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# Co-movement of ASEAN stock markets: New evidence from wavelet and VMD-based copula tests<sup>☆</sup>

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## ABSTRACT

This paper aims to study the co-movement and the volatility fluctuation between stock markets in the Association of Southeast Asian Nations (ASEAN) countries from a new perspective. The analyses also delve more deeply into the effect of ASEAN trading link establishment on the short-term interdependency. By applying three-dimensional continuous wavelet transform (CWT) on daily returns of stock markets for the period 2009 to 2016, the interdependence level and lag-lead relationship among ASEAN trading link participants are estimated. The degree of interdependence in ASEAN stock markets is found to be stronger in the short term, especially following particular external shocks. A Variational Modes Decomposition (VMD)-based copula estimation shows that the effect of economic shock – in our case, ASEAN trading link establishment – on the stock markets' level of comovement is only temporary and will progressively diminish within approximately two years. Only Indonesia and Malaysia display strong fundamental linkages between each other. Both the CWT and Copula methods consistently show that Vietnam (Indonesia) has the lowest (highest) interdependence with the rest of ASEAN trading link participants, as opposed to previous empirical evidence obtained from conventional methods. Investors who want to construct optimal portfolios and policymakers who aim to make effective macroeconomic policies should take these findings into account.

## 1. Introduction

Since the Asian financial crisis of 1997, many economists have been concerned about the causal influence of one country's stock market performance on the stock markets of other countries within the region. The topic of price linkages among the international stock markets and between stock prices has been examined in recent years and is a widely studied topic in empirical finance. The knowledge of interactions between stock markets is useful for determining the amount of risk hedging and for constructing the optimal global portfolio. The level of interdependence is also important for policymakers in speculating the timing of market intervention during periods of stock market instability and recession. In general, markets with low correlation tend to have higher diversification benefits due to a higher dispersion of risk. Several studies have been conducted in the literature on linkages between

global stock market movements. The general consensus by Arshanapalli et al. (1995), Copeland and Copeland (1998), Janakiraman and Lamba (1998), and Jeong (1999) is that the US stock market and shocks derived from it have a considerable spillover effect on the global stock markets, including the ASEAN stock market. Dewandaru et al. (2016) conduct an interdependence and contagion study on the major equity market in the Asia-Pacific region through wavelet decomposition and find that shocks are transmitted via excessive and fundamental linkages<sup>1</sup> to affect the equity markets simultaneously. The highlights show that negative external shocks, such as the subprime crisis, reveal fundamental contagion. In line with this reasoning, Shahzad et al. (2016b) perform a study on interdependence and contagion in the Greek and other European equity markets with a similar approach, suggesting that the short-run dependency shows a sudden increase in the comovement during the global financial

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<sup>1</sup> Dewandaru et al. (2016) describe excessive linkages as excessive transmissions of shocks beyond any idiosyncratic disturbances and fundamental linkages as transmissions by way of financial market integration and trade linkages or interdependence.

crisis. The short-run dependency post-external shock is further supported by Hyeonwoo et al. (2015) in their study of the spillover effects of the US financial crisis on emerging Asian countries.

The recent literature on interdependence has derived different results for the stock market interrelationship, depending on the particular region. Alagidede and Mensah (2016) study Africa's emerging stock market and suggest that dependence is time varying and weak for most African markets; in contrast, Wang et al. (2011) find that the China market has high interdependency with the markets in Japan and Pacific. Past studies on the comovement between the Southeast Asian countries by Lee (2009) and Lee and Jeong (2016) also conclude that the 5 ASEAN founding countries are highly cointegrated and prone to experiencing a higher short-term interdependence level after a negative shock, such as a financial crisis.

The main objective of this study is to solve the issue of the linkages among ASEAN stock markets and the effect of the establishment of ASEAN exchanges on the comovement level. On 18 September 2012, 6 exchanges from ASEAN countries, including Indonesia, Malaysia, Singapore, Philippines, Thailand, and Vietnam, collaborated to form ASEAN Exchanges. These exchanges aim to improve the efficiency and liquidity amongst its members in the region. The purpose of the exchange integration is also to promote growth and to facilitate cross-border transactions. Many financial analysts believe that this integration will ultimately increase the level of interdependence in ASEAN countries.

The frequency analysis approach, namely, the Wavelet Squared Coherence (WSC) method, will be utilized in our study to search the level of dynamic dependence between time series data in the long run. This method transforms time series data into a frequency that makes it easier to analyse the correlation between each spectrum. Myriad empirical studies can be found in the recent literature based on a frequency approach (see, e.g., Eickmeier and Breitung, 2006; Ftiti, 2010; Lemmens et al., 2008; Ramsey et al., 1995; Rahim and Masih, 2016). The WSC approach is different from conventional time-series models in that we decompose the return series into two domains, the frequency and time window of the interrelationship, which allows us to differentiate between interdependence and short-term contagion. It is known that stock returns commonly exhibit tail dependence; a possibility that comovement between stock markets occurs in extreme deviations. Since the correlation method only takes into account the linear relationship between time series data, it overlooks the comovement in the tails of the data distributions. To remedy this issue, the bivariate copula method, such as the Student- $t$  copula and the Archimedean copula, will be used to measure the degree of symmetric and asymmetric tail dependence between time series data. To examine the effect of ASEAN exchange establishment on the comovement level in the short run, another approach, called the Variational Mode Decomposition (VMD)<sup>2</sup>-based copula, will be utilized.

We contribute to the literature in two ways. First, the previous studies on the comovement between ASEAN stock markets are conducted mainly through regression analysis, Grange causality tests, and the cointegration method (see, e.g., Arshanapalli et al., 1995; Azman-Saini et al., 2002; Click and Plummer, 2005; Lee, 2009; Mandigma, 2014). Although these methods are appropriate for analysing the short-term and long-term level of dependence, they fail to analyse the phase in which one stock market is lagging or leading in the specific period

<sup>2</sup> Dragomiretskiy and Zosso (2014) show that the VMD approach is adopted following empirical evidence for its ability to decompose time series into modes that reconstruct the input signal within limited bandwidth, which allows for more detailed observation on collective volatility within a certain period. Lahmiri (2015) proves the superiority of the VMD approach in decomposing data compared to discrete wavelet transform. Lahmiri (2016) also shows the advantages of the VMD approach by comparing the forecasting results of the VMD with three other kinds of methods to prove that the VMD is an effective and promising technique for the analysis and prediction of economic and financial time series. Shahzad et al. (2016b) prove that variations in the VMD modes are stable over time, and it is important to do a preliminary de-noising work.

due to some limitations of the method. Moreover, the aforementioned methods are also unable to capture the tail dependence that generally exists in financial time series. However, we employ wavelet analysis in this paper to observe the lag-lead relationship between stock markets and the time after which one will follow the other. The VMD-based copula method used in our study will also provide us with information about the contagion effect caused by the establishment of ASEAN trading link. Using both the WSC and copula methods allows us to observe the stock market comovement from a new perspective and simultaneously allows us to obtain a more comprehensive comovement analysis from the lead-lag relationship and tail dependence. Employing the two methods together also provides a robustness check by showing consistent results that are in line with each other.

Second, there are few studies conducted on the level of cointegration between ASEAN countries during and after the establishment of ASEAN exchanges. As we have daily data for 5 years since the establishment of ASEAN exchanges, an empirical study based on these time series is now possible and may yield more accurate results. Moreover, most studies that consider the effect of an economic shock focus mainly on the spillover effect of external negative shocks, such as the global financial crisis (see, e.g., Lee, 2009; Lee and Jeong, 2016; Thanh and Lan, 2016), but fewer studies have been conducted on the effect of positive internal shock<sup>3</sup> on price movement in the ASEAN stock markets, such as stock exchange integration or monetary union. Therefore, this paper attempts to partially fill the gap in the literature and to provide recent empirical evidence on the stock market integration among the ASEAN stock markets. The findings of this study may have implications for determining the amount of risk hedging, optimizing the capitalization structure and constructing the optimal global portfolio. It is also important for policymakers and central banks that aim to maintain a country's financial stability.

The paper is outlined as follows: Section 2 reviews the recent literature on stock markets, including the various methods used in these studies. In Sections 3 and 4, the methodologies and the data used for this study will be explained thoroughly. Section 5 will present the empirical results on the long-term and short-term interdependence amongst stock markets and the comovement level during and after the establishment of ASEAN trading links. Section 6 summarizes by drawing conclusions and discusses the empirical results.

## 2. Literature review

The concept of price comovement in stock markets has been extensively studied in a wide range of contexts. Baffes (2009) classifies the concept of price comovement into two groups: spatial price comovement and across-industry market. Yusof and Majid (2006) define market cointegration based on either asset pricing or statistical perspectives. Jorion and Schwartz (1986) define market integration in terms of asset pricing as a situation where investors earn the same risk-adjusted expected returns on a similar financial instrument in different national markets. On the other hand, Bachman et al. (1996) and Narayan et al. (2004) define market integration statistically as the situation where the stock prices in national markets have a tendency to move together in the long run because of factors such as arbitraging or changes in financial regulations. Moreover, increases in the comovement and integration between ASEAN stock market exchanges will ultimately decrease the benefits of global portfolio diversification.

Earlier studies by Grubel (1968), Levy and Sarnat (1970), and Solnik (1974) provide empirical evidence of lower correlations among domestic stock markets. In contrast, Goldstein and Michael (1993) find that the linkages between international stock markets have risen in recent years. The emerging markets are more closely integrated.

<sup>3</sup> Le and Bui (2016) reveal that positive internal shock generates less volatility than negative external shock.

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