flows in the payment systems. Both internationally and in Finland, the volume of large-value funds transfers in the money, foreign exchange and stock markets has increased rapidly. In 1993 the value of funds transfers was nearly as much as 100 times GDP in Japan and Switzerland; in Finland it was 13 times GDP and in Luxemburg the ratio was the lowest, 3 times GDP (Chart 1).

Chart 1. **Value of funds transfers in the payment systems of different countries, ratio to GDP, 1993**



Source: BIS and central banks (Italian data from 1994; Irish, Greek and Luxembourg data from 1992).

This study attempts to measure empirically the probability, extent and resulting effects of a systemic crisis in the Finnish payment system. Systemic risk refers to the risk that one clearing system participant's inability to settle will cause one or more other participants to be unable to settle. Systemic risk can lead to a systemic crisis, ie an undermining of the stability of the whole system, if the failure of one participant to settle sets off a chain reaction wherein a significant number of system participants are unable to settle.

There is a danger of systemic crisis in a payment system in which payment messages are exchanged during the day but covering funds are not transferred until the end of the day. In the absence of effective risk control systems, large intraday positions may, in the event of a settlement failure, lead to liquidity problems and to settlement failure by a second and third participant and even to an undermining of the stability of the entire financial system. In order to prevent payment problems from spreading and to contain systemic risk, the central bank may be obliged to provide support to a system participant facing payment problems and to take upon itself the

credit risk involved. The central bank then implicitly assumes the role of guarantor of the system's stability. This may to some extent reduce participants' incentive to pay attention to the risks inherent in the payment system.¹

In order to reduce the risk associated with payment intermediation and indirectly their own risk in connection with payment systems, central banks have made suggestions and recommendations for improving system security. One means of improving system security that has recently been given high priority is a changeover to real-time gross settlement systems, in which individual payments are immediately final and irrevocable.

To reduce its own credit risk, the central bank requires the banks to have adequate reserves for settling payments and, in connection with intraday credit, either requires the posting of collateral or sets bank-specific overdraft limits (caps). These procedures however increase system participants' liquidity needs or reduce payment flow and can thus impair the fluidity of the payment system. At worst, a lack of liquidity can lead to payment gridlock, in which the system grinds to a halt as each participant awaits payment from another participant. In order to unlock the system, the central bank may be obliged to temporarily assume the risks associated with the payments of a particular participant.

The supervisory role and interests of the central bank in connection with the payment system are related to the preservation of the system's stability and operability. One key objective is to minimize the systemic risks that derive from the actions of third parties and other externalities. In practice, this refers to efforts to reduce systemic risk and gridlock of funds transfers.

Section two contains a general description of the risk structures of alternative settlement arrangements. In section three we discuss those parts of the Finnish payment system that are relevant to the settlement process and consider their exposure to systemic risk. In section four we use empirical methods in an attempt to quantify potential systemic risk in the Finnish net settlement systems, and section five contains the concluding remarks.

¹ This is so-called moral hazard problem.

2 Large-value transfer systems and systemic risk

In the context of a payment system, the settlement method (gross or net) and what it implies for the timing of payment finality have a crucial impact on the risks and costs involved.

2.1 Characteristics of different types of settlement systems

Table 1 shows the risks associated with net and gross settlement systems. The purpose is to provide a rough comparison of the risks inherent in the two types of settlement systems in order to provide a thumbnail sketch of the risks involved in Finland's payment systems.

Table 1. **Characteristics of large-value funds transfer systems¹**

| | Net settlement systems | | Gross settlement systems | |
|-----------------------------|-------------------------|-------------------------|-----------------------------------|--------------------------------|
| | Without safety features | Limits and loss-sharing | Noncollateralized intraday credit | Collateralised intraday credit |
| Participants' risks: | | | | |
| Liquidity risk | high | low | none | medium |
| Credit risk | high | small | none | none |
| Externalities: | | | | |
| Systemic risk | high | low | none | none |
| Gridlock risk | none | low | none | medium |
| Settlement risk | high | low | none | none |
| Central bank risk | high | medium | very high | low |
| Efficiency | high | medium | high | medium |
| Costs | low | medium | low | high |

¹ Following Schoenmaker 1994.

In Table 1 settlement risk refers to the risk that a third party's payments are not made on time because the entire settlement is either delayed or aborted due to a single participant's failure to settle. Besides risk classifications, the table gives efficiency and cost levels for the two types of settlement. Efficiency here refers to the fluidity of payments intermediation from the viewpoint of system participants. In practice this refers to the system's liquidity needs or to the flexibility with which liquidity can be obtained. The costs involved are the costs of system reserves or the liquidity that is tied up in the form of collateral. The table does not include a valuation of the technical or legal risks involved.

The key legal risk relates to the finality of netting. Even if the obligations under netting are clearly stated in the clearing agreement, they will not necessarily be legally valid because, for example, bankruptcy law might take precedence. There is in principle a small legal risk attached to the multilateral netting of securities deals in the Helsinki Money Market Center clearing system. In a possible conflict, Finnish bankruptcy law would take precedence and the bankruptcy trustee would have the right to demand the unwinding of a netting. In practice, it would not be reasonable for the trustee to make such a demand. If the netting were unwound and the debtor failed to settle, the posted collateral would revert to the clearing centre and would thus not be available to the trustee. However, securities legislation in Finland is being developed so as to ensure the legal validity of netting. If the participant were to go into bankruptcy before the clearing centre had guaranteed the trade, the participant's loss due to the interruption of the trade would be the 'replacement cost' of the trade.

Both net and gross settlement have their advantages, nor is there unanimity of opinion as to the optimal type of settlement system. In Europe the emphasis in limiting intraday credit risk in payment systems has been on the collateral for intraday credit while in the USA discussion has focused on the pricing of intraday credit (eg Humphrey 1989 or Mengle, Humphrey and Summers, 1987). Recommendations made by European central banks (Minimum Common Features for Domestic Payment Systems 1993) have clearly favoured wider use of real-time gross settlement systems. The main argument for this choice is the desire to minimize the systemic risk of the payment system.

2.2 Settlement of payments in Finland

In Finland the most important large-value interbank payments are settled by the gross method in the central bank's system. In connection with their current accounts at the Bank of Finland, the banks are required to post collateral for intraday credit, and there are bank-specific limits on the amount of intraday credit (present collateral requirement is 100 per cent for all banks). There is no credit risk to participants, and the central bank's risk is small. The collateral requirement is costly to participants, and liquidity shortages are possible (see Table 1, last column). Although interbank payments are at the final stage settled by the gross method, there are also interbank arrangements for netting payments prior to final settlement. These include the netting of cross-border markka-denominated (loro) payments, ordinary domestic customer payments and payments in respect of domestic securities trades. Loro payments are generally large-value payments whereas customer and securities trade payments can be large or small. In the netting arrangements for loro and ordinary payment transactions, the settlement risk profile is nearly the same as in the second column of Table 1, ie the risks to both the participants and the central bank are large. In securities trade (Helsinki Money Market Center and Helsinki Stock Exchange), the risk profile is closest to that of the third column, ie participants' risks are small because of the collateral requirements. In the following section, the above-mentioned aspects of Finland's payment system will be examined in greater detail.

3 Payment and settlement systems in Finland

To provide some background for the analysis, we examine briefly the Bank of Finland interbank funds transfer system (BOF system), which is a real-time gross settlement system, as well as loro clearing, ordinary payment clearing and zeroing of postal giro accounts, which are net settlement arrangements. We conclude by examining the net settlement system used in securities trade.

3.1 The Bank of Finland interbank funds transfer system (BOF system)

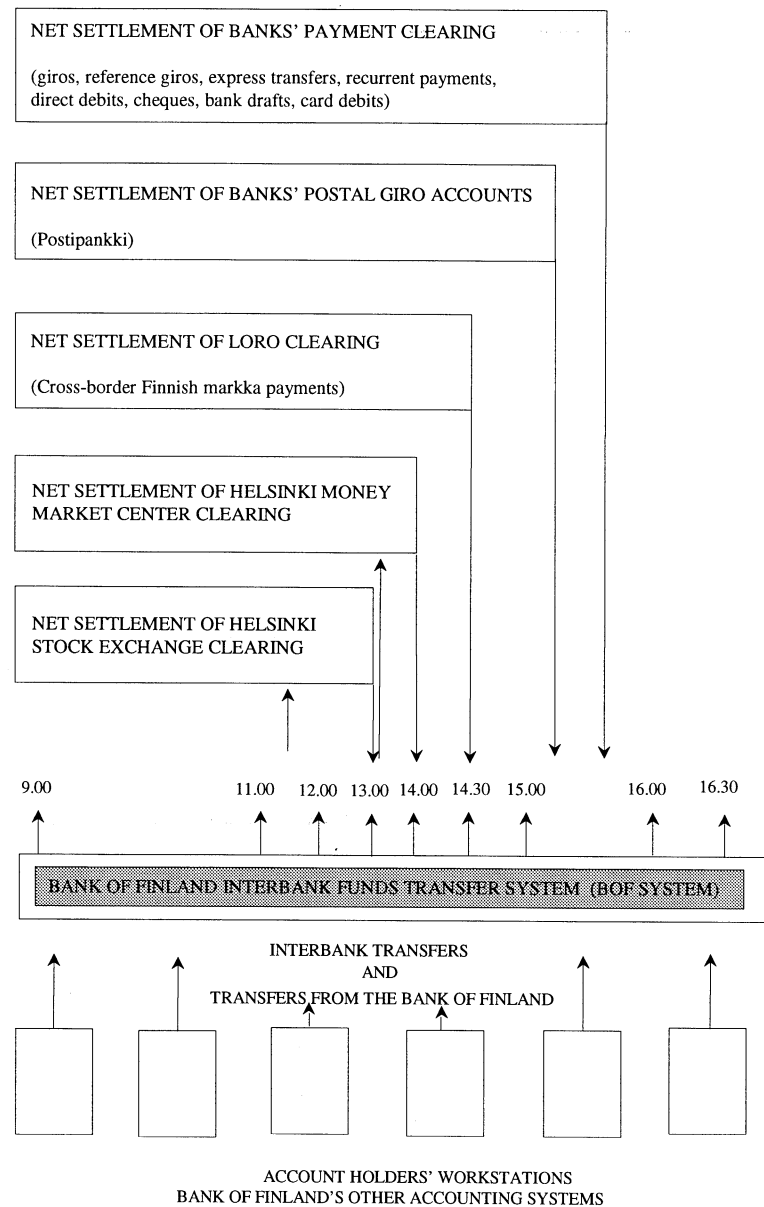
In the Bank of Finland's interbank funds transfer system, interbank payments are based on real-time gross settlement. The participants in the system make account transfers at their own workstations and can monitor their account balances in real time. Payment messages and covering funds are transferred synchronously, so that payments are final immediately upon execution. The transfer of covering funds for transactions in other systems (such as banks' ordinary customer payments, cross-border markka (loro) payments and Helsinki Money Market Center and Helsinki Stock Exchange payments) is based on net settlement. Clearing systems linked to the BOF system are shown in Chart 2.

In a real-time gross settlement system, no credit risk arises to the participants from having to wait for covering funds because the payment message and covering funds are transferred synchronously. Since there is no uncertainty attached to the effecting of the payment, there is no settlement risk, which also eliminates the possibility of a systemic crisis stemming from the payment system. The intraday credit collateral requirement and credit limits reduce the central bank's credit risk while on the other hand increasing participants' liquidity risk. The collateral requirement increases banks' costs and so reduces their propensity to use central bank credit. However, poor liquidity slows down payment transfers and may at worst result in system gridlock. Consequently, the central bank must aim for a suitable balance between its own credit risk and the efficiency and flexibility of banks' payment transfers. At present, banks' credit limits in the BOF system are fairly high, which reduces the likelihood of payment system gridlock. In spite of this, it has been necessary to temporarily increase banks' intraday limits; and actual gridlock has once occurred but there has never been an unwinding of settlement.

In October 1995 the introduction of averaging provisions for banks' minimum reserves at the Bank of Finland and the transfer of reserve deposits to banks' current accounts in the BOF system allowed banks greater flexibility in their intraday liquidity management. Now banks can also even out intraday variations in payments by adjusting their reserve holdings. This has reduced the gridlock risk.

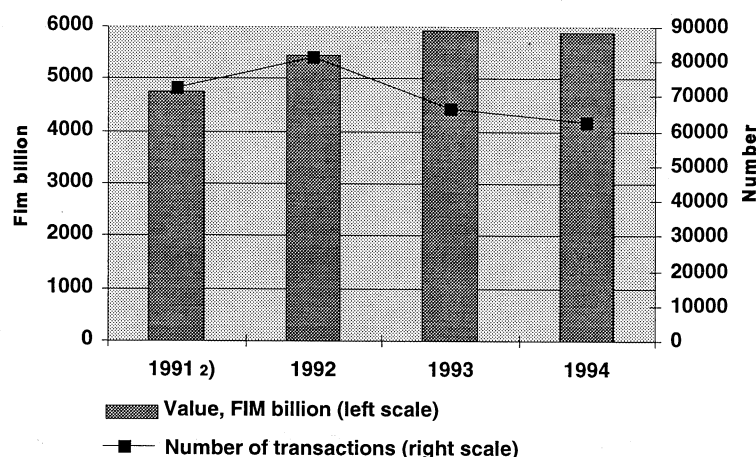
Chart 2.

Clearing systems linked to the Bank of Finland interbank funds transfer system (BOF system)



Gross settlement of interbank payments has been in effect in Finland since 1991. Multilateral netting of money market transactions began when the Helsinki Money Market Center started operations in April 1992. In spite of this, the markka volume of interbank payments transferred to the BOF system has been increasing steadily (Chart 3). Internationally too, the value of interbank payments has continued to grow, also in relation to GDP (cf. BIS 1994, p. 173).

Chart 3. **Trend in the volume of transactions in the BOF system¹**



¹ The time series have only been compiled since the changeover to the gross settlement system (ie since 1991). In Finland the most rapid growth in the volume of interbank payments took place in the 1980s, when the money market was undergoing rapid development.

² As from 18 March 1991.

3.2 Payment netting systems

3.2.1 Loro clearing system

Loro payments are banks' cross-border Finnish markka payments. Banks clear their mutual loro payments during the day and the net covering funds are transferred in the BOF system at about 2.30 p.m. The largest banks clear payments bilaterally; smaller banks use Merita Bank or Postipankki as their loro clearing agent. In bilateral settlement, the remitting party transfers covering funds from its own current account to the recipient's current account. In the centralized clearing system, the clearing agent transmits data on each loro clearing participant's claims/debts to the Bank of Finland, which makes the necessary account transfers in the BOF system.

The markka volumes of loro clearing have at times been relatively large. Loro clearing volume is a little over FIM 3 billion per day on average (April-May 1994). The following table 2 presents some key bank-specific figures on multilateral clearing.

Table 2. **Daily net positions of banks in multilateral loro clearing, April-May 1994 (FIM million)**

| Bank | Average | Maximum | Minimum |
|-----------------------|---------|---------|---------|
| A | -5 | 463 | -311 |
| B | -67 | 1 311 | -1522 |
| C | -37 | 1 135 | -1499 |
| D | 19 | 40 | -75 |
| E | 31 | 779 | -690 |
| F | 0 | 10 | -2 |
| G | 43 | 973 | -1473 |
| H | -1 | 22 | -25 |
| I | 2 | 254 | -330 |
| J | -11 | 826 | -497 |
| K | 25 | 955 | -1210 |
| Total clearing volume | 3 095 | 6 636 | 662 |

+ = receivable, - = payable

3.2.2 Banks' Payment Clearing System

Throughout each banking day, banks transmit data on their customers' payments-related debits and credits to each other. Each clearing bank nets bilaterally against all other banks the payment orders effected in its branch network and automated teller machines. The nettings are reported to the Bank of Finland and covering funds are transferred to the banks' accounts at the Bank of Finland in connection with the daily payment clearing at about 3.45 pm. Daily turnover in payment clearing amounted on average to just over FIM 3 billion in April-May 1994; even at its lowest it was FIM 1.7 billion (Table 3). The annual volume of payments has been increasing continually (Chart 4).

Chart 4.

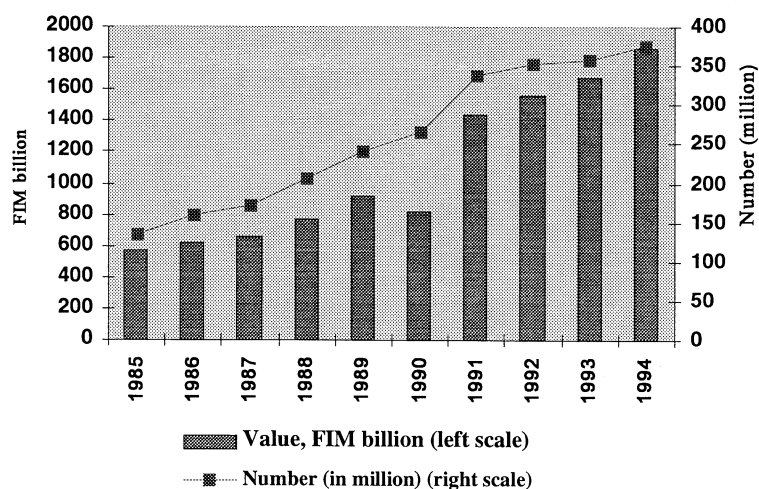
Trend in the volume of domestic payment clearing

Table 3.

Daily net positions of banks in multilateral payment clearing, April-May 1994 (FIM million)

| Bank | Average | Maximum | Minimum |
|-----------------------|---------|---------|---------|
| A | -23 | 18 | -809 |
| B | -696 | 863 | -2 107 |
| C | -104 | 110 | -495 |
| D | 1 | 33 | -2 |
| E | 33 | 147 | 0 |
| F | 288 | 1 948 | -410 |
| G | 228 | 582 | 1 |
| H | -275 | -94 | -554 |
| I | 196 | 1 043 | -875 |
| J | 351 | 2 069 | -1 742 |
| Total clearing volume | 3 254 | 5 117 | 1 722 |

+ = receivable, - = payable

3.2.3 Net settlement of banks' postal giro accounts

Almost all banks have a postal giro account at Postipankki for making payment transfers. Previously these accounts were used for making transfers between the bank giro and postal giro systems. However, with the increasing integration of the two systems, the use of postal giro accounts has diminished. At present, postal giro accounts are mainly used in connection with certain central government payments which by law must be paid via the postal giro system. The balances on banks' postal giro accounts are zeroed in the daily clearing by transferring postal giro credit

balances to the appropriate banks' BOF accounts and transferring funds from the appropriate BOF accounts to cover postal giro debit balances.

The average daily volume of postal giro accounts zeroed was FIM 400 million in May-April 1994, ie much lower than that of loro or ordinary payment clearing. Table 4 presents some key figures for April-May 1994. Because this clearing is of minor importance, it is not dealt with separately in the empirical part of this study.

Table 4. **Daily net positions of banks in multilateral postal giro clearing, April-May 1994 (FIM million)**

| Bank | Average | Maximum | Minimum |
|-----------------------|---------|---------|---------|
| A | -2 | 0 | -18 |
| B | -62 | 0 | -779 |
| C | -84 | 86 | -1 128 |
| D | 292 | 2 714 | -450 |
| E | -45 | 0 | -289 |
| F | -37 | 232 | -591 |
| G | 1 | 127 | -134 |
| H | -64 | 109 | -843 |
| I | 0 | 0 | -1 |
| Total clearing volume | 391 | 2 714 | 15 |

+ = receivable, - = payable

3.3 Securities netting systems – Helsinki Money Market Center Ltd.

The Helsinki Money Market Center Ltd (HMMC) is a clearing and settlement centre for transactions in money market book-entry securities. At the HMMC, clearing can be done on either a trade-by-trade or net basis. In trade-by-trade settlement, the settlement schedule and terms and conditions can be determined by the parties involved; net settlement is carried out in regular phases. The operating model of the HMMC fulfils the minimum requirements set by the Group of Thirty (1989) on securities clearing and settlement.²

Normally, the delivery date for spot transactions in the money market is the second day after the trade. Instruments are delivered against a payment effected simultaneously in the BOF system. On the day preceding delivery, the HMMC checks the parties' ability to pay and calculates the net obligations, which replace the gross payables and receivables. At this stage, the system requires sufficient collateral from the purchaser clearing party to ensure that the trades can be effected. After the clearing run, each party has only one net sum due to or from the HMMC.

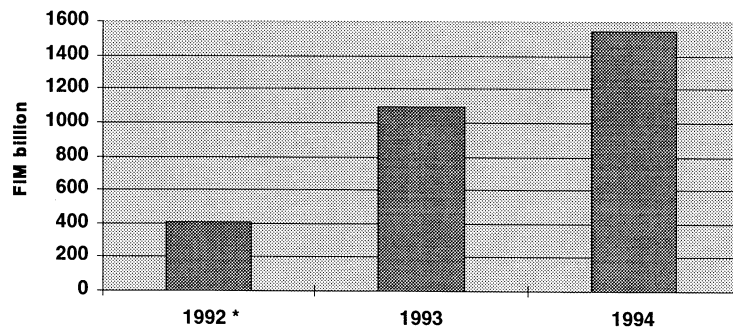
² Vehkamäki (1992) discusses the HMMC operating model in more detail.

Correspondingly, there is a single delivery obligation or claim for each instrument type.

The HMMC guarantees payment even in case of payment disturbances between the parties involved. The payment guarantee comes into effect as soon as the HMMC has cleared the trade, ie on the day preceding delivery. If a clearing party is unable to pay its net liability, the HMMC grants the party credit against the above-mentioned collateral. This type of payment guarantee is essential in a multilateral netting system in order to avoid an unwinding of a chain of trades and a possible domino effect. The Bank of Finland guarantees the HMMC's ability to pay and grants it liquidity credit, if necessary, against full collateral. Through their investments in share capital, HMMC shareholders stand behind the obligations of the HMMC. Thus any possible losses would be distributed between the shareholders pro rata to their shareholdings.

The markka volume of the trades settled at the HMMC has grown rapidly to almost FIM 1,600 billion (Chart 5). Almost one-half of the trades settled at the HMMC are internal trades between intermediaries. However, the markka value of internal trades is much smaller than that of interbank trades, which account for the bulk of the volume. In addition to commercial banks, the State Treasury and the Bank of Finland account for a significant share of the trades settled at the HMMC.

Chart 5. **Volume of trades settled at the HMMC**



* Since April.

4 An analysis of systemic risk in Finnish net settlement systems

The danger of a systemic crisis is present in systems where payment messages are exchanged in the course of the day but covering funds are not transferred until the end of the day. In Finland *loro* payments and ordinary payments are settled in this way. In this section, the exposure of these activities to systemic risk is analysed empirically and the results are compared with findings of similar studies done in other countries.

4.1 Results of studies carried out in other countries

Very little empirical research has been done on the systemic risk associated with payment systems. The main studies that have been published are those of Humphrey (1986) and Angelini, Maresca and Russo (1993). Humphrey analyses the effects of systemic risk on the US Clearing House Interbank Payment System (CHIPS) by simulating the chain reaction that would follow a system participant's failure to settle. The simulation is carried out by 'unwinding' the netting, ie deleting from the netting all funds transfers to and from the problem bank and recalculating the net positions of the remaining participants. Negative changes in position resulting from the recalculation are compared with the liquidity of the respective participants and those banks that are found to lack sufficient liquidity are deleted from the netting and the net positions are again recalculated. The process continues until all parties to a netting are able to fulfil their obligations. The scope of a possible systemic crisis is measured by simulating the domino effects of payment failures. Humphrey's data covers two randomly chosen business days, and the simulation is carried out for one direct participant in the CHIPS system and one indirect participant (uses the intermediation services of a direct participant) .

The main finding of Humphrey's study is that one participant's failure to settle has far-reaching consequences. Almost half of the CHIPS participants failed to settle their obligations due to knock-on effects. The value of cancelled payments amounted to about one-third of the total value of the payment messages sent on the day in question. This shows that systemic risk can be significant in CHIPS and that its consequences may be of a magnitude sufficient to disrupt the entire financial system. After Humphrey's study CHIPS has enhanced its risk management systems and nowadays it fulfils the so-called Lamfalussy standards for multilateral net settlement systems.

Angelini et al. apply the same approach to study the Italian payment system. However, their data is more comprehensive than Humphrey's data, and they examine the probability of systemic crisis and the consequences for all the system participants over all the business days in a month. In contrast to Humphrey's findings, the main outcome of the Italian experiment is that the probability and consequences of a systemic crisis are rather insignificant. Hence, from the standpoint of financial stability, systemic risk cannot be considered a problem, at least at present. Nevertheless, if payment flows were to grow rapidly, the situation could change, and

therefore it is desirable that risk management methods be improved with a view to the future.

The clearing organization Multinet International has studied the effect of net settlement of foreign exchange trades on the magnitude of systemic risk (see Glass 1994). The study, which is based on simulations carried out over one business day, finds that systemic risk is a significant threat to international foreign exchange trade and may have far-reaching consequences if risk management is ignored. In Multinet however positions vis-à-vis the clearing centre are minimized through multilateral netting, and the clearing centre's risks are covered by collateral requirements. In this manner, systemic risk and possible knock-on effects are eliminated.

Schoenmaker (1995) analyses the differences between gross and net settlement systems in order to clarify which system is closer to the social optimum. He finds that the extra costs of the liquidity requirements for gross settlement outweigh the benefits gained from the elimination of systemic risk. In other words, it would be less costly to use a net settlement system which includes bilateral limits and collateral cover of net positions. In Schoenmaker's model however it is assumed that the central bank is risk neutral, and as the author points out, the outcome of the analysis could be different if the central bank were assumed to be risk averse.

4.2 Estimation methodology and data

4.2.1 Methodology

The methodology used here to study systemic risk associated with net settlement systems corresponds to that used in similar foreign studies (Humphrey 1986, Angelini et al. 1993). This study attempts to estimate the probability and scope of systemic risk by using ex post settlement data and simulating situations in which a participant fails to settle and is deleted from the netting.

The simulation is carried out by recalculating the net debit/credit positions of the remaining participants each time one problem bank is removed from the netting. All payments to and from the problem bank are deleted from the netting and new net positions are calculated for the remaining banks. If the change in a bank's net position is negative enough it implies an insolvency situation and the bank is considered to have failed. An insolvency is defined to obtain if the net position deteriorates by more than 50 per cent of the bank's own funds (cf section 27 of the Commercial Bank Act). Banks that fail by this criterion are removed from the settlement and the remaining participants' net positions are recalculated. This 'unwinding' procedure is repeated until all remaining banks are able to fulfil their obligations.

As a second criterion we use illiquidity and so the adequacy of the overdraft limit on a bank's current account at the Bank of Finland is checked once another bank has been removed from a netting. The purpose here is to estimate the liquidity and gridlock risk under the assumption that the central bank does not automatically raise a participant's overdraft limit to enable it to borrow more and remain in the netting. The debits and credits obtained in this simulation are added to the the banks' current

account balances at the start of the clearing run, and the new balance for each bank is compared with the bank's overdraft limit. If the limit is exceeded, the netting is unwound by removing the defaulted bank from settlement and recalculating the net positions of the remaining participants. The new account balances are compared to the respective limits of remaining banks and again the defaulting banks are deleted from the netting. This procedure is repeated until all the remaining banks have adequate liquidity, ie the net positions do not exceed the respective limits.

4.2.2 Data

The simulations were run using transactions data from the Bank of Finland's current account system. They consist of the bilateral net positions (clearing and settlement of *loro* and ordinary payments) which are determined in the daily clearing run. A two-month period was used for the study. One month represents a fairly normal month (May 1994) and the other an exceptionally 'lively' month (April 1994) in terms of current account activity. Systemic and gridlock risk simulations were carried out for every bank on every business day during both months.

The bilateral net positions after a clearing run reflect only interbank positions at the end of the clearing period. An exact analysis of risk positions would require time-series data on intraday net positions. Such data are not available, and this limitation must be borne in mind in interpreting the results. However, it is fairly unlikely that a participant in the Finnish banking system would default unexpectedly on just a few hours' notice.

It is also worth noting the limited scope of a study of systemic risk which focuses on net clearing over a certain period. Such a study cannot estimate the effects of serious settlement failure of a bank on other segments of the economy. The combined effect of one participant's problems on the different markets may accumulate in such a way that a counterparty's crisis tolerance may be exceeded. This paper however focuses specifically on the risks associated with the funds transfer system.

4.3 Results of the study

In simulating the probability of systemic crisis, the choice of the criterion for triggering a crisis is crucial. In this study, two different criteria are used. First, the effects of one participant's settlement failure are compared with the other banks' own funds for the purpose of assessing the risk of a chain reaction of bank failures. Second, we examine the effects on participants' net positions in their current accounts at the Bank of Finland and the adequacy of intraday credit limits. The purpose here is to estimate the disruption or gridlock risk associated with the illiquidity of one or more participants in the net settlement.

4.3.1 The relationship between credit risks and own funds

The probability that the default of one bank will have chain effects on loro clearing and ordinary payment clearing is fairly small. In respect of ordinary payment clearing, the counterparty risk of only one of the banks under review exceeded half of its own funds. Using this as a criterion, the bank in question would have failed altogether six times as a result of failures of other banks. However, not one of these failures would have resulted in serious payment disruptions for other banks. In the case of clearing and settlement of cross-border markka payments, the corresponding counterparty risk limit (50 per cent of a bank's own funds) was exceeded four times during the period studied. In these cases however the margin by which risk limit was exceeded was smaller than in ordinary payment clearing (see Tables 5 and 6).

Finnish banks' own funds are large relative to the volume of interbank clearing. Moreover, banks' outgoing and incoming payments often practically match, thus reducing the size of banks' bilateral net payments. Although the probability that a payment failure of one bank will cause another bank to fail is relatively small, exposure to counterparty risk may nevertheless cause considerable problems, eg in respect of capital requirements or unpredicted market reactions. The 50 per cent own funds criterion used in this study is not very strict, as a bank's solvency may be jeopardized by smaller exposures.

Appendix Charts 1 and 2 show each domestic bank's largest daily net debit position as a percentage of its own funds in loro clearing and ordinary payment clearing. Tables 5 and 6 below depict the average and maximum sizes of these net debit positions in respect of both types of clearing. A bank's largest net debit position represents its maximum bilateral clearing exposure. In ordinary payment clearing, the largest bilateral net debit position represented 93 per cent of own funds; in cross-border markka payment clearing the maximum was 55 per cent. These averages are not in themselves relevant to system risk, but they illustrate the general levels of counterparty risk. In cross-border markka payment clearing, the largest risk recorded amounted to 8 per cent of the bank's own funds; in ordinary payment clearing 7 per cent. There appears to be no notable difference between risks in April and May.

Measured in markka terms, the maximum counterparty risks are substantial. In ordinary payment clearing, the largest international debit markka position of a single participant was more than FIM 1.5 billion; in cross-border markka payment clearing, the corresponding figure was as much as FIM 2.5 billion.

Table 5.

Maximum counterparty risks in ordinary payment clearing, April-May 1994

| Bank | Largest net debit position average, % of own funds | Largest net debit position maximum, % of own funds |
|-----------|---|---|
| A | 4 | 16 |
| B | 11 | 30 |
| C | 18 | 92 |
| D | 2 | 11 |
| E | 0 | 4 |
| F | 3 | 19 |
| G | 15 | 40 |
| H | 3 | 14 |
| All banks | 7 | 92 |

Table 6.

Maximum counterparty risks in loro clearing, April-May 1994

| Bank | Largest net debit position average, % of own funds | Largest net debit position maximum, % of own funds |
|-----------|---|---|
| A | 1 | 8 |
| B | 15 | 55 |
| C | 5 | 37 |
| D | 11 | 31 |
| E | 9 | 53 |
| F | 0 | 5 |
| G | 14 | 53 |
| H | 9 | 34 |
| All banks | 8 | 55 |

4.3.2 Risks in connection with current account positions and credit limits

This section examines liquidity risks associated with net clearing and settlement. The own-funds criterion used in the previous section is replaced by the overdraft-limit criterion. By adjusting the credit risk associated with net clearing according to banks' intraday positions at the time of clearing, it is possible to estimate the probability that a bank will fail because of a liquidity shortfall (gridlock risk) as a consequence of another bank's failure to settle. If, because of a settlement failure, one of the banks is excluded from clearing, this may cause liquidity problems for the other participants, and without the central bank's assistance the entire payment system may end up in gridlock, ie a situation where payment flows are stemmed.

In the case of ordinary payment clearing, the simulation experiment indicates that it is fairly unlikely that liquidity problems will occur and a gridlock situation arise when one participant defaults. Settlement failure simulation produced only two cases where the intraday credit limit was exceeded. On both occasions, the same bank triggered the systemic crisis. The limit overruns represented 59 and 14 per cent, respectively, of the bank's limit. However, on both occasions repeated simulation did not produce any new multiple settlement failures. Except for these two cases, all parties managed to settle their clearing commitments within their intraday credit limits irrespective of which bank was assumed to fail.

Appendix Chart 3 shows the extent to which banks used their current account overdraft facilities in settling their ordinary payment obligations assuming the largest possible counterparty failure occurred at every clearing round. Of the eight limit overruns shown in the chart, six reflect situations in which the bank actually (not only in simulation) exceeded its overdraft limit. Naturally, banks' liquidity was otherwise tight during the days under review, and even a minor settlement failure could have caused problems for them. In such conditions, simulating and interpreting the results are difficult, since in practice the central bank has already bailed out the banks by granting them the required extra liquidity and thus the simulation assumption that the central bank holds a very tight rein on its lending does not hold. In respect of the actual overruns in April-May, the major counterparty settlement failures were nonetheless relatively small and if they had occurred on a 'normal' day, they would not have had a serious impact on banks' liquidity.

In loro simulations there were a total of 15 limit overruns. In these simulations, the problem is that the large banks do not necessarily settle at the same time as the settlement of the net debts of small banks as calculated by Merita Bank. This may result in inaccuracies when comparing the balances on the banks' current accounts at the central bank. The aim has been to handle these problems case by case.

Appendix Chart 4 shows the degree to which banks used their current account overdraft facilities in settling their loro payments in situations where the largest possible counterparty failure occurred at every netting round. Table 7 shows the banks' limit overruns in the simulations. Systemic crises led to a total 15 credit limit overruns for April-May. However, the overruns triggered in the simulations were often fairly small. On average, an overrun amounted to 21 per cent of the bank's limit. In value terms, the overrun due to counterparty failure amounted to FIM 884 million on average, and to about FIM 2.2 billion at maximum. After one bank defaulted, repeated simulation did not lead to any further overruns.

According to the results, it is more probable that one counterparty failure causes another counterparty failure in loro settlements than in ordinary settlements. The data used here shows no marked correlation between loro settlements and ordinary settlements. Under such circumstances, the combination of the two types of settlement should not result in an increase on average in credit risk associated with net settlement. Similar results were obtained from settlement failure simulations using simulated data for combined loro, ordinary and postal giro settlement.

Table 7.

**Simulated credit limit overruns in loro settlements,
April-May 1994**

| Number of limit overruns | Overrun relative to bank's credit limit, % |
|--------------------------|---|
| 1 | 62 |
| 2 | 22 |
| 3 | 9 |
| 4 | 27 |
| 5 | 6 |
| 6 | 18 |
| 7 | 77 |
| 8 | 15 |
| 9 | 10 |
| 10 | 13 |
| 11 | 21 |
| 12 | 3 |
| 13 | 6 |
| 14 | 9 |
| 15 | 19 |
| Average overrun ratio | 21 |

4.3.3 Systemic risk analysis of the HMMC net clearing and settlement system

The systemic risk associated with funds transfers in money market trade at the Helsinki Money Market Center (HMMC) clearing and settlement system was analysed by carrying out settlement failure simulations similar to those reported above on all the business days in August 1994. The trigger for a settlement failure was 50 per cent of a participant's own funds. Table 8 shows the participants' largest daily counterparty risks for August. Appendix Chart 5 shows the ratio of each bank's largest bilateral net claims to its own funds.

Table 8.

**Participants' largest daily counterparty exposures
at the HMMC, August 1994**

| | Largest bilateral net credit position, interbank trade | Largest bilateral net credit position, total trade ¹ |
|---|---|--|
| | % of own funds | % of own funds |
| A | 10 | 42 |
| B | 4 | 8 |
| C | 13 | 116 |
| D | 7 | 8 |
| E | 6 | 18 |
| F | 25 | 462 |
| G | 8 | 8 |

¹ Including Bank of Finland, State Treasury, Export Credit Ltd and the Regional Development Fund of Finland trades.

The banks' bilateral net credit positions in connection with securities transactions are relatively small. In part, this is due to the fact that securities trading by the Bank of Finland and the State Treasury as well as interbank trade is free of counterparty risk. As is discernible from the above table, the potential counterparty risk in relation to participants' own funds was fairly small in August 1994. The largest bilateral net credit positions amounted to 25 per cent of the respective bank's own funds. The simulations did not lead to any new settlement failures. The Helsinki Money Market Center system is protected against multilateral netting exposure by means of a requirement of full collateralization of overdrafts.

5 Concluding remarks

The arguments concerning systemic risk are generally based largely on assumptions and calculations using theoretical models, because there are very few actual observations available. In this study, simulations with ex-post settlement data are used to evaluate the exposure to systemic risk of the net-settlement parts of the Finnish payment system. Using simulation, assumptions must again be used, but in this way one is able to get a rough picture of the counterparty risks inherent in the real-life payment system and the consequences of a potential settlement failure.

One participant's failure to settle in the payment system can lead to serious problems for other participants. However, on the basis of our simulations of net settlement, the danger of systemic failure and the extent of the consequences are at present relatively small in Finland. On average the banks' largest daily counterparty risks amount to less than 10 per cent of their own funds. However, on peak days these risks can amount to over 50 per cent of own funds and thus pose a systemic risk. The 50 per cent criterion applied in this study is not very strict, as banks' ability to operate may clearly be seriously impaired if much smaller problems arise. If we had used a 10 per cent criterion, the simulations would have produced daily situations in which one bank's failure to settle would have caused potential payment problems for other participants.

The key result of the simulations was that large counterparty risks do not snowball into long interbank chains that could lead to a domino effect. Even if a payment system participant were to suddenly encounter a serious payment problem, the other participants would probably manage to avoid serious crises. If another participant encountered a payment problem, the difficulty would probably end at that point and not lead to a longer chain reaction involving other parties.

The probability of liquidity and gridlock problems was estimated using as the default criterion the overrun of an overdraft limit on a current account at the Bank of Finland. The probability of a liquidity problem is higher for *loro* clearing than for ordinary payment clearing. The key result was that in ordinary payment clearing the elimination of one bank from the clearing because of a liquidity problem, would cause another bank to exceed its overdraft limit on two days and in *loro* clearing the second bank would exceed its overdraft limit on 15 days out of 40. The limit overruns did not however spread to more than two banks.

Using empirical data from the Helsinki Money Market Center, simulations of settlement defaults to study systemic risk in securities payments indicated that the counterparty risks are small. This is partly because a large share of trades were free of counterparty risk, ie they were internal to the banks, the Bank of Finland or the State Treasury. In respect of ordinary interbank trades, HMMC is protected from systemic risk with the aid of the full collateral requirement.

In international comparisons, the exposure of Finland's payment system to systemic risk seems to be roughly of the same magnitude as has been found in the Italian study. In Finland and Italy, the counterparty risk inherent in net settlement systems appears to be of a significantly smaller magnitude than in corresponding US systems. With respect to Finland, the main reason lies in the structure of our payment and banking systems. Compared to large countries (Japan, USA), the total payment flow in the Finnish system is relatively small relative to GDP (see Chart 1).

Moreover, our interbank payment system is a gross settlement system and thus net settlement constitutes just one part of the Finnish payment system. And because of the centralized nature of the Finnish banking system, a large share of the flow of customer payments remains within the same bank or banking group.

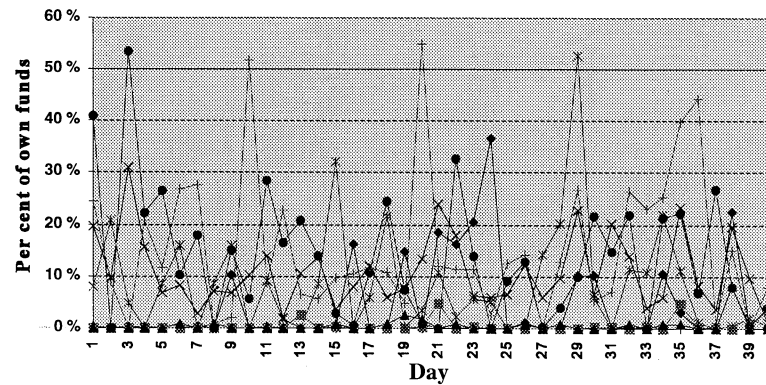
Although the simulations with empirical data indicate that in Finland the probability of a systemic crisis is presently quite small, it is important to continue to develop risk control and management systems for payments. The environment in which payment systems operate is changing rapidly, and as the volume of payments grows so do the risks. As their systems are opened up to foreigners, Finns also will find themselves dealing more and more often with heretofore unknown counterparties. Entry into the system and system risk control can no longer be based solely on trust; instead, clear playing rules must be put in place. Within its task of overseeing the payment system, the central bank will need to monitor developments closely, promote market awareness of payment system risks and aim to prevent the creation of systems in which it is possible for settlement failures to spread. This work should be done in cooperation with international organizations and with the EU.

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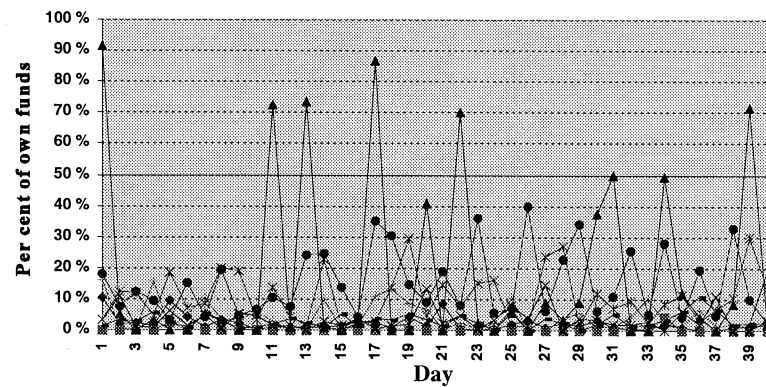
Appendix Chart 1.

Largest daily bank-to-bank credit exposures in loro clearing, per cent of own funds, April-May 1994



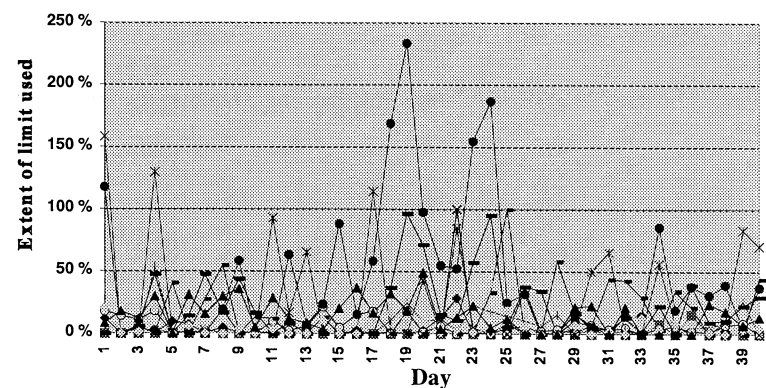
Appendix Chart 2.

Largest daily bank-to-bank credit exposures in ordinary payment clearing, per cent of own funds, April-May 1994



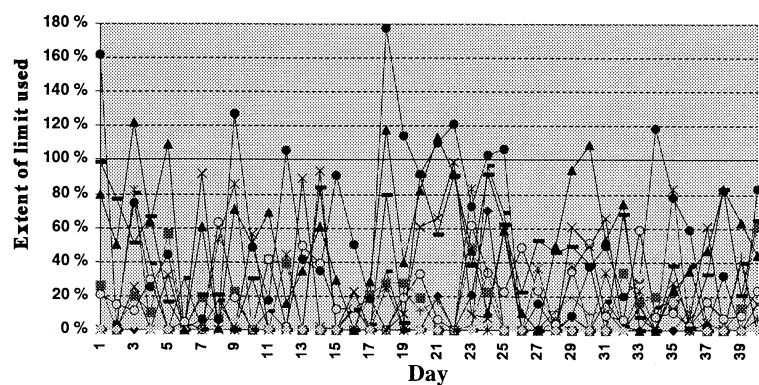
Appendix Chart 3.

Extent of limit used daily in case of largest counterparty default; ordinary payment clearing; April-May 1994



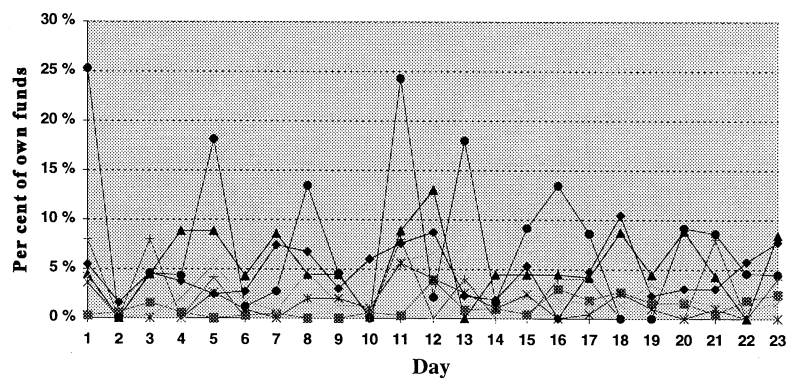
Appendix Chart 4.

Extent of limit used daily in case of largest counterparty default, loro clearing, April-May 1994



Appendix Chart 5.

Largest daily bilateral net claims at the Helsinki Money Market Center, per cent of own funds, August 1994



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