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Return and Volatility Connectedness between Stock Markets and Macroeconomic Factors in the G-7 Countries

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Abstract. We examine the relationship between return and volatility of the stock markets and macroeconomic fundamentals for the G-7 countries by using monthly data ranging from July 1985 to June 2015. To meet this end, we apply the spillover index approach based on the generalized VAR framework developed by Diebold and Yilmaz (2012, 2014). The empirical analysis shows strong interactions between the returns and volatilities of the G-7 stock markets and the considered set of corresponding macroeconomic factors including industrial production, money supply, interest rates, inflation, oil prices and exchange rates. The return and volatility spillover transmission/reception dynamics of the relationships between these stock markets and the macroeconomic fundamentals have changed after the global financial crisis of 2008. Our findings provide useful insights for investors and policy makers concerned with the unprecedented swings in the stock markets of G-7 countries.

Keywords: G-7 return, volatility, connectedness, macroeconomic factors, generalized VAR

1. Introduction

The volatility of stock markets has gained considerable attention in academic and policy discussions due to the recent global financial crisis of 2007-08 and the Eurozone crisis of 2012-13. Volatility usually significantly increases during economic recessions and turmoil periods when the need for tranquility is paramount. For example, Schwert (1989) documents that the U.S stock market's volatility remains high during major episodes such as the American Civil War, World War I, the Great Depression, World War II, the OPEC oil shocks and the post 1979 recession period of the U.S economy. Some more recent studies also report similar results regarding the behavior of stock market volatility during the recent global financial crisis of 2008 and the European sovereign debt crisis.[1]

The relationship between stock market volatility and macroeconomic fundamentals is intuitively appealing, and there are also several theoretical justifications that have been made for this nexus (Boudoukh and Richardson, 1993). However, the empirical identification of the major factors that drive stock market volatility during rapidly changing economic and political conditions and structural break is a challenge to analysts seeking to find a consistent and stable relationship between these variables. This study is an effort to demystify this link and bridge the stock-economy gap by analyzing the relationship between influential macroeconomic factors and stock market volatility. In fact, the linkages between stock markets and macroeconomic fundamentals are primarily based on the theoretical framework of the dividend discount model (DDM) and the arbitrage pricing theory (APT), through which the behavior of macroeconomic fundamentals are factored into stock prices. These models predict that if a market is efficient, then any changes in its macroeconomic variables will influence the expected dividends or cash flows of the firms and their financing and investment decisions. Consequently, the profitability of the listed firms will be changed, which would further affect the aggregate stock market returns (Chinzara, 2011).

The analysis of financial markets' volatility and its determinants is crucial for asset pricing, risk management and funds allocation (Martens and Zein, 2004). Moreover, policy makers would also like to understand the macroeconomic factors that are relevant to market volatility and the impact of volatility spillovers on the economy in order to devise a stable, effective and well-directed financial and economic policy (Corradi et al., 2012). The current study extends the existing literature for the G-7 developed markets by examining the volatility relationship between these markets and their macroeconomic variables and using extended monthly data spanning over the last three decades. During these decades, various local, regional and global economic and financial crises have affected this relationship between stock market and macroeconomic variables. But this current study analyzes the impact of the most recent global financial crisis on this relationship before and after this crisis.

In this study, we investigate how a buildup of macroeconomic risk in the G-7 countries increases the risks in the stock markets and vice versa. Specifically, we exploit the large set of existing measures of macroeconomic uncertainty to quantify how fluctuations in systematic risk factors impact the probability of a stock markets downturn. For that purpose, we employ a spillover index approach of Diebold and Yilmaz (2009, 2012, 2014, 2015a, and 2015b) that efficiently aggregates the global financial crisis of 2008 information across the gamut of individual measures including industrial production, money supply, interest rate, inflation, exchange rate and oil prices. In Addition, the study also contributes in terms of data and broad spectrum of developed markets that would add significant value to the existing literature. The study uses an updated high frequency monthly data of the last 30 years for the G-7 countries, with France and Italy having a relatively shorter data base[2]. To the best of our knowledge, no empirical evidence is available on the G-7 stock markets with such an extensive set of macroeconomic factors[3]. Methodologically, the spillover index approach of Diebold and Yilmaz offers several advantages over the multivariate VAR model and MGARCH models which have been used very commonly in the existing literature (Morelli, 2002; Chinzara, 2011; Engle et al., 2013; Kumari and Mahakud, 2015). First, the forecast error variance decompositions (FEVDs) are not affected by the ordering of the variables because the invariant FEVDs do not depend on the Cholesky factor identification of VAR (Awartani and Maghyereh, 2013). Second, it helps to measure the returns and volatility spillovers of multiple assets classes over time (Zhang and Wang, 2014). Third, the spillover index approach also allows the measurement of the net directional spillovers in either direction from one market to another market (Wang et al., 2016). Finally, the spillover index approach provides more information on dynamic directional spillovers that gives advantage over the variance-covariance matrix parameters in the MGARCH model (Zhou et al., 2012).

A set of new stylized facts emerges from our empirical investigation as our results show considerable interactions between the volatilities of the G-7 stock markets and their macroeconomic factors. The volatilities of the stock markets and the macroeconomic factors contribute more to the forecast error variance at second moment as compared to the return spillovers at the first moment. The volatility of money supply (M2) is identified as the most dominant macroeconomic factor of the stock market volatility, followed by inflation (CPI), industrial production (IPI), oil prices (OIL) and exchange rates (ER) for the majority of G-7 countries. Surprisingly, the volatility of the short-term interest rate (GBR) is found to be an insignificant macroeconomic factor to the stock market volatility of all G-7 countries. As expected, the rolling window spillovers of the returns and volatilities of the G-7 stock markets and the macroeconomic variables show a significant increase in the connectedness among those markets, starting immediately after the global financial crisis of 2008. These results are in line with Barunik et al., (2016), who also report a strong and homogenous correlation among gold, oil and stocks in USA after the global financial crisis of 2008. Moreover, the net pair-wise return and volatility transmissions changed for all G-7 countries differ significantly during the pre- and post-financial crisis of 2008.

The remainder of this study is organized as follows. Section 2 provides the relevant literature and Section 3 presents the data and the descriptive statistics. Section 4 presents the econometric procedures and Section 5 discusses the empirical results. Section 6 concludes.

2. Related Literature

There are two main streams of the literature on the linkages between stock prices and macroeconomic variables. In the first stream, many researchers (e.g., Fama, 1981; Hashemzadeh and Taylor, 1988; Abdullah and Hayworth, 1993; Darrat and Dickens, 1999; Chaudhuri and Smiles, 2004; Malliaris and Urrutia, 1991; Mukherjee and Naka, 1995; Mookerjee and Yu, 1997; Sadorsky, 2003; Serletis, 1993; Thornton, 1993, 1998; Nieh and Lee, 2001; Gunasekarage et al., 2004; Gan et al., 2006; Gjerde and Saettem, 1999; Maysami et al., 2004; Rahman and Ashraf, 2008; Ratanapakorn and Sharma, 2007; Abbas and McMillan, 2014; Abouwafia and Chambers, 2015 among others) investigate the relationship between stock market prices/returns and macroeconomic variables for different countries, using the multivariate vector autoregressive models, the Johansen cointegration and the Granger causality tests. These studies document the significant impact of macroeconomic variables on stock market prices/returns. However, the results show that the coefficient signs and significance are mixed.

The second stream of the literature examines the relationship between systematic risk factors and stock market volatility using different volatility models. These studies mainly focus on the time-varying conditional variance process in the macroeconomic and financial data. The main motivation of this research that examines the second conditional moment is to discern the importance of volatility in portfolio managements, investment decisions and other policy-making matters. The early works of Officer (1973), Chen et al. (1986), French et al. (1987) and Schwert (1989), among others, examine the volatility of macroeconomic variables and stock market returns, which was further enhanced by the introduction of the autoregressive conditional heteroscedasticity (ARCH) model developed by Engle (1982)[4]. Following these works, many other studies (e.g., Liljeblom and Stenius, 1997; Morelli, 2002; Chowdhury and Rahman, 2004; Beltratti and Morana, 2006; Corradi et al., 2012; Erdem et al. 2005; Arnold and Vrugt, 2006; Diebold and Y?lmaz, 2007; Adjasi, 2009; Chinzara, 2011; Hsing and Hsieh, 2012; Lai et al. 2013; Su et al., 2014; Kumari and Mahakud, 2015) analyze the relationship between the volatility of macroeconomic fundamentals and stock market prices/returns for India, using volatility models.

Schwert (1989) investigates the linkage between macroeconomic factors (industrial production, short term interest rate, long and medium-term bond returns, money growth and inflation) and stock market volatility for the U.S. He argues that volatility is not only persistent in the stock market returns but some of the macroeconomic variables are relatively more volatile. Similar to Officer (1973), Schwert (1989) also finds that in the U.S. the volatility of stock markets is inexplicably high during the recession periods and World War II in the United States. Erdem et al. (2005) also examine the volatility spillover impact of inflation, interest rate, exchange rate, money supply and industrial production on the stock prices in Turkey. They find that inflation has a significant and negative volatility spillover to the Istanbul Stock Exchange (ISE) index while interest rate, exchange rate and industrial production have positive volatility spillover to this stock index. Morelli (2002) reports no strong connection between the conditional macroeconomic volatility and the conditional stock market volatility for UK, while Diebold and Yilmaz (2007) document a positive linkage between macroeconomic volatility and stock market volatility using a panel of 45 developed and emerging countries for the period 1984-2004.

Liljeblom and Stenius (1997) conduct a study for Finland and find that a significant portion of the changes in its stock market volatility is explained by the volatility of industrial production, money supply and inflation. Similarly, Chinzara (2011) studies the macroeconomic uncertainty and conditional volatility of the stock market in South Africa, by using the AR-GARCH and VAR models, and finds the results are quite similar to those of Erdem et al., (2005). More specifically, this author finds that the volatility of short term interest rate, oil price, exchange rate and inflation significantly influence the aggregate stock market volatility of South Africa. Similarly, a number of studies (e.g., Sadorsky, 1999; Papapetrou, 2001; Park and Ratti, 2008; Aloui and Jammazi, 2009; Ewing and Malik, 2015) find a significant negative relationship between oil price increases and stock market returns for different countries. Park and Ratti (2008) claim that oil price volatility accounts for about 6% of the stock market returns in the European economies, while Diaz et al., (2016) report that the stock markets began to react negatively in response to oil price volatility in the case of the G-7 countries. The findings of Kumari and Mahakud (2015) for India also advocate a close connection between macroeconomic and stock market volatility.

Since the onset of the global financial crisis of 2008, one of the growing trends in the literature is related to the importance of the US stock market volatility on domestic stock markets in other countries. The US stock market commonly serves as a benchmark for the majority of the markets across the world, and thus many researchers (e.g., Zhang and Li, 2014; George, 2014; Dimpfl, 2011; Chan et al., 2008 among others) find a strong impact of US stock market variations on the domestic stock market volatility of other countries. Dimpfl (2011) establishes a dependence relationship between the German stock market and the US counterpart and argues that the German stock market strongly follows the opening of the New York Stock Exchange (NYSE). Similarly, Zhang and Li (2014) document a strong impact of the US stock market on the Chinese stock market. Very similar results are also reported by George (2014), which reports that since the GFC, the US stock market has a strong ability to forecast the opening of the Chinese stock market.

Thus, based on the literature on the linkages between stock market volatility and systematic risk factors, it has been observed that the theoretical relevance between stock market volatility and macroeconomic factors for the different countries is quite mixed, and there is a lot more that need to be explored to resolve this puzzle. The current study is an effort to revisit the connection between stock market and macroeconomic volatilities by employing a vector autoregressive (VAR) model and the Diebold and Yilmaz spillover index (2012) to the G-7 countries.

3. Data and Methodology

3.1 Data Overview

We use monthly stock markets data from July 1985 to June 2015 for the G-7 countries, namely the Dow Jones Industrial Average (DJIA) Index for the United States, the Financial Times Stock Exchange 100 Index for the UK, the Toronto Stock Exchange Index for Canada, the Nikkei 225 Index for Japan, the German Deutscher Aktien Index (GDAXI) for Germany, the CAC40 Index for France and the FTSE MIB-30 Index for Italy. The macroeconomic variables are the industrial production index (IPI), consumer price Index (CPI), broad money supply (M2), government bill rate (GBR)[5], exchange rates with respect to the US dollar (ER)[6] and crude oil prices in local currency (OIL)[7]. The majority of the macroeconomic and stock market data series are collected from the Thomson Reuters DataStream and CEIC global data bases[8], while some of the series like the government bill rate for Japan, France and Italy are not available from the above data sources. Thus, we retrieved these series from the Organization of Economic Co-operation and Development (OECD) website. The time series plots of the G-7 stock market indices are displayed in Figure 1. Although there are many economic ups and downs over the sample time period, the original stock market index plots indicate two major downward swings for all G-7 countries except Japan[9]. The first downward trend starts from the early 2000s economic recession in the U.S, while the second downward trend starts with the global financial crisis of 2008.

We do not claim that the selected set of macroeconomic variables and their volatilities gives a complete explanation of the stock market returns and their volatility exhaustively. The selection of the variables is based on the theoretical relevance of these variables to the stock market returns/volatility. A significant body of aforementioned empirical literature has established the underlying relationship between stock market and macroeconomic variables at the first and second moments by using a different set of variables on different countries. Essentially, the indirect connection between stock prices and systematic risk factors is based on the expected cash flows and corporate earnings, and variations in the

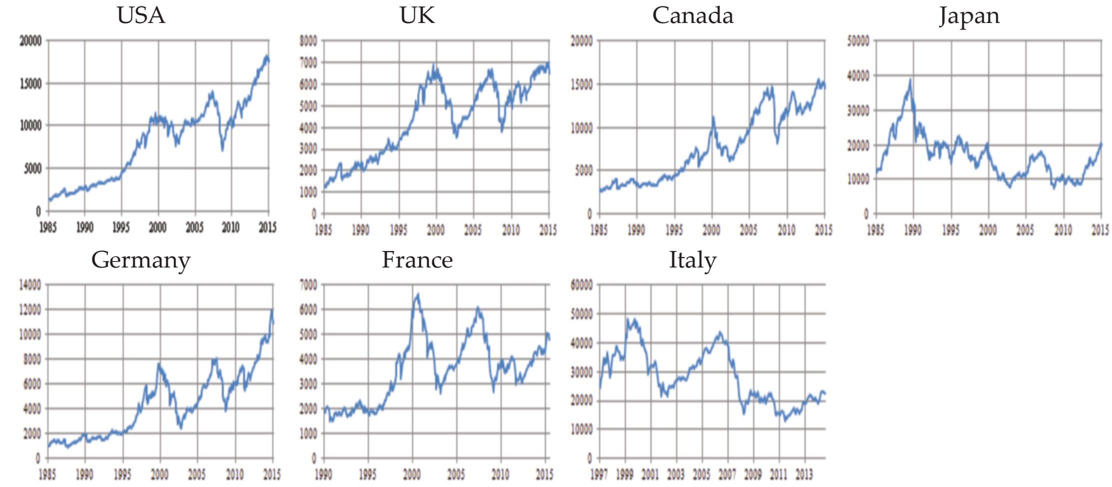


Figure 1 Time Series Plots of the Stock Market Indices for the G-7 Countries

macroeconomic variables will be ultimately reflected in asset prices of the listed firms through the conduits of corporate earnings. Fama (1990) explains the theoretical rationale of linkage between stock returns and production growth. He argues that future cash flows of firms are strongly related to the production growth of the country that is impounded in the stock prices/returns.

The connection between money supply and stock prices can be viewed through the inflationary expectations or the real activity approaches in the market. According to the inflationary expectation approach propagated by Keynesian economists, an increase in money supply could have a negative impact on stock prices due to rising inflation in the economy which may lead to an increase in interest rates. As a result, the discount rate would go up and in turn would decrease the present value and expected cash flows of the firms, leading to declines in stock prices. Sellin (2001) further argues that declines in economic activity as a result of increased interest rates would further depress stock prices. On the other hand, as perpetuated by the real activity theorists, an increase in money supply means that there is more demand for money in the market due to increased economic activity. High economic activity is positively linked with the profitability of firms, and consequently stock prices increase due to higher corporate earnings. Hence, the Keynesian economists propose a negative relationship between money supply and stock prices, while the real activity theorists offer a positive connection between money supply and stock prices. The economic theories of interest rate have also built a strong relationship between stock returns and term structure of interest rates. Chen et al. (1986) explain that any unanticipated changes in interest rates will affect future cash flows and profitability of the firms which would be reflected in the stock prices/returns.

Concerning the exchange rates, there are two different approaches which are the "flow-oriented" approach and "stock-oriented" approach that explain the theoretical relevance of exchange rates and stock prices. In the flow-oriented approach, Dornbush and Fisher (1980) explain that the exchange rate fluctuations affect the stock prices through the channel of the international trade balance. The depreciation of local currency encourages domestic firms to increase their exports by offering more competitive prices in the international market. As a result, an increase in exports will increase output, income and expected cash flows of the firms that would affect their stock prices positively. On the other hand, Branson (1983) and Frankel (1983) explain that exchange rates are simply determined by the supply and demand of financial assets. As per the stock-oriented approach, there are two different models namely the portfolio balance model and the monetary balance model that explain this approach. Both of these models establish a negative relationship between stock market returns and exchange rates. The portfolio balance model reflects the movement of exchange rates while balancing the internationally diversified portfolios of domestic and foreign financial assets. In this regard, an increase in stock returns of domestic financial assets would appreciate the local currency that would trigger the international investors to set a new portfolio of financial assets. In the revised portfolio, they will sell foreign assets and buy more domestic assets due to the depreciation of their local currency, and consequently the domestic currency will depreciate. Finally, crude oil is one of the major inputs in the production processes, and any change in the oil price can have a direct or indirect impact on the output level through various transmission channels. Consequently, the cost of production and commodities prices will be changed, that will eventually influence the stock prices of the listed companies and consumer spending. Kilian and Park (2009) discover that the demand-driven oil price shocks have positive impact on stock market prices, while the supply-side and other oil market specific shocks have negative impact on the stock market prices.

All the data series are transformed into the natural logarithmic growth form for conducting the econometric analysis. The descriptive statistics are reported in Table 1. The results indicate that highest average stock market returns are for the United States and Germany, followed by Canada, UK, France, Japan and Italy. It is quite surprising to note that the average stock market return for Italy is not only the lowest on the list, but also is negative along with the highest amount of risk as shown by the value of its standard deviation. When it comes to volatility, the stock markets of the US, UK and Canada are almost identical, exhibiting a low risk, while the markets of Japan, Germany, France and Italy have a higher amount of risk.

One of the interesting anecdotal findings from the descriptive statistics is that the short-term government bill rate (GBR) has a negative growth rate on average and has the highest amount of risk, while M2 has the highest amount of growth rate but with a minimum amount of risk among all the macroeconomic variables for all countries in the sample, reflecting deleveraging on the part of the consumers and caution on the part of banks. The industrial production growth rate for the US and Canada is also identical and the highest on the list of the seven countries, while Italy has its lowest and is negative. It means that highest stock market growth for the U.S. and Canada underpins the strong industrial production growth of these countries. In the case of Italy, both variables have a negative growth rate. The average growth rate of inflation for the U.S., the UK and Canada are the highest and identical in magnitude, which is followed by the inflation growth for Italy, France, Germany and Japan. The lowest average inflation growth for Japan may be due to its slow and deflationary economic growth for the last two decades which are also termed as the "two lost decades" of the Japanese economy. Concerning the exchange rates for all countries except the U.S.[10] which are taken

Table 1 Descriptive Statistics of Stock Market Returns and Growth in Macroeconomic Variables for the G-7 Countries

	SMI	IPI	M2	GBR	CPI	ER	OIL
USA							
Mean	0.0066	0.0018	0.0044	-0.0125	0.0022	0.0010	0.0014
Std. Dev.	0.0444	0.0062	0.0035	0.1340	0.0026	0.0163	0.0882
Skewness	-1.0948	-1.7021	1.1181	-0.8172	-1.4745	-0.0821	-0.2006
Kurtosis	6.6528	12.4069	8.1008	17.3529	14.2289	3.5792	5.9946
Jarque-Bera	272.06***	1501.1***	465.29***	3130.1***	2021.7***	5.437*	136.93***
ADF	-17.706***	-5.0804***	-5.8512***	-15.717***	-11.785***	-18.982***	-13.582***
PP	-17.697***	-17.786***	-14.304***	-15.664***	-11.491***	-18.982***	-13.095***
Q(12)	7.3741	152.44***	169.54***	44.620***	84.156***	11.832***	65.643***
Q2(12)	22.110**	104.33***	19.048*	52.656***	71.394***	28.868**	82.337***
UK							
Mean	0.0046	0.0004	0.0062	-0.0087	0.0022	-0.0003	0.0011
Std. Dev.	0.0455	0.0096	0.0052	0.0786	0.0023	0.0241	0.0917
Skewness	-1.1414	-0.5306	1.7863	-2.1778	2.3845	0.5420	-0.2057
Kurtosis	8.3357	5.5047	23.7521	18.3873	22.0776	4.7261	5.0032
Jarque-Bera	505.21***	110.99***	6651.2***	3836.1***	5800.4***	62.314*	62.731***
ADF	-18.407***	-25.322***	-5.2256*	-12.463***	-6.4085*	-14.472***	-13.729***
PP	-18.398***	-24.509***	-21.043***	-12.887***	-16.702***	-14.344***	-13.115***
Q(12)	6.4746	55.239***	86.520***	94.806***	365.87***	35.914***	71.489***
Q2(12)	8.2234	21.036**	9.3626	146.81***	46.502***	73.408***	78.758***
Canada							
Mean	0.0047	0.0018	0.0051	-0.0077	0.0020	-0.0003	0.0011
Std. Dev.	0.0436	0.0058	0.0048	0.1010	0.0036	0.0158	0.0889
Skewness	-1.4945	-0.8594	-0.0788	-0.4602	0.5901	0.5957	-0.1886
Kurtosis	9.1829	5.9701	4.6642	14.3153	8.7565	9.2534	5.4952
Jarque-Bera	707.43***	176.63***	41.915***	1933.2***	517.95***	607.86***	95.526***
ADF	-16.441***	-7.4715**	-6.0090***	-9.4828***	-16.400***	-13.974***	-13.553***
PP	-16.408***	-19.937***	-15.214***	-16.463***	-16.459***	-14.053***	-12.826***
Q(12)	14.058	70.545***	362.80***	55.926***	39.315***	46.655***	81.350***
Q2(12)	6.8218	113.73***	53.200***	52.455***	2.6115	43.817***	81.259***
Japan							
Mean	0.0013	0.0004	0.0031	-0.0159	0.0004	-0.0019	-0.0005
Std. Dev.	0.0611	0.0199	0.0033	0.3225	0.0026	0.0274	0.0942
Skewness	-0.5808	-2.7941	1.0802	0.2718	1.3129	-0.4328	-0.2598
Kurtosis	4.2041	24.2390	4.7628	15.9909	8.7065	3.8500	6.0892
Jarque-Bera	41.985***	7234.8***	116.62***	2535.9***	591.88***	22.075***	147.19***
ADF	-17.628***	-11.464***	-4.0745***	-22.139***	-15.986***	-13.624***	-13.541***
PP	-17.699***	-18.389***	-13.049***	-22.241***	-16.479***	-13.397***	-13.013***
Q(12)	9.8243	16.454	1080.4***	42.326***	43.781***	94.989***	69.041***
Q2(12)	28.872***	20.055**	411.47***	90.502***	2.2745	27.965***	88.035***
Germany							
Mean	0.0066	0.0013	0.0062	-0.0127	0.0012	-0.0015	-0.0001
Std. Dev.	0.0631	0.0158	0.0240	0.0674	0.0037	0.0259	0.0941
Skewness	-0.8984	-0.5354	15.9209	-1.6876	0.9472	-0.0161	-0.2329
Kurtosis	5.6906	5.3041	283.864	9.1323	6.6546	3.1458	5.2654

Table 1 Descriptive Statistics of Stock Market Returns and Growth in Macroeconomic Variables for the G-7 Countries (*Continued*)

	SMI	IPI	M2	GBR	CPI	ER	OIL
Germany							
Jarque-Bera	157.01***	96.827***	119848***	734.97***	254.17***	0.334	80.238***
ADF	-17.572***	-9.0446***	-19.648***	-5.7916***	-15.585***	-12.163***	-13.702***
PP	-17.572***	-22.981***	-19.670***	-10.700***	-16.549***	-13.377***	-13.097***
Q(12)	7.8622	40.936***	1.3623	309.95***	56.195***	43.128***	72.930***
Q2(12)	26.008***	55.181***	0.0359	150.96***	37.781***	10.211	93.169***
France							
Mean	0.0031	-0.0001	0.0039	-0.0199	0.0014	0.0000	0.0045
Std. Dev.	0.0550	0.0121	0.0078	0.0932	0.0016	0.0246	0.0938
Skewness	-0.5157	-0.1737	0.1246	-2.4498	0.1729	0.1304	-0.1547
Kurtosis	3.3907	4.7052	4.7099	16.4399	4.3145	3.2300	5.8712
Jarque-Bera	15.459***	38.484***	37.945***	2583.5***	23.479***	1.537	105.97***
ADF	-15.777***	-23.086***	-19.858***	-10.036***	-14.354***	-12.669***	-12.442***
PP	-15.753***	-22.203***	-20.044***	-10.612***	-14.744***	-12.430***	-12.459***
Q(12)	12.267	56.058***	43.929***	194.86***	58.727***	34.239***	59.164***
Q2(12)	42.214***	37.217***	8.7070*	67.387***	26.501**	14.428*	69.747***
Italy							
Mean	-0.0004	-0.0011	0.0044	-0.0212	0.0017	-0.0001	-0.0005
Std. Dev.	0.0644	0.0136	0.0175	0.2364	0.0075	0.0245	0.0966
Skewness	-0.2301	-0.3532	1.1106	-1.5146	-0.3478	-0.0041	0.2214
Kurtosis	3.7223	3.8172	6.4028	20.9491	5.8546	3.1356	5.4426
Jarque-Bera	6.418**	10.210***	144.48***	2899.2***	75.535***	0.161	53.919***
ADF	-13.742***	-6.0117***	-6.4720***	-11.877***	-10.664***	-10.584***	-10.124***
PP	-13.760***	-16.290***	-17.179***	-11.468***	-10.952***	-10.635***	-10.042***
Q(12)	13.807	39.764***	30.321***	18.386***	86.189***	22.918**	39.051***
Q2(12)	20.243***	150.56***	6.1369***	65.967***	50.044***	19.679***	44.385***

Note. Q(12) and Q2(12) are the Ljung-Box statistics for the residuals and squared residuals of stock markets and macroeconomic growth series at the 12th lag. ADF and PP are Augmented Dickey Fuller and Philip Parren tests of unit roots. The results presented in Table 1 are the authors' own estimates based on the data collected from the Thomson DataStream and CEIC global database. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. SMI=stock market index; IPI=industrial production index; M2=money supply; GBR=government bill rate; CPI=consumer price Index (inflation); ER=exchange rate; OIL=oil price.

with respect to the US dollar, the negative growth of the exchange rates for Japan, Germany and Italy indicates an appreciation of the value of the US dollar on average as compared to the values for the Japanese yen, German mark[11] and Italian lira[12] over the period of the last 30 years. The average oil price growth rate is the highest for France and is the lowest and negative for Japan and Italy due to their slow economic growth.

Most of the monthly growth of the series is negatively skewed, except for M2 for all G-7 countries, TBR (government bill rate) for Japan, CPI (consumer price index) for the UK, Canada, Japan and Germany, ER (exchange rate) for the UK, Canada and France and oil prices of Italy. Their values of high kurtosis indicate that the distributions of all the series of the G-7 countries are fatter tailed and non-normal. Moreover, the highly significant

Jarque-Bera values for all the variables of the G-7 countries underscore the presence of a non-normal distribution, except ER for Germany, France and Italy that follow the normal distribution.

Concerning the unit root tests, the Augmented-Dickey Fuller (ADF) and Phillips-Perron (PP) tests are used to check the stationarity of the data. All the growth series are found to be stationary in the level as shown by the results of those tests in Table 1. The Ljung-Box (LB) tests for the return series and the squared return series are also performed to check the serial correlation and ARCH effects. The results of those tests justify the application of the GARCH model to capture the volatility of the monthly data series for the stock market returns and other macroeconomic variables of the G-7.

3.2 Methodology

In this part of the methodology, we use the spillover index approach developed by Diebold and Yilmaz (2012, 2014) to analyze the spillover effects between the stock market and macroeconomic variables in the G-7 countries. This spillover index approach is the generalized form of Diebold and Yilmaz (2009) and is based on the forecast error variance decomposition under the VAR framework of Koop et al. (1996) and Pesaran and Shin (1998), which is invariant to the ordering of the variables in the model. The basic objective of this spillover index methodology is to examine the spillover contribution "to" and "from" other variables in the model through a simple and intuitive forecast of the error variance decomposition under the VAR model. Moreover, in order to capture the magnitude and direction of spillovers, this methodology also uses a rolling window estimation that determines whether a particular variable is a net transmitter or a receiver of the spillovers at each point in time.

The specifications of the spillover index measures start with the following equation of the p-th order for the stationary N-variable VAR:

$$x_t = \sum_{i=1}^{p} \Phi_i x_{t-i} + \varepsilon_t \tag{1}$$

where x_t is a vector of N endogenous variables, Φ_i denotes the $N \times N$ matrix of the parameters to be estimated, $t = 1, \ldots, T$ is the time index and $i = 1, \ldots, p$ is the variable index. In addition, $\varepsilon \sim (0, \Sigma)$ is a vector of the error terms that are distributed independently and identically over time.

The moving average representation of the VAR system in Equation (1) can be rewritten as follows:

$$x_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i} \tag{2}$$

where A_i are the $N \times N$ coefficient matrices that are recursively derived as $A_i = \sum_{t=1}^{p} A_{i-t}\Phi_t$, with A_0 being the $N \times N$ identity matrix and $A_i = 0$ for $i < 0$. The moving average coefficients translate the dynamics of the VAR model, and the main benefit of this approach is its invariant behavior to the ordering of the variables in the model[13].

Following Diebold and Yilmaz (2012, 2014), we use the generalized VAR framework of Koop et al. (1996) and Pesaran and Shin (1998), which produces a forecast of the error variance decompositions that are invariant to the variable ordering. The H-step-ahead generalized forecast error variance decomposition is given by:

$$\theta_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma A_h' e_i)} \tag{3}$$

where Σ denotes the variance matrix of the error vector ε, σ_{jj} is the standard deviation of the error term for the jth equation and e_i is a selection vector, with one as the ith element and zeros otherwise. This yields a $N \times N$ matrix $\theta(H) = [\theta_{ij}(H)]_{i,j=1,\ldots,N}$, where each entry gives the contribution of variable j to the forecast error variance of variable i. The main diagonal elements of the $\theta(H)$ matrix represent the own shock contributions, whereas the off-diagonal elements represent the contributions "to" other and "from" other variables in the forecast error variance decomposition. The sum of the variance contributions by own- and cross-variables is not equal to one under the generalized variance decomposition, i.e.,

$$\sum_{j=1}^{N} \theta_{ij}^{g}(H) \neq 1,$$

because the shocks to each variable are statistically independent. Therefore, each entry of the $\theta(H)$ matrix is normalized by dividing by the row sum as:

$$\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{g}(H)} \tag{4}$$

with $\sum_{j=1}^{N} \tilde{\theta}_{ij}^{g}(H) = 1$ and $\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H) = N$ by construction.

As mentioned by Fengler and Gisler (2015), Equation (4) is the representation of approximate fraction of the H-step ahead forecast error variance of variable i coming from variable j. By using a statistically independent variance contribution, we can construct several spillover measures that would justify the degree of independence of the variables' ordering in in the system. The total spillover index that measures the average contribution of the spillover effect to the variance decomposition of all variables is written as follows:

$$S^{g}(H) = \frac{\sum_{\substack{i,j=1 \\ i\neq j}}^{N} \tilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} = \frac{\sum_{\substack{i,j=1 \\ i\neq j}}^{N} \tilde{\theta}_{ij}^{g}(H)}{N} \tag{5}$$

The spillover index in Equation (5) measures the average contribution of spillovers to the forecast error variance. This methodology of the spillover index forwarded by Diebold and Yilmaz (2012, 2014) is not only flexible in terms of the ordering of the variables but also determines the direction of spillovers. Specifically, the directional spillovers transmitted from the i variables to the j variables are defined as:

$$S_{i\to j}^{g}(H) = \frac{\sum_{\substack{i,j=1 \\ i\neq j}}^{N} \tilde{\theta}_{ji}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ji}^{g}(H)} = \frac{\sum_{\substack{i,j=1 \\ i\neq j}}^{N} \tilde{\theta}_{ji}^{g}(H)}{N} \tag{6}$$

Similarly, the directional spillovers received from j variables to i variables are given by:

$$S_{j\to i}^{g}(H) = \frac{\sum_{\substack{i,j=1 \\ j\neq i}}^{N} \tilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} = \frac{\sum_{\substack{i,j=1 \\ j\neq i}}^{N} \tilde{\theta}_{ij}^{g}(H)}{N} \tag{7}$$

Here, the directional spillovers provide a breakdown of the spillover index into a spillover effect "from" and "to" the ij variables where $i \neq j$. Thus, the directional spillovers allow to identify the key factors of the total spillover index.

Moreover, the net directional spillovers from the i to the j variables, where $i \neq j$ can be obtained by the net result of Equations (6) and (7), and can be written as follows:

$$S_{i}^{g}(H) = S_{i\to j}^{g}(H) - S_{j\to i}^{g}(H) \tag{8}$$

The positive values of the net spillover index indicate that variable i is the transmitter of the spillover effect and that the direction of spillover is from variable i to all the j variables, while the negative values imply that variable "i" is the receiver of net spillovers and spillover direction is from the j variables to i variable. The directional spillover is also decomposed further into pairwise directional spillovers to analyze the bivariate spillover connection. The net pairwise directional spillovers nexus between the i and j variables is measured by the difference of shocks transmitted in either direction of the variables

ij, and is represented as follows:

$$S_{ij}^{g}(H) = \frac{\tilde{\theta}_{ij}^{g}(H) - \tilde{\theta}_{ji}^{g}(H)}{N} \qquad (9)$$

The value of the net pairwise spillover index provides information on whether a variable is a receiver or a transmitter of shocks. If the values of the net pairwise spillover index are positive, then variable i is a net transmitter of the spillover effect, while the negative values imply that variable "i" is the net receiver of spillovers. To sum up, the spillover index approach measures the intensity of interdependence across the variables and allows a decomposition of the spillover effects by the source and the recipient.

4. Estimation Results

4.1 Full Sample Spillover Analysis

The conditional volatilities are estimated by the appropriate GARCH models, and then further used in estimating the spillovers of G-7 stock markets and selected macroeconomic variables[14]. The summary of the results of the overall return and volatility spillovers contributions "to" and "from" the stock markets and the macroeconomic variables for the G-7 countries are reported in Table 2 (i.e., Panel A & B respectively). The country wise results of the return and volatility spillovers are given in the appendix (see Tables A-G in appendix). The directional spillovers table provides the decomposition of the spillover index. For example, the directional spillovers result for returns in Panel A indicates that the innovations to the overall macroeconomic variables are responsible for 25.2% of the 12-months ahead forecast error variance for Canada, while only 5.1% for Germany. Similarly, the return spillovers contribution of the stock market to the 12-months ahead forecast error variance of the overall macroeconomic growth are 10.4% for Canada and 7.2% for Germany.. Although the return spillover contribution of macroeconomic variables to the stock markets for all the countries except Germany are significantly higher, however, it does not differ too much in magnitude. In the case of volatility spillovers presented in Panel B of Table 2, for the majority of G-7 countries, the spillover contribution of the stock market to the macroeconomic variables is significantly higher, albeit the volatilities of the stock markets of US and Germany are comparatively more sensitive to the macroeconomic uncertainty. The significance of macroeconomic risk factors justifies that the stock markets of G-7 countries are efficient at first level and the macroeconomic variations into the stock prices. However, at variance level, the level of sensitivity increases significantly high and from both ends as shown by the results of directional spillovers both "to" and "from" the stock market and macroeconomic variables that are much higher, as compared to the return spillovers in Panel A. Therefore, it is important for both policy makers and investors to consider the importance of volatility spillovers of the stock markets and macroeconomic factors while making important decisions.

By distilling all the returns and the volatility spillovers of the stock markets and the macroeconomic variables into a single Spillover Index (SOI) for each of the G-7 countries, we once again find that a higher percentage of the forecast error variance comes from the volatility spillovers, compared to the returns spillovers. One of the major reasons of strong causal connection between the stock markets and macroeconomic fundamentals at variance is that the net impact of economic and financial crises is transmitted very quickly. Therefore, the SOIs are significantly higher at variance. For example, in the case of USA, 25.8% of the

Table 2 Directional and Total Spillovers between the Macroeconomic Variables and the G-7 Stock Markets

	Stock markets						
From	**US**	**UK**	**Canada**	**Japan**	**Germany**	**France**	**Italy**
Panel A: Return Spillovers							
Stock markets	92.10	92.43	89.57	93.70	92.83	93.25	89.27
Industrial production index	4.08	1.52	0.52	1.83	1.70	3.59	1.21
Money supply	0.73	0.80	0.49	1.06	1.73	0.93	2.37
Government bill rate	0.66	1.67	1.46	0.51	0.36	0.05	3.93
Consumer price inflation	0.53	0.27	0.07	0.51	1.90	1.29	0.64
Exchange rate	0.08	0.97	6.05	1.01	0.48	0.76	0.70
Oil price	1.82	2.34	1.85	1.37	1.00	0.13	1.88
Contribution to others	7.90	7.57	10.43	6.30	7.17	6.75	10.73
Contribution from others	9.24	9.79	25.20	11.04	5.11	7.27	18.79
SOI	10.9%	11.6%	12.1%	9.4%	10.6%	9.3%	14.2%
Panel B: Volatility Spillovers							
Stock markets	75.49	82.24	86.08	88.69	74.53	86.85	85.69
Industrial production index	14.04	3.24	1.80	0.19	3.90	0.14	5.17
Money supply	2.09	0.63	2.14	0.13	1.07	1.42	0.19
Government bill rate	0.46	0.96	0.95	0.01	10.40	4.98	0.12
Consumer price inflation	0.66	0.42	0.20	8.38	7.95	5.98	2.51
Exchange rate	0.51	8.92	3.42	0.67	0.71	0.27	3.27
Oil price	6.75	3.59	5.42	1.94	1.44	0.35	3.05
Contribution to others	24.51	17.76	13.92	11.31	25.47	13.15	14.31
Contribution from others	18.21	26.92	25.63	28.22	7.78	20.17	49.43
SOI	25.8%	18.2%	17.5%	12.8%	14.2%	10.8%	20.9%

Note. This table reports the forecast error variance (through the GVAR approach) of the G-7 stock markets explained by each of the macroeconomic variable, the total contribution FROM stock markets to the macroeconomic variables, total contribution TO stock markets from the macroeconomic variables and the total spillover index (SOI) for the full sample. The usual full spillover tables for the G-7 markets are provided in the Appendix.

forecast error variance comes from the volatility spillovers but only 10.9% of the forecast error variance comes from the return spillovers for USA. The same is true for the rest of the G-7 countries, where SOIs for the volatility spillovers are higher than for the returns spillovers. Therefore, the volatility spillovers are considerably more important relative to the return spillovers in forecasting and policy issues.

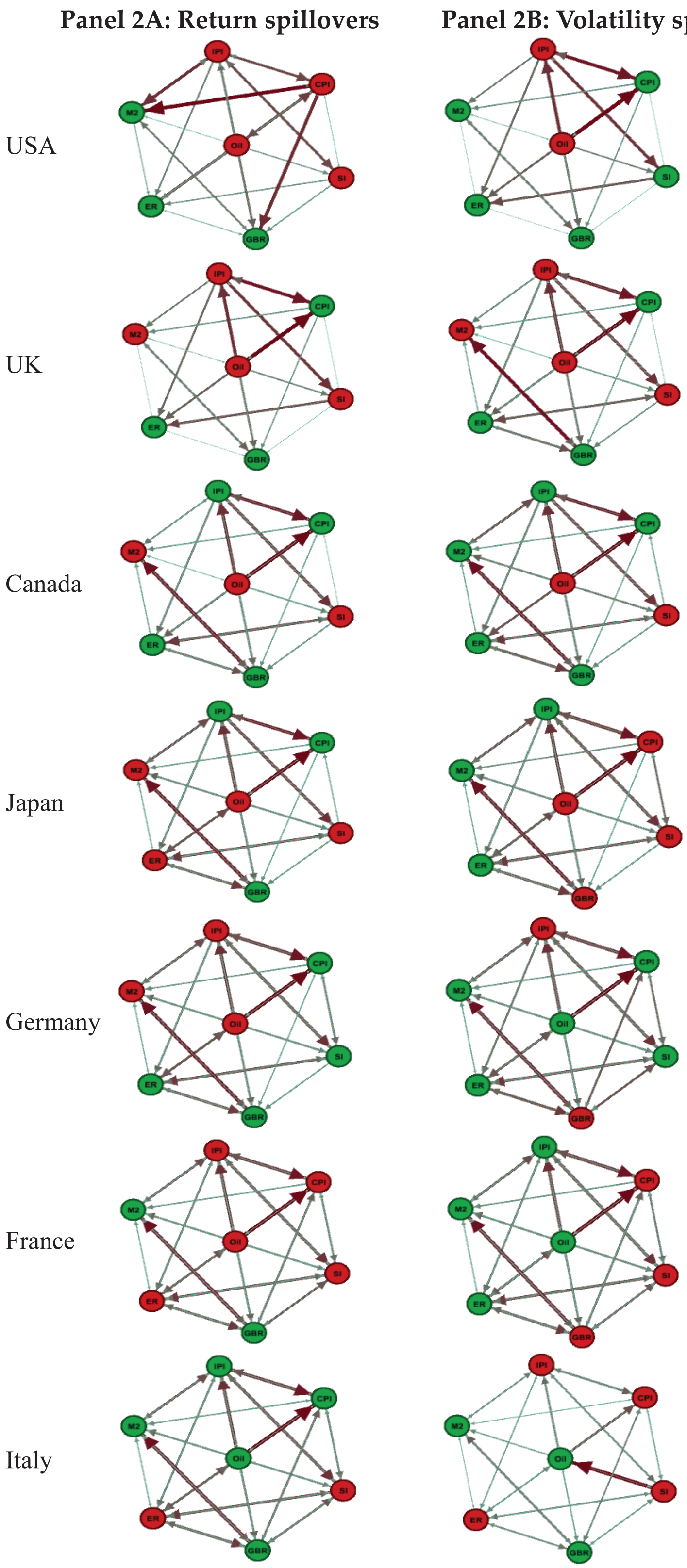
Before, we move further from the static analysis to dynamic rolling sample analysis, we first analyze the return and volatility net directional spillovers in order to determine whether the variables are spillover transmitters or receivers. The network diagrams of net directional spillovers for returns and volatilities of the stock markets and the macroeconomic variables are presented in Figure 2 (i.e., Panel 2A & 2B respectively). In the network diagrams, the red (green) color of the node implies that the variables are the net transmitter (receiver). The net directional spillovers for the returns in Panel 2A indicate that the stock market return is the net transmitter of spillover effects for all G-7 countries except Germany. In case of macroeconomic factors, industrial production growth (IPI) is the net transmitter of spillovers for US, UK, Germany and France. Money supply (M2) is the net transmitter of spillover for the UK, Canada, Japan and Germany, while exchange rate (ER) is the net transmitter of spillovers for Japan, France and Italy. Similarly, oil price (OIL) is the net transmitter of spillovers in all G-7 countries except Italy. Interestingly, short-term interest rate (GBR) and inflation (CPI) are the net receiver of spillovers from other variables in the system for all G-7 countries except for USA, where CPI is the net transmitter of spillovers.

Similarly, the net directional spillovers of the volatilities in Panel 2B indicate that volatility of the stock market returns is the net transmitters of spillovers in the case of all G-7 countries, except USA and Germany. In the case of the macroeconomic variables, the volatility of IPI is the net transmitter of the spillovers for the US, UK, Germany and Italy, while the volatility of M2 is the net receiver of spillovers, except for UK. Unlike the spillover effect of TBR for first moment as displayed in the network diagram in Panel 2A, the volatility of TBR is the net transmitter of spillovers for Japan, Germany, France and Italy. In the same way, the volatility of CPI is the net transmitter for Germany, France and Italy, while the volatility of ER is the net receiver of spillover in all G-7 countries except Italy. Finally, the volatility of the oil price is the net transmitter of the volatility spillover to other variables in the system in USA, UK, Canada and Japan, while for the rest of countries it is a net receiver of the volatility spillover. The edge size from small to large and from green to red indicates the strength/magnitude of the spillover transmission.

4.2 Rolling Window Spillover Analysis

It is important to note that many changes took place during the sample period of the last 30 years covering from July 1985 to June 2015. These changes can be attributed to the structural reforms and the more-or-less financial markets integration at the local and international levels due to the continuous evolution of globalization. In fact, the rapid transfer of technology has reshaped the level of integration of economies across the world. Thus, by keeping in view the economic and financial turbulences over the economic history of the G-7 countries, the spillover model with a single fix parameter may not be a good choice to apply to the whole sample, and most likely it misses the important secular and cyclical movements in spillovers. To deal with this issue, we estimate the return and volatility spillovers by using a 200-month rolling sample and also estimate the 12 step-ahead forecasts. The time series plots of the dynamic rolling window spillovers in Figure 2 help to analyze the exact nature of variations in the return and volatility spillovers for all G-7 countries over the sample time period.

The time series plots of the rolling window spillovers both for the return and volatility give approximately identical results for all the sample countries in a sense that the return and volatility spillovers before the global financial crises are quite consistent on average. During the global financial crisis of 2008, the spillovers for both the returns and volatility increase very sharply. Then after that, the average spillovers for the return and volatility remain higher, as compared to the average spillovers before the global financial crises, for most of the G-7 countries. This postulates that the impact of global financial crisis is clearly factored into the return and volatility spillovers; however, the it is more evident in the volatility spillovers in comparison to return spillovers. The two exceptions are Japan and Germany where the returns spillovers stay almost identical to the



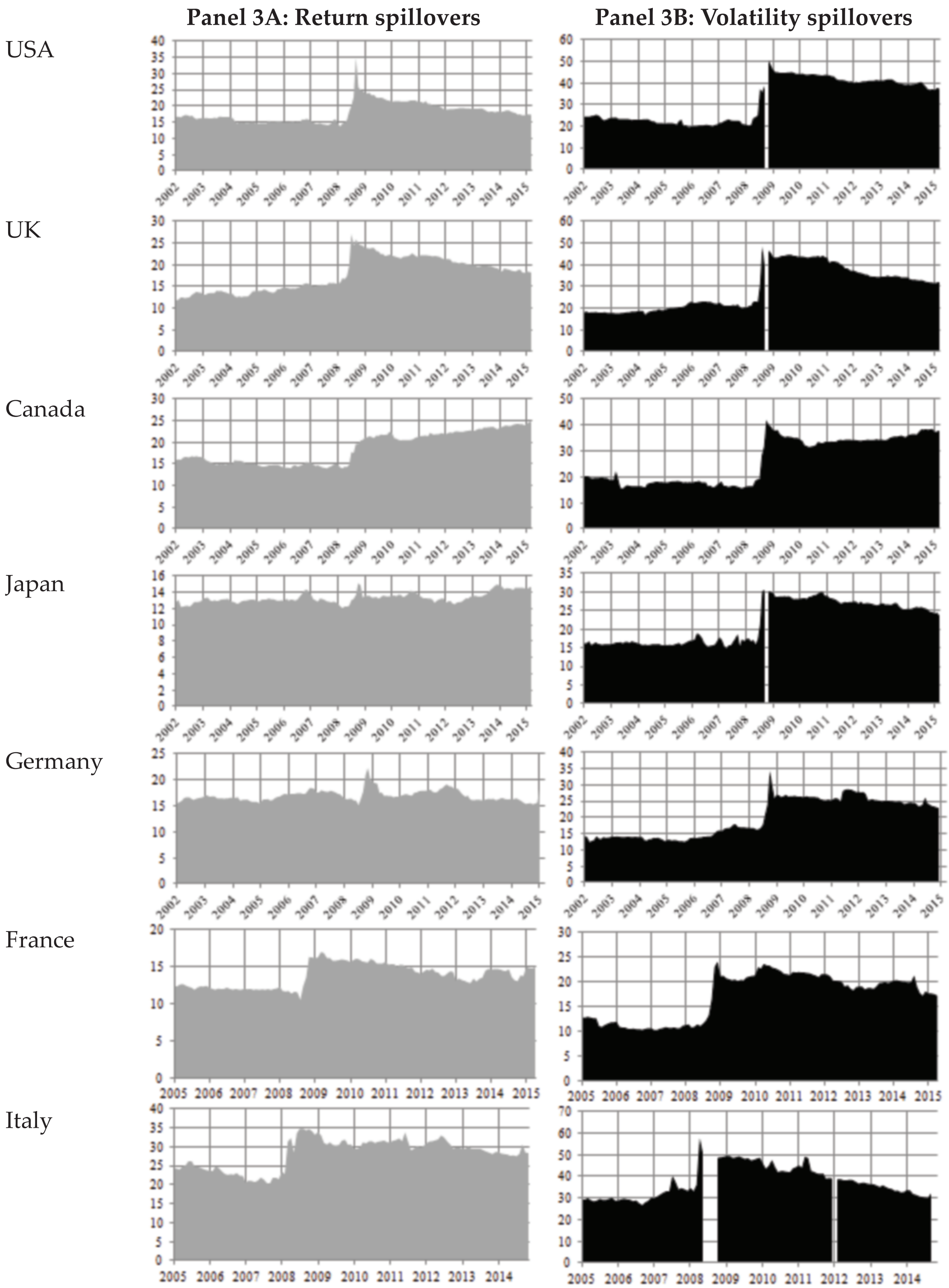
Note. These Figures show the network diagrams of the net directional spillovers. A variable is a net contributor (*NC*), when the node color is red, the contribution from that variable to all other variables is higher than the contribution to it from other variables. Otherwise, if it is a net recipient (*NR*), the node color is green. The direction of pair-wise spillovers is shown through the edges, the colors (from green-less to red-high) and sizes of the edges are based on the spillover magnitudes. SI=stock market index; IPI=industrial production index; M2=money supply; GBR=government bill rate; CPI=consumer price index (inflation); ER=exchange rate; OIL=oil price. The detailed results (contribution values) are available in the Appendix.

Figure 2 Network Diagrams of the Directional Spillovers averages before the global financial crises. Otherwise, there is a clear difference in the behavior of total Spillover Index for the returns and volatility before and after the global financial crises. For example, in the case of the US, the values of the total return and the volatility spillovers at the first window start around 17% and 25%, respectively, and remain consistent until the global financial crisis took place. There can be various reasons of these global financial crises including the credit crunch from July to August 2007, the financial market crunch from January to March 2008 that was followed by the unprecedented cuts in the federal fund rate by the Federal Reserve, and finally the collapse of Lehman Brothers from September to December 2008.

The full effect of global financial crisis across the world started during the first half of 2009, and then were coupled with the subsequent Russian oil crisis in the second half of 2009. The spillover indices surged significantly high during the financial market crunch and prevailed until the latter half of 2009. Due to all these crises, the values of the total spillover indices increase by 35% for the returns and 52% for the volatilities. After the end of the global financial crisis in late 2009, the values of total spillover indices remain high as compared to before the crisis. However, the values of the total spillovers indices for the returns and the volatility decrease sharply and remain on average 20% and 40% respectively. A quite similar behavior for the volatility rolling spillovers is also observed for the rest of the G-7 countries. In case of rolling window spillovers for the returns, the values of spillover indices increase significantly after the crisis period with the exception of Japan and Germany, where no significant differences have been observed in the values of spillover indices before and after the crisis period. Although the global economies including Japan and Germany were hit hard by the global financial crisis of 2007-2008. However, the average return spillovers for these two countries remain stable over the sample time line, which indicate a relatively weak causal connection between the stock market and the macroeconomic fundamentals at level.

After the rolling window total Spillover Index analysis, we next estimate the pairwise rolling window directional spillovers (returns and volatility). Figure 3 presents the plots of the pairwise rolling window directional spillovers (returns and volatility) from the macroeconomic variables to the forecast error variance of the stock market returns. In the case of the USA, the highest contribution of the rolling window returns spillovers effect to the forecast error variance of the stock market returns is made by industrial production index (i.e. 4%). In the case of the rolling window volatility spillovers effect, the highest contributors are the industrial production index and the oil price which contribute about 14% and 7%, respectively. Similarly, for the rest of the G-7 countries, the highest contribution of the rolling window returns spillovers to the forecast error variance of the stock market returns is made by the oil price (i.e., 2.3%) for the UK, the exchange rate (6%) for Canada, the industrial production index (2%) for Japan, inflation (2%) for Germany, the industrial production index (4%) for France and the interest rate (4%) for Italy.

While in the case of the rolling windows volatility spillovers, the highest contribution to the forecast error variance of the stock market volatility is made by the exchange rate (9%) for UK, the oil price (5.4%) for Canada, inflation (8.4%) for Japan, the interest rate (10.4%) for Germany, inflation (6%) for France and the industrial production index (5%) for Italy. Moreover, the plots of all the pairwise rolling window directional spillovers,



Note. These figures display the total spillover index for the returns (shaded grey in panel 3A) and the volatility (shaded black in panel 3B) series. The rolling window spillover index is calculated by using the 200-month rolling window and is based on 12-months step-ahead forecast error variance decompositions except for France and Italy. For France, the rolling window size is 180-months and for Italy the window size is 90-months.

Figure 3 Rolling Window Return and Volatility Spillovers for the G-7 Countries especially the rolling window volatility directional spillovers indicate that the volatility spillovers behavior is quite unusual during the global financial crisis, more-or-less for all G-7 countries. That is the reason that many of the economists consider global financial crisis of 2007-2008 as the most dangerous crisis since the great depression of 1930s. A number of multinational institutions such as Lehman Brothers, City bank, and American International Group and so on went on to bailout and became bankrupt as a result of these crisis. The GFC of 2008 were immediately followed by the Russian great recession and European sovereign debt crisis that also doubled the impact of these crisis.

4.3 Pre- and Post GFC Analysis

To analyze the impact of the global financial crisis on the return and volatility spillover transmissions, we segregate the sample period into two sub-samples. Notably, the rolling window spillover analysis also indicates that both return and volatility spillovers significantly increase from the onset of the global financial crisis. The first subsample represents the pre-crisis period that covers the time before June 2007, and the second subsample represents the post-crisis period that covers the time from June 2007 and onward. The network diagrams of the pre- and post-crisis periods for the return and volatility spillovers are displayed in Figure 5 (i.e., Panel 5A & 5B respectively). We can see that there are significant differences in the spillover effects between the macroeconomic variables and the stock market returns in the pre- and post-crisis periods. The network diagrams of the return spillovers in Panel 5A indicate that SPI is the net transmitter of the return spillovers for all G-7 countries with the exception of the UK and Germany in the pre-crisis period, and only the UK in the post-crisis period. Similarly, IPI is the net transmitter of the return spillovers for the USA, the UK, Germany, France and Italy in the pre-crisis. In the post-crisis period, IPI is the net transmitter of the return spillover only for France. M2 is the net transmitter of the spillovers for all G-7 countries in the pre-crisis period, but in the post-crisis period it is the net transmitter of returns spillover for Japan, Germany and France. Unexpectedly, GBR is the net receiver of the return spillovers for all G-7 countries except USA and UK in the pre-crisis period and only Italy in the post-crisis period. The results of the return spillover for CPI are quite mixed for all G-7 countries in the pre- and post-crisis period. In the case of ER, the exchange rate is the net receiver of the return spillovers for all G-7 countries except the USA and Japan in the pre-crisis period, while it is the net transmitter of the return spillovers in the post-crisis period for all sample countries except Germany and Italy. Finally, OIL is the net transmitter of the return spillovers for all G-7 countries in the pre-crisis period, and in the post-crisis period it is the receiver of the return spillovers for Canada, Japan and Italy.

Similarly, the network diagrams of the volatility spillover in Panel 5B show that SPI is the net transmitter of the volatility spillovers for all G-7 countries in the pre- and post-crisis periods, except for the UK in the post-crisis period where it is the net receiver of the volatility spillover. In the pre-crisis period, IPI is the net transmitter of the volatility spillover only for the UK, Japan and Germany, while it is the net receiver of the volatility spillover in the port-crisis period except France. Unlike the return spillovers of M2 in Panle-6A where M2 is the net transmitter of spillovers for most the G-7 countries in the pre-crisis period, in Panel 5B, M2 is the net transmitter of the volatility spillovers for the USA, Canada and Germany, while in the post-crisis period, M2 is the net transmitter of the volatility spillovers for the USA, Canada and Italy.

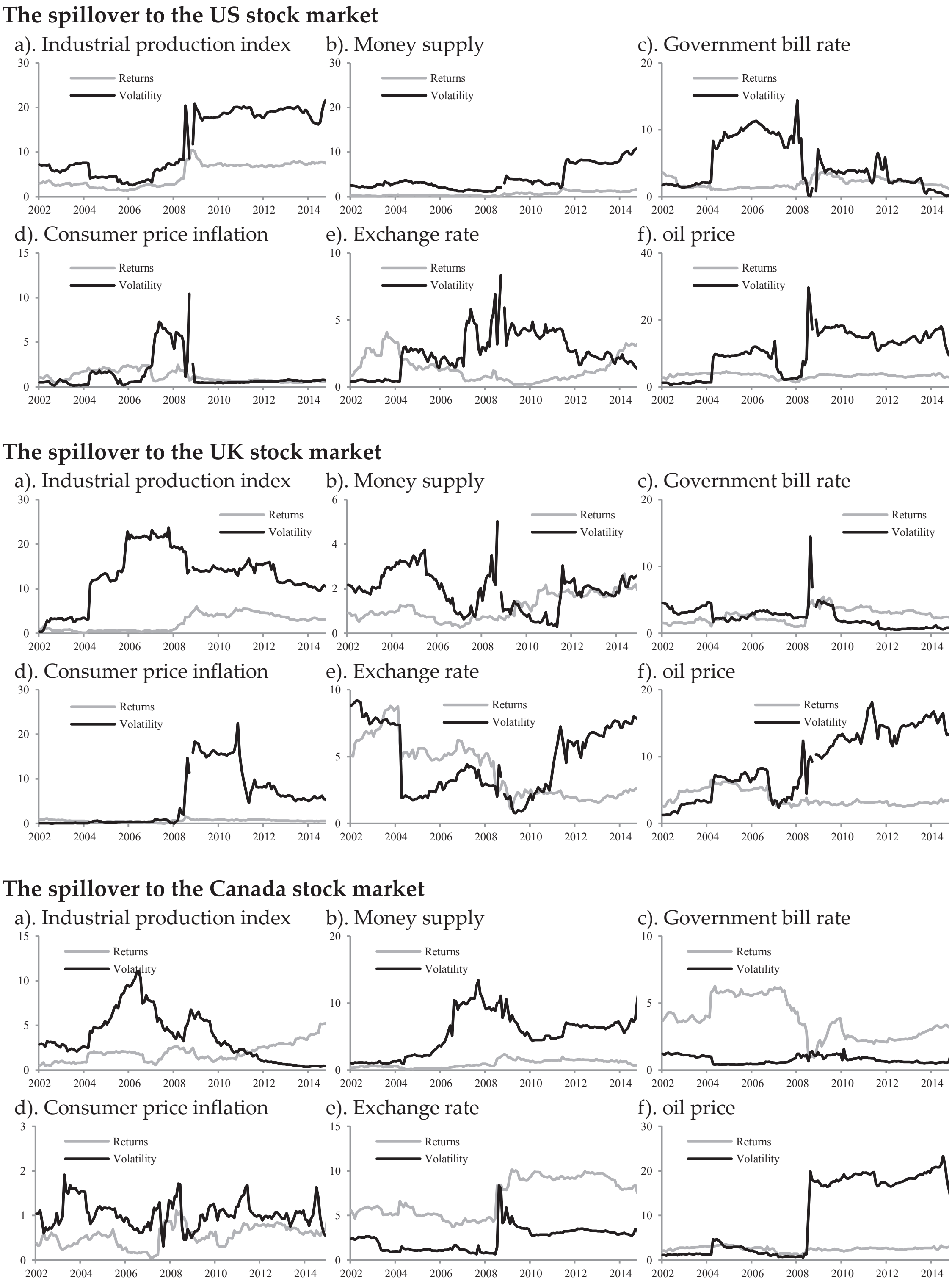


Figure 4 Bilateral (Directional) Return and Volatility Spillovers from the Macroeconomic Variables to the Stock Markets for G-7 Countries

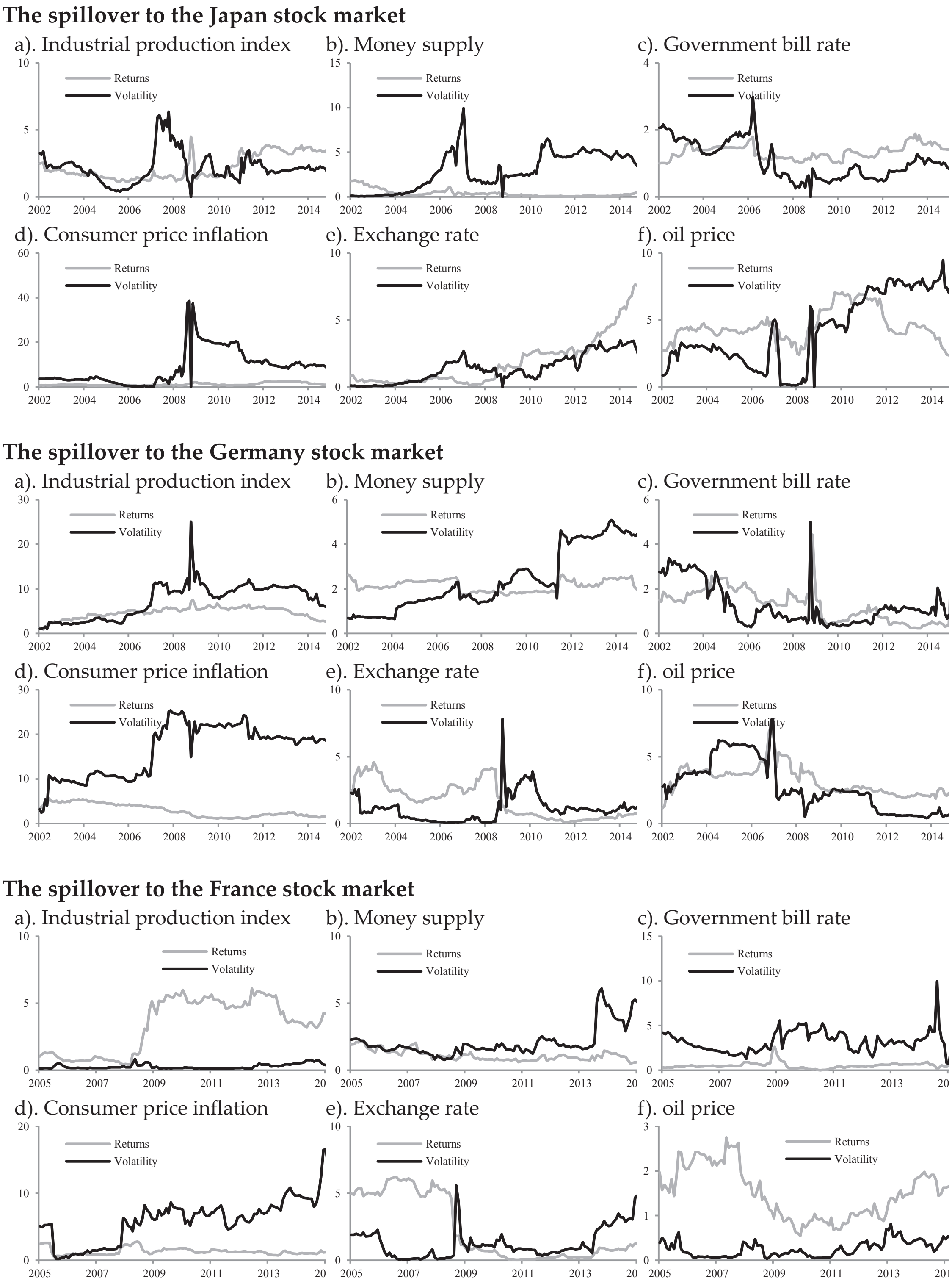
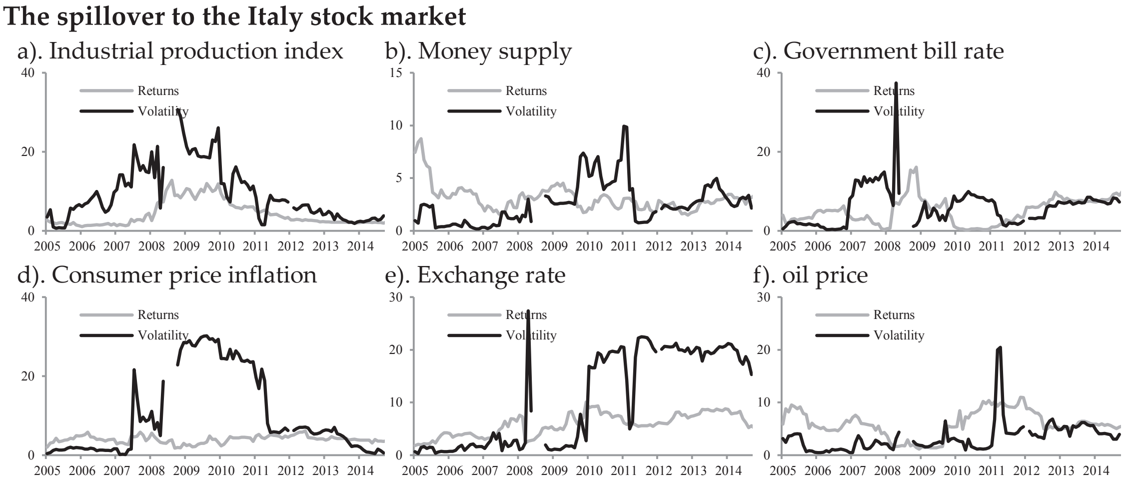


Figure 4 Bilateral (Directional) Return and Volatility Spillovers from the Macroeconomic Variables to the Stock Markets for G-7 Countries (*Continued*)



Note. These Figures display the rolling window based forecast error variance of the G-7 stock markets explained by different macroeconomic variables. The rolling window sizes and the step sizes are the same as explained in the notes to Figure 3.

Figure 4 Bilateral (Directional) Return and Volatility Spillovers from the Macroeconomic Variables to the Stock Markets for G-7 Countries (*Continued*)

Similar to the return spillover results, GBR is the net receiver of the volatility spillovers for all G-7 countries except Japan in the pre-crisis period, and Germany, France and Italy in the post crisis period. CPI is the net receiver of the volatility spillover for the majority of the countries during the pre-crisis period, while it is the net transmitter of the volatility spillover for the majority of the countries in the post-crisis period. The results of the volatility spillovers show that ER is the net receiver of the volatility spillovers for the majority of the G-7 countries except the UK and Canada in the pre-crisis period, and France and Italy in the post-crisis period. In the case of the volatility spillovers for OIL, it is the net receiver of the volatility spillovers for all G-7 countries except the USA in the pre-crisis period, and is the net transmitter of the volatility spillovers for the majority of the countries except France and Italy. The significant differences of the return and volatility spillover transmissions during the pre- and post-crisis periods are also supported by the edge size (small to large) and color (green to red) that indicate the strength of the spillover transmission. The overall spillover indices for the all G-7 countries also show significant differences in the return and volatility transmissions for the rest of the G-7 countries during the pre- and post-financial crisis of 2008.

4.4 Robustness Checks

After the detailed analysis of the return and volatility spillovers, we now check the robustness of the results to different rolling window sizes and different forecast step sizes. As a sample for the other countries, we just report the robustness check results for the United States. The results in Figure 6 (i.e., Panel 6A & 6B) present the total Spillover Index robustness check with respect to different rolling window sizes (180-months, 200-months and 220-months), and diverse forecast horizons ($h = 12$, $h = 18$, $h = 24$), respectively. The results of the rolling window size robustness checks in Panel 6A(i) and Panel 6A(ii) indicate that the rolling

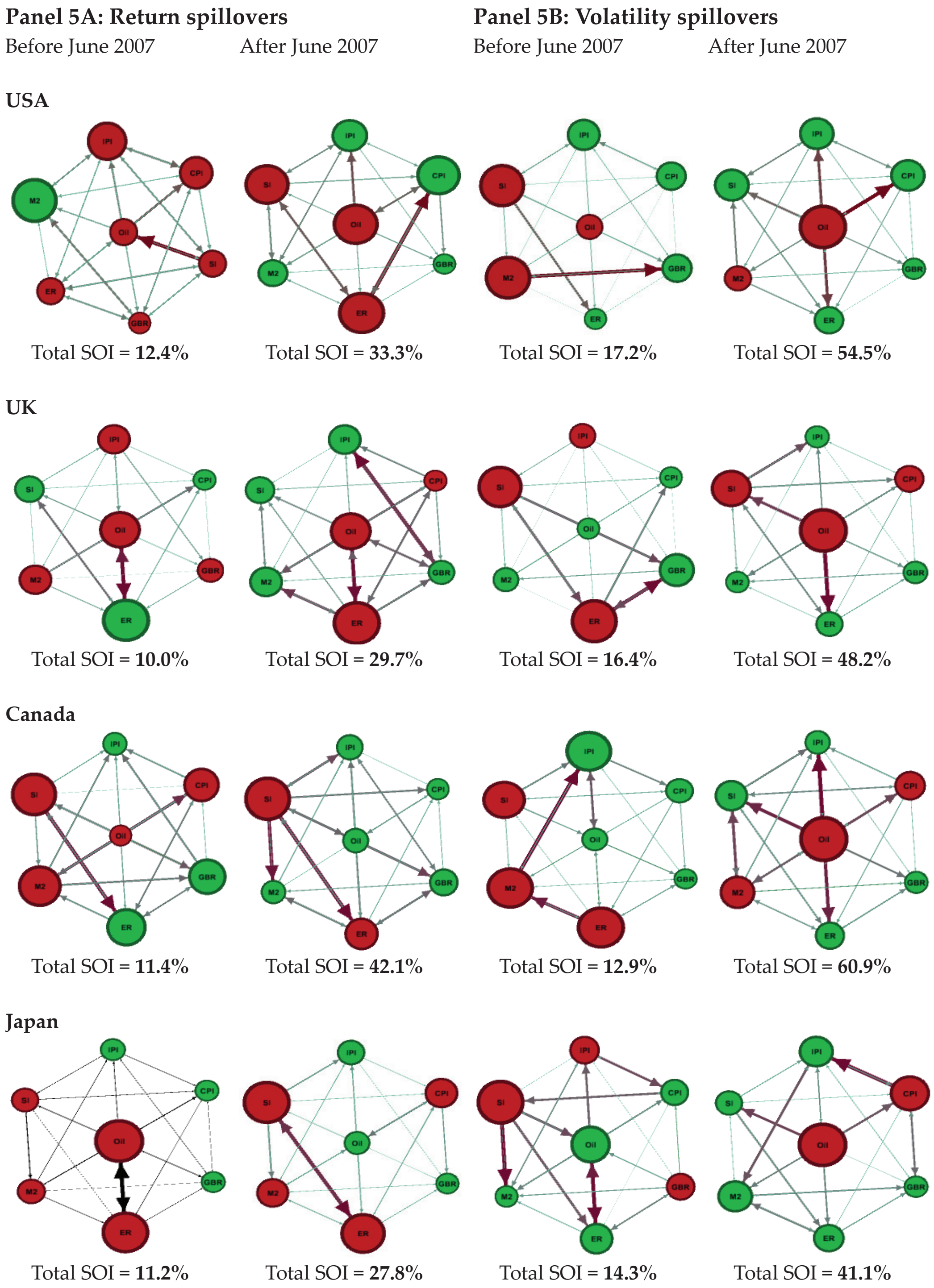
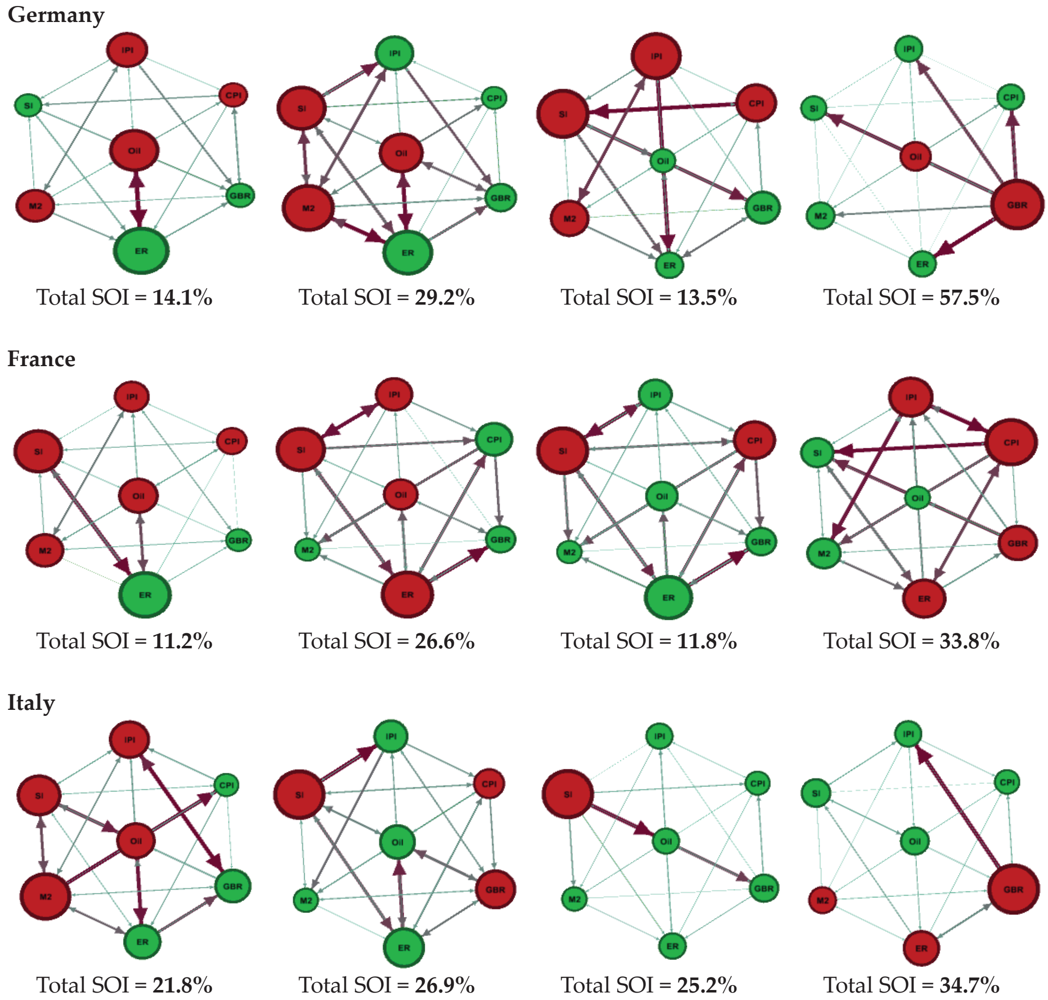


Figure 5 Network Diagrams of Return and Volatility Spillovers before and after June 2007



Note. The red (Green) color of the nodes implies that the variables are a net transmitter (receiver). The edge size (small to large) and the color (green to red) also indicate the strength of transmission. SI=stock market index; IPI=industrial production index; M2=money supply; GBR=government bill rate; CPI=consumer price index (inflation); ER=exchange rate; OIL=oil price.

Figure 5 Network Diagrams of Return and Volatility Spillovers before and after June 2007 (*Continued)*

window total spillover indices for the returns and volatility for the US do not exhibit any significant variations in their movement over time. Similarly, the results of the rolling window total spillover indices for the returns and volatility for this country in Panel 6B(i) and Panel 6B(ii) show that by changing the forecast horizon period, the results of the rolling window total spillover indices do not show any deviations. Therefore, the selected rolling window size and forecast horizon period are adequate to achieve the best possible results in our returns and volatility spillover analysis.

5. Conclusion

We examine the connectedness between both the return and volatility of the stock markets and the macroeconomic factors for the G-7 countries. The spillover analysis is based on the generalized VAR-based approach proposed by Diebold and Yilmaz (2012). The

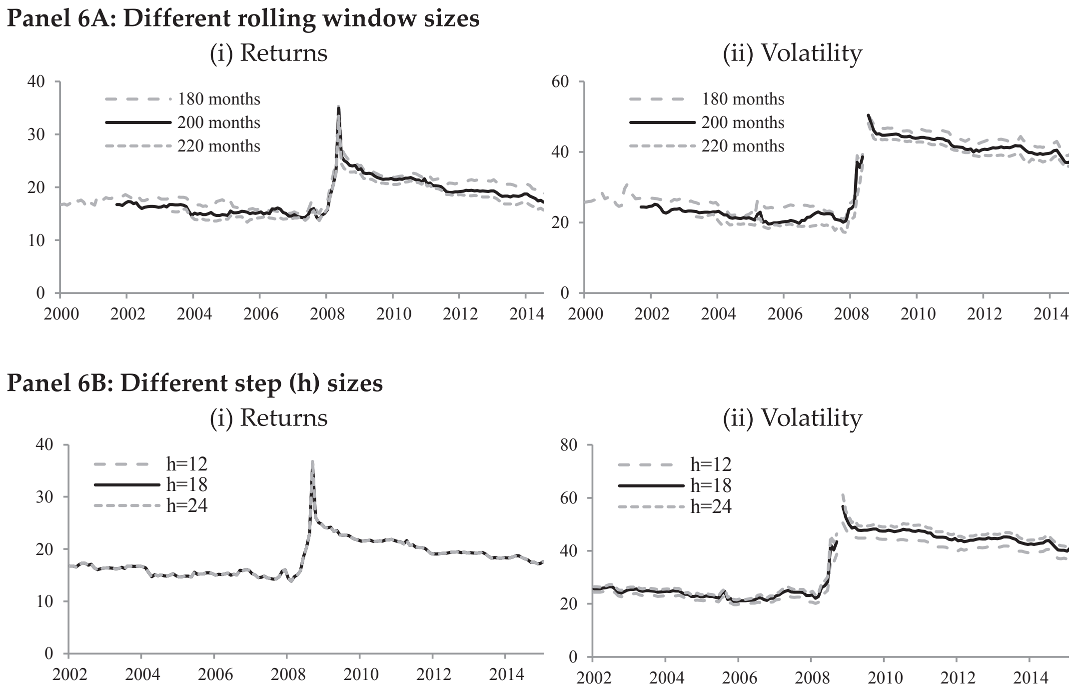


Figure 6 Total Spillover Index Robustness Checks Using the US Data

overall returns and volatility spillover indices show that a higher percentage of the forecast error variance comes from the volatilities of the stock markets and macroeconomic factors as compared to the return spillover counterparts. Consistent with Choudhry et al., (2016), this study also finds that business cycle (industrial production growth) is an important net spillover transmitter of macroeconomic volatility to the G-7 stock markets. In the case of industrialized economies, it is quite common that stock markets behave differently during the recession and expansion periods, and closely follow the movement of the business cycle. One of the important conjecture of monetary economics implies that there is a strong and negative connection between inflation and real sector growth (Fama, 1981). However, the real sector economic theory implies that there is a strong positive relationship between real economic activity and stock returns. Therefore, according to the real sector and monetary sector economic theories, a strong volatility spillover transmission of inflation to the volatility of stock market is the outcome of significant volatility spillovers of the real sector growth.

Similarly, changes in the money supply have a more significant impact on the volatility of stock markets than short term interest rates of the G-7 countries except Japan. Therefore, what central banks in those countries do to money supply including money supply targeting has an important impact on returns and volatility of their stock markets. Targeting short term interest rates seems to be more impact neutral than targeting money supply when it comes to stock markets. A money supply target is costly and difficult to maintain in an interconnected world with high financial integration. In other words, the U.S. central bank for example, started to lose control of the money supply as financial integration increased. This may also have to do with the dominant spillover role of money supply. Moreover, in the case of Canada, for example, one of the reasons for the interest rates not having a significant spillover transmission to the stock markets is the existence of a strong crowding out of public sector investment (Cumming and MacIntosh, 2006). Crowing out hinders private investment and corporate earnings.

With respect to the exchange rate, the return and the volatility spillover impact of this macroeconomic variable is quite mixed across the G-7 countries. It is found to be a net receiver of return and volatility spillover for the majority of the G-7 countries as many of the changes in an economy are eventually recorded in the exchange rate. However, the different results regarding the spillovers of exchange rates of the G-7 countries can be attributed to differences in their economic conditions, government policies, investors' expectations and credit ratings (Nieh and Lee, 2001). Moreover, the degree of internationalization, trade liberalization and capital flows can also be the crucial factors that determine the predicting power of an exchange rate with respect to its stock market. Finally, the oil price is the net transmitter of the return and volatility spillovers for most of the sample countries. Because all G-7 countries are industrialized economies and crude oil is one of the main inputs of industrial production. Therefore, changes in the oil price affect the industrial output directly or indirectly. Consequently, the cost of production and commodities prices change which eventually influences the stock prices of the listed companies. Furthermore, the majority of the G-7 countries except Canada spend lot of money on the oil imports, thus oil price fluctuations can ultimately affect the stock prices.

Moreover, the results of the directional spillovers show that the relationship between the volatility of the stock market and the macroeconomic variables is surprisingly unidirectional for the UK, but for the rest of the G-7 countries the relationship is bidirectional. This bidirectional causality collaborates the level of market efficiency in the G-7 markets and the interdependence of the macroeconomic fundamentals and the stock market returns. In this study, we have also analyzed the linkage between the returns and volatilities of the stock market and the macroeconomic factors in the pre- and post-global financial crisis of 2008. A significant increase in the values of the return and volatility spillover indices has been found after the global financial crisis period ended.

The level of connectedness between the G7 stock markets and the macroeconomic factors is quite significant. Predominantly, there is a significant return spillover transmission from the exchange rate and the oil price toward the other economic variables in the system, and a significant volatility spillover transmission from inflation and the oil price during the post-GFC period (in recent time) for the majority of the G-7 countries. Therefore, it is important for investors, portfolio managers and policy makers to make appropriate decisions by keeping in view the level of integration between the stock markets and their macroeconomic factors at the first and second moment levels for the G-7 stock markets and for developed stock markets in general.

Acknowledgments

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Appendix A Tables

Table A1 Returns and Volatilities Spillovers for USA (in %)

	DJIA	ER	M2	GBR	CPI	IPI	OP	From Others	Net	Conclusion
USA - returns										
DJIA	92.10	0.08	0.73	0.66	0.53	4.08	1.82	7.90	1.33	Net-contributor
ER	2.07	90.31	1.28	0.70	2.30	2.37	0.97	9.69	-2.13	Net-recipient
M2	0.91	0.34	84.31	2.74	6.38	4.93	0.40	15.69	-8.55	Net-recipient
GBR	1.96	1.23	1.72	86.38	5.08	3.33	0.29	13.62	-6.02	Net-recipient
CPI	0.78	4.51	0.69	0.24	88.81	4.19	0.78	11.19	8.92	Net-contributor
IPI	3.04	1.14	2.46	3.02	1.99	86.83	1.52	13.17	5.94	Net-contributor
OP	0.47	0.26	0.24	0.25	3.83	0.21	94.73	5.27	0.50	Net-contributor
Contribution to others	9.24	7.56	7.13	7.60	20.11	19.11	5.77	76.52		Total spillover index:
Contribution including own	101.33	97.87	91.45	93.98	108.92	105.94	100.50			10.9%
USA - volatilities										
DJIA	75.49	0.51	2.09	0.46	0.66	14.04	6.75	24.51	-6.30	Net-recipient
ER	11.81	66.35	1.07	0.10	2.29	8.76	9.62	33.65	-30.53	Net-recipient
M2	1.83	0.15	78.73	5.67	4.32	7.36	1.94	21.27	-2.99	Net-recipient
GBR	0.30	1.40	9.44	73.38	4.80	8.97	1.71	26.62	-18.55	Net-recipient
CPI	1.53	0.67	0.97	0.56	61.47	16.39	18.41	38.53	-14.29	Net-recipient
IPI	2.07	0.33	2.38	0.97	10.35	69.70	14.21	30.30	25.52	Net-contributor
OP	0.67	0.06	2.35	0.31	1.82	0.30	94.49	5.51	47.14	Net-contributor
Contribution to others	18.21	3.12	18.28	8.07	24.24	55.82	52.64	180.38		Total spillover index:
Contribution including own	93.69	69.46	97.01	81.45	85.7104	125.51	147.13			25.8%

Table A2 Returns and Volatilities Spillovers for UK (in %)

	FTSE 100	ER	M2	GBR	CPI	IPI	OP	From Others	Net	Conclusion
UK - returns										
FTSE 100	92.43	0.97	0.80	1.67	0.27	1.52	2.34	7.57	2.21	Net-contributor
ER	0.66	82.22	2.14	1.30	1.48	2.17	10.03	17.78	-2.71	Net-recipient
M2	1.29	0.80	95.14	0.86	0.58	1.16	0.17	4.86	6.25	Net-contributor
GBR	4.00	3.38	1.06	82.64	1.10	6.61	1.21	17.36	-4.61	Net-recipient
CPI	2.03	0.65	5.14	1.93	89.19	0.40	0.65	10.81	-6.36	Net-recipient
IPI	1.29	1.60	0.86	4.34	0.43	91.12	0.36	8.88	4.09	Net-contributor
OP	0.51	7.67	1.10	2.64	0.59	1.12	86.36	13.64	1.12	Net-contributor
Contribution to others	9.79	15.07	11.11	12.75	4.45	12.97	14.76	80.90		Total spillover index:
Contribution including own	102.21	97.29	106.25	95.39	93.64	104.09	101.12			11.6%
UK - volatilities										
FTSE 100	82.24	8.92	0.63	0.96	0.42	3.24	3.59	17.76	9.16	Net-contributor
ER	11.53	72.93	0.65	5.02	2.70	4.03	3.15	27.07	7.47	Net-contributor
M2	3.42	4.53	71.26	16.75	1.87	1.69	0.48	28.74	-19.21	Net-recipient
GBR	6.43	10.97	3.72	76.28	0.75	1.26	0.59	23.72	1.40	Net-contributor
CPI	1.94	6.52	2.11	0.59	85.91	1.62	1.31	14.09	-6.50	Net-recipient
IPI	2.21	2.71	0.59	1.36	0.86	90.54	1.73	9.46	3.70	Net-contributor
OP	1.40	0.88	1.83	0.45	0.99	1.33	93.13	6.87	3.98	Net-contributor
Contribution to others	26.92	34.54	9.52	25.12	7.59	13.17	10.85	127.72		Total spillover index:
Contribution including own	109.16	107.47	80.79	101.40	93.50	103.70	103.98			18.2%

Table A3 Returns and Volatilities Spillovers for Canada (in %)

	TSX	ER	M2	GBR	CPI	IPI	OP	From Others	Net	Conclusion
Canada - returns										
TSX	89.57	6.05	0.49	1.46	0.07	0.52	1.85	10.43	14.77	Net-contributor
ER	13.29	77.98	2.35	1.39	1.41	0.23	3.35	22.02	-7.76	Net-recipient
M2	1.31	2.75	90.56	2.42	1.33	0.92	0.71	9.44	2.73	Net-contributor
GBR	5.80	2.93	2.57	85.42	0.10	2.40	0.79	14.58	-0.84	Net-recipient
CPI	2.05	0.59	1.47	2.64	90.94	0.63	1.67	9.06	-3.29	Net-recipient
IPI	1.67	0.52	4.38	5.13	0.72	87.47	0.11	12.53	-7.16	Net-recipient
OP	1.09	1.42	0.92	0.70	2.13	0.67	93.07	6.93	1.55	Net-contributor
Contribution to others	25.20	14.26	12.18	13.74	5.77	5.37	8.48	84.99		Total spillover index:
Contribution including own	114.77	92.24	102.73	99.16	96.71	92.84	101.55			12.1%
Canada - volatilities										
TSX	86.08	3.42	2.14	0.95	0.20	1.80	5.42	13.92	11.70	Net-contributor
ER	5.82	70.32	0.16	6.39	2.17	4.48	10.65	29.68	-6.41	Net-recipient
M2	9.10	3.58	83.25	1.24	0.09	1.21	1.53	16.75	-0.08	Net-recipient
GBR	4.03	13.11	1.96	75.67	0.11	1.01	4.10	24.33	-12.22	Net-recipient
CPI	4.57	1.49	0.30	1.79	87.74	1.81	2.30	12.26	-8.28	Net-recipient
IPI	0.13	0.64	11.46	1.25	0.13	82.17	4.22	17.83	-5.06	Net-recipient
OP	1.97	1.04	0.65	0.49	1.28	2.46	92.11	7.89	20.35	Net-contributor
Contribution to others	25.63	23.27	16.67	12.11	3.98	12.76	28.24	122.65		Total spillover index:
Contribution including own	111.70	93.59	99.92	87.78	91.72	94.94	120.35			17.5%

Table A4 Returns and Volatilities Spillovers for Japan (in %)

	Nikkei-225	ER	M2	GBR	CPI	IPI	OP	From Others	Net	Conclusion
Japan - returns										
Nikkei-225	93.70	1.01	1.06	0.51	0.51	1.83	1.37	6.30	4.74	Net-contributor
ER	2.56	84.02	1.18	0.37	0.24	1.64	9.99	15.98	1.51	Net-contributor
M2	3.50	0.22	93.92	0.11	1.54	0.28	0.43	6.08	0.04	Net-contributor
GBR	0.25	1.87	0.17	94.87	0.54	0.57	1.73	5.13	-1.39	Net-recipient
CPI	1.15	0.88	2.55	0.78	91.22	0.96	2.46	8.78	-3.63	Net-recipient
IPI	3.19	1.91	1.06	0.68	0.08	92.40	0.68	7.60	-2.23	Net-recipient
OP	0.40	11.59	0.10	1.28	2.25	0.08	84.29	15.71	0.96	Net-contributor
Contribution to others	11.04	17.49	6.12	3.73	5.16	5.37	16.66	65.57		Total spillover index:
Contribution including own	104.74	101.51	100.04	98.61	96.37	97.77	100.96			9.4%
Japan - volatilities										
Nikkei-225	88.69	0.67	0.13	0.01	8.38	0.19	1.94	11.31	16.91	Net-contributor
ER	8.04	80.41	0.45	1.87	0.53	0.25	8.46	19.59	-7.49	Net-recipient
M2	5.98	3.15	81.91	0.72	5.61	1.05	1.58	18.09	-15.47	Net-recipient
GBR	0.01	1.59	0.58	96.66	0.22	0.77	0.18	3.34	0.91	Net-contributor
CPI	2.63	0.89	0.79	0.09	94.00	0.75	0.86	6.00	19.96	Net-contributor
IPI	8.29	0.08	0.26	0.42	10.75	80.10	0.10	19.90	-16.79	Net-recipient
OP	3.28	5.72	0.42	1.15	0.48	0.10	88.85	11.15	1.96	Net-contributor
Contribution to others	28.22	12.10	2.62	4.26	25.97	3.11	13.11	89.39		Total spillover index:
Contribution including own	116.91	92.51	84.53	100.91	119.96	83.21	101.96			12.8%

Table A5 Returns and Volatilities Spillovers for Germany (in %)

	DAX	ER	M2	GBR	CPI	IPI	OP	From Others	Net	Conclusion
Germany - returns										
DAX	92.83	0.48	1.73	0.36	1.90	1.70	1.00	7.17	-2.06	Net-recipient
ER	0.72	81.60	2.76	1.63	1.62	1.27	10.40	18.40	-3.12	Net-recipient
M2	0.58	0.28	94.83	0.34	0.51	2.83	0.64	5.17	4.85	Net-contributor
GBR	0.10	2.91	0.27	89.76	0.28	3.52	3.16	10.24	-0.39	Net-recipient
CPI	1.33	0.42	0.66	2.84	92.72	0.62	1.40	7.28	-2.08	Net-recipient
IPI	2.26	1.02	2.84	1.66	0.44	90.85	0.92	9.15	1.90	Net-contributor
OP	0.13	10.17	1.74	3.01	0.44	1.12	83.38	16.62	0.91	Net-contributor
Contribution to others	5.11	15.28	10.01	9.85	5.19	11.04	17.53	74.02	Total spillover index:	
Contribution including own	97.94	96.88	104.85	99.61	97.92	101.90	100.91			10.6%
Germany - volatilities										
DAX	74.53	0.71	1.07	10.40	7.95	3.90	1.44	25.47	-17.70	Net-recipient
ER	3.63	75.37	3.01	8.73	0.51	6.99	1.77	24.63	-14.75	Net-recipient
M2	0.22	0.35	88.30	5.44	1.50	3.64	0.55	11.70	-2.51	Net-recipient
GBR	0.47	0.89	0.01	97.50	0.08	0.20	0.86	2.50	34.59	Net-contributor
CPI	0.86	0.44	0.71	9.38	86.21	0.03	2.37	13.79	-2.59	Net-recipient
IPI	0.27	5.29	3.34	1.63	0.55	88.26	0.65	11.74	5.00	Net-contributor
OP	2.33	2.20	1.04	1.50	0.61	1.98	90.33	9.67	-2.03	Net-recipient
Contribution to others	7.78	9.87	9.19	37.09	11.20	16.73	7.63	99.49	Total spillover index:	
Contribution including own	82.30	85.25	97.49	134.59	97.41	105.00	97.97			14.2%

Table A6 Returns and Volatilities Spillovers for France (in %)

	CAC-40	ER	M2	GBR	CPI	IPI	OP	From Others	Net	Conclusion
France - returns										
CAC-40	93.25	0.76	0.93	0.05	1.29	3.59	0.13	6.75	0.52	Net-contributor
ER	1.56	87.97	0.20	1.68	1.09	0.05	7.45	12.03	2.81	Net-contributor
M2	0.64	0.26	93.87	1.00	0.52	2.53	1.19	6.13	-1.15	Net-recipient
GBR	0.35	3.57	0.82	86.87	4.20	1.77	2.43	13.13	-6.36	Net-recipient
CPI	1.84	1.66	0.55	1.34	92.05	1.76	0.79	7.95	1.03	Net-contributor
IPI	2.70	1.19	2.00	1.25	0.56	92.19	0.11	7.81	2.07	Net-contributor
OP	0.17	7.40	0.49	1.45	1.33	0.19	88.98	11.02	1.08	Net-contributor
Contribution to others	7.27	14.84	4.98	6.77	8.98	9.88	12.10	64.82		Total spillover index:
Contribution including own	100.52	102.81	98.85	93.64	101.03	102.07	101.08			9.3%
France - volatilities										
CAC-40	86.85	0.27	1.42	4.98	5.98	0.14	0.35	13.15	7.02	Net-contributor
ER	6.95	84.64	1.45	1.39	5.25	0.16	0.16	15.36	-1.68	Net-recipient
M2	7.35	0.87	82.67	3.29	4.47	0.39	0.96	17.33	-11.82	Net-recipient
GBR	0.58	5.36	0.50	90.57	0.04	2.81	0.14	9.43	2.39	Net-contributor
CPI	3.57	3.77	0.89	0.33	89.84	1.41	0.19	10.16	7.53	Net-contributor
IPI	0.51	2.07	0.83	1.40	1.39	93.71	0.11	6.29	-1.17	Net-recipient
OP	1.20	1.34	0.42	0.43	0.56	0.22	95.83	4.17	-2.27	Net-recipient
Contribution to others	20.17	13.68	5.51	11.82	17.69	5.13	1.90	75.89		Total spillover index:
Contribution including own	107.02	98.32	88.18	102.39	107.53	98.83	97.73			10.8%

Table A7 Returns and Volatilities Spillovers for Italy (in %)

	MIB - 30	ER	M2	GBR	CPI	IPI	OP	From Others	Net	Conclusion
Italy - returns										
MIB - 30	89.27	0.70	2.37	3.93	0.64	1.21	1.88	10.73	8.06	Net-contributor
ER	1.20	82.37	1.31	2.54	1.73	2.43	8.41	17.63	0.06	Net-contributor
M2	3.17	1.54	88.55	1.26	1.82	3.00	0.66	11.45	-0.46	Net-recipient
GBR	1.65	2.02	1.89	83.97	4.78	2.38	3.32	16.03	-0.99	Net-recipient
CPI	0.61	3.40	4.08	1.35	88.08	2.04	0.44	11.92	-1.83	Net-recipient
IPI	8.29	0.79	0.62	2.20	0.42	86.83	0.86	13.17	-1.71	Net-recipient
OP	3.87	9.23	0.72	3.76	0.70	0.41	81.30	18.70	-3.13	Net-recipient
Contribution to others	18.79	17.69	10.99	15.04	10.10	11.46	15.57	99.63		Total spillover index:
Contribution including own	108.06	100.06	99.54	99.01	98.17	98.29	96.87			14.2%
Italy - volatilities										
MIB - 30	85.69	3.27	0.19	0.12	2.51	5.17	3.05	14.31	35.12	Net-contributor
ER	3.80	78.69	3.98	4.05	2.37	5.49	1.62	21.31	5.12	Net-contributor
M2	9.37	3.19	78.93	0.59	1.70	3.73	2.49	21.07	-14.96	Net-recipient
GBR	0.45	12.31	0.61	72.91	10.66	0.06	3.01	27.09	-12.81	Net-recipient
CPI	1.00	5.69	1.02	3.98	84.15	3.41	0.76	15.85	3.67	Net-contributor
IPI	3.84	1.64	0.22	5.48	1.61	86.82	0.39	13.18	6.13	Net-contributor
OP	30.97	0.33	0.10	0.08	0.68	1.45	66.40	33.60	-22.28	Net-recipient
Contribution to others	49.43	26.43	6.11	14.29	19.53	19.31	11.32	146.41		Total spillover index:
Contribution including own	135.12	105.12	85.04	87.19	103.67	106.13	77.72			20.9%

Notes

[1]See Karunanayake et al., 2009; Manda, 2010; Chinzara, 2011; Schwert, 2011; Kumari and Mahakud, 2015.

[2]Data availability problem restricted us to use less than 30-year data for France and Italy. For France, we have used monthly data for almost 25 years that start from January 1990 to June 2015, while for Italy we have used 18.5 years of monthly data that cover the period from December 1997 to June 2015.

[3]There are quite a few studies on the G-7 countries in the existing literature. For example, Nieh and Lee (2001), who studies the linkage between exchange rate and stock markets in G-7 countries. Similarly, another study of Diaz et al. (2016), who studied the connection between the stock market and oil prices in G-7 countries. Apart from these two studies, we have not found any study on the relation of the stock markets with a broad set of macroeconomic varaibles in case of G-7 countries.

[4]Engle (1982) first introduced the autoregressive conditional heteroscedasticity (ARCH) model and then Bollerslev (1986) independently developed the generalized autoregressive conditional heteroscedasticity (GARCH) model to capture volatility clustering. Later on, many extensions (EGARCH, TGARCH, MGARCH, GARCH-in-mean, Multivariate GARCH, etc.) of these autoregressive conditional heteroscedasticity models have been advanced leading to different criticisms and arguments regarding the applications.

[5]The six months government bill rates have been used for the US, the UK, Canada and Italy, and the short-term interest rate for Japan, Germany and France are collected from OECD website (https://data.oecd.org/).

[6]Exchange rates for the US have been taken as units of USD per Euro.

[7]Oil Prices in local currency have been calculated by using the exchange rates as per USD.

[8]CEIC is a European institutional investor company founded in 1992 that provides most expansive and accurate economic and financial data about the emerging and developed markets.

[9]The Japanese economy faced various ups and downs over the sample time period, so is the case with NIKKEI 225. Therefore, the graph of the Japanese stock market shows frequent and multiple swings over the sample time period. For Italy, the time series plot starts from January 1998, and afterword the graph is identical to the rest of the G-7 countries.

[10] Trade weighted U.S. dollar index-the major currencies (TWEXM) is taken as a measure of the exchange rate for the U. S.

[11]The German mark (DEM) also known as Deutsche Mark was formally replaced by the euro (EUR) on January 1, 1999, but DEM had remained in circulation until 2002. Even in 2012, it was estimated that about 13.2 billion German marks were in circulation.

[12]Since January 1, 1999, the Italian lira (ITL) was also formally replaced by euro (EUR).

[13]The spillover measures proposed by Diebold and Yilmaz (2009) use the Cholesky factorization of the variance matrix to orthogonalize the errors. However, the results of this method depend heavily on the particular ordering of the variables in the VAR system. Furthermore, the Cholesky decomposition does not allow one to analyze the direction of spillovers.

[14]The univariate GARCH models i.e. GARCH (1,1) and EGARCH (1,1) are estimated for all stock market returns and macroeconomic growth series of the G-7 countries to measure the volatility series. The asymmetry coefficient in the EGARCH (1, 1) model estimates provides significant evidence of asymmetry in all the stock market returns with the exception of the UK. The significant and negative value of asymmetry coefficient indicates that negative news has more significant impact on the volatility of the stock market returns and the macroeconomic variables than positive news of the same magnitude. This is a very common characteristic of financial data and those results are consistent with the findings of Chinzara (2011), Kumari and Mahakud (2015), Boons (2016) and Giglio et al. (2016). In such a case, the EGARCH (1,1) model is considered as an appropriate model to capture the volatility. But for those variables in which there is no evidence of asymmetry in the volatility, the most appropriate model from the two univariate GARCH models is selected on the basis of the lowest Akaike Information Criterion (AIC) and the highest log likelihood value.

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