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AN ASSESSMENT OF SYSTEMIC RISK IN THE ITALIAN CLEARING SYSTEM

by P. Angelini (*), G. Maresca (**) and D. Russo (***)

Abstract

In clearing systems, failure to settle by one participant may prevent settlement of direct creditors, which may in turn jeopardize settlement of other institutions. The paper presents an empirical assessment of the potential size of this "domino effect" in the Italian clearing system. A participant's settlement failure is simulated, and the impact on its counterparts is measured. According to our simulations, on average about 4 per cent of the system participants are able to trigger systemic crises; less than 1 per cent default due to systemic reasons; the average monetary value of systemic losses is 200 billion Italian lire, equal to 2.7 per cent of the daily flow of funds in the system. Similar simulations performed by other authors for the US clearing system yielded a much larger impact of systemic risk. We argue that the difference with respect to our results is mainly due to the much lower volume of funds flowing through the Italian system and to structural differences between the latter and the US system.

Contents

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1. Introduction[1]

The history of national banking systems records a large number of episodes of crisis, often triggered by single troubled institutions, that rapidly spread to the rest of the system. In those episodes the risk borne by banks as a natural counterpart to their normal operational activity would take on a different, systemic nature. The expression "systemic risk" was designed for situations of this type, whose incidence was dramatically reduced in connection with the development of modern banking systems, characterized by the presence of central banks, deposit insurance schemes and active risk control policies.

Recently systemic risk has come again to represent more than a mere theoretical possibility, as a consequence of the development of electronic large-value[2] interbank funds

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1. We thank P. Allsopp, J. Marquardt, P. Van den Bergh, a number of colleagues in the Research Department and in the Bank Lending and Clearing Department of the Banca d'Italia and an anonymous referee for useful comments on previous drafts. Neither they nor the Banca d'Italia are responsible for the views expressed and remaining errors.

2. According to Committee of Governors of the Central Banks of the Member States of the European Economic Community (1992a), a large-value or wholesale payment is a transfer "which has an urgent nature (for example, because incoming funds are used for out payments on the same day) and/or which needs to be irrevocable in order to ensure final settlement. The following four categories of payments relate to one or both of these two criteria: incoming or outgoing payments stemming from central bank operations in the interbank money market; payments linked to the functioning of the financial markets (for example the domestic currency side of foreign exchange transactions, Eurocurrency market and interbank lending operations); high-value or urgent payments made by non-bank customers, mostly corporate; payments representing settlement operations for netting schemes or 'delivery versus payment' mechanisms". For an overview of large-value payment systems in the major industrialized countries, see BIS (1990a).

transfer systems, which allow banks to move huge amounts of funds within fractions of the time and cost that were required even only a decade ago (figure 1). The problem is more evident in present-day clearing systems, in which operators exchange payment messages in real time during the business day, settling net balances at the end. Thus, payments are final[3] only if every participant is able to settle. Clearly, if a participant with a large debitory balance is unable to meet its obligations, its creditors' ability to settle may be jeopardized as well, possibly setting off a chain reaction on other participants. Settlement failure may materialize for several reasons: not only a bankruptcy but also a temporary liquidity shortage or a computer breakdown. As a result of the operator's greater awareness of the problems raised by risks in interbank payment systems, increasing emphasis has been placed on settlement finality,[4] which may be achieved through two main approaches.

The first one is based on the so-called gross settlement. A radical version of this approach entails settling large-value payments individually through real-time transfers of monetary base, forgoing the benefits of clearing altogether; this eliminates risks, but implies heavy liquidity costs for private system participants.

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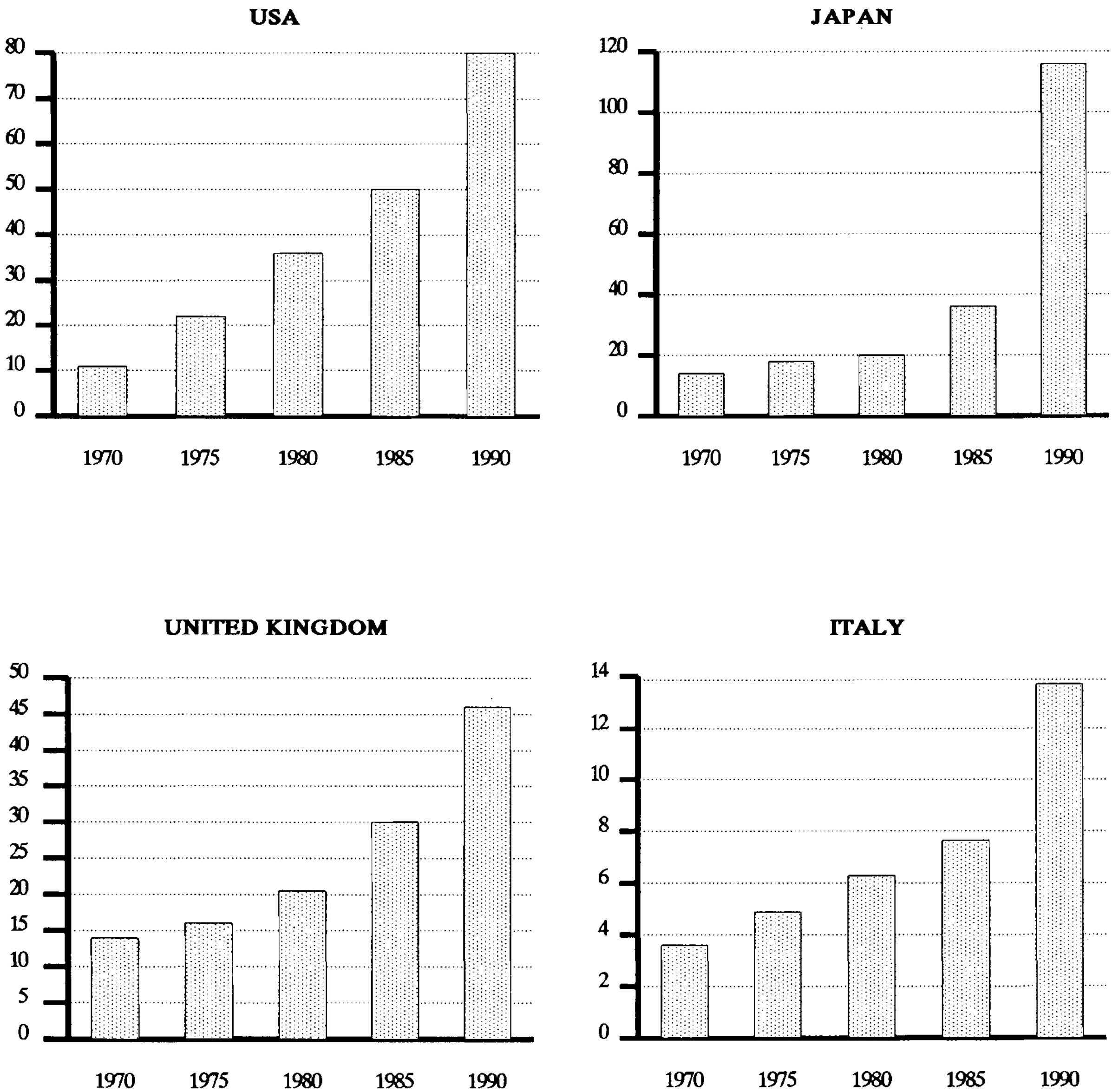
3. According to BIS (1992) a final payment is an irrevocable and unconditional transfer which effects a discharge of the underlying payment obligation. See also Mengle (1990), Committee of Governors of the Central banks of the Member States of the European Economic Community (1992a), Borio and Van den Bergh (1993).

4. See e.g. Board of Governors of the Federal Reserve System (1988, 1989), Padoa-Schioppa (1988).

Fig. 1

TRENDS IN INTERBANK FUNDS TRANSFERS

(ratio of transactions value to GNP)



Source: BIS, Annual Report, Basle, 1992; Banca d'Italia, Annual Report, Roma, 1992.

Alternatively, payments for which sufficient funds are not available may be queued and released as soon as enough liquidity becomes available on the sender's account; this option represent a way to trade-off risk for liquidity requirements.[5] In a third variant of this approach the central bank supplies daylight credit to participants; in this case liquidity costs borne by banks are substantially reduced, but risk is shifted on the central bank.

The second approach is based on the introduction of risk management features in clearing systems.[6] These measures include limits on bilateral and multilateral net positions aiming at reducing the size of intraday exposures; legal arrangements such as novation, or adoption of the so-called finality rules, such as loss-sharing formulae that distribute the losses accruing from a settlement failure among surviving participants, guaranteeing settlement in a worst-case scenario;[7] collateralization of intraday exposures.

A discussion of the merits and drawbacks of the two approaches is beyond our purpose;[8] however, it must be noted that for systemic risk to be reduced to zero it is crucial

5. See Angelini and Giannini (1993).

6. Throughout the paper the expressions clearing, netting and net settlement shall be used indifferently. BIS (1990b) agreed on minimum standards for the design and operation of cross-border multicurrency netting systems, so that both participants and service providers have the incentives and the ability to manage the associated liquidity and credit risks. Committee of Governors of the Central Banks of the Member States of the European Economic Community (1992a) suggested the application of these minimum standards also to domestic netting schemes.

7. For a definition of novation see e.g. BIS (1990b); for a discussion on finality rules see Mengle (1990).

8. For a discussion of these issues see Padoa-Schioppa (1992), Angelini and Giannini (1993), Angelini and Passacantando (1993).

that one hundred per cent reliability of settlement is assured; in principle this is possible only under arrangements based on real-time transfers of central bank money, or with the guarantee of the central bank. Indeed, concerns about systemic risk are warranted not only by the potentially disruptive effects brought about by participants' failure to settle, but also by the external nature of systemic risk itself.[9]

The reduction of systemic risk is one of the main reasons for the introduction of mechanisms ensuring finality, generally regarded as desirable; however, the issue of the related costs is often overlooked. In fact, minimization of systemic risk, however desirable, cannot be obtained free of charge. Since the mechanisms for achieving payments finality (either through extended use of gross settlement or through the adoption of risk reduction policies in clearing systems) are costly to implement, a natural question to ask is: are these costs lower than the expected costs related to systemic risk? The implicit answer given by a large part of the existing literature is affirmative, although few attempts have been made to address the issue empirically.

The present work tries to set the stage for a more systematic approach to the problem of systemic risk in electronic interbank fund transfer systems. A simple method for its quantitative assessment is outlined. The main questions addressed in the empirical part of the paper concern the relevance of systemic crises for the Italian net settlement system, the number of banks potentially affected by a systemic crisis and the size of the monetary losses, the type of banks more likely to cause systemic problems

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9. Systemic risk affects third parties who have no direct relations with the origin of the risk. See Humphrey (1986), Board of Governors of the Federal Reserve System (1988), Banca d'Italia (1992), BIS (1990b).

("triggering" banks) or to be affected by them ("defaulting" banks); we also investigate the existence of bilateral relationships among "triggering" and "defaulting" banks.

Section 2 summarizes the results of the existing literature on the subject. Section 3 briefly reviews the main features of the Italian clearing system, which is the source of the data used in the simulations. The empirical results are described in section 4, which also contains a discussion of the main differences between our results and those obtained by previous authors. The main findings are summarized in the final section, together with some concluding remarks. A description of the methodology adopted for the simulations is contained in the Appendix.

2. The results of the existing literature

Humphrey (1986) is to our knowledge the only work assessing the potential disruptive effects of systemic risk in a net settlement system. Using data on CHIPS transactions from a randomly selected business day, Humphrey simulates a major participant's failure by "unwinding" all the day's transactions to and from that agent.[10] He then recalculates the remaining participants' multilateral net balances. If the change in a participant's net exposure is greater than or equal to its capital and its revised net position is a debitory one, then that participant is assumed to "have failed" due to systemic effects; its payments are canceled and a new settlement position is computed. The process is repeated

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10. CHIPS (Clearing House Interbank Payment System) is the US clearing system for large-value payments. In the "unwinding" procedure the gross transactions to and from the bank which is incapable of settling are canceled from the system, and the multilateral net positions are then computed again.

until no participant "fails". Since CHIPS is characterized by a "two-tiering" structure (some operators participate in the netting procedure through the intermediation of a direct participant), Humphrey also simulates the default of a large associate participant; finally, he replicates both simulations with data from another business day, in order to check the robustness of his findings. The main results of the exercise are the following:

a) on both days, a high percentage of CHIPS institutions defaults as a consequence of a major participant's default (about 37 per cent). The value of messages deleted over the daily total is also very high (well over 30 per cent). Similar results are obtained by simulating the failure of a large associated participant.

b) on different days different institutions are affected: "In view of the correspondent relationship among institutions one might expect that those affected by a particular institution's failure would be fairly constant; in fact, there is a fair amount of variation." (Humphrey, 1986, p. 108). It follows that it is not easy to predict which institutions will be affected by a particular institution's failure.

3. The Italian clearing system[11]

The new multilateral net settlement system, which came into operation in 1989, consists of four subsystems. The first is the Local clearing for paper-based transactions (which has existed since 1881); all operators' paper-based

11. For a more detailed description see Banca d'Italia (1988a, 1988b), BIS (1990a), Committee of Governors of the Central Banks of the Member States of the European Economic Community (1992b).

transactions with the Banca d'Italia, the State Treasury and the Postal Administration are exchanged via this channel. The second subsystem is the Retail systems for automated small-value payments. The third is the SIA-based[12] Interbank Payment System (SIPS), which handles large-value paperless transactions and in particular giro transfers of external lire and the domestic leg of foreign exchange transactions. The last subsystem is the Electronic Memoranda for large-value payments, used in particular for screen-based transactions in the interbank deposits market.

The subsystems have different but coordinated timetables (figure 2). All the clearing operations start at 8:00 a.m.; the first to close is the Retail system (at 12:00 a.m.), followed by the Local clearing (at 1:30 p.m.) and SIPS (at 2:00 p.m.). Treasurers can subsequently cover their positions by using the Electronic Memoranda, which is the last to close. At 4:00 p.m. an automatic clearing procedure calculates a single multilateral net balance at the national level for each participant by adding the gross transactions processed through the Local clearing and the Electronic Memoranda procedures, and the bilateral "novated" net balances of SIPS and Retail system.

Settlement is effected on the banks' centralized accounts with the Banca d'Italia. Access to the clearing system is strictly confined to credit institutions. The central bank on its own account and on behalf of the Treasury, and the Postal administration also participate in the system. At the end of 1992 participants were 291 and the amount of payments processed throughout the year totaled 29,100 trillion lire.

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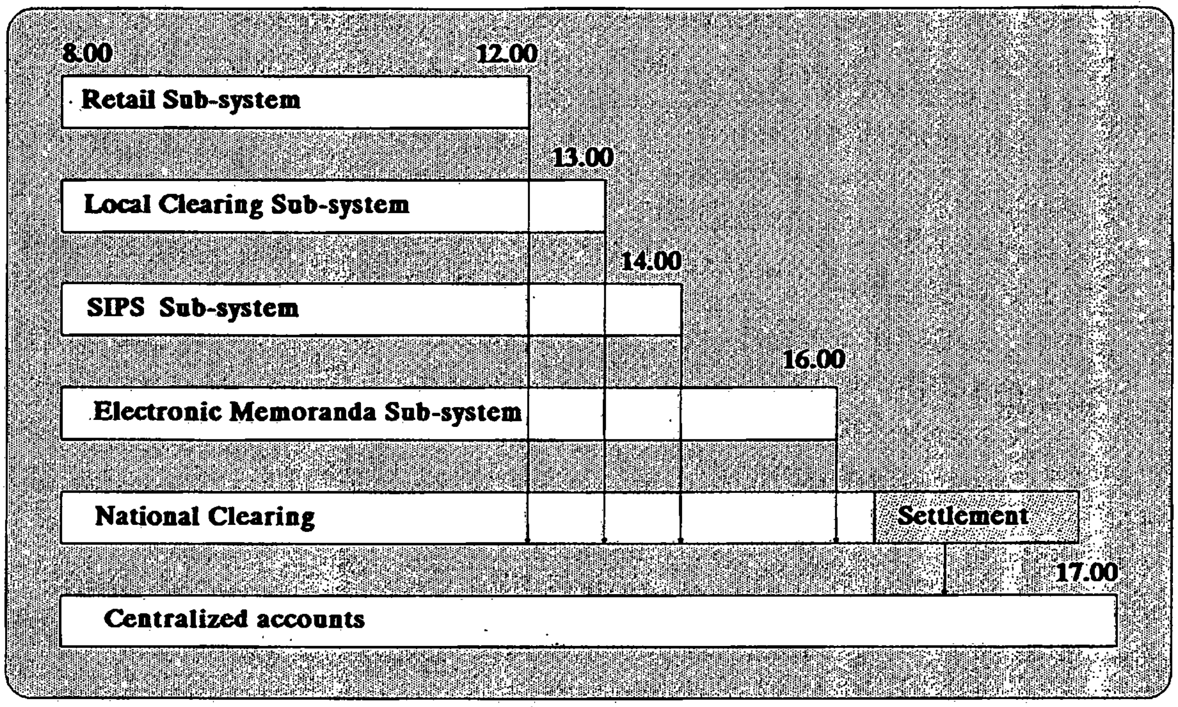
12. SIA is the Italian interbank association for the automation; it is jointly owned by the Italian banking association (ABI) and by the Banca d'Italia.

Fig. 2

The Italian Clearing System



4. Systemic risk in the Italian clearing system

The purpose of this section is to assess the relevance of systemic risk for the Italian case. Specifically, we will try to answer the following set of questions:

a) is the net settlement system likely to be affected by systemic crises?
b) is the number of banks potentially affected by a systemic crisis relevant?
c) in the event of a systemic crisis, would the monetary losses be large?
d) are there banks whose default would likely cause systemic

problems more than others?

e) what type of institutions would most likely be involved?

f) are there close bilateral relationships among "triggering" and "defaulting" banks?

g) are systemic crises more likely to occur as a consequence of liquidity problems or of solvency problems?

4.1 The methodology

Our dataset comprises the actual record of bilateral net balances of the 288 participants in the Italian netting system for the 21 business days of January 1992. Following Humphrey (1986), the unwinding was performed in successive steps:

a) all the transactions to and from the defaulting member were canceled, and new multilateral net balances for each participant left were computed;

b) for all members with negative new balances (independently on the previous balance) the ratio between the change in the balance itself and a bank-specific indicator of ability to settle was computed. The party was then assumed to be insolvent, and canceled from the clearing, if the ratio was greater than one;

c) the process was iterated until all participants left could settle their multilateral net positions.

We used two measures of ability to settle. As an indicator of solvency we used capital.[13] As an indicator for

13. For Italian banks we used the definition of eligible capital reported in BIS (1988) (the Basle Capital Accord). For Italian branches of foreign banks we used the guaranty fund (so-called "fondo di dotazione"). According to the Law n. 1620 of 1919 and to the Presidential decree n. 350 of 1985, Italian branches of foreign banks must only constitute a guaranty fund whose

liquidity conditions we constructed a variable accounting for banks' liquid assets, including the securities portfolio (bonds and shares). We then used these indicators to run two separate sets of simulations.

Our methodology differs from Humphrey's (1986) in two main respects: first, we simulated the default of all the members of the system, one at the time, for all the business days in the sample; this allows us to compute relative frequency estimates of conditional probabilities and expected values. Secondly, we grouped banks into four categories: "large", "medium" and "small" (defined in terms of the monetary value of total deposits), and Italian branches of foreign banks ("foreign" henceforth).[14] The details of the methodology are given in the Appendix.

4.2 An empirical assessment of credit risk

In this first exercise, participants were assumed to

(Continuazione nota 13 dalla pagina precedente)
amount is fixed administratively by the Banca d'Italia. In case of a crisis the head office is legally liable for foreign branches, hence the guaranty fund would practically underestimate the latter's solvency. We nevertheless adopted it as an indicator of solvency, mainly due to the uncertainty concerning the timing of the intervention by the head office, which might force national authorities to act in an emergency and to retrieve the costs borne through a legal action.

Based on a new regulation (Decreto legislativo n. 481 of December 1992) recently enforced to conform to the Second Banking Coordination Directive, branches of banks incorporated in EC countries no longer need to constitute the guaranty fund, since the parent institution is held responsible for the soundness of the foreign branch.

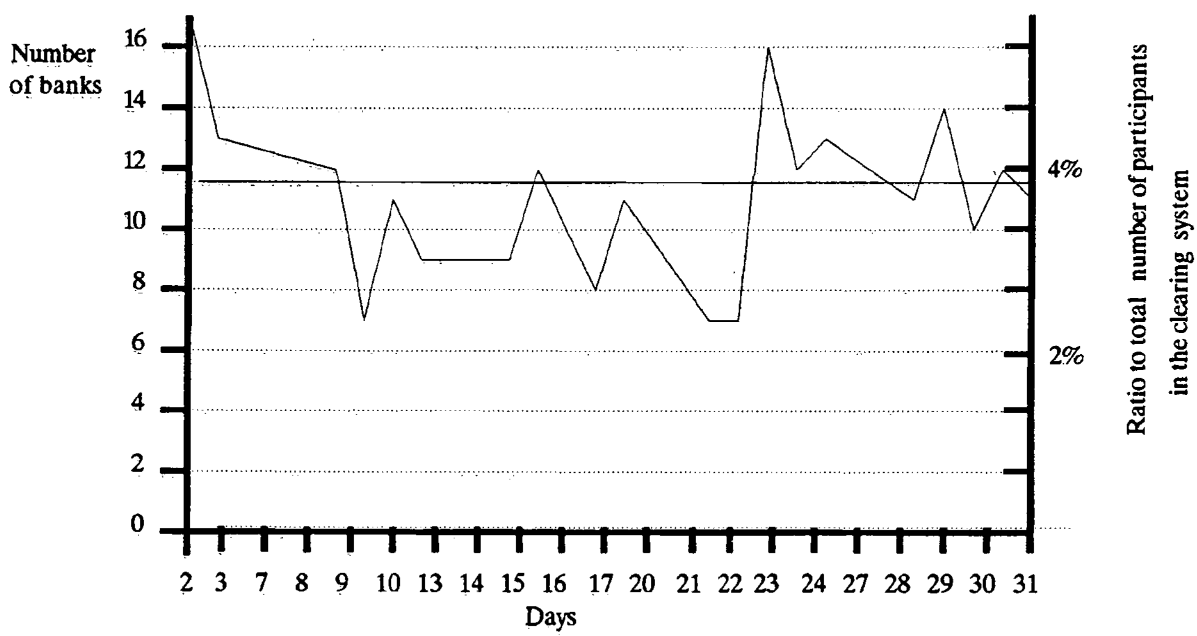
14. In general, there is a high correlation between the size of a bank in terms of total deposits and in terms of the monetary value of total turnover in the clearing system; foreign banks however handle relatively high volumes of payments in spite of a relatively low volume of deposits.

be insolvent, and canceled from the clearing, if the change in their multilateral net debitory position exceeded their capital. The main results of the simulations are presented in figures 3 through 7.

In general the <u>number</u> of banks able to trigger systemic crises has been rather small, from 7 to 17 for each business day (about 12 on average, i.e. 4.2 per cent of participants in the system; figure 3). In other words, out of 288 participants in the clearing system, on average only 12 were capable of triggering the default of at least one other bank. The phenomenon is also highly concentrated: over the whole sample period, only 55 participants were able to trigger at least one systemic crisis.

Fig. 3

BANKS ABLE TO TRIGGER SYSTEMIC CRISES
(January 1992)

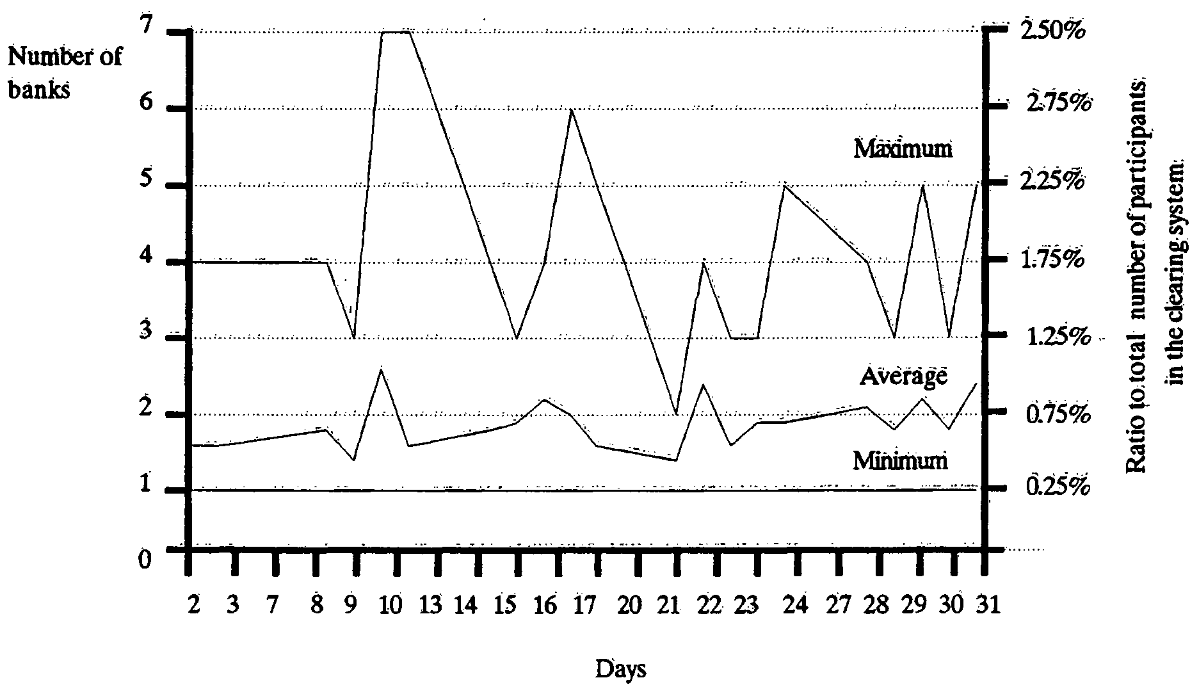


The <u>size</u> of systemic crises is also very limited: for each business days the number of banks defaulting due to systemic reasons ranges from 1 to 7 (about 2 on average, i.e. less than 1 per cent of the participants in the system;

figure 4); in other words, in the worst crisis recorded in our dataset the default by one bank caused a chain default of 7 other participants in the clearing system.

Fig. 4

BANKS INVOLVED IN SYSTEMIC CRISES
(January 1992)



In this respect the phenomenon is even more concentrated: on the whole, only 25 banks out of 288 were involved in systemic crises at least once; the remaining 263 never defaulted as a consequence of another participant's default.

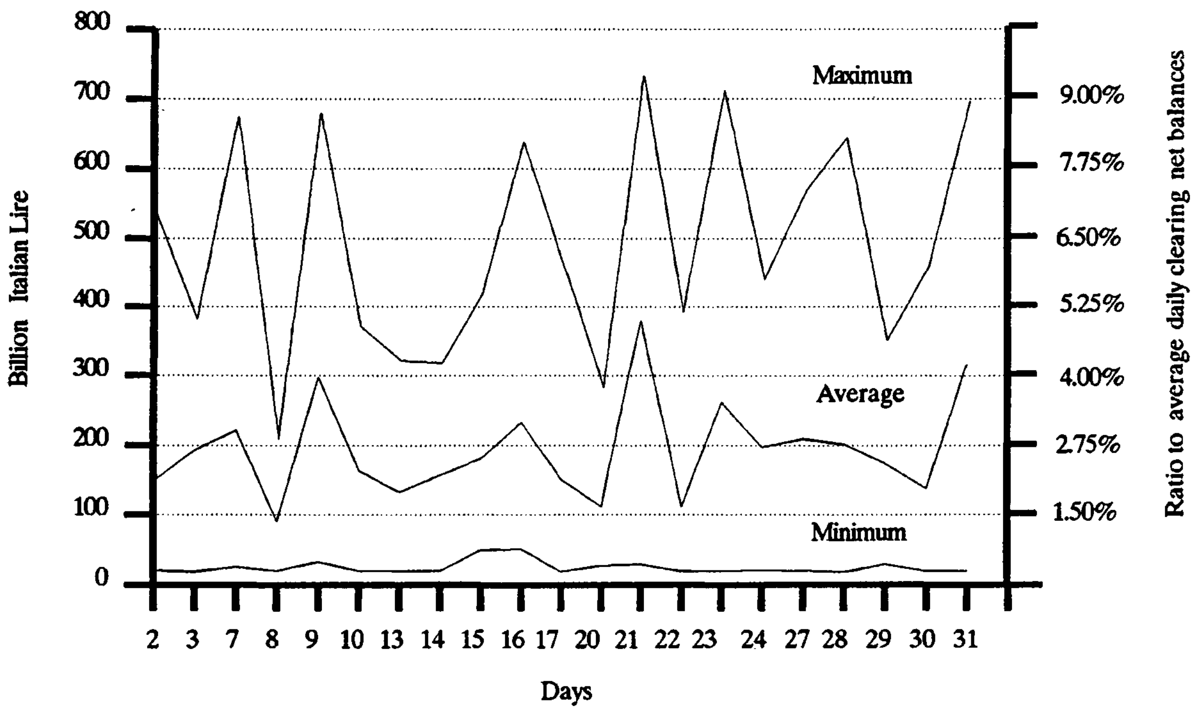
With reference to the amounts, the size of daily crises was measured in terms of differentials between the original balances and the new ones, i.e. those obtained after the unwinding. Summing the differentials of each bank involved in systemic crises yielded an average amount of about 200 billion Italian lire, i.e. 2.75 per cent of the overall average amount of debtor balances settled daily in the clearing system. Figure 5 reports the smallest, average and worst crisis, in terms of monetary value, recorded on each business day. In the worst crisis, recorded on January 21, the maximum value was around 700 billion (that is, 9 per cent of total debtor balances).

The largest net position worsening recorded for a defaulting bank has been remarkable, 18.5 times its capital, although still lower than the value recorded by Humphrey (1986), equal to 32.4.

Let us now consider the situation at a disaggregate level. About 50 per cent of the overall number of crises was caused by large banks. An almost equal share was due to medium (20 per cent), small (15 per cent) and foreign banks (15 per cent). On the whole, 90 per cent of banks involved in systemic crises are foreign banks.

Fig. 5

VALUE OF SYSTEMIC CRISES
(January 1992)



This result is mainly due to the limited size of the guaranty fund, the measure of capitalization that we used for this group of institutions (see footnote 13).

Figures 6 and 7 show the probability of default due to a settlement failure with reference to the whole clearing system and some categories of banks, respectively. Specifically, figure 6 represents the estimated conditional mass function corresponding to expression (5) of the Appendix; it says that there is a 96 per cent probability that the default of <u>any one</u> bank in the system causes no chain default at all, a 1.9 per cent probability that the chain default involve one bank, and so on. Similarly, figure 7 portrays the estimated conditional mass function corresponding to expression (4) of the Appendix for i equal to "small" and "foreign".[15]

The comparison between figures 6 and 7 shows that the probability distribution of the overall system coincides <u>de facto</u> with that of foreign banks. Even for this category, which according to our simulations is the most exposed to systemic risk, however, the probability of having no domino effect at all is very high (96 per cent).

Table 1, which reports the expected values of the number of defaults by category, gives a detailed picture of the situation at a more disaggregate level. The table has the following interpretation. The inner cells, computed with probabilities of type (2) of the Appendix, give the number of institutions belonging to the category displayed by column that are <u>expected</u> to default if <u>one</u> bank belonging to a type

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15. The figures corresponding to the mass functions of large and medium banks are not reported because virtually all the mass is concentrated at zero.

Fig. 6

PROBABILITY OF DEFAULTS DUE TO A SETTLEMENT FAILURE

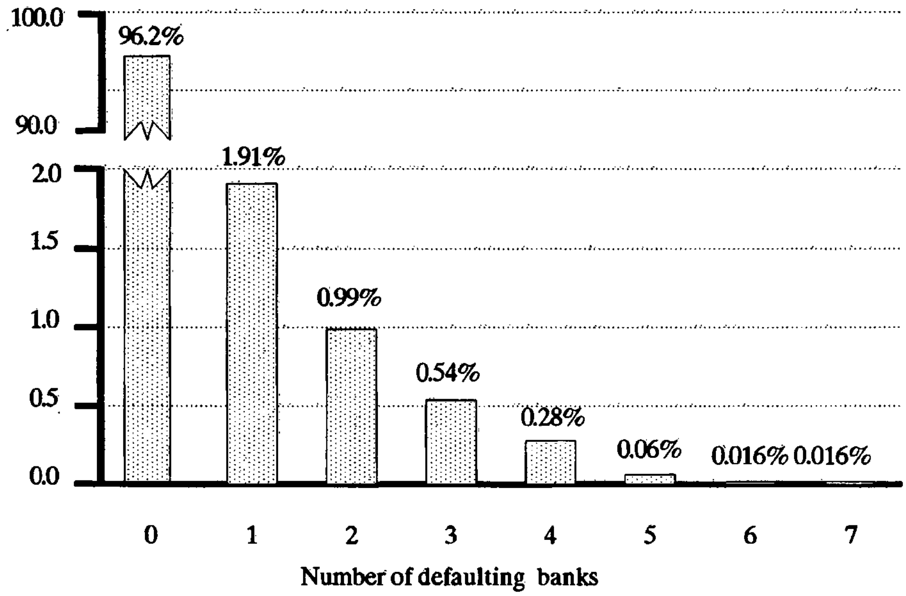
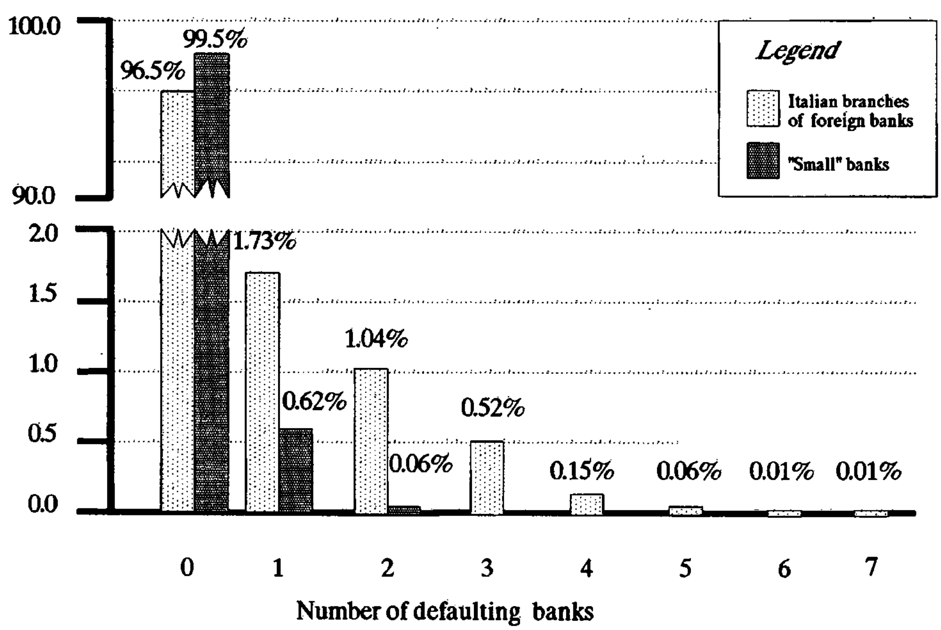


Fig. 7

PROBABILITY OF DEFAULTS DUE TO A SETTLEMENT FAILURE



displayed by row defaults. Thus, for instance, 0.793 at the intersection of line "large" and column "foreign" means that if five large banks were to default on five different days we would expect four foreign banks to default as a consequence.

Table 1

AVERAGE NUMBER OF BANKS INVOLVED IN A SYSTEMIC CRISIS

		Banks defaulting due to systemic reasons				
		Large	Medium	Small	Foreign	Total
"Triggering" banks	Large	0	0.003	0.057	0.793	0.854
	Medium	0	0	0.053	0.174	0.201
	Small	0	0	0.002	0.005	0.008
	Foreign	0	0	0.023	0.125	0.132
	Total	0	0.001	0.01	0.06	0.072

The row totals, computed with probabilities of type (3) of the Appendix, relate to banks capable of triggering systemic crises; thus, 0.854 banks regardless of the dimension, i.e. less than 0.3 per cent of the system participants, are expected to default following a large bank's default. The latter value can be directly compared to Humphrey's simulations, in which about 37 per cent of the participants defaulted as a consequence of the default by a large participant: the difference is clearly dramatic.

The column totals, computed with probabilities of type (4) in the Appendix, relate to participants involved in systemic crises and highlight extremely low values for all categories: for instance, the default of a generic bank causes on average the systemic default of 0.06 "foreign" banks (i.e. one foreign bank six days out of one hundred).

Finally, the value 0.072 reported in the lower right-hand side corner of the table is the number of banks (regardless of the category) that are expected to default as a consequence of one other bank's default (regardless of the category); it is the expected value corresponding to the mass function of figure 6 and to expression (5) in the Appendix.

The expected values of table 1 require a few comments, since they hide a remarkable degree of heterogeneity among banks belonging to the same category; although the probability of a systemic crisis is on average very low, there are a few banks whose default is very likely to have systemic repercussions, however limited they may be. In general, 7 banks in our sample were capable of generating domino effects more than 10 days out of 21; 48 banks caused crises from 1 to 10 days out of 21; the remaining 233 never created systemic problems. Thus, even though the overall probability to have systemic crises is very small, there are some banks whose default is very likely to produce systemic problems.

4.3 Comments on the results and on the differences with the previous literature

A number of factors may have determined these results. First of all, the total amount of transactions in the Italian clearing system is relatively small compared to that of other developed countries (the ratio of total payments to GNP is 15 vs. 80 in the United States and more than 100 in Japan; see figure 1). In turn, this may be mainly due to structural features of the Italian financial system, that has not yet reached full development; for instance, about 80 per cent of CHIPS payments stem from foreign exchange transactions, whereas in the Italian system the weight of these operations is still less than 40 per cent.

Secondly, the Italian clearing system is characterized by a high level of payment concentration: about ten banks handle more than 50 per cent of the total value of the transactions; thus, considering the criterion that we used to "fail" banks, it is unlikely that banks handling very low volumes of payments get involved in a systemic crisis or are able to trigger one.

Third, the number of settling participants of small dimension, which are practically unable to cause systemic crises, is relatively high (about 200); this helps explain the low number of banks that are able to trigger (but not the low number of banks that are involved in) systemic crises.

Fourth, using end-of-day balances may bias downwards estimates of systemic effects, since end-of-day exposures are normally smaller than intraday positions, due to adjustment operations performed in the final stages of the clearing among market participants or with the central bank. If a crisis breaks out during the business day the ability of the defaulting party to obtain credit from other participants may be substantially reduced and the smaller balance normally recorded by the end of the day would never be reached.[16]

The differences of our findings with respect to Humphrey's (1986) are due to some of these factors, as well as to specific structural features of CHIPS and the Italian

16. This is the case in the US CHIPS. See BIS (1990a, tab. 2, p. 143).

netting system.[17] In particular, in the United States large-value payments are equally distributed between the gross settlement system Fedwire and CHIPS. As a consequence, high debit exposures on one network may be offset by high credit positions in the other. In Italy, on the contrary, virtually all large-value payments are currently channeled through the clearing system; this may contribute to generate relatively small end-of-day balances.[18] In addition, in the Italian system branches of foreign banks are 5.8 per cent of participants, while on CHIPS they are 84 per cent; this could also help explain the difference with Humphrey's results, given that in our simulations this category proved to be the most exposed to systemic risk. Although it is impossible to ascertain the validity of this hypothesis since no disaggregation is reported for the simulations based on the US system, Board of Governors of the Federal Reserve System (1989) reports some features of US branches of foreign banks that resemble the situation in Italy. In particular, it notes that "(1) most of a foreign bank's assets and liabilities are located and controlled outside of the United States and are not under the supervisory review by U.S. authorities, and (2) for many foreign banks the volume of dollar payments is substantial relative to the level of their U.S. branches assets and their dollar funding capacity" (p. 6), and that "CHIPS daily average peak overdrafts of U.S. branches and agencies of foreign banks have risen more rapidly than have

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17. CHIPS adopts a two-tiering structure, in which only 21 banks out of 120 participants settle directly. In principle, this structure could facilitate the domino effect in the simulation, as the failure of one settling participant might affect the ability to settle of all the related non-settling participants. However, Humphrey assumed that the latter could find another settling participant or, if necessary, settle directly at the end of day.

18. See Maresca (1993). End-of-day balances in the Italian system are relatively small; in 1990 the ratio to GDP was 0.6, as opposed to 0.86 on CHIPS.

those of U.S. chartered entities" (p. 42).[19]

4.4 An empirical assessment of liquidity risk

The simulations of the previous section used capital as an indicator of solvency, thereby yielding a picture of the credit risk nature of systemic risk. Conceptually, however, a system may well be totally safe as far as credit risk is concerned, and yet quite exposed to liquidity risk; even participants with a good credit standing may experience liquidity shortages, e.g. because of technical problems (a computer breakdown) or errors in the programming of treasury flows. To have an idea of the exposure of the Italian clearing to liquidity-related systemic risk, we ran a second set of simulations replacing capital by a liquidity indicator.

The definition of an appropriate indicator of liquidity for this purpose is not obvious. The indicator that we used, mainly composed of Government bonds, approximates the collateralized liquidity that banks could borrow from the central bank in an emergency.

The results of this exercise did not significantly differ from those of the previous set of simulations and need no specific comments, except for two aspects. First, like in the simulations run with capital, foreign banks were the most affected by systemic crises, due to the fact that their securities holdings are relatively limited. In this case,

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19. In 1989, this induced the Board of Governors of Federal Reserve System to propose the extension of collateral requirements to all Fedwire overdrafts (funds and book entry) of US branches and agencies of foreign banks. On the other hand, foreign banks complain that their worldwide capital is not used as their base for Fedwire purpose but only for cross-system cap purposes.

however, the interpretation of the results is not affected by the considerations made concerning foreign banks' guaranty fund (see footnote 13). Indeed, although in case of failure the parent bank is legally accountable for its foreign branches, the latter must be able to handle autonomously liquidity problems. Second, the average value of crises was of 88 billion of Italian lire - far smaller than in the previous simulation - as a significant share of them was caused by small banks (33 per cent vs. 15 per cent in the previous hypothesis).

4.5 Cross-links between banks

Further analysis has been undertaken with a view to identifying possible stable cross-links between couples of banks. The objective was to assess Humphrey's conclusion according to which the institutions most likely to be affected by a particular institution's failure cannot be readily identified beforehand.

The frequency with which a specific bank is able to trigger the crisis of another specific credit institution seems to confirm Humphrey's finding. In other terms, no stable bilateral link between "triggering" and "failing" banks has emerged. This may depend on the very limited systemic effects recorded in our simulations; it may also depend on the fact that a share of bilateral relationships between banks still occurs outside the clearing system, since a formal tiering structure has not yet been introduced.

5. Conclusions

Although a number of factors would in practice decrease the likelihood of an unwinding, the simulations presented in the present paper constitute the basis for an assessment of the size of systemic risk and of the dynamic interdependence of institutions in the Italian clearing system. The main results of the exercise may be summarized as follows:

a) the average number of systemic crises due to solvency problems is small: for each business day, only 12 banks on average (i.e. about 4 per cent of the participants) were able to trigger systemic crises, i.e. the default of at least one other participant;

b) the average size of systemic crises is also very small: in the largest crisis recorded in our simulations only seven banks defaulted as a consequence of a participant's failure to settle, and in the average crisis less than two banks were involved, i.e. less than 1 per cent of participants. In the simulation performed by Humphrey (1986) on the US clearing system CHIPS, 37 per cent of participants failed;

c) the monetary value of the losses suffered by banks involved in systemic crises was relatively small: the average amount was about 200 billions of Italian lire, that is 4 per cent of the total amount of debtor balances settled daily in the clearing system;

d) the phenomenon presents a high degree of concentration on the side of banks triggering systemic crises. On different days almost always the same 9-10 institutions were able to cause systemic crises; as expected, they are mainly constituted by "large" banks, whose payments account for 50 per cent of total transactions flowing through the clearing system;

e) an even higher concentration emerged as far as banks involved in systemic crises are concerned, which are mostly Italian branches of foreign banks. Banks in this category are particularly vulnerable to crises because of their inadequate capital structure. This result depends in part on the indicators of capital adopted in the simulations for the category; however, the simulations replicated with a liquidity indicator again pointed out a higher fragility of this category relative to the rest of the participants;

f) in spite of the strong concentration of triggering banks as well as of failing banks, no stable relationship between couples of banks was detected; this result is similar to that in Humphrey (1986), where the simulated default of the same participant on two different days affected different institutions. This may depend on the limited systemic effects stemming from the simulation and on the fact that in Italy a relevant share of bilateral relationships between banks still occurs outside the clearing system;

g) the simulations performed using a proxy for liquidity instead of capital as an indicator of participants' ability to settle yielded very similar results.

These results are determined by a number of factors, in particular the relatively small volume of transactions flowing through the Italian system compared to that of other developed countries, the high number of settling participants of small dimension, the high level of payment concentration among banks. The remarkable difference of our results from those reported in Humphrey (1986) for the US clearing system CHIPS can also be explained by specific structural features of the Italian netting system; in particular, the share of Italian branches of foreign banks, which in our simulations proved to be the more fragile category, is relatively small

(5.8 per cent against 84.2 per cent on CHIPS).

Summing up, the simulations discussed above demonstrate that at present systemic risk is unlikely to be significant in the Italian netting system and hence that possible effects on the stability of financial markets are not substantial enough to constitute a problem. It must be noted however that the spectacular dynamics of payment flows recorded with the recent inception of electronic systems could rapidly modify the situation: as a ratio to GDP, total payments flowing through the Italian interbank system rose from 15.5 in 1991 to 22.1 in 1992. This warrants close monitoring of the phenomenon and a search for risk control mechanisms capable of optimizing the performance of our system in the perspective of further growth of payment flows.

Appendix

The estimation method

A clearing system can be viewed as a structure governed by a multivariate mass function, which can in principle be estimated. Taking this view, Humphrey's (1986) simulations amount to drawing a realization from a conditional mass function describing the probability of failure of participants in an electronic payment system conditional on one specific major participant's failure. If enough realizations are available, the whole parametrization of the density can be recovered.

In other words, using several sets of daily data on transactions recorded in netting systems and "failing" each participating bank at the time, one can generate as many realizations as are needed to compute relative frequency estimators of the probability that a given institution will become insolvent as a consequence of given bank's insolvency.

For example, assume that bank A is often a large intraday creditor to bank B. On those days, if A's net position after the credit due from B has been canceled is such that A cannot afford to settle it, a default by B will cause A to default as well.[20] Suppose now that x datasets are available, containing the record of daily transactions on a netting system. One may then "fail" B (say) x times, and compute the number of times z that A fails as well. The relative frequency z/x is an unbiased and consistent estimator of the probability of failure of A conditional upon B's failure. In what follows we spell out the details of the

20. Humphrey (1986) analyzes in detail the variables that may concretely affect a bank's solvency. In paragraph 4 two different assumptions are made regarding the indicator of ability to settle, and the sensitivity of the results to these assumptions is assessed.

procedure followed.

Every institution participating in an electronic payment system may default due to internal or external shocks, or to payment system-related reasons. The former category includes any event affecting a bank's liquidity, soundness or solvency (e.g. a major borrower may go out of business). We define the latter category as the set of defaults triggered by another participating institution's default, i.e. a systemic crisis. Accordingly, we define the following events:

i1: institution i defaults due to internal or external shocks
i2: institution i defaults due to a systemic crisis
i3: institution i does not default.

Letting P(.) denote the probability of each of these events and n the number of participants, we assume:

(a1) $P(\bigcap_{i=1}^{n} is)=0$ except for those cases in which only one s is equal to 1;

(a2) P(i1) is exogenously given for every i.

Assumption (a1) states that no two or more banks can fail at the same time due to internal or external shocks[21] and that for a participant to fail due to payment system-related reasons at least one counterpart must fail due to internal reasons. Assumption (a2) cannot be dispensed with, as within this context nothing can be said about an institution's intrinsic (i.e. unrelated to the netting system) riskiness.

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21. This is reasonable to the extent that bank failures due to internal or external shocks are independent events. However, this assumption can be relaxed without affecting the logic of the methodology.

For the sake of notation simplicity, let's focus on a payment system made of three institutions, A, B and C. Using the trick of "failing" one bank at the time, 12 conditional probabilities can be estimated. For example, canceling A's transactions 4 possible, disjoint outcomes may be observed:

1) $B2 \cap C2 \cap A1$
2) $B3 \cap C3 \cap A1$
3) $B2 \cap C3 \cap A1$
4) $B3 \cap C2 \cap A1$

The relative frequencies of these events are consistent estimators of

1) $P(B2 \cap C2 | A1)$
2) $P(B3 \cap C3 | A1)$
3) $P(B2 \cap C3 | A1)$
4) $P(B3 \cap C2 | A1)$

in the order. Using the exogenous P(A1) in Bayes' formula, one can directly identify

1) $P(B2 \cap C2 \cap A1)$
2) $P(B3 \cap C3 \cap A1)$
3) $P(B3 \cap C2 \cap A1)$
4) $P(B2 \cap C3 \cap A1)$

The same process can be repeated for B and C, thus ending up with 12 estimates. The multivariate mass function describing the possible combinations for the three banks can be arranged in a cubic relative frequency matrix including 27 possible outcomes. The overall probability of default by a bank i would then be $P(i) = P(i1) + P(i2)$, where $P(i2)$ would be given by the marginal distributions; in our three banks example:

$$P(A2) = \sum_i \sum_j P(A2 \cap Bi \cap Cj) \qquad (1)$$

As the number of participating institutions increases, so does the dimension of the mass function, whose relative frequency array becomes a hypercube, but this just increases its dimension.[22] The same procedure could be applied to assess the pattern of systemic risk during the day.

Due to the substantial difficulties involved in obtaining estimates of the exogenous P(i1),[23] in the empirical section we confine ourselves to estimating conditional probabilities of the type P(i2|j1) and the respective conditional expected values, which can be consistently and efficiently estimated without knowing the P(i1). Conditional probabilities of the type P(i2|j1) are what we need to

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22. The 12 estimates obtained in the three banks example are sufficient for exact identification of the mass function. Notice in fact that by assumption (a1) $P(Bx \cap Cz \cap Ak)=0$ if any two x, z, k are both equal to 1, and $P(Ax \cap Bz \cap Ck)=0$, if no x, z, k is equal to 1, (except for x=z=k=3) as at least one bank has to fail due to internal or external shocks. This takes care of 14 outcomes. Hence we are left with $P(A3 \cap B3 \cap C3)$, which can be determined as a residual.
    Perfect identification will attain regardless of the number of participants considered. With n participants the p.d.f. hypercube will contain 3^n probabilities. Out of these, $n2^{(n-1)}$ are estimable and

$$(2^n-1) + \binom{n}{2}2^{(n-2)} + \binom{n}{3}2^{(n-3)} + \ldots + \binom{n}{n-1}2 + \binom{n}{n}$$

can be set to zero because of assumption (a1).

23. Note that P(i1) is likely to be an increasing function of P(i2). In fact, banks in the system hold other participants' liabilities, which become more risky as their issuers' riskiness in the intraday credit market goes up. We assume that the share of bank-related assets appearing on a participant's balance sheet is negligible. However the validity of this assumption should be checked case by case.

readdress point b) of section 2, as they allow us to make more precise statements about the relationships between banks in their daily payments activity.

Specifically, since we do not deal with single institutions but with categories of banks, we estimate probabilities of the form:

$$P(i2=x:i\in K|j1:j\in M) \quad (2)$$

$$P(i2=x|j1:j\in M) \quad (3)$$

$$P(i2=x:i\in K|j1) \quad (4)$$

$$P(i2=x|j1) \quad (5)$$

where e.g. (2) is the probability that x banks belonging to category K fails as a consequence of the internal failure of one bank belonging to category M, and similarly for the other expressions. These probabilities are then used to compute the respective expected values. In particular, probabilities of type (2) yield an idea of the cross-links between categories of banks; type (3) point out which categories are more likely to cause systemic risk, whereas type (4) allow to highlight which categories are more likely to suffer from systemic effects. Finally type (5) summarize the overall exposure of the system to systemic risk. In section 4 these probabilities are estimated as relative frequencies; for instance, an estimate of (2) is computed as:

(number of times that x banks belonging to category K fail as a consequence of the failure by one bank belonging to category M)/[(number of banks belonging to category M)*(number of days of available data)].

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