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Random Walk Test on Hedge Ratios for Stock and Futures

Seol, Byungmoon(Gyeongnam National University of Science and Technology)*

Abstract

The long memory properties of the hedge ratio for stock and futures have not been systematically investigated by the extant literature. To investigate hedge ratio' long memory, this paper employs a data set including KOSPI200 and S&P500. Coakley, Dollery, and Kellard(2008) employ a data set including a stock index and commodities foreign exchange, and suggested the S&P500 to be a fractionally integrated process.

This paper firstly estimates hedge ratios with two dynamic models, BEKK(Bollerslev, Engle, Kroner, and Kraft) and diagonal-BEKK, and tests the long memory of hedge ratios with Geweke and Porter-Hudak(1983)(henceforth GPH) and Lo's modified rescaled adjusted range test by Lo(1991). In empirical results, two hedge ratios based on KOSPI200 and S&P500 show considerably significant long memory behaviours. Thus, such results show the hedge ratios to be stationary and strongly reject the random walk hypothesis on hedge ratios, which violates the efficient market hypothesis.

Keywords: Time varying hedge ratios, Long memory, Random walk

I. Introduction

One of the important issues in finance is an evaluation of a stochastic memory. Given a stochastic memory in an asset return, it is possible to obtain increased profit on the basis of price-change predictions that contradict the efficient market hypothesis and deny the random walk process on financial returns. Along with this aspect, a long memory existence for hedge ratios of financial instrumentals may have some implication for effectively managing risks. In such a case, it may decrease a reliance on the impact of statrup's financing risk.

Numerous empirical studies for this theme have tested the random walk hypothesis(RWH) for various stock and futures assets. For instance, Grammatikos and Saunders(1983) examine the stability of hedge ratios. Authors of the paper find that the hedge ratios for five major foreign currency futures are unstable over time. With commodity futures assets such as live cattle and corn, McNew and Fackler(1994) support the constant hedge ratios hypothesis. Ferguson and Leistikow(1998) strongly reject the random walk hypothesis, using the OLS regression and the Dickey-Fuller test for currency markets. Such results do mean that time varying dynamic approaches for forecasting hedge ratios is not effective.

On the other hand, Malliaris and Urrutia(1991) address an evidence that the futures hedge ratios do follow a random walk for currencies and equities introduced Standard and Poor’s 500 Index, New York Stock Exchange Index, Deutsche mark, British pound, Japanese yen, and Swiss franc. Perfect and Wiles(1994) also support the finding of Malliaris and Urrutia(1991) as well. The findings imply that hedgers cannot consistently fit on an optimal hedge and so dynamic hedging techniques must be considered. Most of the previous literatures on the RWH for hedge ratios of assets focus on currency markets or commodities, while literatures which investigate hedge ratios of stock markets, if any, are few. This paper tries to contribute to current literatures by examining the RWH of hedge ratios on stock and futures markets. For the end, in this paper, hedge ratios are estimated by time varying methods and the long memory tests for the estimated ratios are conducted through the R/S analysis and GPH Spectral Regression.

This paper collects the stock and futures data from Korea Composite Stock Price Index 200(KOSPI200) and Standard and Poor’s 500(S&P500). Here, the KOSPI200 represents the emerging market and the S&P500 is the most famous stock index in the world. Especially, the Korean futures market has experienced rapid and explosive growth since the opening of the KOSPI200 index on 3rd May 1996. According to the annual report(2006) from World Federation of Exchanges, the notional value for KOSPI200 futures contract is 2,983 billions US dollars

*Professor, Graduate School of Business & Entrepreneurship, Gyeongnam National University of Science and Technology, bmseol@gntech.ac.kr
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in 2005, which is ranked to the 1st position in the Asia-pacific exchanges, except Chicago Mercantile Exchange(CME).

The remainder of the paper is organized as follows. Section 2 describes the primary methodologies for the study. Data and the results of stationary test are presented in section 3. Section 4 is devoted to the empirical results. Finally, section 5 briefly concludes.

II. Methodology

2.1 Estimation on hedge ratios

Following a unit root test for stock and futures of KOSPI200 and S&P500, this paper conducts a co-integration test on each series. If stock and futures are co-integrated, the paper employs the Vector Error Correction Model(VECM) as the conditional mean equations of the model, shown as equation (1). In the VECM model, $\epsilon_t = [\epsilon_{st}, \epsilon_{ft}]$ represents an innovation vector from the stock and futures models respectively and $S_{t-1} - \theta F_{t-1}$ represents an error correction term.

$$\begin{aligned} R_{st} &= \beta_{10} + \beta_{11}(S_{t-1} - \theta F_{t-1}) + \beta_{12} R_{st-1} + \beta_{13} R_{ft-1} + \epsilon_{st} \\ R_{ft} &= \beta_{20} + \beta_{21}(S_{t-1} - \theta F_{t-1}) + \beta_{22} R_{ft-1} + \beta_{23} R_{st-1} + \epsilon_{ft} \\ \epsilon_t &= \begin{bmatrix} \epsilon_{st} \\ \epsilon_{ft} \end{bmatrix} \mid \Phi_{t-1} \sim N(0, H_t), \; H_t = \begin{bmatrix} h_{sst} & h_{sft} \\ h_{fst} & h_{fft} \end{bmatrix} \end{aligned} \qquad (1)$$

Engle and Kroner(1995) propose the Bollerslev, Engle, Kroner, and Kraft(BEKK) parameterization. Normally the coefficients of BEKK are needed the exclusively 11 parameters in the conditional variance-covariance structure and H_t is required to be positive definite. The BEKK model can be presented as an eq (2). An eq (3) and an eq (4) are the coefficients matrix for BEKK and diagonal-BEKK respectively. Noticeably, in the diagonal-BEKK model, the non-diagonal elements of A and B are zero.

$$H_t = C'C + A' H_{t-1} A + B'(\epsilon_{t-1}\epsilon'_{t-1})B \qquad (2)$$

$$C = \begin{bmatrix} C_{11} & 0 \\ C_{21} & C_{22} \end{bmatrix}, \; A = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}, \; B = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} \qquad (3)$$

$$C = \begin{bmatrix} C_{11} & 0 \\ C_{21} & C_{22} \end{bmatrix}, \; A = \begin{bmatrix} A_{11} & 0 \\ 0 & A_{22} \end{bmatrix}, \; B = \begin{bmatrix} B_{11} & 0 \\ 0 & B_{22} \end{bmatrix} \qquad (4)$$

2.2 Testing for the RWH for hedge ratios

Normally, a stationary time series has correlation that depends only on the time lag k between time t and $t-k$ observations, and decays to zero as k increases. The stochastic "memory" in the random process is basically measured through a decaying speed. It is said that a process with all observations uncorrelated is a white noise, and the process is the random walk without any long memory. In reference, a short memory process has autocorrelations decaying to zero at a geometric rate whereas a long memory process holds autocorrelations that decay much more slowly, asymptotically following a hyperbolic decay(Crato and Ray, 2000).

Several tests and statistics have been suggested that detect the existence of long memory in each of series. Among them, Geweke and Porter-Hudak(1983)(henceforth GPH) and R/S statistics modified by Lo(1991) are the most famous methods.

Thus this paper uses the two methods, namely, GPH and R/S for determining the existence of long-range dependent process. Firstly, the R/S statistic, then is defined as R_T / S_T where R_T is computed as $R_T = \max_{1<k<T} (\sum_{j=1}^{k} X_j - \overline{X}) - \min_{1<j<T} (\sum_{j=1}^{k} X_j - \overline{X})$ and S_T is the standard deviation for sample data. For short memory processes, the value of R_T / S_T converges to n^J with $J = 1/2$. The parameter J is called the Hurst exponent and is related to the long memory parameter d by $J = d + 1/2$.

Mandelbrot and Taqqu(1979) prove that a process has long memory when $J > 1/2$. A natural estimate for a series of length n is simply $\hat{J} = \log(R_T / S_T)/\log_n$.

The second method for capturing an existence of the long-memory is the GPH spectral regression by Geweke and Porter-Hudak(1983). According to Crato and Ray(2000), "The regression is performed using a set of Fourier frequencies close to zero, where the slope of log spectrum relative to the frequency is dependent directly on the long-memory parameter d. The regression estimator could capture the long memory characteristic of the process without being contaminated in the estimation by short memory correlation in the time series evident at higher frequencies"(Crato and Ray, 2000).

III. Data and stationary test

3.1. Data

The data sets employed in this study comprise 525 weekly observations on the KOSPI200 and 1141 weekly observations on the S&P500, containing stock index and stock index futures contract. The time periods under study extend from May 3rd, 1996 through December 29th, 2005 for the KOSPI200 and from April 22th, 1982 through February 26th, 2004 for the S&P500.

Coakley, Dollery, and Kellard(2008) employ a data set 1995-2005 including a stock index and commodities foreign exchange, and suggested the S&P 500 to be a fractionally integrated process. The prices used is Thursday closing ones(Wednesday and Friday closing prices are alternatively used, given a Thursday closing prices missed). More importantly, to avoid thin trading and expiration effects, this paper uses the nearest contracts, rolling over to next nearest contract prior to expiration month of the current contract.

Let S_t and F_t represent the logarithms of the stock index and stock index futures prices. The daily return on a spot position held from $t-1$ to t are calculated as $R_{st}=(S_t-S_{t-1})\times 100$. Similarly, the actual return on a futures position is as $R_{ft}=(F_t-F_{t-1})\times 100$.

A Summary statistics for the data is indicated in table 1. Noticeably, four series show excess kurtosis, implying fatter tails than a normal distribution. This result is backed by the Jarque-Bera statistics. The values of Ljung-Box(hereafter LB) for the return series of KOSPI200 stock and futures are significant at the 1% level. The LB(10)s for squared return series of KOSPI200 and S&P500 are highly significant equally, suggesting the possibility of the presence of autoregressive conditional heteroskedasticity.

<Table 1> Descriptive statistics for stock-futures return series

	KOSPI200		S&P500	
	Stock	Futures	Stock	Futures
Mean	0.034	0.034	0.087	0.087
Std. Dev.	2.076	2.301	0.959	1.012
Skewness	0.344	0.371	-0.737	-0.778
Kurtosis	5.755	7.103	8.347	8.929
Jarque-Bera	176.072	379.531	1461.482	1784.601
LB(10)	31.470**	40.214**	15.112	15.942
LB2(10)	123.297**	143.684**	73.566**	78.516**
Observations	525	525	1141	1141

Note: The LB(n) is the Ljung-Box statistic for up to n lags, distributed as χ^2 with n degrees of freedom. The ** indicates significance at the 1% level.

3.2. Stationary test

The Panel A of table 2 reports the results of stationary test for the raw and return series both stock and futures of KOSPI200 and S&P500.

The ADF(augmented Dickey-Fuller) test and the PP(Pillips-Perron) test fail to reject the null hypothesis of the presence of a unit root in both the stock and futures prices. The results indicate that these series are nonstationary. However, the hypothesis of being unit roots in all the returns series is rejected at the 1% level.

To test a co-integration between stock and futures on KOSPI200 and S&P500, Johansen methodology is adopted in this study. The specific results for the test are reported in Panel B of table 2. Specifically, the λ_{trace} statistics on stock and futures of KOSPI200 is 52.668, exceeding a 1 percent critical value of the λ_{trace} statistic.

<Table 2> Stationary test for Stock and futures series

Panel A: Unit root test				
	KOSPI200		S&P500	
	ADF	PP	ADF	PP
S_t	-0.004 (-0.813)	-0.002 (-0.565)	-0.000 (-0.511)	-0.000 (-0.567)
F_t	-0.005 (-0.915)	-0.003 (-0.707)	-0.000 (-0.537)	-0.000 (-0.612)
R_{st}	-0.823** (-8.821)	-1.107** (-25.413)	-1.088** (-16.052)	-1.012** (-34.321)
R_{ft}	-0.861** (-8.987)	-1.137** (26.269)	-1.139** (-16.378)	-1.045** (-35.161)

Panel B: Cointegration test				
Null Hypothesis	Alternative Hypothesis		1% Critical value	5% Critical value
KOSPI200				
λ_{trace} test		λ_{trace} value		
$\gamma=0$	$\gamma>0$	52.668**	20.04	15.41
$\gamma\le 1$	$\gamma>1$	0.445	6.65	3.76
$\lambda_{\max}$ test		$\lambda_{\max}$ value		
$\gamma=0$	$\gamma=1$	52.223**	18.63	14.07
$\gamma=1$	$\gamma=2$	0.445	6.65	3.76
S&P500				
λ_{trace} test		λ_{trace} value		
$\gamma=0$	$\gamma>0$	70.405**	20.04	15.41
$\gamma\le 1$	$\gamma>1$	0.214	6.65	3.76
$\lambda_{\max}$ test		$\lambda_{\max}$ value		
$\gamma=0$	$\gamma=1$	70.191**	18.63	14.07
$\gamma=1$	$\gamma=2$	0.214	6.65	3.76

Note: The t-statistics are reported in parentheses. **, * indicate significance at the 1% level. γ is the number of co-integrationvector.

Accordingly, it is possible to reject the null hypothesis of no co-integration vectors. However, the null of $\gamma\le 1$ is not rejected, since the value of λ_{trace}(0.445) is less than the 5%

critical value. For the value of λ_{max} statistics, the null of $\gamma = 0$ is soundly rejected, whereas $\gamma = 1$ is not. Shortly, there is at least one co-integrating vector between two series.

Similarly, the story for S&P500 is very close to that of KOSOPI200. The value of λ_{max} statistics also rejects the null hypothesis of no co-integration.

IV. Empirical results

4.1. The estimation of hedge models

Given the evidence of a long memory or a co-integrating relationship between S_t and F_t, the conditional mean equations are parameterized as a VECM rather than a VAR to avoid the loss of long memory information.

<Table 3> Estimates for models

Panel A: Estimation results				
	KOSPI200		S&P500	
	BEKK	Diagonal-BEKK	BEKK	Diagonal-BEKK
β1.0	0.001	0.001	0.001**	0.001**
β2.0	0.000	0.001	0.001**	0.001**
β1.1	0.001	0.001	-0.000	-0.000
β2.1	0.003**	0.003*	0.000	0.000
β1.2	0.119	-0.185	-0.260**	-0.313
β2.2	-0.344**	-0.022	-0.038*	0.009
β1.3	-0.166	0.104	0.201**	0.269
β2.3	0.318	-0.036	-0.034	-0.066
C11	0.000	0.002**	-0.000**	0.001**
C21	0.002**	0.002**	0.116**	0.001**
C22	0.003*	0.000*	0.002**	0.000**
A11	1.098**	0.958**	0.930**	0.974**
A12	0.156**	-	-0.055*	-
A21	-0.133**	-	-0.001	-
A22	0.803**	0.955**	0.982**	0.974**
B11	0.719**	-0.274**	0.217**	0.210**
B12	1.077**	-	0.058**	-
B21	-0.489**	-	0.116**	-
B22	0.803**	-0.283**	0.281**	0.208**

Panel B: Diagnostic tests					
		KOSPI200		S&P500	
		BEKK	Diagonal-BEKK	BEKK	Diagonal-BEKK
R_{st}	LB(10)	19.988	21.839	14.904	12.988
	LB2(10)	25.968	28.590	9.543	16.058
R_{ft}	LB(10)	21.088	25.751	16.264	14.468
	LB2(10)	24.715	16.322	10.652	17.785

Note: LB(n) is the Ljung-Box statistic for up to n lags, distributed as χ^2 with n degrees of freedom. **, * indicate significance at the 1%, 5% level, respectively.

The estimated parameters are presented in Table 3. Almost all parameters in variance equations are statistically significant, suggesting that the variances, the covariances, and the risk minimizing hedge are indeed changing over time(Wang and Low, 2003).

The ARCH process is significantly found in all stock and futures tests. The size and the significance of the ARCH parameters indicate volatility clustering in those markets. The covariance parameters indicate a significant interaction between the two returns. Almost all values of LB(20) for the innovation series and the squared innovation series are not statistically significant, suggesting that the hedge models are adequate.

4.2 Hedge ratios and random walk test

The hedge ratios, estimated using two models of the BEKK and the diagonal-BEKK, are reported in panel A of table 3. The table 4 indicates summary statistics for the hedge ratios series. All the hedge ratio means are less than unit. A Diagonal-BEKK hedge ratio for the S&P500 is larger than that for the other one. Those series show excess kurtosis, implying fatter tails than a normal distribution. Such results are backed by the Jarque-Bera statistics well.

The values of LB for every model and the values of LB(20) for squared series are statistically very significant as well. It suggests the possibility of the presence of an autoregressive conditional heteroskedasticity and the existence of long memory in hedge ratios series.

<Table 4> Descriptive statistics for hedge ratio series

	KOSPI200		S&P500	
	BEKK	Diagonal - BEKK	BEKK	Diagonal - BEKK
Mean	0.917	0.908	0.940	0.942
Variance	0.004	0.005	0.002	0.001
Skewness	-1.324	-1.032	-1.173	-0.822
Kurtosis	3.171	1.055	1.426	0.448
Jarque-Bera	373.32	117.61	358.31	138.16
LB(10)	2802.51**	3759.25**	8992.94**	9300.17**
LB2(10)	2820.41**	3782.75**	9009.43**	9316.81**

Note: LB(n) is the Ljung-Box statistic for up to n lags, distributed as χ^2 with n degrees of freedom. **, * indicate significance at the 1%, 5% level, respectively.

The table 5 reports the results of long memory test using two techniques, the R/S and the GPH on stock and futures markets for KOSPI200 and S&P500. The results for two long memory tests show very significant long memory behaviours on hedge ratios of each of the cases. Normally, it can be said that the existence of the long memory behaviours contradicts the random walk hypothesis, violating the efficient market hypothesis for financial markets. Thus, those results are inconsistent with Malliaris and Urrutia(1991)'s findings that show stock market' hedge ratios to be random walk for advanced markets. On the other hand, results are consistent with Ferguson and Leistikow(1998)'s study which reports a existence of long memories on hedge ratios estimated from 4 advanced countries currency markets. In addition, the figure 1 and the figure 2 respectively display the trends that two hedge ratios studied in this paper and have apparent long memory processes.

<Table 5> Long memory estimates for hedge ratio series

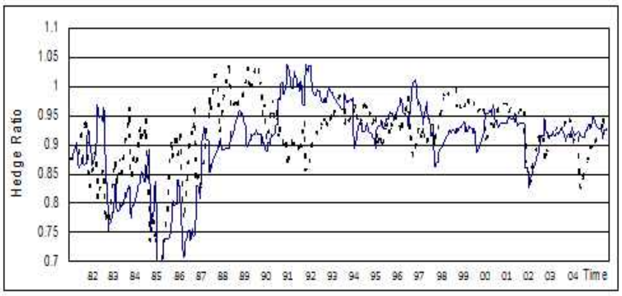
	KOSPI200		S&P500	
	BEKK	Diagonal - BEKK	BEKK	Diagonal - BEKK
Hurst Estimates	0.950** (0.002)	0.995** (0.003)	1.008** (0.003)	1.006** (0.003)
GPH Estimates	0.726** (0.181)	0.637** (0.141)	0.808** (0.116)	0.761** (0.118)

Note: ** indicates significance at the 1% and a standard error is reported in parentheses.

[Figure 1] The trend for S&P500 hedge ratio series

Note: The Dot-line and the line figure the BEKK and the BEKK-diagonal respectively.

[Figure 2] The trend for KOSPI200 hedge ratio series



Note: The Dot-line and the line figure the BEKK and the BEKK-diagonal respectively.

V. Concluding remarks

This paper seeks to contribute to current literatures by examining the random walk hypothesis of hedge ratios on stock and futures. It estimates hedge ratios through dynamic models such as BEKK and diagonal-BEKK and investigates the long memory behaviours of hedge ratios using R/S analysis and GPH Spectral Regression.

Results show that raw data of each of stock and futures for the KOSPI200 and the S&P500 are nonstationary, whereas the returns series on all the stock and futures of two indices are stationary. From the Johansen test, this paper finds that there exists a meaningful co-integrating relationship between stock and futures on each of the KOSPI200 and the S&P500.

Most importantly, this paper' results provide for an obvious evidence of the long persistence existence on hedge ratios between stock and futures on each of KOSPI200 and S&P500. In a nutshell, those results contradict the efficient market hypothesis, strongly reject the random walk hypothesis. Thus, it does imply that a more efficient controlling for volatilities and an improved optimizing of hedge performances can be consistently placed, using the stationary property of hedge ratio.

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헤지비율의 시계열 안정성 연구

설병문(경남과학기술대학교)*

국 문 요 약

주식과 선물간의 헤지비율의 시계열 안정성에 대한 연구는 아직 찾아보기 어렵다. 본 연구는 KOSPI200과 S&P500의 주식과 선물 지수를 이용하여 한국과 미국, 두 금융시장의 헤지비율에 대한 시계열 안정성을 연구한다. Coakley, Dollery, and Kellard(2008)는 1995년부터 2005년의 S&P500 현물을 대상으로 시계열 안정성을 확인하였다. 본 연구는 선행연구에서 시계열 안정성이 검증된 기간을 분석기간에 포함하여 두 시장을 분석함으로써 연구결과의 강건성을 얻고자 한다. 한국시장의 분석기간은 주식선물시장이 개설된 1996년부터 2005년이다. S&P500은 1982년부터 2004년을 분석대상으로 하고 있다. 본 연구는 BEKK and diagonal-BEKK을 사용하여 헤지비율을 구하며, 시계열 안정성 검증을 위하여 R/S와 GPH 방법을 사용한다. 분석결과는 시장효율성의 이론적 근거가 되는 랜덤워크가설을 지지하지 않는다. 이 결과는 헤지비율을 이용한 위험관리 방안에 대한 시사점을 제공한다.

핵심주제어 : 헤지비율, 장기기억, 랜덤워크

* 경남과학기술대학교 창업대학원 창업학과 전담교수, bmseol@gntech.ac.kr