WORKING PAPER 7/2014

THE GLOBAL FINANCIAL CRISIS AND TRANSMISSION CHANNELS:

AN INTERNATIONAL NETWORK ANALYSIS

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August 2014

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Abstract

This paper analyzes the effects of the trade and financial networks on the propagation of the global financial crisis of 2008. We adopt a new methodology that incorporates a dynamic network approach into econometric analysis. Some interesting results are obtained. Firstly, both the trade and financial networks provide clear pictures of international economic linkages. Secondly, both the trade and financial networks do not have any significant effect on the growth rate of real GDP worldwide, but have a significant effect within particular country groups. The trade network especially, contributes a negative contagion impact on the Chiang Mai Initiative (CMI) and Latin economies while the financial network contributes a negative contagion effect on the Asia-Pacific and inflation targeting countries. Thirdly, the financial network, however, has a worldwide positive consequence on share price index. Finally, the real effective exchange rate overvaluation among the country-specific fundamentals has a significant negative impact on the real GDP growth rate and stock market performance.

JEL Classification Number: F40, F41, F42, F43, F62, G01

Keywords: Global Financial Crisis, Transmission, Network Analysis, Trade Network, Financial Network

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1. Introduction

The global financial crisis has shown diverse effects across countries. This paper investigates the possible channels through which the global financial crisis of 2008 was transmitted across countries. The world has observed a rapid increase in trade and financial linkages across countries since 1980s, especially in the emerging market economies (Kose, et al., 2012). Increase in international economic linkages may heighten the degree of negative contagion effects that individual countries face. The question arises whether countries have become more interdependent to common shocks with the rapid increase in economic linkages. This question leads us to investigate the trade and financial channels through which the global crisis is propagated.

Several studies have tried to explain the incidence and causes of the global financial crisis by using cross-country regressions. The changes in real GDP, stock market performance, country credit ratings, and the exchange rate are the usual crisis incidence found in the existing literature.

A host of economic variables are tested whether they are robust determinants of the global crisis (Imbs, 2006; Rose and Spiegel, 2010). Berglöf, et al. (2009) show that external debt liabilities, export, real effective exchange rate, and political instability are the causes of the output declines in emerging Europe after the global financial crisis. Obstfeld, et al. (2009, 2010) find that the excess of reserves over the predicted values is the cause of currency depreciation over 2008.

The empirical results on the effects of economic linkages on output co-movement are not very clear. Baxter and Kouparitsas (2005) show that the level of bilateral trade linkages is positively associated with output co-movement via spillover effects across economies. Imbs (2006) shows that financial integration among countries is also positively associated with business cycle co-movement through the wealth effects. Regarding the 2008 global financial crisis, Berkmen, et al. (2009) and World Bank (2009) suggest that the levels of trade and financial exposure are the causes of the different degrees of output declines among economies after crisis. Trancoso (2014) finds that the global recession of 2009 was propagated rapidly due to high levels of real and financial interdependence between economies. Kose, et al. (2008, 2012) find that there has been a convergence of business cycles only within the group of advanced economies and emerging market economies.

However, other studies find real decoupling and financial recoupling between advanced economies and emerging market economies (Levy-Yeyati and Williams, 2012; Park and Shin, 2009). Rose and Spiegel (2010, 2012) find no evidence that international trade and financial dependence can be associated with 2008 crisis incidence. They also suggest that it is impossible to predict future crisis incidences with the help of early warning systems. In sum, there seems no consensus on the determinants of crisis propagation. Furthermore, the question of whether the higher levels of trade and financial linkages increase contagion effects of the crisis also needs further empirical investigation.

We use a new methodology that incorporates a dynamic network approach into econometric analysis, which is one of the first attempts in identifying the crisis transmission channels. With the high international economic linkages and constantly occurring global crisis, network models are becoming useful tools in the investigation of the complex crisis incidence (Caballero and Simsek, 2009). Our main contribution is made by the following method. First, we construct the trade and financial networks and provide a fine visualization of the structures of the trade and financial networks for the first time. This enables us to discern the structures at one glance. Second, we combine the trade and financial networks with crisis incidence and investigate the dynamic nature of the crisis effect along the networks. Third, we incorporate the network analysis into the econometric approach and identify the network effects on the crisis incidence. Furthermore, we can also identify whether the network effects are found worldwide or within some specific country group. Finally and most importantly, our approach includes not only the direct but also the indirect dependency of other countries all in the procedure. This is the main difference from the existing studies which use the bilateral dependence between two countries.

This paper is organized as follows. Section 2 constructs a network structure for the trade and financial linkages by using the minimum spanning tree (MST). This provides us with a fine visualization of the trade and financial networks during the 2001-2012 period. Section 3 analyzes the transmission of crisis incidence along with the trade and financial networks. Among the major crisis incidence, the responses of real GDP and stock market after the global financial crisis are the main focus. Section 4 provides the robustness check of the network analysis by incorporating the network analysis into the econometric analysis. This will strengthen and corroborate the result of the network analysis. Section 5 concludes the analysis.

2. Constructing the Trade and Financial Networks

We construct a network structure for investigating the trade and financial channels by using the minimum spanning tree (MST) method. The MST method has been applied to the stock market (by Mantegna, 1999; Onnela et al., 2003; Bonanno et al., 2004; and Rea and Rea, 2014), and to the foreign exchange market (by Naylor et al., 2007; and Keskin et al., 2011). Most of the existing studies apply the MST method directly to the financial market indices and analyze the topological properties.

This paper adopts a different approach. First, we construct a dynamic network structure for trade. This allows us to obtain a much clearer visualization of the trade linkages such as the hub, secondary-hub, and clusters in the structure. Second, we also construct a dynamic network structure for financial portfolio investment flows, which provides us with a clear visualization of the network out of complex financial assets movements. By combining these networks with crisis incidence, we can assemble the crisis transmission pattern.

The data set we use is mainly collected from the IMF and BIS, and comprises quarterly data starting from 2000 Q1 to 2012 Q4 for 61 countries. The element of the trade matrix for the trade network is the total trade (exports plus imports) between country i and country j. The element of the financial matrix for the financial network is the total portfolio assets flows

(outflows plus inflows) between country i and country j. The total number of countries in the data set is 61. The macroeconomic variables which represent the crisis incidence are the rates of change in real GDP and in share price index of each country. We also divide the countries into several groups according to various criteria such as monetary policy regime, regional group, the degree of economic development, and the level of integration into global trade and finance. For example, we can divide the countries into two groups: one group with the inflation targeting system and the other group without (see Table 1).

The MST method considers all the pairwise distances between the nodes and joins the two that are closest to each other using the distance as the weight. We use the matrix of total trade for constructing the trade network, and the matrix of total portfolio assets flows for constructing the financial network. The procedure partitions the data into two groups, one that is part of the tree and the other which is not. Then the procedure also finds the closest node to the tree from the unattached ones and attaches that to the tree. This procedure continues until the unattached node is exhausted (Rea and Rea, 2014).

We need to estimate all the pairwise distances from the export (and the portfolio assets) matrix of the countries in the data set. We define the metric distances between two economies as equation (1). The bigger is the trade between the two countries, the closer the distance between the two countries becomes. We then construct the distance matrix as equation (2), and the adjacency matrix as equation (3) by applying MST method to the distance matrix.

As we have 61 countries in the matrix, the number of links in the network is $61(61-1)/2$. The MST shows a graph of 61 countries connected by the most important 61-1 links, and thus has the advantage of simplification. We also construct the size of country, ranging from 0.1 to 4.1, by using the size of trade (or of total portfolio flows) of each economy as equation (4) indicates. The procedure is as follows:

(1) $D_{i,j} = \frac{1}{X_{i,j}+X_{j,i}}$, where $X_{i,j}$ represents the total exports (or total portfolio outflows in absolute value) from country i to country j.

(2) $(D_{i,j})_{i,j=1,2,\ldots,N}$ is the distance matrix with the elements of pairwise distances.

(3) $(L_{i,j})_{i,j=1,2,\ldots,N}$ is the adjacency matrix computed by applying MST method to the distance matrix.

(4) $W_i = 4\frac{w_i - min_j w_j}{max_j w_j - min_j w_j} + 0.1$, where $w_i = \sum_{j=1}^{N}(X_{i,j} + X_{j,i})$ is the total trade flows (or total portfolio flows in absolute value) between country i and all the other countries in the matrix.

Table 1
Consequences of the Global Crisis over the Period Q1 2008 – Q1 2009

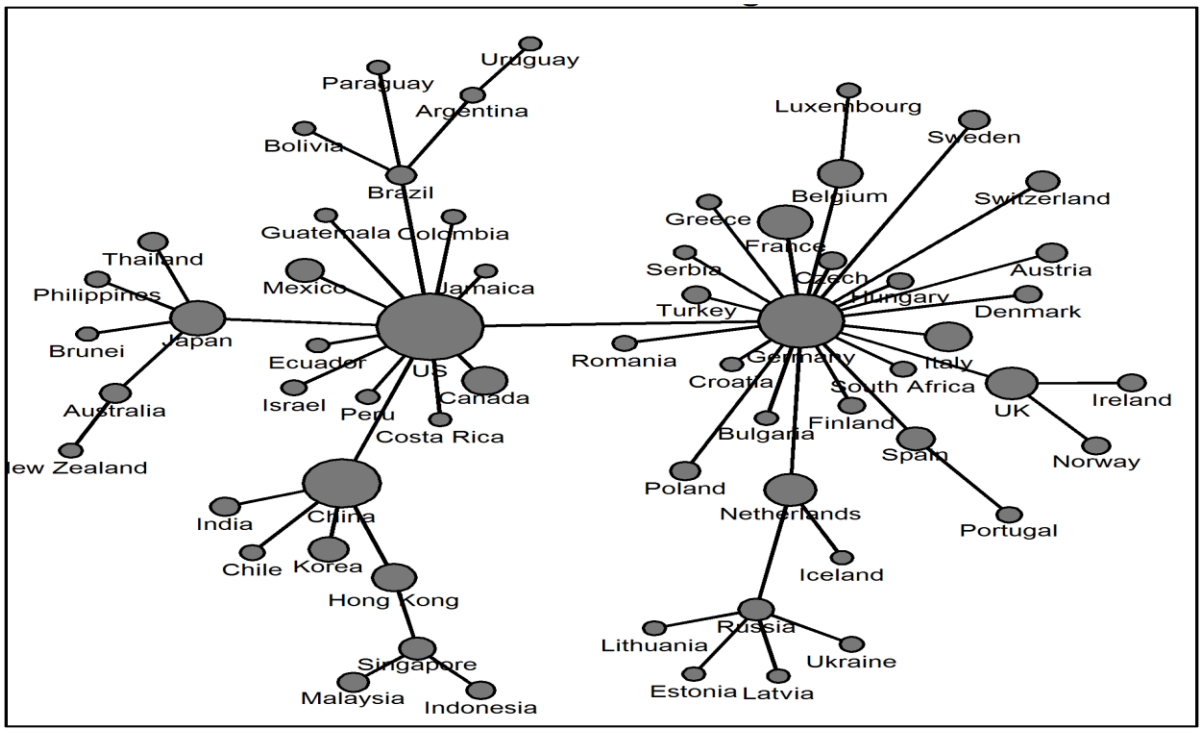
Country	Group	Real GDP growth (%)	Share price change (%)	Country	Group	Real GDP growth (%)	Share price change (%)
Argentina	d, e	0.88	-28.5	Jamaica	d	-1.79	-11.4
Australia	a, c	0.55	-17.5	Japan	b, c	-4.19	-22.2
Austria		-2.58	-36.8	Korea, Republic of	a, b, c, e	-1.86	-16.9
Belgium		-1.78	-31.9	Latvia	e	-8.83	-38.9
Bolivia	d	1.26	n.a.	Lithuania	e	-6.47	-44.3
Brazil	a, d, e	-1.22	-18.8	Luxembourg		-3.01	-37.9
Brunei Darussalam	b, c	-1.22	n.a.	Malaysia	b, c, e	-2.57	-18.6
Bulgaria		-2.19	-69.3	Mexico	a, d, e	-2.34	-16.9
Canada	a	-0.96	-19.1	Netherlands		-1.62	-28.0
Chile	a, d, e	-1.38	-4.6	New Zealand	a, c	-0.96	-13.5
China, P.R.	b, c, e	2.74	-32.4	Norway	a	0.43	-25.6
Colombia	a, d, e	0.56	-6.2	Paraguay	d	2.58	n.a.
Costa Rica	d	-2.06	n.a.	Peru	a, d, e	0.82	-34.2
Croatia		-3.76	-44.6	Philippines	a, b, c, e	0.42	-9.0
Czech Republic	a, e	-1.63	-32.0	Poland	a, e	0.25	-30.1
Denmark		-2.26	-25.3	Portugal		-1.83	-24.4
Ecuador	d, e	1.67	n.a.	Romania	a, e	-2.79	20.9
Estonia	e	-6.17	-36.8	Russian Federation	e	-4.19	-39.6
Finland		-4.11	-32.4	Serbia, Republic of	a	-1.64	-63.8
France		-1.91	-22.4	Singapore	b, c, e	-3.92	-25.7
Germany		-3.06	-24.9	South Africa	a, e	-0.22	-18.0
Greece		-1.87	-39.7	Spain		-1.50	-23.2
Guatemala	a, d, e	-0.36	n.a.	Sweden	a	-2.88	-20.3
Hong Kong SAR	b, c, e	-3.51	-25.7	Switzerland		-1.19	-18.2
Hungary	a, e	-3.23	-31.8	Thailand	a, b, c, e	-3.17	-26.8
Iceland	a	-2.43	-124.5	Turkey	a, e	-6.93	-25.4
India	c, e	3.12	-25.3	Ukraine	e	-9.47	-64.6
Indonesia	a, b, c, e	1.92	-28.7	United Kingdom	a	-2.74	-16.9
Ireland		-2.79	-46.8	United States		-1.55	-20.2
Israel	a, e	0.27	-16.1	Uruguay	d	0.84	n.a.
Italy		-3.15	-28.2				

Notes: a) Refers to the inflation-targeting countries, b) Refers to the participants of the Chiang Mai Initiative (CMI), c) Refers to Asia-Pacific economies, d) Refers to Latin economies, and e) Refers to emerging market economies, respectively.

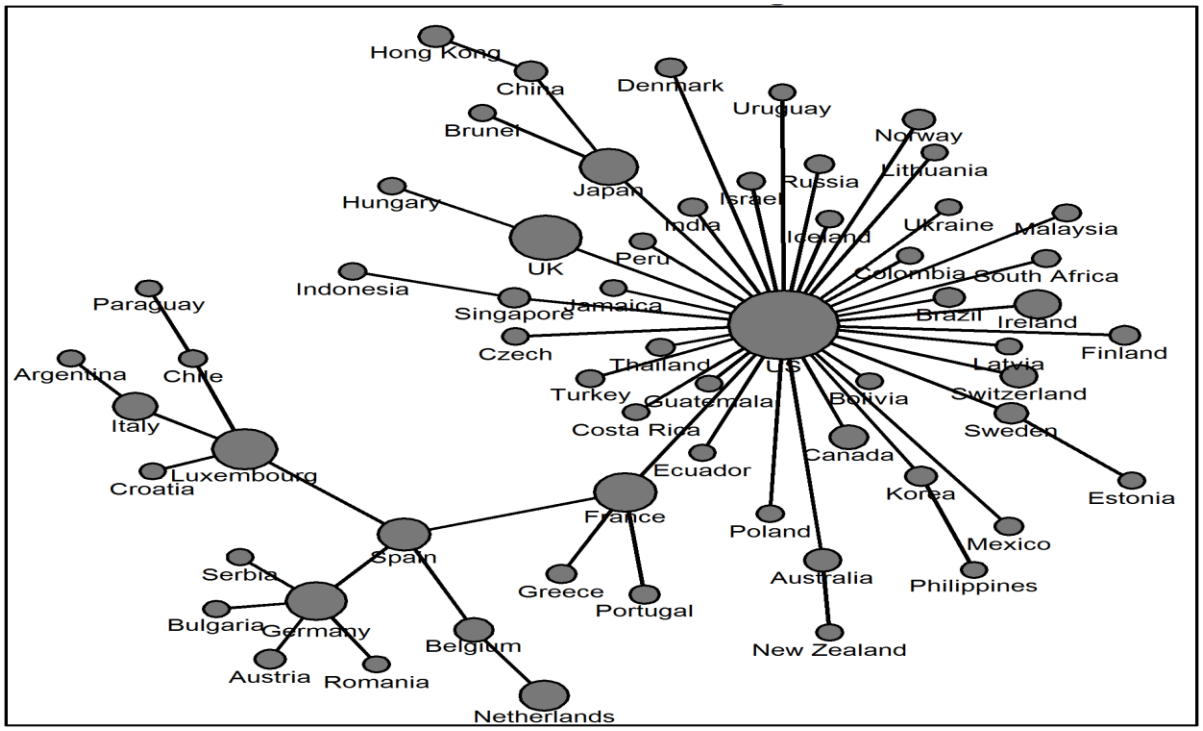
Figure 1 shows the trade and financial networks of the 61 economies. The size of country represents the adjusted relative size of trade of each country. Uruguay, for example, is on the top left hand side of the trade network. Among the 60 distances between Uruguay and the other countries, only the distance to Argentina is retained while the remaining distances are abandoned. In spite of the simplifying procedure, useful information is still retained.

Figure 1
Trade and Financial Networks during 2001-2012

Trade Network: Annual Average 2001-2012



Financial Network: Annual Average 2001-2012



We find there are some important countries which form hubs and clusters. The trade network comprises two main hub economies (United States and Germany) and 5 secondary-hub economies (Japan, China, Brazil, Russia, and the United Kingdom). Each secondary-hub comprises a cluster that is connected to main hubs with a smaller scale than the main hub. The United States, one of the main hubs, has trade linkages with the Japan cluster (around which Australia, New Zealand, Philippines, Thailand, Brunei Darussalam are clustered as leaves), the China cluster (around which Hong Kong SAR, Singapore, Malaysia, Indonesia, India, Korea and Chile are clustered as leaves), and the Brazil cluster (around which Argentina, Bolivia, Paraguay, Uruguay are clustered as leaves). Germany, the other main hub, has also trade linkages with the Russian Federation cluster (around which Ukraine, Lithuania, Latvia, Estonia are clustered as leaves), and the United Kingdom cluster (around which Ireland and Norway are clustered as leaves.

The financial network reveals a substantially different structure from the trade network. There is one main hub (United States) and a few secondary-hubs (United Kingdom, France, Spain, Germany, Luxembourg and Japan). The European countries constitute a slightly more complicated structure, in which all the clusters are connected with Spain. Spain is in the center of several routes that are connected to the Germany cluster (Austria, Bulgaria, Romania and Serbia), the Luxembourg cluster (Croatia, Italy, Argentina, Chile and Paraguay), the France cluster (Greece and Portugal), and the Belgium-Netherlands route. All of the European clusters are connected to the United States hub through France. The Japan cluster (China, Hong Kong SAR and Brunei Darussalam) is the only secondary-hub connected to the United States. Countries like China and Brazil which act as secondary hubs and show independent response in the trade network are no longer important players in the financial network. They are all integrated into the financial network as countries on the route or as independent leaves.

The two network structures suggest some interesting findings, i.e., geographical proximity plays an important role in the trade network, but disappears in the financial network. Also, the countries are more integrated around the United States in the financial network than in the trade network. This result also corroborate the Park's (2013) finding that while the pace of financial integration among Asian economies has accelerated in recent years, these markets remain more integrated with global financial hub than with other financial markets in the Asia region.

3. Crisis Transmission Channel: Trade vs. Financial

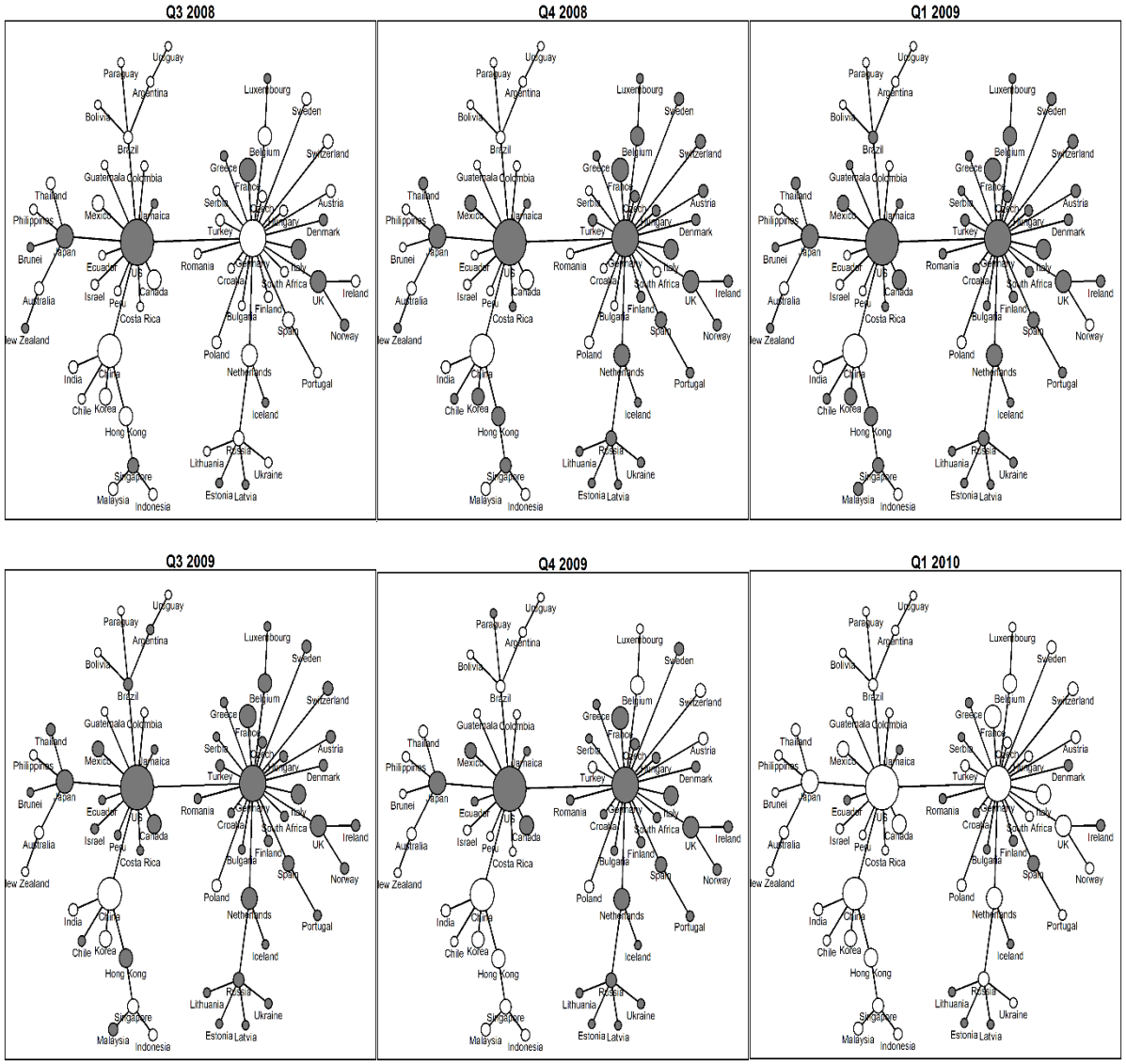
The 2008 crisis effects defined in the literature are variables such as the rate of exchange rate depreciation (Obstfeld, et al., 2009; 2010), a combination of changes in real GDP, stock prices, country credit ratings and the exchange rate (Rose and Spiegel, 2010; 2012) and the change in growth forecasts before and after the crisis (Berkmen et al., 2009). The focus of our paper is on the crisis effects on the changes in real GDP and the stock market performance in the crisis propagation.

3.1 Trade Network

3.1.1 Real GDP

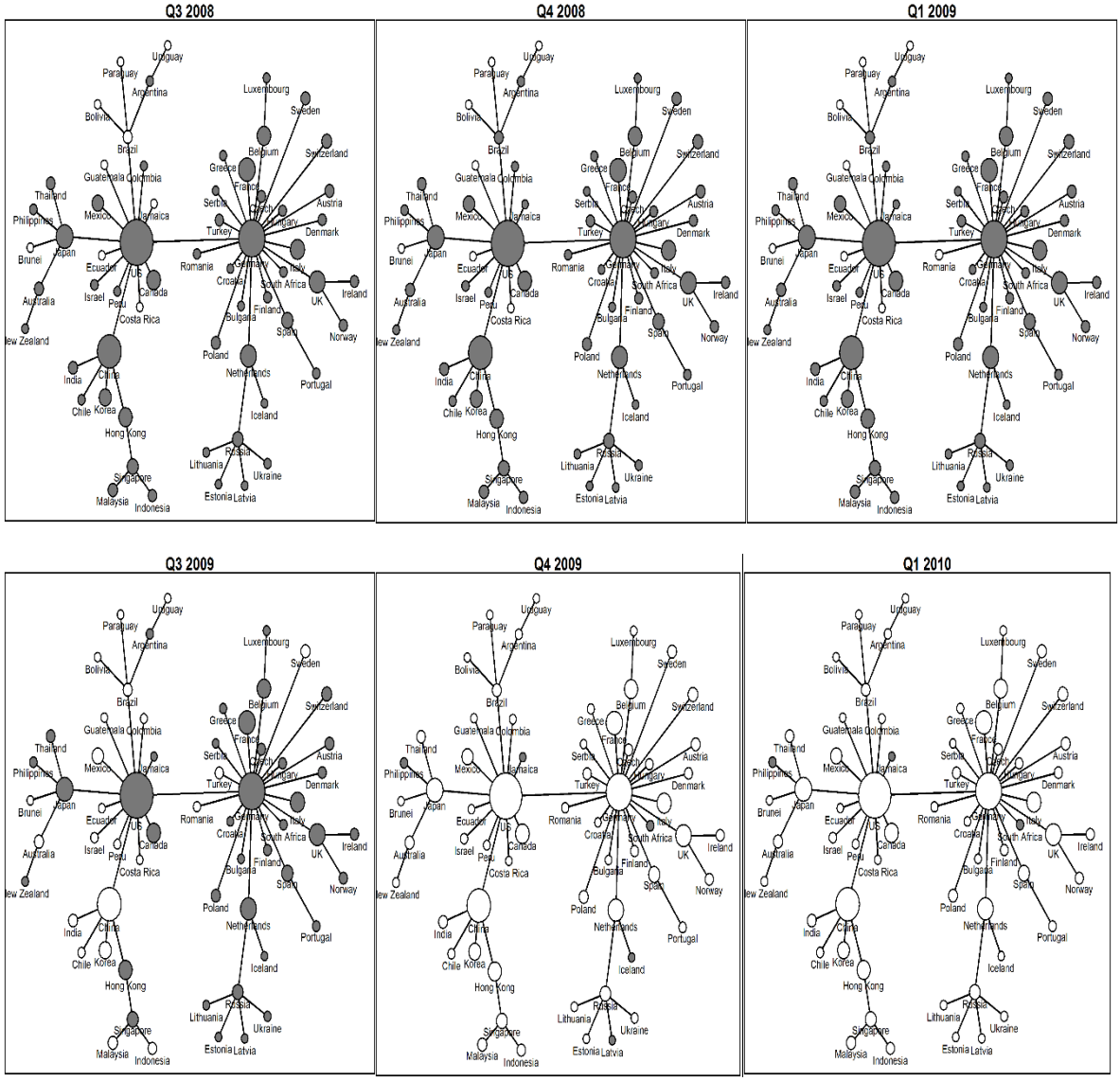
The convergence hypothesis suggests that business cycles are getting more synchronized across countries with closer economic integration. Figure 2 presents the transmission procedures of output decline and recovery along the trade network. The shaded circle in each network indicates the negative rate of change in real GDP or in share price index. Reflecting the global crisis, the real GDP growth rate in the United States turns negative from the third quarter of 2008. The output decline is also observed partly in Japan cluster which includes Japan, Brunei Darussalam, and New Zealand. Although some of the United Kingdom

Figure 2
The Trade Network and Changes in Real GDP



and Russian clusters show negative real growth rates in the same quarter, they are not directly connected with the United States. Germany, the European hub, still shows a positive real growth rate in the third quarter of 2008. The remaining China cluster, Brazil cluster, and half of the Japan and Russian Federation clusters do not enter into recession in the third quarter of 2008.

Figure 3
The Trade Network and Changes in Share Price Index



In the following two quarters (Q4 2008-Q1 2009), however, the European hub and secondary hub countries enter into recession simultaneously. Germany, the United Kingdom

clusters (with Norway and Ireland), the Netherlands cluster (with Ireland), the Russian Federation cluster (with Ukraine, Lithuania, Estonia, and Latvia) are countries showing output decline. France, Italy, and Spain which are directly connected to Germany, also show output decline. One important observation is that developing economies such as the China cluster (with India and Indonesia), the Brazil cluster (Argentina, Bolivia, Paraguay, and Uruguay), the Japan cluster (Australia and the Philippines), Colombia, Ecuador, Peru, and Israel do not enter into a recession. These developing economies were much less affected and recovered more rapidly than advanced economies. The process of output recovery (Q3 2009-Q1 2010) tells us a similar story in the opposite direction.

3.1.2 Stock Market Performance

Share price indices start to respond in the first quarter of 2008, more quickly than real GDP. Although share price indices plummet in most European and the United States clusters in the first and second quarter of 2008, the indices in some of the countries in the China cluster and Japan cluster do not decrease until then. In the third quarter of 2008, however, most economies experience a drop in share price indices (Figure 3). This result suggests a similar implication in line with the real GDP response. Even with the increasing trade linkage, some Asia-Pacific countries do not reveal convergence of share price changes. In sum, trade linkage has some limitation in explaining the co-movement of share price fluctuations after the global crisis.

3.2 Financial Network

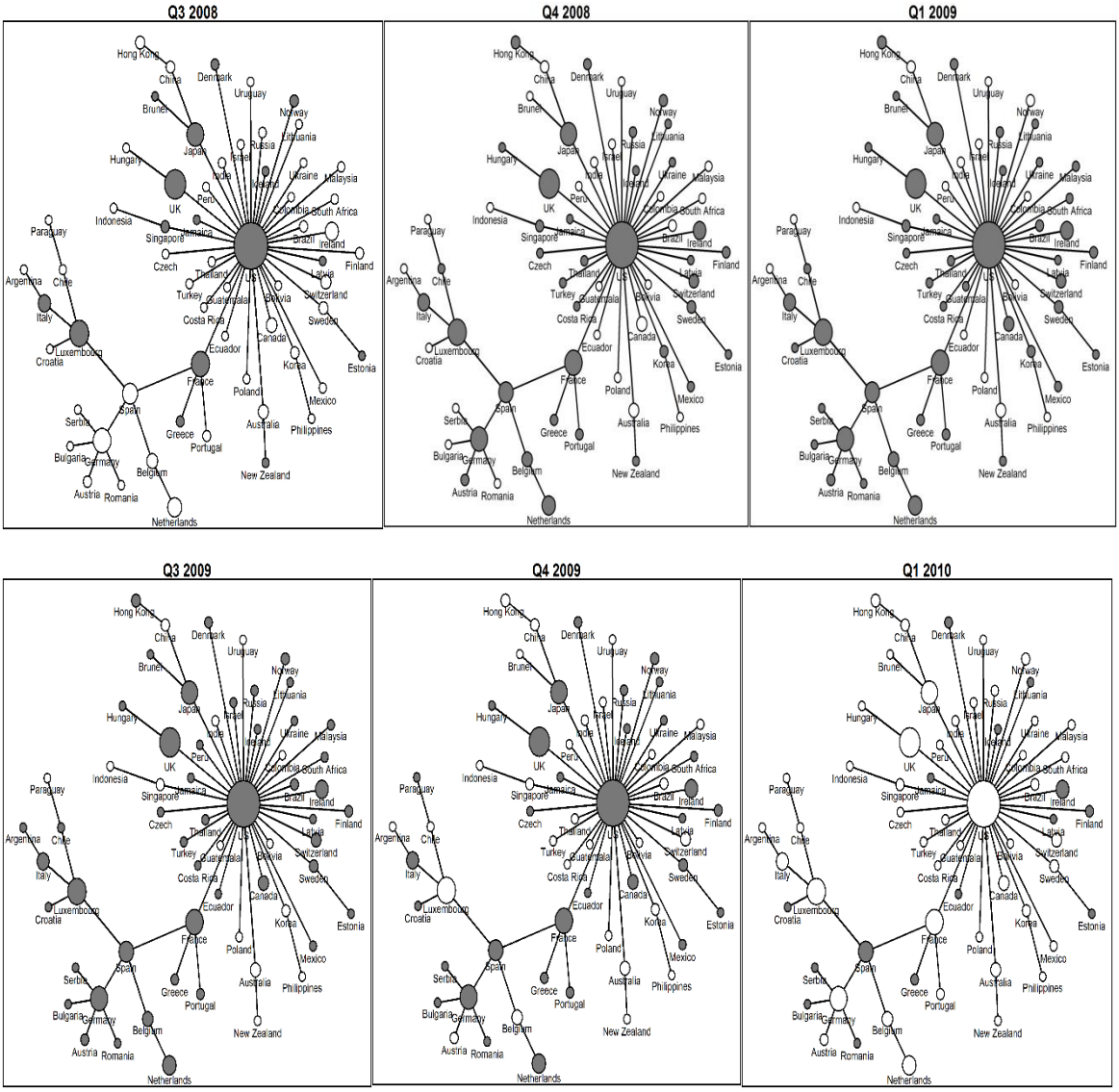
3.2.1 Real GDP

Figure 4 shows a slightly different procedure of output decline and recovery along the financial network. Reflecting the financial crisis from the third quarter of 2008, the real GDP growth rate in the United States turns negative with several secondary hubs. The output decline which started in the United States is transmitted to the secondary hub economies such as the United Kingdom, France, Japan, Luxembourg, and Italy.[2] The Germany cluster, however, is not affected and independent of the crisis effect in the same quarter.

Even in the first quarter of 2009, when most European countries enter into a recession, some Asia and Latin economies do not enter into recession. Although more countries are directly connected to the United States in the financial network, there is still some divergence in the crisis propagation depending on regional groups. The recovery process is in the reverse order, except for Luxembourg which initiates the recovery process. By the first quarter of 2010, most economies have recovered from the crisis.

[2] The big players in portfolio investment assets are the United States, the United Kingdom, Japan, Luxembourg, Germany, France, Ireland, Netherlands, Switzerland, and Italy.

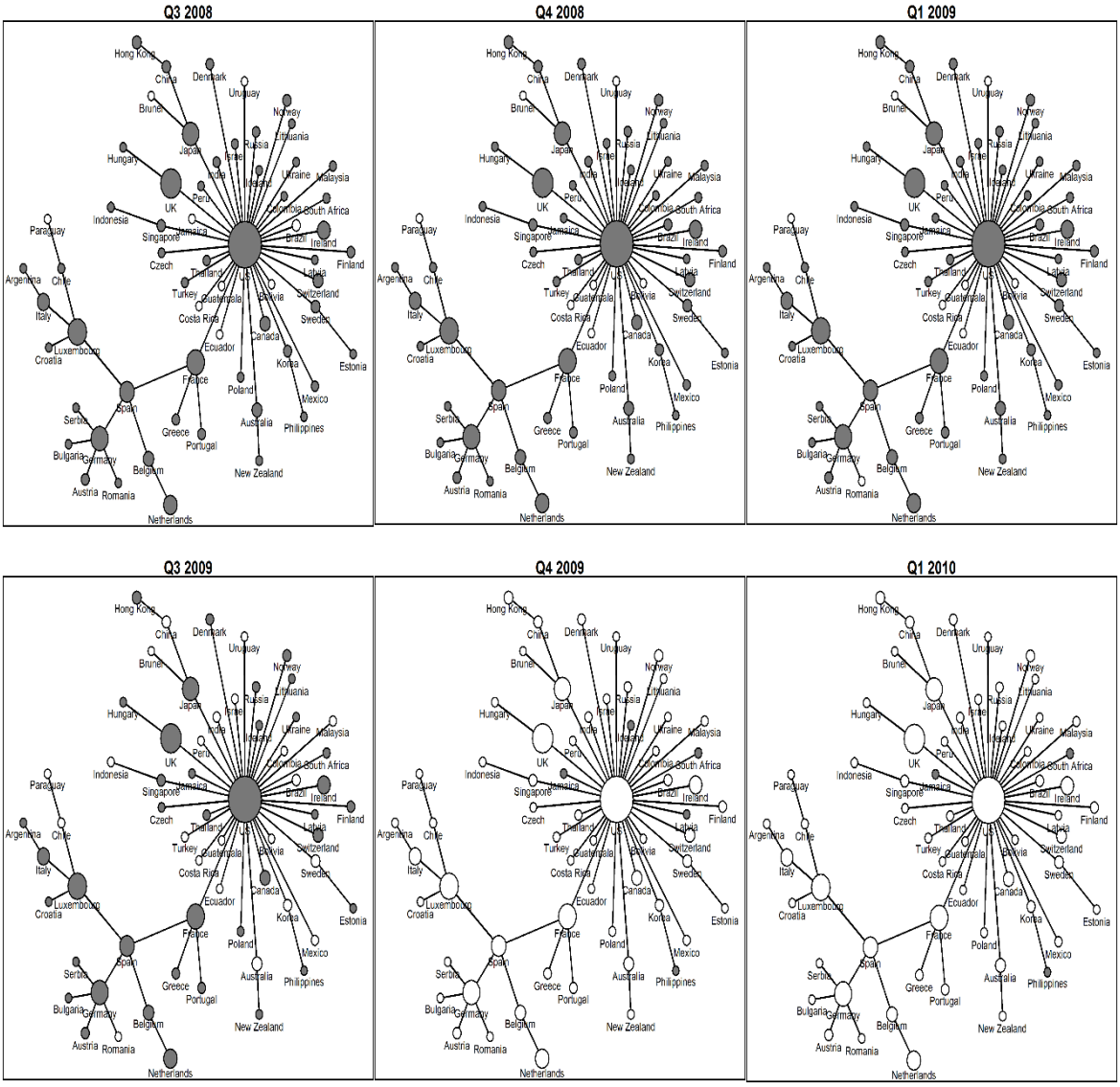
Figure 4
The Financial Network and Changes in Real GDP



3.2.2 Stock Market Performance

In the third quarter of 2008, share price indices plummet in most of the main and secondary hub countries and clusters. There is no delay in response of share price co-movement across any type of country groupings. In sum, financial linkage provides a quick and easy transmission channel for share price co-movement after the global crisis (Figure 5).

Figure 5
The Financial Network and Changes in Share Price Index



3.3 Country Group

3.3.1 Asia-Pacific Economies and the Chiang Mai Initiative

How were Asia and Pacific economies affected by the global financial crisis of 2008? Asia has experienced two strands of change: the rise of China in its trade on the one hand, and the regional monetary policy cooperation after the Asian crisis of 1997 on the other. Figure 6 and Figure 7 show how each country group, marked with lozenge, is affected by the global crisis.

The output decline is observed only in Japan, Brunei Darussalam, New Zealand, and Singapore in the third quarter of 2008. Most of the other Asia-Pacific economies are not much affected, showing positive real GDP growth rates. Figure 6 shows that even in the deep recession of the first quarter of 2009, some Asia-Pacific countries do not enter into recession (left panel). The rebound from the recession has also been more significant in Asia-Pacific economies in the following quarters of 2009. The countries hit by the Asian crisis in 1997 (especially Korea, Malaysia, Philippines, and Thailand) show substantially sound response in the wake of the global crisis.

This result suggests two important possible explanations. One is that regional factors are still more important in the process of crisis transmission. The rising role of China in regional and global trade may have helped in slowing down the propagation of the global crisis of 2008. China has emerged as a regional economic hub and absorbed external shock as a big purchaser of manufacturing goods and a big supplier of surplus capital. The other possible explanation is that financial policy coordination in the Asia-Pacific region may have also helped in slowing down the crisis propagation. The Asian crisis of 1997 has driven Asian economies into stronger regional financial policy coordination[3]. The main objective of the Chiang Mai Initiative, for example, is to provide financial support through currency swap transactions to the participants facing balance-of-payments and short-term liquidity difficulties. This has contributed in strengthening the resilience of Asian countries to the global economic crisis.

In the case of stock market (right panel of Figure 6), however, Asia-Pacific countries enter into recession with other countries simultaneously. This is in line with Park (2013) who shows that the global financial shock hit Asian equity markets significantly, and to the degree of which is greater than that of regional shocks. This is consistent with the observation that capital flows to emerging Asia have increased substantially over time, and that movements in the region's domestic equity index have converged with those in global markets.

3.3.2 Inflation Targeting Economies

The global financial crisis has casted an open-ended question as whether inflation-targeting is an appropriate policy tool for the purpose of financial stability. Several inflation-targeting countries such as Hungary, Iceland, Romania, and Serbia, have been hit by the global crisis and have entered into IMF-supported programs (Roger, 2010). The inflation targeting system faces a severe challenge that it may not be an appropriate policy tool in the event of a financial crisis. It is not proven or clear whether the rigid application of inflation targeting has made these countries more susceptible to crises compared to other economies with other policy regimes.

[3] Examples of such cooperation include the ASEAN+3 Economic Review and Policy Dialogue, the Chiang Mai Initiative (CMI), the Asian Bond Market Initiative (ABMI), and the Asian Bond Fund Initiative (ABF1 and ABF2).

Figure 6
The Trade Network and Country Groups: Q1 2009

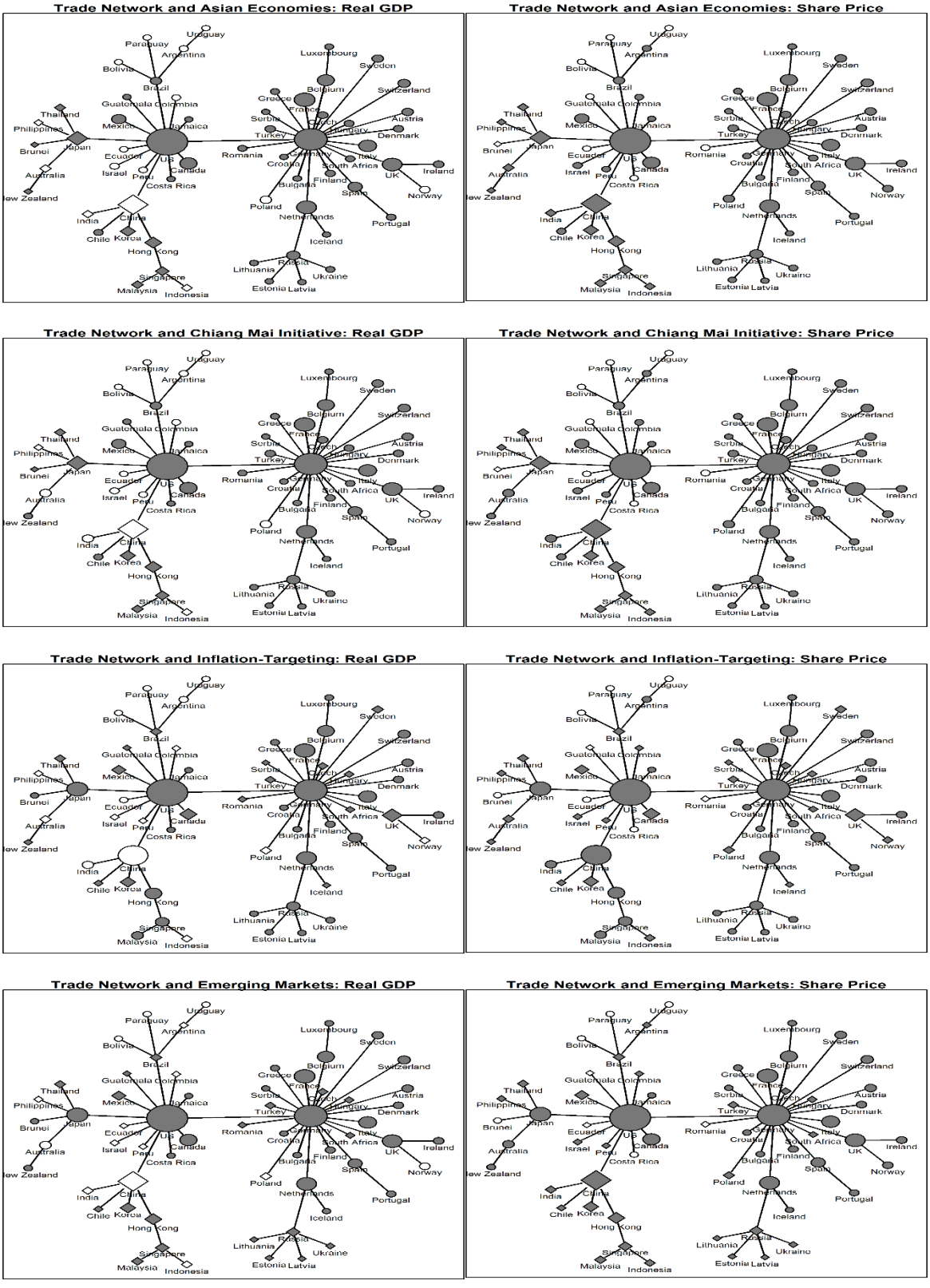
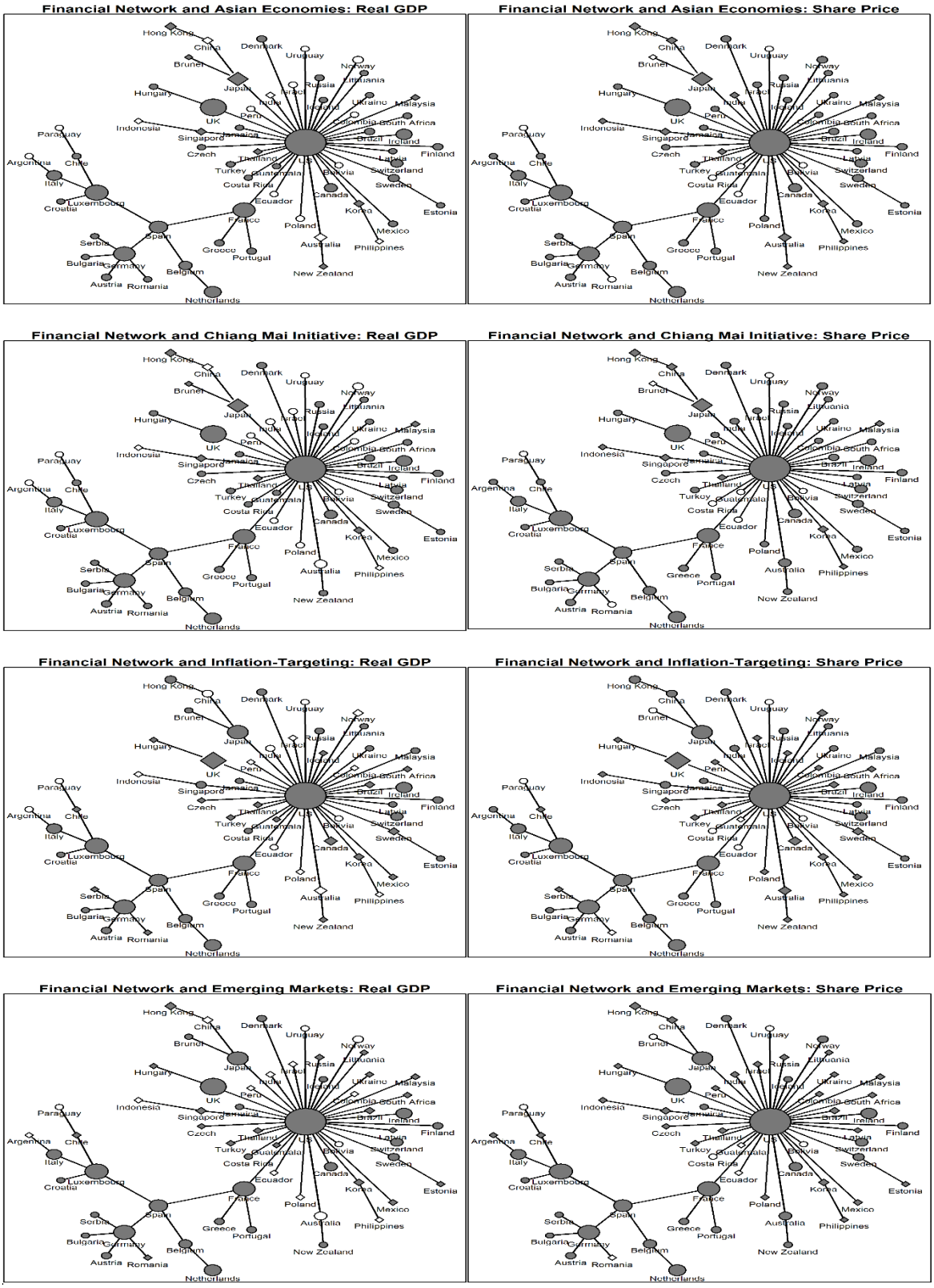


Figure 7
The Financial Network and Country Groups: Q1 2009



As Figure 6 (left panel) reveals, inflation-targeting countries seem to be less affected by the global crisis. The inflation-targeting emerging economies, especially in Asia and Latin America, are less adversely affected by the global financial crisis. In the third quarter of 2008, only high-income inflation-targeting countries enter into negative output growth. The United Kingdom, Norway, Iceland, and New Zealand took the lead with other inflation-targeting countries following.

3.3.3 Emerging Market Economies

If we restrict our discussion to the trade network, the finding that regional factors are more important in the process of crisis transmission seems also true to emerging market economies. Figure 6 reveals that emerging market economies show output co-movement by regional country groups such as Asia-Pacific, but not as a whole emerging market (left panel). Therefore, the co-movement of the whole emerging market economies needs to be tested in more detail in the next section.

However, financial markets (right panel) are still more integrated with the global financial hub than with any other regional financial markets. This result is similar to that in Park (2013).

4. Robustness Check: Regression Analysis

We have analyzed, so far, the trade and financial networks through which the global crisis is propagated. In addition to the network approach, we also want to investigate the robustness of the results of the network analysis. In order to incorporate the network approach into econometric analysis, we need to go a few more steps. First, we have to calculate indices that represent the nature of the trade network and financial network. Second, we also have to define and collect additional pre-crisis fundamentals. Then, we can simultaneously investigate the effects of the economic networks as well as the additional pre-crisis fundamentals on the crisis propagation.

We calculate two kinds of network measures for each network. $Trade_i$ is the measure of trade network of country i, which is the degree of trade integration of country *i* with the rest of the world. Likewise, $Finance_i$ is the measure of financial network of country i, which is the degree of financial integration. The network measure is calculated by both the eigenvector centrality method and the geodesics from the US. Each network measure is the average for the pre-crisis period over 2001-2007, since the main focus in this study is to investigate the effects of the pre-crisis factors on the global crisis. The eigenvector centrality score (S_i) for the trade network ($Trade_i$) and the financial network ($Finance_i$) for country i is given by equation (5):

(5) $S_i = \frac{1}{\lambda}\sum_j A_{ij}S_j$

where, λ is the eigenvalue of the matrix $\left(A_{ij}\right)_{i,j=1,2,\ldots,61}$

$A_{ij} = \frac{1}{7}\sum_{t=2001}^{t=2007} X_{ij}(t)$ is the weight of the link between country i and j,

$X_{i,j}(t)$ is the total trade flows (exports+imports) between country i and j in the trade network ($Trade_i$), and total portfolio asset flows (outflows+inflows) between country i and j in the financial network ($Finance_i$)

Also, the network measures by using the geodesics from the United States are also calculated. The R-package calculates the geodesics by using the inverse of the weight of the link between country i and j (A_{ij}^{-1}) as the distance of the link.

The effects of the economic networks as well as the additional pre-crisis fundamentals on the macroeconomic shocks can be traced using the following relationship. The shock on the macroeconomic variable j in country i is a function of a country's level of trade and financial networks with the rest of the world. The pre-crisis fundamentals are also included as explanatory variables.

(6) $Crisis^i = F(Trade_i,\ Finance_i,\ Fundamental_i)$

The crisis effects ($Crisis^i$) are the rates of changes in real GDP (or, in share price index) in each economy, over the crisis period of the first quarter of 2008 and the first quarter of 2009. The above crisis period is selected because the first and second quarters of 2009 are the bottom of the crisis and the recovery starts from the third quarter of 2009 as a whole. However, problem occurs because of the different growth potential and timing of entering into recession across countries. In order to overcome the possible problem, we also use the rate of change in terms of the deviation from the trend, namely the shocks in the growth rates of real GDP and of share price index.

$Fundamental_i$ represents all other pre-crisis fundamentals such as international reserves, the current account, the real exchange rates, monetary policy regime, regional proximity and development level that could affect transmission of global shocks to country i.

In addition to the network measure, we include the constant dummy and slope dummy variables. The constant dummies represent several country groups such as countries with inflation targeting system (TARGET), participants in the Chiang Mai Initiative (CMI), Asia-Pacific economies (ASIA), Latin economies (LATIN), and emerging market economies (EME). These constant dummy variables are included to investigate whether there are any differences in crisis effect on the rate of change in real GDP (or, in share price index) among different country groups. The slope dummy variables in the form of interaction terms are also included for both the trade and the financial networks. These slope dummy variables are included to test whether the trade and financial networks play different roles in transmitting crisis effects among different country groups.

Several country-specific variables such as the current account/GDP ratio, the foreign reserves/GDP ratio, and the real effective exchange rate (REER) overvaluation are also tested for its significance. The current account/GDP ratio and the foreign reserves/GDP ratio are measured by the data in pre-crisis year 2007. The REER overvaluation in Q4 2007 is proxied by the detrended cyclical component of the REER in the fourth quarter of 2007, by using the Hodrick-Prescott filter over the period Q1 2000 and Q1 2014. We examine all countries, where the quarterly real GDP statistics are available from the International Financial Statistics. While the total number of countries in this study is 61, when we consider the country-specific fundamentals, the number of countries is reduced to 51 due to missing data.

4.1 Network Effects on Real GDP

We estimate the crisis effects on the rates of growth in real GDP and in share price index by using the Newey-West HAC (heteroskedasticity and autocorrelation consistent) estimator. We also use two alternative measures of network, the eigenvector centrality and the distance from the US. Table 2 summarizes the results on the rates of growth in real GDP. The two alternative measures of the network provide almost the same results.

When we focus on the eigenvector centrality measure of the networks (equation (1) and (2)), both the trade and the financial networks do not have any significant effect on the growth rate for the whole sample countries. However, most of the interaction terms of the network variables and country group dummies have a statistically significant effect on real GDP growth rates in each sample. We find that the trade network contributes a positive effect on real GDP growth rates of Asia-Pacific countries, but a negative effect on real GDP growth rates of participants in the Chiang Mai Initiative (CMI) and Latin countries. This result implies that the trade network contributes a less severe impact on the growth rates of countries in Asia-Pacific region in the propagation of the global crisis. However, the trade network seems to exert a more severe impact on the growth rates of the CMI participants and Latin economies. This result also corroborates the result of the network graphical analysis of the previous section.

We find significant but opposite signs in the case of the financial network. The financial network seems to contribute a negative effect on real GDP growth rates of Asia-Pacific countries and inflation targeting countries. However, the financial network exerts a positive effect on real GDP growth rates of CMI participants. This implies that the financial network helps CMI participating countries to demonstrate resilience in the advent of the global crisis. Since we standardize the two network measures as relative indices to the US (US measure=100), the relative magnitudes imply that the trade network dominates the financial network as the propagation of output declines.

Table 2
Crisis Effects on the Rate of Growth in Real GDP

	Eigenvector Centrality[a]		Distance from the US[b]	
	Actual Rates (1)	Detrended Shocks (2)	Actual Rates (3)	Detrended Shocks (4)
$Trade\ (Trade\ Network)$	-0.00 (0.92)	-0.01 (0.79)	0.06 (0.59)	0.01 (0.97)
$Trade \times TARGET$	0.01 (0.61)	0.02 (0.55)	-0.03 (0.77)	0.02 (0.88)
$Trade \times CMI$	-2.17** (0.00)	-1.52** (0.00)	-6.87** (0.00)	-4.81** (0.00)
$Trade \times ASIA$	2.25** (0.00)	1.53** (0.00)	7.02** (0.00)	4.80** (0.00)
$Trade \times LATIN$	-0.81** (0.01)	-0.04* (0.08)	-0.12** (0.00)	-0.06** (0.03)
$Finance\ (Financial\ Network)$	0.01 (0.43)	0.02 (0.44)	0.12 (0.26)	0.16 (0.30)
$Finance \times TARGET$	-0.04** (0.02)	-0.04** (0.04)	-0.22** (0.03)	-0.20* (0.06)
$Finance \times CMI$	0.52** (0.00)	0.39** (0.00)	0.67** (0.03)	0.56** (0.03)
$Finance \times ASIA$	-0.66** (0.00)	-0.46** (0.00)	-1.23** (0.00)	-0.86** (0.00)
$Finance \times LATIN$	-0.18 (0.25)	-0.12 (0.32)	-0.53 (0.24)	-0.31 (0.34)
REER Overvaluation in Q4-2007	-0.16** (0.01)	-0.13** (0.01)	-0.16** (0.01)	-0.13** (0.01)
TARGET (Inflation-Targeting)	3.30** (0.01)	2.74** (0.00)	3.46** (0.01)	2.83** (0.00)
CMI (Chiang Mai Initiative)	4.89** (0.05)	3.38* (0.07)	6.56** (0.02)	4.54** (0.03)
ASIA (Asia-Pacific)	-3.04** (0.04)	-2.14* (0.06)	-4.53** (0.01)	-3.21** (0.02)
LATIN (Latin Countries)	3.61** (0.04)	2.01 (0.12)	3.58** (0.05)	1.99 (0.13)
EME (Emerging Market)	-2.46** (0.04)	-2.84** (0.00)	-2.35** (0.04)	-2.82** (0.00)
Constant	-2.91** (0.00)	-3.05** (0.00)	-3.16** (0.00)	-3.14** (0.00)
R-squared	0.61	0.55	0.62	0.55

Notes: The growth rates in real GDP (the dependent variable) are measured over the crisis period between Q1-2008 and Q1-2009. The actual growth rates in real GDP are used in equation (1) and (3), while the detrended growth rates (by the Hodrick-Prescott filter) are used in equation (2) and (4). Newey-West HAC method is used to correct the heteroskedasticity and autocorrelation, and the associated probabilities are in parentheses. ** and * indicate the significance level at 5% and 10%, respectively. a) uses the network measure calculated by the eigenvector centrality method, and b) uses the network measure calculated by the inverse of the distance from the US. Each centrality measure is the average for the pre-crisis period over 2001-2007.

Regarding the country-specific fundamentals, we find that the real effective exchange rate (REER) overvaluation plays an important, but negative effect on the growth rate (and the detrended growth rate) for the sample countries. When a country has an overvalued currency (in terms of positive cycles from the trend), it is likely that the overvalued currency can exert a downward effect on the country's real GDP growth rate. However, the current account/GDP ratio and the foreign reserves/GDP ratio are not found to be significant in any form of specification, which is in line with Berkmen et al. (2009).

Since the United States is the epicenter of the 2008 global financial crisis, we also analyze the effects of networks measured by the inverse of the distance from the US (equation (3) and (4)). The results are not very different from those of networks measured by the eigenvector centrality method. The results for the detrended growth rates are also not different from those for the actual growth rates.

We can summarize a few interesting findings from the regression analysis of growth effect. First, the trade and financial networks do not have any significant effect for the whole sample country. Second, the two networks enter significantly (with different signs) in the case of country group such as inflation targeting economies, CMI participants, Asia-Pacific countries, and Latin countries. Third, the trade network dominates the financial network in its magnitude of growth effect within each of the country group.

4.2 Network Effects on Stock Market

Table 3 presents the crisis effects on the rates of changes in share price index. The main thing to note is that the financial network enters significantly and with a positive sign in the share price equation for the whole sample countries. This implies that higher financial integration among countries seems to exert less intense stock market decline. The result that higher international financial linkage leads to less intense crisis seems counterintuitive. Rose and Spiegel (2010) suggest a similar result that countries with greater exposure to the US assets experienced less severe stock market crises. The main reason for the surprising result is that countries with higher financial network index (such as the United States, the United Kingdom, Germany, Japan, Netherlands and Spain) have experienced less stock market declines. On the other hand, most of the countries with lower financial network index (such as Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Iceland, Latvia, Lithuania, Russia and Serbia) have shown dramatic stock market declines. These stock market performances may have brought the surprising result that higher financial network among countries seems to exert less intense stock market declines.

Table 3
Crisis Effects on the Rates of Changes in Share Price Index

	Eigenvector Centrality[a]		Distance from the US[b]	
	Actual Rates (1)	Detrended Shocks (2)	Actual Rates (3)	Detrended Shocks (4)
$Trade$ ($Trade\ Network$)	0.12 (0.51)	0.07 (0.62)	0.31 (0.12)	0.18 (0.30)
$Trade \times CMI$	1.62 (0.39)	3.15** (0.05)	8.10 (0.29)	12.0* (0.06)
$Trade \times ASIA$	-1.65 (0.35)	-3.23** (0.04)	-8.50 (0.25)	-12.5** (0.05)
$Finance$ ($Finance\ Network$)	0.19** (0.03)	0.18** (0.02)	1.64** (0.02)	1.33** (0.02)
$Finance \times CMI$	-0.31 (0.62)	-0.69 (0.18)	-1.34 (0.43)	-1.58 (0.26)
$Finance \times ASIA$	-0.03 (0.96)	0.60 (0.20)	-0.77 (0.54)	0.57 (0.58)
REER Overvaluation in Q4-2007	-2.18* (0.09)	-1.45 (0.15)	-2.48** (0.03)	-1.68* (0.06)
TARGET (Inflation-Targeting)	16.0** (0.00)	11.3** (0.01)	13.3** (0.01)	9.21* (0.06)
CMI (Chiang Mai Initiative)	-21.4 (0.21)	-23.0 (0.11)	-26.2 (0.20)	-27.5 (0.11)
ASIA (Asia-Pacific)	25.9** (0.02)	24.5** (0.01)	33.2** (0.03)	30.9** (0.02)
EME (Emerging Market)	10.6* (0.07)	6.26 (0.19)	11.8* (0.08)	6.84 (0.19)
Constant	-41.3** (0.00)	-36.5** (0.00)	-41.0** (0.00)	-35.9** (0.00)
R-squared	0.42	0.31	0.45	0.33

Notes: The rates of changes in share price index (the dependent variable) are measured over the crisis period between Q1-2008 and Q1-2009. The actual rates of changes in share price index are used in equation (1) and (3), while the detrended rates of changes in share price index (by the Hodrick-Prescott filter) are used in equation (2) and (4). Newey-West HAC method is used to correct the heteroskedasticity and autocorrelation, and the associated probabilities are in parentheses. ** and * indicate the significance level at 5% and 10%, respectively. a) uses the network measure calculated by the eigenvector centrality method, and b) uses the network measure calculated by the inverse of the distance from the US. Each centrality measure is the average for the pre-crisis period over 2001-2007.

The trade network does not have a significant effect on share price changes for the whole sample countries. However, when we use the detrended share price changes as a dependent variable (equation (2) and (4)), the trade network enters significantly in CMI participants with a positive sign, and in Asia-Pacific countries with a negative sign. Countries that participate in the CMI seem to have less severe stock market declines with the help of the swap agreements. The overvalued currency also exerts a downward effect on the country's stock market performance.

5. Conclusion

This paper investigates the possible networks through which the global crisis of 2008 was transmitted across economies. The question arises as to whether or not countries have become more vulnerable to common shocks through the trade and financial networks.

We use an eclectic approach that incorporates the dynamic network approach into econometric analysis in identifying the crisis transmission channels. The main premise of this paper is made by using the following steps. First, we construct the trade and financial networks and provide clear visualizations of the networks. Second, we combine the trade and financial networks with crisis incidence such as the changes in real GDP and share price index. Third, we re-incorporate the network analysis into cross-country regression analysis to identify the network effects.

We find some interesting results regarding the network effects on the crisis incidence. First, both the trade and the financial networks do not have any significant effect on the growth rate of real GDP for the whole sample countries. However, in the case of stock market, the financial network has a significant positive effect on the rate of change of share price index for the whole sample countries.

Second, when considering specific country group such as Asia-Pacific countries, the two networks have a significant effect on real GDP growth rates within some country groups. The trade network contributes a positive effect on the real GDP growth rates of Asia-Pacific countries, but a negative contagion effect on those of participants in the Chiang Mai Initiative (CMI) and Latin countries. This result implies that the trade network contributes a less severe impact on the growth rates of Asia-Pacific countries, but a more severe impact on the growth rates of the CMI participants and Latin economies in the propagation of the global crisis. On the other hand, the financial network contributes a negative contagion effect on real GDP growth rates of Asia-Pacific countries and inflation targeting countries, but a positive effect on real GDP growth rates of CMI participants. This implies that the financial network helps CMI participating countries to demonstrate resilience to impacts of the global crisis. This result also corroborates the result of the network graphical analysis of the previous section.

Regarding the country-specific fundamentals, we find that only the real effective exchange rate (REER) overvaluation plays an important, but negative effect on the growth rate. When a country has an overvalued currency (in terms of deviations from the trend), it is likely for the overvalued currency to exert a negative impact on the country's real GDP growth rate and stock market performance.

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