What Is Systemic Risk Today?*

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Abstract

This paper develops a broad concept of systemic risk, the basic economic concept for the understanding of financial crises. It is claimed that any such concept must integrate systemic events in banking and financial markets as well as in the related payment and settlement systems. At the heart of systemic risk are contagion effects, various forms of external effects. The concept also includes financial instabilities in response to aggregate shocks. The quantitative literature studying systemic risk is surveyed in the light of this concept. Rigorous theoretical models of contagion have only started to be developed, so that a sound theoretical basis of the notion of systemic risk is still lacking. Econometric tests of contagion effects seem to be mainly limited to the United States regarding banking markets, to international spill-over effects during the 1987 stock market crash and to contagious currency crises. Geographical coverage as well as coverage of financial markets and their settlement systems appear to be very incomplete. Moreover, the literature surveyed reflects the general difficulty of developing tests that can make a clear distinction between rational revisions of depositor or investor expectations ("information-based" contagion) and "pure" contagion. It is concluded that, given the importance of systemic risk for the understanding of financial crises and for policies to ensure the stability of financial systems, it would be desirable if additional research could fill the gaps identified.

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1 Introduction

There is under way a significant rise in concerns about the stability of national and international financial systems. These concerns are reflected in a series of recent official summits and reports, private initiatives and academic papers,[1] and they have been underlined by the on-going East-Asian crisis, the Russian crisis and now also the Brazilian crisis. Fears exist that such developments may spill over to even more countries. Although the increase in theoretical, empirical and policy analyses of financial instability has been substantial, practically all writings share—in our view—the following limitation: while "systemic risk" is now widely accepted as the fundamental underlying concept for the study of financial instability and possible policy responses, most work so far tackles one or several aspects of that risk, and there is no clear understanding of the *overall* concept of systemic risk and the linkages between its different facets.

In this paper we attempt to set a starting point for a more comprehensive analysis of systemic risk as the primary ingredient to understand financial crises and as the main rationale for financial regulation, prudential supervision and crisis management. In the first step we bring together the most important elements of systemic risk and integrate them into a coherent working concept, which could be used as a base line for monetary and prudential policy decisions to preserve the stability of financial systems. While the "special" character of banks plays a major role, we stress that systemic risk goes beyond the traditional view of single banks' vulnerability to depositor runs. At the heart of the concept is the notion of "contagion," a particularly strong propagation of failures from one institution, market or system to another. Especially nowadays the way in which large-value payment and securities settlement systems are set up as well as the behaviour of asset prices in increasingly larger financial markets can play an important role in the way shocks may propagate through the financial system. While in the presence of rapidly evolving financial institutions and markets and the particular characteristics of each financial crisis it might be futile to look for a single, ultimate definition of systemic risk, it may still be useful to give some general structure to our thinking in this area in order to help avoiding piece-meal policy making.

In the second step we review the existing theoretical and empirical literature about systemic risk in the light of the overall concept developed before, in order

[1] Financial stability issues have recently been addressed at the G-7 1995 Halifax, 1996 Lyon and 1997 Denver summits. Among the reports and papers are Committee on Payments and Settlements Systems (1996), Federal Reserve Bank of Kansas City (1998), Goodhart et al. (1998), Group of Thirty (1997), International Organization of Securities Commissions (1998), Lindgren et al. (1996), Peek and Rosengren (1997), and Working Party on Financial Stability in Emerging Markets (1997). By the time of this paper's last revision, the world was also awaiting a report by Bundesbank President Hans Tietmeyer on whether and how the international financial architecture could be reformed to better withstand situations of crisis.

to identify areas in which future research efforts are needed. More specifically, the survey of the empirical evidence on systemic effects, in particular on contagion effects, endeavours to clarify the practical relevance of several risk elements identified in the conceptual part. We focus primarily on the quantitative literature in this area. This should not be interpreted as meaning that we consider the more descriptive literature of particular crisis periods in history as not being important. This choice has rather been taken, first, to limit the amount of information to be surveyed to that which can be dealt with within a single paper and, second, to focus on analyses for formulating and testing very specific hypotheses with the most advanced techniques.[2]

The somewhat unusual procedure to proceed from the general concept to a survey of the current literature is motivated by the fact, that—from prior reading—this literature appears to be very incomplete, when one confronts it with the issues raised by actual crisis situations. In this sense we try to set out, first, what we think is important for the understanding of systemic risk and, second, study where—in our view—satisfying answers have been given and where not. Considerable gaps are identified. First, there do not yet seem to be models which can provide a sound theoretical basis for contagion, neither in banking markets, nor in financial markets nor in payment and settlement systems. Models linking all the three areas are simply non-existent. Second, the overwhelming part of econometric tests for contagion effects is limited to data for the United States. Event studies of bank equity returns, debt risk premia, deposit flows or physical exposures for European or Japanese data are rare or virtually absent. Similarly, while there are numerous studies about the correlations of asset prices in general, the evidence about cases where one financial market crash causes another market crash is much more limited. Where those securities market contagion studies exist, they mainly look at contagion within the same asset class without looking at potential contagion (or at "flight to quality") with other asset classes. For both banking and financial markets it appears to be hard to disentangle "rational," information-based revisions of expectations from "pure" contagion. Finally, most quantitative analyses of contagion effects in payment systems seem to be limited to net payment systems, widely ignoring securities settlement systems or "network externalities" potentially resulting from "gridlock" situations in real-time gross payment systems.

We very much hope that our paper will help stimulate further research efforts aiming at filling the gaps identified as quickly as possible. This should provide important conceptual inputs for the understanding of concrete examples of finan-

[2] The only other large literature surveys in the area of systemic risk we are aware of have been written by Kaufman (1994) and Davis (1995). However, the former is narrower in scope than ours, focusing on bank contagion alone, mainly but not exclusively taking an empirical perspective. The latter is broader than this, but it does not consider the latest developments nor interpret the earlier literature within one coherent concept of systemic risk. Freixas and Rochet (1997, chapter 7) give a thorough theoretical exhibition of a selection of key models in the bank run literature. Dowd (1992) reviews this literature critically. Masson (1998) provides a short survey in the area of contagious currency crises (see section 3.2.1.).

cial crises and for potential policies to prevent or alleviate future crises. However, undertaking this research or giving any policy advice is beyond our present scope.

The remainder of the paper is organised as follows. Section 2 contains the general conceptual discussion. It provides the framework within which the theoretical and empirical literature will be interpreted in the following parts. Section 3 gives a detailed account of systemic risks in banking markets, financial markets and payment and settlement systems, surveying theoretical models explaining them and adding theoretical considerations where no model is available. Section 4 surveys a large number of econometric tests and some other quantitative assessments of the various facets of systemic risk described before. Section 5 concludes.

2 The concept of systemic risk

Systemic risk in a very general sense is in no way a phenomenon limited to economics or the financial system. Maybe the most natural illustration of the concept is possible in the area of health and epidemic diseases. In severe cases (e.g. the Great Plague in the Middle Ages) widespread contamination with a disease may wipe out a significant portion of a population. In the area of economics it has been argued that systemic risk is a particular feature of financial systems. While contamination effects may also occur in other sectors of the economy, the likelihood and severity in financial systems is often regarded as considerably higher. A full systemic crisis in the financial system may then have strong adverse consequences for the real economy and general economic welfare.

The objective of this section is to provide a general framework for the economic analysis of systemic risk. We start out by proposing a specific terminology, clarifying some general elements of the concept of systemic risk and leading to a general working definition of it. Then, the main arguments are discussed as to why financial systems can be regarded as more vulnerable to systemic risk than other parts of economic systems. Since information asymmetries can play a crucial role we proceed in the next section by distinguishing between self-fulfilling systemic events and those that can be regarded as individually rational responses to the revelation of new information between agents. Finally, the relevance of systemic risk for public policy is briefly examined.

2.1 Systemic events

In order to reach a definition of systemic risk in financial systems, we first clarify a number of concepts—illustrated in Table 1—needed for that definition. We define a *systemic event* in the *narrow* sense as an event, where the release of “bad news” about a financial institution, or even its failure, or the crash of a financial market leads to considerable adverse effects on one or several other financial institutions or markets, e.g. their failure or crash. Essential is the “domino effect” from one institution to another or from one market to another.[3] Systemic events in the *broad* sense include not only the events described above but also severe and widespread ("systematic") shocks which adversely affect a large number of financial institutions or markets at the same time. A systemic event in the narrow sense is *strong*, if the institution(s) affected in the second round or later actually fail as a consequence of the initial shock, although they have been fundamentally solvent ex ante, or if the market(s) affected in later rounds also crash and would not have done so without the initial shock.[4] (Otherwise, i.e. if the external effect is less than a failure or a crash, we denote a systemic event in the narrow sense as weak.) Similarly, systemic events related to systematic shocks are strong (weak), if a significant part of the financial institutions simultaneously affected by them (do not) actually fail.

Based on this terminology a *systemic crisis* (in the narrow and broad sense) can be defined as a systemic event that affects a considerable number of financial institutions or markets in a strong sense, thereby severely impairing the general well-functioning (of an important part) of the financial system. The well-functioning of the financial system relates to the effectiveness and efficiency with which savings are channelled into the real investments promising the highest returns. For example, a systemic financial crisis can lead to extreme credit rationing of the real sector ("credit crunch").[5]

Systemic risk (in the narrow and broad sense) can then be defined as the risk of experiencing systemic events in the strong sense.[6] In principle, the spectrum of systemic risk ranges from the second-round effect on a single institution or market (column "single systemic event" in Table 1) to the risk of having a systemic crisis affecting most of the (or even the whole) financial system at the upper extreme (column "wide systemic event" in Table 1).[7] The geographical reach of systemic risk can be regional, national or international.

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[3] Notice that such systemic events do not include the failure of a single financial institution as a consequence of a wild decline of some asset value.

[4] A market crash can be defined as an unusually large general price fall. In statistical terms this fall can be made more precise by relating it to the extreme percentiles of the respective market's empirical return distribution. E.g. cases where a representative price index decreases by a higher percentage than the 1 or 5 percentile of the historical return distribution (i.e. the left tail of the distribution) could be defined as crashes.

[5] Other accompanying factors of a systemic crisis may include severe liquidity shortages in various markets, major inefficiencies in the allocation of risks and severe misalignments of asset prices.

[6] Bartholomew and Whalen (1995) as well as Goldstein (1995) review various definitions of systemic risk. We think that our definition can "nest" most other definitions used so far. See also Aglietta and Moutot (1993) and Davis (1995).

[7] However, as pointed out by Kaufman (1988), due to "flight to quality" it is unlikely in practice that, for example, all banks of a country face a deposit run at the same time. A similar point will apply to financial market crashes.

Table 1: Systemic events in the financial system

Type of initial shock	**Single systemic events (affect only one institution or one market in the second round effect)**		**Wide systemic events (affect many institutions or markets in the second round effect)**	
	Weak (no failure or crash)	**Strong (failure of one institution or crash of one market)**	**Weak (no failure or crash)**	**Strong (failures of many institutions or crashes of many markets)**
Narrow shock that propagates				
• **Idiosyncratic shock**	✓	✓contagion	✓	✓contagion leading to a systemic crisis
• **Limited systematic shock**	✓	✓contagion	✓	✓contagion leading to a systemic crisis
Wide systematic shock			✓	✓systemic crisis

The key element in this definition of systemic risk, the systemic event, is composed of two important elements itself, shocks and propagation mechanisms. Following the terminology of financial theory, *shocks* can be idiosyncratic or systematic. In an extreme sense *idiosyncratic* shocks are those which, initially, affect only the health of a single financial institution or only the price of a single asset, while *systematic* (or widespread) shocks—in the extreme—affect the whole economy, e.g. all financial institutions together at the same time.[8] An example of an idiosyncratic shock to a national financial system is the failure of a single regional bank due to internal fraud. The sudden devaluation of a non-internationalised currency due to an unsustainable domestic budget deficit can be regarded as an idiosyncratic shock to the world financial system. Examples of systematic shocks to national financial systems are general business cycle fluctuations or a sudden increase in the inflation rate. A stock market crash in itself acts as a systematic shock on most financial institutions. The same applies to a liquidity shortage in an important financial market, which can be related to a crash or to some other event throwing doubt on the financial health of counterparties usually trading in this market.

[8] Since it is widely used in finance, we prefer the term “systematic” for wide shocks. Whereas a systematic shock implies a systemic event, as explained above, a systemic event does not need to originate in a systematic shock. Therefore, the two terms have to be distinguished.

Of course, there is a continuum of intermediate types of shocks (e.g. sector-wide or regional) between the theoretical extremes of idiosyncratic and wide systematic shocks. It is important to note that idiosyncratic shocks that do not propagate widely are "insurable," in the sense that an investor can protect herself against them via diversification, whereas wide systematic shocks are "uninsurable" or non-diversifiable. Negative systematic shocks, such as a severe recession, will—when they reach a certain strength—always adversely affect a wide range of financial institutions and markets, so that they have been included in the broad concept of systemic risk.

The second key element in systemic events in the narrow sense is the mechanism through which shocks propagate from one financial institution or market to the other. In our view, this is the very core of the systemic risk concept. Systematic shocks are equally important for the non-financial sectors in the economy. The propagation of shocks within the financial system, which work through physical exposures or information effects (including potential losses of confidence), must be "special." In what follows we shall look at the various propagation chains in banking and financial markets in much detail. However, from a conceptual point of view it is important that the *transmission* of shocks is a natural part of the self-stabilising adjustments of the market system to a new equilibrium. What one has in mind with the concept of systemic risk (in the narrow sense) are propagations that are not incorporated in market prices ex ante or can lead to general destabilisation. Such propagations, including those taking the form of externalities, may show particularly "violent" features, such as cumulative reinforcement ("non-linearities"), for example through abrupt changes in expectations.

Obviously, both the occurrences of shocks as well as subsequent propagations are uncertain. So the importance of systemic risk has two dimensions, the severity of systemic events as well as the likelihood of their occurrence. Strong systemic events, in particular systemic crises, are low probability events, which might lead some to consider them as less of a concern. However, once a crisis strikes the consequences could be very severe.

This leads to another dimension of the concept of systemic risk, namely the impact of systemic events occurring in the financial sector on the real sector, more precisely on output and general welfare. One may distinguish *horizontal* systemic risk, i.e. the concept which is limited to the financial sector alone (through the bankruptcy of financial intermediaries or the crash of financial markets), from *vertical* systemic risk, where the impact of a systemic event on output is taken to gauge the severity of such an event. In order to keep the scope of the paper manageable we have to concentrate on horizontal systemic risk in the first place.[9]

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[9] See Lindgren et al. (1996) for a synthesis of the output effects of a large number of financial crisis situations. As is evident from systematic shocks as one potential source of systemic crises (Table 1), the relationship between the performance of the real and financial sectors can go in both directions (see section 3.1.1).

2.2 The financial fragility hypothesis

Why is it then that systemic risk, in particular potential contagion effects, is of special concern in the financial system? There are three interrelated features of financial systems which can provide a basis for this "financial fragility hypothesis": (i) the structure of banks, (ii) the interconnection of financial institutions through direct exposures and settlement systems, and (iii) the information intensity of financial contracts and related credibility problems.

(i) Traditionally, commercial banks take fixed-value deposits that can be withdrawn (unconditionally) at very short notice and lend long-term to industrial companies (Gurley and Shaw, 1960). Normally, i.e. when the law of large numbers applies, only a small fraction of assets needs to be held in liquid reserves to meet deposit withdrawals. This fractional reserve holding can lead to illiquidity and even default, when exceptionally high withdrawals occur and long term loans cannot be liquidated, although the bank might be fundamentally solvent in the long run. Moreover, single bank loans do not have an "objective" market price. Since usually the lending bank alone has most information about the real investments funded, they are largely non-fungible. (However, nowadays this statement needs to be qualified to the extent that single loans to certain types of borrowers (or the credit risk incorporated) can be bundled and traded via securitisation techniques (or credit derivatives). See, for example, Goodhart et al., 1998, chapter 5.) So, the health of a bank not only depends on its success in picking profitable investment projects for lending but also on the *confidence* of depositors in the value of the loan book and, most importantly, in their confidence that *other* depositors will not run the bank. Notice that this "special" character of banks does not apply to most other financial intermediaries, such as insurance companies, securities houses and the like (see, for example, Goodhart et al., 1998, chapter 1).[10] However, if banks and other intermediaries form groups, as is now more often the case, the latters' problems might still become a source of bank fragility. Obviously, the more depositors are protected through some deposit insurance scheme—as it exists now in most industrialised countries—, the less likely (ceteris paribus) confidence crises will become.[11]

(ii) There is a complex network of exposures among banks (and potentially some other financial intermediaries) through the interbank money market, the large-value (wholesale) payment and security settlement systems. In fact, banks tend to play a key role in wholesale and retail payment and settlement systems. At certain points during the business day, these exposures can be very large, so that the failure of one bank to meet payment obligations can have an immediate impact on the ability of other banks to meet their own payment obligations. Even worse, a crisis situation can trigger difficulties in the technical completion of the

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[10] The speciality of banks and their vulnerability to runs is widely recognised in the economic literature, which will be surveyed in detail in section 3.

[11] The problems associated with deposit insurance and their relationship to systemic risk are addressed in section 2.4.

different steps of the payment and settlement process, which would amplify effective exposures and "domino" effects. Various techniques used in securities and derivatives markets, such as margin requirements and portfolio insurance, can also account for large and immediate payments needs by banks and other intermediaries in times of large asset price changes. To the extent that financial conglomerates encompass banks and other financial intermediaries, securities or insurance subsidiaries might also play a role in these interlinkages.[12]

(iii) The third feature is the information intensity of financial contracts (Stiglitz, 1993). More precisely, financial decisions aim at the intertemporal allocation of purchasing power for consumption purposes and are, therefore, based on expectations on what the value of the respective asset is going to be in the future or whether the future cash flows promised in a financial contract are going to be met. Hence, when uncertainty increases or the credibility of a financial commitment starts to be questioned, market expectations may shift substantially and "rationally" in short periods of time and so may investment and disinvestment decisions. For example, this can lead to large asset price fluctuations, whose sizes and sometimes also directions are virtually impossible to explain through "fundamental" analysis alone.[13]

These three features taken together seem to be the principal sources for the occasionally higher vulnerability of financial systems to systemic risk than other sectors of the economy.

2.3 "Efficient" versus self-fulfilling systemic events

Regarding the assessment of various systemic events, the information intensity of financial contracts underlines the importance of the distribution of information among the agents acting in the financial sector. General uncertainty and agents' awareness of potential asymmetries of information highlight the role that expectations can play for the occurrence or not of systemic events. In fact, systemic events driven by expectations might be individually rational but not socially optimal.

It is useful to distinguish three potential causes of narrow systemic events related to asymmetric information and expectations. These are, first, the full revelation of new information about the health of financial institutions to the public; second, the release of a "noisy signal" about the health of financial institutions to the public; and, finally, the occurrence of a signal which co-ordinates the expectations of the public without being actually related to the health of financial institutions ("sunspot"). Analogous cases apply to the release of information about asset values in financial markets, but for the purpose of illustration

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[12] Financial intermediaries' interconnection through payment and settlement systems is further studied in section 3.3.

[13] Fundamental analysis attempts to explain or predict asset price changes through the factors influencing the "intrinsic" values of assets. For example, "fundamentals" influencing shares are companies' earnings, "fundamentals" influencing exchange rates are inflation rates.

we shall continue with the example of banks.

Suppose that, hidden from depositors, a bank has made a number of loans that turn bad, so that it is basically insolvent but continues to survive for some time since it can roll over debts in the interbank market. Suppose further that other banks—having neglected to monitor their counterparties properly—develop substantial exposures to it. If the information about these facts were then released in full, it would be rational for depositors to withdraw their funds and force those banks into liquidation. Ceteris paribus such an outcome, which can be denoted as a "fully revealing" equilibrium, would also be "efficient."[14]

Second, suppose that the information about bad loans and interbank exposures is not revealed in full but that depositors only receive imperfect information (a "noisy" signal) from some outside source, which from their point of view increases the likelihood for those facts. In such a situation it might still be rational for them to try and withdraw their funds early and thereby force the default of those banks. Whether the signal has been "right" or "wrong" would determine, ceteris paribus, whether this outcome is "efficient" or not. As it is triggered by imperfect information on fundamentals, this type of contagion could be denoted as "information-based."

Finally, suppose that the level of deposit withdrawals in itself provides an imperfect signal for all depositors about the healthiness of banks and their counterparties. This fact enters an element of circularity in depositor behaviour that results in the possibility for multiple equilibria. In these circumstances, even if all the banks have been healthy ex ante, any event that co-ordinates depositors' expectations about other depositors' withdrawals might induce them to rush to withdraw and force those banks into liquidation. The related systemic event might still have been "individually rational" ex ante, while the outcome in the form of a self-fulfilling panic or "pure" contagion is inefficient.

The asymmetric information problems also illustrate how financial problems can build up over an extended period of time before an "efficient" or "inefficient" crisis occurs. In other words, the systemic event is only the effect of a more fundamental underlying problem, which has been hidden from policy makers or the general public for some time. For example, reckless lending and bad loans might have built up for some time in the banking sector before some explicit shock triggers a systemic event. Similarly, stock market prices might have stayed overvalued for an extended period until specific news bursts the bubble. Hence, before we now turn to potential policy responses to inefficient systemic events, it needs to be stressed that ex ante policies, measures trying to prevent a fundamental problem from actually arising (such as financial regulation and supervision or measures allowing market forces to be more effective), should always be

[14] The efficiency holds under the assumption that there would not be any subsequent problems in the payment system amplifying the problem beyond the group of unsound banks. In a somewhat related vein, Kaufman (1988) points to a "benefit" of bank crises, forcing governments to step in and close all insolvent banks so that asymmetric information between the public and bank managers is removed.

the primary defence line, so that it needs to be resorted to ex post policies in the form of crisis management in as few instances as possible.

2.4 Systemic risk and public policy

On the basis of the conceptual considerations presented so far, a first assessment of the extent to which systemic risk is relevant for economic and financial policies can be undertaken. Musgrave and Musgrave (1973) have introduced the "classical" distinction of three functions for public policies: the allocation function, the stabilisation function and the distribution function. It appears that systemic risk is, first, relevant for allocation policies. Strong systemic events, such as contagious failures, may involve external effects; i.e. the private costs of the initial failure can be lower than the social costs. As a consequence, individually rational bank management may lead to a higher level of systemic risk than would be socially optimal. This is one, maybe even the fundamental rationale, for the regulation and supervision of banks. Notice that in this sense, the socially optimal probability of bank failures is *not* zero. However, the socially optimal probability of "pure" contagion (a self-fulfilling systemic event as described above) and certain cases of "information-based" contagion are. Apart from investor protection considerations, this is another fundamental rationale for the introduction of deposit insurance schemes. Moreover, to the degree that *any* systemic event might involve payment and settlement system problems, which may amplify the strength and extent of externalities, it also provides a rationale for policies to ensure the safety of those systems.[15]

Second, a systemic crisis affecting a large number of financial institutions or markets can—via a "credit crunch" or "debt deflation"—lead to a recession or even to a depression. In such situations macroeconomic stabilisation policies, such as monetary or fiscal expansions, may be used to dampen the recessionary impact on the real economy. Interestingly, in the case of systemic risk, allocation and stabilisation problems can be closely intertwined. If contagion is very strong, then the microeconomic risk allocation problem can degenerate to a macroeconomic destabilisation.[16]

It is now widely recognised that public safety nets, whether they take the form of deposit insurance or lender of last resort facilities, bear the risk of creating moral hazard. For example, if deposit insurance premia do not reflect the banks' relative portfolio risks, then the protection may incite the insured to take on higher risks (Merton, 1976). Such effects may be countered by very effective prudential supervision. However, to the extent that this is not successful, the insured institutions will become more vulnerable to adverse shocks, so that the

[15] Private market initiatives may sometimes also offer a route to reduce systemic risk.

[16] In principle, systemic crisis can also have distribution effects. Since the poor will have invested most of their small savings in bank deposits, etc. and not in physical property, for example, and since they might be even less able to judge the health of a bank, they are particularly exposed to lose out. In virtually all industrialised countries at present this problem is dealt with in the form of deposit insurance schemes.

likelihood of propagation across institutions may rise as well. This latter scenario implies a higher level of systemic risk through inadequate safety net provisions.

3 Various facets of systemic risks

We now consider in greater detail the forms that systemic risk may take, distinguishing between banking, financial markets and payment systems. The focus is on "horizontal" systemic risk. The theoretical literature on systemic risk is surveyed in the light of these facets. Nevertheless, as indicated above, all these different elements are clearly related and interact with each other. In addition, their relative importance may change over time. While systemic risk has traditionally been associated with banking markets, the growth of securities markets has probably increased their role in the transmission of shocks.

3.1 Systemic risk in banking markets

As has been observed numerous times in the past, banks may, in the absence of a safety net, be prone to runs. On some occasions, individual runs may spill over to other parts of the banking sector, potentially leading to a full-scale panic. While the theory of individual runs is well developed, the same does *not* apply to bank contagion, which brings in the *systemic* component. One can distinguish two main channels through which contagion in banking markets can work: the "real" or exposure channel and the informational channel.[17] The former relates to the potential for "domino effects" through real exposures in the interbank markets and/or in payment systems. The information channel relates to contagious withdrawals when depositors are imperfectly informed about the type of shocks hitting banks (idiosyncratic or systematic) and about their physical exposures to each other (asymmetric information). In principle, these two fundamental channels can work in conjunction as well as quite independently. More elaborate theories of bank contagion, such as Flannery (1996) or Rochet and Tirole (1996a), which explicitly model these channels working through the liability side, have only just now begun to be developed. We start out in the next sub-section with the old lending boom literature before coming to this incipient contagion literature.

3.1.1 Lending booms as a source of systemic risk

The early analyses of "systemic risk" emphasise the role of uncertainty (where agents even have no information about the probability distribution of asset returns) as opposed to risk and the inability of banks to take the appropriate decisions in some circumstances (Kindleberger, 1978). The concept of credit overexpansion by Minsky (1977) is based on (contagious) euphoria and gregarious behaviour. Banerjee (1992), Bikhchandani et al. (1992) as well as Avery and

[17] See, for example, Saunders (1987, pp. 205f.).

Zemsky (1998) introduce more formal models where each agent only observes the actions of other agents and uses Bayesian updating to derive his or her own subjective probabilities of future returns. When pricing errors occur ex ante, such behaviour can also lead to price discontinuities (Guttentag and Herring, 1984). Myopia and short memory of agents about past events may also increase systemic risk, since they can lead to an underestimation of the likelihood of large shocks. A possible weakness of this literature, however, is the absence of a clear explanation of what triggers the initial deviation from the optimal behaviour as well as the burst of the bubble. In contrast, the relevance of such an analysis is more obvious when structural changes affect the institutional or regulatory environment (see in particular Davis, 1995), or when the institutional or regulatory and supervisory environment leads to moral hazard in risk taking. The latter issue has been raised in the context of the US S&L crisis (Kane, 1989) or more recently regarding the lending boom that partly led to the East Asian crisis (Krugman, 1998). Applying modern corporate finance models of firms' capital structure to banks, Dewatripont and Tirôle (1993) argue that banks' excessive reliance on debt financing (partly related to their provision of retail payment services to a large number of small and relatively uninformed depositors) also leads to more risk-taking in lending.

This traditional lending boom literature clearly relates to the potentially slow build-up of structural problems in the financial sector. These structural problems increase the likelihood as well as the severity of systemic events. However, it remains to investigate the precise conditions under which any bubbles burst and lending breaks down from one bank to another. Finally, many theoretical models of herd behaviour are not specifically formulated within a banking framework.

3.1.2 Bank runs versus bank contagion

The banking literature in the last 15 years has developed sophisticated models of *single* banks' fragility (see also point (i) in section 2.2). However, regarding systemic risk the speciality of "the bank contract" is only part of the story. The other parts are interbank linkages through direct exposures (and payment systems), which can only be studied in a model of a multiple bank system (point (ii) in section 2.2). In other words, one should distinguish between a "run" which involves only a single bank and a "banking panic" where more than one bank is affected (Calomiris and Gorton, 1991). We will start by reviewing the traditional bank run literature before covering the more recent models of contagion in multiple bank systems encompassing models applying the logic of the single bank run literature to multiple bank systems, theories explicitly modelling physical interbank exposures, and extensions of credit rationing models to the interbank context.

The first class of models, following Diamond and Dybvig (1983), was designed to address the issue of the instability of the fractional reserve banking system. Banks transform short-term deposits into long-term investments, with a liquidity premium, while depositors face an externality due to a "sequential service constraint" (when depositors withdraw their deposits, a first-come-first-served rule applies) and there is no market for investment or bank shares. A fraction of bank customers experience a liquidity shock and wish to withdraw their deposits. The crucial element is that the fear of withdrawal by a too large number of depositors may trigger a run on the bank in the form of a self-fulfilling prophecy.[18] In the second class of models depositors are unable to value bank assets correctly, in particular when economic conditions worsen. In the model of "information based" or "efficient" bank runs by Jacklin and Bhattacharya (1987), some informed depositors receive an imperfect signal that the risky investment made by the bank may yield a lower than expected payoff. They may therefore decide to withdraw their deposits, forcing the bank to liquidate its assets prematurely. In this model a trade-off arises in that equity contracts are vulnerable to asymmetric information but not runs (since they are conditional on the performance of bank assets) whereas (unconditional) deposit contracts are vulnerable to runs but not so much to asymmetric information.[19] As indicated by Chari and Jaghanathan (1988), agents can only identify the real performance of a bank *ex post*. In their model, which provides a synthesis between the first two approaches, some agents receive information about the performance of the bank's assets. Although the other agents can observe the length of the "queue at the bank's door," they are not informed about the actual proportion of agents experiencing a liquidity shock, so that they may decide to run the bank when the queue is too long.

Smith (1991) extends Diamond and Dybvig's model to correspondent banking in the US during the National Banking Era. In his model, local correspondent banks may run the money center banks following a local shock. De Bandt (1995) extends Jacklin and Bhattacharya's (1987) model to a multiple banking system and considers that an aggregate and an idiosyncratic shock affect the return on banks' assets. If depositors in one bank are the first to be informed about the difficulties experienced by their bank, depositors in other banks will then revise their expectations about the aggregate shock, hence the return on deposits in their own bank. This creates a channel for the propagation of bank failures. Temzelides (1997) develops a repeated version of the Diamond and Dybvig model where agents adjust their choices over time through learning from past experience with the banking system. One of the two Nash equilibria of panic/no panic is selected and learning introduces some state-persistence. The author also introduces a multiple banking system, where depositors observe bank failures in their own region and may decide to shift to the panic equilibrium for the next period. In this framework, more concentrated banking systems are less sensitive to idiosyncratic

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[18] In this model banks' deposit contracts are seen as insurance against liquidity shocks. Both "run" as well as "no-run" are possible Nash equilibria.

[19] In general share contracts are superior to deposit contracts in the model. However, when the underlying asset is not too risky, a deposit contract, even with possible runs, may be welfare superior to a share contract.

shocks and are therefore less prone to contagious panics. As for the literature on lending booms, it is clear that the macroeconomic environment plays a crucial role in the transmission of shocks with possible feedback effects between the business cycle and the banking sector's profitability.[20] In particular, through the unconditional character of deposit contracts and the great sensitivity of present asset values to interest rate risk large macroeconomic shocks may easily lead to simultaneous problems in a large number of banks (systemic crisis in the "broad" sense).

A further step are models of the interbank market and direct exposures, which have been developed recently against a background of a substantial growth in uncollateralised interbank lending, in particular at the international level. Rochet and Tirole (1996a) present a model of physical exposures in the interbank market. In their model, banks face funding shocks and lending banks have a natural incentive to monitor the banks to which they are exposed. This creates a linkage between the different banks. Formally, banks experience a solvency shock in the interim phase of a three-period model. When banks are short of reserves, they borrow funds in the second period ("date 1") in order to carry out their project. There is moral hazard on the part of the banks' shareholder-managers as it is not possible to contract on the level of effort provided by the banker. Interbank peer monitoring can provide the right incentives. If monitoring is exerted during the second period ("date 1") and reduces the bank's private benefit from shirking, the failure of one bank jeopardises the profitability of the lending bank and closure decisions of the different banks are intertwined. Domino effects and propagation of failures across banks may occur, since liquidity shocks affecting one bank increase the probability that other banks may be liquidated. "Chain" liquidations affecting a fraction of the banking system are likely to occur, although this is not explicitly mentioned. Only the global collapse of the whole banking system receives an explicit treatment by the authors, along the following lines: under some realisation of the liquidity shocks, the optimisation of banks' and depositors' utilities yields exactly two maxima (all banks fail/no banks fail). In this framework, a small increase in a bank's funding shock may imply the closure of the entire banking system.

3.1.3 Credit rationing in the interbank market

As conjectured by Davis (1995), the literature on credit rationing can be extended to the relationships among banks in the interbank market. If banks face a demand for credit by banks of unknown quality *ex ante* (adverse selection), lenders may decide to ration the amount of credit to all banks instead of raising interest rates, in order to avoid that the proportion of bad risks increases with interest rates. In the same vein, Flannery (1996) suggests a model of adverse selection in the interbank market. It is assumed that banks receive imperfect signals about the

[20] See in particular Bernanke and Gertler (1990) as well as Mishkin (1991).

quality of prospective borrowers. In this simple model, banks only lend when they receive a “good” signal. However, on some occasions, following a large shock in the financial system, banks may become uncertain about the accuracy of their assessment of the borrowing banks’ credit quality. As they feel less able to distinguish between “good” and “bad” banks, lenders raise interest rates across the board. If the loan rate becomes too high, “good” banks might not be able to repay their interbank loans any more, so that illiquid but solvent banks may go bankrupt. There is no successive process of propagation in this model, so we include it in our concept of systemic risk in the “broad sense.”

3.2 Systemic risk and financial markets

The role of financial markets is perhaps the most difficult element in the analysis of systemic risk. On the one hand, their tremendous growth over the previous decades has made them much more important, even in the more bank-based financial systems of Continental Europe. On the other hand, despite a general awareness about the occasional occurrence of market crashes, their role in truly systemic events has not really been explored in a systematic fashion. This contrasts with the existence of some theories of systemic risk in banking markets and some practical studies of systemic risk in payment and settlement systems.

In fact, markets are different from financial corporations. They do not go bankrupt, as institutions can.[21] So while there can be price crashes and propagation of them from one market to another, the main concern will be with the shocks that financial market crashes and temporary liquidity crises—be they contagious or not—impose on the rest of the financial sector and the real economy. Due to the high fungibility of the instruments traded in secondary markets their prices can be very information sensitive and fluctuate sharply. Whereas financial institutions and agents acting in the real economy should be able to adapt to and protect themselves against the normal amplitude of financial market price changes (“volatility”), this cannot be taken for granted for some truly extreme and general fluctuations. These extreme events may be, among others, the consequence of the burst of a “bubble,” possibly reinforced by certain trading strategies, such as program trading and positive feedback strategies.[22]

In the remainder of this sub-section the potential for contagious financial market crashes is reviewed first (systemic risk in financial markets in the narrow sense), and then financial market crashes and liquidity crises as *shocks* to financial institutions and the real economy are considered.

[21] While the shares or bonds of a defaulting company will disappear from markets, it is hard to imagine a situation in industrial countries in which a previously existing stock, bond or foreign exchange market disappears, let alone the disappearance of several of those markets through contagion. An exception might be some segments of high-risk markets, which might disappear after a crisis.

[22] See De Long et al. (1990) as well as Gennotte and Leland (1990) for models showing how these strategies can cause multiple equilibria and non-linearities in financial market prices.

3.2.1 Contagion across financial markets

Our first step is the discussion of contagion effects between financial markets leading to a systemic event in the narrow sense. This may be due to technical factors (e.g. collateral sell-offs may lead to the propagation of price changes across markets or arbitrage between cash and future markets may cause co-movements between the two markets.[23] However, we concentrate here on contagion based on the revision of expectations. In spite of the existence of a unified framework, a fraction of the post-1987 finance literature has attempted to uncover possible contagion effects among international securities markets, defined either as changes in securities prices (conditional mean or variance) that affect other countries beyond what is justified by fundamentals, or unexpected volatility spill-over effects during crisis periods. As for banking markets, we review successively what we identified in section 2.1 as two main channels of propagation, namely "information based" and "pure" contagion.

3.2.1.1 Contagion based on noisy signals under asymmetric information

"Information-based" contagion should be distinguished from "fully revealing" equilibria, that we define as connections between securities markets through fundamentals. In particular, in integrated financial markets, there is full risk sharing and (national) systematic disturbances or shocks to fundamentals are transmitted to other markets. In the seminal model of King and Wadhwani (1990), information is "not fully revealing" and agents in different markets have access to different sets of information. In particular, investors make decisions on the basis of information from prices in other markets as it is less costly to process information accruing in the form of unanticipated changes in asset prices than "news" on Reuter's screens. There is therefore a significant effect on prices in market *i* of an idiosyncratic shock in market *j*. Hence, mistakes in one market are transmitted to other markets. They argue that if a shock creates more volatility but is not generated by "news" (e.g., as during the 1987 stock market crash), agents are led to pay greater attention to other markets in an attempt to determine the effect of the shock on the demand for equity. Shiller (1995) also suggests a similar model where traders around the world have access to the same information, but process it differently, based on their own national experience. Individual (national) reactions to a systematic shock provide signals about the global implications of the initial shock. Dramatic conclusions drawn by the operators in one country lead operators in other countries to revise their expectations, hence creating an information cascade.

There is, however, a debate in the literature about the identification of the relevant changes in "fundamentals," as opposed to "noisy signals," since a broad

[23] Referring to the introduction of futures markets Guesnerie and Rochet (1993) make the distinction between gains in terms of volatility reduction and the greater difficulty for agents to co-ordinate expectations.

concept of "fundamentals" would tend to downplay the role of asymmetric information and the process of progressive revelation of information to the market and to equity prices. Whereas fundamentals are often defined as the main macroeconomic indicators that may have an effect on returns in securities markets, fundamentals are extensively defined by Hamao et al. (1990) as the whole information set of traders. Contagion can occur across markets given the non-coincidence of trading periods (e.g. the Tokyo market closes before the New York market opens). If one decomposes daily returns into Close-to-Open and Open-to-Close and if it is assumed that currency markets are efficient, any information occurring before the opening of a trading session should be fully included in the opening price and should not affect the Open-to-Close return. This provides a test of contagion (see section 4.2).[24]

3.2.1.2 "Pure" contagion across financial markets

Finally, "pure" contagion across markets may also be present. Currency markets with managed floating are the most likely to face such contagion effects as regulation may create some market incompleteness, giving rise to speculative attacks on currencies. However, the analysis is usually limited to a single currency. In particular, following models based on fundamentals (Krugman (1989), Gerlach and Smets (1995)[25]), Bensaid and Jeanne (1997) show that a sunspot is sufficient to destabilise a fixed exchange rate as long as the cost of leaving the arrangement is finite. More recently, Masson (1998) suggests a model of contagion across currency markets, which corresponds neither to common causes (labelled "monsoonal effects"), nor to spillover effects driven by fundamentals. In order to explain the effect of the currency crisis in Mexico and Thailand, the author uses a two-country model of balance of payments, which exhibits multiple equilibria for the probability of devaluation. Multiple equilibria only occur when fundamentals are poor. This formalises the intuition that sunspots lead speculators to re-evaluate their assessment of the fundamentals. Following the failure of a single fixed exchange rates arrangement, traders realise that the other arrangements are also fallible, so that speculation is transmitted to other weak currencies.

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[24] One related question is the process of change in fundamentals or the arrival of "news." However, such a question has not been addressed in a systematic way in the finance literature. One can only report the classification suggested by Lin and Ito (1995) who argue that one should distinguish between two causes of increasing correlation among international stock returns: (i) an increase in price volatility which signals a faster rate of transmission of news to the market and which is consistent with securities market efficiency and (ii) higher trading volumes which indicate more heterogeneity among traders and induce contagion of liquidity traders' sentiments. However, such an identification scheme is only assumed by the authors and not derived from an explicit model encompassing the two sources of shocks. In particular, it could be argued that increasing volatility might also, to some extent, measure information heterogeneity and create informational contagion.

[25] Gerlach and Smets (1995) offer a model of contagion between two countries connected through trade in goods and financial assets. A successful speculative attack against one currency boosts the competiveness of that country at the expense of its neighbours which are likely to be its direct competitors. This is likely to weaken the currency of the neighbouring countries that may become subject to a speculative attack.

To conclude, it appears that securities markets may constitute a crucial vector for the transmission of large systematic shocks. However, if the finance literature has achieved substantial progress in the understanding of large swings, non-linearities, multiple equilibria occurring in individual securities markets, much remains to be done regarding the transmission of shocks across markets and to institutions. In particular serious identification problems need to be overcome to distinguish between the efficient response to news and over-reaction of securities markets.

3.2.2 Financial markets as sources of systematic shocks

Large general price fluctuations or liquidity crises are themselves shocks to financial institutions and other agents. Extreme events in any of the major financial markets (stock market, government bond market, etc.) affect a large number of agents at the same time and are therefore of a "systematic" nature. Such systematic shocks from the markets will be even more widespread if they are contagious across markets, as discussed in section 3.2.1.

3.2.2.1 Shocks to financial institutions

In the recent past formerly "commercial" banks have become more and more involved in financial market trading activities (as opposed to traditional lending). Their larger trading books potentially lead to larger exposures to shocks originating in those markets. This implies that the structurally higher systemic risk in banking markets due to fixed value deposits and cross-exposures, as described in sections 2.2 and 3.1, will be more dependent on financial market fluctuations than has been previously the case. Similarly, it may have also become more dependent on the safety of the security settlement process (see section 3.2.2). The same applies to the banks' participation in financial conglomerates where other units are involved in securities activities.

Investment banks, securities houses, hedge funds, etc. are generally more risky than traditional commercial banks (e.g. in terms of earnings volatility), but as separate entities they are less vulnerable to the type of contagion that may affect the latter.[26] However, to the extent that they are involved in interbank money market borrowing their failure due to a large shock originating from market crashes may still spill over to the banking system (see section 3.1.2).

Alternatively, various events in financial markets (such as the failure of a large institution or a significant price fall) may increase uncertainty about the ability and willingness to trade by the main participants acting in these markets, in particular among market makers (Davis, 1994). Somewhat analogous to the

[26] One study investigates the effect of the announcement of OTC derivative losses by four clients of Bankers Trusts on other investment banks' stock prices during the first 9 months of 1994 (Clark and Perfect, 1996). The results tend to indicate that capital markets discriminate between derivative dealers on the basis of their exposure levels.

case of the interbank money market discussed above, liquidity in the respective financial instruments traded may dry up through adverse selection (Flannery, 1996). For example, market makers might increase bid-ask spreads to reduce the likelihood of being hit by a transaction (price rationing) or even “refuse” to trade at all (quantity rationing). Such a liquidity “freeze” could involve a systematic shock on all those banks and non-bank financial institutions, whose risk management strategies depend on the ability to trade in these markets.[27]

3.2.2.2 Shocks to the real economy

Already Fisher (1933) in his debt-deflation theory examined the connection between the poor performance of financial markets and the Great Depression. One link between financial markets and the business cycle was also formally explained by Kiyotaki and Moore (1997) through the effect of depressed asset prices on agents’ ability to borrow against available collateral. Their model does not address the issue of systemic risk, but rather stresses explanations for business cycle fluctuations. However, the same mechanism might work with greater strength in times of financial market crashes.

3.3 Systemic risk in payment and settlement systems

By providing the technical infrastructure through which banking and securities market transactions are settled, payment and settlement systems determine to an important extent the physical exposures among financial institutions. In a way, looking at payment and settlement systems is like looking at the network of interbank exposures with a magnifying glass. Hence, depending on their internal organisation they also determine how shocks may propagate through the financial system, in particular how severe contagion can be. The analytical literature on systemic risk has largely overlooked their importance until very recently. The fundamental underlying risks in these systems are similar to those encountered by financial institutions in general: operational risk (such as the failure of a computer, as for the Bank of New York in 1985), liquidity risk (reception of final or “good” funds, not being realised at the desired time but at an unspecified time in the future), and credit risk (failure of an insolvent participant with a subsequent loss of principal).

3.3.1 Interbank payment systems

There are three main types of interbank payment systems: net settlement systems, gross settlement systems and correspondent banking. In what follows we shall first describe “prototypes” of these systems and then refer to the most important practical deviations from these types. In *net settlement systems* payments among

[27] A recent event that has raised these issues in practice is the bail-out of Long Term Capital Management, a large hedge fund, in September 1998.

members are collected over a certain period of time, e.g. a whole day or several hours, and at the settlement time the gross payments between members are netted against each other, so that only the net balances have to be settled with finality. With bilateral net settlement the members effectively remain the only counterparties to each other, while in multilateral net settlement systems debit and credit positions are accumulated vis-à-vis a central counterparty (usually a clearing house) until they are offset at the settlement time. Net settlement systems involve relatively low costs, because actual settlement is relatively rare—normally occurring only once at the end of the day (and in some cases twice a day)—and thus liquidity costs are low. Because of the more limited number of direct counterparties, these cost savings are usually more pronounced in multilateral systems than in bilateral netting. The netting of reciprocal gross positions between institutions can considerably reduce the effective debit positions, and thereby systemic risk, as compared to pure gross settlement undertaken on the same time scale, where incoming and outgoing payments are settled independently (without any netting). However, without additional provisions, net settlement systems are still comparatively vulnerable to systemic risk, since gross exposures accumulating between settlement times can become very large.

In *real-time gross settlement systems* (RTGS) payment finality is virtually immediate for every transaction, so that the systemic risk from unsettled claims appears to be very limited, at least at first glance. Due to the heavy charge for intra-day liquidity management (in order to have always enough liquid funds available during the day) it is comparatively costly for member banks. Moreover, banks' ability to pay out may depend on the timeliness of incoming payments, but counterparties may sometimes have the incentive to delay outgoing payments. Therefore, RTGS can be characterised by relatively frequent queuing phenomena, which can lead to wide-spread liquidity ("network") externalities or even system "gridlock" when participants economise on their intra-day liquidity or default. This shows that even RTGS may not be totally free of systemic risk.

Most real-life systems have specific additional institutional features in order to reduce systemic risk or liquidity costs (and gridlock risk) in net and gross systems, so that both types become actually more similar. For example, net settlement systems now often introduce caps on the exposures between settlement times and loss-sharing arrangements between members for cases of defaults. Regarding the latter, "decentralised" multilateral net systems are to be distinguished from "centralised" systems, where the central counterparty takes over the risks and can, therefore, default itself. Also, legally binding netting-arrangements can apply for the periods between settlement times or the number of settlement times during the day could be increased.[28] In order to reduce the liquidity costs of real-time gross systems the possibility of intra-day overdrafts vis-à-vis the settle-

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[28] The legal enforcement of these netting arrangements can be particularly difficult for international transactions. For example, in some jurisdictions a liquidator may be able to engage in "cherry picking" favouring the general creditors of a failed institution (BIS, 1990).

ment agent are now often allowed. Since they are a potential source of systemic risk, these overdrafts are either secured through collateral requirements, as will be the case for the Trans-European Automated Real-time Gross settlement Express Transfer System (TARGET) and the connected national RTGS, or through daylight overdraft fees, as in the case of Fedwire in the United States. Alternatively, routine queuing facilities can be established, which however imply similar risks as net settlement systems.

Correspondent banking relationships appear to be very diverse. Correspondent banks provide payment services for groups of usually smaller or foreign banks, which do not have cost-effective access to the primary domestic net or gross systems. Each of the latter groups of banks settles bilaterally with the correspondent via debits and credits on nostro and loro accounts, whereby gross exposures can be netted against each other.[29] Therefore, the failure of an important correspondent bank can directly affect a large number of those institutions. Moreover, correspondent banking is used by large credit institutions for international transactions. In this respect, it could become one of the major channels for the transmission of the so-called Herstatt risk (see the next section).[30]

There is only an incipient literature of theoretical models describing the risks of different payment system arrangements. Angelini (1998) models profit-maximising banks' behaviour in an RTGS where intraday liquidity is available from the central bank against a fee proportional to the size of the overdraft. (Following the example of the US Fedwire system, overdrafts are not collateralised.) Delaying payments has also a cost in terms of customer dissatisfaction. Angelini derives in the framework chosen that the competitive (Nash) equilibrium is not welfare optimal, since the cost of intra-day credit induces banks to delay payments rather than to draw on the overdraft facility. These payment delays result in network externalities, since payees attempt to free ride on other banks' reserves, thereby reducing overall liquidity. (However, the author does not address explicitly the question whether a "gridlock" equilibrium can exist, in which payment activity comes to a standstill; a stronger form of systemic risk). He concludes that in RTGS intra-day overdrafts (by the central bank) must be made sufficiently cheap, so as to remain lower than banks' customer dissatisfaction costs through payment delays. Moreover, he suggests that banks could be induced to pay earlier during the day via variable overdraft fees, which penalise late payments. In contrast, Humphrey (1989) has argued that payment delays in gross systems with uncollateralised overdraft facilities may be desirable to reduce the actual overdrafts and therefore systemic risk or the costs of the system guarantor.

Schoenmaker (1995) compares multilateral net settlement systems (à la US CHIPS) and collateralised RTGS systems both theoretically and through the

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[29] In a way correspondent banking can be seen as a step from bilateral net settlement towards multilateral net settlement, although happening on a smaller scale.

[30] For other reviews of payment system arrangements and the risks involved, see Folkerts-Landau (1991), Borio and Van den Bergh (1993), Summers (1994), Berger et al. (1996), Rochet and Tirole (1996), Schoenmaker (1996), Kobayakawa (1997) and Rossi (1997).

simulation of average costs with real transactions and historical bank default data. It turns out that the average costs through settlement failures (defined as historical failure rates times maximum open intraday positions) are higher in the net than in the gross system, but those through settlement delays (or gridlock) and collateral requirements are lower in the net systems. This might explain why central banks often prefer “safer” gross systems while market participants favour “less costly” net systems, and it also reflects the trade-off between risks and costs described in Berger et al. (1996). In particular, Schoenmaker explicitly derives the potential occurrence of systemic events in the form of gridlock in the RTGS variant (proposition 4.1).

Elaborating on Schoenmaker’s comparative approach and using a theoretical framework akin to Angelini’s, Kobayakawa (1997) provides a broad analysis of multilateral net settlement and both types of RTGS, with full collateralisation of intraday overdrafts (“EU type”) and with fees on uncollateralised overdrafts (“US type”). However, like Angelini he focuses on their relative efficiency and (apart from externalities through payment delays) he does not derive explicitly any systemic events that might occur.

In contrast, in a careful theoretical study of foreign exchange netting (see also section 3.3.2) Yamazaki (1996) focuses entirely on the relative importance of systemic exposures in bilateral net settlement as compared to multilateral net settlement (decentralised variant with loss-sharing among participants and without a clearing house). He establishes that for single failures multilateral netting reduces other banks’ exposures as compared to bilateral netting, if the initial loss is not “extreme.” However, when a chain reaction of failures occurs, he shows that there are plausible cases in which the systemic event under multilateral netting is more severe than under bilateral netting. Moreover, he points to moral hazards that can be associated with multilateral netting.

In a more abstract model, Freixas and Parigi (1998) (building on McAndrews and Roberds, 1995) introduce geographical consumption preferences in a Diamond-Dybvig-type model, which lead to “interbank payments” between two regions. With “gross settlement” banks have to liquidate investments to the full amount of outgoing payments in the same period, which imposes a relatively high opportunity cost through foregone interest on investments. With “net settlement” the banks can, first, offset incoming and outgoing payments and, second, extend credit lines to each other in order to finance future consumption of “foreign” consumers. In this framework the “gross system” is free of contagion but exhibits high opportunity costs. The “net system” exhibits systemic risk and potential welfare losses in so far as inefficient banks may stay open for longer.

3.3.2 Foreign exchange and securities settlement systems

In contrast to national interbank payments, foreign exchange and securities transactions involve the settlement of two “legs.” Foreign exchange transactions involve the opposite payment of the same principal amount in each of the two currencies, and securities transactions involve the “delivery” of the security in one direction and the opposite “payment” of funds in the other, which can enhance credit and liquidity risks. The credit risk resulting from defaulting counterparties in these transactions may not only cause the loss of principal (“principal risk”), but it has also a market risk component known as “forward replacement cost,” the potential loss implied by having to replicate a transaction in the market when the counterparty has defaulted and the market price has become less advantageous for the non-defaulting party.[31]

Asynchronous settlement of the two legs leads to additional channels through which contagion between financial institutions and markets can work. Regarding international transactions the existence of different time zones can create “Herstatt risk,” the danger that one leg is already settled while the counterparty in charge of settling the other leg defaults before the systems in the respective other time zone already operate. Similarly, in the case of national securities market transactions, the payment leg through interbank transfer systems may have a different timing than the delivery leg of Central Securities Depositories (CSDs). Increased concerns about principal risk in securities settlement has led to major initiatives to achieve “delivery versus payment” (DVP), the simultaneous settlement of both transaction legs (Committee on Payment and Settlement Systems (CPSS), 1992). On the other hand, it is also true that DVP mechanisms by connecting real time payment systems and securities settlement systems accelerate the transmission of risks from one system to another (i.e. if settlement of cash cannot take place because of a problem in the settlement system securities will not be settled either and vice versa). Alternatively, securities can also be used to offset other securities transactions in a simultaneous fashion (“delivery versus delivery,” DVD).

The CPSS identified three main approaches to securities settlement systems in G-10 countries: 1) systems that settle both securities and funds on a gross basis and in a simultaneous fashion, 2) systems that settle securities on a gross basis and funds on a net basis at the end of the settlement cycle, and 3) systems that settle both legs on a net basis in parallel at the end of the settlement cycle. Practical implementations of the first approach share many of the risks of RTGS in interbank payments and operational responses to those risks are very similar (e.g. collateralised intraday or even overnight credit facilities). In most implementations of the second model the risk of unsettled payment legs is limited through “assured payments” via guarantors, which however could fail themselves. In many type 3) systems the failure of a counterparty to settle a net funds debit position leads to an unwinding procedure, which may create considerable systemic risk through liquidity pressures on other participants. Therefore, in several cases the systems operator or a clearing corporation guarantees the completion of settlement.

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[31] The systemic dimension of principal risks associated with bilateral and multilateral forex netting systems are studied in the paper by Yamazaki (1996) discussed in section 3.3.1.

CSDs, which play the role of the settlement agent in national securities transactions, may sometimes also be at risk of failing, potentially implying substantial systemic repercussion due to "custody risk." If claims of financial institutions on the securities in custody with the depository are not clearly segregated, some of them may experience unexpected losses. A similar problem may arise with "global custodians" on the international level. These custodians, usually big investment banks, maintain accounts with the different national CSDs in order to execute securities transactions for other banks which do not have access to foreign CSDs. While playing an important intermediary role in connecting separated national CSDs, their failure can be an element in the international transmission of crises since, unlike CSDs, global custodians are normally also large participants in payment systems.

The payment and the delivery side of securities transactions show the potential for contagion working from members of interbank payment systems to those of securities settlement systems and vice versa. In fact, most credit institutions are active in both interbank payment and securities settlement systems. Experiences from the 1987 stock market crash reported in Brimmer (1989) and Bernanke (1990) show that these types of cross-system propagations can easily become real in a major crisis. However, we are not aware of any theoretical models describing the particular risks of securities settlement systems in a rigorous way.

The risk of cross-system spillover effects may be more severe between foreign exchange settlement and national interbank payment systems. The CPSS (1996, fn. 3) reports system operator estimates saying that "FX settlements account for 50% of daily turnover value in CHIPS and CHAPS, 80% of the daily turnover value of EAF, and 90% of the daily turnover value of SIC." Industry groups such as FXNET, S.W.I.F.T. or VALUNET provide various bilateral foreign exchange netting services for various groups of banks. ECHO and Multinet provide multilateral netting services. A major new development will be the establishment of a continuously linked settlement (CLS) bank by 20 major banks in the forex settlement business.

4 Empirical evidence on systemic risk

In this section we survey the existing empirical evidence on systemic events and systemic crises in the light of the concepts developed in Section 3, mainly focusing on rigorous empirical analyses of contagion. The objective is to identify how much we know about the pervasiveness of the different elements of systemic risk in different countries as well as on the international platform. Another objective is to detect those areas of the empirical analysis of systemic risk, which have not yet received enough attention to be properly understood. This will point us to necessities for future research efforts.

4.1 Evidence on bank contagion

As has been pointed out in Section 3, the risk of contagious bank failures may be viewed as the "classical" case of systemic risk. Testing for bank contagion amounts to testing whether "bad news" or the failure of a specific bank (or group of banks) adversely affects the health of other banks. The literature that has developed around this can be separated into several groups. One group of papers tries to link bank failures with subsequent other bank failures directly. A second group studies the relationship between failures or "news" and other banks' stock market values. A third group looks at the link between "news" or failures and deposit withdrawals at other banks. A fourth group analyses the effect of "news" or failures on the *probability* of other banks' defaults, as perceived by market participants and reflected in risk premia in interbank lending. Finally, one can measure the physical exposures among operating banks (or between those and banks which have been "bailed out" by the government) to evaluate whether a default would render other banks insolvent. We proceed in successive order.

4.1.1 Intertemporal correlation of bank failures

The common ground of this first branch of the bank contagion literature is a test for autocorrelation in bank failures. Basically, the rate of bank failures in a period t is regressed on the rate in the previous period (t-1) and a number of macroeconomic control variables. Provided that all macroeconomic shocks are effectively covered by the control variables a positive and significant autocorrelation coefficient indicates that bank failures and periods of tranquility cluster over time, which is consistent with the contagion hypothesis. Since the safety net provisions in modern financial systems, such as deposit insurance schemes and lender-of-last-resort facilities tend to prevent that a single bank failure can lead to effective failures of competitors, these tests have to be undertaken for historical periods in countries without strong (public) safety nets.

Grossman (1993) finds with a simple OLS regression analysis of quarterly US data for the period between 1875 and 1914 (i.e. before the establishment of the Federal Reserve System) that a 1 per cent increase in failures in a quarter led on average to a 0.26 per cent increase in the following quarter. Hasan and Dwyer (1994) and Schoenmaker (1996) have substantially refined this approach and provide more evidence of intertemporal failure clustering in "free banking" markets. Hasan and Dwyer (1994) apply a probit analysis to data from the US Free Banking Era (1837 through 1863). Depending on the crisis considered in this interval and the respective region they find evidence compatible with contagion or not. By applying an autoregressive Poisson (count data) model to the number of bank failures, Schoenmaker (1996) finds strong results for a sample of monthly data covering the second half of the US National Banking System and the early years of the Fed (1880 through 1936). The autoregressive parameters are strongly significant up to a lag of 3 months and they increase in size and significance for the sub-sample encompassing the Great Depression, while macroeconomic factors appear to become less informative for the prediction of failures.

In sum, this approach seems to have been relatively successful in making the case in favour of the contagion hypothesis. However, the main disadvantages of this approach are that, first, the negligence of macroeconomic factors exhibiting autocorrelation themselves would cloud any "evidence" of contagion and, second, it can only detect intertemporal contagion at the frequencies of macroeconomic data and not at shorter time intervals.

4.1.2 Event studies on stock price reactions

The most popular approach to test for contagion effects turned out to be event studies of bank stock price reactions in response to "bad news," such as the announcement of an unexpected increase in loan-loss reserves or the failure of a commercial bank or even of a country to serve its debt. The presence of contagion is usually tested by comparing the "normal" return of a bank stock, as predicted by a standard capital market equilibrium model (such as the CAPM) estimated with historical data, to the actually observed returns at the announcement data or during a window around this date. "Bad news" for a bank *i* leading to significantly negative "abnormal" returns of another bank *j* is interpreted as evidence in favour of contagion.

The forerunners in applying this approach were Aharony and Swary (1983) who studied the effects of the three largest bank failures in the United States before 1980: United States National Bank of San Diego (1973), Franklin National Bank of New York (1974) and the Hamilton National Bank of Chattanooga (1976). The sources of each of these three failures seem to have been of a rather idiosyncratic nature, related to in-house fraud, illegal real-estate loans or foreign exchange losses. The Franklin National case, the failure of the 12th largest US bank at the time, caused substantial negative abnormal returns in money-center, medium-size and small banks, whereas no external effects of the smaller two other cases occurred.[32]

Swary (1986) applies the same approach to the Continental Illinois National Bank failure in 1983-84, the 8th largest bank in the United States. Although larger than Franklin National and confronted with somewhat less idiosyncratic problems (bad domestic and international loans), negative abnormal returns of 67 other US banks turned out to be weaker and somewhat proportional to these other banks' own pre-crisis solvency situations. Wall and Peterson (1990) find that part of these negative stock market reactions can also be explained by more general "bad news" arriving about the Latin American debt crisis. Jayanti and Whyte (1996) show that stock market values of British and Canadian banks with significant LDC debt exposures were also adversely affected by Continental's failure but not those British banks which were unexposed to debt crisis countries. Peavy and

[32] However, Aharony and Swary caution that there were a number of other banks which faced foreign exchange losses similar to those of FNBNY shortly after the switch to floating exchange rates (notably Germany's Herstatt bank).

Hempel (1988) show that the Penn Square Bank failure of Oklahoma in 1982 had only regional repercussions.

In a similar vein, Madura and McDaniel (1989) analyse the effect of the 3 billion-dollar loan-loss reserve announcement of Citicorp in 1987 on the stock prices of the 11 other US money-center banks, which also issued loan-loss announcements later in the same year. Their results indicate that most of the losses had been anticipated earlier by the market. Docking et al. (1997) study the effect of 188 loan-loss reserve announcements by nine leading money-center banks and 390 announcements by 102 regional banks in the United States from 1985 to 1990. It turns out that there is little impact of money-center bank announcements on other money-center banks' stock prices, but regional banks' announcements (from certain areas) can have detrimental effects on other regional or money-center banks. These results are compatible with the hypothesis that investors better anticipate unfavourable announcements from the large and "visible" money-center banks than from regional banks.

The early results of adverse "external" stock market reactions to "bad news" triggered a debate about whether they can be interpreted as evidence of "pure" contagion effects or whether they rather reflect rational investor choices in response to the revelation of new information. In a series of papers the strength of abnormal returns during the international debt crisis of the 1980s was linked to banks' own exposures to problem countries. Cornell and Shapiro (1986) undertook cross-sectional regressions for 43 US bank stocks and for various subperiods during 1982 and 1983 and Smirlock and Kaufold (1987) performed seemingly unrelated regressions for 23 exposed and 37 non-exposed US banks around the 1982 Mexican debt moratorium. Musumeci and Sinkey (1990) and Karafiath et al. (1991) study the effects of the 1987 Brazilian debt moratorium on US bank stocks. The former use an OLS cross-section regression for 25 banks, the latter a Generalised Least Squares (GLS) cross-section regression for 46 bank holding companies. Madura et al. (1991) assess the impact of Citicorp's announcement of substantial loan-loss reserves on the share prices of 13 large British banks. The general result of this debate was that abnormal returns varied in proportion to banks' exposures to problem countries, which is consistent with the hypothesis of rational investor choice.

Since most of these results are found for US data, an interesting question to ask is whether they carry over to other financial systems. Unfortunately, not much seems to have been published for other countries. An exception is Gay et al. (1991) who chose to examine bank failures in Hong Kong during the 1980s. These cases are interesting, because first Hong Kong did not have an explicit deposit insurance scheme (which might dampen any contagion effects) and second at least two of the three failures studied (Hang Lung Bank in 1982 and Overseas Trust Bank in 1985) seem to have had rather idiosyncratic sources, such as management misconduct and embezzlement, while the third (Ka Wah Bank in 1985) seems to be related to the failure of Overseas Trust Bank and to that of a specific foreign borrower. In the first two cases strong negative abnormal returns occurred for locally listed bank stocks, but the evidence provided on rational investor reactions differentiated according to exposures seems to be rather inconclusive.

In terms of the concept developed above this literature shows *weak* systemic events in the narrow sense, since stock price fluctuations do not imply failures.

4.1.3 Analyses of deposit flows

Another test of contagion measures the reaction of depositors (wholesale and retail) to "bad news." If in response to problems revealed about a bank (or a group of banks) *i* depositors also withdraw funds from another bank *j*, there is evidence of a contagious bank run.

Saunders (1987) examines whether two key announcements about the shape of Continental Illinois Bank in April and May 1984 had any discernible effect on other banks' US or overseas deposits. The April 18th announcement of a US$ 400 million increase in Continental's problem loans seemed to have no effect on US deposits, while the May 10th "denial of rumours" by the US Office of the Comptroller of the Currency (OCC) seems to have triggered "flight to quality" (i.e. shifts to safer banks and more secure deposits) by large US banks but not a general run. The total of non-sterling deposits at either American, Japanese or other overseas banks in London did not decline in April or May (but risk premia on these deposits generally increased, see section 4.1.4 below).

Saunders and Wilson (1996) study the deposit flows of 163 failed national banks and 229 surviving banks in the United States during the Great Depression (1929 through 1933). They find that in the sub-period 1930-32 there is evidence of both "pure" contagion, defined as significant withdrawals from institutions which in the end turned out to be healthy, as well as "informed" withdrawals from institutions which appeared already unhealthy before the crisis. While recognising the presence of "pure" contagion, the authors point out that "uninformed" withdrawals have not been more important than "informed" withdrawals.

Calomiris and Mason (1997) examine the June 1932 Chicago bank panic during the Great Depression. They group their sample of 114 Chicago banks into 3 categories: non-panic failures, panic failures and survivors. Statistically significant deposit withdrawals from the 62 survivors, which are only weakly smaller than those from the 28 panic failures, indicate the presence of contagion due to asymmetric information regarding individual banks' solvency situation. The authors further ask whether these contagious withdrawals led to contagious failures or whether the failures observed were rather those of relatively weak banks in the face of a common asset price decline. To that end they apply a logit estimation of "ex-ante" failure probabilities (based on balance-sheet data) for these groups, either including panic failures, or excluding them. Since in both cases panic failures received a higher *predicted* failure probability than survivors, the authors conclude that only already ex ante weaker banks actually failed during the panic, which is consistent with the hypothesis that "pure" contagious failures did not occur. They explain this finding with the existence of private cooperative arrangements among banks.

4.1.4 Examinations of bank debt risk premia

Some work has been done to see whether contagion effects can be detected in the market prices of bank debt instruments. Carron (1982, Table 1) shows that the Franklin National failure in New York (and perhaps also the Herstatt failure in Germany) in mid-1974 led to an increase in the quarterly average spread between US “jumbo” certificates of deposits (CDs) and 3-month Treasury bills by a factor of at least six, which is consistent with contagion via risk premia. Giddy (1981) argues that bid rates for Eurodollar deposits of 30 banks in London during July and August 1981 varied only very little between individual banks and that the differentials were hardly related to proxies of individual bank or country risk. Saunders (1986) computes correlations of interbank rate risk premium indices for three different country groups before and after the start of the 1982 debt crisis. He observes statistically significant increases of the correlation of risk premia between industrial countries and middle-income LDCs and between middle income and low-income LDCs, which he considers to be consistent with contagion between those two groups of countries. However, in a follow-up study (Saunders, 1987) he derives that the correlation of risk premia between industrial countries, non-oil exporting LDCs and countries with debt re-scheduling was actually *lower* in the “crisis period” 1974 through 1978 than in the “non-crisis period” 1979 through 1983, so that “there appears to be no evidence of contagion in the crisis period” (p. 215). In any case, the correlations approach cannot distinguish between systematic shocks and contagion, as defined in the conceptual section above (Section 2).

Karafiath et al. (1991) undertake an event study of the effect of the 1987 Brazilian debt moratorium on bond prices of 22 US bank holding companies (all with country exposures to Brazil). In contrast to the equity price reactions reported in the previous section, the cross-section of weekly bond yields in excess of Treasury note yields were far from being significantly abnormal. One interpretation of their differential results between equity and bond returns is that the market expected that those banks would earn lower profits (and therefore pay less dividends) due to the debt crisis but that none of the bank holding companies would actually default on its debt. Finally, Jayanti and White (1996) estimate statistically significant increases in the average certificate of deposit (CD) rates—at constant Treasury bill reference rates—for both UK and Canadian banks after the Continental Illinois failure in the United States in May 1984. In their case this result is consistent with the international contagion effect visible in equity returns mentioned in the previous section. Saunders (1987, fn. 28) also acknowledges that the average spread between 3-month Euro-dollar deposits and T-Bills doubled during the Continental Illinois problem months of April and May, which again is consistent with international systemic risk in the weak sense. An even stronger effect was visible in the average monthly domestic risk premium, as measured by the difference between 3-month CD rates and 3 month T-Bill rates, which more than tripled during April and May (Saunders, 1987, fn. 27).

The evaluation of the event study approach applied to risk premia in debt rates, as a test for contagion effects is, of course, similar to the application to equity returns.

4.1.5 Measurement of effective exposures

A last approach is to directly measure whether exposures to certain (potentially or effectively failing) banks are larger than capital. While prudential rules limiting large exposures should usually prevent banks from lending more than a small share of their capital to a single borrower, very large exposures can occur temporarily vis-à-vis “core institutions,” namely large clearing banks.

Kaufman (1994) reports some results from the US inquiry into the Continental Illinois case, one of the “core institutions” at the time. Shortly before the failure, 65 financial institutions had uninsured exposures in excess of their capital to the bank. It was estimated by the Congressional study that, if Continental’s losses had been 60 per cent (i.e. creditors would lose 60 cents of every dollar lent), then 27 banks would have been legally insolvent and 56 banks would have suffered losses above 50 per cent of their capital. The actual losses of Continental finally amounted to below 5 per cent, so that none of its correspondents suffered solvency-threatening losses. Michael (1998) reports some effective exposures from London interbank markets.

This approach is strongly linked to empirical research on the impact of failures in payment and settlement systems, which we survey in section 4.3 below.

4.2 Evidence on contagion in financial markets

In the recent past some evidence has been accumulated that contagion phenomena can also occur among financial markets. We focus here on the contagion across markets (section 3.2.1 above). Although there is potentially a large literature on international financial integration, our review is relatively selective since financial integration in itself does not imply contagion. We only report evidence that support our definition of contagion, namely the existence of spillover effects across securities markets that are not justified by fundamentals and operate differently in “crisis periods” than in “normal times.” We present four types of contributions: (i) return correlation across markets, (ii) volatility spillover effects, (iii) the analysis of the dependence of extreme price deviations across markets, and (iv) event studies of the determinants of currency crisis. These different approaches are complementary and some papers cover them jointly. In addition, they rely, to a large extent, to the same analytical tools, namely GARCH modelling, in the wake of the findings that most financial series exhibit autoregressive conditional heteroscedasticity.

4.2.1 Correlation across markets

The first type of tests measuring contagion is simply based on the correlation of returns across markets. The main stylised fact is that correlation increases when markets are more volatile, hence reducing the completeness of financial markets and the gain from international diversification. This may undermine the stability of financial institutions. Evidence is based on contemporaneous as well as lagged correlations.

4.2.1.1 Contemporaneous correlation

As indicated above, contemporaneous correlation does not directly measure contagion, which, in principle, would require studying the transmission of shocks over time. However, in securities markets the speed of transmission of a large systematic shock may be such that the propagation of the disturbance may be almost instantaneous. In addition, the econometrician may be not able to use data at a sufficiently high frequency, if she or he wants to control for changes in fundamentals. Finally, the allocation of risks by securities markets may worsen and therefore have systemic consequences if, on certain occasions, the correlation between individual securities markets increases. In that area of research, there is substantial evidence on equity markets following the 1987 stock market crash.

In a seminal paper, King and Wadwhani (1990) regress daily equity returns in London and New York on each other and show that during the period from 19 October to 30 November 1987 the correlation between returns on the FTSE-100 and the Dow Jones was significantly positive, while it was not significantly different from zero during the rest of the year. In a more systematic fashion, King, Sentana and Wadwhani (1994) extend the analysis to monthly returns on 16 stock markets during the period January 1970 to October 1988, assuming that the innovations on equity returns follow a multivariate GARCH (1,1) process which depends on observable macroeconomic "observable" as well as "unobservable" components. Their finding is that only a small proportion of the covariance between national stock markets can be accounted for by "observable" economic variables. While the "unobserved" components might include omitted variables, they can also reflect market sentiment and contagion. In particular, it appears that the observed factors fail to explain the substantial increase in correlation during the 1987 crash. The authors also show that the apparent upwards trend of the equally weighted average of conditional correlations between the national excess equity returns may actually be explained by a simple dummy variable accounting for the 1987 stock market crash.

4.2.1.2 Leads and lags between securities markets

In a study corresponding very closely to our definition of contagion in securities markets, Malliaris and Urrutia (1992) run causality tests on daily closing returns for 6 major stock market indexes (SP 500, Tokyo Nikkei, London FT-30 and other Asian markets) from May 1987 to March 1988, taking into account differences in time-zone trading. Practically no lead-lags are uncovered for the pre- and post-crash periods, but important unidirectional as well as feedback relationships are found during the October 1987 crash. The results also provide evidence of the "passive" role of Tokyo but fail to confirm the leading role of New York during that period.

Lin et al. (1994) qualify King and Wadwhani's (1990) analysis, using intraday equity returns in order to account for differences in time zone trading. They divide close-to-close returns into close-to-open and open-to-close returns and argue that for two markets without overlapping trading periods, a test of contagion should be based on the existence of a significant lagged correlation between daytime (Open-to-Close) returns in the two countries. Under the hypothesis of market efficiency, news revealed in the foreign market in daytime (Open-to-Close) or overnight (Close-to-Open) is completely incorporated into the opening prices so that the Open-to-close return should not be affected. They report that contemporaneous correlation between foreign daytime (Open-to-Close) and domestic overnight (Close-to-Open) returns was much smaller around the crash, while the correlation between foreign daytime returns and subsequent domestic daytime returns rose around the crash. One possible explanation is that traders took more time to figure out the implications of a sharp decline in prices. Lin and Ito (1995) also found that for the period October 1985 to December 1991 and considering the Tokyo Nikkei and the New York S&P index, the contemporaneous effect of the foreign daytime return on the domestic overnight return is statistically significant, whereas the lagged effect of the foreign daily return on the domestic daily return is insignificant, once lagged effects of home return are taken into account. Such a result provides evidence in favour of international efficiency and against contagion, although the introduction of the lagged home return in the equation indicates that domestic markets may not be fully efficient. In addition, the authors are unable to provide significant evidence in favour of an effect of trading volume—which measures heterogeneity of information and the contagion of investors' sentiment—on the international correlation of equity returns. During the 1987 crash period, however, the coefficients on lagged spillover effects are much more significant and contemporaneous correlation less significant, in particular from Tokyo to New York, indicating that news revealed in the foreign markets could not be incorporated in the opening price due to heightened uncertainty.

4.2.2 Volatility spill-over effects across markets

We survey now the different contributions that have attempted to measure volatility spillover effects across markets to shed light on possible contagion. Following the discussion in section 2.2.2, it is however necessary to stress that volatility can be predictable as a result of the fact that the arrival rate of news is correlated over time. Volatility spillover effects may also be explained by responses to changes in common fundamentals. Against this background, a drawback of that literature is that focusing on high frequency data (daily or intra-daily) there is no room for a direct measure of macroeconomic determinants, apart from the effect of unexpected "news."

Similarly to the analysis of correlation reviewed in section 4.2.1, this literature which has developed since the late 1980s / early 90s, first attempted to find evidence of more significant transmission of volatility during the 1987 stock crash. In particular, Hamao, Masulis and Ng (1990) study intra-daily returns on equity in Tokyo, London and New York. Open-to-close returns are measured as a GARCH (1,1) process and the authors test whether the conditional variance of innovations may be explained by volatility surprises in the foreign market. Surprises are measured by the squared residual derived from the foreign market that trades the most recently (i.e. Tokyo for London, London for New York and New York for Tokyo). Using observations on the 1985-1988 period, they show that the foreign volatility has a significant effect only when the post-October 1987 period is included. Lin et al. (1994) provide a little more formal structure to the arrival of news and decompose the unexpected return in the foreign market into a local and a global factor. However, they are unable to distinguish between "shocks to international fundamentals" and "internationally contagious psychology." Investors solve a signal-extraction problem in order to uncover the two types of shocks affecting the foreign return, since only the global factor may create a spillover effect on the domestic market. The authors find that the signal extraction model provides a better fit to the Tokyo overnight return data than a simple GARCH-in mean, especially when the 1987 crash is included in the sample period. However, Susmel and Engle (1994), using hourly data on equity markets, conclude that there is no strong evidence of spill-over effects for the period including the 1987 crash: spill-over effects seem to be limited to the opening hour of the trading period.

As new observations have become available, subsequent works have addressed the more general question of asymmetric effects in the transmission of volatility. Koutmos and Booth (1995) investigate daily open-to-close returns from March 1986 to January 1993 in Tokyo, London and New York. They assume that the three markets open sequentially and that return innovations follow an exponential GARCH process, which allows the size as well as the sign of the shocks to be distinguished. Their finding is that volatility spill-over effects are more pronounced when the news arriving on the last market to trade is bad (i.e. when standardised return innovations are negative). Kanas (1998) finds comparable results when applying the same methodology to a sample of European stocks (London, Paris and Frankfurt) for the period 1984-1993, using close-to-close daily returns.

To our knowledge, only a limited number of studies have attempted to investigate volatility spill-over effects across other types of assets since the seminal paper by Engle et al. (1990). These authors concluded that volatility in foreign exchange markets was not an isolated phenomenon affecting a given currency (a "heat wave"), but a global issue (akin to a "meteor shower"). However, such analysis did not address the origin of such a feature, namely whether it corresponds to correlated fundamentals or a failure of a strong form of market efficiency and did not investigate the robustness of the transmission channel when markets are more volatile. One should also note that until 1994, the conclusion of the literature was that bond markets were not characterised by excess volatility, so that volatility spill-over effects seemed pointless. In contradiction with the latter view,[33] Borio and McCauley (1994) use indicators of implied volatility derived from option prices in order to test whether volatility spill-over effects—measured by the regression coefficient between pairs of countries—are more pronounced during periods where volatility is high. As their equations also include an autoregressive term measuring volatility persistence, the authors are able to conclude that the coefficient of the spill-over effect is effectively larger in a period of high volatility, but that its effect dies out more quickly.

4.2.3 Dependence of extreme price deviations across markets

The first attempts to measure the dependence between extreme price deviations were indirect and based on the study of conditional correlation between asset returns.[34] Recent applications of "extreme value" theory (Embrechts et al., 1997) to financial markets have focused on the correlations between the tails of the distribution of returns in equity and exchange markets. Consistent with our concept of systemic risk, the intuition is that economic agents are more interested in estimating "extremal dependence" rather than statistical dependence for the whole distribution. Another methodological issue is that no correlation does not imply independence when returns are not normally distributed as is usually the case for asset prices with fat tails. Using daily data on equity and currency returns in G7 countries, Straetmans (1998) computes the conditional probability that two financial markets crash simultaneously (i.e. that they jointly exhibit excess returns above a certain threshold) given that at least one of the two markets experiences a large deviation. For currency markets, where a threshold of 5% is taken to measure large deviation, there is significant dependence in the tails. In addition, conditional crash probabilities seem to be much higher under free float than under a target zone. Regarding stock returns, apart from high linkages between the US and Canada as well as between France and Germany, market contagion seems to be very weak. One explanation of this result is that spillover effects are not si-

[33] Rodrigues (1996) who studies the determinants of the volatility of equity and bond returns, shows that observed macroeconomic variables explain a less significant part of the variability in the conditional variance of bonds in the US and Canada than in other countries.

[34] A few studies have investigated whether large deviations in equity returns affected the correlation across markets. Longin and Solnik (1995) conclude that the correlation between equity returns rises during periods of high volatility in the US market. Karolyi and Stulz (1996) provide evidence that large shocks to the overall market indices increase the return correlation. De Santis and Gerard (1997) find that during "bear" markets US equities are more correlated with the "World" portfolio than during other periods. Borio and Mc Cauley (1996) show that the cross correlation of bond yield volatility tended to increase during the periods of market turbulence in 1994.

multaneous, in particular due to the existence of different trading hours, so that the crash probability is downward biased.

4.2.4 Event studies of the determinants of currency crisis

With a view to measuring contagion in currency markets, Eichengreen et al. (1996) investigate an original panel of 20 industrial countries for the period 1959-1993. They estimate a binary probit model, where the explained variable is a quarterly index of exchange rate pressures. The authors test whether a crisis elsewhere in the world has any explanatory power. They provide evidence suggesting that, even controlling for political and economic fundamentals, a crisis elsewhere in the world increases the probability of a speculative attack by an economically and statistically significant amount of 8 percentage points. Although this constitutes one of the most consistent measures of contagion, one may wonder whether the quarterly horizon is really appropriate for testing contagion across currency markets and whether one should not use higher frequency data. Finally, Glick and Rose (1998) show that currency crises tend to be regional due to trades linkages, although as indicated above, this is not “pure” contagion, but reflects changes in fundamentals.

To conclude, the finance literature provides some evidence in favour of contagion in securities markets. However, due to the lack of a coherent theoretical model of transmission in securities markets, the literature fails to address the issue in a convincing way. Models of signal extraction have been suggested but the underlying definition of “news” remains unsatisfactory. In addition, evidence is generally provided for contagion within the same class of assets (e.g. equity or bonds markets) while the cross-asset dimension (i.e. spill-over effects from equity to bonds and currency markets) is ignored. Finally, contagion is usually investigated across industrial countries or some emerging countries, while the analysis of contagion between these two sets of countries remains to be done.

4.3 Evidence on contagion in payment systems

Published empirical studies about the importance of systemic risk in payment systems are very rare. To our knowledge, there are only three rigorous analyses of it, which all apply a simulation approach to examine the scope for contagion effects in large-value interbank net payment systems.

Humphrey (1986) simulates the potential effects of a major participant’s failure in the US CHIPS by “unwinding” all the transactions involving such a participant on two randomly selected business days in January 1983. When this event rendered another bank’s net debit position larger than its capital this bank’s transactions were also cancelled due to “insolvency,” and so on. This simulation suggested that a large share of all CHIPS participants could default (around 37 percent), with a high value of deleted payment messages. Also, Humphrey finds that the institutions affected by the initial failure were quite different between the two days examined.

In a very careful study, Angelini et al. (1996) apply a substantially generalised simulation exercise to the Italian net settlement system, considering end-of-day bilateral net balances for all 288 participants during January 1992. Basically, the authors generate frequency distributions of defaults, eliminated payments, etc. by letting each system member alone fail once per business day. From these simulations, the systemic risk in the Italian settlement system seems to be lower than that for CHIPS (on the basis of a comparison with Humphrey's (1986) results). Recorded chain defaults involved on average less than 1 per cent of system participants and never more than seven banks. The share of participants potentially triggering a systemic crisis amounted to 4 per cent of the total, and the "suspects" did not change a lot over time (many of them being foreign banks).[35]

McAndrews and Wasilyew (1995) undertake a similar study of systemic risk in net systems with unwinding provisions based entirely on Monte Carlo simulations. In each run the number of system participants and their bilateral payments are drawn from random distributions. Then the participant with the largest overall net debit position is made to fail on all its payment obligations. It turns out that system-wide repercussions of such a failure increase with the average size of bilateral payments, the number of system participants and with the degree of "connectedness" between the participants (as measured by the likelihood that any two banks exchange payments).

One advantage of this type of simulation approach to payment system risk is the quantitative measurement of the extent of contagion and its very practical implications, in particular when real payments data are considered. It can be objected that this approach does not allow for reactions of other payment system participants to initial failures and might therefore somewhat overstate contagion risk. Moreover, nowadays many net payment systems have reduced or removed potential unwinding of transactions for exactly the reason that they might enhance systemic risk. Most other evidence of systemic problems in payment (and settlement) systems seems to be of rather anecdotal nature, such as that described in the context of the 1987 stock market crash (see, for example, Brimmer, 1989, and Bernanke, 1990).

5 Conclusions

In this paper we discussed the various elements of systemic risk with a view to, first, developing a broad concept of this risk, which underlies the understanding of financial crises and which can be used as a baseline for financial and monetary policies to maintain stable financial systems. We argue that a comprehensive view of systemic risk has to integrate bank failure contagion with financial markets spill-over effects and payment and settlement risks. At the very basis of the concept (in the narrow sense) is the notion of contagion—often a strong form of

[35] The largest individual worsening of a net position was 18.5 times capital (as compared to 32.4 times capital in Humphrey (1986)).

external effect—working from one institution, market or system to the others. In a broad sense the concept also includes wide systematic shocks which by themselves adversely affect many institutions or markets at the same time. In this sense, systemic risk goes beyond the vulnerability of single banks in a fractional reserve system.

We reviewed the quantitative literature in the light of our concept of systemic risk and identified a number of important gaps, which appear worthwhile filling in future research. Rigorous theoretical models of interbank contagion only started to be developed, for example, regarding the interaction between asymmetric information and physical exposure—two crucial elements in potential propagations. Models linking banking and financial markets, as well as payment/settlement systems are simply nonexistent. The overwhelming part of econometric tests for bank contagion effects is limited to data for the United States. Event studies of bank equity returns, debt risk premia, deposit flows or physical exposures for European, Japanese or emerging market data are rare or virtually absent. Some more recent event studies of bank failures based on equity returns indicate that weak systemic events were in proportion to bank exposures, whereas there is some historical evidence of “pure” contagion during US banking crises.

Similarly, while there are numerous studies about the correlations of asset prices in general, the evidence about cases where one market crash causes another market crash is much more limited. Where those financial market contagion studies exist, they mainly look at contagion within the same asset class without considering potential contagion (or “flight to quality”) to other asset classes and they fail to achieve the difficult task of identifying “pure” contagion effects as opposed to the efficient adjustment of market prices. Finally, empirical analyses of contagion effects in payment and settlement systems seem to be limited to net payment systems, widely ignoring securities settlement systems or “network externalities” potentially resulting from “gridlock” situations in gross payment systems.

Overall, we feel that the recent financial crises (Nordic banking crises, Mexico, East Asia, Japanese banking crisis, Russia, Brazil, etc.) sufficiently underline the importance of understanding systemic risk as a tool in defining policies and encouraging market initiatives aiming at financial stability. It was not our objective to explain any of these crises in themselves. If we succeeded in convincing some researchers to try filling some of the gaps we identified regarding more fundamental issues, which could then help explain and prevent real crisis situations, then we have achieved our objective.

References

Aglietta, M., and P. Moutot, 1993, “Le risque de système et sa prévention,” *Cahiers Economiques et Monétaires* (Banque de France) 41, 21-53.

Aharony, J., and I. Swary, 1983, "Contagion Effects of Bank Failures: Evidence from Capital Markets," *Journal of Business* 56(3), 305-317.

Angelini, P., 1998, "An Analysis of Competitive Externalities in Gross Settlement Systems," *Journal of Banking and Finance* 22, 1-18.

Angelini, P., G. Maresca, and D. Russo, 1996, "Systemic Risk in the Netting System," *Journal of Banking and Finance* 20, 853-868.

Avery, C., and P. Zemsky, 1998, "Multidimensional Uncertainty and Herd Behaviour," *American Economic Review* 88(4), 724-748.

Banerjee, A.V., 1992, "A Simple Model of Herd Behaviour," *Quarterly Journal of Economics* 107(3), 797-811.

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

Bartholomew, P. F., and G.G. Kaufman, eds., 1995, "Banking, Financial Markets and Systemic Risk," *Research in Financial Services: Private and Public Policy*, 7, Greenwich, CN: JAI Press.

Bartholomew, P. F., and G.W. Whalen, 1995, "Fundamentals of Systemic Risk," in Banking, Financial Markets and Systemic Risk, *Research in Financial Services: Private and Public Policy*, 7, Greenwich, CN: JAI Press, 3-17.

Bernanke, B. S., 1990, "Clearing and Settlement during the Crash," *Review of Financial Studies* 3(1), 133-151.

Bernanke, B. S., and M. Gertler, 1990, "Financial Fragility and Economic Performance," *Quarterly Journal of Economics* 105(1), 87-114.

Berger, A. N., D. Hancock, and J.C. Marquardt, 1996, "A Framework for Analyzing Efficiency, Risks, Costs, and Innovations in the Payment System," *Journal of Money, Credit and Banking* 28(4), 696-732.

Bhattacharya, S., and C. Jacklin, 1988, "Distinguishing Panics and Information-Based Runs: Welfare and Policy Implications," *Journal of Political Economy* 96, 568-592.

Bikhchandani, S., D. Hirshleifer, and I. Welsh, 1992, "A Theory of Fads, Fashions, Customs and Cultural Changes as Informational Cascade," *Journal of Political Economy* 100, 992-1026.

Blanchard, O., and S. Fisher, 1989, *Lectures on Macroeconomics*. Cambridge, MA: MIT Press.

Bollerslev, T., R.Y. Chou, and K. F. Kroner, 1992, "ARCH Modelling in Finance—A Review of the Theory and Empirical Evidence," *Journal of Econometrics* 52, 5-59.

Borio, C. E. V., N. Kennedy, and S. D. Prowse, 1994, "Exploring Aggregate Asset Price Fluctuations Across Countries," BIS Economic Papers, no. 40, Basle: Bank for International Settlements, April.

Borio, C. E. V., and R. N. McCauley, 1996, "The Economics of Recent Bond Yield Volatility," BIS Economic Papers, no. 45, Basle: Bank for International Settlements, July.

Borio, C. E. V., and P. Van den Bergh, 1993, "The Nature and Management of Payment System Risks: An International Perspective," BIS Economic Papers, no. 36, Basle: Bank for International Settlements, February.

Brimmer, A. F., 1989, "Distinguished Lecture on Economics in Government: Central Banking and Systemic Risks in Capital Markets," *Journal of Economic Perspectives* 3, 3-16.

Buser, S. A., A. H. Chen, and E. J. Kane, 1981, "Federal Deposit Insurance, Regulatory Policy, and Optimal Bank Capital," *Journal of Finance* 35(1), 51-60.

Calomiris, C.W., and G. Gorton, 1991, "The Origins of Banking Panics: Models, Facts, and Bank Regulation," in G. Hubbard, ed., *Financial Markets and Financial Crises*. Chicago, IL: The University of Chicago Press.

Calomiris, C.W., and J. R. Mason, 1997, "Contagion and Bank Failures During the Great Depression: The June 1932 Chicago Banking Panic," *American Economic Review* 87(5), 863-883.

Carron, A. S., 1982, "Financial Crises: Recent Experience in U.S. and International Markets," *Brookings Papers on Economic Activity*, no. 2, 395-418.

Chari, V. V., and R. Jagannathan, 1988, "Banking Panics, Information, and Rational Expectations Equilibrium," *Journal of Finance* 43, 749-761.

Clark, J. A., and S. B. Perfect, 1996, "The Economic Effects of Client Losses on OTC Bank Derivative Dealers: Evidence from the Capital Markets," *Journal of Money, Credit, and Banking* 28(3), 527-545.

Committee on Payment and Settlement Systems, 1996, *Settlement Risk in Foreign Exchange Transactions* (*Allsopp Report*), Basle: Bank for International Settlements, March.

Cooperman, E. S., W. B. Lee, and G. A. Wolfe, 1992, "The 1985 Ohio Thrift Crisis, the FSLIC's Solvency, and Rate Contagion for Retail CDs," *Journal of Finance* 47(3), 919-941.

Cornell, B., and A. C. Shapiro, 1986, "The Reaction of Bank Stock Prices to the International Debt Crisis," *Journal of Banking and Finance* 10, 55-73.

Darby, M. R., 1994, "Over-the-Counter Derivatives and Systemic Risk to the

Global Financial System," NBER Working Paper, no. 4801, Cambridge, MA: National Bureau of Economic Research, July.

Davis, E. P., 1994, "Market Liquidity Risk," in D. Fair, ed., *The Competitiveness of Financial Institutions and Centres in Europe*. Dordrecht: Kluwer Academic Publishers.

Davis, E. P., 1995, *Debt, Financial Fragility and Systemic Risk*. Oxford: Clarendon Press, 2nd. ed.

De Bandt, O., 1995, "Competition among Financial Intermediaries and the Risk of Contagious Failures," *Notes d'Etudes et de Recherches*, no. 30, Paris: Banque de France.

De Bandt, O., 1996, "Risque de panique et liquidité interbancaire," *Revue d'Economie Politique* 106(4), 705-726.

De Long, J. B., A. Schleifer, L. H. Summers, and R. J. Waldmann, 1990, "Positive Feedback Investment Strategies and Destabilising Rational Speculation," *Journal of Finance* 45, 379-395.

De Santis, G., and B. Gerard, 1997, "International Asset Pricing and Portfolio Diversification with Time Varying Risk," *Journal of Finance* 52(5), 1881-1912.

Diamond, D. V., and P. Dybvig, 1983, "Bank Runs, Deposit Insurance, and Liquidity," *Journal of Political Economy* 91, 401-419.

Docking, D. S., M. Hirschey, and E. Jones, 1997, "Information and Contagion Effects of Bank Loan-Loss Reserve Announcements," *Journal of Financial Economics* 43(2), 219-240.

Dowd, K., 1992, "Models of Banking Instability: A Partial Review," *Journal of Economic Surveys* 6(2), 107-132.

Eichengreen, B., A. Rose, and C. Wyplosz, 1996, "Contagious Currency Crises: First Tests," *Scandinavian Journal of Economics* 98(4), 463-484.

Embrechts, P., C. Klüppelberg, and T. Mikosch, 1997, *Modelling Extremal Events*. Berlin: Springer-Verlag.

Engle, R., T. Ito, and W.-L. Lin, 1990, "Meteor Shower or Heat Wave? Heteroskdastic Intra-daily Volatility in the Foreign Exchange Market," *Econometrica* 58(3), 525-542.

Federal Reserve Bank of Kansas City, 1998, "Maintaining Financial Stability in a Global Economy," *Proceedings of the 1997 Jackson Hole Symposium*, August 28-30, Jackson Hole, WY: Kansas City Fed.

Fischer, I., 1933, "The Debt Deflation Theory of Great Depressions," *Econometrica* 1, 337-357.

Flannery, M., 1996, "Financial Crises, Payment System Problems, and Discount Window Lending," *Journal of Money, Credit and Banking* 28(4), 804-824.

Folkerts-Landau, D., 1991, "Systemic Financial Risk in Payment Systems, in: Determinants and Systemic Consequences of International Capital Flows," IMF Occasional Paper, no. 77, Washington, DC: IMF, March, 46-67.

Folkerts-Landau, D., P. Garber, and D. Schoenmaker, 1996, "The Reform of Wholesale Payment Systems and its Impact on Financial Markets," Group of Thirty Occasional Paper, no. 21, Washington, DC: Group of Thirty.

Freixas, X., and B. Parigi, 1998, "Contagion and Efficiency in Gross and Net Interbank Payment Systems," *Journal of Financial Intermediation* 7(1), 3-31.

Freixas, X., and J.-C. Rochet, 1997, *Microeconomics of Banking*. Cambridge, MA: MIT Press.

Gay, G. D., S. G. Timme, and K. Yung, 1991, "Bank Failure and Contagion Effects: Evidence from Hong Kong," *Journal of Financial Services Research* 14(2), 153-165.

Genotte, G., and H. Leland, 1990, "Market, Liquidity and Crashes," *American Economic Review* 80(5), 999-1021.

Gerlach, S, and F. Smets, 1995, "Contagious Speculative Attacks," *European Journal of Political Economy* 11, 5-63.

Giddy, I. H., 1981, "Risk and Return in the Eurocurrency Interbank Market," *Greek Economic Review*, 158-186.

Glick, R., and A. R. Rose, 1998, "Contagion and Trade: Why Are Currency Crisis Regional," CEPR Discussion Paper, no 1947.

Goldstein, M., 1995, "International Financial Markets and Systemic Risk," mimeo, Washington, DC: Institute of International Economics, December.

Goodhart, C. A. E., P. Hartmann, D.T. Llewellyn, L. Rojas-Suarez, and S. R. Weisbrod, 1998, "Financial Regulation: Why, How and Where Now?," Monograph prepared for the Bank of England Central Bank Governors' Symposium 1997, London: Routledge.

Grossman, R., 1993, "The Macroeconomic Consequences of Bank Failures under the National Banking System," *Explorations in Economic History* 30, 294-320.

Grossman, S. J., 1988, "An Analysis of the Implications for Stock and Future Price Volatility of Program Trading and Dynamic Hedging Strategies," *Journal of Business* 61(3), 275-298.

Group of Thirty, 1993, *Derivatives: Practices and Principles*. New York, NY: Group of Thirty.

Group of Thirty, 1997, *Global Institutions, National Supervision and Systemic Risk*. Washington, DC: G 30.

Guesnerie, R., and J. C. Rochet, 1993, "(De)stabilizing Speculation on Futures Markets," *European Economic Review* 37, 1043-1063.

Gurley, J., and E. Shaw, 1960, *Banking in a Theory of Finance*. Washington, DC: Brookings Institution.

Guttentag, J., and R. Herring, 1984, "Credit Rationing and Financial Disorder," *Journal of Finance* 39(5), 1359-1382.

Hasan, I., and G. Dwyer, 1994, "Bank Runs in the Free Banking Period," *Journal of Money, Credit and Banking* 26, 271-288.

Hellwig, M., 1998, "Systemische Risiken im Finanzsektor," *Zeitschrift für Wirtschafts- und Sozialwisenschaften, Beiheft* 7, 123-151.

Humphrey, D. B., 1986, "Payments Finality and Risk of Settlement Failure," in Anthony Saunders and Lawrence J. White, eds., *Technology and the Regulation of Financial Markets: Securities, Futures, and Banking*. Lexington, MA: Lexington Books, 97-120.

Humphrey, D. B., 1989, "Market Responses to Pricing Fedwire Daylight Overdrafts," Federal Reserve Bank of Richmond, *Economic Review* 75, 23-34.

International Organization of Securities Commissions, 1998, *Risk Management and Control Guidance for Securities Firms and their Supervisors*, Montreal: IOSCO, March.

Jayanti, S. V., and A. M. Whyte, 1996, "Global Contagion Effects of the Continental Illinois Failure," *Journal of International Financial Markets, Institutions and Money* 6(1), 87-99.

Jeanne, O., 1997, "Are Currency Crises Self-Filling? A Test," *Journal of International Economics* 43, 263-286.

Kane, E. J., 1985, *The Gathering Crisis in Federal Deposit Insurance*. Cambridge, MA: MIT Press.

Kane, E. J., 1989, *The S&L Mess: How Did it Happen?* Washington, DC: Urban Institute Press.

Kanas, A, 1998, "Volatility Spillovers across Equity Markets: European Evidence," *Applied Financial Economics* 8, 245-256.

Karafiath, I., R. Mynatt, and K. L. Smith, 1991, "The Brazilian Default Announcement and the Contagion Effect Hypothesis," *Journal of Banking and Finance* 15, 699-716.

Kaufman, G. G., 1988, "Bank Runs: Causes, Benefits and Costs," *Cato Journal* 7, 559-587.

Kaufman, G. G., 1994, "Bank Contagion: A Review of the Theory and Evidence," *Journal of Financial Services Research* 7, 123-150.

Kindleberger, C., 1978, *Manias, Panics and Crashes. A History of Financial Crises*. London: Macmillan.

King, M., and S. Wadhwani, 1990, "Transmission of Volatility between Stock Markets," *Review of Financial Studies* 3(1), 5-35.

King, M., E. Sentana, and S. Wadhwani, 1994, "Volatility and Linkages between National Stock Markets," *Econometrica* 62(4), 901-933.

Kiyotaki, N., and J. Moore, 1997, "Credit Cycles," Financial Markets Group Discussion Paper, no. 205, London: London School of Economics.

Kobayakawa, S., 1997, "The Comparative Analysis of Settlement Systems," CEPR Discussion Paper, no. 1667, London: Centre for Economic Policy Research, July.

Koutmos, G., and G. G. Booth, 1995, "Asymmetric Volatility Transmission in International Stock Markets," *Journal of International Money and Finance* 14(6), 747-762.

Krugman, P., 1989, "A Model of Balance of Payment Crises," *Journal of Money, Credit and Banking* 11, 311-325.

Krugman, P., 1998, "Boom, Bubble, Crash: Theoretical Notes on the Asian Crisis," mimeo, Massachusetts Institute of Technology, January.

Lin, W.-L., R. F. Engle, and T. Ito, 1994, "Do Bulls and Bears Move across Borders? International Transmission of Stock Returns and Volatility," *Review of Financial Studies* 7(3), 507-538.

Lin, W.-L., and T. Ito, 1995, "Price Volatility and Volume Spillovers between the Tokyo and New York Stock Markets," in J. Frankel, ed., *The Internationalisation of Equity Markets*. Chicago University Press, 309-330.

Lindgren, C.-J., G. Garcia, and M. I. Saal, 1996, "Bank Soundness and Macroeconomic Policy," Washington, DC: International Monetary Fund.

Longin, F., and B. Solnik, 1995, "Is the Correlation in International Equity Returns Constant: 1960-1990," *Journal of International Money and Finance* 14(1), 3-26.

Loretan, M., 1996, "Systemic Risk in a Model with a Stylized Banking System," *Proceedings of the First Joint Central Bank Conference on Risk Measurement and Systemic Risk*, Washington: Board of Governors of the Federal Reserve System.

Madura, J., A. M. Whyte, and W. R. McDaniel 1991, "Reaction of British Bank

Share Prices to Citicorp's announced $3 Billion Increase in Loan-Loss Reserves," *Journal Banking and Finance* 15, 151-163.

Malliaris, A. G., and J. L. Urrutia, 1992, "The International Crash of October 1987: Causality Tests," *Journal of Financial and Quantitative Analysis* 27(3).

Masson, P., 1998, "Contagion: Monsoonal Effects, Spillovers, and Jumps between Multiple Equilibria," forthcoming as IMF Working Paper.

McAndrews, J. J., and W. Roberds, 1995, "Banks, Payments, and Coordination," *Journal of Financial Intermediation* 4, 305-327.

McAndrews, J. J., and G. Wasilyew, 1995, "Simulations of Failure in a Payment System," Working Paper, no. 95-19, Philadelphia, PA: Federal Reserve Bank of Atlanta, June.

Merton, R. C., 1976, "An Analytical Derivation of the Cost of Deposit Insurance and Loan Guarantees: An Application of Modern Option Pricing Theory," *Journal of Banking and Finance* 1(1), 3-11.

Michael, I., 1998, "Financial Interlinkages and Systemic Risk," *Financial Stability Review* 4, 26-33.

Minsky, H. P., 1977, "A Theory of Systemic Fragility," in E. I. Altman and A.W. Sametz, eds., *Financial Crises*. New York: Wiley.

Minsky, H. P., 1982, "The Financial-Instability Hypothesis: Capitalist Processes and the Behavior of the Economy," in C. P. Kindleberger and J.-P. Laffargue, eds., *Financial Crises: Theory, History, and Policy*. Cambridge, UK: Cambridge University Press, 13-39.

Mishkin, F. S., 1991, "Asymmetric Information and Financial Crises: A Historical Perspective," in G. Hubbard, ed., *Financial Markets and Financial Crises*. Chicago, IL: The University of Chicago Press.

Mishkin, F. S., 1997, "The Causes and Propagation of Financial Instability: Lessons for Policy Makers," *Maintaining Financial Stability in a Global Economy*. Jackson Hole, WY: Federal Reserve Bank of Kansas City.

Morgenstern, O., 1959, *International Financial Transactions and the Business Cycle*. Princeton, NJ: Princeton University Press, National Bureau Of Economic Research Studies in Business Cycles.

Musgrave, R. A., and P. B. Musgrave, 1973, *Public Finance in Theory and Practice*, 2nd. edition, New York, NY: McGraw-Hill.

Musumeci, J. J., and J. F. Sinkey, 1990, "The International Debt Crisis, Investor Contagion, and Bank Security Returns in 1987: The Brazilian Experience," *Journal of Money, Credit and Banking* 22(2), 210-233.

Park, S., 1991, "Bank Failure Contagion in Historical Perspective," *Journal of*

Monetary Economics 28, 271-286.

Paroush, J., 1988, “The Domino Effect and the Supervision of the Banking System,” *Journal of Finance* 43(5), 1207-1218.

Peavy, J. W., and G. H. Hempel, 1988, “The Penn Square Bank Failure: Effect on Commercial Bank Security Returns—A Note,” *Journal of Banking and Finance* 12, 141-150.

Peek, J., and E. S. Rosengren, 1997, “The International Transmission of Financial Shocks: The Case of Japan,” *American Economic Review* 87(4), 495-505.

Portes, R., and A. K. Swoboda, eds., 1987, *Threats to International Financial Stability*. New York, NY: Cambridge University Press.

Postlewaite, A., and X. Vives, 1987, “Bank Runs as an Equilibrium Phenomenon,” *Journal of Political Economy* 95, 485-491.

Rochet, J.-C., and J. Tirole, 1996a, “Interbank Lending and Systemic Risk,” *Journal of Money, Credit and Banking* 28(4), 733-762.

Rochet, J.-C., and J. Tirole, 1996b, “Controlling Risk in Payment Systems,” *Journal of Money, Credit and Banking* 28(4), 832-862.

Rossi, M., 1997, *Payment Systems in the Financial Markets: Real-time Gross Settlement Systems and the Provision of Intraday Liquidity*. New York: St. Martin Press.

Saunders, A., 1986, “An Examination of the Contagion Effect in the International Loan Market,” *Studies in Banking and Finance* 3, 219-247.

Saunders, A., 1987, “The Inter-bank Market, Contagion Effects and International Financial Crises,” in R. Portes and A. K. Swoboda, eds., *Threats to International Financial Stability*. New York, NY: Cambridge University Press, 196-232.

Saunders, A., and B. Wilson, 1996, “Contagious Bank Runs: Evidence from the 1929-33 Period,” mimeo, New York, NY: New York University, Stern School of Business, January.

Schoenmaker, D., 1995, “A Comparison of Alternative Interbank Settlement Systems,” L.S.E. Financial Markets Group Discussion Paper, no. 204, London: London School of Economics.

Schoenmaker, D., 1996a, “Contagion Risk in Banking,” L.S.E. Financial Markets Group Discussion Paper, no. 239, London: London School of Economics, March.

Schoenmaker, D., 1996b, “Central Banking and Financial Stability: The Central Bank’s Role in Banking Supervision and Payment Systems,” unpublished Ph.D. thesis, London: London School of Economics and Political Science, May.

Scholes, M., 1996, "Global Financial Markets, Derivative Securities and Systemic Risk," *Journal of Risk and Uncertainty* 12, 2711-286.

Sharpe, W. F., 1978, "Bank Capital Adequacy, Deposit Insurance and Security Value," *Journal of Financial and Quantitative Analysis* 13, 701-718.

Shiller, R., 1995, "Conversation, Information and Herd Behavior," *American Economic Review Papers and Proceedings* 85, 181-185

Smirlock, M., and H. Kaufold, 1987, "Bank Foreign Lending, Mandatory Disclosure Rules, and the Reaction of Bank Stock Prices to the Mexican Debt Crisis," *Journal of Business* 60(3), 347-364.

Smith, B. D., 1991, "Bank Panics, Suspension and Geography: Some Notes on the Contagion of Fear in Banking," *Economic Inquiry*, 230-248.

Straetmans, S. 1998, "Extreme Financial Returns and their Comovements," Ph.D. dissertation, Erasmus University, Tinbergen Institute Research Series, 181.

Stiglitz, J. E., 1993, "The Role of the State in Financial Markets," paper presented to the Annual Bank Conference on Development Economics, Washington, DC: World Bank.

Summers, B. J., ed., 1994, *The Payment System: Design, Management and Supervision*. Washington, DC: International Monetary Fund.

Susmel, R., and R. F. Engle, 1994, "Hourly Volatility Spillovers between International Equity Markets," *Journal of International Money and Finance* 13, 3-25.

Swary, I., 1986, "Stock Market Reaction to Regulatory Action in the Continental Illinois Crisis," *Journal of Business* 59(3), 451-473.

Temzelides, T., 1997, "Evolution, Co-ordination and Banking Panics," *Journal of Monetary Economics* 40, 163-183.

Wall, L. D., and D. R. Peterson, 1990, "The Effect of Continental Illinois' Failure on the Financial Performance of other Banks," *Journal of Monetary Economics* 26, 77-99.

Working Party on Financial Stability in Emerging Markets, 1997, *Financial Stability in Emerging Markets*. Basle: Bank for International Settlements, Secretariat of the Group of Ten, April.

Yamazaki, A., 1996, "Foreign Exchange Netting and Systemic Risk," IMES Discussion Paper Series, no. 96-E-23, Tokyo: Bank of Japan, June.