



Bank of Japan Working Paper Series

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Masazumi Hattori *

masazumi.hattori@boj.or.jp

Yuko Suda **

yuuko.suda@boj.or.jp

Bank of Japan

2-1-1 Nihonbashi Hongoku-cho, Chuo-ku, Tokyo 103-8660

No.07-E-21

September 2007

* Financial Systems and Bank Examination Department (currently, Institute for Monetary and Economic Studies)

** Financial Systems and Bank Examination Department

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Developments in a Cross-Border Bank Exposure "Network"*

Masazumi Hattori[†] and Yuko Suda^{††}

September 2007

Abstract

In this paper we explore the developments in the cross-border bank exposures using the BIS International Banking Statistics. To this end, we treat the web of the cross-border bank exposures as a "network" and investigate the characteristics of the network topology, and compute various statistical measures for the network topology. We find that the network of cross-border bank exposure has become more tightly connected over time. The network 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 such tendency has never been hampered by any disturbances or crises in international financial markets (such as the East Asia currency crisis in 1997 or the LTCM near-default event in 1998). We see both costs and benefits from these developments in the 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, efficiency of international financial markets is expected to further improve in terms of capital and risk allocation.

Key words: BIS International Banking Statistics, network, topological statistical measures, systemic risk

JEL Classification code: F23 F34 F36 G15 G21

* In the preparation of this paper, we received insightful comments from the participants of a BIS CGFS Workshop "Research on Global Financial Stability: the Use of BIS International Financial Statistics", Bank of England "Selected Economists' Research Forum: Modelling the Financial Sector", Bank Indonesia "The 5th International Seminar on Financial Stability: Financial Sector Deepening and Financial Stability – Benefits and Challenges" and some staff members of the Financial Systems and Bank Examination Department, Bank of Japan. The views expressed in this paper are solely those of the authors and do not necessarily reflect those of the Bank of Japan. Any errors or omissions are the responsibility of the authors. The corresponding author is Masazumi Hattori.

[†] Financial Analysis and Research, Financial Systems and Bank Examination Department (currently, Institute for Monetary and Economic Studies), Bank of Japan (Email: masazumi.hattori@boj.or.jp)

^{††} Financial Analysis and Research, Financial Systems and Bank Examination Department, Bank of Japan (Email: yuuko.suda@boj.or.jp)

I. 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; such as the amounts of international capital or credit flows, foreign exchange rates, sovereign bond credit spreads, and so on. This line of research helps us understand the structure and functioning of international financial markets more deeply (For example, Bisignano *et al.* [2000], Glick *et al.* [2001]).

In this paper we employ a new approach, "network analysis," to understand the developments in international financial markets. We explore the changes in the 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. We thereby attempt to gain some new insights regarding the developments in international linkage via bank exposures¹.

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, such as Inaoka *et al.* (2004), Soramaki *et al.* (2006), Bank of Japan (2006) and Soejima (2007).

This paper is organized as follows. Section II briefly introduces some key elements in network analysis and presents case in which international financial markets can be understood using BIS International Banking Statistics, with due consideration of the limitations in available data. Section III introduces several topological statistical measures to characterize a network, then applies these measures to the analysis of the cross-border exposure "network" of banks. Section IV 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 V offers a concluding discussion.

¹ Bank of Japan (2007) includes a belief summary of this paper referring to some selective figures.

II. BIS International Banking Statistics for Network Analysis

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

A. Networks

A *network* consists of *nodes* and the connection between them, *links*. 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 analyze 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]).

B. 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 the data to the BIS. The statistics in use in this paper give us data of risk exposures to individual countries by the nationalities of the reporting banks.

Following the definitions in the literature of 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. The 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 exposure from each reporting country to the other countries at the end of each quarter are available.² The amounts outstanding of credit exposure from non-reporting countries to the other countries are not available. Thus, the reporting countries have both inward and outward links, while the 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 data, we make some adjustments in the BIS International Banking Statistics.

First, we treat just sixteen countries out of the current 30 countries as reporting countries: Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Spain, Sweden, Switzerland, United Kingdom, and the United States. We include Finland and Spain as reporting countries. Though Finland and Spain do not actually become reporting countries until the second half of 1985, their inclusion does not seem to give 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 become reporting countries after 1998. We also exclude Norway because its data is 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 member of reporting countries, because the data of their exposures to other countries is 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 impacts of changes in the number of sample countries. The largest change in the number of sample countries occurs when the Soviet Union collapses in 1991, and is divided into 15 countries. This discontinuity seems to mislead us in

² The credit exposure from one reporting country to another reporting country was not been filed before the second half of 1998. Thus, we detect a sudden increase of 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 as long as the authors explore the BIS website. Even if we can include those countries as a reporting country, we believe, the findings in this paper on trends and changes in topological characteristics of the cross-border bank exposure network will not be affected to a considerable degree.

understanding the developments in the cross-border bank exposure network over time.

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 large volatility because, presumably, data collection operations did not work well at the beginning 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.

C. Preliminary Checking by Visualization

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

Figure 1: Cross-Border Bank Exposure Network (1)

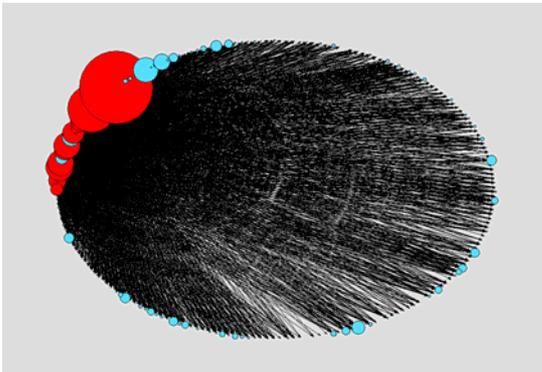
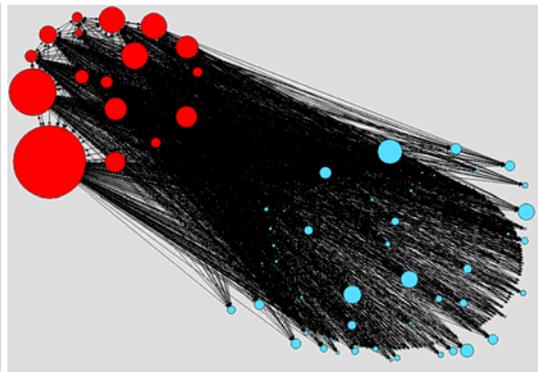


Figure 2: Cross-Border Bank Exposure Network (2)



Figures 1 and 2 are different visualizations of the same network, based on the data of 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 the

order of size, United States, United Kingdom, France, Germany, Italy and Cayman Islands.

When we are interested in the changes of the network over time, it may be effective to draw the figures for every period, compare the figures period by period, and extract tendencies and changes. Readers are likely to agree, however, that this visualization approach is not very fruitful, especially when we want to understand changes over a long time course 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 viewpoint of the topological characteristics. This is what we attempt in the sections below.

III. 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

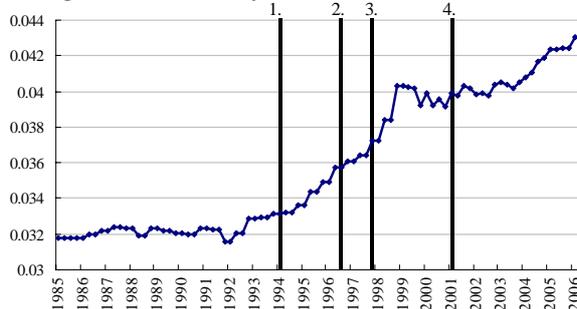
A. Connectivity: Likelihood of Connection between Countries

In this paper, the number of sample countries (i.e., nodes, n) is 215. The number of links m is counted as follows in our analysis. When gross credit exposure from one country (node) to another country (another node) is filed 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 $p = \frac{m}{n(n-1)}$.

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 insightful for us to take this approach in our analysis. Instead we focus on changes of the topological statistical measures over time to discuss the evolution of the characteristics of the cross-border bank exposure network.

Figure 3: Connectivity



Note: Each line with the numbers 1 to 4 represents the timing when the crisis occurred. One (1.) is the Mexico crisis in December 1994. Two (2.) is the East Asia currency crisis in July 1997. Three (3.) is the LTCM near-default event in August 1998. And four (4.) is Argentine crisis in December 2001.

The time series of connectivity is shown in Figure 3. The figure shows two points below. First, the connectivity follows an increasing trend, implying that the likelihood of the connection of two countries via bank exposure keeps increasing throughout almost the entire sample period. Second, in retrospect, the increasing trend is not hampered severely by any well-known disturbance in international financial markets (e.g., the Mexico crisis, the East Asia crisis, the LTCM near-default, 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 small value of this statistic. The value of the statistic will be higher if the potential links directed from one non-reporting country to another country are reported in the BIS statistics.⁵

B. 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 any 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

⁵ A closely related statistical measure 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 characterize or compare the cross-border bank exposure network across time in this paper.

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.

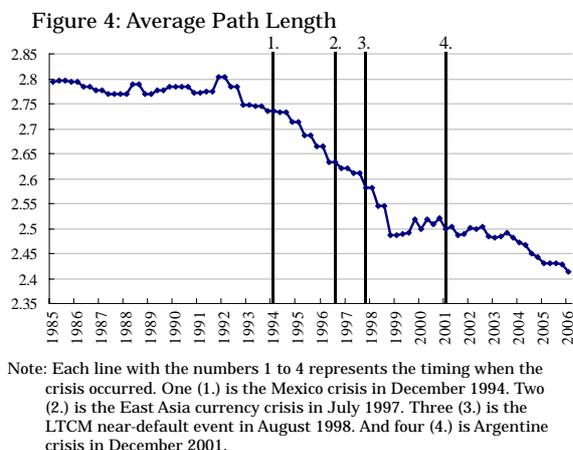


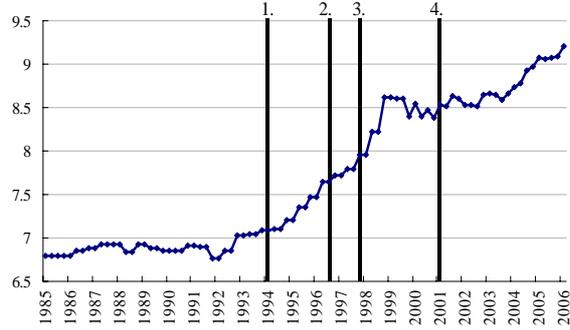
Figure 4 shows the time series of the average length of path in the cross-border bank exposure network. The average length of a path declines rapidly after the mid-1990s, suggesting that the network becomes increasingly compact in the second half of the 1990s.⁶

C. Degree: Multilateral Connections

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

⁶ We use an approximation to get the average path length. We use a formula $\langle l \rangle \approx \frac{\ln(n)}{\ln(p \cdot n)}$ for a random network. This approximation is non-sense 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 for gaining an overview of trends and changes in the characteristics of the cross-border bank exposure network.

Figure 5: Average Degree



Note: Each line with the numbers 1 to 4 represents the timing when the crisis occurred. One (1.) is the Mexico crisis in December 1994. Two (2.) is the East Asia currency crisis in July 1997. Three (3.) is the LTCM near-default event in August 1998. And four (4.) is Argentine crisis in December 2001.

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 on 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.

Another way to depict the basically same phenomenon is a comparison between histograms of in-degree per country in two different points in time. Figure 6 and Figure 7 are the histogram of in-degree in the second quarter of 1999 and in the fourth quarter of 2006, respectively. For comparison we show the histogram in 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 of in the fourth quarter of 2006 has more countries in higher range of in-degrees than the one in the fourth quarter of 1999 and the average and the median are both higher in the former than the latter.

Figure 6: Histogram of In-degree in 1999.2Q

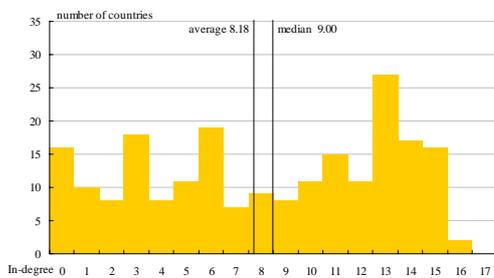
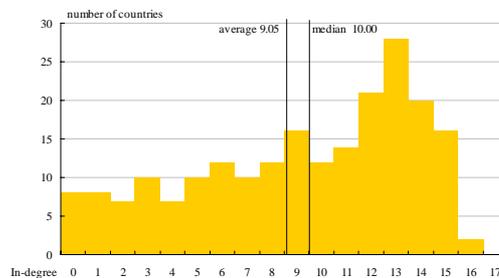


Figure 7: Histogram of In-degree in 2006.4Q



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 directed to reporting countries. In the fourth quarter of 2006, the number is almost the same, 239. Given that there are sixteen reporting countries in our analysis and $16 \times 15 = 240$, the network among the reporting countries 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 countries to non-reporting countries had 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 the average of the regional average degrees is the average degree of the whole network by definition.⁸

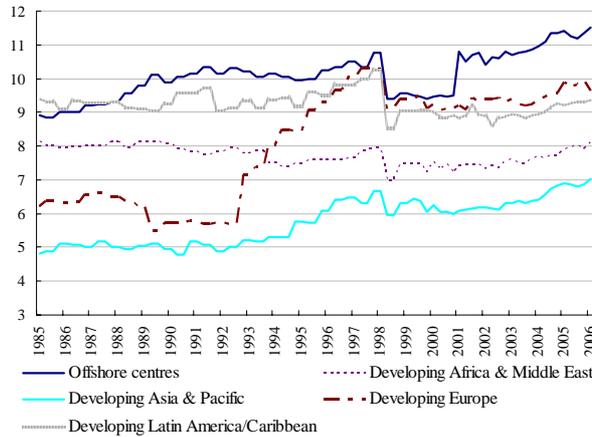
The figure shows that each region contributes to the increase in the average degree of whole network in the second half of the 1990s, before the LTCM near-default event, to a different extent. Developing Europe most significantly contributes to the one of whole network and the increase in the average degree of Developing Asia and Pacific looks the second contributor. Other three regions also have an increase in the average degree but it is smaller than 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 almost to the same extent. That is, the development of the cross-border bank

⁷ Only exception is the second quarter of 1999 when the banks in the reporting countries started to report their credit exposure to reporting countries. The trajectory of the average degree of whole network is affected by it 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 at the second quarter of 1999.

⁸ The same caveat in Footnote 7 applies here.

exposure network in the recent period goes on evenly, from the view point of the average degree, in all the parts of the world.

Figure 8: Average Degree by Region



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 mentioned afterwards. Thus, it is worth checking who contributes to the increase in number of directed-out links in the network. Focusing the recent phenomenon, we list the names of countries in the order of increase in the number of out-degree from the fourth quarter of 2003 to the fourth quarter of 2006 in Table 1. It is obvious that the significant contributors are banks in European developed countries.

Table 1: Changes in Out-degree between 2003.4Q and 2006.4Q

No.	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 links directed out of each reporting country, Table 2 ranks the out-degree of a node. France is the biggest contributor and several other European countries are ranked in high positions. Table 3 also 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. We point out that 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 twelfth position (out-degree of 105) in the ranking of out-degree contributors.

Table 2: Top 10 Out-Degree in 2006.4Q

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
8	United States	144
10	Sweden	134

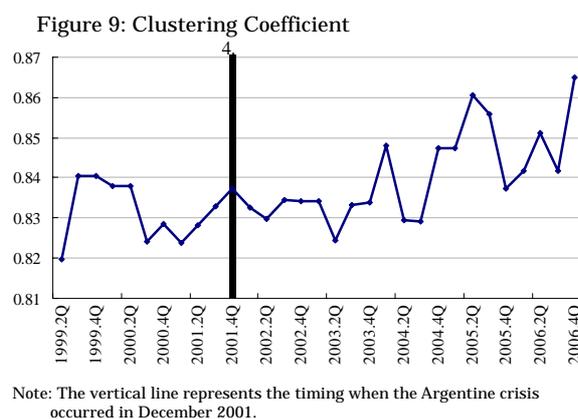
Table 3: Top 10 Total Exposures in 2006.4Q

No.	Country	Exposures (mil. US dollars)
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

D. Clustering Coefficient: Likelihood of Connection between Neighbors

The *clustering coefficient* is another commonly used topological statistical measure. This measure shows the probability that two neighbors 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 *neighbors* of node i ($m_{m,i}$) over the number of potential links among them. *Neighbors* of a node i is defined as nodes which are directly linked to node i . Then, when the number of the neighbors of node i is m_i , the number of potential links among the neighbors of node i is $m_i(m_i-1)$. Therefore, we can calculate the clustering coefficient of node i as $C_i = \frac{m_{m,i}}{m_i(m_i-1)}$. 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-degree 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 certain 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 neighbors with a direct link to the non-reporting country are linked together. As we checked in the previous sub-section, 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 in-degree of non-reporting countries results in an increase in the clustering coefficient.



Some limitations in 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, 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.

IV. Discussions

A. 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 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 the total gross cross-border bank exposure.

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 accelerated its pace of growth since 2002. Following such a significant increase in the total gross exposure, the average degree started increasing in 2003.

Figure 10: Average Degree and Exposures, level, billion US dollars

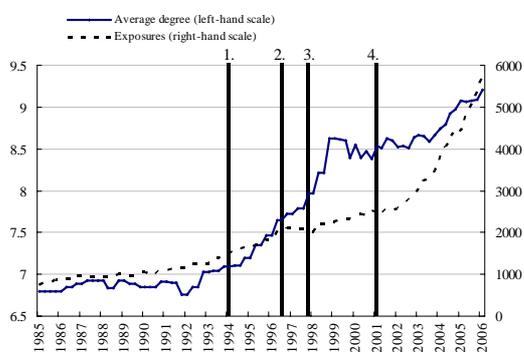
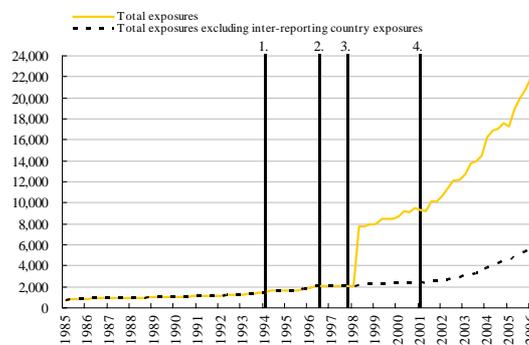


Figure 11: Total Exposures, billion US dollars



Note: Each line with the numbers 1 to 4 represents the timing when the crisis occurred. One (1.) is the Mexico crisis in December 1994. Two (2.) is the East Asia currency crisis in July 1997. Three (3.) is the LTCM near-default event in August 1998. And four (4.) is Argentine crisis in December 2001.

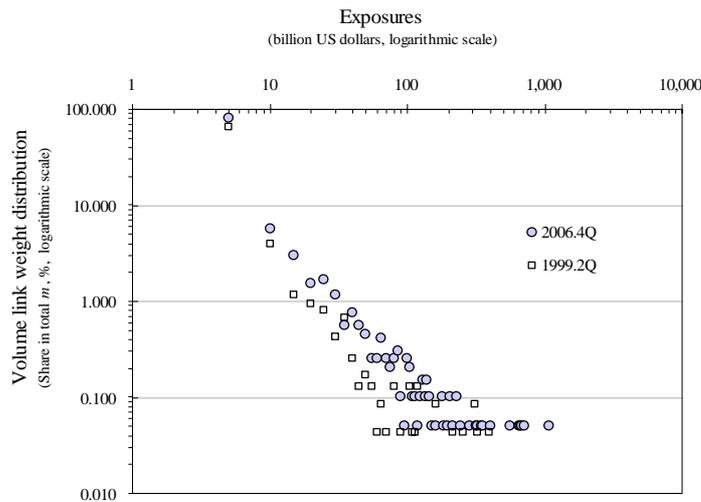
From the second observation above, we may be able to conjecture that the expansion of total gross exposures might have propelled the developments in the network. International banks seek entry into new countries with opportunities for profits. Once

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. Figure 11 shows both time series, including and excluding exposures between reporting countries, for reference.

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 will be required to be conclusive.

Figure 12 shows another way to depict the relationship between links and amounts of exposure. 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 exposure 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.

Figure 12: Power-law Distribution



We detect some facts in the power-law distribution. First, links bearing less than 5 billion US dollar have weight of about 80% of 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 weight of links bearing amounts of exposure, roughly, between 35 billion and 100 billion US dollars and to increases in the amount of exposures of a small number of links bearing largest amount of exposures in the second quarter of 1999.

B. 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 Argentina crisis in 2001 were all such events. Our interest in this sub-section is to investigate how these turbulent crises influenced the cross-border bank exposure network.

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

C. Driving Forces: Conjectures

As shown in the previous sections, the cross-border bank exposure network filed by the BIS statistics has been getting more connected, smaller, and more clustered. We have described how these are parallel phenomena propelled by an almost constant increases 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 that increases their out-degrees.

We can point out several possibilities. One is the globalization 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 a firm in a foreign country.

The second possibility is acceleration of economic development in developing countries. With help from the abovementioned globalization 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" behavior of financial institutions when the returns of financial assets in domestic markets stay low. We already have checked the relationship between the time series of average-out-degree and the total gross cross-border bank exposures. In recent years, the average-out-degree has increased almost in parallel with the total gross cross-border bank exposure. This would mean that an increase in the total exposure is not only attributable to an increase in exposure 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 starts making credit exposure to a country to which it has never had credit exposure. 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 credit spreads of domestic financial assets. Financial institutions need to find opportunities for yield and start looking outside. They start 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 liberalization. This allows the entry of foreign banks into domestic financial markets and will raise the possibility for cross-border credit exposure. We may ask, in relation to this: What is the driving force behind financial liberalization? One driving force would be the finance needs of firms in developing countries. This is the phenomenon mentioned already as the second possible cause for the increasing out-degree of developed countries. Some may point out a possible relationship between this question and the behaviors of financial institutions sketched in the last paragraph.

D. Implications for International Financial Stability

In this sub-section, we discuss implications of changing characteristics of 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, from the viewpoint of cross-border bank exposure (Allen and Gale [2000]). A higher average degree implies a higher possibility for agents such as firms and the government in a country to finance

from outside the country and this will lower the probability of occurrence of a financial crisis in a country triggered by a domestic cause. At the same time, once a financial crisis occurs in a country the impact could be more significant to the system because a country in the system is exposed to a greater number of countries in the second round effect of the initial financial crisis in one country.

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

Figure 13: HHI in 1999.2Q

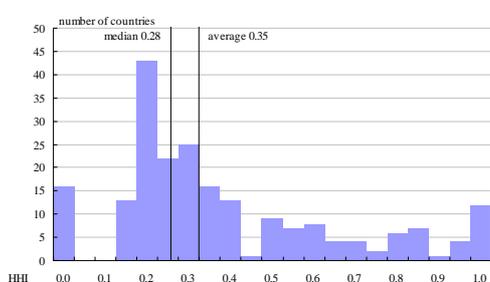
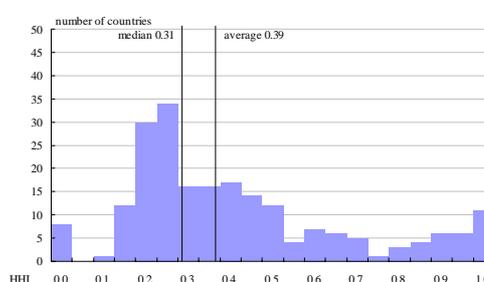


Figure 14: HHI in 2006.4Q



We have so far investigated changes in characteristics of a cross-border bank network and in exposure concentrations in terms of HHI, and we have explored their implications for international financial stability. However, it seems to be reasonable for us 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 domestic financial markets of a country 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 been changing over time, which imply changes in risk-sharing and transmission of a shock. The bottom line is the past may not be a good guide to the future (Clark [2007]).

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

V. Concluding Remarks

In this paper we have explored the developments in the cross-border bank exposures using the BIS International Banking Statistics. We have treated the web of the 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 exposure has become more tightly connected over time. The network 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 such tendency has never been hampered by any disturbances or crises in international financial markets (such as the East Asia currency crisis in 1997 or the LTCM near-default event in 1998).

We point out that 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 the cross-border bank exposures. On the one hand, systemic risk in international financial markets is likely to increase because of more wide-spread and direct spillover effects of a crisis in one country once it occurs. On the other hand, efficiency of international financial markets is expected to further improve in terms of capital and risk allocation.

¹⁰ Summers (2000) argues this kind of views 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 realized, not to stifle the change."

As a final remark, we should point out a limitation of our analysis mainly due 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 have information on the bank exposures directed from a reporting country to another country in the sample, but no information on the one 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 will not be undermined with the limitation of the statistics: the cross-border exposure network for banks has become more connected with more direct linkages, and the world has gotten smaller over time.

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