# Modeling Volatility of Sector Indexes with Multivariate GARCH Model [a]

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**Abstract:** The volatility spillover effect has always been an attractive issue for financial market participants. This research aims to investigate volatility spillover between two major sector indexes, namely BIST Financial and BIST Services of Borsa Istanbul by using a multivariate GARCH model. Granger causality and Hong's causality tests were used to determining causal relation between them. Examining two major sector indexes from January 4, 2010, to July 24, 2018, the findings indicated that there was volatility spillover BIST Financial and BIST Services sector indexes. As for causality analyses, the volatility spillover between two sector indexes indicated bivariate causal relation in accordance with both the results of the Granger causality and Hong's causality tests. The findings are of great importance for market participants and investors to make properly asset allocation and optimal portfolio management.

**Keywords:** Hong's causality, DCC-GARCH model, volatility spillover, sector indexes.

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# Çok Değişkenli GARCH Modeli ile Sektör Endekslerinin Volatilitesinin Modellenmesi

**Öz:** Oynaklık yayılımı etkisi finansal piyasa katılımcıları için her zaman cazip bir konu olmuştur. Bu çalışma çok değişkenli GARCH modelini kullanarak Borsa İstanbul'daki BIST Mali ve BIST Hizmetler olan iki önemli sektör endeksi arasındaki oynaklık yayılımını araştırmayı amaçlamaktadır. İki sektör arasındaki nedensellik ilişkisini belirlemek için Granger ve Hong'un Nedensellik testleri kullanılmıştır. 4 Ocak 2010'dan 24 Temmuz 2018'e kadar kapsayan iki önemli sektör endekslerini incelemenin ardından, bulgular BIST Mali ve BIST Hizmetler sektör endeksleri arasında oynaklık yayılımı olduğunu göstermiştir. Nedensellik analizlerine gelince, hem Granger nedensellik hem de Hong'un nedensellik testlerinin sonuçlarına göre iki sektör endeksi arasındaki oynaklık yayılımı iki yönlü nedensel ilişkiyi göstermiştir. Sonuçlar, en uygun varlık tahsisi ve portföy yönetimi yapmak için, piyasa katılımcıları ve yatırımcılar açısından büyük önem arz etmektedir.

**Anahtar Kelimeler:** Hong nedensellik, DCC-GARCH modeli, oynaklık yayılımı, sektör endeksleri.

## Introduction and Literature Review

The volatility spillover effect has always been attractive issue for financial market participants. It can often come to exist in different ways. It may vary from region to region, from market to market as well as from sector to sector. In this situation, investors or portfolio managers are willing to diversify their portfolios in the most effective way in order to protect their portfolios against negative impacts of the spillover.

Volatility represents the risk affecting the decision-making processes of investors in financial markets. Therefore, taking into account the volatility spillover is very important for investors to forecast the returns of financial assets, especially in decision-making processes. In order to make effective investment decisions in volatile markets, the volatility of these markets should be forecasted.

Equity indices are a general indicator of the stock market and they provide information about market performance as they are based on prices. At the same time, these indexes allow for comparative performance measurements between industries and sectors, as they are continuous. With these indices, investors determine the sector in which they will invest or end their investment. Any crises in the sector both can cause increased volatility in index and can cause volatility spillover to other indices (Elmas, 2013).

Among sectors, financial sector is the sector in which all institutions play a role in order to finance economic activities in an economy. Banking system, credit cooperatives, capital market, collective savings organizations, social security system, insurance companies, unorganized credit market are the basic institutions that constitute the financial sector. There are ninety-three companies in BIST Financial sector index of Borsa Istanbul. On the other side, the service sector is gaining increasing importance in the development process of the economy. Today, the service sector constitutes the most important part of national income and employment, and this sector also constitutes the large and growing part of the costs of international trade and traditional manufacturing industry in the industrial societies. The service sector also includes a broad concept that covers a wide range of business lines. There are sixty-one companies in BIST Services sector index of Borsa Istanbul.

High fluctuations in the stock market lead to risk-averse investors to be more careful when making a portfolio and to create a portfolio from different indices. For this reason, investors and portfolio managers take into account the volatility and the interaction between sector indexes in the portfolio creation process. That's why, this research aims to investigate volatility spillover between BIST Financial and BIST Services sector indexes of Borsa Istanbul. For this, Dynamic Conditional Correlation (DCC-GARCH) model, which is a Multivariate GARCH model was used. After that, the causal relation between these indexes and the direction of the causality were determined by using Granger causality and Hong's causality in variance tests. Daily close prices of financial and services sector indexes in Borsa Istanbul were used, which span from January 4, 2010 to July 24, 2018.

There are a lot of studies that examine the volatility spillover of different markets over time (Kim et al., 2006; Goeij and Marquering, 2009; Malik and Ewing, 2009; Narayan and Narayan 2010; Arouri et al. 2013; Haesen et al. 2017) using a multivariate GARCH model. On the other side, there are some studies that analyze volatility spillover across sector indices. Hassan and Malik (2007) examined volatility transmission across the U.S. sector indices. They emphasized that there was volatility transmission among the U.S. sectors. Kouki et al. (2011) examined volatility spillover five sector indices and between oil and these sectors in developed markets. They concluded cross border relationship and integration of some sectors through the volatility. Tokat (2010) investigated four sector indexes in Turkey by using a trivariate GARCH model. His results indicated volatility spillovers between industrial and financial; and between services and technology sectors.

In other respects, some studies deal with the relationship between oil and sector indices (Arouri et al., 2011; Malik and Ewing, 2009; Çağlı et al., 2014). Among these studies, Malik and Ewing (2009) observed the evidence of crucial volatility transmission and shocks between oil prices and the various U.S. sector indexes. Similarly, Arouri et al. (2011) determined the volatility spillover was significant between oil prices and sector stock returns. They concluded that the direction of the volatility was from oil to sector stock markets. While a uni-directional relationship from oil to the European stock market existed, there was a bi-directional relationship between the oil and the U.S. stock market. Çağlı et al. (2014) researched the effect of oil on sub-sector indices of Turkey. They concluded that oil prices affected sub-sector indices.

This study is structured as follows. Section two gives methodology. Section three introduces data and descriptive statistics. Section four makes empirical findings. Lastly, section five presents conclusion.

## 1. Methodology

In this section multivariate GARCH model and causality analysis tests such as Granger Causality test and Hong's Causality test were briefly explained.

### 1.1. DCC-GARCH Model

DCC-GARCH model was introduced by Engle (2002), focusing on a dynamic matrix process. DCC-GARCH method, which depends on the correlation dynamics of the variables, is a general condition of the CCC-GARCH model. DCC-GARCH models can be applied for multivariate and high dimensional data sets. It provides necessary information to estimate more extensive conditional covariance matrices. The model is provided from below mentioned specification:

$$H_t = D_t P_t D_t \quad (1)$$

$$Dt = diag(h_{1t}^{\frac{1}{2}}, \dots, h_{Nt}^{\frac{1}{2}}) \quad (2)$$

$$Q_t = (1-\alpha-\beta)M + \alpha\epsilon_{t-1}\epsilon'_{t-1} + \beta Q_{t-1} \quad (3)$$

$Pt$ presents a time-varying correlation matrix, M gives unconditional correlation matrix of standardized residuals $\epsilon_t$. $\alpha$ shows positive whereas $\beta$ shows non-negative scalar parameter in the condition of $a+\beta<1$.

**1.2. Causality Analyses**

In this study, Granger causality test and Hong's causality test were used. Granger causality test was introduced in 1969 to determine the availability and direction of the causality. The model is as follows:

$$X(t) = \sum_{j=1}^{m} A_{11,j} X(t-j) + \sum_{j=1}^{m} A_{12,j} Y(t-j) + E_1(t) \quad (4)$$

$$(t) = \sum_{j=1}^{m} A_{21,j} X(t-j) + \sum_{j=1}^{m} A_{22,j} Y(t-j) + E_2(t) \quad (5)$$

where X and Y are the two variables of the model, A presents the coefficients of the model, m is the lagged observations with maximum number, $E_1$ and $E_2$ are the residuals for the series.

As for Hong's causality test, it focuses on the estimation of univariate GARCH model of the variables, whereas Granger causality test, which is a classical method, is based on the changes in the mean of two variables. Hong's causality test has also a powerful fit. It was proposed by Hong (2001). The formulation of Hong's causality test is as follows:

$$Q_1 = \frac{T\sum_{j=1}^{T-1} k^2(\frac{j}{M})\, \hat{p}^2_{\xi_u \xi_v}(j) - C_{IT}(k)}{\sqrt{2} D_{IT}(k)} \quad (6)$$

k $\frac{j}{M}$ gives a weight function and M is a positive integer.

$$C_{IT}(k) = \mathrm{T}\sum_{j=1}^{T-1} k^2(\frac{1-j}{T})\left(\frac{j}{M}\right) \quad (7)$$

$$D_{IT}(k) = \mathrm{T}\sum_{j=1}^{T-1} k^4(\frac{1-j}{T})\{1-(j+1)/T\}\left(\frac{j}{M}\right) \quad (8)$$

$C_{IT}(k)$ and $D_{IT}(k)$ presents mean and variance of the model. There are some steps before starting Hong's Causality test. The first step is to determine standardized residuals which derive from GARCH model for two sector indexes series. Secondly, cross-correlation coefficients for paired series are used. After M which is an integer is specified, the test statistic $Q_1$ is computed. The null hypothesis is rejected if the critical value is smaller than test statistic $Q_1$. After all, Hong's Causality test is analyzed to determine the causal relationship between financial and services series in this research.

## 2. Data and Descriptive Statistics

Daily close prices of two sector indexes namely BIST Financial and BIST Services in Borsa Istanbul were used. The data spans from January 4, 2010 to July 24, 2018 with 2146 observations. The data obtained from Global Financial Data Database. E-Views, Ox Metrics, and R package programs were used.

Figure 1 shows the changes of the financial and services sector indexes between the years 2010-2018. It was observed an increase in the year of 2013 and between the half of 2016 and 2018 for financial sector index. As for service sector index, the prices showed a tendency to rise in time, and it hit peak in half of 2017.

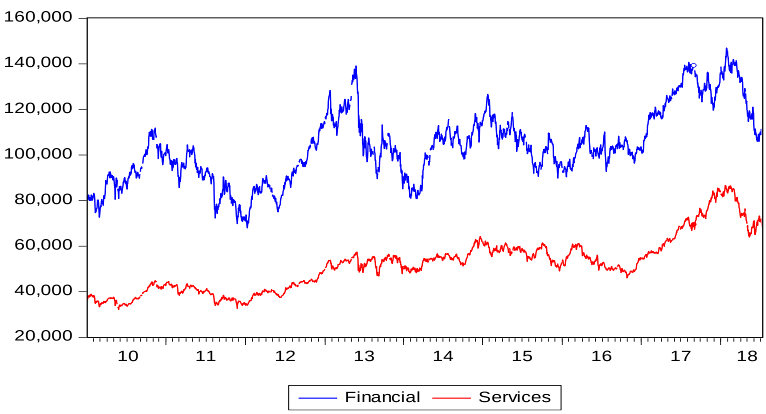


Figure 1: Time Variations of Financial and Services Sector Indexes (2010-2018)

The common log transformation on two daily sector indexes was used to determine the daily log returns of these indexes. The formula is as follows:

$$X_{it} = \log(P_{it}) - \log(P_{it-1}) \qquad (9)$$

where, $X_{it}$ represents the log return series for each individual sector indices.

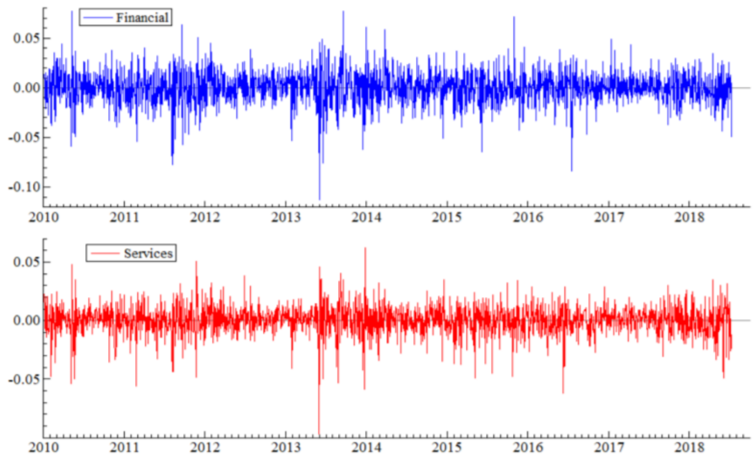


Figure 2: Rate of Returns of Financial and Services Sector Indexes (2010-2018)

Figure 2 demonstrates rate of returns of financial and services sector indexes. According to Figure 2, there were volatility clustering in both financial and services returns around the years of 2013 - 2014.

Table 1: Descriptive Statistics of Sector Returns

| | Financial | Services |
|---|---|---|
| Mean | 0.000129 | 0.000287 |
| Median | 0.000381 | 0.000903 |
| Maximum | 0.077151 | 0.062034 |
| Minimum | -0.112947 | -0.096993 |
| Std. Dev. | 0.016576 | 0.012426 |
| Skewness | -0.347529 | -0.665142 |
| Kurtosis | 5.715316 | 7.159194 |

| | | |
|---|---|---|
| Jarque-Bera | 702.4614*** | 1705.046*** |
| Probability | 0.000000 | 0.000000 |
| Sum | 0.277808 | 0.615426 |
| Sum Sq. Dev. | 0.589379 | 0.331177 |
| Observations | 2146 | 2146 |

*** denotes the significance level at 1%.

Table 1 provides descriptive statistics of returns of sector returns between 2010 and 2018.The average returns of two sectors were positive value. Both financial and services sector returns were negatively skewed. All series provided excess kurtosis. According to Jarque-Bera test, sector indexes rejected null hypothesis of normality with the significance level of 1%.

Table 2: Empirical Statistics of the Unit Root Tests of Sector Indexes

| | Financial | Services |
|---|---|---|
| ADF | -48.04039*** | -46.35416*** |
| PP | -48.08217*** | -46.35446*** |

Source: ADF for Dickey and Fuller (1979), PP for Phillips and Perron (1988)

*** denotes the significance level at 1%.

Table 4 demonstrates empirical statistics of the unit root tests of financial and services sector indexes. All indices were stationary in accordance with the unit root tests.

## 3. Empirical Findings

Constant conditional correlation (CCC) model was first estimated for financial and services sector returns. The null of constant correlations was rejected in accordance with the LM test of Tse (2000). Due to inappropriate CCC model for the series, DCC model was estimated for the volatility spillover between two series.

### 3.1. DCC-GARCH Model

This model of Engle (2002) was used for volatility spillover between financial and services sector returns. Firstly, we applied DCC-GARCH (1, 1) model to analyze the volatility spillover between financial and services sector returns. Table 3 depicts the empirical findings of DCC-GARCH (1, 1) model. Panel A shows findings from mean estimates, Panel B illustrates the results from conditional variance estimates, Panel C and D give Ljung-Box Q-Statistics tests results. According to findings of DCC-GARCH model in Panel B, there was a volatility spillover between financial and services sector returns at significance level of 1%. Besides, one squared past shocks affected current conditional volatility of these sector returns at 1% significance level. Also, the volatility was quite persistent at 1% significance level. The Ljung-Box Q-statistics in Panel C and D provide that both of the series are adequately estimated by the result of using minimum number of lags in mean estimates (Jones and Olson, 2013: 4).

Table 3: DCC-GARCH Model for Financial and Services Sector Returns

| Panel A: Mean Estimates | | | |
|---|---|---|---|
| | Estimate | t value | Pr(>\|t\|) |
| Financial.mu | 0.000623 | 2.2353 | 0.025398 |
| Financial.omega | 0.000014 | 16.3382 | 0.0000 |
| Financial.alpha1 | 0.079175 | 17.9606 | 0.0000 |
| Financial.beta1 | 0.875613 | 127.9026 | 0.0000 |
| Services.mu | 0.000860 | 4.1967 | 0.000027 |
| Services.omega | 0.000018 | 4.0837 | 0.000044 |
| Services.alpha1 | 0.174494 | 4.6615 | 0.0000 |
| Services.beta1 | 0.718652 | 14.3933 | 0.000003 |
| Panel B: Conditional Variance Estimates | | | |
| | Estimate | t value | Pr(>\|t\|) |
| $\gamma$ 1 | 0.705312 | 6.045 | 0.0000 |
| $\alpha$ 1 | 0.029639 | 7.9402 | 0.0000 |
| $\beta$ 1 | 0.969380 | 240.2961 | 0.0000 |

| Panel C: Ljung-Box Q-Statistics (significance level in []) | | |
|---|---|---|
| Standardized Residuals (Lags) | Financial | Services |
| Q( 5) | 1.95773 [0.8549626] | 0.461266 [0.9934730] |
| Q( 10) | 10.3777 [0.4080058] | 3.39715 [0.9704757] |
| Q( 20) | 21.6487 [0.3598724] | 14.3306 [0.8133478] |
| Q( 50) | 47.9991 [0.5540389] | 35.9836 [0.9320090] |
| Panel D: Ljung-Box Q-Statistics (significance level in []) | | |
| Squared Standardized Residuals (Lags) | Financial | Services |
| Q( 5) | 4.46157 [0.485041] | 9.54025 [0.0893609] |
| Q( 10) | 7.94269 [0.634435] | 13.6073 [0.1916694] |
| Q( 20) | 18.8911 [0.528915] | 22.2209 [0.3286462] |
| Q( 50) | 42.9939 [0.748175] | 49.9577 [0.4750801] |

Figure 3 and 4 display 20-day rolling correlations and co-variance between financial and services sectors.

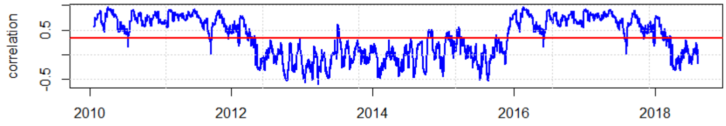


Figure 3: 20-day Rolling Correlations between Financial and Services Sectors

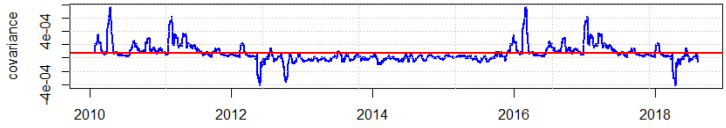


Figure 4: 20-day Rolling Covariance between Financial and Services Sectors

### 3.2. Causality Analyses

Table 3 depicts Granger causality test result, while Table 4 illustrates Hong's causality test result for financial and services sector.

Table 4: Granger Causality Test Result for Financial and Services Sector

| **Financial →Services** | | **Services → Financial** | |
|---|---|---|---|
| **F-Statistic** | **p-value** | **F-Statistic** | **p-value** |
| 6.64280 | 0.0013 | 29.8084 | 0.0000 |

According to Table 4 and 5, there was a bidirectional volatility spillover between financial and services sectors in accordance with the results of Granger causality and Hong's causality tests.

Table 5: Hong's Causality Test Result for Financial and Services Sector

| | **Financial →Services** | | **Services → Financial** | |
|---|---|---|---|---|
| **M** | **Q** | **p-value** | **Q** | **p-value** |
| 1 | -0.552 | 0.710 | 31.087 | 0.000 |
| 2 | 1.299 | 0.097 | 30.340 | 0.000 |
| 3 | 2.505 | 0.006 | 29.140 | 0.000 |
| 4 | 3.026 | 0.001 | 28.099 | 0.000 |
| 5 | 3.223 | 0.001 | 27.091 | 0.000 |

M and Q denote a positive integer and test statistics, respectively.

## Conclusion

This study investigated volatility spillover between BIST Financial and BIST Services sector indexes in Borsa Istanbul covering daily close prices of indexes between January 4, 2010 and July 24, 2018. According to findings of the DCC-GARCH model, the sign of the relationship was positive indicating that the increases in financial sector affected services sector positively. Besides, there was volatility spillover between financial and services sector returns. As for causality analyses' findings, there was a causal relation between the two sector indexes and both Granger Causality and Hong's Causality in variance tests indicated bi-directional causal relation between financial and services sector indexes. Furthermore, financial and services indexes are integrated with each other. Because of that, investing in financial sector index might not provide a diversification benefit for the investors holding services sector index in the same portfolios.

The findings are also important for market participants and investors when it comes to making properly asset allocation and optimal portfolio management.

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