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journal homepage: www.elsevier.com/locate/gfjVolatility linkage across global equity markets^{☆,☆☆}Liang Ding^a, Yirong Huang^{b,*}, Xiaoling Pu^{c,**}^a Authority of Qianhai^b Sun Yat-sen University^c Kent State University

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ABSTRACT

This paper analyzes the volatility linkage across the U.S., European, German, Japanese, and Swiss equity markets from 1999 to 2009. Both the unconditional and conditional correlations exhibit large fluctuations during the sample period. The results from the VAR analysis show an asymmetric two-way relation between the VIX and other market volatility indices, in which VIX has a larger impact in both the tranquil and crisis times. The structure of the volatility correlation before and during the recent global financial crisis does not show significant changes. In addition, robust test results from realized volatilities confirm the results from implied volatility indices.

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1. Introduction

In the past decade, the connection across financial markets has been significantly strengthened due to globalization. The trend is important for investors with international portfolios, whose investment decisions heavily rely on the information of cross-market linkage. The general wisdom of international portfolio theory states that investors should benefit from cross-market diversification, based on the assumption that the degree of co-movement across different markets is low. A series of financial crises in 1980s and 1990s, such as the crash of 1987, Mexican “Tequila crisis” in 1994, East Asian “Asian flu” in 1997, “Russian virus” in 1998, and Brazil’s currency crisis in 1999, have undermined the assumption. More often than not, the international markets are no longer the haven to diversify the risk due to strong cross-market linkage. Recently, investors witnessed the simultaneous plummet of stock markets in almost every market around the world during the

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financial turmoil of 2008–2009. Thus, it is of interest to understand the global cross-market linkage in the past decade, which had both tranquil and crisis times.

Volatility linkage across markets represents an important avenue through which the fluctuation on markets can affect security prices and alter investors' behavior. When an investor's portfolio spans over several markets, his or her net risk (volatility) exposure will be affected by the changes of the cross-market volatility linkage. The investors should incorporate such information into their trading strategies and risk management. Several papers have examined the implied volatility linkage in different markets, such as Nikkinen and Sahlström (2004) and Äijö (2008). Nikkinen and Sahlström (2004) examined the implied volatility indices in the United States, the United Kingdom, German, and Finnish markets from July 1996 to February 2000, and Äijö (2008) analyzed the VDAX, VSMI, and VSTOXX volatility indices from January 2000 to December 2004. Their papers are comprehensive studies to examine the correlation among implied volatility indices in the world. To extend the research along the line, our paper focuses on both implied volatility and realized volatility linkages in major equity markets from January 1999 to December 2009. Our sample period covers the recent global financial crisis. The advantage of sample period gives us an opportunity to examine the impact of the recent 2008–2009 crisis on the cross-market volatility linkage.

The methodology for describing the market linkage usually has two categories. One is the correlation analysis. Most previous literature employs this method to describe the simultaneous correlation across markets, which represents the static status of market linkage. Along this line, our paper uses the rolling correlation analysis, and investigates both unconditional and conditional correlations. The recent literature tends to describe the dynamic linkage across markets using time series models, such as GARCH and VAR models (e.g., Lin, Engle, and Ito (1994)). We examine information transmission across volatility channel through the VAR model, and identify an asymmetric two-way information transmission in which the U.S. market volatility plays a stronger role. In addition, we employ the breakpoint tests and find that there is no significant time varying of the coefficient estimates in the VAR model before and after the crisis.

The remainder of the paper is organized as follows. Section 2 is the literature review. Section 3 describes the data and descriptive statistics. Section 4 presents the results of implied volatility correlations. Section 5 presents the empirical tests of the VAR models with implied volatilities. The robustness tests with realized volatility are provided in Section 6 and Section 7 concludes.

2. Literature review

The global market linkage should be caused by the various linkage channels that connect markets and through which the information is diffused. One argument is that shocks are transmitted by fundamental channels, such as trade (Dornbusch, Park, & Claessens, 2000), and the balance sheet (Kiyotaki & Moore, 2002). The other argument is that information is transferred through market channels such as return (King & Wadhvani, 1990), volatility (Äijö, 2008; Hamao, Masulis, & Ng, 1990; Nikkinen & Sahlström, 2004), and liquidity (Allen & Gale, 2000; Brunnermeier & Pedersen, 2009).

Most early studies of market linkage focus on the return co-movements across countries. For example, Agmon (1972) finds a substantial relationship among the equity markets in the U.S., the U.K., Germany, and Japan. Eun and Shim (1989) analyze the daily stock returns for nine markets from 1980 to 1985, and find that there exists strong correlation among international stock markets and that the U.S. stock market is the most influential.¹

Recently, volatility linkage in the global equity markets has attracted much research attention. Since implied volatility index contains the market investors' expectations of uncertainty regarding the future stock price movements, the study of volatility linkage has important implications for the equity markets. In addition, implied volatility has supplementary information content for the returns (e.g., Blair, Poon, & Taylor, 2001; Fleming, Ostdiek, & Whaley, 1995; Jorion, 1995). Thus, our interest is to investigate the cross-market linkage through implied volatilities.

A number of papers examine the implied volatility correlations in the global equity markets. Nikkinen and Sahlström (2004) analyze the implied volatilities from the stock index option prices in the U.S., the U.K., German, and Finnish markets. They find a strong relation, and the U.S. stock market is the leading source of uncertainty. Äijö (2008) examines the implied volatility term structure linkages between the

¹ Related studies include Hilliard (1979) and Barclay, Litzenberger, and Warner (1990).

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