Return and Volatility Spillover among Banks and Insurers: Evidence from Pre- and Post-Crisis Periods

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Abstract

We investigate the interdependencies among the U.S., U.K., EU and Japanese banking and insurance industries within a VAR-BEKK multivariate-GARCH framework. Cross-market and cross-industry return and volatility transmissions and the changes in these effects during the 2007-2009 crisis are examined. Several main results are obtained. First, linkages across the banking markets considered are strong at both return and volatility levels and mostly of a contagious nature, especially during the crisis. Second, U.S. emerges as the leading provider of volatility information in the banking industry. Return transmission is also in effect from U.S. banks to those in EU and U.K., while Japanese banks show weaker integration. Third, U.S. and EU insurance markets show bidirectional return and volatility contagion, which remain equally strong during the crisis, while Japanese insurers are little affected by cross-market shocks. Fourth, global banking and global insurance portfolios exhibit strong return and volatility spillovers which become more potent during the crisis. Information about return and volatility spillovers among banks and insurers sheds light on the interdependencies of the world financial markets, guides hedging and diversification strategists and aids investment advisors and fund managers interested in accurate asset pricing and risk management. More importantly, understanding of the shifts in market linkages during stressed market conditions can help in the design of regulatory standards aimed at reducing the frequency and intensity of future systemic crises and formulation of successful monetary policy across industrialized countries.

Key words: Banks, Insurers, Spillover, Contagion, Multivariate GARCH, Crisis

JEL Classification Codes: G21, G22, G15, G01, C58

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1. Introduction

In the recent decades, banking and insurance industries have witnessed a tremendous pace of geographic and product diversification, product convergence and consolidation at the domestic and international levels in response to increased deregulation[1], heightened competition and advancement in technology. These trends have strengthened the degree of interconnectedness and widened the global scope of activity in the financial services industry, resulting in a financial system which is more integrated and more prone to spillover of shocks and crises. Examples of spillover of crises include the U.S. market crash in 1987 (Koutmos and Booth, 1995), the Mexican currency crisis of 1994 (Forbes and Rigobon, 2002), the Asian financial crisis of 1997-98 (Bekaert et al., 2005) and the credit crunch of 2007-2009 (Pukthuanthong and Roll, 2009; Goldsmith-Pinkham and Yorulmazer, 2010), all of which threatened the stability of the world financial system.

Product diversification by banks and insurers and convergence of the two industries occurred in the comparatively relaxed operating environment of the 1990s. In the U.S., the Gramm-Leach-Bliley Act (1999) allowed banking, investment banking and insurance services to be offered under the same umbrella through the establishment of financial services holding companies. This period also witnessed a large wave of mergers and acquisitions (M&A) within and between the banking and insurance industries and within and across the regional borders[2]. The rapid pace of convergence, consolidation, integration and globalization of the financial industry strengthened the linkages among banks/insurers (Berger et al., 1999; Cummins and Xie, 2008) and across industries and national borders. These phenomena have

[1]Deregulatory Acts in the U.S. financial markets include: the Depository Institutions Deregulation and Monetary Control Act (1980), the Competitive Equality in Banking Act (1987), the Financial Institutions Reform Recovery and Enforcement Act (1989) and the Gramm-Leach-Bliley Act (1999).

[2] See the report on *Consolidation in the Financial Sector* (2001) available via the Bank for International Settlements' website: http://www.bis.org. Smith and Walter (1998) have documented the increasing trend in cross-border M&As during the late 1980s till late 1990s across both developed and emerging economies.

increased the vulnerability of the international financial system to shocks and prepared the background for greater and more frequent turmoil (De Nicoló and Kwast, 2002)[3]. They have also increased the need for policy co-ordination and regulatory harmonization across borders and reduced potential gains from international portfolio diversification.

Given the severity of economic consequences of these phenomena, clearly manifested during the financial crisis of 2007-2009, investigation of the degree of interconnectedness and intensity of the interactions among the global banking and/or insurance industries before and during this turbulent period is imperative. Information about the mechanisms, speed and intensity of the return/volatility spillover among banks and insurers can shed light on the interdependencies of the world financial markets, guide hedging and diversification strategists and aid investment advisors and fund managers interested in accurate asset pricing and risk management (Karolyi, 1995). More importantly, this information can help in the design of regulatory standards worldwide aimed at reducing the intensity of future crises and formulation of successful coordinated monetary policies among industrialized countries. This study investigates the extent and nature of these spillovers.

We make the following contributions. First, this is the first study to investigate return and volatility interdependencies within and between banking and insurance industries located in the U.S., major European countries and Japan. Existing studies have either focused on the global spillover of shocks among one particular financial intermediary (FI) type, such as banks or insurance companies (Elyasiani and Mansur, 2003; Carson et al., 2008), or they have limited their analysis to interactions among various types of FIs within a single economy, e.g. the U.S. (Elyasiani et al., 2007). We extend this line of research by investigating the international transmission of shocks within and across banks and insurers, using data on the largest financial markets of the world over the 2003-2009 period.

[3] Cummins and Weiss (2011) argue that core activities by the U.S. insurers do not raise systemic risk.

Second, we focus on market interdependencies at the industry level, rather than the aggregate market level, as pursued by most extant studies (Hamao et al., 1990; King and Wadhwani, 1990; Koutmos and Booth, 1995; Karolyi, 1995; Forbes and Rigobon, 2001). In so doing, we emphasize: a) the specialness of FIs, as the origin of shock spillovers to industrial sectors and global financial markets, within a given economic system (Saunders and Cornett, 2010; Kaminsky and Reinhart, 1999; Tai, 2004), and b) sector heterogeneity in shock transmission and the importance of industry-specific factors in determination of the impact of the shocks (Campbell et al., 2001; Baca et al., 2000; Cavaglia et al., 2000). Understanding the interaction dynamics between banking and/or insurance industries is crucial to regulators and policy makers in formulating coordinated monetary policies and designing regulatory frameworks conducive to the stability of the financial system. Knowledge of these interdependencies is also useful to investors and portfolio managers in search of new diversification opportunities, the gains from which are highly sensitive to the strength of the linkages among the chosen markets.

Third, our choice of the sample period allows us to investigate whether the cross-market linkages within and between banking or insurance industries were altered in response to the 2007-2009 crisis. This will help us better delineate of the cross-market, cross-industry impact of the FI activities during stressed conditions at the international level (Goetzmann et al., 2005)[4]. Fourth, we employ a generalized version of the multivariate VAR-BEKK model introduced by Baba et al. (1989) to simultaneously evaluate the interdependencies across returns as well as across volatilities of industry portfolios. This approach captures the well-documented time variation in the conditional covariance matrix of industry portfolio returns (Longin and Solnik, 1995; Engle, 2002); a clear advantage over the models that impose the

[4] The recent crisis had two phases, it started as a sub-prime mortgage crisis in the U.S. housing market in early 2007 then transformed into a global financial meltdown in the later part of 2008 (Eichengreen et al., 2009). Extant studies fail to cover the entire crisis period. For instance, Pukthuanthong and Roll (2009) examine the contagion effects of this crisis among 81 countries, but their sample period ends in February 2008.

restrictive assumption of constant asset correlations over time. Our model is also flexible enough to accommodate asymmetries in the impact of shocks to volatility, namely, it allows good and bad news to exert differential effects on volatility and, hence, on spillover effects.

To preview our key results, we find evidence of international return spillover and volatility spillover within the banking industry with return spillovers being stronger for small banks but volatility spillovers showing more prominence for large banks. Return and volatility spillovers are also observed within the insurance industry across the countries included in the sample indicating integration. The exception is the Japanese financial industry which emerges as relatively immune to shocks from other markets, even during the crisis period. Moreover, we find evidence of international cross-industry linkages between banks and insurers. Finally, there is significant strengthening in the level of interdependence during the crisis period in the banking industry, though not as much in the insurance sector.

At a more detailed level, several interesting findings are notable. First, in the banking sector, there is evidence of significant contagious return spillovers and of increased contagion effects between US, U.K and EU during the crisis period. A return spillover effect running from the U.S. banks to the U.K. banks, which is competitive in nature becomes contagious during the crisis. Same holds true of all competitive return spillover effects[5]. Second, the volatility spillover across banking portfolios is always of a contagious, rather than a competitive, nature and it is more prevalent than the return spillover. Moreover, our findings point towards the existence of an asymmetric transmission mechanism whereby negative

[5] A variety of definitions appear in the literature regarding spillover and contagion effects. Spillover and contagion are (interchangeably) referred to when changes in prices, liquidity and/or volatility in one market are transmitted to others. While spillover has been embraced in the context of transmission of both first and second moments of prices across markets (Hamao et al., 1990); contagion has been defined as a significant increase in cross-market linkages after a shock to an individual country or group of countries (Forbes and Rigobon, 2001). Kodres and Prisker (2002) define contagion quite generally as a price movement in one market resulting from a shock to another market; while Kyle and Xiong (2001) refer to contagion when returns become more volatile and more strongly correlated. Finally, spillover effects have been classified as 'contagion' when they become stronger during economic downturns (Allen and Gale, 2000; Forbes and Rigobon, 2002; Elyasiani et al., 2007). Here, we define spillover effect as the transmission of first and/or second moments of price information from one industry/market to another. We refer to positive (negative) spillover as contagion (competitive) effect.

shocks to an industry portfolio have a disproportionately larger impact on its volatility, and, consequently, on spillovers to other markets, than positive shocks. Our results also provide solid evidence in support of the leadership role of the U.S. banking industry as the origin of volatility spillovers. Prevalence of interdependence limits the gains due to international diversification and furthers the need for policy co-ordination among the countries considered.

Third, insurance markets emerge as strongly interconnected across regions, with mostly contagious return and/or volatility shocks from all other insurance markets, while Japanese insurers are largely insulated from international shocks indicating its segregation from the latter markets. Interestingly, in no case there is a shift in the magnitude of the return spillover effects among the insurers worldwide during the crisis period, an indication that the insurance industry was less heavily affected by the crisis, than the banking industry.

Finally, globally aggregated bank and insurance portfolios emerge as strongly inter related. There is evidence of contagion in returns spillover running from the insurance industry to the banking industry, which significantly strengthens during the crisis. The competitive return spillover effect running from banks to insurers during the crisis, can be attributed to the fact that insurers benefited from bankers misfortune because of flight to quality. Volatility transmission between the two industries is strong and bidirectional.

Our findings bear important implications for the regulatory objective of improving the resilience of financial institutions to stressed market conditions. The significant rise in cross-market dependence of banking sectors should be embedded in determining bank capital requirements as envisaged in the Basel III proposal (2011) for the introduction of stressed Value at Risk (VaR). Further, the rise in the extent of interdependence between global bank and insurance portfolios during periods of market stress should be factored in risk management practices of FIs in the light of regulatory initiatives for reduction of systemic risk. Finally, the finding that Japanese FIs are largely immune to shocks from other markets points to a direction for diversification for international investors.

The rest of the paper is organized as follows. Section two provides a brief overview of the literature. Section three describes the dataset and the estimation framework. Section four analyzes the empirical findings on the interdependence among banking and insurance industries across regions. Section five concludes.

2. Literature Review

Among the early studies of return/volatility spillover across FIs, Eun and Shim (1989) discover the dominance of return spillovers originating from the U.S. to nine major economies during 1979-1985; while Hamao et al. (1990) and King and Wadhwani (1990) unveil the prevalence of volatility spillovers from the U.S. to Japan and the U.K. during the 1987 stock market crash. These studies are, however, limited to only one type of spillover effect (either return or volatility) due to the shortcomings of their estimation frameworks. Subsequently, Koutmos and Booth (1995) and Karolyi (1995) use a simultaneous equation system of return and volatility spillovers and confirm the dominance of the U.S. market during the 1987 market crash. In the same vein, Elyasiani and Mansur (2003) find significant return spillover effects running from the U.S. to the German banks, but not to the banks in the Japanese market. Based on regionally syndicated indices, Bekaert et al. (2005) also unveil spillovers from the U.S. to Europe, Asia and Latin America during 1980-1986.

Focusing on corporate announcements, Lang and Stulz (1992) show that bankruptcy announcements by banks can have a negative effect on other banks, which is in line with Kaufman's (1994) argument that failure of one bank can spread to the rest of the banking system through bank runs. In a similar fashion, liquidity-related announcements (secondary equity offerings) and profit-related announcements (dividend cuts) by banks can impact the banking sector in a contagious manner (Slovin et al., 1992; Bessler and Nohel, 2000). As an example, Slovin et al. (1999) provide evidence that dividend cuts by U.S. regional banks exerted a competitive effect on their geographic rivals during 1975-1992.

More recently, Bartram et al. (2007) confirm the prevalence of spillovers across European countries and show that these countries are indeed more integrated in the aftermath of the introduction of the Euro than before. Dungey and Martin (2007) offer strong evidence of cross-market links between currency and equity markets during the 1997-1998 Asian crisis. Elyasiani et al. (2007) and Carson et al. (2008) focus, respectively, on the spillover among banks, insurers and investment banks and among different types of insurers (accident and health, life, property and casualty), within the U.S. market during 1991-2001. The former study shows that return (volatility) spillovers among the small institutions are stronger (weaker) compared to larger ones; while the latter study reveals strong (weak) return (volatility) spillover among the sub-sectors of the insurance industry.

Goldsmith-Pinkham and Yorulmazer (2010) investigate the bank run in the U.K. during the failure of Northern Rock (September 2007) and reinforce Kaufman's (1994) theory of transmission of bank failures via bank runs. Looking at market indices, Asgharian and Nossman (2011) offer evidence in support of the dominance of the U.S. market as the price and volatility information provider during 1982-2007. Eichengreen et al. (2009) suggest that during the 2007-2009 crisis default probabilities of large international banks, measured by their credit default swap (CDS) spreads, were interrelated, especially after the collapse of Lehman Brothers. Elyasiani et al. (2011) find that FIs which accepted the U.S. government rescue funding (TARP) had a positive impact spillover to the ones which did not.

While the existing literature has identified a number of interdependencies, it has failed to investigate the return and volatility interdependencies simultaneously. Moreover, given the pervasive time variations in market and sector correlations, the employment of basic constant correlation models and broad indices[6], rather than sector-specific portfolios, to investigate the integration of equity markets is likely to produce unreliable conclusions and policy implications. Similarly, focusing on a single type of FI, or on a single geographic market and/or industry can be misleading as it overlooks the prevailing high cross-industry, cross-market. We employ a comprehensive framework to avoid these shortcomings.

3. Data and Methodology

3.1. Data

We focus on two types of FIs: banks and insurers (life / non-life), and investigate the interdependencies within and between these FIs across geographical regions during normal economic conditions as well as crisis conditions. The sample includes the U.S., European, and Japanese banking and insurance industries. The European sample comprises France, Germany, Portugal, Italy, Greece and Spain, considered as a single portfolio in the Euro area (EU) while the U.K. banking and insurance firms are considered as a separate portfolio because U.K. is not a part of the Euro zone[7]. The sample period spans from January 1, 2003 to March 9, 2009 encompassing the recent financial crisis, which started on April 2, 2007 and ended on March 9, 2009[8]. Equity prices, stock market indices, long-term government bond yields (for Japan, the U.S., and the U.K.), syndicate EU long-term benchmark bond yield (for the EU countries) and trade-weighted foreign exchange indices (for the Euro, Japanese Yen, British Pound and U.S. Dollar) are collected from DataStream International. Prices are

[6] Several studies examine the spillover effects among regional markets (e.g. European, Latin American, and Asian markets in Bekaert et al., 2005) by investigating the influence of these markets on an individual national market. However, conventional regional indices contain all national market indices within the region, which introduces bias into the analysis of spillover effects. On the other hand, modified regional indices exclude the country under examination from the index (Asgharian and Nossman, 2011; Bartram et al., 2007).

[7] The 2010 Global Financial Stability Report by the International Monetary Fund (IMF) reveals that the combined EU, Japanese, U.K. and U.S. banking assets amount to over 60% of the global banking industry. The 2010 SIGMA report by Swiss Re also shows that over 75% of the insurance premiums in 2009 was generated by the North American, Western European and Japanese insurers.

[8] On April 2, 2007, the largest U.S. sub-prime lender - New Century Financial - filed for bankruptcy. On March 9, 2009, major equity markets reached their lowest levels during the crisis period, and recorded the biggest single day rally since 2007 in the following day (See Appendix 1).

reported in local currencies to avoid any potential bias due to relative currency fluctuations. In order to eliminate the issue of survivorship bias while maximizing the sample size, at any point in time the dataset contains all listed institutions whose stocks are actively traded.

For each country, equally-weighted portfolios are constructed for the banking and insurance industries separately. All banking (insurance) firms within the EU region; Germany, French, Portugal, Italy, Greece, Spain, form the EU banking (insurance) industry portfolio. As mentioned earlier, EU is treated as a single market due to the adoption of the Euro and the efforts of the EU countries to align their financial/legal frameworks. The sample starts in 2003 to avoid the early years of Euro as a single currency. In order to account for the institutions' size effect, banks are sorted into large and small-size portfolios based on their market capitalizations, using the top quartile market cap as the threshold. These size-based portfolios are rebalanced monthly to reflect variations in the market capitalization and to ensure that at any point in time the banks in the large size portfolio are the main players in the industry. The number of insurance firms within each market does not permit further disaggregation into meaningful size portfolios. Similarly, the number of banks in the U.K. is too small to form portfolios of different sizes.

The summary statistics of the industry close to close logarithmic portfolio returns over the entire sample period are presented in Table 1. Leptokurtosis in the portfolio return distribution evidenced by the kurtosis statistic and normality test, and volatility clustering evidenced by the Ljung-Box test on the squared returns support the use of the non-linear GARCH estimation framework adopted here. The mean portfolio returns reported in Table 1 illustrate that banking and insurance portfolios were strongly affected by the recent financial crisis with the effect on bank returns being more solid than that on the insurer returns. While before the crisis, all portfolios earned positive mean returns, which were particularly high for the insurance sectors, they all suffered huge losses during the crisis period. The U.K. banks and the U.S. insurers were the most severely affected among their peer institutions. As a result, the average daily returns over the entire sample period (2003-09) are negative for all the portfolios of all regions (Row 1). A graphical depiction of the banks/insurers equity values, presented in Appendix 1, documents the strong degree of co-movement among FIs in the U.S., U.K. and Europe, which is not mirrored by those in Japan.

TABLE 1

Looking into cross-border market interdependencies requires accounting for different trading time zones. The Tokyo Stock Exchange opens at GMT 0:00 and closes at GMT 6:00; followed by the London Stock Exchange opening at GMT 8:00 and ending at GMT 16:30. The New York Stock Exchange operates from GMT 14:30 to GMT 21:00. Thus, the daily price information generated from Japan and the U.K. is likely to influence the U.S. the same day, the U.S. market will affect Japan and the U.K. the next day and Japan will be affected by the U.K. the following day. Non-synchronous trading is addressed by adjusting for these time-lags in the model. The advantages of daily return data used here include the following: a) they capture the short-lived spillover effects among financial assets better than weekly and monthly data (Eun and Shim, 1989; Hamao et al., 1990, De Santis and Gerard, 1997), and b) they provide more observation points and, thus, enhance the estimation efficiency. On the negative side, daily data are subject to more noise.

3.2. Model and Estimation Framework

Our estimation framework is based on the diagonal VAR-BEKK model (Baba, Engle, Kraft and Kroner (1989) aiming to capture the return and volatility transmissions among portfolio equity returns. Existing studies have employed a constant correlation model (Elyasiani et al., 2007) in spite of the evidence that correlations are time-varying (Cappiello et al., 2006). The BEKK framework facilitates the estimation of the conditional multivariate covariance matrix (H_t) of asset returns and can accommodate the time variation in return co-movement. Moreover, simultaneous estimation of the industry portfolios' conditional mean returns and covariance matrix improves parameter estimation efficiency and produces more reliable inferences. The mean return equation (eq. 1 below) is specified as a multifactor equation[9]. The factors include unexpected changes, estimated via an appropriate-lag ARMA filter, in daily holding period returns of long-term government bonds, trade-weighted foreign exchange indices and national/regional stock market indices. Interdependencies between domestic and foreign banks (insurers) are conceptualized as spillovers of returns and volatilities from foreign FIs in either of the two industries. Changes in industry interdependencies during the 2007-2009 financial turmoil are captured by the use of interaction dummies with cross-return and cross-volatility regressors with the dummy taking the value of 1 during the April 2, 2007 – March 9, 2009 period. The four equation system describing the returns on industry portfolios of the EU, Japan, U.K. and U.S., can be presented in a matrix form as follows:

$$R_t = \beta \circ F_t \cdot 1 + \Theta \circ R_t^* \cdot 1 + D \cdot \Gamma \circ R_t^* \cdot 1 + \varepsilon_t \qquad \varepsilon_t \sim N(0, H_t), \tag{1}$$

$$F_t = \begin{bmatrix} 1 & r_{m,EU,t} & FX_{EU,t} & IR_{EU,t} \\ 1 & r_{m,JP,t} & FX_{JP,t} & IR_{JP,t} \\ 1 & r_{m,UK,t} & FX_{UK,t} & IR_{UK,t} \\ 1 & r_{m,US,t} & FX_{US,t} & IR_{US,t} \end{bmatrix} \qquad R_t^* = \begin{bmatrix} r_{JP,t} & r_{UK,t-1} & r_{US,t-1} \\ r_{EU,t-1} & r_{UK,t-1} & r_{US,t-1} \\ r_{EU,t-1} & r_{JP,t} & r_{US,t-1} \\ r_{EU,t} & r_{JP,t} & r_{UK,t} \end{bmatrix}$$

$$\Theta = \begin{bmatrix} \theta_{EU,JP} & \theta_{EU,UK} & \theta_{EU,US} \\ \theta_{JP,EU} & \theta_{JP,UK} & \theta_{JP,US} \\ \theta_{UK,EU} & \theta_{UK,JP} & \theta_{UK,US} \\ \theta_{US,EU} & \theta_{US,JP} & \theta_{US,UK} \end{bmatrix} \qquad \Gamma = \begin{bmatrix} \gamma_{EU,JP} & \gamma_{EU,UK} & \gamma_{EU,US} \\ \gamma_{JP,EU} & \gamma_{JP,UK} & \gamma_{JP,US} \\ \gamma_{UK,EU} & \gamma_{UK,JP} & \gamma_{UK,US} \\ \gamma_{US,EU} & \gamma_{US,JP} & \gamma_{US,UK} \end{bmatrix} \text{ where:}$$

$\circ$ is the Hadamard product (element-by-element multiplication of two matrices)

R_t is a [k × 1] vector representing the bank/insurance portfolio returns ($r_{i,t}$) over day t, while k refers to the number of portfolios employed. $i \in [EU, JP, UK, US]$ represents the European, Japanese, the U.K. and the U.S. market, respectively.

[9] The expected impacts of the risk factors on portfolio returns are available on request.

β is a [k × 4] parameter matrix with the first column representing the constants, while the second to fourth columns represent market ($\beta_{i,MKT}$), foreign exchange rate ($\beta_{i,FX}$) and interest rate ($\beta_{i,IR}$) betas for the corresponding portfolios.

F_t = a [k × 4] matrix with the first column representing the constants. The second to fourth column contain the market ($r_{mi,t}$), foreign exchange ($FX_{i,t}$) and interest rate ($IR_{i,t}$) risk factors for the corresponding portfolios over day *t,* proxied by the wide market return, the unexpected changes in trade-weighted currency index return, and the unexpected changes in daily holding period return of long-term government bond, respectively.

1 is a k-dimensional column vector of unities.

R_t* is a [k × k-1] matrix of lagged returns according to non-synchronous trading adjustment.

Θ is a [k × k-1] matrix with parameters (θ_{ij}) representing the return transmission effects over the sample period[10]. θ_{ij} represents the return transmission effect from a portfolio (banking or insurance) in market *j* to a portfolio in market *i* over the sample period. That is, looking at the first line of the Θ matrix, we can see the impact of the Japanese ($\theta_{EU,JP}$), the U.K. ($\theta_{EU,UK}$) and the U.S. ($\theta_{EU,US}$) sector portfolios on the EU sector portfolio for the sample period.

Γ is a [k × k-1] matrix with parameters (γ_{ij}) representing the change in the return transmission effect from a portfolio (banking or insurance) in market *j* to a portfolio in market *i* over the crisis period. That is, looking at the first line of the Γ matrix, we can see the incremental impact of the Japanese ($\gamma_{EU,JP}$), the U.K. ($\gamma_{EU,UK}$) and the U.S. ($\gamma_{EU,US}$) sector portfolios on the EU sector portfolio during the crisis period.

D is the crisis dummy; D = 0 before April 2, 2007 and D = 1 afterwards.

The error terms (ε_{it}) from each mean equation are assumed to follow a multivariate normal distribution with zero mean and conditional variance-covariance matrix H_t, which

[10] The parameter matrix $\boldsymbol{\Theta}$ measures the return transmission for the pre-crisis period and Γ measures the change during the crisis period. Same holds for the conditional variance coefficient matrices ($\boldsymbol{G}$, $\boldsymbol{Z}$).

evolves over time according to an extended BEKK framework. We employ a diagonal BEKK multivariate GARCH (MGARCH) specification (Engle and Kroner, 1995) to model the evolution of the conditional covariance matrix (H_t) of the portfolios in the four markets and extend it to incorporate cross-market volatility transmission effects. The extended BEKK-MGARCH model incorporating the spillover dynamics in the conditional covariance matrix can be described as equation 2 below:[11]

$$H_t = CC' + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'H_{t-1}B + I \circ [G \cdot H_t^{*\prime}] + D \cdot I \circ [Z \cdot H_t^{*\prime}] \tag{2}$$

$$H_t^* = \begin{bmatrix} h_{JP,t} & h_{UK,t-1} & h_{US,t-1} \\ h_{EU,t-1} & h_{UK,t-1} & h_{US,t-1} \\ h_{EU,t-1} & h_{JP,t} & h_{US,t-1} \\ h_{EU,t} & h_{JP,t} & h_{UK,t} \end{bmatrix} \quad G = \begin{bmatrix} g_{EU,JP} & g_{EU,UK} & g_{EU,US} \\ g_{JP,EU} & g_{JP,UK} & g_{JP,US} \\ g_{UK,EU} & g_{UK,JP} & g_{UK,US} \\ g_{US,EU} & g_{US,JP} & g_{US,UK} \end{bmatrix} \quad Z = \begin{bmatrix} z_{EU,JP} & z_{EU,UK} & z_{EU,US} \\ z_{JP,EU} & z_{JP,UK} & z_{JP,US} \\ z_{UK,EU} & z_{UK,JP} & z_{UK,US} \\ z_{US,EU} & z_{US,JP} & z_{US,UK} \end{bmatrix}$$

where H_t is a [k × k] matrix representing the conditional variance-covariance matrix of the error term (ε_t) over day t, while k refers to the number of portfolios employed.

ε_t is the [k × 1] day-t vector of error terms from the conditional mean equation (1).

C is a [k × k] lower triangle matrix. The product of CC' represents the unconditional part of the conditional variance-covariance matrix.

A and B are [k × k] diagonal parameter matrices dictating the multivariate ARCH and GARCH evolution of the conditional covariance matrix (H_t).

H_t* is a [k × k-1] matrix of lagged conditional variances ($h_{i,t}$) from H_t according to non-synchronous trading adjustment.

I is a [k × k] identity matrix.

G is a [k × k-1] matrix of parameters (g_{ij}) representing the volatility transmission from portfolio in market j to portfolio in market i in the pre-crisis period. That is, looking at the first line of the G matrix, we can see the impact of the Japanese ($g_{EU,JP}$), the U.K. ($g_{EU,UK}$) and the U.S. ($g_{EU,US}$) sector portfolios on the EU sector portfolio during the pre-crisis period.

[11] This system is a four equation model, with sector portfolios from EU, Japanese, U.K. and U.S. markets.

Z = a [k × k-1] parameter matrix with parameters (z_{ij}) representing the change in volatility transmission effect during the crisis period. z_{ij} represents the change in volatility transmission effects from the portfolio in market j to the portfolio in market i during the crisis period. That is, looking at the first line of the Z matrix, we can see the change in the impact of the Japanese ($z_{EU,JP}$), the U.K. ($z_{EU,UK}$) and the U.S. ($z_{EU,US}$) sector portfolios on the EU sector portfolio during the crisis period. D is as defined before.

In the proposed model, we assume that the volatility originating from the financial sector portfolio in one market can influence the volatility of portfolios in the other markets considered, but will not explicitly affect the covariance (correlation) between these portfolios. The rationale is threefold. First, Bekaert et al. (2005) have argued that changes in correlations among financial markets are due to changes in the common risk factors, not of volatility transmission. Therefore, it is unnecessary to introduce a full parameter matrix to incorporate volatility transmission effects on correlations. Second, the main purpose of our study is to investigate the cross-sectional return/volatility spillover across the domestic and international markets, not changes in correlations due to volatility spillover effects[12]. Third, by using a diagonal parameter matrix for volatility spillover we achieve parsimony and estimation tractability advancing the efficiency of the parameter estimates as a result.

The BEKK model can be extended to allow for asymmetry in the conditional variances and covariances. The asymmetric BEKK model allows for negative shocks to have a disproportionately bigger impact on the portfolio's own variance and on its covariance with other portfolios than positive news do. This model can be described as follows:

$$H_t = CC' + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'H_{t-1}B + N'\eta_{t-1}\eta'_{t-1}N \tag{3}$$

[12] The variance inflation factors (VIF) for the exogenous variables (F_t, R^*_t) in the mean equation (1) are in the range of 1.2 to 2.1; well below the critical value of 10. Multicollinearity can also be largely ruled out for the regressors in the variance equation (2) as the VIFs for the fitted variances (H_{t-1}, H^*_t) are below the critical value for 12 out of 14 of the sector portfolios. For the two exceptions correlations were high only in the crisis period.

In this model η_t is an indicator function $I[\varepsilon_t < 0] \circ \varepsilon_t$ where $\circ$ indicates the Hadamard product, and N is a [k × k] diagonal parameter matrix that captures the incremental effect of the past negative shocks on the covariance matrix (H_t). Our estimation and inferences are based on the non-normality-robust quasi-maximum likelihood framework of Bollerslev and Wooldridge (1992) in the context of models that jointly parameterize conditional mean and covariance.

4. Empirical Results

In this section we discuss our findings based on the extended VAR-BEKK model delineated in the previous section used to estimate the return and volatility interdependencies among banking and insurance portfolios in the EU, Japan, U.K. and the U.S. Demarcation of significant links between banking and insurance industries among the major markets considered unveils the interaction of these markets before and during the turmoil of 2007-2009, i.e. how markets affected one another during the ordinary times and the crisis period.

Several sets of results are discussed. First, results of joint hypothesis tests on multidirectional and unidirectional return and volatility interdependence (Tables 2-3). Second, detailed results on return and volatility transmission among banking portfolios across different geographic markets (Table 4). Third, results based on the extended model allowing for asymmetric effects (Table 5). Fourth, results on return and volatility transmission among insurance industry portfolios across different geographic markets (Table 6). Fifth, shock transmission effects between large (small) banking portfolios across different regions (not tabulated due to space limitation). Sixth, results on cross-industry shock transmission running from the U.S. banking portfolio to insurance portfolios of the remaining markets (Table 7). Seventh, results on interdependencies between global banking and global insurance portfolios (Table 8). Given that insurers have performed differently than banks during the recent crisis (Eling and Schmeiser, 2010; Harrington, 2009), it is interesting to examine the empirical evidence on cross-industry transmission using data from global capital markets in these two industries in order to determine to what extent the banking crisis influenced the insurance industry. Our analysis takes a U.S. perspective and primarily focuses on transmission effects from the U.S. to the other three markets and vice versa[13].

4.1. Industry Interdependence across Geographic Markets

Factors contributing to linkages among financial markets are several: a) these markets are influenced by similar macroeconomic/financial risk factors (Kodres and Pritsker, 2002); b) they are affected by actions of their "common creditors" such as shifting investments across markets (liquidity effect)[14]; c) they have trade interactions (Glick and Rose, 1999); d) they are subject to coordinated policy actions of the governments; and e) they have all undergone consolidations that combine banking, investment banking and insurance activities under one umbrella (De Nicoló et al., 2004). Two additional factors strengthen these linkages. First, FIs use similar models/techniques of risk measurement and risk management and, thus, expose themselves to similar risks. Second, advancement in technology allows speedy transmission of information across markets/industries and intensifies the shocks introduced to any of the markets/industries (Karolyi, 1995). Bekaert et al. (2005) have found that linkages among markets have increased during the last two decades. If market/industry movements are in the same direction, the phenomenon reflects common information spillover and is referred to as contagion; while movements in opposite directions represent competitive effects (see footnote 5). To investigate shock spillovers among FIs in different financial markets, we formulate the following eight joint hypotheses on return and volatility spillovers and their changes during the crisis and conduct tests of their validity by imposing parametric restrictions on the conditional mean and variance equations (1-2) in our model:

[13] The justification for this approach is that the U.S. market was the epicentre of the subprime mortgage crisis, which was later "transmitted" into the insurance sector and spread across geographic borders and transformed into a global financial crisis (Blackburn, 2008; Brunnermeier, 2009).

[14] The common creditors are "global investors", e.g., institutional investors, who concurrently operate in different markets and shift their investments in search of assets with higher liquidity (Vayanos, 2004), better credit quality (Eichengreen et al., 2009), or international diversification of their financial portfolios.

Multidirectional Return Interdependencies across Markets:

***H_1**: No cross-market return transmission in the pre- or post-crisis period ($\Theta = \Gamma = 0$).*

***H_2**: Cross-market return transmissions are identical in the pre- or post-crisis period ($\Gamma = 0$).*

Multidirectional Volatility Interdependencies across Markets:

***H_3**: No cross-market volatility transmission in the pre- or post-crisis period ($G = Z = 0$).*

***H_4**: Cross-market volatility transmissions are identical in the pre- or post-crisis period ($Z = 0$).*

Unidirectional Return and Volatility Transmissions across Markets:

***H_5**: No cross-market return/volatility transmission from the EU industry portfolios towards industry-based portfolios in the other markets (Japan, U.K., U.S.) in the pre- or post-crisis period.*

***H_6**: No cross-market return/volatility transmission from the Japanese industry portfolios towards industry portfolios in the other markets (EU, U.K., U.S.) in the pre- or post-crisis period.*

***H_7**: No cross-market return/volatility transmission from the U.K. industry portfolio towards industry portfolios in the other markets (EU, Japan, U.S.) in the pre- or post-crisis period.*

***H_8**: No cross-market return/volatility transmission from the U.S. industry portfolios towards industry portfolios in the other markets (EU, Japan, U.K.) in the pre- or post-crisis period.*

Table 2 and 3 present the likelihood ratio (LR) test results of the aforementioned joint hypotheses of interdependence[15]. In Table 2, rows 1-2 show the test results for the null hypotheses (H_1) of zero return interdependence across the banking markets and across the insurance markets, respectively. Rows 3-4 test whether these interdependencies changed during the crisis period (H_2). Rows 5-8 report the corresponding results on volatility interdependence (H_3, H_4). The LR test statistics for hypotheses (H_1-H_4) are highly significant for all subsamples of FIs examined, indicating that spillovers were in effect at both return and volatility levels and that these linkages did alter during the financial crisis of 2007-2009. The only case where the null hypothesis is not rejected is H_2 for the insurer portfolios, indicating that return transmission among insurers did not change during the crisis period.

[15] The LR test is carried out by assessing the difference in log-likelihood ratios (LLR) of the unrestricted and restricted versions of the VAR-BEKK model (equations 1–2) according to a given hypothesis.

TABLE 2

When large and small banks are separated (columns 2-3), the return spillover hypothesis (H_1) is found to be slightly more prominent across smaller banks, compared to their larger counterparts, while the volatility interdependence and the shifts in return/volatility interdependence during the crisis are all stronger for the larger banks. The prominence of return spillover for smaller banks can be attributed to costliness of information collection and the resulting herding behavior. Given the paucity of information on smaller banks and the greater cost of information collection for these firms (Calvo and Mendoza, 2000), some investors/institutions with lack of access to information prefer to follow other investors/ institutions or to "herd", to a greater extent than in the case of large institutions. The greater volatility spillover, and the greater shift in return/volatility spillover during the crisis, for the large banks are to be expected because common risk factors are more prevalent for large banks, especially during crises, due to their tendency to consolidate and become global (De Nicoló et al., 2004, DeYoung et al., 2009).

Table 3 summarizes the test results for hypotheses H_5-H_8, which investigate the return and volatility spillover effects from the industry-based portfolio in one market to those of the same industry in the remaining markets. The results indicate that financial markets across major economies are tightly connected as the null hypothesis of no return and volatility spillovers from one market to the remaining markets is rejected for all industry-based portfolios. These results hold for the aggregate industry portfolios as well as the large and small banking portfolios (columns 2-3). However, return and volatility spillovers originating from the U.S. towards other markets (the EU, Japan and the U.K.) are stronger as the LR test statistics for the U.S. industry-based portfolios are notably greater than the ones originating from other markets, regardless of the size and type of the institution (banks and insurers) examined. This finding is consistent with previous empirical studies, which find the U.S.

market to play a "leadership role" in price and volatility information transmission (Hamao et al., 1990; Asgharian and Nossman, 2011). It follows that policy makers and market participants outside the U.S. have to pay attention to the developments in the U.S. market as well as those of their own markets. In particular, the policy makers in the former regions would benefit from policy co-ordination with policy makers in the U.S. Comparatively, the spillover effects originating from the Japanese banking portfolios seem to have the least impact on the banking portfolios in the other markets as indicated by the relative size of the LR statistic (H_6 in Table 3). These results mirror the argument that relative to other developed markets, Japan has a more closed economy (Lawrence and Krugman, 1987; Flath, 2005).

TABLE 3

4.2.1. Interdependence across Banking Markets

Table 4 presents the VAR-BEKK estimation results for the spillover of return and volatility shocks among banking portfolios across different geographic markets. The spillover effects for the pre-crisis period as well as the shifts in the magnitude of the effects during the crisis of 2007-2009, relative to the pre-crisis period, are produced[16]. The latter effects are derived by introducing interaction terms between cross-returns or cross-volatilities and the crisis dummy[17]. Each column in Table 4 represents a shock-receiving market (EU, Japan, U.K., U.S.). Rows 1-6 (7-12) of a given column present the return (volatility) spillover effects from the other three markets in the order they appear in the table (EU, Japan, U.K., U.S.). For example rows 1-3, column 1 show the effect on the EU market of a shock in Japan, U.K., and U.S., respectively. Similarly, rows 1-3 of column 2 show the effect on Japan of a shock in the EU, U.K. and U.S. and rows 4-6 show the shift in the effect during the crisis.

[16] The estimates for parameter matrices A and B in equation 2, that drive the evolution of the covariance matrix, are available on request. As a robustness check we also present the estimated parameters obtained from the baseline BEKK model with no spillover effects in the conditional variance ($G = Z = 0$). The results largely coincide with the ones from equation (2). This serves to alleviate concerns regarding adverse effects of the contemporaneous correlation among the fitted variances of the different portfolios on the latter specification.

[17] To obtain the magnitude of the spillover during the crisis period, the coefficient obtained for the pre-crisis period and the coefficient of the interaction term obtained for the crisis period should be added up (footnote 10).

TABLE 4

Figures reported in Table 4 unveil some interesting results. First, there are significant return spillovers across the banking markets, three positive and three negative cases, indicating contagion and competitive effects, respectively. Cases of contagion include Japan to EU, U.K. to EU and EU to the U.K. Cases of a competitive effect include transmission of return shocks from EU to the U.S., U.S. to U.K., and U.K. to Japan before the crisis period. These latter three cases indicate the presence of rivalry between the corresponding pairs of geographic markets considered within the worldwide banking industry. Second, volatility spillovers across different geographic banking markets are in all cases of a contagious nature, indicating that volatility shocks to any of these banking markets would get transmitted to others in the same direction, elevating systemic risk.

Third, and more interestingly, during the crisis period of 2007-2009, the spillovers in returns across geographic markets alter in character and overwhelmingly support the presence of contagion during the market turmoil, based on the signs and the magnitudes of the interaction terms (rows 4-6). In all cases the competitive return spillover effect observed during the pre-crisis period changes to contagion effect during the crisis, as suggested by the positive sum of the cross-return coefficient and the coefficient of the interaction term. For instance, the return effect of the U.S. banks on the U.K. bank returns changes direction from negative (-0.161) in ordinary times to positive (0.273) as a result of a shift during the crisis period, indicating the strengthening of contagion forces at the expense of the competitive effects[18]. In other cases the pre-existing contagion sustains itself or further strengthens; in no case we observe a weakening of the contagion in returns during the crisis.

The volatility spillover also generally maintains its potency or strengthens during the crisis (rows 10-12). In two cases the volatility spillover does weaken during the crisis;

[18] Values reported for the cross-market spillover effects are per 1 unit change in the same or different industry.

transmission of volatility from the U.K. to EU and from EU to Japan. These lesser volatility spillover effects may have been caused by reduced market activity due to the frozen state of financial markets in response to high uncertainty and the unusual volatility observed during some phases of the crisis. This is an indication that results of ordinary times cannot be generalized to crisis conditions and that spillover need not necessarily strengthen in all cases. Some effects manifest themselves in a significant manner only during the crisis. For instance, the U.S. does not demonstrate any return transmission to the EU banking sector before the crisis, but it does exhibit a positive effect during the crisis period. Overall, these findings call for increased regulatory attention to the banking industry at the global level, along with the domestic markets, and the need for policy coordination among the regions because of their implications on systemic risk.

Fourth, most of the spillover effects are found to be asymmetric in terms of direction. For example, during the crisis, the statistically significant increase in return transmission from EU banks to their U.S. counterparts is substantially greater (0.298) than the reverse effect (0.115). Volatility spillover is present from the U.S. to EU (0.013 and significant) but not in the opposite direction (insignificant). This calls for greater attention to the markets which play a leadership role in originating or curbing the shocks. Fifth, some other results are also notable. The spillover in returns can be quite dissimilar to that in volatility. Particularly, in the case of the U.S. and Japanese banks, neither side has a return effect on the other even during the crisis, while both sides do exert a positive and mutual impact on one another's volatility, raising concern about systemic risk at the world level. While the lack of return spillover between the U.S. and Japan stands in contrast to some previous studies showing positive return transmission from Japan to the U.S. (Karolyi and Stulz, 1996; Peek and Rosengren, 1997)[19], it is consistent with the closed nature of the Japanese economy. This result is also in line with Elyasiani and Mansur (2003) who find insignificant return spillover from the Japanese banking sector to its U.S. counterpart and with Eun and Shim (1989), Hamao et al. (1990) and Koutmos and Booth (1995) documenting that price information generated from the Japanese equity market has no influence on the U.S. equity market.

The lack of return transmission between the U.S. and Japan may be, at least partially, due to the differences in the financial systems of these two countries. Under the bank-orientated system, adopted by Japan, financial resources of the public are mainly collected and distributed via bank retail deposits (Allen and Gale, 2001)[20], while under the market-orientated system, adopted by the U.S., banks' financing depends on the wholesale money and inter-bank market flows[21]. To be more specific, during the crisis period, the wholesale money/interbank market dried up quickly as banks were highly reluctant to provide funding and liquidity to one another[22]. As a result, liquidity shortages in the interbank market had a greater impact on banks in the U.S. financial system than those in the Japanese financial system[23]. In particular, when the U.S. banks suffered from low funding liquidity and were

[19] It is notable that the economic condition during the sample period 1988 to 1995, adopted by Karolyi and Stulz (1996) and Peek and Rosengren (1997) is different from ours. In the late 1980s, Japanese banks were the main credit supplier to the U.S. economy (Peek and Rosengren, 1997). Therefore, shocks in the Japanese banking sector had a positive impact on the U.S. financial market as the former directly influenced the liquidity condition in the latter. However, after the deep recession experienced by Japan in the early 1990s, Japanese FIs no longer played a dominant role in global financial markets. It is also possible that the nature of return generating models used in earlier studies where the volatility interaction dynamics are ignored biases the measurement of the shock transmission effects. Indeed, the return spillovers may be an artifact of volatility interdependence.

[20] Data from *Japanese Bankers Association* show that on average more than 68% of the Japanese banking assets is financed by retail deposits over the sample period. Backus et al. (2009) show that the Japanese saving rate was more than 30% of their GDP for most of the 44-year period from 1960 to 2004. In contrast, the U.S. national saving rate was only around 15% and dropped by almost 50% in the late 1990s (Page 21, Figure 1).

[21] See further discussion in Beck and Levine (2002), Blackburn (2008), and Goldsmith-Pinkham and Yorulmazer (2010). Data from the Federal Deposit Insurance Corporation (FDIC) show that on average only around 46% of the U.S. banks' assets are financed by retail deposits (03/2003–03/2009).

[22] Acharya and Merrouche (2010) and Ashcraft et al. (2011) show that the interbank lending market 'freeze' during the crisis period was mainly due to the precautionary hoarding of liquidity by banks. Precautionary hoarding occurs when banks hold more reserve and liquidity than the level needed to self-insure against shocks. This reduces the amount of available funding for interbank loan market.

[23] De Nicoló et al. (2004) suggest that retail deposits are the fundamental funding channel in a financial system, which is more reliable and stable compared to wholesale money market instruments. Therefore, banks financed through retail deposits enjoy a lower funding risk.

forced to de-leverage, their asset values dropped considerably due to the loss spiral[24] while Japanese banks were influenced to a smaller extent because their liquidity position was relatively strong and more resilient to the liquidity shocks.

4.2.2. Robustness of Bank Spillovers to the Size of the firm and the Sign of the shocks

In order to investigate the robustness of our findings, we conduct further tests by disaggregating the banks in the sample according to their size. Detailed results are not reported but are available upon request. Our results unveil only minor differences in spillover patterns of large and small banks. Specifically, the magnitude of return (volatility) transmission seems to be stronger for small (large) banking portfolios consistent with our joint hypothesis test results in Table 2[25]. We also deploy the asymmetric BEKK specification (eq 3) to allow for the possibility of asymmetric response of the conditional variance (h_t) to negative and positive shocks) of the same magnitude. The incremental effect of bad news, compared to good news, is represented by the parameter matrix *N.* Presence of asymmetric effects in the volatility of a given market, validated by significance of matrix *N,* implies asymmetric propagation of negative versus positive shocks to other markets. The results from the asymmetric BEKK model are displayed in Table 5.

TABLE 5

According to the parameter estimates reported in Table 5, no significant asymmetric effects (n_i) exist in the volatility of the banking sector portfolios across the four markets. Nonetheless, when the banking portfolios are disaggregated by size, significant asymmetries do manifest themselves. Specifically, large EU and U.S. banks respond more vigorously to bad news than to good news with the incremental effects of bad news being 0.088 and 0.031, respectively. This implies that under adverse market conditions volatility shocks to large

[24] For further discussion on the liquidity and loss spirals, refer to Blackburn (2008), Brunnermeier (2009) and Brunnermeier and Pedersen (2009).
[25] Elyasiani et al. (2007) find similar results based on spillover effects among the U.S. financial institutions.

banks in these countries will have a more potent effect on their counterparts in other countries. This phenomenon also holds for small EU banks for which bad news increase volatility by 0.040 more than good news do. This asymmetric transmission process could be a potential source behind the significant contagion effects associated with U.S. and EU banks.

4.2.3. Factors Driving Global Bank Spillovers

The spillover effects observed across banking sector portfolios can be mainly attributed to the following three elements. First, according to the Financial Stability Report 2008, issued by the Bank of England, the U.K./U.S. banks had \$192/\$195 billion invested in structured products. This extensive common investment by the U.K./U.S. banks in products such as mortgage-backed securities and structured investment vehicles (SIVs) originating in other regions, as well as the common holding of these products by banks in other regions considered, strengthened the potential for co-movement between these markets. Since investment in structured products was concentrated within the large banks, it was conducive to stronger volatility spillover among these banks. Second, the massive and simultaneous write-offs of the SIVs and liquidity shortages in the interbank market during the crisis were fundamental to pervasiveness, strength and duration of the effect of the shocks received (Brunnermeier, 2009). The fact that large banks were more heavily dependent on money market sources of funds and, hence, affected more severely by liquidity shortages, contributed to greater volatility spillover among them. Third, increased integration and globalization of financial markets in recent years (DeYoung et al., 2009) has increased the risk similarities among different types of FIs and across regions. These trends have led to common sources of underlying risk across FIs as well as adoption of similar risk assessment/ management models by these institutions (Carey and Stulz, 2006), exacerbating FI interdependencies and heightening systemic risk, especially during the economic downturn.

Shifts in the prevailing returns/volatility spillovers during the crisis can be similarly attributed to three elements. First, a sharp reduction in the appetite for risk within the global investment community including banks (Gonzalez-Hermosillo, 2008) triggered massive short positions in 'poor quality' mortgage-related structured products in international markets (Demyanyk and Hemert, 2009) and the well-known freeze of these markets. Second, the fair value accounting practice, known to engender pro-cyclicality and asset bubbles, led to the sharpening of the collapse in the market (Allen and Carletti, 2008). To elaborate, a 'synchronized' decrease in asset values across markets during the crisis exacerbated interdependencies among FIs as they were forced to write-down many of their investments from their balance sheets simultaneously, curtailing their market values (Blackburn, 2008; Brunnermeier, 2009). Third, the larger average size of the financial firms due to M&As in the recent decades and the greater level of concentration in the banking sectors led to stronger reactions by market players to any given shock to the system, further strengthening the interconnectedness of the financial industries (De Nicoló et al., 2004).

Finally, when size is taken into account, the findings on return and volatility spillover on large and small banks and their changes during the crisis are also consistent with the aforementioned arguments. The extent of similarity of risks among large FIs is positively associated with industry concentration (Carey and Stulz, 2006). As large FIs diversify into more products and enter new geographical regions, their similarities increase and ultimately lead to provision of similar products in similar regions (De Nicoló and Kwast, 2002). This view is reinforced by Cetorelli et al. (2007) who claim that dominant players in financial markets are becoming more and more alike and will be exposed to a greater number of common risk factors. Moreover, as consolidated FIs are likely to obtain more funding via the interbank markets, they tend to become exposed to similar funding and liquidity risks as well

(Berger et al., 1999). All these forces strengthen the potency of spillover across FIs and can, at least partially, explain the greater volatility contagion across larger firms.

4.2.4. Interdependence across Insurance Markets

Results for interdependencies across the international insurance industries are presented in Table 6. The format of the table is the same as Table 4. Analyzing the spillover effects among the four insurance markets considered (EU, Japan, U.K. and U.S.) unveils some notable results. First, all statistically significant return spillovers are of contagious nature, most of them pertaining to EU and the U.K, indicating a direct (positive) co-movement across the insurance markets. There is significant return interdependence between the EU and US sectors, whereas cross-market linkages with the Japanese insurance sector are relatively weaker. These findings indicate that the insurance sectors in the EU, UK, and US markets are subject to the same faith; they all do well or they all suffer, rather than one benefiting at the expense of another. This feature strengthens the contribution of the insurance industry worldwide to systemic risk.

TABLE 6

Second, unlike the banking sector, there are no shifts in the magnitude of the return spillover effects during the crisis period, indicating a lower scale of impact from the crisis on the insurance industry, compared to the banking industry. Third, cases of volatility spillover are infrequent and limited to EU and the U.S., denoting a lesser degree of integration among insurers, compared to banks. Fourth, according to the (unreported) asymmetric BEKK results, the incremental impact of negative shocks pertaining to EU insurers compared to the positive shocks stands at 0.025 and it is significant at the 1% level but insignificant for all other markets. Therefore, this asymmetric transmission mechanism could be the main driver behind the significant contagion effects found from the EU to the U.S. insurance portfolio. Fifth, significant shifts in volatility effects during the crisis period are also limited to EU and the U.S. Again, this is an indication that the insurance industry was not as substantially affected by the recent downturn, as the banking industry, and it contributed to a lesser extent to the systemic risk.

A few of the pair-wise results are notable. We find bidirectional positive return, as well as volatility transmission effects, between the EU and the U.S. insurers, with volatility spillover from EU to the U.S. strengthening during the crisis. These results indicate mutual contagion between the EU and U.S. insurance markets and a potential for raising systemic risk. In the case of the U.S. and the U.K., the return transmission effect runs from the U.S. to the U.K., reflecting the leadership role of the former, while the volatility transmission runs in the reverse direction. These results remain valid also during the crisis period with no significant changes in magnitudes of the effects. The U.K. and EU demonstrate strong bidirectional and symmetric return interdependence which remains unaltered during the crisis. Volatility spillover between these two markets is unidirectional from the U.K. to EU with a negative sign before the crisis, indicating a competitive effect, but it becomes a contagion effect during the crisis. These findings suggest that volatility shocks to the U.K. insurer market have a calming effect on EU, except during the crisis when they show contagion.

The Japanese insurance industry emerges as unaffected in terms of both return and volatility spillover shocks from the other markets. Specifically, only the U.K. and EU affect the Japanese insurer returns and they do so weakly, while the U.S. market fails to exert a return effect on Japan and there is no volatility spillover from any of the other markets (U.S., U.K., EU). Besides, there are no significant shifts in these return or volatility transmission effects during the crisis period. Nevertheless, the Japanese insurance industry does exert effects on both returns and volatilities of some other insurance markets. Return transmissions from Japan to the U.K. and EU are positive and significant and remain unchanged during the crisis period. However, the volatility transmission effects from the Japanese insurers towards all other markets are insignificant in the pre-crisis period though they do become significant during the crisis for EU and the U.K. (negative) and for the U.S. (positive). The interpretation is that heightened volatility in the Japanese insurance industry during the crisis had a calming effect on the former two markets (competitive), but it did result in increased fluctuations in the U.S. market (contagion). The negative signs of volatility spillover effects from Japan on the insurance sectors in EU and the U.K. during the crisis reflect the prevalence of rivalry between the latter and the insurance sector in Japan. The positive volatility impact from Japan on the U.S. is mainly due to the common risk factors shared by insurers across the two markets, e.g., the considerable write-offs of their financial assets during the crisis (Harrington, 2009).

The findings that return transmission effects across the insurance markets considered remain universally unchanged during the crisis for all of these markets (insignificant shifts due to crisis) may be because the nature of the common risk factors was unaffected in the post-crisis period. The finding of shifts in volatility co-movement during the crisis can be attributed to the sharp decrease in financial asset values held by the insurers in these markets and the consequent increase in their default probabilities. Since the default probability can be measured by the variability of a firm's equity value (Zhang et al., 2009), the increase in default probability of insurers operating across different markets enhances their volatility interdependence during the crisis.

In summary, our results establish interdependencies among the insurance sectors of the markets under consideration at both return and/or volatility levels, rejecting the null hypotheses H_1 and H_3, though these interdependencies are weaker than those among the banking industries and, hence, potentially contributed less to the systemic risk. Our H_2 hypothesis purporting insignificant changes in the intensity of return spillover among insurers during the crisis cannot be rejected. Our H_4 hypothesis purporting insignificant changes in the intensity of volatility spillover during the crisis does get rejected in some cases. This result, which is found to be driven by the life insurer component of the industry, is suggestive of some changes in the nature of interdependencies in response to the crisis.[26]

4.3. Cross-market and Cross-industry Spillover: U.S. Bank Effects on Global Insurers

Over the years, insurance companies have gone closer to the banking firms in terms of their products and services under the umbrella of financial conglomerates (Staikouras, 2006; Saunders and Cornett, 2010). For example, insurers have invested heavily in mortgage-backed securities and have issued new instruments of financing, similar to those issued by banks[27]. Given their current sets of operations, one would expect that there are strong links between the insurance industry and the U.S. banking sector. The focus of our analysis is on the two-way channel between the U.S. banking market and the three geographic insurance markets considered (EU, Japan and U.K.). Results from the VAR-BEKK model describing the interdependence between these two industries are presented in Table 7.

TABLE 7

According to the parameter estimates reported in Table 7, the U.S. banking sector is unaffected by the concurrent returns generated in the EU, Japanese and the U.K. insurance markets during the pre-crisis period and affected only by the U.K. insurers during the crisis period. In this latter case, the spillover is positive and strong, indicating robust cross-market contagion from U.K. to the U.S. that needs to be watched, especially in conditions of industry downturns. In terms of magnitude, a 1% point change in the U.K. insurers' equity returns results in 0.259% points change in the U.S. banking equity returns in the same direction.

[26] A breakdown of the results by type of insurance business is available from the authors upon request.
[27] Insurance-linked securities (ILS) are a special type of asset-backed security issued by insurers/reinsurers to enhance their funding ability and to transfer their underwriting risk to capital market. There are many different products that can be categorized as ILS, such as CAT-bond, CAT-option, sidecars, CAT-equity puts, catastrophic risk swaps, industry loss warranties and weather derivatives (Cummins, 2005).

The strong positive return spillover between U.S. banks and U.K. insurers might be attributed to the fact that these firms were exposed to similar risks during the market downturn, including extensive investments in real-estate-related assets and tight connections with global markets. For example, U.K. insurers had more than 15% of their assets invested in real estate loans during the downturn and around 20% of their net premium income was generated from overseas markets[28]. Insurance sectors in the other regions exert no significant effect on U.S. banks.

The cross-market spillover from the U.S. banks to the three insurance markets considered is more often significant than the shocks in the reverse direction reflecting asymmetric effects. However, the effect still emerges to be relatively weak. In terms of return transmission, we observe that while EU insurers are unaffected by the U.S. banking sector, U.K. and Japanese insurers are impacted by 0.08% and 0.221%, respectively, for a 1% shock to the U.S. banking sector. These effects remain unchanged during the crisis period. Our findings are an indication of cross-industry return contagion across major geographic markets in the world. These interdependencies should be taken into account by managers of the insurance firms as well as investors in the equity markets and regulators of financial institutions in seeking ways to protect the insurer firms, investments in insurer stocks and systemic risk, respectively. An interesting question in this context would be whether promotion of universal banking in the U.S. (Gramm-Leach-Bliley Act, 1999) and other markets considered weakens or strengthens such cross-industry linkages. This effect is likely to be positive because when banks and insurers operate under the same umbrella they would have a greater degree of business activity with one another and would be affected by the risk emanating from same affiliates and by decisions made by the same parent organization.

[28] The real estate loan holding comes mainly from non-life insurance sector. The data are collected from the *SIGMA – Insurance Investment in a Challenging Global Environment* (2010) report by Swiss Re. See also documents issued by Association of British Insurers (ABI) including the *U.K. Insurance – Key Facts* and the *Annual General Insurance Overview Statistics*; available from www.abi.org.uk.

Looking at the volatility interdependencies, increased U.S. bank volatility is found to be transmitted only to the EU insurers and even that only during the crisis and at the meager level of 0.006, for a 1% shock to the U.S. banking sector. It does not seem that the U.S. banking industry is in a position to exert a marked pure contagion effect on the insurance industries considered and to threaten a systemic collapse. The observed link between banking and insurance industries across geographical regions is contributed to by the two-way direct investment between the U.S. and these regions, their trade relationships and their exposure to similar financial risks e.g. credit risk, off balance sheet risk, and interest rate risk (See also Cummins and Trainar, 2009; Cummins and Weiss, 2009).

4.4. Cross-Industry Transmission Effects: Global Banking and Insurance Markets

It is known that insurers were not as severely affected by the recent crisis as banks. The report from The Geneva Association[29] shows that most insurers were able to absorb the credit losses within their own balance sheets during the crisis. In the U.S., around six hundred banks were rescued by the Troubled Asset Rescue Program (TARP) while only three insurance companies needed funding from the government[30]. Thus, it would be interesting to examine any transmission or co-movement effects across the banking and insurance industries at a global level. To this end, we construct an aggregated banking (insurance) portfolio, which contains all the banks (insurers) across the four major markets considered.

Estimation results, presented in Table 8, suggest strong and almost symmetric volatility transmission between the aggregate bank and insurance sectors over the sample period (0.019 from banks to insurers and 0.015 in the opposite direction). The bidirectional volatility interdependence between the global banking and insurance industries highlights their risk sharing characteristics. These characteristics are the result of changing financial markets, convergence between banks and insurers (Staikouras, 2006; Saunders and Cornett,

[29] The report is titled *Systemic Risk in Insurance. An analysis of insurance and financial stability* (March 2010).
[30] Based on a report by the U.S. Treasury titled *Financial Stability Transactions Report* (July 2009).

2010) and the use of identical models of risk assessment and similar risk management procedures. The slightly stronger impact from banks on insurers can be attributed to the fact that insurers do face the risk factors to which banks are exposed, though banks are not exposed to certain insurance risks, which are exclusive to insurers. Moreover, the banking industry is greater in size and can exert a larger effect. The volatility interactions between the two sectors remain unaffected by the crisis.

TABLE 8

The prevailing bidirectional return transmission between the two industries is found to be economically more relevant during the crisis. Specifically, the aggregate banking portfolio experienced a return transmission of 0.038 from the aggregated insurance sector in the pre-crisis period, with the return effect strengthening considerably during the crisis (by 0.103 points). In the reverse direction, the aggregated insurance portfolio was unaffected by the fluctuations in the aggregated banking sector return before the crisis, but did experience a return spillover effect from it during the crisis period. This effect is of a competitive character and its magnitude stands at -0.126, an indication that when the world banking industry is in trouble, the world insurance industry stands to gain in terms of profitability, possibly because banking customers switch over to insurers for many banking-like products. The negative return transmission from banks to insurers during the crisis also provides support for the 'flight-to-quality' argument proposed by Lang and Nakamura (1995). To elaborate, the increase in investor risk aversion during the crisis, led them to switch to insurance companies, which were performing relatively better than banks. Along the same lines, Caramazza et al. (2004) find support for the 'flight-to-quality' trend during the 1987 U.S. crisis, 1994 Mexican peso devaluation, and the 1997 Asian turmoil.

5. Concluding Remarks

This study investigates the interdependencies among the banking and insurance industries in the EU, Japan, U.K. and U.S. markets. Transmissions of shocks in returns and in volatility are both considered. Changes in the magnitude and nature of these cross-market/ industry return and volatility transmissions during the crisis of 2007-2009 are also investigated in order to shed light on the impact of the crisis on the global financial dynamics.

The findings suggest that return contagion among the banking industries in the EU, U.K. and U.S. is strong, especially during the crisis period. This calls for regulatory attention in designing a co-ordinated regulatory landscape as well as the need for co-ordination of monetary policy across the industrialized world. As an exception, the connections between the banking sectors in the Japanese and the U.S. markets seem to be weak as no return spillover is recorded between these two markets even during the crisis period. One source of dissimilarity in effects across different regional banking markets is their structural differences. To elaborate, since U.S. is a market-oriented economy while Japan is a bank-oriented economy, banks in these two countries are operating in different environments and, consequently, have different attitudes towards competition and risk taking. Our findings also document the prominence of the U.S. banking sector as the main origin of volatility information to its EU, Japanese and U.K. counterparts demonstrating its continuing leadership role in global markets and the asymmetry of volatility contagion mechanisms.

For the insurance sector, once again the EU, U.K. and the U.S. markets show strong linkages. Positive and significant return spillovers are documented on the EU and U.K. markets while the effects on U.S. and Japan are more limited. Unlike banks, the magnitudes of the return spillovers across insurance markets remain unaltered during the crisis period, perhaps because the risk factors faced by the insurers were not affected by the turmoil. However, volatility spillovers to the U.S. and EU insurance sectors do intensify during the crisis period raising concerns about contribution of the insurance sector to systemic risk. The U.S. insurance sector receives contagion type volatility spillovers from the U.K. and the EU insurance markets with the former intensifying during the crisis. The increase in default probability due to the sharp decline in asset values could be the reason behind the stronger volatility linkage across the insurance portfolios during the crisis. As an exception, Japanese insurers appear to be mostly insulated from shocks originating in other markets even during the crisis, reflecting the segmented nature of the Japanese markets.

In regards to interdependence between banks and insurers, at the country/aggregate market level, we find that the U.S. banking sector affects the returns on the U.K. and Japanese and the volatility of the EU insurance industries. The interdependence among global banking and insurance portfolios is bidirectional and strong, again validating concerns over systemic risk. This finding is in line with the trend of integration between the two financial intermediary types over the last two decades. There is also evidence of contagious volatility transmission between the two industries. The spillover in returns, mostly evident during the crisis, is of a competitive nature and favors the insurance industry in the sense that when banks suffer, insurers benefit by attracting their customers ('flight-to-quality' effect). Industrial reports and empirical studies on the general performance of the global banking and insurance sectors also confirm our empirical results[31]. Our findings highlight the importance of monitoring and managing the contagion effects at the international level and the need to design an appropriate regulatory framework to curb it. Further globalization of financial markets, advancement of technology and the consolidation trend among "Systemically Important Financial Institutions" intensify this necessity.

[31] For industrial reports, please refer to report *Systemic Risk in Insurance, An analysis of insurance and financial stability* (2010) by Geneva Association, and the report *Eight Key Messages on the Financial Turmoil* (2008) by CEA. Both reports claim that insurers are less exposed to the credit risk and liquidity risk compared to banks, and the insurance industry is less involved in the mortgage related security market. For empirical studies, please refer to Harrington (2009) and Eling and Schmeiser (2010) among others.

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Table 1. Summary Statistics of the Financial Sector Portfolio Returns

Bank		EU			Japan			U.K.	U.S.		
Raw Return (%)		All	Small	Large	All	Small	Large	All	All	Small	Large
1	Mean	-0.048	-0.037	-0.088	-0.024	-0.024	-0.029	-0.083	-0.093	-0.086	-0.105
2	Mean-Pre†	0.060	0.065	0.043	0.040	0.032	0.060	0.003	0.009	0.008	0.017
3	Mean-Post††	-0.288	-0.263	-0.378	-0.166	-0.150	-0.229	-0.275	-0.321	-0.295	-0.375
4	Maximum	6.615	4.864	13.289	13.467	13.207	15.026	15.174	10.811	9.770	14.029
5	Minimum	-6.627	-5.694	-10.825	-8.665	-8.006	-12.262	-11.634	-13.951	-12.675	-18.092
6	Std. Dev.	0.872	0.723	1.642	1.571	1.504	1.970	1.768	1.434	1.278	2.197
Distribution Property											
7	Skewness	-0.940	-1.350	-0.215	0.193	0.270	0.069	0.038	-1.469	-1.959	-0.765
8	Kurtosis	13.237	14.097	13.514	9.559	9.828	9.181	17.499	28.416	34.583	9.062
9	Normality Test	6486 ***	7810 ***	6630 ***	2585 ***	2809 ***	2289 ***	12588 ***	39196 ***	60643 ***	15587 ***
10	LB Test	327.3 ***	343.6 ***	343.3 ***	442.6 ***	441.5 ***	464.0 ***	256.6 ***	539.2 ***	535.4 ***	540.9 ***
11	ADF Test	-21.7 ***	-20.4 ***	-35.4 ***	-39.1 ***	-39.6 ***	-37.8 ***	-24.0 ***	-12.1 ***	-7.4 ***	-9.62 ***

Insurance		EU	Japan	UK	US
Raw Return (%)		All	All	All	All
1	Mean	-0.041	-0.021	-0.010	-0.075
2	Mean-Pre	0.055	0.101	0.048	0.039
3	Mean-Post	-0.254	-0.294	-0.139	-0.328
4	Maximum	6.009	12.328	5.202	8.781
5	Minimum	-7.770	-17.581	-5.054	-16.563
6	Std. Dev.	1.108	2.487	0.876	1.727
Distribution Property					
7	Skewness	-0.695	-0.382	-0.188	-1.729
8	Kurtosis	9.305	9.863	7.272	21.164
9	Normality Test	2496 ***	2855 ***	1101 ***	20469 ***
10	LB Test	405.3 ***	530.0 ***	429.7 ***	597.7 ***
11	ADF Test	-22.6 ***	-37.7 ***	-36.6 ***	-9.3 ***

The sample period is from the January 1, 2003 to March 9, 2009.

Data sample adjusted for non-trading days: 1,437 observations.

† "Mean-Pre" refers to the average daily return of the sector portfolio from January 1, 2003 to April 1, 2007.

†† "Mean-Post" refers to the average daily return of the sector portfolio from April 2, 2007 to March 9, 2009.

The Normality Test is conducted following the Jarque-Bera test statistic.

The LB Test refers to the Ljung-Box Q-test for dependence in the squared returns.

The ADF Test refers to the Augmented Dickey-Fuller Unit Root test.

***, ** and * represent significance at the 1%, 5% and 10% level, respectively.

Table 2. Joint-Hypothesis Tests for Multidirectional Return and Volatility Interdependencies

			Log-likelihood Ratio Test Statistics (LLR) and Degrees of Freedom (DF)†					
			All††		Large†††		Small†††	
	Return Interdependence		DF	LLR	DF	LLR	DF	LLR
1	**H_1:** No return transmission across sector portfolios	Bank	24	990 ***	12	66 ***	12	74 ***
2	$\theta_{i,j} = 0$ and $\gamma_{i,j} = 0$ with $i \neq j$	Insurance	24	108 ***				
3	**H_2:** No change in return transmission over the crisis period	Bank	12	914 ***	6	100 ***	6	12 *
4	$\gamma_{i,j} = 0$ with $i \neq j$	Insurance	12	12				
	Volatility Interdependences		DF	LLR	DF	LLR	DF	LLR
5	**H_3:** No volatility transmission across sector portfolios	Bank	24	144 ***	12	106 ***	12	26 **
6	$g_{i,j} = 0$ and $z_{i,j}$ =i 0 with $i \neq j$	Insurance	24	208 ***				
7	**H_4:** No change in volatility transmission over the crisis period	Bank	12	338 ***	6	42 ***	6	16 **
8	$z_{i,j} = 0$ with $i \neq j$	Insurance	12	36 ***				

The LLR represents the test statistic of the log-likelihood ratio test. DF denotes the degrees of freedom of the associated Chi-squared distribution.

***, ** and * represent significance at the 1%, 5% and 10% level, respectively.

The unrestricted model for H_1-H_4 is the VAR-BEKK model proposed in the methodology section without restrictions on any of the parameters.

† The LLR test is based on two systems of equations (restricted/unrestricted) from the four markets using either bank or insurance portfolios.

†† The "All Bank/Insurance" test is based on the aggregated banking/insurance sector with all the banks/insurers from each market.

††† For the banking portfolio only the U.S., Japan and EU samples have enough firms to be disaggregated by size (small versus large). Therefore, the "Large/Small Bank" test is based on the large/small banking portfolio across the U.S., Japanese and EU markets.

Note: The test result for H1 (H3), which examines the overall return (volatility) transmission effect among the banking/insurance portfolios during the whole sample period, is illustrated in row 1/2 (row 5/6).

The test result for H2 (H4), which examines the potential alterations in the return (volatility) transmission effect among the banking/insurance portfolios during the crisis period, is illustrated in row 3/4 (row 7/8).

Table 3. Joint-Hypothesis Tests for Unidirectional Return and Volatility Interdependencies

		Log-likelihood Ratio Test Statistics (LLR) and Degrees of Freedom (DF)†					
		All††		Large†††		Small†††	
		DF	LLR	DF	LLR	DF	LLR
H_5: No return and volatility transmission from the EU sector Portfolios	Bank	6	40 ***	4	142 ***	4	130 ***
	Insurance	6	12 *				
H_6: No return and volatility transmission from the Japanese sector Portfolios	Bank	6	16 **	4	112 ***	4	58 ***
	Insurance	6	20 ***				
H_7: No return and volatility transmission from the U.K. sector Portfolios	Bank	6	32 ***	N/A		N/A	
	Insurance	6	52 ***	N/A		N/A	
H_8: No return and volatility transmission from the U.S. sector Portfolios	Bank	6	68 ***	4	282 ***	4	162 ***
	Insurance	6	138 ***				

The LLR represents the test statistic of the log-likelihood ratio test. DF denotes the degrees of freedom of the associated Chi-squared distribution.

***, ** and * represent significance at the 1%, 5% and 10% level, respectively.

The unrestricted model for H_5-H_8 is the VAR-BEKK model proposed in the methodology section without restrictions on any of the parameters.

† The LLR test is based on two systems of equations (restricted/unrestricted) from the four markets using either bank or insurance portfolios.

†† The "All Bank/Insurance" test is based on the aggregated banking/insurance sector with all the banks/insurers from each market.

††† For the banking portfolio only the U.S., Japan and EU samples have enough firms to be disaggregated by size; small versus large. Therefore, the "Large/Small Bank" test is based on the large/small banking portfolio across the U.S., Japanese and EU markets.

N/A stands for non-available data due to limited number of firms to form meaningful size portfolios.

Table 4. Shock Transmission across Banking Sectors of Different Regions: EU, Japan, U.K., U.S.

The following table summarizes the return and volatility transmission effects among all size banking portfolios across markets. The all size banking portfolio contains all banks in one market. The first three rows in each panel show the spillover effects while the next three rows show the shift in spillover during the crisis. The estimated transmission coefficients are categorized as return and volatility transmission effects.

		Impacted Markets											
		EU			Japan			U.K.			U.S.		
	Return Transmission	Coeff.	Z-stat.		Coeff.	Z-stat.		Coeff.	Z-stat.		Coeff.	Z-stat.	
1	Cross-Return 1 (θ_{i1})	0.024	2.20	**	0.031	0.56		0.151	2.46	**	-0.069	-2.97	***
2	Cross-Return 2 (θ_{i2})	0.033	2.51	**	-0.066	-2.52	**	0.005	0.15		0.002	0.22	
3	Cross-Return 3 (θ_{i3})	-0.021	-0.82		0.046	0.72		-0.161	-2.56	**	0.015	1.12	
4	Change in Cross-Return 1 (γ_{i1})	0.014	0.63		-0.075	-0.91		-0.090	-0.89		0.298	2.70	***
5	Change in Cross-Return 2 (γ_{i2})	-0.024	-1.23		0.075	2.10	**	-0.027	-0.54		-0.042	-1.13	
6	Change in Cross-Return 3 (γ_{i3})	0.115	3.67	***	-0.031	-0.47		0.273	2.77	***	0.136	2.31	**
	Volatility Transmission												
7	Cross-Volatility 1 (g_{i1})	-0.002	-1.27		0.008	1.85	*	0.050	1.84	*	0.039	1.61	
8	Cross-Volatility 2 (g_{i2})	0.005	1.98	**	0.012	1.20		0.038	1.09		0.006	2.89	***
9	Cross-Volatility 3 (g_{i3})	0.013	3.23	***	0.062	3.02	***	0.089	3.47	***	0.002	0.73	
10	Change in Cross-Volatility 1 (z_{i1})	0.008	1.93	*	-0.019	-4.26	***	0.044	1.44		0.013	0.53	
11	Change in Cross-Volatility 2 (z_{i2})	-0.007	-2.32	**	0.000	0.73		0.005	0.93		0.040	0.56	
12	Change in Cross-Volatility 3 (z_{i3})	-0.006	-1.02		0.016	0.77		0.027	1.78	*	0.057	1.68	*

***, ** and * represent significance at the 1%, 5% and 10% level, respectively.

Cross-return/volatility *i* (*i* = 1-3, rows 1-3 / rows 7-9) represent the return (θ_i)/volatility (g_i) transmission from each of the three markets to the fourth during the whole sample period. That is, looking at the EU column, the impact of the Japanese, U.K. and the U.S. banks on the EU banking portfolio is represented by the coefficients numbered as 1, 2 and 3, respectively. Similarly, for the Japanese banks, the impact of the EU, U.K. and the U.S. banking portfolios on the Japanese banking portfolio is measured by the coefficients numbered as 1, 2 and 3, respectively. The same pattern applies for the remaining countries. For instance, the impact of the cross-return/volatility spillover of the UK on the US market is 0.015/0.002.

Change in Cross-return/volatility *i* (*i* = 1-3, rows 4-6 / rows 10-12) represent the change in the return (γ_i)/volatility (z_i) transmission from each of the three countries to the fourth during the crisis period. That is, looking at the EU column, the incremental impact of the Japanese, U.K. and the U.S. banks on the EU banking portfolio is represented by the coefficients numbered as 1, 2 and 3, respectively. Similarly, for the Japanese banks, the incremental impact of the EU, U.K. and the U.S. banking portfolios on the Japanese banking portfolio is measured by the coefficients numbered as 1, 2 and 3, respectively. The same pattern applies for the remaining countries. For instance, the change of the cross-return/volatility spillover of the UK on the US market is 0.0136/0.057.

Note: The full magnitude of the cross-sectional return and volatility transmission effect over the crisis period is given by ($\theta_i + \gamma_i$) and ($g_i + z_i$), respectively. That is, the total cross-return/volatility spillover of the UK on the US market is 0.136/0.057 (0.015 + 0.0136 / 0.002 + 0.057). Note here that insignificant coefficients are not taken into account.

Table 5. Volatility Parameters from the Asymmetric BEKK Model

The following table reports the parameter estimates driving the conditional volatility of the banking sector portfolios across markets for the aggregate banking sector and for the two size banking portfolios.

Parameters	a^2_i	b^2_i	n^2_i
Market		**All Size Banking Portfolio**	
EU	0.018 ***	0.967 ***	0.029
Japan	0.024 ***	0.976 ***	0.003
U.K.	0.189 ***	0.875 ***	0.000
U.S.	0.137 ***	0.888 ***	0.001
		Large Banking Portfolio	
EU	0.002 ***	0.956 ***	0.088 ***
Japan	0.071 ***	0.908 ***	0.000
U.S.	0.053 ***	0.929 ***	0.031 ***
		Small Banking Portfolio	
EU	0.020 ***	0.957 ***	0.040 ***
Japan	0.050 ***	0.917 ***	0.000
U.S.	0.179 ***	0.838 ***	0.002

***, ** and * represent significance at the 1%, 5% and 10% level, respectively.

The parameters a^2_i, b^2_i and n^2_i pertain to the diagonal matrices A, B and N in the VAR-BEKK specification in equation (3). Significance of a^2_i and b^2_i indicates time variation in volatility, whereas significance of n^2_i indicates asymmetric response of the conditional volatility to negative news, where the magnitude of the effect is given by the estimated value of the n^2_i parameter.

Table 6. Shock Transmission across Insurance Sectors of Different Regions: EU, Japan, U.K., U.S.

The following table summarizes the return and volatility transmission effects among insurance-industry portfolios across markets. These portfolios contain all the insurers from one market. The first three rows in each panel show the spillover effects while the next three rows show the spillover shifts during the crisis. The estimated transmission coefficients have been categorized into return and volatility transmission effects.

		Impacted Markets											
		EU			Japan			U.K.			U.S.		
	Return Transmission	Coeff.	Z-stat.		Coeff.	Z-stat.		Coeff.	Z-stat.		Coeff.	Z-stat.	
1	Cross-Return 1 (θ_{i1})	0.022	2.36	**	0.109	1.78	*	0.072	2.98	***	0.056	2.40	**
2	Cross-Return 2 (θ_{i2})	0.073	2.71	***	-0.146	-1.82	*	0.036	3.74	***	0.008	0.96	
3	Cross-Return 3 (θ_{i3})	0.043	1.96	*	0.110	1.60		0.048	1.99	**	-0.036	-1.37	
4	Change in Cross-Return 1 (γ_{i1})	-0.018	-1.05		0.000	0.01		-0.045	-1.26		-0.009	-0.12	
5	Change in Cross-Return 2 (γ_{i2})	-0.034	-0.87		0.025	0.23		-0.059	-1.60		-0.024	-1.11	
6	Change in Cross-Return 3 (γ_{i3})	0.005	0.16		0.092	1.16		0.013	0.42		0.033	0.41	
	Volatility Transmission												
7	Cross-Volatility 1 (g_{i1})	0.000	0.83		0.168	0.92		0.007	1.12		0.096	2.23	**
8	Cross-Volatility 2 (g_{i2})	-0.011	-2.28	**	0.067	0.83		0.001	0.40		0.003	0.57	
9	Cross-Volatility 3 (g_{i3})	0.024	4.82	***	0.183	1.11		-0.001	-0.65		0.094	2.51	**
10	Change in Cross-Volatility 1 (z_{i1})	-0.006	-2.66	***	0.003	0.58		0.004	1.13		0.113	2.54	**
11	Change in Cross-Volatility 2 (z_{i2})	0.042	1.95	*	-0.038	-0.60		-0.014	-1.72	*	0.022	2.37	**
12	Change in Cross-Volatility 3 (z_{i3})	-0.001	-0.58		0.036	0.54		0.000	0.73		0.015	0.54	

***, ** and * represent significance at the 1%, 5% and 10% level, respectively.

Cross-return/volatility *i* (*i* = 1-3, rows 1-3 / rows 7-9) represent the return (θ_i)/volatility (g_i) transmission from each of the three countries to the fourth one during the whole sample period. That is, looking at the EU column, the impact of the Japanese, U.K. and the U.S. insurers on the EU insurance portfolio is represented by the coefficients numbered as 1, 2 and 3, respectively. Similarly, for the Japanese insurers, the impact of the EU, U.K. and the U.S. insurance portfolios on the Japanese insurance portfolio is measured by the coefficients numbered as 1, 2 and 3, respectively. The same pattern applies for the remaining countries. For instance, the impact of the cross-return/volatility spillover of the UK on the US market is -0.036/0.094.

Change in Cross-return/volatility *i* (*i* = 1-3, rows 4-6 / rows 10-12) represent the change in the return (γ_i)/volatility (z_i) transmission from each of the three countries to the fourth one during the crisis period. That is, looking at the EU column, the incremental impact of the Japanese, UK and the US insurers on the EU insurance portfolio is represented by the coefficients numbered as 1, 2 and 3, respectively. Similarly, for the Japanese insurers, the incremental impact of the EU, UK and the US insurance portfolios on the Japanese insurance portfolio is measured by the coefficients numbered as 1, 2 and 3, respectively. The same pattern applies for the remaining countries. For instance, the change of the cross-return/volatility spillover of the UK on the US market is 0.033/0.015.

Note: The full magnitude of the cross-sectional return and volatility transmission effect over the crisis period is given by ($\theta_i + \gamma_i$) and ($g_i + z_i$), respectively. That is, the total cross-return/volatility spillover of the UK on the US market is 0.000/0.094 (-0.036 + 0.033 / 0.094 + 0.015). Note here that insignificant coefficients are not taken into account.

Table 7. Cross-Market, Cross-Industry Shock Transmission

The following table summarizes the return and volatility transmission effects among the U.S. banking portfolios and the insurance sector portfolios of the remaining three markets, namely EU, Japanese and U.K. market. The first three rows in each panel show the spillover effects while the next three rows show the spillover shifts during the crisis. The estimated transmission coefficients are categorized as return and volatility transmission effects.

		Impacted Markets											
		EU-Insurance			Japan-Insurance			U.K.-Insurance			U.S.-Bank		
	Return Transmission	Coeff.	Z-stat.		Coeff.	Z-stat.		Coeff.	Z-stat.		Coeff.	Z-stat.	
1	Cross-Return 1 (θ_{i1})	0.040	3.47	***	0.100	1.45		0.082	3.63	***	-0.005	-0.27	
2	Cross-Return 2 (θ_{i2})	0.089	3.43	***	-0.154	-1.87	*	0.036	3.40	***	-0.001	-0.23	
3	Cross-Return 3 (θ_{i3})	0.039	0.96		0.221	1.83	*	0.080	1.90	*	-0.013	-0.66	
4	Change in Cross-Return 1 (γ_{i1})	-0.003	-0.14		-0.009	-0.08		-0.074	-2.15	**	0.075	1.05	
5	Change in Cross-Return 2 (γ_{i2})	-0.087	-2.25	**	-0.040	-0.27		-0.032	-1.76	*	0.008	0.34	
6	Change in Cross-Return 3 (γ_{i3})	0.036	0.78		0.056	0.44		-0.030	-0.64		0.259	3.10	***
	Volatility Transmission												
7	Cross-Volatility 1 (g_{i1})	-0.001	-0.47		0.084	0.16		0.009	2.35	**	0.020	1.61	
8	Cross-Volatility 2 (g_{i2})	0.047	1.74	*	0.027	0.76		0.001	1.13		0.000	0.98	
9	Cross-Volatility 3 (g_{i3})	0.004	0.55		0.104	0.17		0.000	-0.28		0.005	0.42	
10	Change in Cross-Volatility 1 (z_{i1})	-0.002	-0.61		0.000	-0.36		-0.005	-1.22		-0.001	-0.47	
11	Change in Cross-Volatility 2 (z_{i2})	0.001	0.20		-0.005	-0.49		-0.028	-0.59		0.017	2.47	**
12	Change in Cross-Volatility 3 (z_{i3})	0.006	2.05	**	0.017	0.23		0.003	0.44		-0.001	-0.68	

***, ** and * represent significance at the 1%, 5% and 10% level, respectively.

Cross-return/volatility i (i = 1-3, rows 1-3 / rows 7-9) represent the return (θ_i)/volatility (g_i) transmission from each of the three countries to the fourth one during the whole sample period. That is, looking at the US column, the change on the impact of the EU, Japanese, and the UK insurers on the US banking portfolio is represented by the coefficients numbered as 1, 2 and 3, respectively. The same pattern applies for the remaining countries. For instance, the impact of the cross-return/volatility spillover of the UK on the US market is -0.013/0.005.

Change in Cross-return/volatility i (i = 1-3, rows 4-6 / rows 10-12) represent the change in the return (γ_i)/volatility (z_i) transmission from each of the three countries to the fourth one during the crisis period. That is, looking at the US column, the incremental impact of the EU, Japanese, and the UK insurers on the US banking portfolio is represented by the coefficients numbered as 1, 2 and 3, respectively. The same pattern applies for the remaining countries. For instance, the change of the cross-return/volatility spillover of the UK on the US market is -0.259/-0.001.

<u>Note:</u> The full magnitude of the cross-sectional return and volatility transmission effect over the crisis period is given by ($\theta_i + \gamma_i$) and ($g_i + z_i$), respectively. That is, the total cross-return/volatility spillover of the UK on the US market is 0.259/0.000 (-0.013 + 0.259 / 0.005 – 0.001). Note here that insignificant coefficients are not taken into account.

Table 8. Interdependence between the Aggregated (Global) Banking and Insurance Portfolios

The following table summarizes the return and volatility transmission effects between the aggregated banking and insurance portfolios. The first row in each panel shows the spillover effects while the second row shows the spillover shifts during the crisis. The estimated transmission coefficients are categorized as return and volatility transmission effects.

		Impacted Markets					
		Bank			Insurance		
	Return Transmission	Coeff.	Z-stat.		Coeff.	Z-stat.	
1	Cross-Return (θ_{i1})	0.038	1.83	*	-0.001	-0.04	
2	Change in Cross-Return (γ_{i1})	0.103	3.24	***	-0.126	-3.24	***
	Volatility Transmission	Coeff.	Z-stat.		Coeff.	Z-stat.	
3	Cross-Volatility (g_{i1})	0.015	4.48	***	0.019	3.37	***
4	Change in Cross-Volatility (z_{i1})	0.000	-0.89		0.015	1.36	

***, ** and * represent significance at the 1%, 5% and 10% level, respectively.

Cross-return/volatility i (i = 1) represent the return (θ_i)/volatility (g_i) transmission from one portfolio to the other during the whole sample period. That is, looking at the Global-Bank column, the impact of the Global-Insurance portfolio on the Global-Banking portfolio is represented by the coefficients 1, and vice versa. For instance, the impact of the cross-return/volatility spillover of the insurance on the banking industry is -0.038/0.015.

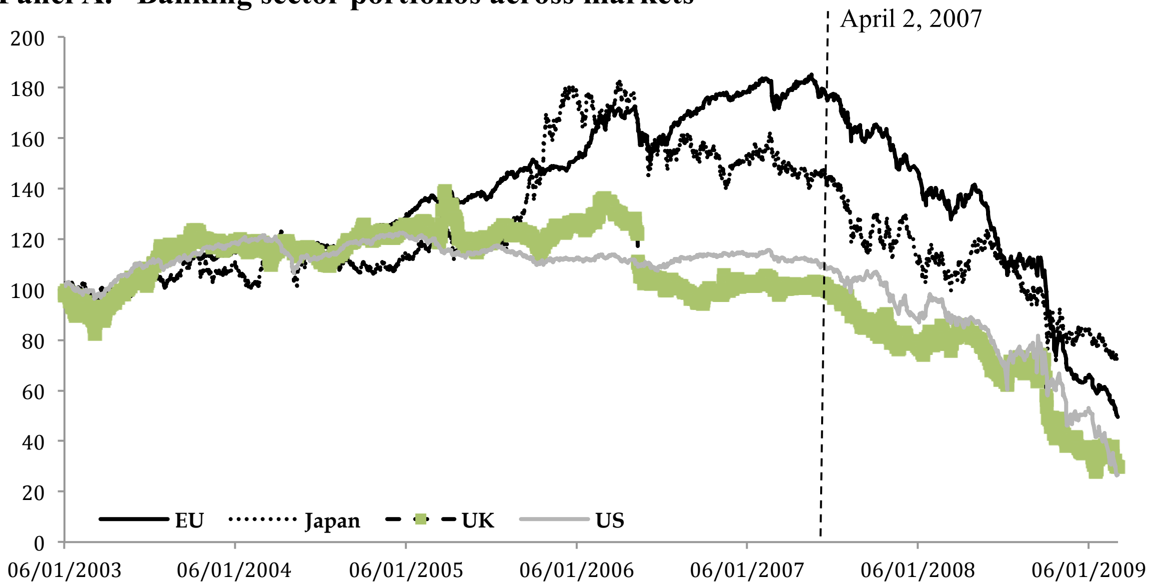
Change in Cross-return/volatility i (i = 1) represent the change in the return (γ_i)/volatility (z_i) transmission from one portfolio to the other during the crisis period. That is, looking at the Global-Bank column, the incremental impact of the Global-Insurance portfolio on the Global-Banking portfolio is represented by the coefficients 1, and vice versa. For instance, the change of the cross-return/volatility spillover of the insurance on the banking industry is 0.103/0.000.

Note: The full magnitude of the cross-sectional return and volatility transmission effect over the crisis period is given by ($\theta_i + \gamma_i$) and ($g_i + z_i$), respectively. That is, the total cross-return/volatility spillover of the insurance on the banking industry is 0.141/0.015 (0.038 + 0.103 / 0.015 + 0.000). Note here that insignificant coefficients are not taken into account.

Appendix 1. Time Series of Banks/Insurers Equity Value

The following figures represent the daily movements of the banks/insurers equity values. In order to demonstrate the value of the portfolios in a better manner, the initial values of these portfolios are rebased at the 100 level at the beginning of the sample period. The area to the right of April 2, 2007 represents the crisis period (April 2, 2007 till March 9, 2009). On April 2, 2007, the largest U.S. sub-prime lender - New Century Financial - filed for bankruptcy.

Panel A. Banking sector portfolios across markets



Panel B. Insurance sector portfolios across markets