Developments in a cross-border bank exposure “network”*

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Abstract

In this paper we explore the developments in cross-border bank exposures using the BIS international banking statistics. To this end, we treat the web of cross-border bank exposures as a “network”, investigate the characteristics of the network topology and compute various statistical measures for that topology. We find that the network of cross-border bank exposures has become more tightly connected over time. It now has higher connectivity, a shorter average path length, a higher average degree and a higher clustering coefficient than in the past. In particular, we observe that this tendency has never been hampered by any disturbances or crises in international financial markets (such as the East Asian currency crisis in 1997 or the LTCM near-default event in 1998). We see both costs and benefits from these developments in cross-border bank exposures. On the one hand, systemic risk in international financial markets is likely to increase because of the more direct and more widely spreading spillover effects of a crisis in one country once it occurs. On the other hand, the efficiency of international financial markets is expected to further improve in terms of capital and risk allocation.

1. Introduction

In an overview of developments in international financial markets and global financial crises, we generally focus on the time series movements of prices, transaction volumes and outstanding amounts, eg the amounts of international capital or credit flows, foreign exchange rates and sovereign bond credit spreads. This line of research helps us understand the structure and functioning of international financial markets more thoroughly (see, for example, Bisignano *et al* (2000), Glick *et al* (2001)).

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In this paper we employ a new approach, network analysis, to understand the developments in international financial markets. We explore the changes in cross-border bank exposures by treating the web of cross-border bank exposures as a network. We first compute various statistical measures for the network topology using the BIS international banking statistics. We then examine the changes in such statistical measures for the network topology over time, thereby attempting to gain some new insights into the developments in international linkage via bank exposures.[1]

To our knowledge, this paper is the first to apply the concepts of network topology in analyses of the changes in international financial markets. A similar approach for network analysis is applied in studies on other financial architectures such as interbank payment flows, for example Inaoka *et al* (2004), Soramaki *et al* (2006), Bank of Japan (2006) and Soejima (2007).

This paper is organised as follows. Section 2 briefly introduces some key elements in network analysis and presents cases in which international financial markets can be understood using BIS international banking statistics, with due consideration of the limitations in available data. Section 3 introduces several topological statistical measures to characterise a network, then applies these measures to the analysis of the cross-border exposure network of banks. Section 4 first investigates the relationship between the topology characteristics and the total gross cross-border bank exposures. Then, it assesses the influence of crises on the topology characteristics. It also discusses some conjectures as to why the cross-border bank exposure network becomes tightly connected and the implications that those developments hold for international financial stability. Section 5 offers a concluding discussion.

2. BIS international banking statistics for network analysis

In this section we introduce some key concepts in order to sketch out a network. The concepts explained are specific to the analysis in this paper. The latter part of this section describes cross-border bank exposures as a network. This will prepare us to characterise the network by some of the topological coefficients often used in papers on network analysis.

2.1 Networks

A *network* consists of *nodes* and the connections between them, *link*s. The number of nodes *n* defines the size of a network. Links can be either *undirected* or *directed*. If the direction of a link from one node to another is known and meaningful, it is often best to analyse the network in question as a network with directed links.

A sequence of nodes in which each node is linked to the next is defined as a *walk*, and a walk is called a *path* if all links are directed. The *length of a path* between two nodes is measured by the number of links between the two nodes. These terms actually differ slightly in papers and books, but the concepts here are equivalent (de Nooy *et al* (2005), Batagelj (2006), Soramaki *et al* (2006)).

[1] Bank of Japan (2007) includes a brief summary of this paper.

2.2 BIS international banking statistics

The BIS international banking statistics cover individual countries and the amounts outstanding of cross-border bank exposures between one country and another country. The analysis in this paper uses consolidated banking statistics on an immediate borrower basis in the international banking statistics from the international financial statistics published by the BIS. The central bank of a country collects the data on foreign claims of reporting banks in the country and reports it to the BIS. The statistics used in this paper give us data on risk exposures to individual countries by the nationalities of the reporting banks.

Following the definitions in the literature on network analysis, we define a country in the database as a *node* and an exposure from one reporting country to another country as a *link*. A link in these statistics is treated as a *directed* link, and we define a *path* and *length of a path* according to the definitions in the last subsection.

In this regard, we should note the difference between reporting and non-reporting countries. Reporting countries are required to report the credit exposures of their domestic banks to the other countries in the country list. The amounts outstanding of credit exposures from each reporting country to the other countries at the end of each quarter are available.[2] The amounts outstanding of credit exposures from non-reporting countries to the other countries are not available. Thus, reporting countries have both inward and outward links, while non-reporting countries have only inward links. We refer to inward and outward links as directed-in and directed-out links, respectively.

Considering some significant discontinuities in the data, we make some adjustments to the BIS international banking statistics.

First, we treat just 16 out of the current 30 countries as reporting countries: Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, Spain, Sweden, Switzerland, the United Kingdom and the United States. We include Finland and Spain as reporting countries; though they did not actually become reporting countries until the second half of 1985, their inclusion does not seem to cause any noticeable discontinuity in the time series of any of the topological statistical measures. We, however, exclude Australia, Brazil, Chile, Greece, Mexico, Panama, Portugal and Taiwan, which became reporting countries after 1998. We also exclude Norway because its data are available only up to the first quarter of 2004. In addition, we need to exclude Hong Kong SAR, India, Luxembourg, Singapore and Turkey from the reporting countries, because the data on their exposures to other countries are not available in the consolidated banking statistics on an immediate borrower basis.[3]

Second, we fix the number of sample countries to be 215 throughout the sample period, to mitigate the impact of changes in the number of sample countries. The largest change in the number of sample countries occurs when the Soviet Union collapsed in 1991 and was divided into 15 countries. This discontinuity seems to mislead us in understanding the developments in the cross-border bank exposure network over time.

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[2] The credit exposure of one reporting country to another reporting country was not recorded before the second half of 1998. Thus, we detect a sudden increase in the total gross amounts outstanding in the first half of 1999, when the reporting countries started reporting their credit exposures to other reporting countries.

[3] This seems to be the case from the authors' investigations of the BIS website. Even if we included those countries as reporting countries, we believe, the findings in this paper on trends and changes in the topological characteristics of the cross-border bank exposure network would not be affected to a considerable degree.

Third, we exclude the period between the second half of 1983 and the first half of 1985 from our analysis. The reason is that data for the period show a high volatility because, presumably, data collection operations did not work well at first in the sample countries.

Finally, we interpolate missing data using data from the subsequent period. The frequency of the data changes from semi-annual to quarterly from the first quarter of 2000. Thus, the data for the first and third quarters up to the end of 1999 are retroactively unavailable.

2.3 Preliminary checking by visualisation

As a first step, the cross-border bank exposure network is visualised in Figures 1 and 2. We see that the network is complex in spite of the extremely low number of nodes in comparison with other networks in preceding papers such as those on interbank payment flows.

Figures 1 and 2 are different visualisations of the same network, based on the data for the fourth quarter of 2006: developed countries are in the top-left area in Figure 1 and the reporting countries are in the top-left area in Figure 2. The nodes in red (or dark shading) are reporting countries with directed-in and directed-out links. The nodes in sky blue (or light shading) are non-reporting countries with only directed-in links. The relative scale of each node represents its weight in the total gross exposures in the network, and the arrows indicate the direction of exposures. The large nodes are, in order of size, the United States, the United Kingdom, France, Germany, Italy and the Cayman Islands.

Figure 1
Cross-border bank exposure network (1)

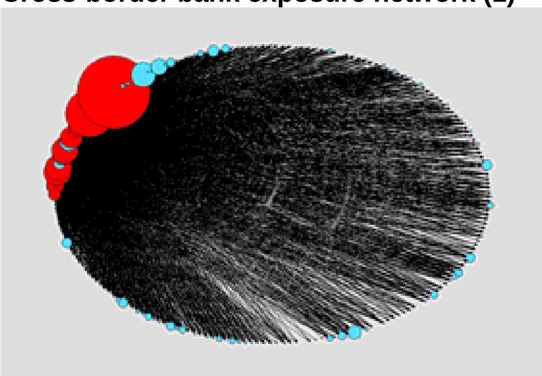
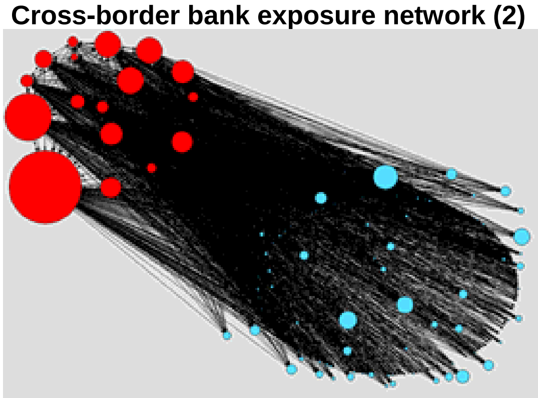


Figure 2
Cross-border bank exposure network (2)



If we are interested in the changes of the network over time, it may be effective to draw the figures for every period, compare them period by period, and extract tendencies and changes. Readers are likely to agree, however, that this visualisation approach is not very fruitful, especially if we want to understand changes over a long time horizon such as that in this paper. Alternatively, we can calculate some commonly used statistical measures in the literature on network analysis and try to understand the trends and changes in the cross-border bank exposure network from the standpoint of the topological characteristics. This is what we attempt in the sections below.

3. Trends and changes in the topological characteristics of the cross-border bank exposure network

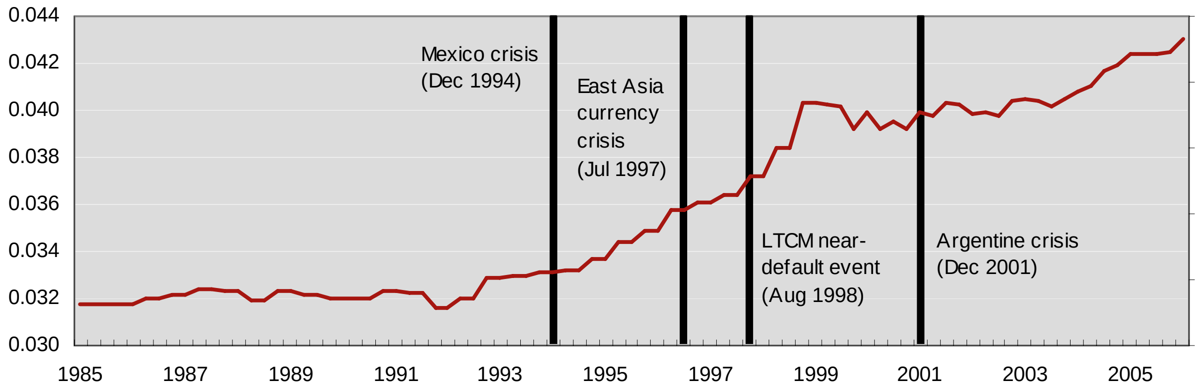
In this section we describe the statistical measures used to elucidate the topological characteristics of the cross-border bank exposure network.[4]

3.1 Connectivity: likelihood of connection between countries

In this paper, the number of sample countries (ie, nodes, *n*) is 215. The number of links *m* is determined as follows in our analysis. When gross credit exposure from one country (node) to another is recorded as neither zero nor "not available", we count it as one link. The number of such links is expressed as *m*.

The number of links relative to the number of "possible" links is defined as the *connectivity* of a network. In other words, the connectivity p is the unconditional probability that two nodes share a link. For a directed network like the one in our analysis with the BIS statistics, the connectivity is calculated as $p = \frac{m}{n(n-1)}$.

Figure 3
Connectivity



The time series of connectivity is shown in Figure 3, which demonstrates two points. First, the connectivity follows an increasing trend, implying that the likelihood of the connection of two countries via bank exposures keeps increasing throughout almost the entire sample period. Second, in retrospect, the increasing trend is not hampered severely by well-known disturbances in the international financial markets such as the Mexican crisis, the East Asian crisis, the LTCM near-default event and the Argentine crisis. Once connectivity rises it is not easily reversed. This is equivalent to the claim that disconnection is a rarity once two countries are connected.

The connectivity in the fourth quarter of 2006 is 0.043. This means that only 4.3% of the potential links (215 times 214 = 46,010) are used. We take care, however, in interpreting the

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[4] Papers on network analysis often compare a topological statistical measure of a network in question with a certain benchmark, such as a *random network* (Soramaki *et al* (2006)). Due to the unavailability of directed-out links from non-reporting countries in the BIS statistics, however, it is not useful for us to take this approach in our analysis. Instead we focus on changes in the topological statistical measures over time to discuss the evolution of the characteristics of the cross-border bank exposure network.

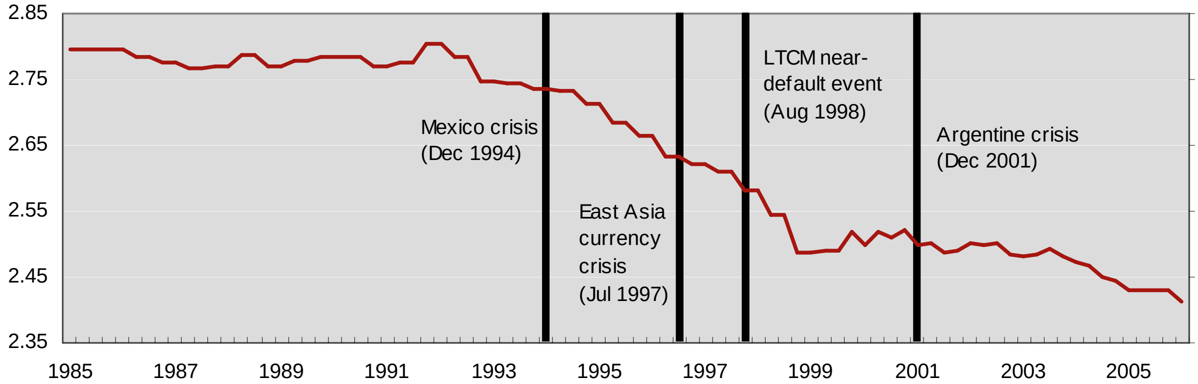
small value of this statistic. It would be higher if the potential links directed from one non-reporting country to another country were reported in the BIS statistics.[5]

3.2 Average path length: distance between nodes

The distance from node i to node j, d_{ij}, can be measured by the length of the shortest path between the two nodes. If node i has a link to node j, then $d_{ij} = 1$. The average distance from node i to other nodes, commonly referred to as the *average path length of node i*, is $\ell_i = \frac{1}{n-1}\sum_{j \neq i} d_{ij}$. The average of the average path length of each node in a network (hereafter, the *average path length*) shows how many steps on average are required to move from one node to another in a network.

Figure 4 shows the time series of the average path length in the cross-border bank exposure network. The average length declines rapidly after the mid-1990s, suggesting that the network becomes increasingly compact in the second half of the 1990s.[6]

Figure 4
Average path length



3.3 Degree: multilateral connections

In a directed network, we can differentiate the number of links originating from a node from the number of links terminating at a node. The first is referred to as the *out-degree* (m_i^{out}) of a node and the second is referred to as the *in-degree* of a node (m_i^{in}). The *average degree* of a

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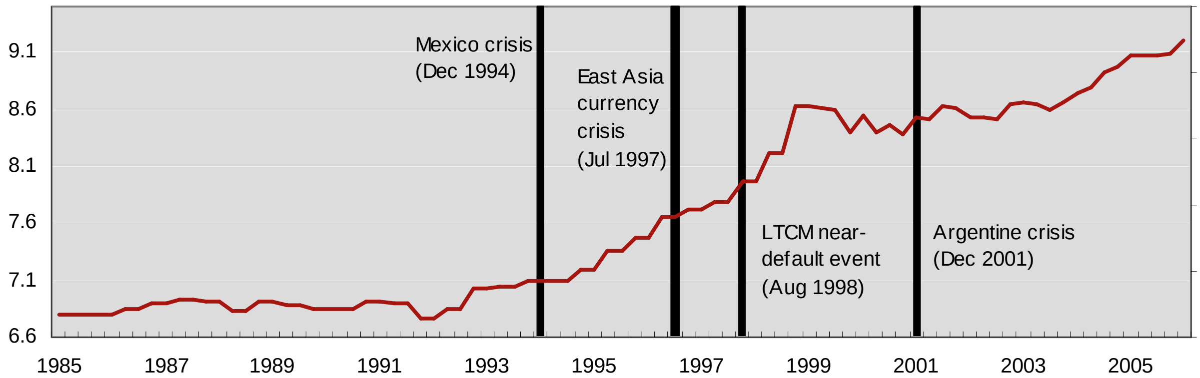
5 A statistical measure closely related with connectivity is *reciprocity*. Reciprocity is the fraction of links in a network which have links in the opposite direction. A reciprocal link can be observed only between the reporting countries in the BIS statistics. Thus, we do not use this measure to characterise or compare the cross-border bank exposure network across time in this paper.

6 We use an approximation to get the average path length. We use a formula $\langle \ell \rangle \approx \frac{\ln(n)}{\ln(p \cdot n)}$ for a random network. This approximation is nonsense if we are interested in comparison between a network in question and a random network as its benchmark; however, we believe that the approximation works without any significant problems as a means to gain an overview of trends and changes in the characteristics of the cross-border bank exposure network.

node in a network is defined as the number of links divided by the number of nodes. In a network, the following holds: $\langle m\rangle = \frac{1}{n}\sum m_i^{out} = \frac{1}{n}\sum m_i^{in} = \frac{m}{n}$.

Figure 5 shows the time series of the average degree in the network. The shape of the line is almost identical to the shape for connectivity in Figure 3. This reflects a feature of the BIS statistics and our adjustment to it; we fix the number of nodes, hence connectivity is determined by the number of links directed from reporting countries, that is, the out-degree of those countries.

Figure 5
Average degree



Another way to depict basically the same phenomenon is a comparison between histograms of in-degree per country at two different points in time. Figures 6 and 7 are the histograms of in-degrees in the second quarter of 1999 and the fourth quarter of 2006, respectively. For comparison we show the histogram for the second quarter of 1999, the year when the BIS statistics started to include bank exposures between reporting countries. It is obvious that the histogram for the fourth quarter of 2006 has more countries in a higher range of in-degrees than the fourth quarter of 1999, and the average and the median are both higher in the former than in the latter.

Figure 6
Histogram of in-degrees in 1992 Q2

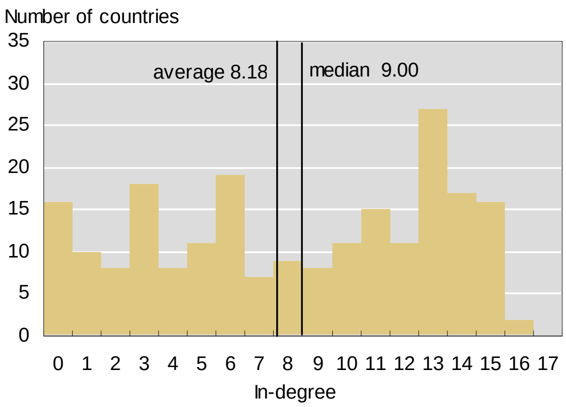
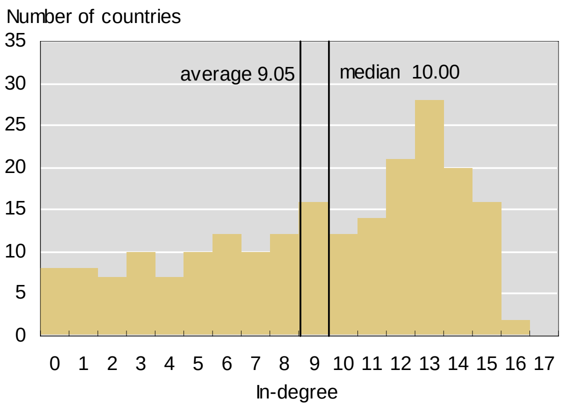


Figure 7
Histogram of in-degrees in 2006 Q4

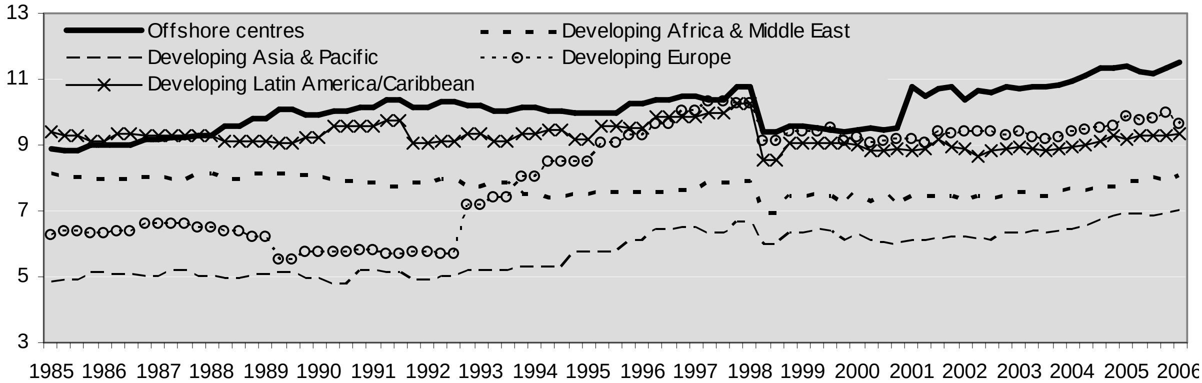


It is illuminating to compare the numbers of directed-out links from reporting countries in two time periods. In the second quarter of 1999, 16 reporting countries had 240 directed-out links to reporting countries. In the fourth quarter of 2006, the number is almost the same, 239. Given that there are 16 reporting countries in our analysis and 16 times 15 = 240, the network among the reporting counties has been almost a *complete network*: all the reporting countries are linked with each other. In contrast, the number of directed-out links from reporting to non-reporting countries increased drastically, from 1,527 to 1,741. Hence, we know that reporting countries are connected directly with more non-reporting countries in the network than before.

Next, we focus on the changes in the regional average degree over time. In particular, we pay due attention to the contribution of each developing region defined by the BIS to the changes in the average degree of the whole network. Their changes virtually determine the trajectory of the average degree of whole network.[7]

Figure 8 shows the average degree of each region: Offshore Centres, Developing Asia and Pacific, Developing Latin America and Caribbean, Developing Africa and Middle East, and Developing Europe. The relative size of an increase in each regional average degree in a period can be interpreted as the extent of its contribution to an increase in the average degree of the whole network, because by definition the average of the regional average degrees is the average degree of the whole network.[8]

Figure 8
Average degree by region



The figure shows that each region contributes to the increase in the average degree of the whole network in the second half of the 1990s, before the LTCM near-default event, to a different extent. Developing Europe most significantly contributes to the average of the whole network, and the increase in the average degree of Developing Asia and Pacific looks to be the second largest contributor. The other three regions also have an increase in average degree, but it is smaller than that in Developing Europe and Developing Asia and Pacific in the same period. In contrast, in the recent period observing an increase in the average degree of whole network after 2003, roughly speaking, all the regions increase their average degree to almost the same extent. That is, the development of the cross-border bank exposure network in the recent period goes on evenly, in terms of average degree, in all parts of the world.

An increase in the sum of the out-degree of each node in the network causes higher connectivity, a shorter average path length and the higher clustering coefficient described below. Thus, it is worth determining which regions contribute to the increase in number of directed-out links in the network. Focusing on the recent phenomenon, in Table 1 we list countries in order of increase in out-degree from the fourth quarter of 2003 to the fourth

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[7] The only exception is the second quarter of 1999, when the banks in the reporting countries started to report their credit exposures to reporting countries. The trajectory of the average degree of the whole network is affected by this and shows a relatively large increase. We have checked the trajectories of average degree of Developed Europe and Developed Others according to the definition in the BIS statistics. They are virtually flat over the whole sample period, except for a large increase in the second quarter of 1999.

[8] The same caveat in footnote 7 applies here.

quarter of 2006. It is obvious that the significant contributors are banks in developed European countries.

Table 1

Changes in out-degree between 2003 Q4 and 2006 Q4

Number	Country	Degree
1	Sweden	27
2	Austria	22
3	United Kingdom	21
4	Switzerland	15
5	Finland	12
6	Netherlands	9
7	Spain	8
8	Canada	6
9	Japan	5
10	United States	3

With regard to the number of links directed out of each reporting country, Table 2 ranks the out-degree of nodes. France is the biggest contributor, and several other European countries are ranked in high positions. Table 3 compares this ranking in terms of total gross outstanding amounts of cross-border bank exposures. The top contributors to the number of directed-out links tend to be the top contributors to the total gross outstanding amounts of cross-border bank exposures. More connected nodes tend to play a bigger role in transferring cross-border risk exposures in terms of amounts outstanding. Japan may appear to be an exception, but it is actually in the 12th position (with an out-degree of 105) in the ranking of out-degree contributors.

Table 2

Top 10 out-degrees in 2006 Q4

No	Country	Degree
1	France	180
2	United Kingdom	178
3	Germany	173
3	Netherlands	173
3	Switzerland	173
6	Belgium	158
7	Spain	151
8	Austria	144
9	United States	144
10	Sweden	134

Table 3

Top 10 exposures in 2006 Q4

No	Country	Exposures[1]
1	Germany	3,527,298
2	United Kingdom	3,087,535
3	France	2,610,978
4	Switzerland	2,456,430
5	Netherlands	2,084,448
6	Japan	1,854,216
7	United States	1,332,218
8	Belgium	1,108,955
9	Spain	986,840
10	Sweden	602,538

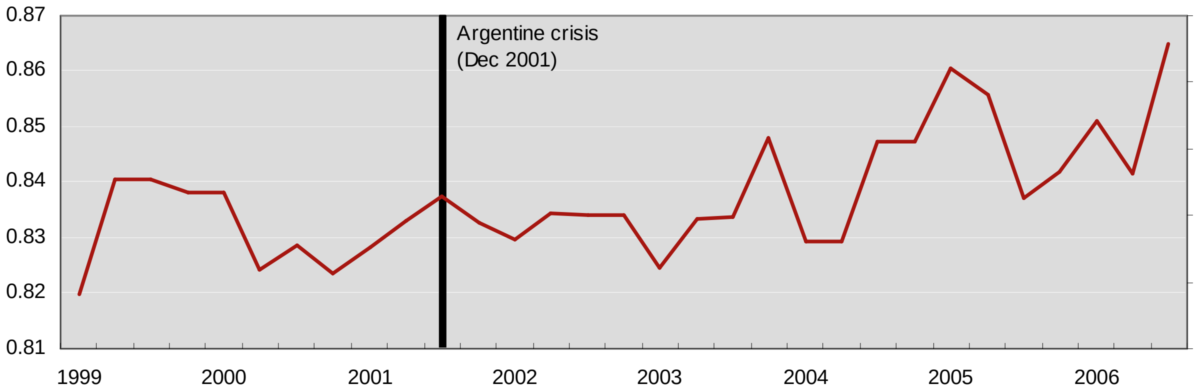
[1] In millions of US dollars.

3.4. Clustering coefficient: likelihood of connection between neighbours

The *clustering coefficient* is another commonly used topological statistical measure. It shows the probability that two neighbours with a direct link to a node are linked together. The clustering coefficient of node i is calculated as the ratio of the actual number of directed links between the *neighbours* of node i ($m_{nn,i}$) over the number of potential links among them. *Neighbours* of a node i are defined as nodes which are directly linked to node i. Then, when the number of the neighbours of node i is m_i, the number of potential links among the neighbours of node i is $m_i(m_i - 1)$. Therefore, we can calculate the clustering coefficient of node i as $C_i = \frac{m_{nn,i}}{m_i(m_i - 1)}$. We can also define the clustering coefficient of a network as the average of the clustering coefficient of each node in the network. The clustering coefficient of a network $C = \frac{1}{n}\sum C_i$ measures the tendency of a network to cluster.

Figure 9 shows that the clustering coefficient of the network increases after 2003. This is due to an increase in the in-degrees of non-reporting countries after 2003. Remember that the in-degree of a node is the number of terminating links at the node. The logic behind this can be explained with the following example. Suppose a non-reporting country has only one directed-in link from a certain reporting country. One day, this non-reporting country receives bank exposures from another reporting country as well. If the two reporting countries are linked with each other, clustering occurs: two neighbours with a direct link to the non-reporting country are linked together. As we found in the previous subsection, almost all the reporting countries are linked with each other. In other words, the network consisting of reporting countries is a virtually complete network. Therefore, it is almost always the case that an increase in the in-degree of non-reporting countries results in an increase in the clustering coefficient.

Figure 9
Clustering coefficient



Some limitations in the data should be noted in interpreting the clustering coefficients. First, it is impossible to precisely calculate the clustering coefficient, because a non-reporting country in the BIS statistics by definition has no directed-out links. Second, we need to choose the sample period for the clustering coefficient only from the second quarter of 1999 onwards, when the reporting countries start reporting their bank exposures to other reporting countries. By definition, the clustering coefficient is zero before the reporting countries start reporting their bank exposures to other countries, and it is meaningless to include the periods before the second quarter of 1999 in the sample period.

4. Discussion

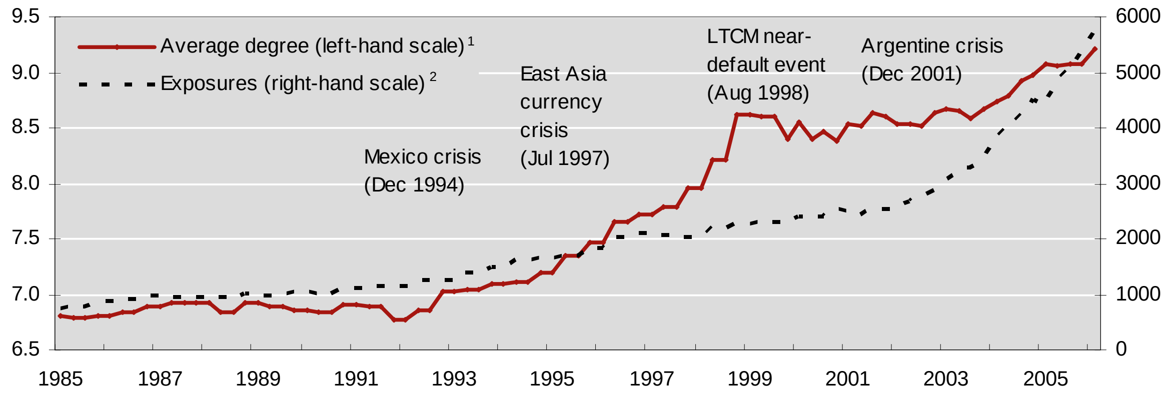
4.1 Topology characteristics and gross cross-border bank exposures

In this section, we investigate the relationship between the topology characteristics of the cross-border bank exposure network and the gross bank exposures in the network. Because we already know that the main cause of the evolution of the topology characteristics of the network is change in the average degree of the network, we investigate the relationship by focusing on the relationship between the average degree and total gross cross-border bank exposures.

Figure 10 shows the time series of the total gross exposures and the average degree.[9] Two observations are worth pointing out in the figure. First, both time series are basically on increasing trends. Second, we can detect that the total gross exposures started increasing before the average degree in recent years. The total gross exposures increased at an accelerated pace beginning in 2002. Following such a significant increase in the total gross exposures, the average degree started increasing in 2003.

From the second observation above, we could conjecture that the expansion of total gross exposures might have propelled the developments in the network. International banks seek entry into new countries with opportunities for profits. Once within a new country, they increase their exposure to the country until the profit opportunity becomes scarce. Next they start seeking entry into a new country, and a new cross-border bank exposure link emerges. The frontier of their business moves from one country to another. We can speculate that the increase in exposures might have preceded the increase in links in this fashion, though clearly more research would be required.

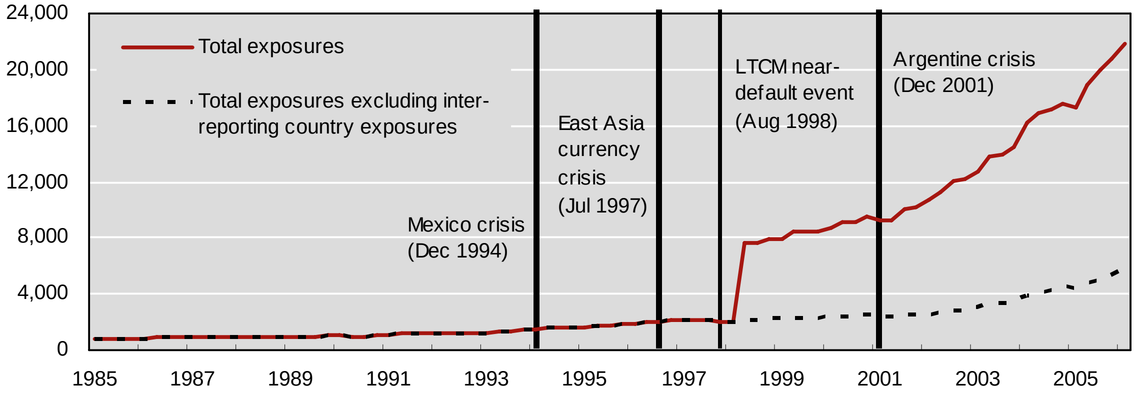
Figure 10
Average degree and exposures



[1] level. [2] In billions of US dollars.

[9] To obtain a longer consistent time series for investigation, we use the time series of the total gross exposures, excluding exposures between reporting countries. The gross exposures, including exposures between reporting countries, are only available from the second quarter of 1999 onwards. Figure 11 shows both time series, including and excluding exposures between reporting countries, for reference.

Figure 11
Total exposures[1]

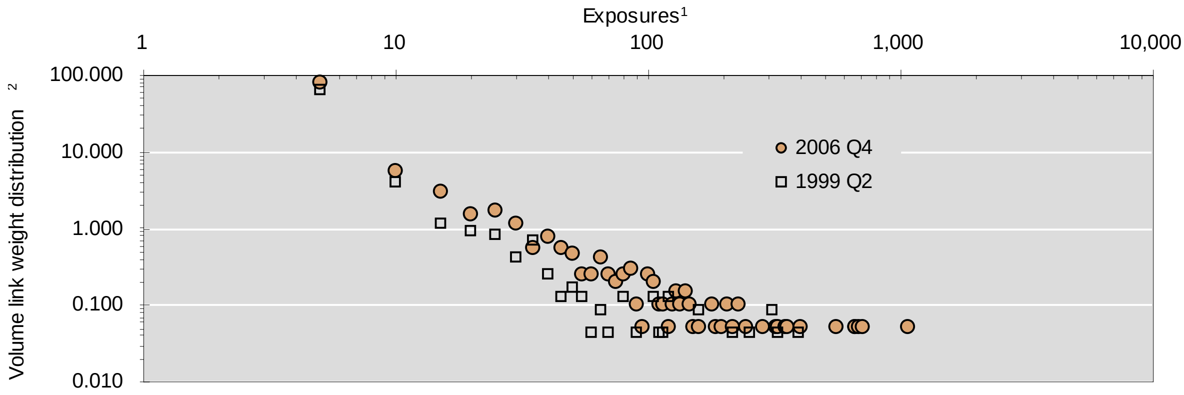


[1] In billions of US dollars.

Figure 12 shows another way to depict the relationship between links and amounts of exposures. The power-law distribution figure in logarithmic scale plots the frequencies of links vis-à-vis the total number of links falling in a certain range of amounts of exposures per link. The range unit for amounts of exposure is 5 billion US dollars. The figure also enables us to compare the state in the fourth quarter of 2006 with the one in the second quarter of 1999.

The power-law distribution reveals the following. First, links bearing less than 5 billion US dollars have a weight of about 80% of the total number of links. Second, the slope of the power-law distribution in the fourth quarter of 2006 is flatter than the one in the second quarter of 1999. This change in slope is attributable to increases in the weight of links bearing amounts of exposures roughly between 35 billion and 100 billion US dollars, and to increases in the amount of exposures of a small number of links bearing the largest amount of exposures in the second quarter of 1999.

Figure 12
Power-law distribution



[1] In billions of US dollars, logarithmic scale. [2] Share in total *m* , in per cent, logarithmic scale.

4.2 Influence of crises

International financial markets are sometimes significantly influenced by turbulent crises, such as currency crises, which tend to be perceived as massive forces when underway. The Mexican crisis in 1994, the East Asian crisis in 1997, the LTCM near-default event in 1998, and the Argentine crisis in 2001 were all such events. Our interest in this subsection is to investigate how these crises influenced the cross-border bank exposure network.

Figure 10 shows the approximate timing of the occurrence of well-known turbulences in the international financial markets (hereafter, crises). We can point to two features of the trajectory of the two time series. First, the trend of increasing average degree has never been severely affected by any crisis. Second, total gross cross-border bank exposures experienced a small dip after the LTCM near-default event, though the average degree was not affected considerably even under those circumstances. These features are closely related to the irreversibility of the connectivity discussed earlier: once a country has a link with another country, the link tends to be very persistent.

4.3 Driving forces: conjectures

As shown in the previous sections, the cross-border bank exposure network recorded by the BIS statistics has become more connected, smaller and more clustered. We have described how these are parallel phenomena propelled by an almost constant increase of the out-degrees (the number of directed-out links of a node) of the reporting countries. Thus, our next task is to identify the driving force behind this increase.

There are several possibilities. One is the globalisation of the business activities of non-financial firms. Banks of a firm's home country will have a lending opportunity to fund the activities of the firm in a foreign country.

The second possibility is acceleration of economic development in developing countries. With help from the above-mentioned globalisation of firms of developed countries, developing countries have tended to achieve historically high economic growth. Firms in those countries may have thus had to seek financing from financial markets. If so, this would have made it easier for international banks to find lending opportunities in those developing countries.

The third possibility is the "search for yield" behaviour of financial institutions when the returns of financial assets in domestic markets stay low. We have already noted the relationship between the time series of average out-degree and total gross cross-border bank exposures. In recent years, the average out-degree has increased almost in parallel with total gross cross-border bank exposures. This would mean that an increase in total exposures is not only attributable to an increase in exposures to already linked countries, but also to an increase in the number of links. An increase in the number of links means that at least one of the reporting countries has new credit exposures to a country to which it never had exposures before. The following may clarify the factors underlying this phenomenon. In domestic financial markets, credit tends to expand when domestic interest rates are low. It is often observed that ongoing credit expansion narrows the credit spreads of domestic financial assets. Financial institutions need to find opportunities for yield, and start looking outside their country. They begin increasing credit exposures to their familiar foreign financial markets, and the spread of assets in these foreign financial markets starts shrinking. Finally, the financial institutions try to enter unexplored territories. Hence, a new directed-out link emerges.

The fourth possibility is a wave of financial liberalisation. This allows the entry of foreign banks into domestic financial markets and will raise the possibility for cross-border credit exposure. In this connection, we may ask what the driving force behind financial liberalisation is. One driving force would be the finance needs of firms in developing countries. This is the phenomenon mentioned above as the second possible cause for the increasing out-degrees of developed countries. Some may point out a possible relationship between this question and the behaviour of financial institutions described in the last paragraph.

4.4 Implications for international financial stability

In this subsection, we discuss the implications of the changing characteristics of the international financial markets for international financial stability.

The changes in the characteristics of the cross-border bank exposure network identified in the preceding sections of this paper imply that the international financial system may be becoming more "robust yet fragile" than in the past, in terms of cross-border bank exposures (Allen and Gale (2000)). A higher average degree implies a greater possibility for agents such as firms and governments to finance from outside a country, and this will lower the probability of a financial crisis in the country triggered by a domestic cause. At the same time, once a financial crisis occurs in one country, the impact could be more significant to the system because a country within it is exposed to a greater number of countries in the second round effects of the initial financial crisis.

With regard to international financial stability, especially systemic risk, in the international financial markets, we introduce additional material for discussion and point to the fact that, on average, countries currently depend on their large financiers more than in the past. The Herfindahl-Hirschman Index (hereafter, HHI) for a country in terms of the amount of exposures directed to the country is a gauge of the extent of concentration: the higher a country's HHI, the fewer countries play an influential role from the perspective of bank exposure provision to the country. Figures 13 and 14 are the histograms of the HHI for countries in the second quarter of 1999 and the fourth quarter of 2006, respectively. Comparison of the histograms for the two periods indicates that, on average, concentration has increased, which means a country is more susceptible to changes in exposures from a small number of countries than before.

Figure 13
HHI in 1999 Q2

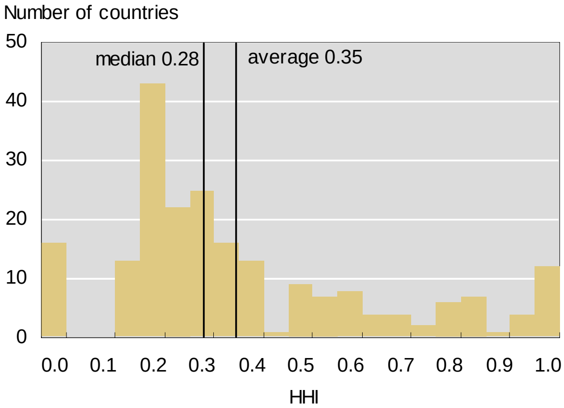
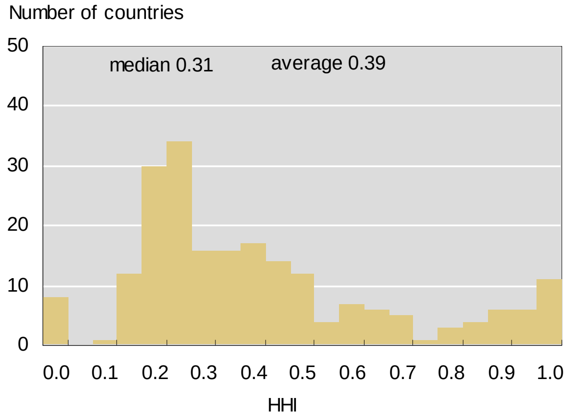


Figure 14
HHI in 2006 Q4



Thus far we have investigated changes in the characteristics of a cross-border bank network and in exposure concentrations in terms of HHI, and have explored their implications for international financial stability. However, it seems prudent not to rush to a conclusion that systemic risk in international financial markets is either higher or lower than before. The size of systemic risk in international financial markets is of course determined by more than just the extent of linkage in the markets and exposure concentrations. The resilience of a country's domestic financial markets to external shocks depends on numerous factors which do not stay unchanged. We need to consider these factors when assessing systemic risk in international financial markets. We have investigated characteristics of the cross-border bank exposure network and have shown they have changed over time, which implies changes in risk-sharing and transmission of a shock. The bottom line is that the past may not be a good guide to the future (Clark (2007)).

Moreover, it should be noted that global financial flows provide important benefits, and we should not pay attention only to possible increases in systemic risk due to the trends and changes in the cross-border bank exposure network (Summers (2000)).[10]

5. Concluding remarks

In this paper we have explored the developments in cross-border bank exposures using the BIS international banking statistics. We have treated the web of cross-border bank exposures as a network and have investigated the characteristics of the network topology by computing various statistical measures.

We find that the network of cross-border bank exposures has become more tightly connected over time. It currently has higher connectivity, a shorter average path length, a higher average degree and a higher clustering coefficient than in the past. Moreover, we observe that this tendency has never been hampered by any disturbances or crises in international financial markets (such as the East Asian currency crisis in 1997 or the LTCM near-default event in 1998).

The above developments in the cross-border bank exposure network have some implications for the stability of international financial markets. In this regard, we should note both costs and benefits from these developments in cross-border bank exposures. On the one hand, systemic risk in international financial markets is likely to increase because of more widespread and direct spillover effects of a crisis in one country once it occurs. On the other hand, the efficiency of international financial markets is expected to further improve in terms of capital and risk allocation.

As a final remark, we should point out a limitation of our analysis due mainly to a feature of the BIS international banking statistics. We have repeatedly explained the difference between a reporting country and a non-reporting country in the statistics. We can obtain information on the bank exposures directed from a reporting country to another country in the sample, but no information on the ones directed from a non-reporting country to any countries in the sample. This limits our knowledge of the international linkage in terms of bank exposures, and the results of our network analysis therefore need to be interpreted with some caution. We note, in particular, that many of the linkages via off-shore markets are out of reach of our analysis using the BIS international banking statistics. Nevertheless, the main findings in this paper are not undermined by this limitation: the cross-border exposure network for banks has become more connected with more direct linkages, and the world has gotten smaller over time.

[10] Summers (2000) argues this view with an illuminating analogy: "The jet airplane made air travel more comfortable, more efficient, and more safe, though the accidents were more spectacular and for a time more numerous after the jet was invented. In the same way, modern global financial markets carry with them enormous potential for benefit, even if some of the accidents are that much more spectacular." He continues, "As the right public policy response to the jet was longer runways, better air-traffic control, and better training for pilots, and not the discouragement of rapid travel, so the right public policy response to financial innovation is to assure a safe framework so that the benefits can be realised, not to stifle the change."

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