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A Wavelet-based Approach to Testing *Shari'ah*-compliant Stock Market Contagion: Evidence from the ASEAN Countries

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Abstract: Recently there has been a heightened global concern over 'contagion' in the conventional financial markets. Our study is motivated by the desire to test empirically whether this contagion is reflected in the fast growing Islamic financial markets as well. This study is the first attempt at testing whether there has been any contagion among the *Shari'ah*-compliant stock markets during the most recent international financial crisis: the US subprime crisis of 2008, with the application of a technique known as 'wavelet approach' which has been very recently imported to finance from engineering science. We analyse the daily data covering the period from June 2006 to August 2009 for the stock market indices of the original ASEAN countries plus Australia and USA such as, NYSE COMPOSITE (US), MSCI Islamic (Australia), MSCI Islamic (Singapore), FTSE Bursa EMAS *Shari'ah* (Malaysia), Jakarta SE Islamic (Indonesia), MSCI Islamic (Thailand) and MSCI Islamic (Philippines). Our findings based on the time-scale decomposition property of wavelet analysis tend to indicate that in all cases of selective *Shari'ah*-compliant stock markets the changes in the wavelet correlation coefficients are insignificant at all time scales during the US subprime crisis. The changes observed in wavelet correlation coefficients are insignificant due to overlapping of confidence intervals implying that there is no clear evidence of contagion at all time scales. These findings are plausible and intuitive and have implications for the *Shari'ah*-compliant stock markets in terms of ass*et al*location strategy of risk managers and for policymakers' optimal policy response to a crisis.

Key words: Wavelet decomposition, Contagion, Interdependence, Wavelet Correlation, *Shari'ah*-Compliant Stocks

INTRODUCTION

The cross-market transmission of financial crisis has been a major interest over the last decade. The financial systems have witnessed numerous financial and currency crises, where most of them with regional or even global consequences, such as the 1987 Wall Street crash, the 1992 ERM collapse, the 1994 Mexican pesos crisis, the 1997 "Asian Flu", the 1998 "Russian Cold", the 1999 Brazilian devaluation, the 2000 Internet bubble burst, and the default crisis in Argentina of July 2001. Recently, the US subprime crisis 2008 that considerably hit the markets all over the world has raised a critical question on the capacity of the global financial system to maintain its financial stability in such a meaningful way.

Some previous studies tend to argue that financial crises are characterized by financial contagion (e.g., Kyle and Xiong, 2001; Kodres and Pritsker, 2002). This issue therefore has become extensively discussed in theoretical and empirical studies in order to measure financial spillovers andto discover channels of transmission of shocks across borders. King and Wadhwani (1990) have mentioned that economic fundamentals on each country have not provided a clear explanation as regards the shock transmissions, suggesting that a stock market reacted to stock price changes across border beyond what economic fundamentals suggest. In another study, Forbes and Rigobon (2002) also define contagion as an excessive transmission of shocks from the origin of crash to others beyond any idiosyncratic disturbances and fundamental linkages.

The main aim of our study is to evaluate the Islamic financial industry which has experienced a relatively high growth in the global financial system. Over the last couple of decades, the Islamic financial sector has developed and gained stronger position, expanding from a banking-based industry into wider areas covering financial market-based instruments and practices. In terms of characteristics, Islamic assets have been strictly restricted to the boundary of *Shari'ah* rules, which in turn has resulted in distinguished features among other assets in the market. It is theoretically expected therefore that S*hari'ah*-compliant assets would have a different behavior compared to the conventional counterparts.

The current trend for Islamic equity to move towards the global markets has encouraged a number of studies to address the performance of Islamic equity markets and funds. In the context of the recent subprime crisis, it appears to be important to evaluate the vulnerability of Islamic stocks. Our study therefore attempts to

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identify whether there is any financial contagion that occurred among the *Shari'ah*-compliant stock markets at this crisis period. Such a question is important because of the nature of *Shari'ah* rules, in particular the limit of interest-based leverage is likely to lead to a lower systemic risk during economic expansion and recession. In addition, Chapra (2008) and Chapra, Ebrahim, Mirakhor, and Siddiqi (2008) also mention that there are four basic conditions in Islamic finance that may prevent the two main causes of recent crisis, which are excessive leverage and the formation of speculative bubbles in credit markets. Also, if we define the contagion to represent financial panics within the market during turbulence, the element of excessive speculation that is likely to weaken the link between financial and real markets has been strongly disallowed by the principle of Islamic teachings (Tag el-Din and Hasan, 2007).

A large number of studies have discussed the proper definition of financial contagion. Our study has followed the application of wavelet decomposition by Gallegati (2010) to detect the contagion as the excessive transmission of shocks above what should be expected by the fundamentals which are reflected in long horizon (high timescale). The paper is organized as follows. Section 2 reviews the basic condition of Islamic finance while Section 3presents some literature reviews associated with the issue of financial contagion. Section 4 introduces wavelet decomposition analysis and the notions of wavelet variance, covariance, and correlation. In Section 5, we will first describe the data used in this study and then present the results of the wavelet-based test for contagion. Finally, Section 6 provides some interpretations while we conclude with section 7.

2. Islamic Investment Criteria:

Shari'ah is a Divine Law which governs the practical aspect of a Muslim's daily life. In commerce, it can determine business style and indicate a desire to comply with 'halal' and ethical investing. *Shari'ah*-compliant investing is growing rapidly as an alternative investment class for all investors, both Muslim and non-Muslim, for its foundation in ethical business practices, social responsibility and fiscal conservatism. While Islamic investors may be mandated to invest only in a *Shari'ah*-compliant manner, other investors do so for the benefits they derive, including greater stability of returns, transparency and diversification.

In Islamic finance, any market is subject to *Shari'ah* constraint where the market is free from prohibited activities and elements such as *riba* (usury), *maisir* (gambling), *gharar* (ambiguity), and other prohibited activities like gambling, alcohol, and so on. To describe the Islamic principle in detail, *riba* technically is defined as the "premium" which should be paid by the borrower to the lender together with the principal amount as a condition in the contract of the loan or for an extension in the duration of loan" (Iqbal and Mirakhor, 2007). More specifically, both the premium and the principal are guaranteed regardless of the investment performance. Islamic stock indexes must not include firms that pay or receive interest of any form. However, the percentage of today's listed firms that are fully in compliance with the *Shari'ah* is in small number. Some degree of tolerance therefore is required.

The modern *Shari'ah* scholars have provided general rules for *Shari'ah*-compliant investors to evaluate or screen whether a particular company is *halal* (lawful) or *haram* (unlawful) for investment (Wilson, 2004; Derigs and Marzban, 2008).There are two types of stock screening approaches such as qualitative and quantitative screens. The first one is qualitative screen, the screening process that focuses on the activity of a company that is used as the main principle in Islamic investment criteria. For a company that does not comply with *Shari'ah* principles, for example, a company involves in production of alcohol for drinking, gambling, and *riba*-based financial institutions, then, investment in this type of company is prohibited. The second one is quantitative screen, where Islamic scholars have applied a principle of tolerance associated with filtering criteria, namely:

(1) Debt/equity ratio. If a company's debt financing is more than 33 percent of its capital, then it is impermissible for investment.

(2) Interest-related income. If interest-related income of a company is more than 10 percent of its total income, then it is not permissible for investment. This income, however, should not come from its main business activities but from placing its surplus funds in investments that could yield interest income (Abdul Rahman *et al*,. 2010).

(3) Monetary assets. This parameter refers to the composition of account receivables and liquid assets (cash at banks and marketable securities) compared to total assets. Various minimums have been set for the ratio of non-liquid assets (assets that are not in the form of money) necessary to make an investment permissible. Some set this minimum at 51 percent while a few cite 33 percent as an acceptable ratio of non-liquid assets to total assets.

On the other hand, the literal meaning of the *gharar* is fraud or *al-khida*. It is interpreted as inadequate market information or uncertainty about exchange objects when there is no practical obstacle to obtain full information about the objects of exchange for the contracting parties. Some *gharar* can be tolerated with the reason that it is sometimes difficult to completely eliminate uncertainty from exchange contracts. Al-Zuhaili (1984) mentions that *gharar* is tolerable if its benefits outweigh its damages. However, if gharar is deliberately embodied in the contract, then it becomes unlawful, as stated by the classical jurist cases of selling birds in the sky or fish in the sea (Al-Dharir, 1967; Saati, 2003). This has involved uncertainty about the outcome of the

contract. As the financial market is concerned, financial securities are pure information-loaded documents which lead to more *gharar*-prone than real goods. Therefore, the jurists prefer to ensure a *gharar*-free stock exchange rather than one of resolving a gambling evil with, of course, the consideration on a matter of degree of uncertainty itself (Tag el-Din, 1985, 1996). In modern finance, the status of derivatives in Islamic finance is subject to this rule where majority Islamic scholars strongly believe that conventional derivatives such as forwards, futures, and options are impermissible. The alternative can be found in Islamic derivatives such as *salam*, *istisna*, etc. Short selling also involves *gharar* which is associated with the prohibition of selling the product before receiving possession.

Maisir or gambling is defined as a game of chance that is a purely competitive zero-sum game which ends up in redistributing total stakes committed by individual parties among only one or a few of them. Gambling is a serious *gharar* where, in capital market, it can be associated with excessive speculation. In financial markets, excessive speculation can be defined as the degree of speculation in excess of the level just needed for an optimal liquidity in the secondary market. Even though the need for liquidity has accommodated speculative activity, a necessary action should be taken to matching between financial and real markets. This may lead Islamic investors to focus on fundamental component in any form of investment.

As our study also covers the period of subprime crisis recovery, we refer to Chapra (2008) and Chapra, Ebrahim, Mirakhor, and Siddiqi (2008) who mention that there are four basic conditions in Islamic finance that may prevent the two main causes of crisis, which are excessive leverage and the formation of speculative bubbles in credit markets. Firstly, all transactions have to be based on real assets rather than merely fictitious or notional assets. This may discourage all speculative transactions which involve excessive ambiguity or gambling. Secondly, the transaction must involve the possession of exchange objects on the seller/lesser where this condition may guarantee that, to obtain certain return, the owner will share the risk with his partner. Thirdly, the transaction must be genuine with full intention to give and take delivery which in turn will prevent the excessive speculation using imaginary assets. Lastly, the credit risk must be borne by the creditor up to the maturity, which is subject to the rule of prohibition of selling the debt except at par value. This is to ensure that the creditor cannot transfer the risk by selling the debt to the market within a speculative and derivative transaction and prevents the excessive growth of the debt beyond reasonable limits.

3. Financial Contagion:

The occurrence of turmoil in international financial markets has drawn a striking interest in the linkages between financial markets during times of crisis. Therefore, in crisis periods we discern an increase in cross-market linkages due to the propagation of shocks from one country to other countries as a result of the high integration of financial and goods markets. The increase in cross-market linkages from the pre-crisis period to the crisis period may take the form of interdependence or contagion. The issue of identifying between contagion and interdependence during periods of high volatility in financial markets has crucial implications for the ass*et al*location strategy of risk managers and for policymakers' optimal policy response to a crisis. In effect, in turbulent periods the usefulness of hedging operations is called into question, as correlations between financial time-series in these periods may differ markedly from those in normal periods. Such a changing correlation pattern, known as ''correlation breakdown'', suggests that the benefits of international diversification for ass*et al*location and portfolio composition may be remarkably reduced in stressful market situations, just when these benefits are needed most.

Even though there are lot of researches on financial market contagion, there is disagreement in the literature on the exact definition of what attributes contagion and how we could measure it. The concept of contagion is derived from the medical vocabulary and indicates the transmission of a contagious disease (Vincent Bodarta, Bertrand Candelon, FDA, 2009). According to Webster's dictionary, contagion is defined as "a disease that can be communicated rapidly through direct or indirect contact." The translation to an economic concept is not straightforward, as illustrated by the numerous definitions of contagion that can be found on the World Bank's website. Referring to the website, we can distinguish three definitions of contagion:

1. *Broad definition*: contagion is identified with the general process of shock transmission across countries. The latter is supposed to work both in tranquil and crisis periods, and contagion is not only associated with negative shocks but also with positive spillover effects.
2. *Restrictive definition*: this is probably the most controversial definition. Contagion is the propagation of shocks between two countries (or group of countries) in excess of what should be expected by fundamentals and considering the co-movements triggered by the common shocks.
3. *Very restrictive definition*: Contagion should be interpreted as the change in the transmission mechanisms that takes place during a turmoil period. For example, the latter can be inferred by a significant increase in the cross-market correlation.

Furthermore, Pericoli and Sbracia (2003) providean overview of the contagion literature by presenting five different classifications of contagion. The main distinction when defining contagion is between "fundamentals-based" and "pure" contagion (see Dornbusch *et al*., 2000; Kaminsky and Reinhart, 2000). The definition of

"fundamentals-based" contagion provided by Calvo and Reinhart (1996) emphasizes the transmission of shocks among countries and/or markets resulting from real linkages and financial market integration in both crisis and non-crisis periods. These forms of co-movements reflect normal interdependence across markets and countries and are often called as spillovers. The term "pure" contagion (see among others Eichengreen *et al*., 1996; Bae *et al*., 2003) refers to the transmission of shocks from one country to another country in excess of what should be expected after controlling for fundamental factors. This kind of contagion is generally related to investors' behavior such as herding, financial panic, loss of confidence, etc., and leads to excessive co-movements. Thus, during crisis periods, some co-movements across markets can be an implication of the effect of contagion rather than the interdependence. An important problem in testing for contagion is to conclude a distinction between "excessive" and normal interdependence across *Shari'ah*-compliant financial markets.

The standard time-domain instruments can have difficulties in discriminating fundamental contagion from other transmission mechanisms due to the difficult task of finding good proxies for the influence of macroeconomic fundamentals by using current econometric techniques. The statistical issues in measuring financial contagion are well documented by the various econometric techniques used for the analysis of co-movements among financial markets: they include testing for changes in correlation coefficients (Bertero and Mayer, 1989; King and Wadhwani, 1990; Lee and Kim, 1993; Loretan and English, 2000;Forbes and Rigobon, 2002), ARCHand GARCH models (Hamao *et al*., 1989; Chou *et al*., 1994; Edwards, 2000; Chiang *et al*., 2007; Wang and Thi, 2007; Saleem, 2009;Billio and Caporin, 2010), cointegrating relationships (Longinand Solnik, 1995; Cashin *et al*., 1995; Yuhn, 1997), probit/logit models (Eichengreen *et al*., 1996; Baig & Goldfajin, 1999; Kaminsky and Reinhart, 2000), regimeswitching (Gallo and Otranto, 2008; Baele and Inghelbrecht, 2010; Guo, Chen and Huang, 2011), the factor model (Corsetti *et al*., 2005; Dungey *et al*., 2005), outlier test (Favero and Giavazzi, 2002), threshold test (Pesaran and Pick, 2007), the copula approach (Costinot *et al*., 2000;Rodriguez, 2007), principal components models (Kaminsky and Reinhart, 2000), local correlation (Bjerve and Doksum, 1993; Inci, Li and McCarthy, 2011), structural breaks (Baek and Jun, 2011), shock models (Samarakoon, 2011), cobreaking analysis (Ahlgren and Antell, 2010), a range-based volatility approach (Chiang and Wang, 2011) and wavelet approach (Gallegati, 2010).

In particular, Forbes and Rigobon (2002) mentioned that past studies have found contagion because they did not appropriately correct the correlation measure for heteroscedasticity. By using a heteroscedasticity-corrected correlation measure, they therefore find little evidence of contagion during several recent major crises. Some other studies have attempted to follow the guidelines of Forbes & Rigobon, and they come up with similar conclusions (Collins and Biekpe, 2003; Lee *et al*., 2007). Nonetheless, the conclusions of Forbes & Rigobon (2002) have recently been criticized. Corsetti *et al*. (2005) has mentioned that the findings of Forbes and Rigobon are basically a result of an assumed model. Bartram and Wang (2005) note that there is a presence of bias in Forbes and Rigobon which follows directly from the assumptions made in their analysis (see also Pesaran and Pick 2007).

In this study, contagion is examined using wavelet correlation. A potentially useful different perspective on the empirical problem of identifying between contagion and interdependence can be solved by frequency domain analysis. By its ability to separate each variable into components of different frequencies, a frequency domain framework can provide a simple and intuitive way to identify between contagion and interdependence by associating each to its corresponding frequency component. This approach avoids the problems of the heteroscedasticity bias of Forbes & Rigobon (2002), because volatility should affect both short and long time scale correlations. Examples of studies testing for contagion by associating contagion and interdependence with distinct frequency ranges (high and low frequencies, respectively) are the recent papers by Bodart and Candelon (2009) and Orlov (2009). Gallegati (2010) by applying the wavelet analysis on the stock market indices of G7 countries plus Brazil and Hong Kong found that: (i) there is evidence for each country of international financial contagion during the US subprime crisis, and (ii) these contagion effects are scale dependent, in the sense that they do not display their effects uniformly across scales. In this paper, we will test the contagion issue in *Shari'ah* compliant stock markets by following Gallegati's methodology.

Wavelet analysis is a filtering method which provides an useful alternative to time series and frequency domain methods because it transforms the raw data into different frequency components with a resolution matched to its scale. This kind of method is useful when dealing with signals that are non-stationary and show changing frequencies over time, as in the case of financial market data. The two important interesting features of wavelet analysis for the purposes of this study: (i) its capability to decompose macroeconomic time series, and data in general, into their time-scale components, and (ii) its ability to provide representation of the variability and association structure of certain stochastic processes on a scale-by-scale basis from different perspective. The multi-resolution decomposition property of the wavelet transform can be used to separately distinguish contagion and interdependence by associating each to its corresponding frequency component. Additionally, another property of wavelet transform such as ''energy-preserving'', enabling for a scale-based decomposition of the energy in a time series, can provide the basis for a wavelet-based test for contagion. Thus, after discriminating contagion and interdependence with wavelet and scaling coefficients, respectively, we test for the

existence of contagion by using a simple graphical test based on non-overlapping confidence intervals of estimated wavelet correlation coefficients in pre-crisis and crisis periods.

Methodology:

Since the use of wavelet is not an unknown technique, in this section we only describe the fundamental methods which are useful for our research purposes. For a more complete and comprehensive development of the theory and use of wavelets, see Percival and Walden (2000) and Gencay *et al*. (2002).

4.1 Wavelet Series Expansion:

The most crucial property of wavelets' ability for the analysis of economic data is to decompose the time series into components associated with different scales of resolution. Any function $f(t)$ in $L^2(R)$ can be represented by the following wavelet series expansion:

$$f(t) = \sum_k \upsilon_{J,k}\, \phi_{J,k}(t) + \sum_k \omega_{J,k}\, _{J,k}(t) + \sum_k \omega_{j,k}\, _{j,k}(t) + \cdots + \sum_k \omega_{1,k}\, _{1,k}(t)$$

Where the coefficients $\upsilon_{J,k} = \sum_k \phi_{J,k} f(t)$ and $\omega_{j,k} = \sum_{k}\, _{j,k} f(t)$represent the underlying smooth behavior of the data at the coarsest scale (the scaling coefficients) and the coarse-scale deviations from it (the wavelet coefficients), respectively, and where $\phi_{J,k}, _{j,k}$ are the so-called scaling and wavelet functions satisfying the following conditions:

$$\int \phi_{J,k}(t)\phi_{J,k^*}(t)dt = \delta_{k,k^*},$$

$$\int _{j,k}(t)_{j^*,k^*}(t)dt = \delta_{,j^*}\delta_{k,k^*},$$

$$\int _{j,k}(t)\phi_{j,k^*}(t)dt = 0, \quad \forall j, k,$$

where $\delta_{j,k}$ is the Kronecker delta. The scaling function, also known as the "father wavelet", is defined by:

$$\phi_{J,k}(t) = 2^{-\frac{J}{2}}\phi(\frac{t - 2^J k}{2^J})$$

and the wavelet function, known as the "mother wavelet", by:

$$_{j,k}(t) = 2^{-\frac{j}{2}}(\frac{t - 2^j k}{2^j})$$

The wavelet function in Eq. (1) depends on two parameters, scale (or frequency) and time: the scale factor *j* controls the length of the wavelet (window), while the translation or location parameter *k* refers to the location and indicates the non-zero portion of each wavelet basis vector. The basis wavelet function is stretched (or compressed) based on the scale parameter to get frequency information (a wide window yields information on low-frequency movements, while a narrow window yields information on high-frequency movements), and moved on the time line (from the beginning to the end) to get time information from the signal in question.

The scaling function integrates to 1 and reconstructs the smooth and low-frequency parts of a signal, while the wavelet function integrates to 0 and describes the detailed and high-frequency parts of a signal. In this way, by applying a *J-level* multi-resolution decomposition analysis we can provide a complete reconstruction of the signal partitioned into a set of *J* frequency components so that each component corresponds to a particular range of frequencies. In this specific application, since "fundamentals-based" contagion reflects normal interdependence due to real and financial linkages and "pure" contagion co-movements over and above those linkages represented by fundamentals, we are interested in decomposing the signal into two parts: a low-frequency part, which can be associated to interdependence, and a high frequency part, which is what remains after interdependence is taken into account, that is contagion.

4.2. Multiscale Analysis Of Correlation:

The wavelet decomposition enables an alternative representation of the variability and association structure of certain stochastic processes on a scale-by-scale basis. Especially, the wavelet coefficients can be straightforwardly manipulated to achieve recognizable statistical quantities such as wavelet variance, wavelet covariance, and as well as wavelet correlation.

The wavelet variance decomposes the variance of a time series into components associated with different scales (Percival, 1995), where the wavelet variance at scale *j*, $\sigma_X^2(\lambda_j)$, of a stationary stochastic process {X} with variance is given by the variance of *j-level* wavelet coefficients:

$$\sigma_X^2(\lambda j) = \mathrm{Var}(\omega_{j,t}^X)$$

Same as their classical counterparts, we can define the wavelet covariance between two processes X and Y at wavelet scale *j* as the covariance between *scale-j* wavelet coefficients of X and Y, that is, $\gamma_{XY}(\lambda_j) = \mathrm{Cov}(\omega_{j,t}^X \omega_{j,t}^Y)$, and the waveletcorrelation between two time series $\rho_{XY}(\lambda_j)$ as the ratio of the wavelet covariance, $\gamma_{XY}(\lambda_j)$, and the square root of their wavelet variances $\sigma_X(\lambda_j)$ and $\sigma_Y(\lambda_j)$ (see Whitcher *et al*., 1999,

2000). The wavelet correlation coefficient $\rho_{XY}(\lambda_j)$ provides a standardized measure of the relationship between the two processes X and Y on a scale-by-scale basis and, as with the usual correlation coefficient between two random variables, $|\tilde{\rho}_{XY}(\lambda_j)| \leq 1$. Specifically, given the unbiased estimators of the wavelet variances, $\tilde{\sigma}_X(\lambda_j)$ and $\tilde{\sigma}_Y(\lambda_j)$, and covariance, $\tilde{\gamma}_{XY}(\lambda_j)$, the unbiased estimator of the wavelet correlation for scale *j*,$\tilde{\rho}_{XY}(\lambda_j)$, may be obtained by:

$$\tilde{\rho}_{XY}(\lambda_j) = \frac{\tilde{\gamma}_{XY}(\lambda_j)}{\tilde{\sigma}_X(\lambda_j)\tilde{\sigma}_Y(\lambda_j)}$$

Starting from the unbiased estimator of the wavelet correlation for scale *j*,$\tilde{\rho}_{XY}(\lambda_j)$, we propose a simple wavelet-basedapproach to test for contagion. Following Forbes and Rigobon's (2002) definition of contagion as a significant increase in cross-market linkages after a shock, we test whether wavelet correlation coefficients on a scale-by-scale basis change significantly after a shock, with the change being revealed by an upward or downward shift of the estimated wavelet correlation values, and the significance of the change detected by examining approximate confidence intervals between crisis and non-crisis periods. Additionally, starting from the spectrum $S\omega_X(\lambda_j)$ of scale-*j* wavelet coefficients, it is not impossible to determine the asymptotic variance V_j of the estimator of the wavelet variance (covariance) and construct a random interval which forms a $100(1-2p)\%$ confidence interval. The formulas for an approximate $100(1-2p)\%$ confidence intervals estimator robust to non-Gaussianity for$\tilde{\sigma}_X^2(\lambda_j)$ are derived in Whitcher *et al*. (2000). Indeed, according to Whitcher*et al*. (2000), non-overlapping approximate confidence intervals of estimated wavelet correlation coefficient values can beconsidered a visual method to statistically test the hypothesis of equality of wavelet correlations at different scales between crisis and non-crisis periods. Specifically, following the Forbes and Rigobon (2002) definition of contagion as a significant increase in cross-market linkages after a shock, if we denote the estimated wavelet correlation coefficient values for the non-crisis and crisis periods as $\tilde{\rho}_{xy}^{I}(\lambda_j)and\tilde{\rho}_{xy}^{II}(\lambda_j)$, respectively, the null hypothesis of no contagion defined by:

H_0: $\tilde{\rho}_{xy}^{I}(\lambda_j) = \tilde{\rho}_{xy}^{II}(\lambda_j)$

can be rejected when 95% approximate confidence intervals are non-overlapping (see Gencay *et al*., 2002, for more details).

Data And Empirical Results:

In this section, we apply the wavelet-based approach proposed in the previous section to test whether contagion occurred during the most recent international financial crisis: the US subprime crisis of 2008.

5.1 Data:

We use close-to-close daily data in local currencies for the stock market indices of original ASEAN countries plus Australian and USA: namely NYSE COMPOSITE (US), MSCI Islamic (Australia), MSCI Islamic (Singapore), FTSE Bursa EMAS *Shari'ah* (Malaysia), Jakarta SE Islamic (Indonesia), MSCI Islamic (Thailand),MSCI Islamic (Philippines). Data are taken from the Datastream and cover the period from 23June 2006 to 31 August2009. These stock market indices are transformed to compounded stock market returns by calculating the natural logarithmic differences of the daily stock prices, that is, $rt = \ln(\frac{p_t}{p_{t-1}})$, where P_t and P_{t-1} represent the stock price index at time t and $t-1$, respectively.

Periods of financial turmoil are generally identified with a rise in asset price volatility. Fig. 1 shows the extent of the increase in volatility characterizing international equity markets after the occurrence of the US subprime mortgage bubble in August 2008. Based on the fundamental subprime event, we chose the end of July 2008 as the structural break date that separates the pre-crisis and crisis periods. In particular, the crisis period begins on 1August 2008 and we take one year period data for crisis period. On the other hand, the crisis period starts on 1 August 2008and ends at the end of the sample, 31 August 2009. Table 1 provides the number of daily observations for the bivariate series for the pre-crisis, crisis, and total sample periods.

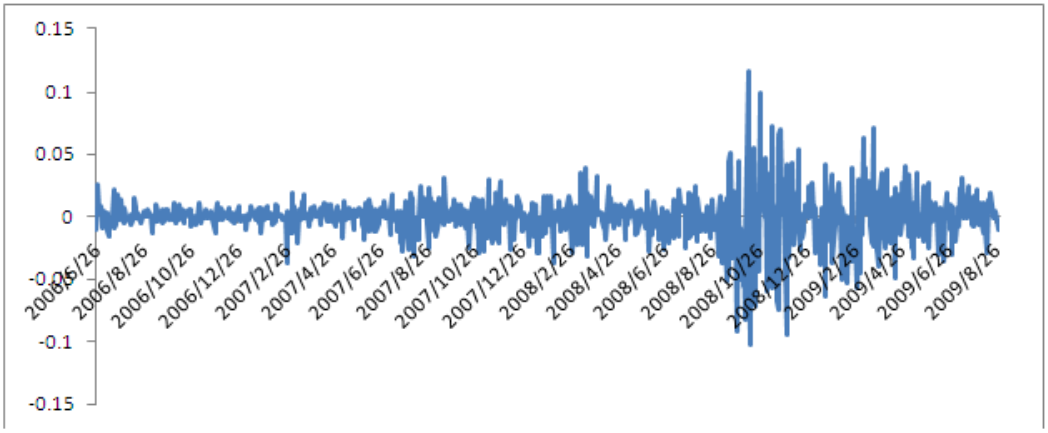

Fig. 1: NYSE returns for the period from 23 June 2006 to 31 August2009.

Table 1: Number of daily observations for each bivariate dataset.

Period	AUSMSCI	SINMSCI	EMAS	JAKSE	THAIMSCI	PHILMSCI
Pre-crisis	304	304	464	549	152	152
Crisis	281	281	281	281	281	281
Total	585	585	745	830	433	433

5.2. Contagion during the 2008 US subprime crisis:

The use of multi-timescale analysis may raise a critical question on how we are able to identify the high-frequency periodicities corresponding to contagion. Several researches show that the transmission of shocks because of contagion in international financial markets is very fast and dies out quickly after a few days, so that most correlations tend to disappear in five days' time or even less (see Baig and Goldfajn, 1998; Ait-Sahalia *et al*., 2010).Since we employ daily data, and considering that the effects of contagion should normally not be more than one week, we can assume that the first three wavelet scales provide a realistic measure of contagion, as these very fine scales are associated to changes of 1, 2, and 4 days, respectively. Therefore, "pure" contagion is measured by wavelet coefficients *w1*,*w2*, and*w3*, i.e., coefficients corresponding to scales up to 1 week, and "fundamental-based" contagion by coarse-scale (scaling)coefficients *v3*.

We employ the time-scale decomposition analysis by applying the maximal overlap discrete wavelet transform (MODWT).

The MODWT is a variant of the discrete wavelet transform (DWT) that, unlike the classical DWT, can handle any sample size, is translation invariant (as a shift in the signal does not change the pattern of wavelet transform coefficients), provides increased resolution at coarser scales, and produces a more asymptotically efficient wavelet variance estimator than DWT. Since previous studies on high-frequency data have shown that a moderate-length filter such as L = 8 is adequate to deal with the characteristic features of these data (see Gencay *et al*., 2001, 2005), we use the Daubechies compactly supported least asymmetric (LA) wavelet filter of length L = 8, denoted by LA(8), based on eight non-zero coefficients (Daubechies, 1992), with reflecting boundary conditions (we also used for comparison the Daubechies extremal phase wavelet filter of length L = 4, denoted D(4), obtaining qualitatively similar results). Then, using MODWT wavelet coefficients, *w3*,*w2*, and *w1*, we estimate the wavelet-unbiased pairwise correlation coefficients, $\tilde{\rho}_{XY}(\lambda_j)$, for crisis andnon-crisis periods from bivariate systems composed of the return in the country where the crisis originated (the "ground-zero" country) and the return in another country.

The results from the application of wavelet correlation analysis to each bivariate system for the different sub-periods, crisis and pre-crisis periods, are presented in Fig. 2. All computations have been performed using the waveslim package developed by Whitcher (and available at http://www.cgd.ucar.edu/~whitcher) running under the R statistical computing environment(R Development Core Team, 2006). Fig. 2 shows the two sample results from the application of wavelet correlation analysis for crisis and non-crisis periods. The blue line deals with the wavelet correlation coefficient for the non-crisis period, whereas the red line corresponds to the wavelet correlation coefficient during the crisis period. The dashed lines denote the upper and lower bound for the approximate 95% confidence interval with the assumption of a non-Gaussian process.

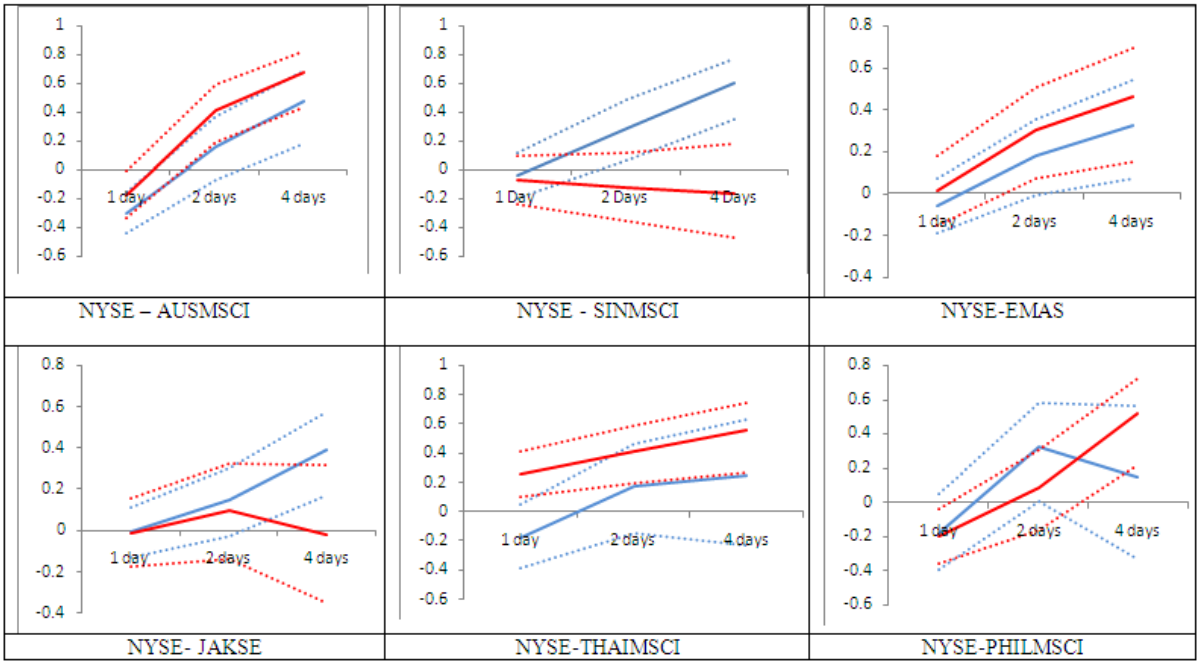

Fig. 2: Estimated wavelet correlation of NYSE with the returns of each other *Shari'ah*-compliant stock index for crisis (red line) and pre-crisis (blue line) periods. The dashed lines both blue and red denote the upper and lower bounds for the approximate 95% confidence interval. The null hypothesis of no contagion can be rejected when the confidence interval are non-overlapping. (For data, please refer to appendix 1).

There are some interesting findings derived from various patterns which are presented by the wavelet-based "correlation-breakdown" test. Firstly, in all cases of selective *Shari'ah*-compliant stock markets, the wavelet correlation coefficients change insignificantly at all scales during the US subprime crisis. Even though, there is slight increase on wavelet correlation coefficients from scale 2 to scale 3, however, these increases are insignificant due to overlapping of confidence intervals; therefore we cannot reject the null hypothesis. As a conclusion, there is no clear evidence of contagion at all scales. For the second finding, both during pre-crisis and crisis, from scale 1 to scale 2, the wavelet correlation coefficients are very low which implies that there is still country-diversification benefits if *Shari'ah*-compliant investors include the selective *shari'ah*-compliant stocks in their portfolios. This enables *Shari'ah* investors to diversify their portfolios by hedging against unforeseen risks. Finally, at the lowest scale that suggests a weakening of the linkages between the all *Shari'ah*-compliant stocks and the US indices. The evidence of the Thailand and Malaysian stock market indices are consistent with the hypothesis that two out of ten countries which are least affected by the US financial crisis.

6. Interpretations:

We argue that there should be some factors to explain insignificant contagion for Islamic stock markets during US subprime crisis. The first reason can be associated with the growing progress of Asian market. Lee and Park (2008) point out that the Asian financial institutions possess relatively lesser direct exposure to US subprime mortgages and other structured credit products. Even though Asia has experienced a fast development towards global financial integration, the use of securitization and auxiliary markets is currently far more modest than that in advanced countries. The study documents that more advanced markets in emerging Asia show higher global integration, while less advanced countries like Indonesia and Philippine possess lower sensitivity, with the spillover from the US to Thailand being modest. South-East Asian countries are relatively different compared to the advanced counterparts like China and Korea that experienced a sharp increase in portfolio investment outflows in the past few years (mainly US debt securities), indicating the higher exposure of these Asian countries to any shock from the US. On the other hand, lower cross-border holdings of financial assets for ASEAN countries will lower down the sensitivity to abrupt adjustments in the valuation of international financial assets.

The strong growth prospects, sound external positions, and improved policies in Asia also have supported investor confidence in the regional economies. Lee and Park (2008) describe the healthy condition of Asian

financial system, which are the stronger regional banking systems and prudential, better risk management practices, more flexible exchange rate regimes, broader corporate financing sources, increasing integration at the global level, fiscal budgets consolidated, and so on.

For the second reason, we argue that the insignificant impact can be due to the specific features of Islamic stocks. The excessive leveraging and credit growth in the U.S. market are the fundamental factors that have ignited the subprime crisis (Haneef and Smolo, 2010). The application of *Shari'ah* principles would prevent excessive leverage and the formation of speculative bubbles in credit markets, thus it will in turn mitigate the adverse impact of the subprime crisis for Islamic finance industry (Chapra (2008); Chapra, Ebrahim, Mirakhor, and Siddiqi, 2008) due to the limit of leverage in Islamic finance, Islamic firms would absorb lesser impact from the crisis.

For another explanation, the limit of interest-based leverage would also lead to lower systemic risks of Islamic stocks, both during expansion and recession. During credit expansion supported by low interest rate, every company may benefit by taking higher leverage which will consequently boost their expected return. This is unlikely to be found in Islamic stocks. *Shari'ah* screening in the form of the twin screen of ethical and financial ratio filters will lead the Islamic index to take highly leveraged firms out of the index. For instance, DJIMI was able to detect the corporate troubles of Worldcom and Enron, due to increasing high leverage, and remove these companies from the DJIMI indices a year before the stock value of these companies became worthless (Hassan, 2002; Hussein, 2004). The leverage limit may lead the performance of individual firms to be less influenced by interest rate movement and would not fluctuate in the same fashion as overall markets. This may conform to study of Askari *et al* (2010) who argue about the lower correlation of individual stock price with other assets as well as whole market.

In addition, other conventional studies also have found the positive relationship between level of leverage and systemic risk. Hamada (1972) and Rubenstein (1973) have decomposed the beta into financial risk and operating risk while Mandelker and Rhee (1984) have provided an alternative way. They suggest that a company's beta have to increase if the company finances more heavily with debt. Hamada (1972) derives the Modigliani and Miller propositions within a portfolio theoretic framework and have found that firms with the same asset risk but different degrees of leverage must have different costs of equity, with the market requiring higher returns on the more highly levered firm. In other words, the levered beta therefore will contain the financial risk of leverage.

The third reason can refer to the complexity and intensive use of structured financial products, derivatives, and other toxic assets with uncertain fundamentals which played an important role in triggering crisis (Haneef and Smolo, 2010). On the other hand, the evidence above is unlikely to be found in Islamic financial sector. Firstly, Islamic Financial Institutions (IFIs) did not have any exposure to toxic assets (largely debt-based). In Islamic teachings, selling the debt at discount or premium is prohibited with the rule of *bay ad-dayn*. The debt should only be traded at par value which has made it impossible for IFIs to purchase these kinds of assets. Secondly, IFIs cannot purchase CDSs and interest rate swaps to cover risks. Given the presence of *gharar* in the contract, the validity of any kind of conventional derivatives is still a debatable issue among Islamic scholars. However, majority of scholars argue that trading derivates is not allowed with the reason that they are neither tangible assets nor intangible assets. It cannot be the subject matter of the sale and purchase. Thirdly, we can refer to the study done by Beck, Demirgüç-Kunt and Merrouche (2010) who mentioned that Islamic financial institutions particularly banks were more resilient to the subprime crisis than their conventional counterparts mainly due to their capital and liquidity buffers before the inception of the crisis in the summer 2007. With these three reasons, Islamic financial sector was not possibly directly affected by the subprime financial crisis.

Appendix 1:

1 NYSE-AUSMSCI

	Pre-crisis			Crisis		
	Wavecor	Lower	Upper	Wavecor	Lower	Upper
1 Day	-0.30609	-0.44367	-0.15441	-0.1791	-0.33505	-0.01361
2 Days	0.155581	-0.07241	0.368124	0.405443	0.188419	0.584712
4 Days	0.470842	0.177943	0.687103	0.671222	0.435358	0.820857

2NYSE-SINMSCI

	Pre-crisis			Crisis		
	Wavecor	Lower	Upper	Wavecor	Lower	Upper
1 Day	-0.0383	-0.1963	0.121646	-0.07563	-0.23854	0.091425
2 Days	0.291863	0.071085	0.48538	-0.12714	-0.35161	0.111155
4 Days	0.603975	0.352318	0.774179	-0.16396	-0.47145	0.179067

3NYSE –EMAS

	Pre-crisis			Crisis		
	Wavecor	Lower	Upper	Wavecor	Lower	Upper
1 Day	-0.05929	-0.18666	0.070044	0.013355	-0.15289	0.178862

2 Days	0.178876	-0.00356	0.349786	0.305672	0.076169	0.504416
4 Days	0.327133	0.075191	0.539816	0.463983	0.154648	0.690469

4NYSE-JAKSE

	Pre-crisis			Crisis		
	Waveco	Lower	Upper	Wavecor	Lower	Upper
1 Day	-0.00918	-0.12754	0.109443	-0.01155	-0.17711	0.15465
2 Days	0.145621	-0.02265	0.305866	0.096649	-0.14154	0.324259
4 Days	0.392351	0.169811	0.576817	-0.0186	-0.34968	0.316609

5NYSE-THAIMSCI

	Pre-crisis			Crisis		
	Wavecor	Lower	Upper	Wavecor	Lower	Upper
1 Day	-0.17714	-0.38714	0.050321	0.259453	0.097758	0.407803
2 Days	0.176409	-0.15184	0.469609	0.407535	0.190836	0.586359
4 Days	0.247805	-0.23258	0.630993	0.55248	0.268705	0.748009

6NYSE-PHILMSCI

	Pre-crisis			Crisis		
	Wavecor	Lower	Upper	Wavecor	Lower	Upper
1 Day	-0.18223	-0.3916	0.045073	-0.20001	-0.35416	-0.03528
2 Days	0.325686	0.006701	0.584512	0.081197	-0.15677	0.310252
4 Days	0.148985	-0.32738	0.564963	0.514684	0.218999	0.723789

Conclusions:

In this research paper, we analyzed the issues of contagion and interdependence by using a wavelet-based framework. Firstly, by taking advantage of the time-scale decomposition property of wavelet analysis, we identified contagion and interdependence on the basis of the frequency domain interpretation of these phenomena: all scales are associated to interdependence rather than contagion. Then, we investigated whether contagion occurred during the US subprime crisis of 2008 by applying wavelet correlation analysis on a scale-by-scale basis through a simple visual method based on approximate confidence intervals of estimated wavelet correlation coefficients in pre-crisis and crisis periods.

The results based on wavelet correlation analysis provide that in all cases of selective *Shari'ah*-compliant stock markets, the wavelet correlation coefficients changed insignificantly at all scales during the US subprime crisis. Even though there is a slight increase in wavelet correlation coefficients from scale 2 to scale 3, these increases are insignificant due to overlapping of confidence intervals; therefore we cannot reject the null hypothesis of no contagion. As a conclusion, there is no clear evidence of contagion at all scales. We argue that the nature of ASEAN market, the investors' confidence on the regional economy, the limit of interest-based leverage for Islamic stocks, and the prohibition of conventional toxic assets have strengthened the position of Islamic stocks against financial panics across border.

In short, this study shows that wavelet analysis can provide a valuable alternative to the existing conventional methodologies in testing international financial contagion, since wavelets can appropriately discriminate between contagion and interdependence effects.

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