MULTISCALE STOCK-BOND RETURN RELATIONS AND MACROECONOMIC FACTORS: EVIDENCE FROM G7 COUNTRIES

[1]FU-LAI LIN, [2]YU-FEN CHEN

Da-Yeh University
E-mail: [1]fllin@mail.dyu.edu.tw, [2]yfchen@mail.dyu.edu.tw

This paper aims to investigate the time variation features of stock-bond return relations and examine how macroeconomic conditions affect dynamic relations across different frequencies. The data covers seven major industrialized economies: United States (USA), Canada, United Kingdom (UK), France, Germany, Italy, and Japan for the sample period April 2, 1991 through December 31, 2014. First, wavelet coherency results show that the stock-bond relations vary across frequencies and over time. The relations shift from sizably positive to predominantly negative in the late 1990s in most G7 countries, except for Japan. Moreover, stock-bond return relations across different frequencies are driven by global and country-specific economic and financial market conditions for each country. We find that an increase in the domestic bond market uncertainty may increase the stock-bond relation, while an increase in the domestic stock market uncertainty tends to reduce the relation. In addition, stock-bond return relations have positive sign sensitivity to TED spread, while their sensitivity to global stock market volatility is negative. Thus, the empirical findings serve to guide not only investors in making their portfolio allocations, but also policy makers in monitoring financial markets by observing changes in domestic and global macroeconomic conditions.

Keywords - Global and country-specific economic and financial conditions, Stock-bond return relations, Wavelet analysis

I. INTRODUCTION

The relationship between stock and bond returns has been received considerable attention in literature. It is widely recognized that the stock-bond return correlation is moderately positive over the long term, but with substantial time variation relations over the short term including sustained periods of negative correlation ([1], [2]). Characterizing this time variation in the stock-bond return correlation has important implications for understanding the economics of joint stock-bond price formation and carries crucial implications for asset allocation and risk management, as they are the two most important asset classes ([2], [3]). Naturally, it is of interest to explore the time-varying features of stock-bond return relations and examine whether the macroeconomic forces drive the time-variation in relations.

The effect of macroeconomic factors on the stock-bond correlation has been studied before. Both the stock market and the bond market are exposed to similar macroeconomic conditions, such as the inflation rate, the business cycle, and the real interest rate, the positive stock-bond return relation is expected in the long term. [4]found that stock-bond relations driven by the business cycle of economy as well as by the inflation rate. [5]investigated the correlations over the last 150 years and also document significant differences across the business cycle. Recently, [6] investigated various possible economic sources of the stock-bond correlation. Their results show that macroeconomic fundamentals contribute little to explaining stock-bond return correlations, but other factors such as proxies offinancial market conditions play a more important role. [2]indicated stock market uncertainty is a major determinant of significant stock-bond correlation changes.However, extant literature usually investigates the impacts of macroeconomic factors on time variation in stock-bond relations at a predetermined frequency ([2],[7]).Since investors may have different investment horizons due to their different patterns of consumption. Different investors have different portfolio management needs. Therefore, it is important to detect the impacts of macroeconomic factors on the time-variation in stock-bond return relations across different frequencies.

Although the short-run and long-run relations can be investigated by using data with different frequencies ([7]), the number of observations used vary with the specified frequency. Apart from the traditional approach by using data with different frequencies, this paper adopts wavelet analysis to decompose data into different time scale components to capture different cyclical features of the data. Here, the local correlation between stock return and bond return is measured by wavelet coherence in the time-frequency domain, which provides the long-term and short-term dynamics simultaneously. It also provides investors with various investing horizons to identify possibilities for portfolio diversification. The purpose of this study is to investigate time variation features of stock-bond return relations for seven major industrialized economies: United States (USA), Canada, United Kingdom (UK), France, Germany, Italy, and Japan and examine how macroeconomic factors affect dynamic relations across different frequencies. First, the wavelet analysis is adopted to provide more rich features in describing the stock-bond return relations simultaneously across different frequencies and over time. Moreover, we examine whether the time variation features of stock-bond return relations can be linked to domestic and global economic and financial conditions for each country. As a whole, the empirical results of this study

provides us with new insights across different time horizons, reflecting the impacts of global and country-specific conditions on multiscale stock-bond return relations.

II. METHODOLOGY

Mathematically, the wavelet transform decomposes a time series in terms of some elementary functions which are derived from a time-localized mother wavelet by translation and dilation. These wavelets result from a mother wavelet, $\psi(t)$ that can be expressed as a function of the time position τ (translation parameter) and the scale s (dilation parameter), which is related with the frequency. The wavelet can be defined as

$$\psi_{\tau,s}(t) = \frac{1}{\sqrt{s}}\psi\left(\frac{t-\tau}{s}\right) \quad (1)$$

where mother wavelet $\psi(t)$ is continuous function in both the time domain and the frequency domain. τacts to translate the function across the data and λacts to vary the time scale of the mother wavelet functionψ. Here, $1/\sqrt{s}$ is a normalization factor to ensure energy normalization that wavelet transform is comparable across time-frequency scale. Given a time-series x(t), its continuous wavelet transform with respect to the mother wavelet ψcan be represented as

$$W_X(\tau,s) = \frac{1}{\sqrt{s}}\sum_{t=1}^{T} x(t)\psi^*\left(\frac{t-\tau}{s}\right) \quad (2)$$

whereτ is the time position and s is the scale which is related with the frequency and the (*) denotes complex conjugation. Here, a Morlet wavelet is chosen as the mother wavelet. Since the mother wavelet $\psi(t)$ is complex-valued, the corresponding wavelet transform $W_X(\tau,s)$ is also complex-valued. With a complex-valued wavelet, we can separate the amplitude and phase information of a time series from real and imaginary parts, respectively. Given two time series x(t) and y(t), with wavelet transforms $W_X(\tau,s)$ and $W_Y(\tau,s)$, where τ is the time position, s is the scale. To examine the relationship between the two time series in the time-scale plane, we consider the cross wavelet spectrum $W_{XY}(\tau,s)$, which is defined as

$$W_{XY}(\tau,s) = W_X(\tau,s)W_Y^*(\tau,s) \quad (3)$$

where (*) indicates complex conjugate. As we discussed above, if the mother wavelet is complex, the cross wavelet spectrum is also complex valued and it can be decomposed into real and imaginary parts. We can then separate the information about amplitude and phase of the two series from real and imaginary parts, respectively. Based this setting, we can obtain both time-dependent amplitude and phase across time and frequency. Here, the localized correlation coefficient in time frequency space can be captured by the wavelet coherency. Likewise in the setting of [8], we define the wavelet coherency as real part of the cross-wavelet spectrum, normalized by the smoothed wavelet power spectra as follows.

$$R(\tau,s) = \frac{\mathcal{R}(W_{XY}(\tau,s))}{\sqrt{WPS_X(\tau,s)WPS_Y(\tau,s)}} \quad (4)$$

where$\mathcal{R}(\cdot)$ represents the real part of cross wavelet spectrum, $WPS_X(\cdot)$ and $WPS_Y(\cdot)$ are the wavelet power spectrum of time series x(t) and y(t), respectively. Likewise the usual correlation coefficient between two time series, $R(\tau,s)$is with a value between -1 and 1. In particular, by inspecting the contour plot of the above measure, one can identify the regions in the time-frequency domain where the existence of relation and captures both time and frequency varying features of the relation.

III. DATA DESCRIPTION AND STATISTICS

A. Data

The data covers seven major industrialized economies: United States (US), Canada, United Kingdom (UK), France, Germany, Italy, and Japan for the sample period April 2, 1991 through December 31, 2014. The daily US, Canada, UK, France, Germany, Italy and Japan stock returns are calculated from the S&P 500 index, S&P/TSX Composite Index, FTSE 100 index, CAC 40 index, DAX 30 index, FTSE MIB index, and Nikkei225, respectively. The bond indices are extracted from benchmark 10-year government bond price indices. All of the data are taken from Thomson Reuters' Datastream and returns are measured by taking the log-difference of price indices times 100. The TED spread is defined as the difference between the short-term 3-month LIBOR Euro-dollar rate and the short-term 3-month Treasury Bill rate. To capture global stock market uncertainty, we use the implied volatility index (VIX) constructed by the Chicago

	Mean	Median	Standard Deviation	Skewness	Kurtosis
Panel A. United States					
Stock	0.028	0.026	1.13	-0.25	12.40
Bond	0.006	0.000	0.46	-0.15	6.01
Panel B. Canada					
Stock	0.023	0.040	1.01	-0.75	14.18
Bond	0.009	0.000	0.40	-0.18	5.04
Panel C. United Kingdom					
Stock	0.016	0.003	1.11	-0.13	9.56

Bond	0.010	0.000	0.40	-0.02	6.49
Panel D. France					
Stock	0.014	0.000	1.38	-0.04	7.85
Bond	0.012	0.000	0.36	-0.14	5.68
Panel E. Germany					
Stock	0.015	0.034	1.38	0.24	16.33
Bond	0.010	0.010	0.33	-0.30	5.80
Panel F. Italy					
Stock	0.013	0.000	1.41	-0.06	6.41
Bond	0.014	0.010	0.46	0.24	17.38
Panel G. Japan					
Stock	-0.006	0.000	1.48	-0.22	8.55
Bond	0.010	0.000	0.28	-0.62	9.38

Table 1 Descriptions statistics for stock and bond returns

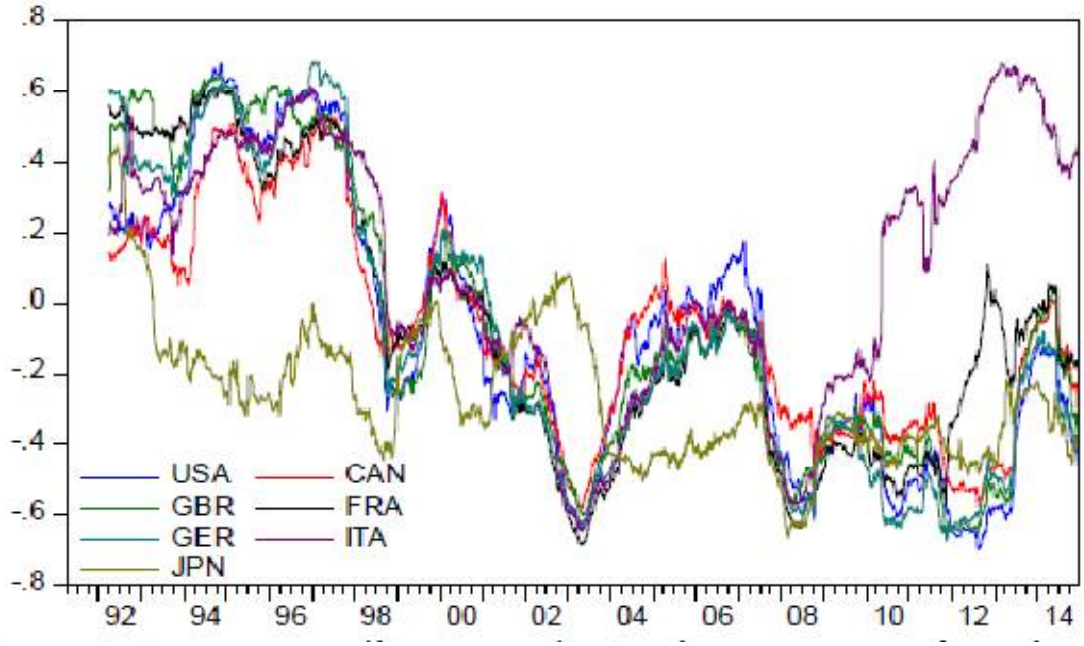


Figure 1 One-year rolling correlation between stock and bond returns

Board Options Exchange (CBOE).The VIX index is constructed from S&P500 options.

B. Summary Statistics

First, we can find that the daily mean returns in stock market are greater than those in bond marketin most G7 countries, except Italy and Japan. However, the average returns in stock market are smaller than that in bond market. Moreover, standard deviations in stock returns are obviously higher than those in bond returns, indicatingthatthestockmarketismorevolatilethanthebondmarket in all G7 countries.Overall, the stock market has higher return accompanied by higher volatilityin most G7 countries, except Italy and Japan.In addition, the skewnessand kurtosis indicate that these returnsleft-skewed and heavy tails, not normally distributed data.

C. Rolling Correlations

Figure 1 illustrates one-year rolling correlations between gold, stock and bond returns. The feature of figure shows that correlations vary widely from this average. Similarly time-variation of stock-bond returns relations have also been apparent in Figure 1. The findings here provide evidences that the relationship between stock and bond returns is dynamic rather than static. We also find that stock-bond relations have changed dramatically over the last two decades, shifting from sizably positive to predominantly negative in the late 1990sin most G7 countries, except for Japan.The correlations shift from sizably positive to predominantly negative. The result is consistent with the findings of [6], [9], and[7]. The correlations of stock-bond returns among these markets display a high degree of co-movement, except for Japan and Italy. This finding reflects a high degree of market integration in most G7 countries.

IV. EMPIRICAL RESULTS

A. Wavelet Coherency Analysis

The wavelet coherency analysis is adopted to examine the relationships between stock and bond returns in time-frequency domain.Figure 2 demonstrates the wavelet coherency of stock and bond returns, where a contourplot

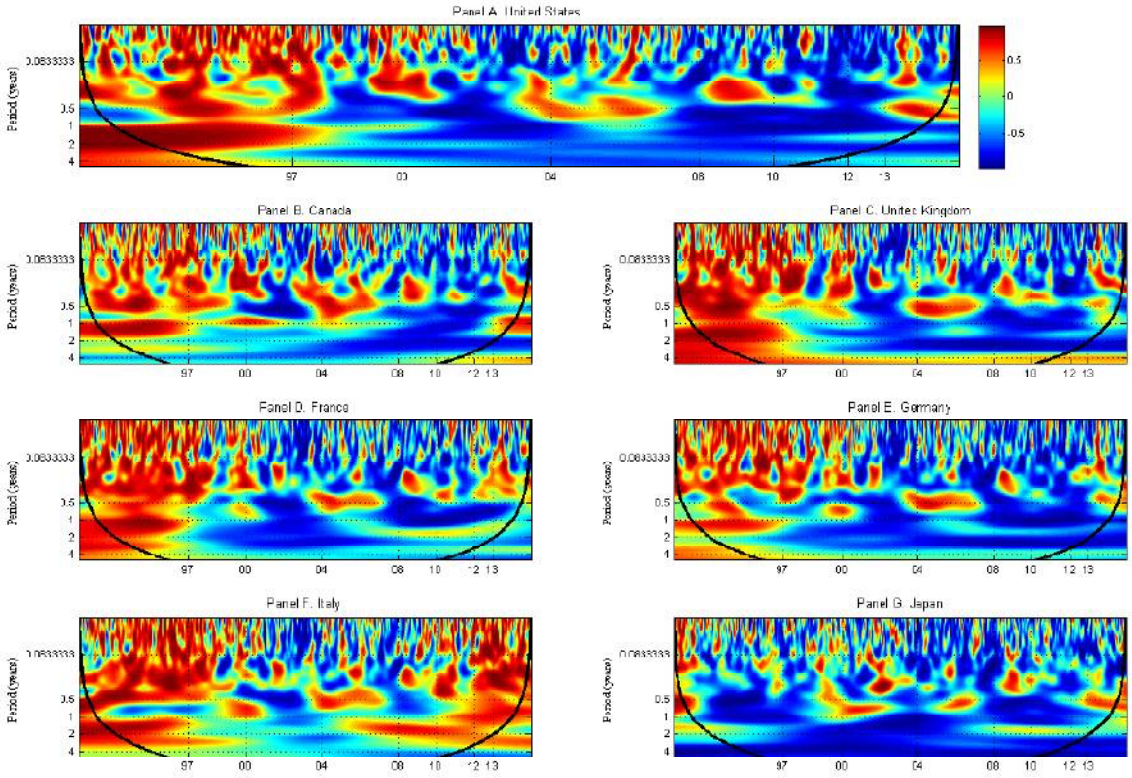


Figure 2 Wavelet coherency between stock and bond returns

with three dimensions is depicted, the time dimension, the frequency dimension and the color code. In Figure 2, the cone of influence, which indicates the region affected by edge effects, is depicted by the bold black line. The color code for wavelet coherency ranges from the blue (negative coherency) to the red (positive coherency).Time and frequency are presented on the horizontal and the vertical axes, respectively. Frequency is converted into the annual scale.

In figure 2, the coherency between stock and bond returns exhibits different behavior both in the short-term and long-term relationships since the late 1990s in most G7 countries, except Japan. There is a significant positive coherency in both higher and lower frequency bands before the late 1990s. However, the coherency between stock and bond returns shifts from sizably positive to predominantly negative since the late 1990s.This is consistent with the finding of [10]. This finding supports that "decoupling" phenomenon between stock and bond returns is no longer a temporary phenomenon. After the late 1990s, the positive relationship is observed onlyduring the periods of years 1997, 2000 and the end of 2009at the higher frequency band (0.08- to 0.5-year frequency) in most G7 countries, except for Italy. That is, the stock and bondreturns exhibit an apparently positive relationship at higher frequencies (short-term horizons) in the periods of crisis.

In this subsection, we examine whether the multi-scale stock-bond relations are linked to domestic and global macroeconomic conditions. We start by examining whether our proxies for domestic economic conditions are related to the different scales of stock-bond wavelet coherency. The domestic stock market returns is used as a proxy for domestic business condition and the domestic financial uncertainty is captured by the stock market and bond market volatility. Here, Fisher transformation of the relation is adopted to transform the range of wavelet coherency. The first model uses a linear regression to regress the stock-bond returns relations on the domestic determinants.

$$\ln\left(\frac{1+R_{X,Y}(t,s)}{1-R_{X,Y}(t,s)}\right) = \alpha_s + \beta_{1s}\sigma^2_{Stock,t} + \beta_{2s}\sigma^2_{Bond,t} + \beta_{3s}IDX_t + \varepsilon_{t,s} \quad (5)$$

where$R_{X,Y}(t,s)$ is the real part of complex wavelet coherency of stock (X) and bond (Y) returns with scale s at time t. σ^2_{Stock} and σ^2_{Bond} are the domestic conditional variance of stock returns and the domestic conditional variance of bond returns, respectively. Both conditional variance variables are independently generated from a GARCH(1,1) process. IDX is the returns of domestic benchmark stock market. Table 3 reports the impacts of domestic determinants on monthly, quarterly, and annual wavelet coherence between stock and bond returns. For the convenience of comparison, we provide the results in form of standardized beta coefficients, which allows for theevaluation of each coefficient as the response of ourdependent variables to a one-standard deviation change in the variable of interest. First, in Table 3, the results in the

	Monthly	Annual
Panel A. Unit States		
σ^2_{Stock}	-0.060***	-0.070***
σ^2_{Bond}	-0.166***	-0.359***
IDX	0.016	0.012
adj. R^2	0.043	0.164
Panel B. Canada		
σ^2_{Stock}	-0.228***	-0.287***
σ^2_{Bond}	0.268***	0.237***
IDX	0.002	0.002
adj. R^2	0.104	0.116
Panel C. Unit Kingdom		
σ^2_{Stock}	-0.169***	-0.359***
σ^2_{Bond}	0.233***	0.201***
IDX	0.002	0.012
adj. R^2	0.062	0.132
Panel D. France		
σ^2_{Stock}	-0.329***	-0.401***
σ^2_{Bond}	0.305***	0.219***
IDX	0.016	0.012
adj. R^2	0.138	0.153
Panel E. Germany		
σ^2_{Stock}	-0.177***	-0.164***
σ^2_{Bond}	-0.072***	-0.179***
IDX	0.021*	0.023*
adj. R^2	0.045	0.080
Panel F. Italy		
σ^2_{Stock}	-0.093***	-0.165***
σ^2_{Bond}	0.282***	0.368***
IDX	0.021*	0.003
adj. R^2	0.074	0.129
Panel G. Japan		
σ^2_{Stock}	0.135***	-0.001
σ^2_{Bond}	0.033***	-0.053***
IDX	-0.027**	-0.005
adj. R^2	0.020	0.002
Observations	6192	6192

Table 3 Domestic determinants of wavelet coherence
Standardized beta coefficients; *p< 0.10, **p< 0.05, ***p< 0.01

first column of Panel A show that a one-standard-deviationincrease in domestic conditional variance of stock returns (σ^2_{Stock}) reduces the monthly stock-bond relation by 0.06 standard deviation and that this is statistically significant at the 1% level. Overall, the domestic stock market volatility term (σ^2_{Stock}) is negative and statistically significant at monthly and annual frequencies in most G7 countries, except for Japan. The finding indicates that stock market volatility has a negative impact on short-term and long-term stock-bond returns relations, supportingthe "flight-to-safety" phenomenon existed in most G7 countries. Second, we find mixed results for the impacts of bond market volatility (σ^2_{Bond}) on stock-bond relations. For example, as shown in Monthly column of Table 3, five of the seven bond market volatility terms have positive and statistically significant sign (those for Canada,the United Kingdom, France,Italy, and Japan), confirming the finding of [7]. Finally, the domestic economic condition term (IDX) has the

	Monthly	Annual
Panel A. Unit States		
σ^2_{Stock}	-0.032	-0.001
σ^2_{Bond}	-0.107***	-0.268***
IDX	0.261***	0.375***
TED	-0.011	-0.033***
VIX	-0.268***	-0.425***

adj. R^2	0.109	0.310
Panel B. Canada		
σ^2_{Stock}	-0.285***	-0.082***
σ^2_{Bond}	0.257***	0.242***
IDX	-0.014	-0.045***
TED	0.339***	0.174***
VIX	-0.204***	-0.431***
adj. R^2	0.190	0.215
Panel C. Unit Kingdom		
σ^2_{Stock}	-0.075***	-0.043**
σ^2_{Bond}	0.209***	0.198***
IDX	-0.026**	-0.040***
TED	0.363***	0.188***
VIX	-0.365***	-0.535***
adj. R^2	0.191	0.256
Panel D. France		
σ^2_{Stock}	-0.165***	0.067***
σ^2_{Bond}	0.274***	0.198***
IDX	-0.012	-0.054***
TED	0.257***	0.215***
VIX	-0.335***	-0.704***
adj. R^2	0.208	0.332
Panel E. Germany		
σ^2_{Stock}	-0.033**	0.056***
σ^2_{Bond}	-0.063***	-0.139***
IDX	-0.014	-0.024**
TED	0.349***	0.312***
VIX	-0.385***	-0.495***
adj. R^2	0.164	0.215
Panel F. Italy		
σ^2_{Stock}	0.071***	0.027
σ^2_{Bond}	0.242***	0.315***
IDX	-0.008	-0.025**
TED	0.136***	0.002
VIX	-0.309***	-0.271***
adj. R^2	0.122	0.167
Panel G. Japan		
σ^2_{Stock}	-0.066***	-0.089***
σ^2_{Bond}	0.012	-0.068***
IDX	0.005	0.006
TED	0.164***	0.153***
VIX	0.239***	0.037**
adj. R^2	0.099	0.024
Observations	6192	6192

Table 4 Global determinants of wavelet coherency
Standardized beta coefficients; *p< 0.10, **p< 0.05, ***p< 0.01

expected positive sign in most G7 countries (except for Japan) and is statistically significant in only two (Germany and Italy).To examine the impacts of global financial conditions on the stock-bond returns relations, TED spread (TED) and CBOE Volatility index (VIX) are added in Equation(5) as follows:

$$\ln\left(\frac{1+R_{X,Y}(t,s)}{1-R_{X,Y}(t,s)}\right) = \alpha_s + \beta_{1s}\sigma^2_{Stock,t} + \beta_{2s}\sigma^2_{Bond,t} + \beta_{3s}IDX_t + \beta_{4s}TED_t + \beta_{5s}VIX_t + \varepsilon_{t,s} \quad (6)$$

hereTED spread and VIX are used as a proxy for credit market uncertainty and global stock market volatility, respectively.To explain howmulti-scale stock-bond return relations are related to macroeconomic factors in more detail, we show how monthly, quarterly, and annual wavelet coherencies relate to TED spread and VIX in Table 5. First, as shown in Table 4, the results in the first column of Panel B show that a one-standard-deviation increase in TED spread increases the monthly stock-bond relation by 0.363 standard deviation and that this is statistically significant at the 1% level. Overall, the TED spread term is positive and statistically significant at monthly and annual frequencies in most G7 countries, except

for the Unit States. That is,the stock-bond return relation increaseswith a higher TED spread. This reflects that a rise in TED spread is likely to generate credit risk, causes widespread uncertainty that impinges on financial markets, and leads to the collapse of both stock and bond markets. More important, the VIX term is uniformly negative and statistically significant in all G7 countries. This evidence is consistent with the findings by [2] and [6]. The negative impact of volatility index on stock-bond relation could contribute to the "flight-to-safety" effect.

REFERENCES

[1] Gulko, L.(2002). Decoupling, Journal of Portfolio Management, 28, 59-66.

[2] Connolly, R. A., Stivers, C. T., and L., Sun (2005). Stock market uncertainty and the stock-bond return relation, The Journal of Financial and Quantitative Analysis, 40(1), 161-194.

[3] d'Addona, S., Kind, A.H., 2006. International stock–bond correlations in a simple affine asset pricing model. Journal of Banking and Finance, 30, 2747–2765.

[4] Ilmanen, A., (2003). Stock–bond correlations, Journal of Fixed Income, 13 (2), 55-66.

[5] Yang J., Zhou Y., and Z. Wang (2009). The stock–bond correlation and macroeconomic conditions: one and a half centuries of evidence. Journal of Banking and Finance, 33, 670-680.

[6] Baele, L., Bekaert G., and K. Inghelbrecht (2010). The determinants of stock and bond return comovements, Review of Financial Studies, 23, 2374-2428.

[7] Chiang, T. C., Li, J., and S.-Y., Yang (2015). Dynamic stock-bond return correlations and financial market uncertainty. Review of Quantitative Finance and Accounting, 45(1), 59-88.

[8] Rua, A. (2010). Measuring comovement in the time-frequency space, Journal of Macroeconomics, 32, 685-691.

[9] Bansal, N., Connolly R., and C., Stivers (2014). The stock-bond return relation, the term-structure's slope, and asset-class risk dynamics, Journal of Financial and Quantitative Analysis, 49, 699-724.

[10] Lin,F.-L., Yang S.-Y., Marsh T., and Y.-F. Chen (2017l). Stock andbond return relations and stock market uncertainty: Evidence from waveletanalysis. International Review of Economics & Finance, Available online 14 July2017.

★★★