UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

MASTER DEGREE PROJECT IN FINANCE

Does real estate deliver diversification when needed the most?

- A dynamic conditional correlation study of REITs in a mixed-asset portfolio

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Abstract

Real estate has traditionally been favored in a mixed-asset portfolio due to its risk-return characteristics and diversification benefits. The recent global financial crisis challenged this perception of advantages attributed to real estate. This thesis aims to examine the relationship between REIT returns and the returns of equity, fixed income, money market and commodities on the US market by examining the dynamic conditional correlations employing the DCC-GARCH(1,1) model. If the relationship strengthens in a downturn market, a portfolio might lose some of its level of diversification when it is needed the most. The findings presented in this thesis suggest that the conditional correlation between REIT and that of equity, fixed income, money market and commodities is time-varying and increases during bear markets. The empirical study led to three primary findings. Firstly, REIT and equity exhibit a moderate to strong positive relationship throughout the sample period. Secondly, despite a somewhat blurry relationship the commodity index seems to behave and react differently to REIT and thus provide potential benefits of diversification. Thirdly, REIT's relationship with fixed income as well as money market provide diversification opportunities. The results of this thesis suggest that investors heavy in the commodity and money market should find allocation towards REIT of particular interest in terms of seeking portfolio diversification.

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1. Introduction

The perfectly optimized portfolio will always possess an immense value, estimating risk and return respectively and balancing these to achieve the optimal composition. Extensive research has been carried out throughout history with Markowitz (1952) as the founding father. Mixed asset class investments increase the diversification of an overall portfolio by distributing investments throughout several classes and utilizing their different correlations.

The standard case made for real estate's role in a mixed-asset portfolio is the favorable risk-return characteristics of direct real estate holdings and the low correlations with other financial asset classes, which bring diversification benefits to a portfolio (Seiler, Webb & Myer, 1999; Feldman, 2003; Hoesli, Lekander & Witkiewicz, 2004; Clayton, 2007; MacKinnon & Al Zaman, 2009). However, it also possesses disadvantages such as low liquidity, information asymmetry and high transaction costs (Georgiev, Gupta & Kunkel, 2003; Worzala & Sirmans, 2003; Knight, Lizieri & Satchell, 2005). Due to these disadvantages, many investors look to REITs as a possible substitute in their mixed-asset portfolio. A REIT, or Real Estate Investment Trust, is a corporation employing pooled capital of many investors to purchase and manage income-producing real estate (Equity REITs) or mortgage loans (Mortgage REITs). According to the National Association of Real Estate Investment Trusts (2017a), to qualify as a REIT a corporation must:

- Invest a minimum of 75 percent of its total assets in real estate.
- Collect a minimum of 75 percent of its gross income from rents of real estate, interest on mortgages financing real estate or from sales of real estate.
- Pay a minimum of 90 percent of its taxable income in shareholder dividends per annum.
- Be an entity that is taxable as a corporation.
- Be managed by a board of directors or trustees.
- Have a minimum of 100 shareholders.
- Have a maximum of 50 percent of its shares held by five or fewer individuals.

REITs are mostly traded on major stock exchanges, but public non-listed and private REITs also exist. They are modeled after mutual funds and the two main types of REITs are Equity REITs and Mortgage REITs. Equity REITs generate income through the collection of rent on and sales of the properties they own. Mortgage REITs invest in mortgages or mortgage securities adhering to commercial and residential properties. REITs typically pay out all of

their taxable income as dividends to shareholders, who pay the income taxes on those dividends.

REITs are said to offer several benefits over direct real estate holding:

- Higher liquidity.
- Granted special tax considerations.
- Allow anyone to invest in portfolios of large-scale properties the same way they invest in other industries through the purchase of stock.
- Shareholders earn a share of the regular income stream produced through real estate investment, without having to buy or finance property.

There has been great discussion whether REITs should be seen more like real estate or more like common stocks (Giliberto, 1990; Myer & Webb, 1993; Clayton & MacKinnon, 2003; Hoesli & Oikarinen, 2012). For listed property returns, there is some evidence that correlation with other asset classes increases when those classes are performing poorly, decreasing the benefits of diversification (Lizieri & Ward, 2001). If the benefits of diversification offered by REITs do not hold in bear markets then the gains from including real estate in a mixed-asset portfolio using this proxy may be overstated.

1.1. Research question

This thesis aims to examine the relationship between REIT returns and the returns of equity, fixed income, money market and commodities, hereafter called non-REITs, on the United States market by examining conditional correlations. If the relationship strengthens in a downturn market a portfolio might lose some if its level of diversification when it is needed the most. The main research question can be stated as: Do REITs have a role in risk management in the mixed-asset portfolio during bear markets?

1.2. Hypotheses

The hypotheses tested follow from the main research question:

Hypothesis 1: The correlation between the returns of REITs and non-REITs is not time-varying.

Hypothesis 2: The correlation between the returns of REITs and non-REITs does not increase during bear markets.

1.3. Limitations

At the time of this publication, REITs have yet to be introduced on the Swedish market. The study is limited to the United States, which makes up the majority of the world REIT market and is regarded as the most mature (EY, 2016).

2. Literature review

2.1. The relationship between listed and direct real estate

2.1.1. Short-term relationship

Studies focusing on the short-term relationship have found that the risk-return characteristics of REITs are more similar to those of stocks than those of direct real estate. REIT returns appear to behave more like the returns of common stocks and closed-end funds, than the returns of direct real estate (Myer & Webb, 1993). The REIT returns exhibits high correlations with the general stock markets (Westerheide, 2006), especially with those of small cap stocks (Liu & Mei, 1992) and less correlation with the underlying appraisal measured real estate market (Lee, Lizieri, & Ward, 2000).

However, Clayton and MacKinnon (2003) find that REITs were driven largely by large cap stocks during the 1970s and 1980s and then became more strongly related to both small cap stock and real estate-related factors in the 1990s. Their overall results are that the returns of securitized real estate gradually began to reflect the nature of the underlying unsecuritized assets over the 1993-1998 growth period.

2.1.2. Long-term relationship

When extending the horizon and observing the long-term relationship there has been found that there exists a stronger linkage between listed real estate and the direct real estate market than with the stock market. Giliberto (1990) shows that residuals from regressions of both listed real estate and direct real estate market series on financial asset returns are significantly correlated. This supports the notion that there is a common factor that drives listed and unlisted real estate, but not other financial assets. Oikarinen, Hoesli and Serrano (2011) results show evidence of a tight long-term relationship between securitized and direct real estate returns, which confirms the results of Pagliari, Scherer and Monopoli (2005).

While many studies have been performed with the United States (US) as a research base due to the large amount of available data and long time series, studies on the European market have shown similar evidence of a long-term relationship. Wang (2001) reports a cointegrating relation between the listed real estate and the direct market indices in the United Kingdom (UK) and the results suggest that the direct market prices adjust to the listed real estate returns; this result is confirmed by Oikarinen et al (2011) and Boudry, Coulson, Kallberg and Liu (2012) using US data. A larger study by Yunus, Hansz and Kennedy (2012) present

similar evidence of the existence of a long-term relationship and also reveals that the listed real estate returns leads, but is not led by the direct market.

In their study, Hoesli and Oikarinen (2012) conclude that listed real estate exhibit a much closer relationship with the direct market than with the general stock market and due to this should be a relatively good substitute in a long-horizon investment portfolio.

2.1.3. Relationship since 1990s

Over time, results have shown that listed real estate gradually begins to reflect the nature of the underlying real estate assets and that the relationship has become stronger since the 1990s (Clayton & Mackinnon, 2003; Lee & Chiang, 2010; Oikarinen et al, 2011). In 1971, the total market capitalization of Equity REITs was less than $1 billion but it has experienced tremendous growth during the last three decades and reached $960 billion in 2016 according to NAREIT (2017b). The growth has been particularly strong since the introduction of the Revenue Reconciliation Act of 1993, which made large-scale investments in REITs more desirable to institutional investors. These developments have led to a substantial body of studies devoted to investigating the impact of this structural change on the behavior of REITs. Ziering, Winograd and McIntosh (1997) and Graff and Young (1997) ask if REITs have become more like common stocks or real estate but provide contradicting evidence.

After these two early studies, others have investigated the impact on the short-term behavior of REITs. Chan, Leung and Wang (2005) and Lee and Lee (2003) find that REITs have become more like common stocks, while Clayton and MacKinnon (2003) and Lee, Lee and Chiang (2008) results show that REIT prices have a closer relationship to the direct market. Glascock, Lu and So (2000) find that REIT prices are not cointegrated with common stocks pre the early 1990s but that cointegration is found post, prompting the authors to argue that REITs behave more like stocks post the structural change.

2.2. REITs in a mixed-asset portfolio

The inclusion of an asset in a portfolio can affect its risk and return properties by decreasing risk while yielding the same return or by increasing return while maintaining the previous risk level. Kuhle (1987) was among the first to study the impact of REITs in mixed-asset portfolios and in accordance with other early researchers he found no significant impact in performance of including REITs in a portfolio consisting of common stocks. This contrasts the later results of Mueller, Pauley and Morrill (1994) and Lee and Stevenson (2005) who found significant evidence of both risk reducing and return enhancing qualities of adding

REITs to a mixed-asset portfolio. When investigating the European real estate securities, Bond and Glascock (2006) find evidence of listed real estate having higher positive correlation to the bond market than to the stock market, which would imply that listed real estate has the quality of providing good growth opportunities to a portfolio while simultaneously lowering its risk level.

Lee and Stevenson (2005) study REITs in terms of investment horizons and find that the asset provided diversification benefits over both short and long term holding periods. They also find that efficient portfolios have a considerable allocation to REITs and the optimal weight of this asset class increase with the length of the horizon. This result complements the previously reviewed literature of listed and direct markets, where the relationship between these markets becomes closer over longer horizons.

In the past, REITs have behaved as a defensive investment with low beta and counter-cyclical characteristics. This is suggested in the study by Bond and Glascock (2006), which shows real estate securities trailing the stock market during the 1990s equity boom market and outperforming the stock market following the dot-com collapse. The trend of REITs being able to diversify risk during turbulent market conditions is supported by Lee and Lee (2003). Additionally, Simon and Wing (2009) find that in the US market REITs provided better protection against severe downturns of the stock market than holding investments in foreign stock markets.

2.3. Time-varying properties in REITs

REITs variance and covariance with other financial assets seem to exhibit time-varying characteristics based on the following studies which suggests that the optimal allocation depends on the market condition. Chandrashekaran's (1999) main findings are that the REIT index variance and covariance with other financial asset classes increased after a downturn in the REIT index and decreased after an upturn in the index. Liang and McIntosh (1998) find time-varying characteristics between REITs, bonds and stocks over the study period.

Further studies find that REITs lose some of its diversification benefits in downturn markets. Goldstein and Nelling (1999) find that the return on REITs exhibit different properties in upturn and downturn markets and that both Mortgage and Equity REITs are to a higher degree correlated with common stocks in downturn markets than in upturn. Knight et al (2005) results show similar evidence with strong tail dependence, particularly in the negative tail. Chong, Miffre and Stevenson (2009) findings show that the correlation between real estate

and equity markets rose especially in periods of above average volatility, reducing real estate's diversification benefits relative to equities. Niskanen and Falkenbach (2010) find that the diversification benefits for equities with REITs decreased with increasing volatility and Hoesli and Reka (2015) identify contagion effects between REIT and equity markets in times of panic. Lizieri (2013) develops this further in his study and finds periods where the equity market and real estate are less correlated and periods when it appears to have stronger influence on real estate. Lizieri's sample period ranges from 1990 to 2011, which includes both the dotcom crash and the financial crisis and he finds an increase in correlation between the equity market and real estate, which seems to be associated with downturn markets. The results would imply that real estate's diversification benefits are eroded when they are needed the most.

The reviewed literature reveal that listed real estate returns are similar to those of the direct market over the long term. For a long-term investor this is of importance since it makes the investor indifferent between the public and private market as a choice for investment in a portfolio with a perpetual horizon. The risk reducing and return enhancing properties of adding real estate to a mixed-asset portfolio are well established. However, more recent studies find evidence that correlation between real estate returns and other financial asset classes increases more than previously expected during severe market declines, decreasing the benefits of diversification. Therefore, it is of importance to investigate the dynamic behavior and benefits of the conditional correlation between REITs and other financial asset classes in order to assist an investor to make an optimal allocation decision.

3. Theory review

In modern portfolio theory investors estimate the correlation coefficient between the returns of financial assets. Based on this value, investors make allocations towards assets less likely to simultaneously lose value and thus optimizing expected return against a certain level of risk (Markowitz, 1959). For the empirical study of this thesis, the strength of correlation is categorized according to Table 1 in order to analyze the benefits of diversification.

Table 1: Explanatory description of correlations (Begiazi, Asteriou & Pilbeam, 2016)

Size of correlation	Strength of correlation
0.0-0.2	Very weak
0.2-0.4	Weak
0.4-0.7	Moderate
0.7-0.9	Strong
1.0	Perfect

In previous literature, both unconditional and conditional correlations have been employed to measure the correlation between financial time series. Unconditional correlations are commonly calculated by the Pearson correlation formula, which originates from descriptive statistics. The formula is defined as two variables' covariance divided by the product of their standard deviations. It is estimated through either a full sample calculation or a rolling window procedure. Conditional correlations are based on econometric models, which use the residuals from estimations on the Generalized Auto Regressive Conditional Heteroskedasticity (GARCH) volatilities to estimate the correlation.

The original Auto Regressive Conditional Heteroskedasticity (ARCH) model was proposed by Engle (1982) who later won the Nobel Prize for his work. It was later extended to the GARCH model by Bollerslev (1986). The main advantage of the GARCH specification is that it allows capturing of the variation in return volatility with considerably fewer parameters than the pure ARCH model. The most common specification is the GARCH(1,1) model, which with the returns r_t is given by:

$$r_t = u_{i,t} + \sqrt{h_{i,t}}\varepsilon_{i,t}, \quad u_t \sim N(0, h_{i,t})$$

$$h_{i,t} = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{i,t-1}$$

In the formulas above $h_{i,t}$ is a matrix of conditional variances, $u_{i,t}$ is the conditional mean of $r_{i,t}$, $\sqrt{h_{i,t}}$ is the matrix of conditional standard deviations and the parameters α_i and β_i

provide information on the dynamics of the volatility time series. GARCH models are estimated with maximum likelihood imposing non-negativity constraints on the parameters.

A further development of the GARCH model is the Dynamic Conditional Correlation (DCC) model, which is able to capture the empirically dynamic contemporaneous correlations of asset returns. The DCC model was introduced by Engle (2002) and is a generalization of Bollerslev's (1990) Constant Conditional Correlation (CCC) model and builds on the GARCH model. The difference between the two conditional correlation models lays in whether the conditional correlation matrix, R, is time-variant or not.

As an econometric tool, the DCC model is mainly used to estimate the correlation between pairs of time series. There are some advantageous features of the DCC model making it prominent in financial research. Engle himself expresses the model's features as having the flexibility of univariate GARCH but not the complexity of multivariate GARCH. Additionally, the DCC model can discover changes in conditional correlations over time, making it possible to observe dynamic investor behavior in reaction to market events. The DCC also estimates correlation coefficients of the standardized residuals and thereby accounts for heteroskedasticity (Chiang, Jeon, & Li, 2007). The procedure of the model adjusts for volatility and thus removes bias from the time-varying correlation, and it does so continuously (Cho & Parhizgari, 2008). Because of its features the DCC-GARCH is a suitable model for exploring markets during bear market conditions (Boyer, Kumagi & Yuan, 2006; Chiang et al, 2007; Syllignakis & Kouretas 2011).

Additionally, the DCC-GARCH model is a widely acknowledged tool in published financial research to analyze dynamic conditional correlations of REITs and its diversification benefits (Chiang et al, 2007; Case, Yang & Yildirim, 2012; Liow, Zhou & Ye, 2015). Chong et al (2009) employ the DCC model on REIT, equity, bond and commodity returns with sample period 1990 to 2005. Case et al (2012) examines the dynamics in the correlation of returns with DCC between REITs and stocks, bond and treasury bills during sample period 1972 to 2008. Lizieri (2013) use a regime-based desmoothing technique to examine correlation structures around the financial crisis during the period 1990 to 2011, but conducts the study on private real estate in the UK. The contribution of this thesis will be in the form of a more recent sample period covering both the financial crisis and the European debt crisis and the following period. In accordance with previous studies the DCC-GARCH will be employed and the relationship between REIT, equity, bond, money market and commodity returns will be investigated during bear markets.

4. Methodology and data

4.1. Methodology

Two shortcomings of Pearson's unconditional correlations are that they do not take time variation and different regimes into account. Time-varying conditional coefficients should therefore be applied to produce more accurate variance predictions and to achieve a better grasp of the time-varying diversification properties of an asset. Such a model would ideally allow a set of return series, r_t, to have a time-varying conditional covariance matrix, H_t, given all available information I_{t-1}:

$$r_t | I_{t-1} \sim N(0, H_t)$$

4.1.1. Rolling window

One of the most common forms of unconditional correlations is rolling correlations based on simple moving averages over a fixed window. The rolling window approach analyses the time series with an assumption that the model uses constant parameters over the observation period. In this thesis, the sample variance of returns for a rolling window of data is estimated using a window size of the previous six months of data before time *t* and a step size of one trading day. The rolling window correlation coefficient is estimated by dividing the weighted covariance equally over the last 130 trading days by the square root of the product of two 130-day estimated variance. The rolling window procedure can be stated as:

$$\rho_{ij,t} = \frac{\sum_{s=t-n-1}^{t-1}(r_{i,s} - \mu_{i,t})(r_{j,s} - \mu_{j,t})}{\sqrt{\left[\sum_{s=t-n-1}^{t-1}(r_{i,s} - \mu_{i,t})^2\right]\left[\sum_{s=t-n-1}^{t-1}(r_{j,s} - \mu_{j,t})^2\right]}}$$

However, modeling correlations using a rolling window have some drawbacks. Primarily, the modeler has to subjectively specify the size of the fixed window *n*. A short window is exposed to the risk of one extreme event leading to massive biases, while a long window may fail to reflect recent market movements sufficiently due to observations being equally weighted.

4.1.2. Dynamic Conditional Correlation GARCH

To assess the empirically dynamic contemporaneous correlations between REIT and non-REIT returns, the DCC-GARCH(1,1) model is employed. The procedure involves estimating the GARCH(1,1) and DCC(1,1) models. The notations specify that the models merely contain one lag for the variance and the squared innovation respectively. The DCC-GARCH model

allows the conditional correlation matrix, R_t, to be time-variant and is specified by Engle (2002) as:

$$H_t = D_t R_t D_t, \quad \text{where} \quad D_t = diag\{\sqrt{h_{i,t}}\}$$

To obtain the model parameters in question, H_t is decomposed into D_t and R_t.

D_t is the (NxN) diagonal matrix of conditional standard deviations at time t. The D_t matrix can have the following form, where the conditional variances $h_{i,t}$ are obtained from a univariate GARCH(1,1) for each time series of returns:

$$D_t = \begin{bmatrix} \sqrt{h_{1,t}} & 0 & \cdots & 0 \\ 0 & \sqrt{h_{2,t}} & \cdots & \vdots \\ \vdots & \cdots & \ddots & 0 \\ 0 & \cdots & 0 & \sqrt{h_{n,t}} \end{bmatrix}, \quad \text{where } h_{i,t} = \omega_i + \sum_{q=1}^{Q_i} \alpha_{iq} \alpha_{i,t-q}^2 + \sum_{p=1}^{P_i} \beta_{ip} h_{i,t-p}$$

The specification of the GARCH(1,1) with the returns r_t was presented in the theory review as:

$$r_t = u_{i,t} + \sqrt{h_{i,t}} \varepsilon_{i,t}, \quad u_t \sim N(0, h_{i,t})$$

$$h_{i,t} = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{i,t-1}$$

R_t is the (NxN) time-varying conditional correlation matrix of ρ at time t and has the following general formulation:

$$R_t = \begin{bmatrix} 1 & \rho_{12,t} & \rho_{13,t} & \cdots & \rho_{1n,t} \\ \rho_{21,t} & 1 & \rho_{23,t} & \cdots & \rho_{2n,t} \\ \rho_{31,t} & \rho_{32,t} & 1 & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \rho_{n-1,n,t} \\ \rho_{n1,t} & \rho_{n2,t} & \cdots & \rho_{n,n-1,t} & 1 \end{bmatrix}$$

In the DCC-GARH model the estimator matrix H_t must be positive definite. To satisfy this, the conditional correlation matrix R_t must be positive definite as well. Furthermore, R_t is estimated using time-varying standard errors $\varepsilon_{i,t}$ obtained from the previous step:

$$R_t = diag\{Q_t\}^{-1} Q_t diag\{Q_t\}^{-1}$$

$$Q_t = S(1 - \alpha - \beta) + \alpha(\varepsilon_{t-1} \varepsilon'_{t-1}) + \beta Q_{t-1}$$

$S = Cov[\varepsilon_t \varepsilon_t']$ is the unconditional covariance matrix of the standardized errors $\varepsilon_t = D_t^{-1} r_t$ and $diag\{Q_t\}$ is a matrix with squared elements of the matrix Q_t in its diagonal. The $diag\{Q_t\}$ matrix can be specified as follows:

$$diag\{Q_t\} = \begin{bmatrix} \sqrt{q_{11t}} & 0 & \cdots & 0 \\ 0 & \sqrt{q_{22t}} & \cdots & \vdots \\ \vdots & \cdots & \ddots & 0 \\ 0 & \cdots & 0 & \sqrt{q_{nnt}} \end{bmatrix}$$

For R_t to be positive definite, Q in turn has to be positive definite. Furthermore, conditions on the scales α and β are imposed to ensure that the matrix H_t is positive definite as well:

$$\alpha \geq 0, \beta \geq 0 \text{ and } \alpha + \beta < 1$$

After the standardized residuals have been obtained, estimating the correlation matrix needs to be solved. The log likelihood for this estimator can be expressed as:

$$L = -\frac{1}{2} \sum_{t=1}^{T} (n log(2\pi) + log|H_t| + r_t'H_t^{-1}r_t)$$

$$= -\frac{1}{2} \sum_{t=1}^{T} (n log(2\pi) + log|D_t R_t D_t| + r_t'D_t^{-1}R_t^{-1}D_t^{-1}r_t)$$

$$= -\frac{1}{2} \sum_{t=1}^{T} (n log(2\pi) + log|D_t| + log|R_t| + \varepsilon_t'R_t^{-1}\varepsilon)$$

$$= -\frac{1}{2} \sum_{t=1}^{T} (n log(2\pi) + log|D_t| + r_t'D_T^{-1}D_T^{-1}r_T - \varepsilon_t'\varepsilon_t + log|R_t| + \varepsilon_t'R_t^{-1}\varepsilon_t)$$

This above expression can be maximized over the parameters of the model. One of the objectives of this formulation is to allow the model to be estimated more easily even when the covariance matrix has large dimensions. The log likelihood function can be stated as the sum of a volatility term and a correlation term:

$$L(\theta, \emptyset) = L_{Vol}(\theta) + L_{Corr}(\theta, \emptyset)$$

$$L_t(\theta, \emptyset) = -\frac{1}{2} \sum_{t=1}^{T} (n log(2\pi) + log|D_t|^2 + r_t'D_t^{-2}r_t) + -\frac{1}{2} \sum_{t=1}^{T} (log|R_t| + \varepsilon_t'R_t^{-1}\varepsilon - \varepsilon_t'\varepsilon_t)$$

The volatility term of the likelihood function is the sum of individual GARCH likelihoods, which are jointly maximized by separately maximizing each term:

$$L_{Vol}(\theta) = -\frac{1}{2}\sum_{t=1}^{T}\sum_{i=1}^{n}\left(\log(2\pi) + \log(h_{i,t}) + \frac{r_{i,t}^2}{h_{i,t}}\right)$$

The second term of the likelihood function is used to estimate the correlation parameters. As the squared residuals are not dependent on these parameters, they will not enter the first order conditions and can be ignored.

The two-step approach to maximizing the likelihood is:

$$\hat{\theta} = \arg max\{L_{Vol}(\theta)\}$$

$$\max_{\emptyset}\{L_{Corr}(\hat{\theta}, \emptyset)\}$$

The first part corresponds to maximizing the volatility term θ over parameters in D_t. The second stage takes this value as given and maximizes the correlation coefficients in $\emptyset$ over parameters in R_t. Added together, the dynamic conditional correlations can be calculated from the dynamic conditional variances applying the formula:

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}q_{jj,t}}}$$

4.2. Dataset

The sample period ranges from 2003/01/01 to 2016/12/31. This period is characterized by both tranquility and volatility and will provide a good foundation to conduct this study. For the empirical analysis daily data is employed and the selection is based upon a diversified mixed-asset portfolio consisting of equities, bonds, money market, commodities and REITs. Based on this criterion one equity index is selected, the Standard and Poor's 500 composite index (S&P500). For bond returns, an index of returns on 10-year maturity US Government bonds (GB10Y) is selected. Money market will be represented by a 1-year treasury bill (TB1Y). For commodity returns, the Goldman Sachs Commodity Index (GSCI) will represent the commodity market. For listed real estate returns, the MSCI US REIT index (REIT) is selected which represents about 99% of the US real estate investment trusts (MSCI Inc, 2016). The indices were sourced from Bloomberg and converted into daily returns by calculating the difference in natural logarithms.

4.2.1. Return and price characteristics of indices

Figure 1-5 illustrates the price movement and the first difference of the logarithm of returns of the chosen indices over the full sample period. The purpose of including these depictions is to show how the assets behave over the selected time frame. All of the first difference series exhibits volatility clustering, which gives reason to further investigate the variances and thereby correlations.
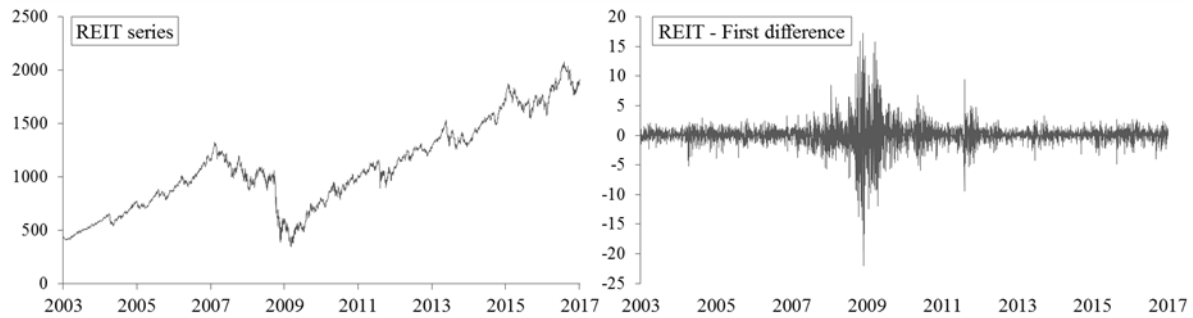

Figure 1: Price series and first difference of the logarithm return series of REIT, 2003/01/01-2016/12/31
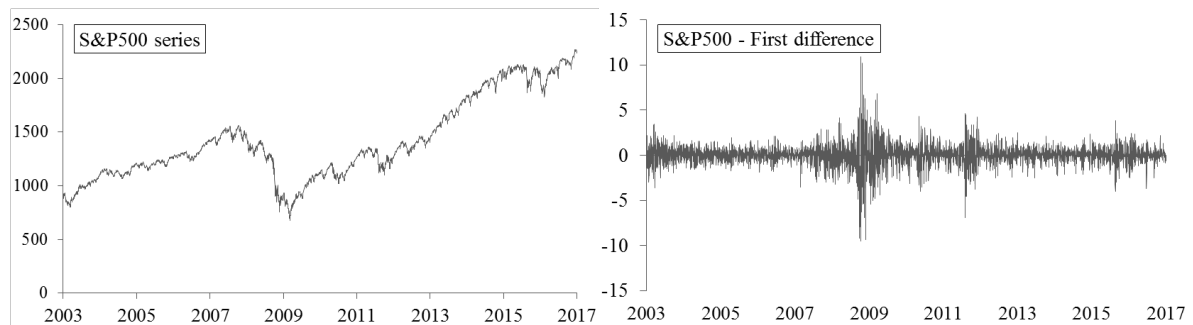

Figure 2: Price series and first difference of the logarithm return series of the S&P500, 2003/01/01-2016/12/31
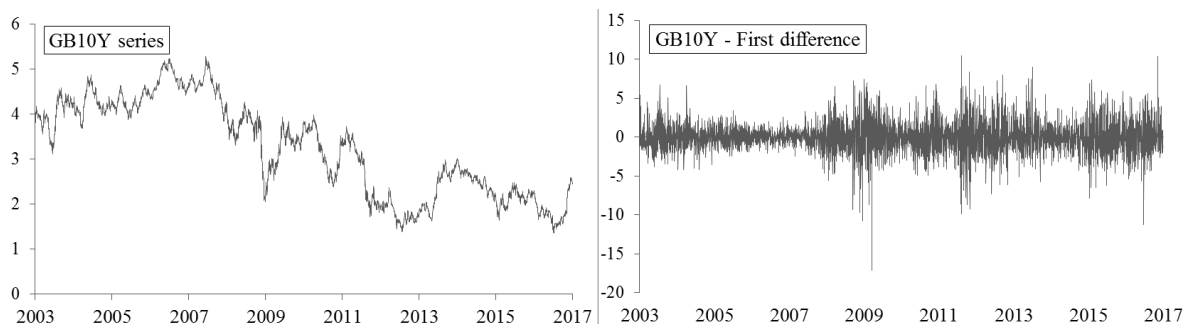

Figure 3: Index series and first difference of the logarithm return series of the GB10Y, 2003/01/01-2016/12/31
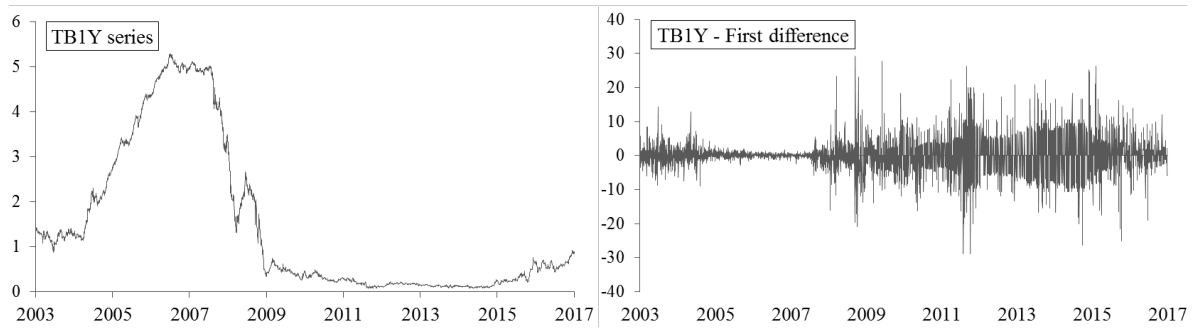
Figure 4: Index series and first difference of the logarithm return series of TB1Y, 2003/01/01 - 2016/12/31
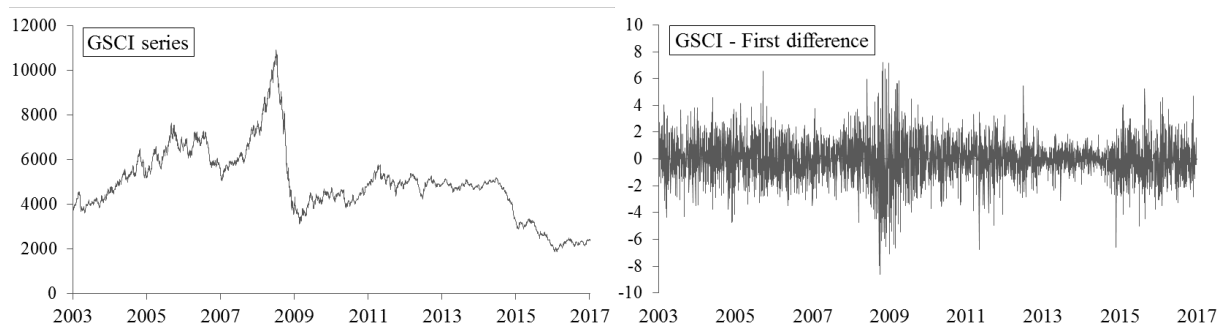
Figure 5: Price series and first difference of the logarithm return series of GSCI, 2003/01/01 - 2016/12/31

4.2.2. Data tests

The selected datasets were tested for stationarity using the Augmented Dickey Fuller test and for autocorrelation using autocorrelograms. Both of the conducted tests indicate stationary return series for all of the selected indices. [1]

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[1] See Appendix 1 for all ADF-tests and Appendix 2 for Autocorrelograms.

5. Empirical results and analysis

The obtained results are presented in the following ordering; firstly, the unconditional correlations from the rolling window method are presented. Secondly, the results from the dynamic conditional correlation GARCH model are presented.

5.1. Rolling window

In Figure 6, the unconditional correlations calculated from the rolling window procedure are presented.[2] The graphical representation depicts that the correlations exhibit time-variation. The correlation between REIT and S&P 500 is strong and increases during the bubble formation leading up to the financial crisis and then more rapidly increases during the financial crisis period, then decreases afterwards. The correlations between REIT and the 10-year government bond and REIT and the 1-year treasury bill exhibit volatility and are negative during the bubble formation. During the financial crisis the correlation increases and becomes positive but weak, then sharply declines during three occasions; the end of the financial crisis, the second half of 2011 and the end of 2013. The correlation between REIT and the GSCI commodity index show no relationship prior to the financial crisis, but exhibit a sharp decline to a moderate negative correlation in the crisis period. There seems to be a general trend of an increase in the unconditional correlation during turbulent markets for all indices correlation with REIT, although the relationship between REIT and the commodity index is more blurry. These findings will be further examined with the more complex DCC-GARCH(1,1) model.
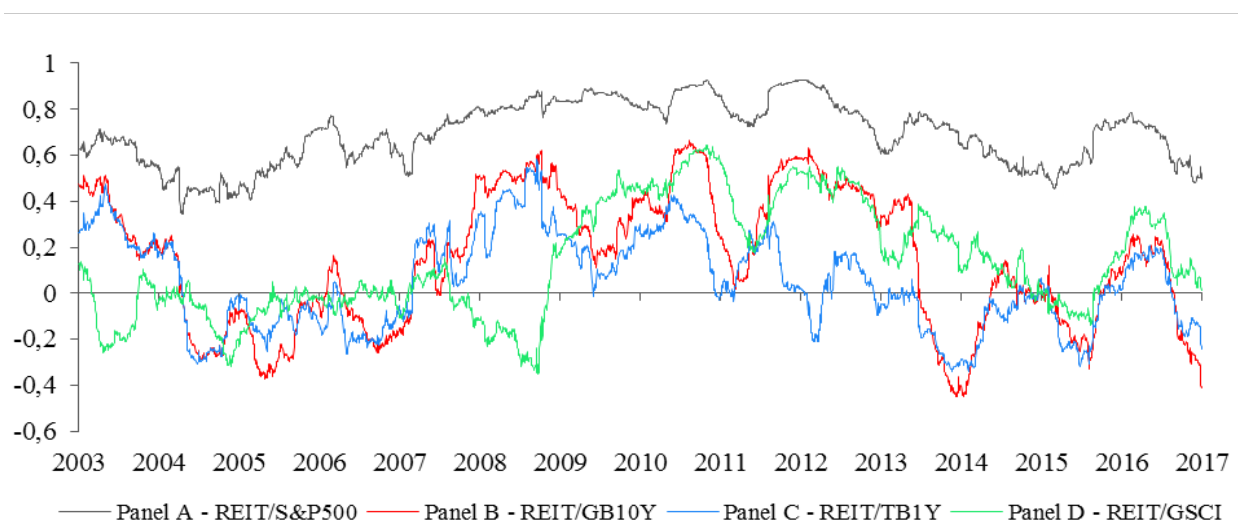

Figure 6: Correlations based on variances from a rolling window of 6 months, 2003/01/01 - 2016/12/31

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[2] For individually presented unconditional correlations see Appendix 3.

5.2. DCC-GARCH

The graphical representation of the correlations from the DCC-GARCH(1,1) in Figure 7 is similar to that of using the more simplistic rolling window procedure in Figure 6, which would indicate that the DCC-GARCH(1,1) is reasonably tuned and applied. However, the more complex DCC-GARCH(1,1) model has better predictive power since it is able to capture variances in a timelier manner and yield dynamic contemporaneous correlations.
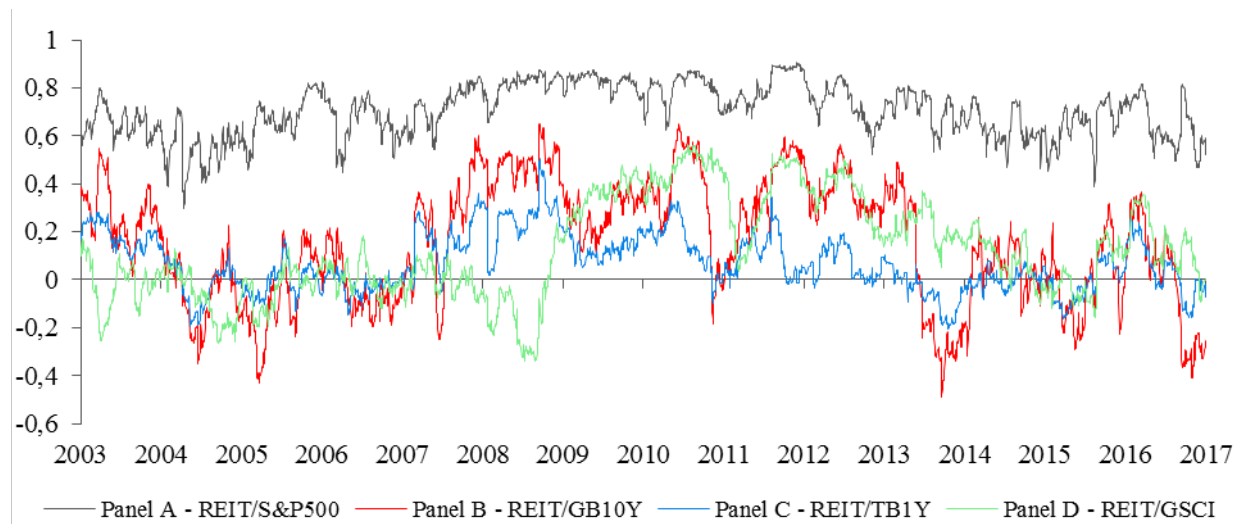
Figure 7: Dynamic conditional correlations based on the DCC-GARCH(1,1) model, 2003/01/01-2016/12/31

Figure 7 presents the graphical representation of the pairwise dynamic conditional correlation estimates obtained from the DCC-GARCH(1,1) procedure and in Panels A-D of Figure 8 these estimates are presented individually. The dynamic conditional correlations in Figure 8 exhibit three primary characteristics. Firstly, REIT and S&P 500 exhibit a moderate to strong positive relationship throughout the sample. Secondly, the GSCI commodity index seems to behave and react differently to REIT and thus provide potential diversification benefits. Thirdly, both fixed income and money market provide diversification opportunities due to their weak correlation. The overall findings suggest that the correlation between REIT and non-REITs increase during bear markets.[3]

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[3] The market events referred to in section 5.2 are summarized in Appendix 4.
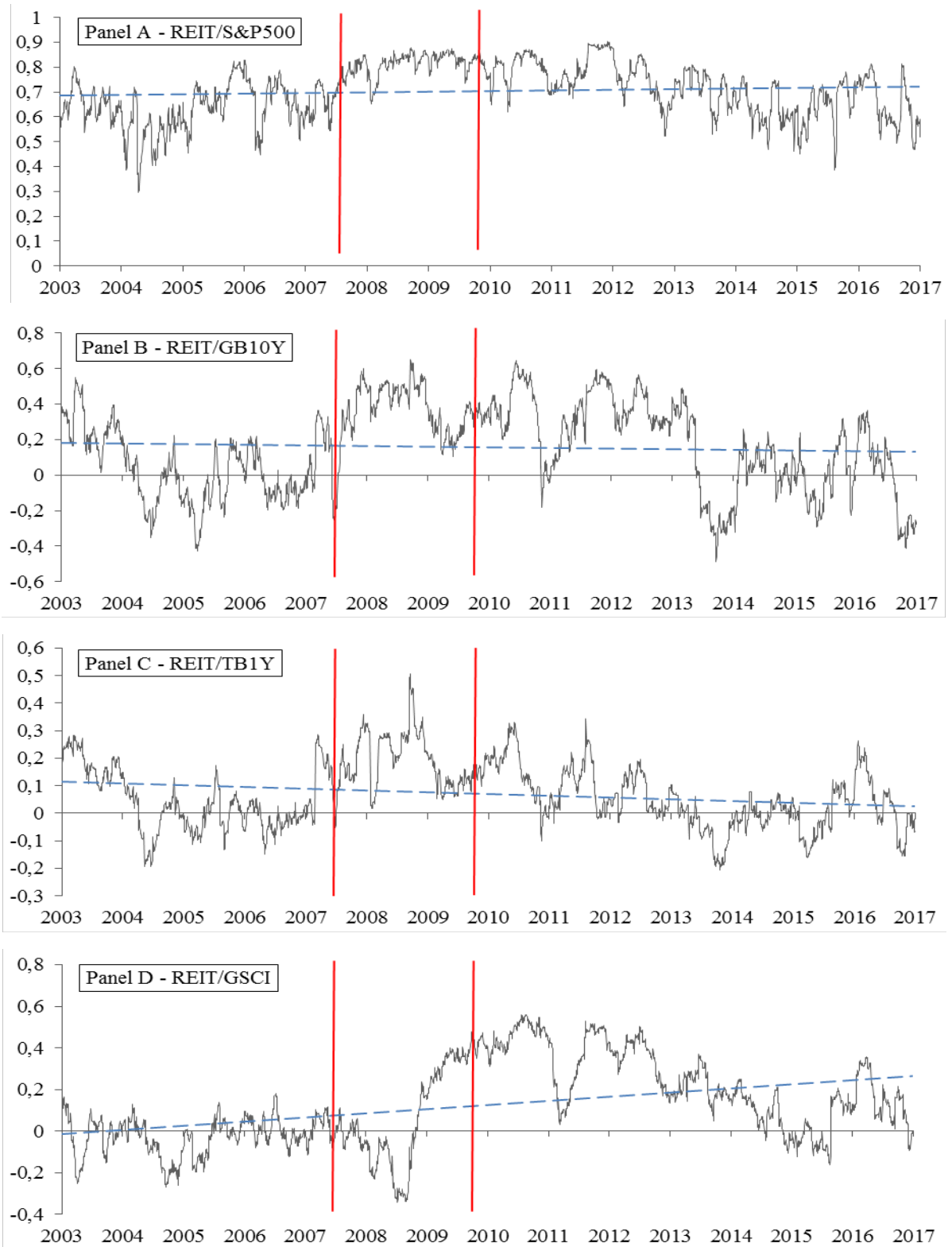
Figure 8: Dynamic conditional correlations based on the DCC-GARCH(1,1) model, 2003/01/01-2016/12/31
Note: The red vertical lines mark the start of the financial crisis and European debt crisis respectively, see
Appendix 4. The trend is visualized by the blue line.

As evident from Panel A of Figure 8, the structural change in the 1990s led to REITs becoming more integrated with common stocks and the relationship is clearly visible, with high and stable correlation throughout the sample period. These results are consistent with the findings of Clayton and MacKinnon (2003), Lee and Chiang (2010) and Oikarinen et al (2011) presented in the literature review. Panel A shows that the correlation is time-varying with a small positive trend. During bear markets small increases in correlation occur. At the time of the financial crisis, the correlation rises from moderate to strong and remains high during the turbulent years and throughout the European debt crisis. This was especially evident in August 2011 when the downgrade of the US credit rating occurred and there was a fear of the European debt crisis spreading, pushing the correlation to its peak at 0.88. In August 2015, Black Monday hit which shook the world stock markets. S&P 500 reacted more strongly than REIT, which explains the huge drop in correlation. The shaky autumn also affected REIT and the correlation increases and spikes when the Chinese market crashed towards the year-end. These findings of increased correlation between equity and real estate stocks during bear markets implies lower diversification benefits between the two assets, results supported by Chong et al (2009), Niskanen and Falkenbach (2010) and Hoesli and Reka (2015).

The relationship between REITs and fixed income is weaker than that of the equity market. From Panel B of Figure 8, one can see that when the financial crisis hits, REITs drop and the correlation peaks in the second half of 2008. This is due to the "flight to quality". Investors move their money to a safer place, government bonds, causing an increase in demand and thus a decline in yield. The general trend for the correlation is slightly negative for the full sample period and the correlation is highly dynamic, moving from moderate positive to moderate negative, making it a quite unpredictable relationship. Overall, the relationship between REITs and the 10-year government bond possess diversification benefits in times of low market stress but lose part of their hedging properties in periods of increased market volatility, which contradicts the findings of Chong et al (2009).

Treasury bills and government bonds share similar investment properties as both asset classes are safer investments in turbulent times and a less attractive option in a booming market. The two indices have a high co-movement and are both driven by the Federal Reserve rate. The 1-year treasury bill have a particularly close relationship with this rate. From Panel C of Figure 8, it can be seen that the correlation between the real estate stocks and money market is less volatile and weaker than the correlation with fixed income, but they still move similarly

during the sample period. What is also more apparent is that the correlation is more spiky, possibly explained by faster movements in money market due to the shorter time horizon. The money market is also closely related with the overall market due to monetary policies. It is therefore sensitive to market conditions and thus the correlation increases during bear markets. However, overall correlation is weak and thus REITs seem to be a good diversifier for a portfolio manager heavy in the money market during periods of tranquility as well as during bear markets.

The conditional correlation between REIT and the GSCI commodity index, illustrated in Panel D of Figure 8, is weak to negative up until the last quarter of 2008. During this period REIT became attractive for strategic asset allocation for commodity portfolio investors, since there are significant diversification benefits of tilting their asset allocation towards real estate stocks more when expecting abnormal fluctuations in commodity prices. This is in line with the findings of Chong et al (2009). The lowest correlation value (-0.35) over the sample period was reported in July 2008 and was due to sharply falling commodity prices while REIT prices were still rising.

A regime switch occurs in late 2008 where the correlation increases significantly due to REIT prices sharply falling as well. After this, the correlation remains moderate for some years, reducing the diversification benefits. That period is a time of turmoil in the market and both assets co-move. However, when the market later stabilizes REIT recovers while commodities stand still. This was partially due to slumping oil prices and market concerns from investors in the commodities market and the GSCI commodity index has seen little to no rally since the financial crisis. This contrasts the price increase of the REIT index, which partially explains the decline in conditional correlation. These patterns suggest that the relationship is somewhat indistinct. The initial reaction to market events differ between the two assets, which might indicate diversificational opportunities. This may be explained by the underlying assets of the indices largely being driven by different external factors. From Panel D, diversification benefits seem to be most attainable during periods of low market volatility. These potential diversification benefits are however deteriorated when rising market volatilities prompts an increase in correlation between REITs and the commodity index, findings contrary to Chong et al (2009). For commodities the overall relationship with REITs is to a large extent indistinguishable, results in line with those of Niskanen and Falkenbach (2010).

Table 2: Statistics from DCC-GARCH(1,1)

Full sample period (January 2002-December 2016)				
Parameters	REIT/S&P500	REIT/GB10Y	REIT/TB1Y	REIT/GSCI
ω_1	0.0291*	0.0214*	0.0213*	0.0221*
	(0.0046)	(0.0043)	(0.0044)	(0.0045)
ω_2	0.0209*	0.0073**	0.0029*	0.0068*
	(0.0031)	(0.0031)	(0.0012)	(0.0025)
α_1	0.0960*	0.1003*	0.1057*	0.1064*
	(0.0085)	(0.0100)	(0.0106)	(0.0107)
α_2	0.0830*	0.0457*	0.0603**	0.0416*
	(0.0074)	(0.0051)	(0.0059)	(0.0053)
β_1	0.8868*	0.8899*	0.8856*	0.8852*
	(0.0094)	(0.0103)	(0.0106)	(0.0107)
β_2	0.8932*	0.9537*	0.9444*	0.9559*
	(0.0092)	(0.0050)	(0.0049)	(0.0054)
$\alpha_1 + \beta_1$	0.9828	0.9901	0.9913	0.9916
$\alpha_2 + \beta_2$	0.9762	0.9994	1.0047	0.9975
Adjustments				
δDCC(I)	0.0293*	0.0300*	0.0160*	0.0196*
δDCC(II)	0.9593*	0.9626*	0.9694*	0.9760*

Note: The parenthesis shows the 'standard error' statistics and the asterisk * and ** reveal significant coefficients at 1% and 5% respectively.

Table 2 represents the result obtained from the DCC-GARCH(1,1). The model is based on three parameters: ω, α and β, which represents the conditional variance of returns for REIT versus non-REITS. ω is a constant parameter. Variance equation parameters α and β support our modeling technique by revealing the presence of conditional heteroscedasticity in the time series. The GARCH(1,1) parameters are highly significant confirming the time-varying variance covariance process. All the estimated parameters are statistically significant at 1% significance level, except for 10-year government bond ω_2 and 1-year treasury bill α_2 which are significant at 5% significance level.

The volatility persistence, and thus the rate of convergence, in these indices is measured by $(\alpha + \beta)$. Persistence refers to how quickly (or slowly) the variance reverts or decays toward its long-run average. A persistence of 1.0 implies no mean reversion while a persistence of less than 1.0 implies reversion to the mean. High persistence equates to slow decay and slow regression toward the mean while low persistence equates to rapid decay and quick reversion to the mean. The values of the above coefficients in Table 2 provide evidence of high volatility persistence in all the indices. The estimated coefficients are significant and close to one for all indices, ranging from 0.9762 to 0.9975, indicating a slow regression toward the mean. All $(\alpha + \beta)$ coefficients are less than one, except for the 1-year treasury bill. This condition is necessary for the unconditional variance to be finite and the series are strictly

stationary. The 1-year treasury bill's coefficient of 1.0047 > 1 which does not meet the conditions of $(\alpha + \beta) < 1$ and thus exhibit weak stationarity.

Similar to the parameters obtained from the estimation of the conditional variance process, the α parameter in the conditional correlation equation are generating small, positive and significant values. The parameter measures the reaction of conditional volatility to market shocks. When it is relatively large (above 0.1) then volatility is very sensitive to market events (Alexander, 2008). In Table 2 α is above 0.1 for all REITs α_1 except for REIT/S&P 500. The GARCH parameter β is large and close to one indicating that time-varying correlation exhibits a high degree of persistence in the conditional volatility. When β is relatively large (above 0.9) then volatility takes a long time to die out following a crisis in the market (Alexander, 2008). In Table 2, the 10-year government bond, 1-year treasury bill and the GSCI commodity index are above 0.9.

Finally, the estimated DCC-GARCH model appears to provide a good representation of the conditional variance of the data. The persistence of the conditional correlations, measured by δDCC(I) and δDCC(II), is close to unity ranging 0.9854 and 0.9956. The δDCC(II) coefficient is always significant and above 0.9 and δDCC(I) is below 0.04, revealing slight response to innovations and major persistency. All of the parameters δDCC(I) and δDCC(II) are positive and statistically significant suggesting evidence of a strong interaction between the returns of the indices. The significance of DCC-GARCH estimates δDCC(I) and δDCC(II) explains that conditional correlation between the returns of REITs and non-REITs indices are highly dynamic and time varying.
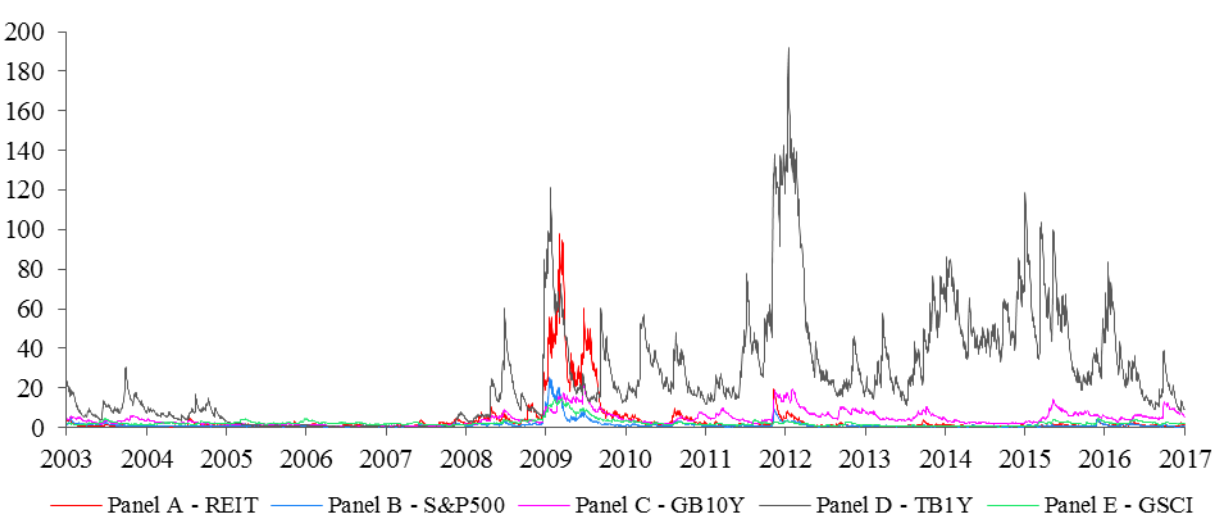
Figure 9: Dynamic conditional variances based on the DCC-GARCH(1,1) model, 2003/01/01-2016/12/31

Figure 9 visualizes the dynamic conditional variances for the five asset classes.[4] In Panel A and B of Appendix 5, representing REIT and S&P 500 respectively, volatilities are centered around the financial crisis as well as in late 2011. In Panel C, the 10-year government bond variance reports low volatility in the variance and then high volatility after the financial crisis with sharp spikes throughout the end of the sample period. The 1-year treasury bill in Panel D exhibits the highest overall variance values of the five panels with high volatility after the occurrence of the financial crisis. In the last Panel, E, the GSCI commodity index exhibits a large spike during the financial crisis but otherwise shows moderate to low volatility in the variance.

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[4] For individually presented dynamic conditional variances see Appendix 5.

6. Conclusion

The standard case made for real estate's role in a mixed-asset portfolio is the favorable risk-return characteristics and the low correlation with other financial asset classes. However, previous research have shown correlation to increase between real estate and other asset classes during bear markets. This might indicate that diversification diminishes when it would be most beneficial. In this thesis, the extent to which the relationship between REIT returns and non-REIT returns varies over time is explored. The aim is to answer the question whether REITs have a role to play in risk management during bear markets.

Through the application of the DCC-GARCH(1,1) model a dynamic conditional correlation study is performed. Three primary findings emerge from the analysis. Firstly, REIT and equity exhibit a moderate to strong positive relationship, which is in line with previous research stating that they have become more integrated since the institutionalization of REITs in the 1990s. Secondly, the commodity index seems to behave and react differently to REIT and thus provide potential diversification benefits, although the relationship remains blurry. Thirdly, both REIT's relationship with fixed income and money market provide diversification opportunities due to weak correlation levels, where especially the relationship with money market offers potential. Combining these insights, the findings presented in this thesis suggests that the conditional correlation between REIT and non-REITs is time-varying. The relationship between REITs and non-REITs seems to increase in most bear markets. However, the conditional correlation between REITs and the commodity index exhibited a decrease during the time of the financial crisis.

The aggregated results highlight that benefits of diversification from including REITs in a mixed-asset portfolio may be diminished in bear markets, which has implications for investors' strategic asset allocation. Additionally, the results of this thesis suggest that investors heavy in the commodity and money market should find allocation towards REITs of particular interest in terms of seeking diversification. In terms of market conditions, REITs could be an especially attractive alternative for strategic asset allocation during tranquil periods as well as when expecting abnormal fluctuations in commodity prices or changes in monetary policies. To conclude, the overall findings suggests that REITs do have a role to play in risk-management during bear markets.

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Appendix

Appendix 1: Five Augmented Dickey-Fuller tests for unit root

```
Augmented Dickey-Fuller test for unit root          Number of obs   =      3688

                         ——————— Interpolated Dickey-Fuller ———————
                  Test       1% Critical        5% Critical       10% Critical
              Statistic          Value              Value              Value
—————————————————————————————————————————————————————————————————————————————
 Z(t)          -48.252           -3.960             -3.410             -3.120
—————————————————————————————————————————————————————————————————————————————
MacKinnon approximate p-value for Z(t) = 0.0000
```

Test 1: ADF-test, trend (1) lag, REIT returns

```
Augmented Dickey-Fuller test for unit root          Number of obs   =      3687

                         ——————— Interpolated Dickey-Fuller ———————
                  Test       1% Critical        5% Critical       10% Critical
              Statistic          Value              Value              Value
—————————————————————————————————————————————————————————————————————————————
 Z(t)          -47.639           -3.960             -3.410             -3.120
—————————————————————————————————————————————————————————————————————————————
MacKinnon approximate p-value for Z(t) = 0.0000
```

Test 2: ADF-test, trend (1) lag, S&P 500 returns

```
Augmented Dickey-Fuller test for unit root          Number of obs   =      3688

                         ——————— Interpolated Dickey-Fuller ———————
                  Test       1% Critical        5% Critical       10% Critical
              Statistic          Value              Value              Value
—————————————————————————————————————————————————————————————————————————————
 Z(t)          -45.515           -3.960             -3.410             -3.120
—————————————————————————————————————————————————————————————————————————————
MacKinnon approximate p-value for Z(t) = 0.0000
```

Test 3: ADF-test, trend (1) lag, 10-year US government bond returns

```
Augmented Dickey-Fuller test for unit root          Number of obs   =      3687

                         ——————— Interpolated Dickey-Fuller ———————
                  Test       1% Critical        5% Critical       10% Critical
              Statistic          Value              Value              Value
—————————————————————————————————————————————————————————————————————————————
 Z(t)          -47.745           -3.960             -3.410             -3.120
—————————————————————————————————————————————————————————————————————————————
MacKinnon approximate p-value for Z(t) = 0.0000
```

Test 4: ADF-test, trend (1) lag, 1-year US treasury bill returns

```
Augmented Dickey-Fuller test for unit root          Number of obs   =      3687

                         ——————— Interpolated Dickey-Fuller ———————
                  Test       1% Critical        5% Critical       10% Critical
              Statistic          Value              Value              Value
—————————————————————————————————————————————————————————————————————————————
 Z(t)          -43.081           -3.960             -3.410             -3.120
—————————————————————————————————————————————————————————————————————————————
MacKinnon approximate p-value for Z(t) = 0.0000
```

Test 5: ADF-test, trend (1) lag, GSCI commodity returns

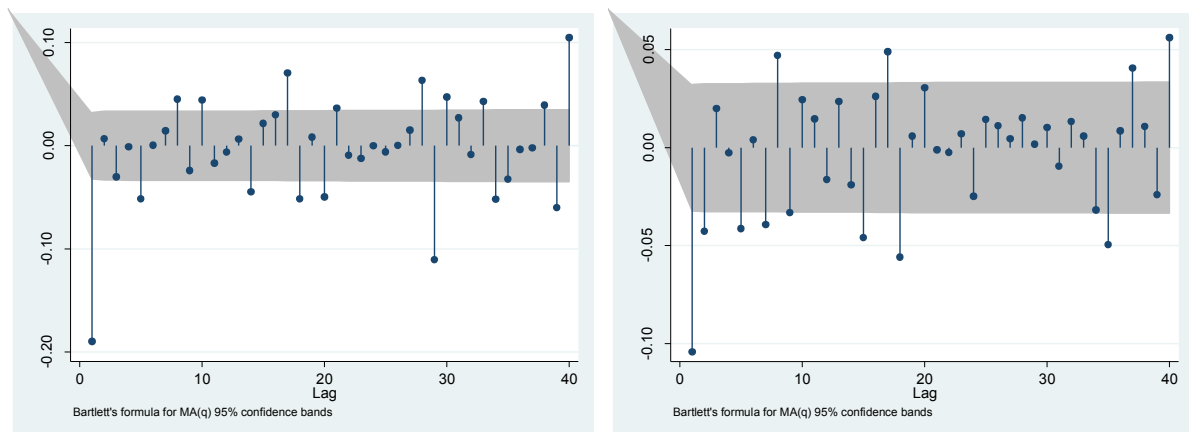**Appendix 2:** Autocorrelograms

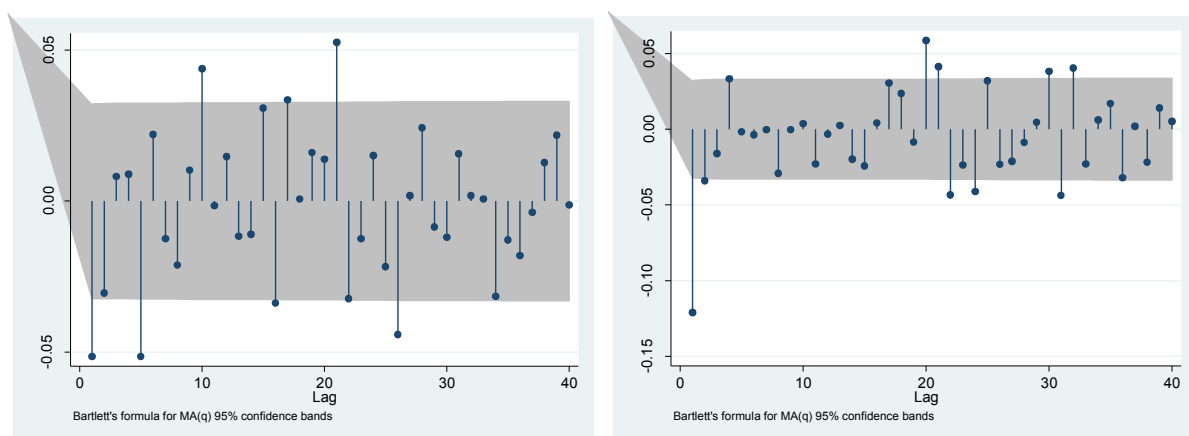Figure 1: Autocorrelograms of REIT (left) and S&P 500 (right)

Figure 2: Autocorrelograms of 10-year US government bond (left) and 1-year US treasury bill (right)
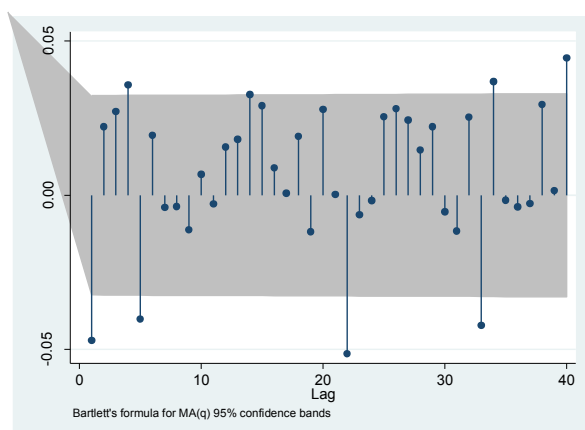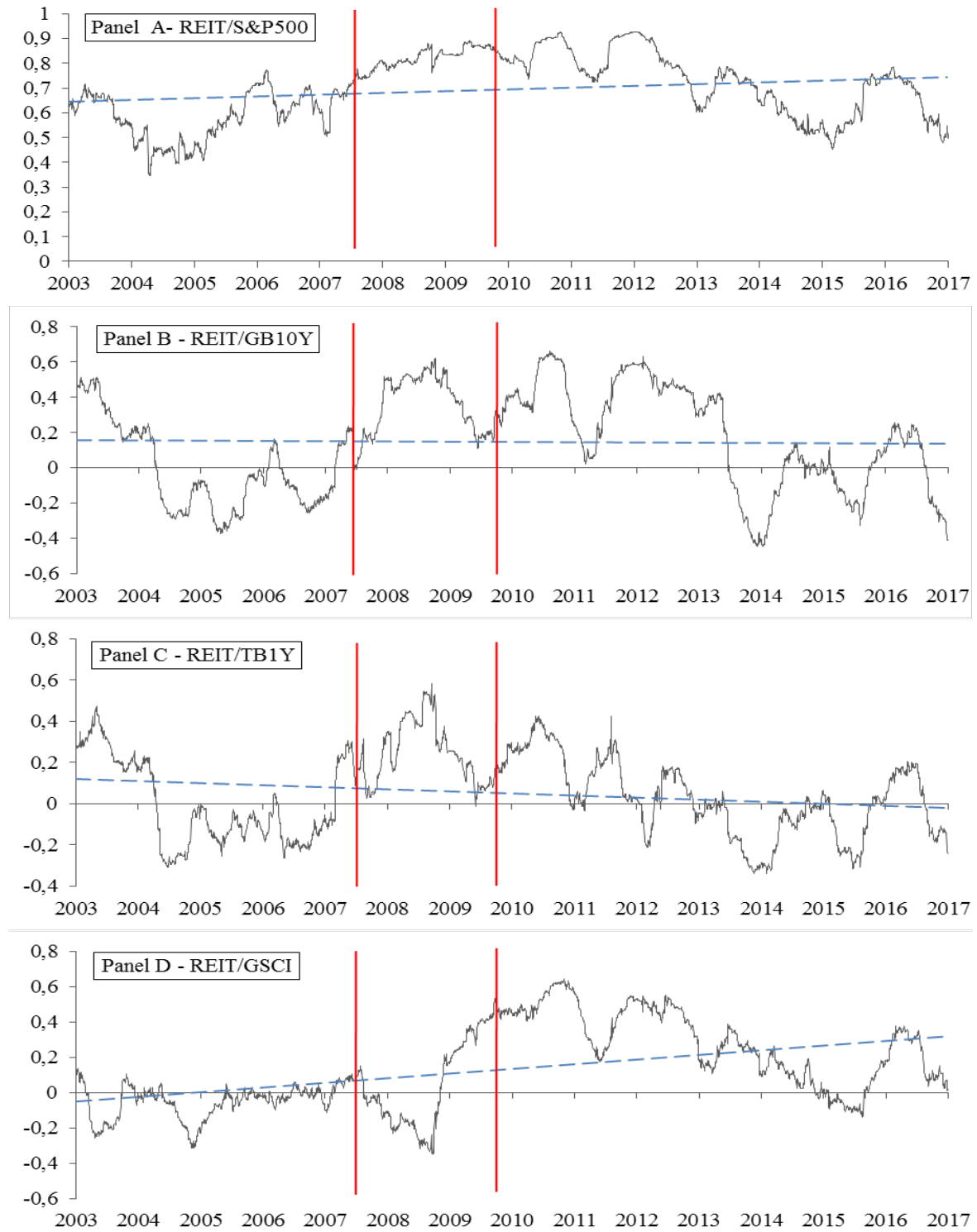

Figure 3: Autocorrelograms of GSCI commodity

Appendix 3: Pairwise correlations from a rolling window of 6 months, 2003/01/01-2016/12/31

Note: The red vertical lines mark the start of the financial crisis and European debt crisis respectively, see Appendix 4. The trend is visualized by the blue line.

Appendix 4: Time line of selected market events, 2000-2017

Timeline 2000-2017	
Date	Event
Mars 2000	The Dotcom crash. The dot-com bubble burst, numerically, on March 10, 2000. Heavy NASDAQ Composite index peaked that day at 5,048.62 (intra-day peak 5,132.52), more than double its value just a year before. The market opened 4% lower on Monday 13 than it closed on Friday.
October 2002	End of Dotcom. On October 9, 2002, the Nasdaq hit a low of 1114.11 points.
June 2004	Interest rates hike. 30rd of June, Fed starts raising interest rates and continues raising June 2004 - June 2006.
January 2006	Boom. Accelerating price growth in the REIT and non-REITS.
July 2007	Beginning of the financial crisis. 31st of July Bear Stearns liquidates two hedge funds that invested in various types of mortgage-backed securities.
September 2008	REITs crashes. Rising debt levels due to previous years purchases of overvalued properties with excessive leverage.
November 2008	QE1 initiated. 25th of November the Fed announces that they will buy $100 billion of agency debt, and $500 billion of mortgage backed securities.
Mars 2009	Beginning of the end of the financial crisis. QE1 extended and Fed purchases another $750 billion of MBS.
Mars 2011	12th of March, the European Union adopts the Euro Plus Pact.
August 2011	Turmoil on the world markets. On the 6th of August the US credit rating is downgraded. The next Monday, S&P500 lost 79,92 points (6,7%) and this followed by fear on the world markets of contagion of the European sovereign debt crisis.
August 2015	Black Monday. On the 24th of August, the world stock markets were down substantially, wiping out all gains made in 2015, with interlinked drops in commodities such as oil, which hit a six-year price low.
January 2016	Chinese market crash. After turbulent times in China, recession fears spread, the oil hits a new low and Japan adopts a negative rate.

Appendix 5: Dynamic conditional variances based on the DCC-GARCH, 2003/01/01-2016/12/31