Macroeconomic determinants of the time-varying correlation between stock and bond returns: A study of the Swedish market

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Abstract

This paper investigates how and to what extent realized fundamental macroeconomic factors affect the time-varying correlation between stock and bond returns on the Swedish financial market. We use daily return data of the OMXS30 and Swedish government bonds, and monthly or quarterly data of macroeconomic factors. We begin by estimating quarterly values of the time-varying correlation between stock and bond returns, using both a sample rolling window model of the Pearson product-moment correlation, and a constant conditional correlation GARCH model. An ordinary least squares multiple regression model is then applied for examining the effect of each macroeconomic factor on the time-varying correlation. Our first finding is that increased realized stock market volatility has a significant negative impact on the correlation, implicating the potential existence of a "flight-to-quality" phenomenon. Our second finding is that currency value also has a significant impact, where a depreciation of the currency tends to increase the correlation. Due to the non-occurrence of research on currency value in this context, three possible explanations are outlined in which the relationship between currency value and inflation expectations, interest rate differentials and the current account, respectively, are discussed.

Keywords: Time-varying correlation, stock-bond correlation, macroeconomic determinants, flight-to-quality, currency value

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Contents

1. Introduction

The purpose of this study is to analyze how and to what extent realized fundamental macroeconomic factors affect the time-varying correlation between stock and bond returns. Analysis of the stock-bond correlation has regularly been on the agenda since it provides significantly useful information to investors and institutions on the financial market. Previous studies have concluded that this correlation constantly fluctuates, and that macroeconomic factors may be important determinants as to why the correlation is very time-varying. To identify these key factors and gain knowledge about how they affect the correlation is important for a number of reasons. The major one is that portfolio allocation strategies are heavily dependent on the correlation between stock and bond returns due to its implications for diversification possibilities. Thus, an understanding of this correlation and the related macroeconomic factors is vital for asset allocation and risk management.

Existing literature has mostly focused on perceptions of the expected macroeconomic environment, where the empirical findings have shown that the correlation varies substantially over time as a consequence of the market's expectations of the future macroeconomic landscape. Some consensus also occurs about how a few certain macroeconomic factors influence the correlation of stock and bond returns. For instance, expected inflation tends to affect the correlation positively while expected or implied volatility has a negative effect. The former corresponds to the effect of expected inflation on discount rates, and the latter finding is consistent with the "flight-to-quality" phenomenon, which we will return to later in this study. Apart from these two factors, conclusions tend to differ depending on time span, market of interest and also methodology.

The analysis in this paper is based on daily data of Swedish stock and bond returns, and monthly or quarterly data on several macroeconomic factors: GDP growth, inflation rate, the repo rate and currency value. Furthermore, stock market volatility is also included in the analysis. We employ the OMXS30 stock index as a stock portfolio proxy and a 5-10 year government bond index as a bond portfolio proxy, together with macroeconomic data gathered from the Swedish Riksbank and Statistics Sweden, covering a 13 years time span between 2004-2016. We begin by measuring the quarterly values of the time-varying correlation between stock and bond returns, using both a sample rolling window model of the Pearson product-moment correlation, and also a CCC (constant conditional correlation) GARCH (Generalized Autoregressive Conditional Heteroscedastic) model, proposed by Bollerslev (1990). The latter one covers the drawbacks of the former one, by better capturing the dynamics of the stock-bond correlation. An ordinary least squares multiple regression model is then applied for examining the effect of each macroeconomic factor on the time-varying correlation.

The first contribution of this paper to existing literature is the examination of the dynamics on the Swedish market, which to our best knowledge, has not been investigated before. Another difference from previous literature is that we focus on the effect of realized macroeconomic factors, instead of expected values. Historically, studies about macroeconomic forecasts have dominated and proven its influence on the correlation between the asset classes. Hence, we find it valuable to understand if that influence only lies in the expectation itself or if realized values, per se, also affect the correlation. If realized macroeconomic factors are able to help predicting the correlation between stock and bond returns, they could help investors to better understand the dynamics of the stock-bond correlation, in order to make more rational choices concerning portfolio allocation. Moreover, realized values might also act as a more tangible tool for some investors, compared to expected values.

The empirical findings in this paper are that there is a short-term negative relationship between realized stock market volatility and the time-varying correlation of stock and bond returns on the Swedish market, which could be explained by a flight-to-quality behavior meaning that investors tend to prefer safer assets during times of market turbulence. We also find that currency value also has a significant impact, where depreciation in the currency tends to increase the correlation. A discussion of potential explanations to this is presented, regarding how currency value relates to inflation expectations, interest rate differentials and the current account, respectively.

2. Previous literature

The correlation between the stock and bond returns is a topic that has been under investigation for a long period of time and many studies have explored the subject.

Irrespective of the approach of different studies, the pattern clearly shows that there is not a constantly lasting mean for the correlation coefficient. Recent studies prove this point through results of either slightly positive or negative correlation. A study of the US and German markets by Andersson et al. (2008) showed that from 1993 through 2003, there was on average a positive correlation in both countries. Proof of high fluctuation in the correlation was made, observing a range between -0.87 and 0.80 in the US during the sample period.

Chiang and Li (2009) used a time span ranging from 1996 through 2008 and, conversely, found a negative correlation on average between the asset classes. This clarifies that the correlation may have historically proved to be highly fluctuating and periods of sustained negative, as well as positive, stock-bond correlation during the last decades have been observed. Furthermore, Baker and Wurgler (2012) focused on different types of stocks and the associated effect on the comovement between stock and bond returns. They divided the stocks into either bond-like stocks, reflected in more mature and stable firms, or speculative stocks. This resulted in a positive correlation of bonds and more bond-like stocks, while speculative stocks were more negatively correlated to bonds.

Research on the underlying determinants of the time-varying correlation between stock and bond returns is more scarce, and the complexity has led to a variety of empirical findings depending on what macroeconomic factors are investigated, what markets are examined, and which angle of approach that is adopted for examination, among other things. However, existing studies are fairly unified about how a few certain factors do affect this correlation. Particularly, expected inflation and volatility are the two determinants where there is most consensus about the effect on the correlation between stock and bond returns. Ilmanen (2003), among others, concludes that higher expected inflation increases the discount rate, which decreases the present value for bonds and hence leads to short-term negative returns. Equivalently, if the discount rate is affected more than expected cash flow for stocks, the implications are the same as for bonds and therefore a short-term positive correlation occurs. On the contrary, a high implied or expected stock market volatility decreases expected risk-adjusted returns for stocks, which might lead to a flight-to-quality behavior where the stock and bond returns take different directions as investors transfer their investments from stocks to bonds.

The flight-to-quality phenomenon, as a consequence of a volatile stock market, recurs regularly in the literature (see e.g. Cappiello et al., 2003; Connolly et al., 2005; Andersson et al., 2008; Baur and Lucey, 2008; Chiang and Li, 2009). Although, Beber et al. (2009) claim that this "flight behavior" is mainly an effect stemmed from liquidity concerns and thus most of it could be derived from the "flight-to-liquidity" phenomenon. Irrespectively, consensus occurs concerning that when there is a high degree of uncertainty about the stock market, investors tend to become more risk averse and reallocate their portfolios towards more stable fixed-income bonds. Moreover, Perego and Vermeulen (2016), who analyzed the stock-bond correlation in different regions, also found results aligned with theory and previous studies regarding expected inflation and stock market volatility. In addition, they also noticed that the current account has a positive effect on the correlation in one of the examined regions.

The vast majority of investigated countries within this area of research are perceived as very large and important economies, like the US and Germany. Consequently, there is a lack of potentially important findings from smaller economies. One of a few breaking this pattern is Skintzi (2017). He considers peripheral economies and found a difference between these compared to core economies regarding the effect of certain macroeconomic factors on the correlation between stock and bond returns. Among other things, it turned out that domestic stock market uncertainty leads to flight-to-quality only in the core economies and that global stock market uncertainty, on the other hand, is what pushing that correlation in a negative direction in the peripheral economies. Thus, this shows that the dynamics of the time-varying correlation are not the same for all economies, which opens the way for more research of smaller ones.

In this study, both a sample rolling window method and a CCC bivariate GARCH model will be employed to estimate the correlation between stock and bond returns. The rolling window methodology has been widely used throughout history and included in many studies that consider correlation between asset classes. Previous studies that applied similar models as in this study are e.g. Chiang and Li (2009) and Andersson et al. (2008). The latter limited the study to three specific macroeconomic factors under consideration; expected inflation, economic growth expectations and implied stock market uncertainty. The authors found a positive correlation when expected inflation is high and that flight-to-quality dynamics occurs during periods of stock market uncertainty. This corresponds to the results of Chiang and Li, who also stated the occurrence of a flight-to-quality phenomenon during periods of expected economic turbulence. Chiang and Li additionally found that expected credit spread has a negative effect on the correlation, and that expectations in net capital inflows, growth of real GDP and federal funds rate, respectively, have positive effects.

We can draw the conclusion that discordance occurs among existing literature regarding what underlying macroeconomic factors that have implications for the stock-bond correlation. The effect of expected inflation and stock market uncertainty are quite constantly prevalent through most studies, but apart from those the results seem to depend on approach, time span and market of interest. As this study focuses on the dynamics on the Swedish financial market, and also on the effect of realized values of macroeconomic factors rather than expectations, we may help to fill some of the gaps left by existing literature in this relatively scarce body of research.

3. Variable selection and description of data

3.1 Return data for stocks and bonds

To measure the correlation between stock and bond returns, two different indices are used as portfolio proxies for the asset classes. For the stock portfolio proxy we use the OMXS30 index and for the bond portfolio proxy we use a 5-10 years Swedish government bond index. Data for the respective indices are gathered from Reuter's Datastream, and both are reported as total return indices. A total return index is calculated as if all proceeds are reinvested in the portfolio. Practically, this means that dividends of stocks are reinvested to purchase more stocks, while yields and face values for bonds are reinvested to purchase more bonds. The reason why a total return index is a more suitable choice than a price index, is because a price index only captures the capital gain component of returns, while a total return index captures both the capital gain component and the dividend/yield component. The indices and quarterly return data are presented in Graph 1 and Table 1 & 2 in Appendix.

3.2 Macroeconomic determinants

Some macroeconomic factors tend to recur for analysis in many previous studies and generate unified results. However, by changing perspective and applying a realized value-based approach, conclusions may be drawn whether this generates different results. The factors examined in this study are outlined below.

A vital factor with huge impact on the overall economy, which we choose to include in this paper, is the *inflation rate*. The development of the inflation rate is crucial to the economy as inflation is substantially connected to discount rates, which are key figures in the stock-bond correlation as mentioned earlier. Hence, the variable constitutes a central point of the economy and the investigation of whether its realized value has any explanatory value regarding the stock-bond correlation is of major interest. To examine the effect of the inflation rate, data of the CPI index are gathered from Statistics Sweden, SCB, which are reported at monthly frequency. The development of the CPI index is presented in Graph 2 in Appendix.

As GDP measures the economic growth and thereby provides a comprehensive picture about the overall health of the economy, we also consider this factor to be a given. Its positive correlation with consumer spending and the subsequent impact on corporate profits support our choice of the variable. Although previous literature mostly shows little significance from GDP on the correlation, our differentiated approach and choice of market makes the factor still highly relevant to examine. Data of inflation-adjusted GDP, benchmarked to 2015 years prices, are reported at quarterly frequency and gathered from SCB, Sweden. The GDP development is presented in Graph 3 in Appendix.

Most of the existing literature covers the US financial market but as mentioned earlier, Skintzi (2017) concludes that smaller economies may be characterized by different dynamics. Therefore, apart from including the most common factors to investigate we also aim to examine forces more important and significant for the Swedish economy. Compared to the US, Sweden is more so dependent on exports, which is highly affected by the nation's currency. Potentially, this might have an impact on the correlation and consequently we will add *currency value* as a variable of interest to our analysis in order to examine its effect. Furthermore, the currency value is also connected to interest rate differentials and inflation expectations, where the latter has in earlier studies been concluded to have a positive effect on the time-varying correlation. To include currency value, we gather quarterly data of average values of the TCW index from the Swedish Riksbank. The TCW index is a total competitiveness index, measuring the strength of the Swedish currency compared to a portfolio of other currencies, constituted by different weights depending on how important they are to the Swedish export sector. An overview of the development of the TCW index is presented in Graph 4**,** and the different weights of the TCW index are reported in Table 3, in Appendix.

We also find it valuable to examine the effect of the official interest rate (in Sweden this rate is referred to as *the repo rate).* Macroeconomic factors in general, and inflation in particular, are all affected by the state of and changes in the repo rate. This relationship is known as the transmission mechanism of monetary policy, which describes how the repo rate impacts several mechanisms in the economic puzzle simultaneously. A change in the repo rate affects the money-market interest rates and thus indirectly the deposit and lending rates. Some of these factors might affect the inflation quite immediately while the implications of other mechanisms appear at a much later stage. Thus, the implications from the repo rate on the monetary policy and general economy makes it an important and interesting factor to explore and determine whether its realized state contains any explanatory value related to the correlation between stock and bond returns. Data of average quarterly values of the repo rate are gathered from the Swedish Riksbank, and are presented in Graph 5 in Appendix.

Discussions about the stock market often involve psychological aspects as well. Uncertainty about the stock market outlook makes the risk averseness of investors apparent, as outlined in previous literature. These studies show empirical findings of great significance of a negative effect of implied and expected volatility on the correlation between stock and bond returns. Hence, insecurity about the future stock market environment has turned out to be consistent with the flight-to-quality phenomenon and in order to decide whether this finding also is applicable to realized stock market fluctuations, we add *volatility* as the last factor in our analysis. The realized volatility parameter is calculated based on the total return data for the OMXS30, and a more detailed explanation is covered in the next section.

4. Methodology

4.1 Estimating correlation

Two methods are used in order to measure the correlation between the daily total stock returns and the daily total bond returns. Firstly, a sample rolling window correlation is estimated, using the Pearson product-moment correlation coefficient. The Pearson product-moment correlation coefficient is measured at the last trading day of each quarter, using a window consisting of all past trading days the bygone quarter. The rolling window correlation can be summarized as following:

$$\hat{\rho}_{r_S,r_B,q} = \frac{\sum_{i=1}^{n}((r_{S,t-i} - \overline{r_{S,q}})\,(r_{B,t-i} - \overline{r_{B,q}}))}{\sqrt{\sum_{i=1}^{n}(r_{S,t-i} - \overline{r_{S,q}})^2}\sqrt{\sum_{i=1}^{n}(r_{B,t-i} - \overline{r_{B,q}})^2}}$$

where t is the last trading day of quarter q, n is the number of trading days during the quarter, $r_{S,t}$ denotes the total stock return on day t, and $r_{B,t}$ denotes the total bond return on day t. Although the Pearson product-moment correlation coefficient may be able to give a good clue of the realized stock-bond correlation, it is sometimes considered to be too simple to capture the dynamics of the covariance between the two asset classes.

To better capture these dynamics by taking volatility clustering into account, we also apply a CCC (constant conditional correlation) bivariate GARCH (Generalized Autoregressive Conditional Heteroscedastic) model to measure the quarterly time-varying correlation between the assets. The model, firstly proposed by Bollerslev et al. (1990), has the ability to measure covariance in heteroscedastic financial time-series data by allowing the conditional covariance to be modeled as a non-linear function of the conditional variances for each asset class. Bollerslev's model estimates the parameters by maximum log-likelihood and is summarized in Appendix**.** In this paper, a CCC(1,1) bivariate GARCH model is specified with one ARCH (α_q) and one GARCH (β_q) term for each quarter and the daily total returns for stocks and bonds as the independent variables $y_{i,t}$. Neither a mean component γ_i, nor a lagged term of $r_{i,t}$ is included in function of $y_{i,t}$, since those parameters are not consequently significant during each quarter. The daily index returns are hence simplified to follow a random walk, $\epsilon_{i,t}$. No explanatory variables are included in the model, because as for the sample Pearson product-moment correlation, the CCC(1,1) bivariate GARCH model is applied to estimate quarterly correlations and not to examine the effect of macro-variables on the time-varying conditional correlation. This is due to uneven frequencies between stock and bond returns and macroeconomic data, where much of available macro-data is reported at quarterly or monthly frequencies. Instead, we apply a similar method like Andersson et al. (2008) by performing multiple regression analyses on the quarterly Pearson product-moment correlation coefficients and the quarterly CCC(1,1) bivariate GARCH correlation coefficients to examine these effects. The estimated correlations are presented in Table 4 in Appendix.

4.2 OLS regression analysis of the effect of macroeconomic determinants

In order to estimate the effect of macroeconomic variables on the time-varying correlation between total returns for stocks and bonds, two OLS multiple regression analyses are performed. In these regression analyses, the quarterly Pearson product-moment correlation coefficients and the quarterly CCC(1,1)-modeled correlation coefficients are regressed on the given set of macro-variables. However, since the dependent correlation coefficients only vary between $(-1, 1)$ whereas the independent variables are not restricted, there may occur errors when estimating the regression coefficients. In order to smooth the restriction of the correlation coefficients, we apply a similar method like Li (2002) by performing a Fisher transformation, in which the flexibility of the dependent correlation coefficient increases by letting it vary between $(-\infty, \infty)$:

$$FisherCorr = \frac{1}{2}\ln\left(\frac{1+\hat{\rho}}{1-\hat{\rho}}\right)$$

The following regression is used to estimate the effect of the macroeconomic determinants on the time-varying correlation.

$$y_{i,q} = \beta_0 + \beta_I Inf_q + \beta_G gGDP_q + \beta_R dRepo_q + \beta_C dCurr_q + \beta_V Vol_q$$

where $y_{i,q}$ is the fisher-transformed correlation coefficients for the rolling window and the CCC(1,1) during the examined quarters q. The macroeconomic variables are presented in the following section.

4.3 Variable smoothing

When it comes to time-series data, there is a usual problem of the variables not being stationary. Having stationary variables without unit roots is an important criterion as non-stationary variables may lead to strong autocorrelation of the regression residuals. To smooth the macro-variables and make them more stationary, the log-difference between average quarterly values of the different indices is calculated, which is an approximation of a percentage change. This is not only a way to make the variables more stationary, as it is also economically intuitive to look at the changes in the key macroeconomic levels rather than index values. However, the repo rate and the stock market volatility variable are treated differently, shown below.

The daily return of each asset class is calculated as the logarithmic change of either the total return index value for OMXS30 or the total return index for Swedish 5-10 years government bonds, depending on asset class, between two consecutive days:

$$r_{i,t} = \ln\left(\frac{TRI_{i,t}}{TRI_{i,t-1}}\right) \times 100$$

where $r_{i,t}$ denotes the daily return of asset class *i* at day *t*, and $TRI_{i,t}$ is the total return index value for asset class *i* at day *t*.

Since quarterly inflation rate is computed using monthly data of the CPI index, quarterly inflation rate is calculated as the logarithmic change of the average CPI levels between two consecutive quarters:

$$Inf_q = \ln\left(\frac{\overline{CPI}_q}{\overline{CPI}_{q-1}}\right) \times 100 = ln\left(\frac{\frac{1}{n}\sum_{n=1}^{3} CPI_n}{\frac{1}{m}\sum_{m=1}^{3} CPI_m}\right) \times 100$$

where q denotes quarter, $n=1,2,3$ denotes each month during quarter q and $m=1,2,3$ denotes each month during quarter $q-1$.

Since fixed-price levels of GDP are reported at quarterly frequency and GDP growth is calculated as the logarithmic change of GDP level between two consecutive quarters:

$$gGDP_q = \ln\left(\frac{GDP_q}{GDP_{q-1}}\right)\times 100$$

where q denotes quarter.

Data of quarterly averages of the repo-rate are gathered from the Swedish Riksbank, but this variable is not transformed through a log-difference. Instead, the normal difference is examined as changes in the repo rate are more often discussed in terms of changes of percentage units, rather than relative measures of percentage. However, as the repo rate is not a cumulative index, this should still be enough to make the variable stationary. The normal change of the repo rate is calculated as following:

$$dRepo_q = (Repo_q - Repo_{q-1})\times 100$$

where q denotes quarter.

Since the effect of currency value is examined, data of the TCW index are collected from the Swedish Riksbank. The TCW index is a "total competitiveness weights" index that measures the value of the Swedish krona against a portfolio of other currencies. The weight of each currency in the portfolio is determined by how important different countries are to Swedish export. The quarterly change is computed as the logarithmic change of average levels of the TCW index between two consecutive quarters:

$$dCurr_q = \ln\left(\frac{\overline{TCW}_q}{\overline{TCW}_{q-1}}\right)\times 100$$

where q denotes quarter, $n=1,2,3$ denotes each month in the quarter q and $m=1,2,3$ denotes each month in quarter $q-1$.

The stock market volatility variable is computed using the stock returns that are computed from the data of the total return OMXS30 index. In the absence of intraday volatility, the volatility variable in this study is calculated as the standard deviation of daily stock returns according to the OMXS30 total return index. The standard deviation is then transformed to a quarterly measure by multiplying it with the root of the median amount of trading days during each quarter, which are 65:

$$Vol_q = \sqrt{\frac{\sum_{t=1}^{n}(r_{S,t} - \overline{r_{S,q}})^2}{n}} \times \sqrt{65}$$

where q denotes quarter, n is the number of trading days in quarter q, t is each trading day out of n trading days during the quarter q, $r_{S,t}$ denotes total stock return at day t and $\overline{r_S}$ is the average return during quarter q. Summaries of quarterly values for the variables are presented in Table 5 in Appendix.

5. Evaluation of model specifications

To evaluate the OLS regression model and search for potential misspecifications, a number of tests are performed to examine if there are any clear evidence of violations of the OLS regression assumptions. The regression specification tests are performed using the CCC(1,1) modeled correlations, as these are the ones of major interest, which will be covered in the results section later.

5.1 Stationary explanatory variables

To examine whether the macroeconomic variables achieve the criterion of being stationary or not, a Phillips-Perron test for a unit root is performed. The results are presented in Table 6, and the null hypothesis of a unit root can be rejected for all variables, except the repo rate, at 5% significance level. Regarding the repo rate, the null hypothesis can be rejected at 10% significance level. This could possibly be due to the softer treatment of the variable, but we consider 10% as good enough. The test results therefore indicate that the explanatory variables are likely to be stationary.

5.2 Heteroscedasticity

If there are misspecifications in the model, errors may not be characterized by constant variance, which leads to heteroscedasticity in the residual distribution. Presented in Graph 6, the relationship between fitted values and regression residuals is examined. The graph does not give clear indications of heteroscedasticity, as the residuals seem to have a constant variance that is not depending on fitted values. To test this, a Breusch–Pagan & Cook-Weisberg test is performed for fitted values, independent variables and also for the time variable as the regression is based on time-series. The results are presented in Table 7, which show that the null hypothesis of constant variance cannot be rejected at any reasonable significance level for any tested variable. The tests results indicate no evidence against homoscedastic residuals, however they neither prove them. Therefore, caution is taken regarding the residual variance and hence a robust regression is applied to account for some of the potential model misspecifications. Further tests are consequently based on the ordinary least squares regression with robust standard errors.

5.3 Multicollinearity

To test for multicollinearity among the explanatory variables, a cross-correlation matrix is presented in Table 8. When looking at the cross-correlations, it can be determined that there is some collinearity between all explanatory variables, though there are no signs of perfect multicollinearity. Relatively high values of collinearity are a recurring issue when it comes to macroeconomic data, where much of macroeconomic effects are usually somewhat correlated. Especially the repo rate and the inflation rate seem to be quite correlated, which is reasonably expected, as one of the main objectives of the repo rate is to control inflation. To further examine this, variance inflation factors of the explanatory variables are presented in Table 9. The variance inflation factors are not dramatically high and as the overall multicollinearity is far from perfect, this should not invalidate any potential results.

5.4 Residual autocorrelation

Furthermore, for every OLS regression and especially when using time-series data, there is a major risk of autocorrelation in the residuals. To examine if the residuals are biased and random or not, we look for potential autocorrelation with a Bartlett's correlogram and periodogram, presented in Graph 7 and Graph 8. The correlogram indicates that there seems to be no autocorrelation for any residual lag within a 95% confidence interval, and the same conclusion can be drawn from the periodogram.

Bartlett's test and a Portmanteau (Q) test are used to formally test the null hypothesis that the residuals are a white-noise process of uncorrelated, random variables, having a constant mean and a constant variance. For both tests, the null hypotheses cannot be rejected at any reasonable significance level. However, this does not prove that the residuals are uncorrelated, random and with a constant mean and a constant variance, but it does tell us that we can neither prove the opposite. The results are presented in Table 10.

5.5 Residual distribution

This leads to a further examination of whether the residuals are normally distributed or not. A histogram of the residual distribution is visualized in Chart 1, which shows that it has many characteristics of a normal distribution, but with the higher end potentially affected by an outlier. To formally test if the residuals may be normally distributed, a Jarque-Bera test and D'Agostino's Skewness-Kurtosis test are performed. Both test indicate that we cannot reject the null hypothesis that the residuals are normally distributed. Results are provided in Table 11.

5.6 Omitted variables bias

Lastly, potential omitted variable bias and non-linearity should be taken into consideration. Ramsey's regression specification-error test is performed to test whether non-linear combinations of the fitted values would make the OLS regression to have a higher explanatory value. As seen in Table 12, we cannot reject the null hypothesis that the current linear combinations are the best fit. Though, it is important to remember that this does not prove the absence of omitted variables bias, as the test rather tells us that presence cannot be proved.

5.7 Evaluation of OLS regression model

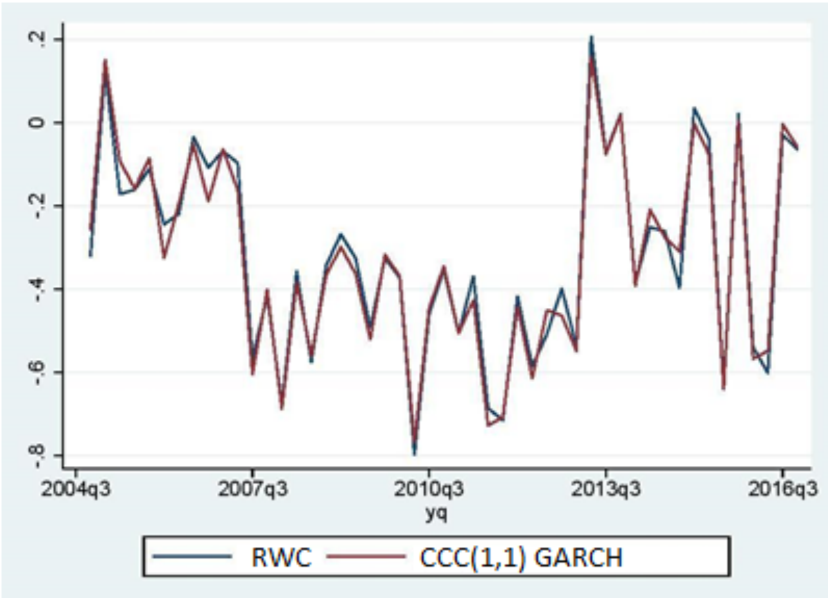
There are no clear indications that the OLS regression model suffers from severe misspecifications, but some of the tests neither indicate that the model is flawless since these tests are based on null hypotheses that there are no misspecifications. However, the model appears acceptable in the most important aspects of OLS regression, and there is no evidence of any assumptions being violated.

6. Results

6.1 Overview of correlations

An overview of the variations in correlation over time is presented in the graph and table below, and it is noticed that the rolling window correlation and the CCC(1,1)-modeled correlation vary quite similarly. This is not particularly unexpected since the quarterly windows are relatively small, not allowing for great differences between the techniques.

Correlations over Time



Summary Statistics for Estimated Correlations

Estimation	N	Mean	Std. Dev.	Min	Max
RWC	49	-0,3151	0,2395	-0,7973	0,2073
CCC(1,1) GARCH	49	-0,3205	0,2383	-0,7677	0,1589

Some interesting observations can be made through examining the results. First of all, the correlation varies a lot with standard deviations almost as large as the means for both estimations. Furthermore, the correlation tends to be more negative than positive. Especially from the end of 2007 to the beginning of 2013, which is during the financial crisis, the correlation varied on a substantially lower level than during times of non-crisis. These years were considerably turbulent, which makes the observation to align with a potential flight-to-quality phenomenon. Apart from this, there are no clear trends and the correlation seems to change quite dramatically between quarters, as in the last decade.

6.2 The effect of the macroeconomic variables

When looking into the results of the multiple regression analyses we see that in both regressions there are two variables, currency value and stock market volatility, which show significant impact on the time-varying correlation at 1% significance level. A positive change in the TCW index, which is a depreciation of the currency, seems to increase the stock-bond correlation. An increase in stock market volatility seems to have the opposite effect, as the correlation becomes more negative if stock market volatility increases. No other variables show significant impact at any reasonable significance level. This means that a change in the repo rate, the approximate GDP growth rate and the approximate inflation rate do not help explain the time-varying correlation in the regression. This is interesting since previous literature has found that especially expected inflation is an important determinant, which lead us to conclude that this effect is limited to expectations and no valuable information can be gathered from its realized values.

As for the difference between the regressions, we note that the regression of the CCC(1,1)-modeled correlations generates a higher R-squared value (44.75% compared to 42.15%), indicating that the macroeconomic variables could better explain the CCC(1,1)-modeled correlations than the sample rolling window correlations. Further analyses are due to this based on the CCC(1,1) OLS regression. Results of the regressions are presented in regression table 1 & 2.

Regression Table 1: RWC with Pearson-product moment correlation

	β	**Std. Error**	**P-value**	**95 % CI**	
gGDP	0.0026	0.0045	0.5690	-0.0065	0.0116
Inf	0.0078	0.0756	0.918	-0.1447	0.1604
dCurr	0.0496***	0.0137	0.001	0.0219	0.0773
Vol	-0.0395***	0.0082	0.000	-0.0560	-0.0230
dRepo	-0.0680	0.1030	0.512	-0.2757	0.1396
Constant	0.0334	0.0784	0.672	-0.1247	0.1915
Number of obs					49
F(5, 43)					8.62
Prob > F					0.0000
R-squared					0.4215
Root MSE					0.2310

*** *p-value<0.01*

Regression Table 2: CCC(1,1)-modeled correlation

	β	Std. Error	P-value	95 % CI	
gGDP	0.0034	0.0042	0.427	-0.0051	0.0119
Inf	0.0090	0.0727	0.903	-0.1377	0.1556
dCurr	0.0484***	0.0130	0.001	0.0221	0.0746
Vol	-0.0405***	0.0081	0.000	-0.0569	-0.0242
dRepo	-0.0729	0.0992	0.466	-0.2729	0.1270
Constant	0.0367	0.0791	0.646	-0.1229	0.1963
Number of obs					49
F(5, 43)					9.37
Prob > F					0.0000
R-squared					0.4475
Root MSE					0.2246

*** *p-value<0.01*

Furthermore, the economic magnitude of currency value and stock market volatility can be interpreted in the regression results. Since a logarithmic change in the TCW index is a close approximation of a percentage change of the currency value, the CCC(1,1) OLS regression results indicate that a one-percentage decrease in currency value compared to the TCW-portfolio currencies, leads to an increase of approximately 0.048 in the time-varying correlation. It can also be seen that an increase of one percentage unit in stock market volatility leads to a decrease of approximately 0.041 in the stock-bond correlation. When considering how this affects the risk of a stock-bond portfolio, we may examine its traditional measure:

$$\sigma^2_{Portfolio} = w_S^2\sigma_S^2 + w_B^2\sigma_B^2 + 2w_Sw_B\sigma_S\sigma_B\rho_{SB}$$

A one-percentage decrease in currency value therefore leads to an approximate increase of $0.048 \times 2w_Sw_B\sigma_S\sigma_B$ units of variance to the portfolio. Furthermore, an increase of a percentage unit in quarterly stock market volatility leads to an approximate decrease of $0.041 \times 2w_Sw_B\sigma_S\sigma_B$ units of variance in the portfolio. To examine the economic magnitude and importance of these effects, a summary of the quarterly values for the explanatory variables that are used in the regression is presented in the summary table below.

Summary Statistics: Explanatory Variables

Variable	N	Mean	Std. Dev.	Min	Max
dRepo	49	-0,051	0,421	-2,1371	0,4239
Inf	49	0,2702	0,5741	-1,4447	1,627
gGDP	49	0,7566	8,5693	-11,2034	13,4072
dCurr	49	0,1276	2,5004	-4,5021	9,2567
Vol	49	10,1157	4,9268	5,0206	29,9132

It can be concluded that the mean of volatility is considerably higher than the mean of changes in currency value. This means that stock market volatility usually has a greater effect than changes in currency value on the fitted values of the regression. However, this has fewer implications when considering portfolio allocation. When investors constantly reallocate their portfolios, they are more likely to consider the magnitude of which the variables tend to change the stock-bond correlation on a quarterly basis.

To examine this, focus shifts to the standard deviations of the two significant variables in the regression. The standard deviation of stock market volatility is 4.9 percentage units, while the standard deviation of changes in currency value is 2.5 percentage units. Thus, multiplying the variable coefficients with their respective standard deviations, we can conclude that a standard deviation of changes in currency value changes the stock-bond correlation with 0.12 units, while a standard deviation of the stock market volatility changes the same correlation with 0.20 units. Considering that the correlation only varies between (-1,1), this is not a major change but still very considerable as 0.12 units and 0.20 units translates to 6% versus 10% of its maximum range. This means that a standard deviation of changes in currency value changes the variance of a stock-bond portfolio with $0.12 \times 2w_S w_B \sigma_S \sigma_B$ units, while a standard deviation of quarterly volatility changes the variance the same portfolio with $0.20 \times 2w_S w_B \sigma_S \sigma_B$ units. Consequently, it can be concluded that stock market volatility usually change the quarterly stock-bond correlations with a larger magnitude than changes in currency value, and the volatility parameter is hence a more important macroeconomic factor for investors to examine when reallocating their portfolios.

However, it is important to remember that stock market volatility explicitly, and currency value perhaps implicitly, affect the risk of each asset class. This means that the total change of portfolio risk is ambiguous. Furthermore, assume an investor want to maximize her portfolio Sharpe ratio:

$$SR = \frac{E[r_p] - r_f}{\sigma_p}$$

It can be seen that not only the ambiguous total portfolio risk, but also changes in expected returns, must be analyzed in order to make a rational choice of allocation. However, the results of this study still bring valuable understanding of how the macroeconomic landscape may affect the covariance risk parameter on a quarterly basis, a factor that is sometimes more or less ignored in favor of how the macroenvironment affects returns and asset specific risks.

6.3 Why may Stock market volatility affect the time-varying correlation?

In accordance with existing literature our results showed a volatility parameter with a significant negative effect on the stock-bond correlation. This indicates a potential transfer of investments from the stock market to the bond market, which implies a potential existence of a flight-to-quality behavior. In other words, investors decrease their exposure against the current turbulent stock market, resulting in a bearish stock market sentiment with falling stock prices. This crowd psychology makes the stable bond returns temporarily more appealing to the investor majority, which consequently chooses the *flight* to the safer asset. Therefore, our aforementioned result of a sustained negative correlation during the crisis period makes perfect sense, as these periods are associated with a deteriorating stock market sentiment. Our interpretation of a “flight behavior” is supported by Baur and Lucey (2008), who established that a flight only exists if a considerable change in the stock-bond correlation level occurs within a relatively short period of time. Whether the flights are mainly caused by quality or liquidity concerns, or the combination of the two theories, lies beyond this paper’s sphere. We are content with just ascertaining the potential existence of such a flight.

However, the most interesting finding to point out is that our approach of examining realized volatility also leads to indications of this behavior. Thus, not only expected and implied, but also realized stock market volatility has implications for portfolio allocation decisions. This provides new valuable information to this body of research as the result indicates that the effect on the stock-bond correlation doesn’t only lie in the expectation itself, but also in the realized state of the stock market volatility, per se.

6.4 Why may currency value affect the time-varying correlation?

When analyzing the result that currency depreciation has a positive impact on the time-varying correlation between stock and bond returns, the first thing that should be taken into account is the mechanisms behind depreciation. A few examples of traditionally documented determinants of a country's exchange rate are interest rate differentials and expected inflation rates.

Although realized inflation has no significant effect according to the regression model, expected inflation may still have an effect on the time-varying correlation between stock and bond returns. The relationship between inflation and exchange rates can be analyzed from a relative purchasing power parity perspective, where a depreciation of the domestic currency could be explained by increased domestic inflation expectations. Such a relationship has been concluded by several researchers, e.g. Ebiringa et al. (2014). As mentioned earlier, researchers such as Andersson et al. (2008) and Ilmanen (2003) have also concluded that expected inflation seems to have a positive impact on the stock-bond comovement. Their explanation to this is that in times of increased inflation expectations, discount rates for both bonds and stocks increase and hence the assets are affected in a similar way, causing the comovement between the assets to increase. When inflation expectations are low, discount rates are more stable and the comovement between the assets become less apparent, and this explains why there may be a positive relationship between correlation and inflation expectations.

Shifting focus to interest differentials and examining their relationship to exchange rates, conclusions are very similar among researchers. For example, Hacker et al. (2009) studied the mechanisms on the Swedish markets, and one of their key findings is that there is short-term negative relationship between the exchange rate, expressed as domestic-currency price of foreign currency, and the nominal interest rate differential, expressed as domestic interest rates minus foreign interest rates. Hence, currency depreciation could possibly be explained by a decreasing interest rate differential. As domestic interest rates are controlled for to a certain degree by including the repo rate in the regression, the decreased differential is more likely to be caused by increasing foreign interest rates. Furthermore, Engel (2016) among some researchers concludes that countries with higher interest rates tend to have higher short-term expected returns, even when controlling for interest rate parity. This means that through increases in foreign interest rates, investors on the Swedish market are given possibilities to greater returns on the international market, which hence should increase the opportunity cost of capital of investing in Swedish assets. If assumed that investors' discount rates are affected by their opportunity cost of capital, Ilmanen's reasoning on how discount rates affect the stock-bond correlation could be reapplied in this context. A potentially possible explanation to the effect of currency depreciation could therefore be that when foreign interest increases, also discount rates on Swedish assets increase due to a rise in the opportunity costs of capital, which causes the comovement between stocks and bonds to increase as well.

The results can lastly be analyzed through the effect of currency depreciation on the current account. Assuming that Sweden's exports and imports are relatively elastic, a depreciation of its currency would lead to an increase in exports and a decrease in imports. Hence an increase in the trade balance can be expected, which in turn increases the current account.

$$Current\ Account = Net\ Export + Net\ Income\ from\ Abroad + Net\ Current\ Transfers$$

As previously mentioned, Perego and Vermeulen (2016) concluded in their study that the current account may have a significant positive effect on the correlation, which could explain why a currency depreciation then also may have a positive effect on the correlation in this study.

This paper does not provide definite answers as to why currency depreciation affects the correlation between stock and bond returns. Though, three potential explanations have been outlined, which are based on the relationship between exchange rate and inflation expectations, interest rate differentials and the current account, respectively.

7. Conclusion

The purpose of this study has been to analyze how and to what extent realized macroeconomic factors affect the time-varying correlation between stock and bond returns on the Swedish financial market. As neither this specific angle of approach nor the Swedish market has been examined within this rather unexplored area of research, this paper contributes to new valuable understanding concerning diversification dynamics on especially the Swedish market, but also in general.

The results show that realized volatility has a negative effect on the correlation at 1% significance level. This finding aligns with those of previous studies on expected and implied volatility, and implicates the existence of a potential flight-to-quality behavior on the Swedish market. This flight may occur when investors decrease their exposure to the turbulent stock market in favor of the safer, thus temporarily more appealing, bond market.

The results also show that currency value has a positive effect on the time-varying correlation at 1% significance level. This variable is of certain interest due to its historical non-occurrence in this area of research. Since the effect of this variable has not been documented prior to this study, there is no explicit research as to how currency value may affect the correlation. However, this paper outlines three possible explanations in which the relationship between currency value and expected inflation rates, interest rate differentials and the current account, respectively, are analyzed and how these mechanisms in turn may act as determinants of the time-varying correlation between stock and bond returns.

To conclude, by taking another angle of approach, our study brings relevant implications to research and portfolio allocation strategies. We state that realized values of stock market volatility and currency value on the Swedish market may act as determinants of the correlation between stock and bond returns.

8. Limitations and suggestions for future research

One of the empirical findings of this study is that currency value seems to have a positive effect on the time-varying correlation between stock and bond returns. However, since currency value is both affected by, and also affects, many other parameters, the underlying mechanisms behind this effect are ambiguous. Hence, the causality between currency value and the correlation between stock and bond returns is ambiguous as well, and currency value itself may not actually be the most appropriate factor to examine. However, this study has outlined three potential explanations as to why the observable effect of currency value might exist. Therefore, our suggestion to future research within this field is to better understand how the underlying mechanisms of especially interest rate differentials, but also the current account, affect the time-varying correlation between stock and bond returns, since research on these factors are absent and scarce, respectively. It would also be valuable to examine if this effect is persistent on other markets than the Swedish.

Furthermore, as Baker and Wurgler (2012) have concluded, the correlation may also depend on different types of stocks, such as growth or value stocks. Therefore it would be valuable to understand if our findings can be applied to all, or just certain types of stocks.

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Appendix

The CCC GARCH model proposed by Bollerslev can be summarized as:

$$y_t = Cx_t + \epsilon_t$$
$$\epsilon_t = H_t^{1/2} v_t$$
$$H_t = D_t^{1/2} R D_t^{1/2}$$

where:

y_t is an $m \times 1$ vector of independent variables;

C is an $m \times k$ matrix of parameters;

x_t is a $k \times 1$ vector if independent variables, which may contain lags of y_t;

$H_t^{1/2}$ is the Cholesky factor of the time-varying conditional covariance matrix, H_t;

v_t is an $m \times 1$ vector of normal, independent, and identically distributed innovations;

D_t is a diagonal matrix of the conditional variances,

$$D_t = \begin{pmatrix} \sigma_{1,t}^2 & 0 & \cdots & 0 \\ 0 & \sigma_{2,t}^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_{m,t}^2 \end{pmatrix}$$

in which each $\sigma_{i,t}^2$ evolves according to a univariate GARCH model in the form of

$$\sigma_{i,t}^2 = s_i + \sum_{j=1}^{p_i} \alpha_j \epsilon_{i,t-j}^2 + \sum_{j=1}^{q_i} \beta_j \sigma_{i,t-j}^2,$$

where α_j are ARCH parameters and β_j are GARCH parameters;

R is a matrix of time-invariant unconditional correlations of the standardized residuals $D_t^{1/2}\epsilon_t$,

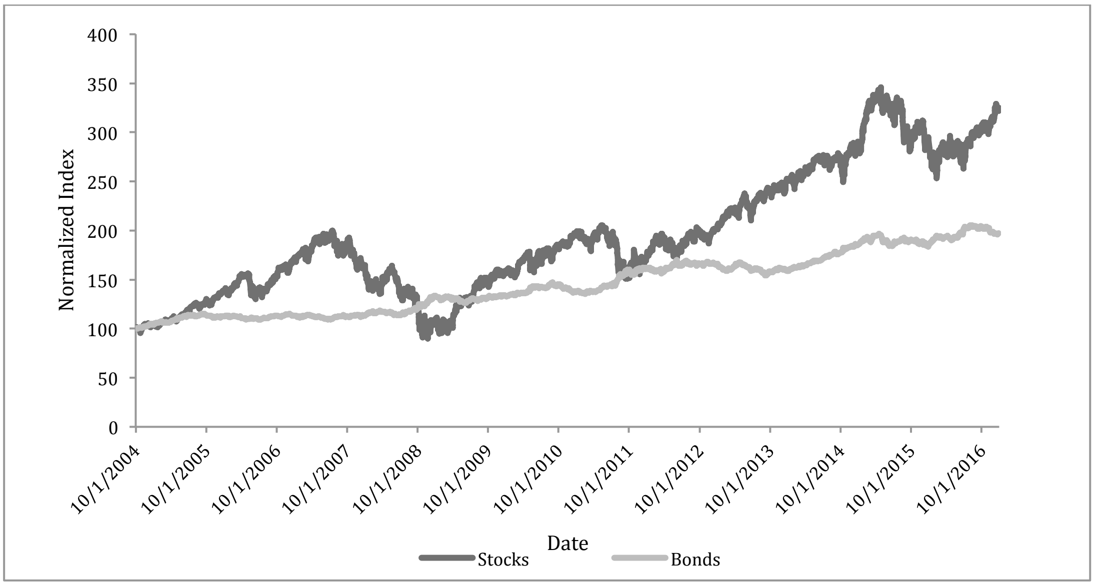
$$R = \begin{pmatrix} 1 & \rho_{12} & \cdots & \rho_{1m} \\ \rho_{12} & 1 & \cdots & \rho_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{1m} & \rho_{2m} & \cdots & 1 \end{pmatrix}$$

The unconcentrated log-likelihood function based on the multivariate normal distribution for observation *t* is

$$l_t = -0.5m \times \log(2\pi) - 0.5 \times \log\{\det(R)\} - log\left\{\det\left(D_t^{1/2}\right)\right\} - 0.5\tilde{\epsilon_t} R^{-1} \tilde{\epsilon_t}'$$

where $\tilde{\epsilon_t} = D_t^{-1/2}\epsilon_t$ is an $m \times 1$ vector of standardized residuals, $\epsilon_t = y_t - Cx_t$, and the log-likelihood function is $\sum_{t=1}^{T} l_t$

Graph 1: Total Return Indices for Stocks and Bonds



Note: The graph shows normalized indices of the development of total returns for bonds and stocks. The OMXS30 is used as the proxy portfolio for total stock returns, and a 5-10 years government bond index is used as the proxy portfolio for total bond returns. Data of for the total return indices are gathered from Reuter's Datastream from 2004-10-01 to 2016-12-31.

Table 1: Quarterly Data of Stock Returns

Quarter	N	Mean	Std. Dev.	Min	Max
2004 Q4	65	0,052	0,799	-2,370	1,713
2005 Q1	64	0,061	0,778	-1,819	1,470
2005 Q2	65	0,148	0,738	-2,262	1,537
2005 Q3	66	0,131	0,651	-1,572	1,653
2005 Q4	65	0,106	0,699	-1,568	2,288
2006 Q1	65	0,157	0,733	-2,060	1,380
2006 Q2	65	-0,121	1,791	-4,880	5,351
2006 Q3	65	0,129	1,069	-1,759	3,948
2006 Q4	65	0,152	0,917	-2,949	2,167
2007 Q1	65	0,094	1,139	-3,860	2,600
2007 Q2	65	0,087	1,018	-3,839	1,871
2007 Q3	65	-0,041	1,559	-3,484	3,564
2007 Q4	66	-0,185	1,278	-3,724	3,324
2008 Q1	65	-0,193	1,974	-4,253	4,092
2008 Q2	65	-0,104	1,389	-3,356	3,452
2008 Q3	66	-0,165	2,290	-5,897	8,597
2008 Q4	66	-0,225	3,710	-7,511	9,874
2009 Q1	64	-0,018	2,502	-5,323	5,544
2009 Q2	65	0,356	1,972	-4,893	5,584
2009 Q3	66	0,183	1,390	-2,652	3,305
2009 Q4	66	0,090	1,196	-3,326	2,791
2010 Q1	64	0,119	0,849	-2,223	1,983
2010 Q2	65	0,010	1,703	-3,379	6,240
2010 Q3	66	0,120	1,215	-2,577	3,641
2010 Q4	66	0,092	0,820	-1,838	2,429
2011 Q1	64	-0,015	1,001	-2,499	1,870
2011 Q2	65	0,011	1,081	-2,553	2,548
2011 Q3	66	-0,307	2,429	-6,972	6,033
2011 Q4	65	0,126	2,001	-4,605	5,022
2012 Q1	65	0,148	1,116	-3,700	2,753
2012 Q2	65	-0,010	1,613	-4,691	3,955
2012 Q3	65	0,079	1,012	-2,344	2,602
2012 Q4	66	0,045	0,739	-1,766	2,339
2013 Q1	64	0,151	0,685	-1,556	2,257
2013 Q2	65	-0,026	1,049	-3,134	2,548
2013 Q3	66	0,137	0,753	-1,715	1,775
2013 Q4	66	0,086	0,693	-1,802	2,020
2014 Q1	64	0,060	0,817	-2,484	2,067
2014 Q2	65	0,046	0,623	-1,429	2,057
2014 Q3	66	0,029	0,779	-1,612	1,923
2014 Q4	66	0,065	1,107	-2,946	3,056
2015 Q1	64	0,226	0,971	-2,327	2,457
2015 Q2	65	-0,093	1,105	-3,060	2,792
2015 Q3	66	-0,127	1,595	-4,606	3,801
2015 Q4	66	0,033	1,149	-2,677	3,072
2016 Q1	65	-0,068	1,771	-4,314	3,774
2016 Q2	65	-0,010	1,657	-8,801	3,178
2016 Q3	66	0,129	0,828	-1,715	1,874
2016 Q4	65	0,086	0,729	-1,255	1,807

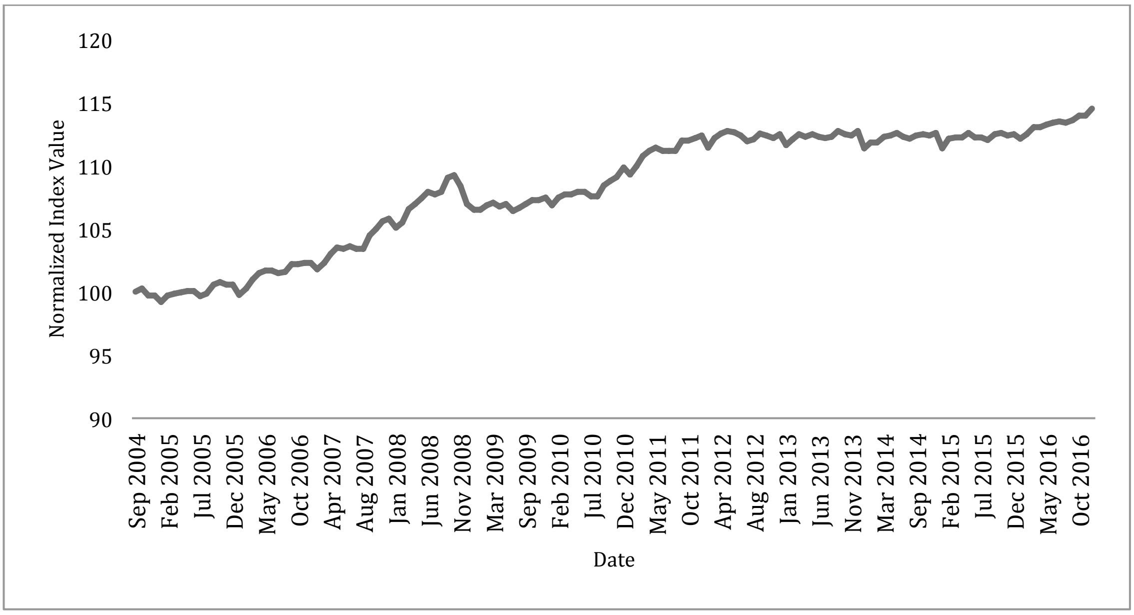
Note: The table shows quarterly summary statistics of the total return data (in %) for stocks on the OMXS30 index. Data are gathered from Reuter's Datastream from 2004-10-01 to 2016-12-31

Table 2: Quarterly Data of Bond Returns

Quarter	N	Mean	Std. Dev.	Min	Max
2004 Q4	65	0,064	0,233	-0,572	0,566
2005 Q1	64	0,045	0,252	-0,666	0,990
2005 Q2	65	0,093	0,256	-0,447	0,822
2005 Q3	66	0,000	0,212	-0,540	0,419
2005 Q4	65	-0,018	0,210	-0,498	0,473
2006 Q1	65	-0,022	0,206	-0,502	0,359
2006 Q2	65	-0,026	0,242	-0,611	0,604
2006 Q3	65	0,055	0,218	-0,415	0,467
2006 Q4	65	-0,004	0,189	-0,478	0,434
2007 Q1	65	0,000	0,197	-0,455	0,635
2007 Q2	65	-0,042	0,183	-0,630	0,330
2007 Q3	65	0,032	0,246	-0,623	0,602
2007 Q4	66	0,014	0,301	-1,246	1,180
2008 Q1	65	0,052	0,316	-0,712	0,641
2008 Q2	65	-0,046	0,283	-0,643	0,448
2008 Q3	66	0,082	0,353	-1,058	0,817
2008 Q4	66	0,161	0,495	-1,343	1,526
2009 Q1	64	-0,025	0,373	-0,900	0,788
2009 Q2	65	-0,030	0,319	-0,799	0,864
2009 Q3	66	0,033	0,328	-0,582	0,970
2009 Q4	66	0,018	0,277	-0,555	0,796
2010 Q1	64	0,039	0,230	-0,592	0,799
2010 Q2	65	0,058	0,384	-1,462	0,809
2010 Q3	66	0,022	0,286	-0,657	0,669
2010 Q4	66	-0,073	0,300	-0,686	0,693
2011 Q1	64	0,009	0,276	-0,582	0,858
2011 Q2	65	0,061	0,262	-0,550	0,646
2011 Q3	66	0,149	0,559	-1,424	1,695
2011 Q4	65	0,034	0,498	-0,888	1,926
2012 Q1	65	-0,034	0,345	-0,969	0,669
2012 Q2	65	0,049	0,515	-2,787	0,896
2012 Q3	65	0,027	0,390	-1,017	0,781
2012 Q4	66	-0,004	0,249	-0,613	0,521
2013 Q1	64	-0,020	0,330	-0,817	0,799
2013 Q2	65	-0,042	0,348	-1,167	0,768
2013 Q3	66	-0,013	0,343	-1,051	0,624
2013 Q4	66	0,006	0,237	-0,620	0,490
2014 Q1	64	0,055	0,234	-0,615	0,548
2014 Q2	65	0,059	0,193	-0,364	0,467
2014 Q3	66	0,056	0,233	-0,548	0,564
2014 Q4	66	0,071	0,273	-0,676	1,127
2015 Q1	64	0,072	0,333	-0,650	1,232
2015 Q2	65	-0,074	0,352	-1,234	0,596
2015 Q3	66	0,032	0,391	-1,040	0,998
2015 Q4	66	-0,035	0,328	-0,991	0,581
2016 Q1	65	0,067	0,278	-0,580	0,805
2016 Q2	65	0,066	0,335	-0,691	1,814
2016 Q3	66	0,019	0,237	-0,669	0,577
2016 Q4	65	-0,048	0,286	-1,254	0,480

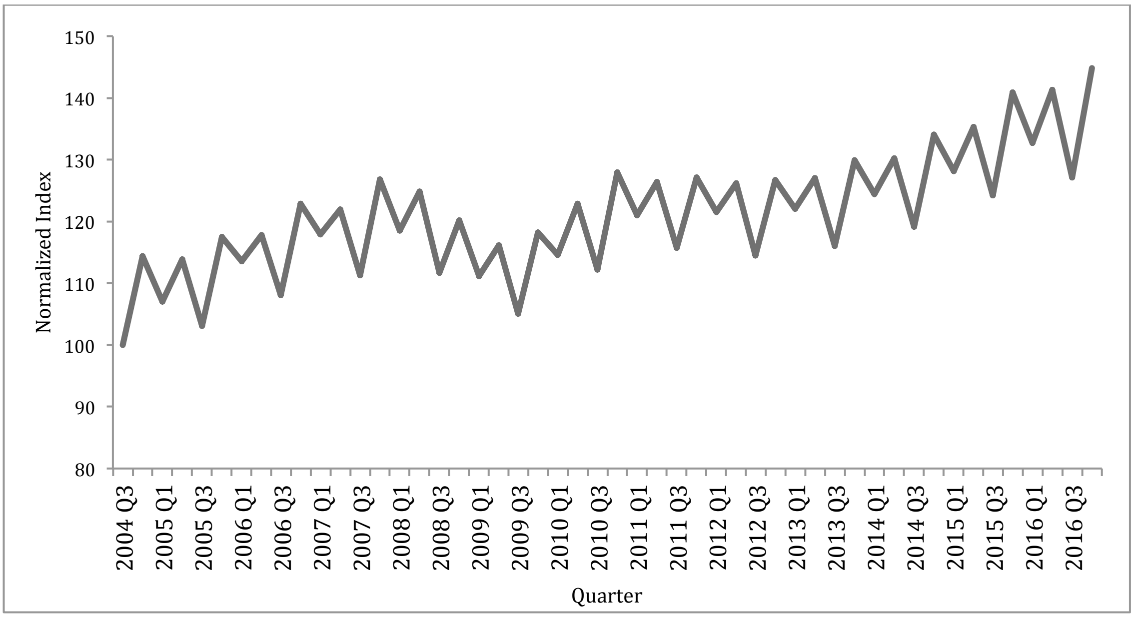
Note: The table shows quarterly summary statistics of the total return data for bonds (in %) in the 5-10 years Swedish government bond index. Data are gathered from Reuter's Datastream from 2004-10-01 to 2016-12-31

Graph 2: CPI Development



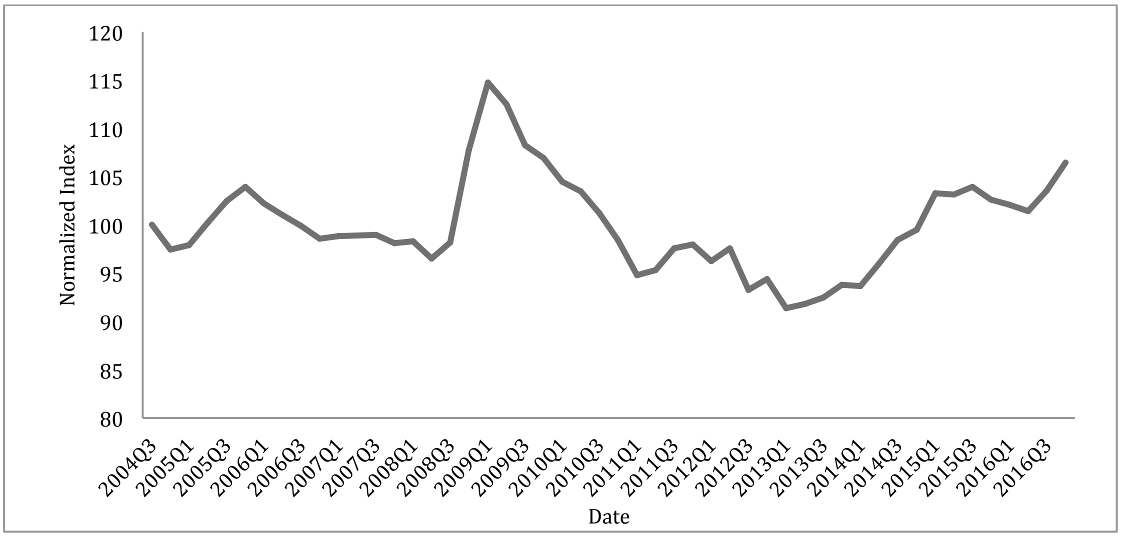
Note: The graph shows the development of monthly values of CPI Index from September 2004 to December 2016. Data for the CPI index is gathered from the official website of Statistics Sweden, SCB.

Graph 3: GDP development



Note: The graph shows the development of quarterly values of GDP from 2004Q3 to 2016Q4. The data are reported with fixed-price levels, benchmarked to prices year 2015. Data are gathered from the official website of Statistics Sweden, SCB.

Graph 4: TCW Index



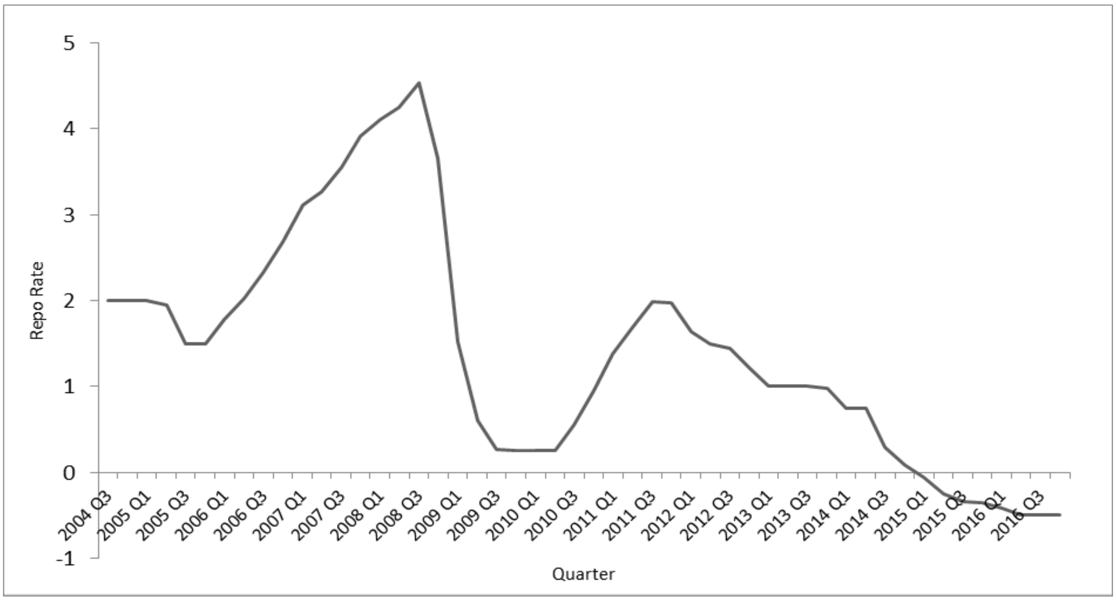
Note: The graph shows the development of quarterly average values of TCW Index from 2004Q3 to 2016Q4. The TCW Index is a total competitiveness weights index that measures the value of the Swedish currency in relation to a portfolio of other currencies. Data are gathered from the official website of the Swedish Riksbank.

Table 3: Weights in the TCW index

Country	Currency	TCW-weight (%)
USA	USD	11.63
Austria	ATS	1.71
Belgium	BEF	3.55
Canada	CAD	1.16
Switzerland	CHF	2.74
Germany	DEM	22.28
Denmark	DKK	5.6
Finland	FIM	6.69
France	FRF	7.15
UK	GBP	11.56
Italy	ITL	6.05
Japan	JPY	5.2
Netherlands	NLG	4.24
Norway	NOK	5.58
Australia	AUD	0.27
Spain	ESP	2.48
Greece	GRD	0.27
Ireland	IEP	0.77
New Zealand	NZD	0.14
Portugal	PTE	0.93

Note: The table shows the weights of different currencies in the TCW index. Weights are based on each country's importance to Swedish export. Data of the weights are gathered from the official website of the Swedish Riksbank.

Graph 5: Development of the Repo Rate



Note: The graph shows the development of quarterly average values of the official interest rate, the repo rate, in Sweden from 2004Q3 to 2016Q4. Data are gathered from the official website of the Swedish Riksbank.

Table 4: Quarterly Correlations

Quarter	Rolling Window	CCC(1,1)
2004 Q4	-0,256	-0,320
2005 Q1	0,151	0,122
2005 Q2	-0,092	-0,171
2005 Q3	-0,157	-0,161
2005 Q4	-0,086	-0,111
2006 Q1	-0,324	-0,244
2006 Q2	-0,194	-0,219
2006 Q3	-0,052	-0,035
2006 Q4	-0,188	-0,107
2007 Q1	-0,064	-0,068
2007 Q2	-0,161	-0,096
2007 Q3	-0,604	-0,567
2007 Q4	-0,402	-0,415
2008 Q1	-0,687	-0,674
2008 Q2	-0,383	-0,358
2008 Q3	-0,559	-0,575
2008 Q4	-0,367	-0,343
2009 Q1	-0,298	-0,268
2009 Q2	-0,362	-0,325
2009 Q3	-0,520	-0,492
2009 Q4	-0,317	-0,325
2010 Q1	-0,369	-0,372
2010 Q2	-0,768	-0,797
2010 Q3	-0,445	-0,460
2010 Q4	-0,345	-0,353
2011 Q1	-0,505	-0,506
2011 Q2	-0,426	-0,369
2011 Q3	-0,728	-0,686
2011 Q4	-0,707	-0,715
2012 Q1	-0,442	-0,416
2012 Q2	-0,614	-0,585
2012 Q3	-0,450	-0,507
2012 Q4	-0,463	-0,398
2013 Q1	-0,548	-0,536
2013 Q2	0,159	0,207
2013 Q3	-0,075	-0,072
2013 Q4	0,020	0,021
2014 Q1	-0,391	-0,385
2014 Q2	-0,209	-0,251
2014 Q3	-0,275	-0,261
2014 Q4	-0,309	-0,396
2015 Q1	-0,002	0,035
2015 Q2	-0,076	-0,039
2015 Q3	-0,640	-0,636
2015 Q4	0,003	0,021
2016 Q1	-0,567	-0,539
2016 Q2	-0,548	-0,601
2016 Q3	-0,004	-0,028
2016 Q4	-0,058	-0,064

Note: The table shows the estimated correlation coefficients for each quarter using the sample rolling window correlation of the Pearson product-moment correlation, and the CCC(1,1)-modeled correlation

Table 5: Macroeconomic variable values

Quarter	*dRepo*	*Inf*	*gGDP*	*dCurr*	*Vol*
2004 Q4	0,000	-0.101	13.407	-2.611	6,443
2005 Q1	0,000	-0.303	-6.593	0.487	6,273
2005 Q2	-0.048	0.466	6.211	2.401	5,946
2005 Q3	-0.452	-0.001	-9.993	2.174	5,247
2005 Q4	0,000	0.597	13.074	1.435	5,638
2006 Q1	0.277	-0.304	-3.417	-1.691	5,907
2006 Q2	0.252	1.262	3.671	-1.144	14,440
2006 Q3	0.29	0.133	-8.636	-1.128	8,619
2006 Q4	0.367	0.498	12.882	-1.368	7,392
2007 Q1	0.423	0.098	-4.132	0.258	9,179
2007 Q2	0.153	1.129	3.375	0.104	8,205
2007 Q3	0.287	0.232	-9.18	0.036	12,570
2007 Q4	0.361	1.627	13.099	-0.896	10,304
2008 Q1	0.198	0.229	-6.793	0.227	15,917
2008 Q2	0.141	1.627	5.267	-1.799	11,195
2008 Q3	0.284	0.731	-11.203	1.678	18,463
2008 Q4	-0.881	-0.039	7.366	9.257	29,913
2009 Q1	-2.137	-1.445	-7.773	6.331	20,172
2009 Q2	-0.908	0.266	4.315	-2.002	15,900
2009 Q3	-0.339	-0.235	-10.01	-3.806	11,203
2009 Q4	-0.019	0.632	11.826	-1.224	9,639
2010 Q1	0,000	-0.003	-3.169	-2.31	6,844
2010 Q2	0,000	0.465	7.025	-0.981	13,729
2010 Q3	0.299	0.032	-9.114	-2.199	9,794
2010 Q4	0.404	1.263	13.17	-2.829	6,614
2011 Q1	0.424	0.695	-5.559	-3.716	8,074
2011 Q2	0.306	1.129	4.294	0.538	8,716
2011 Q3	0.305	0.166	-8.781	2.351	19,583
2011 Q4	-0.016	0.664	9.403	0.355	16,135
2012 Q1	-0.332	-0.139	-4.492	-1.746	9,000
2012 Q2	-0.141	0.498	3.716	1.351	13,003
2012 Q3	-0.05	-0.368	-9.726	-4.502	8,158
2012 Q4	-0.22	0.166	10.141	1.177	5,962
2013 Q1	-0.23	-0.271	-3.75	-3.23	5,520
2013 Q2	0,000	0.265	3.984	0.455	8,460
2013 Q3	0,000	0.033	-8.997	0.759	6,068
2013 Q4	-0.024	0.132	11.254	1.425	5,584
2014 Q1	-0.226	-0.775	-4.312	-0.195	6,584
2014 Q2	0,000	0.665	4.584	2.485	5,022
2014 Q3	-0.455	-0.134	-8.888	2.516	6,281
2014 Q4	-0.215	0.2	11.77	1.052	8,927
2015 Q1	-0.141	-0.507	-4.456	3.743	7,827
2015 Q2	-0.19	0.398	5.381	-0.105	8,911
2015 Q3	-0.092	-0.101	-8.572	0.742	12,859
2015 Q4	-0.008	0.199	12.651	-1.25	9,264
2016 Q1	-0.074	0.066	-5.976	-0.55	14,274
2016 Q2	-0.076	0.598	6.284	-0.67	13,358
2016 Q3	0,000	0.233	-10.612	2.119	6,674
2016 Q4	0,000	0.566	13.057	2.747	5,881

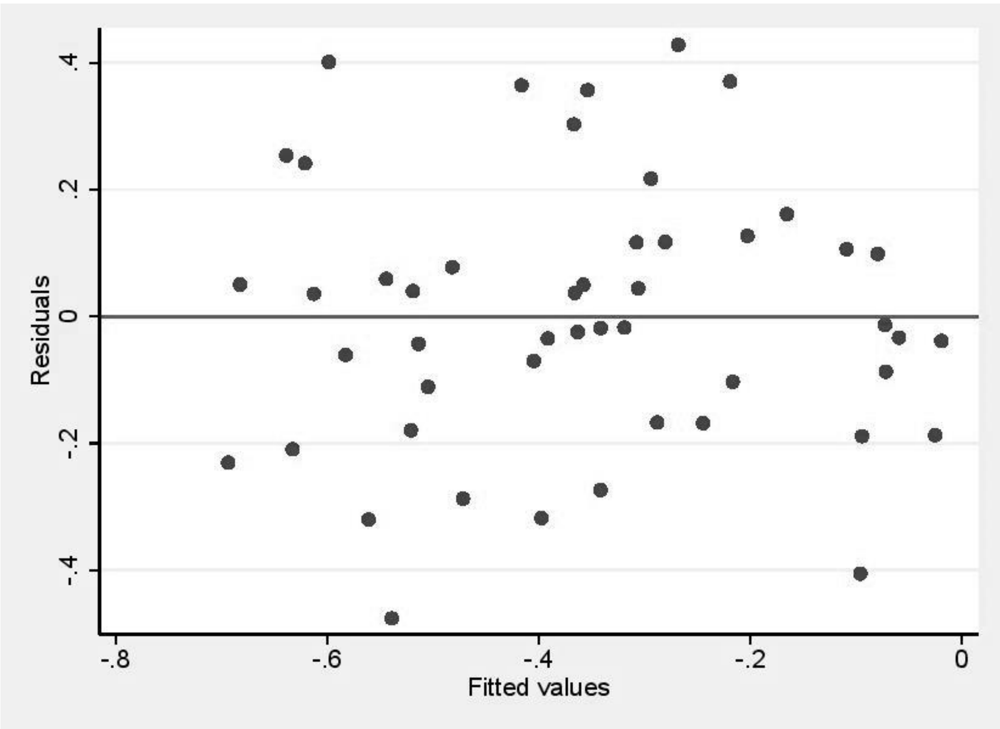
Note: The Table shows the quarterly values of the variables used in the OLS regression models, presented in section 4. Methodology.

Table 6: Phillips-Perron unit root test

Variable	MacKinnon P-value for unit root	N	Newey-West lags
dRepo	0.0696	48	3
Vol	0.0472	48	3
dCurr	0.0009	48	3
gGDP	0.0000	48	3
lnf	0.0000	48	3

Note: The table shows P-values of the Phillips-Perron test for unit roots in the smoothed variables. The test uses a null hypothesis of the variables having a unit root.

Graph 6: Residuals and Fitted values



Note: The graph shows the residuals from the OLS regression using the CCC(1,1)-modeled quarterly correlations, against the fitted values of the regression.

Table 7: Breusch-Pagan & Cook-Weisberg

Variable	χ_2-value	P-value
Fitted Values	0.66	0.4182
dRepo	0.06	0.7997
Vol	0.94	0.3330
dCurr	0.06	0.8141
gGDP	0.34	0.5580
Inf	0.02	0.9014
Time variable	0.00	0.9846

Note: The Table shows P-values of the Breusch-Pagan & Cook-Weisberg heteroscedasticity test for the variables used in the OLS regression of the CCC(1,1) modeled quarterly correlations. The test tests the null hypothesis of constant variance of the residuals in the regression.

Table 8: Correlation Matrix

e(V)	dGDP	dInflation	dTCW	dVol	dRepo
gGDP	1.0000				
Inf	-0.5574	1.0000			
dCurr	-0.1696	-0.1439	1.0000		
Vol	0.3858	0.2308	-0.1784	1.0000	
dRepo	0.1857	-0.6944	-0.4245	0.3623	1.0000

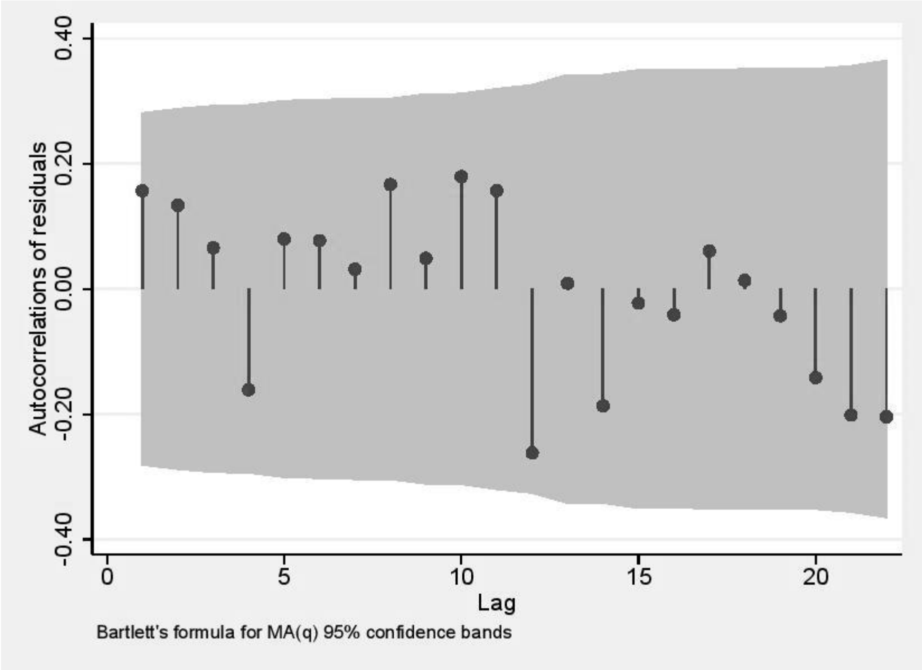
Note: The Table shows the correlation matrix between the explanatory variables in the OLS regression of the CCC(1,1) modeled quarterly correlations.

Table 9: Variance Inflation Factors

Variable	VIF	1/VIF
dRepo	2.28	0.437680
Vol	1.41	0.709473
dCurr	1.43	0.701091
gGDP	1.56	0.641901
Inf	2.45	0.408723
Mean	1.83	

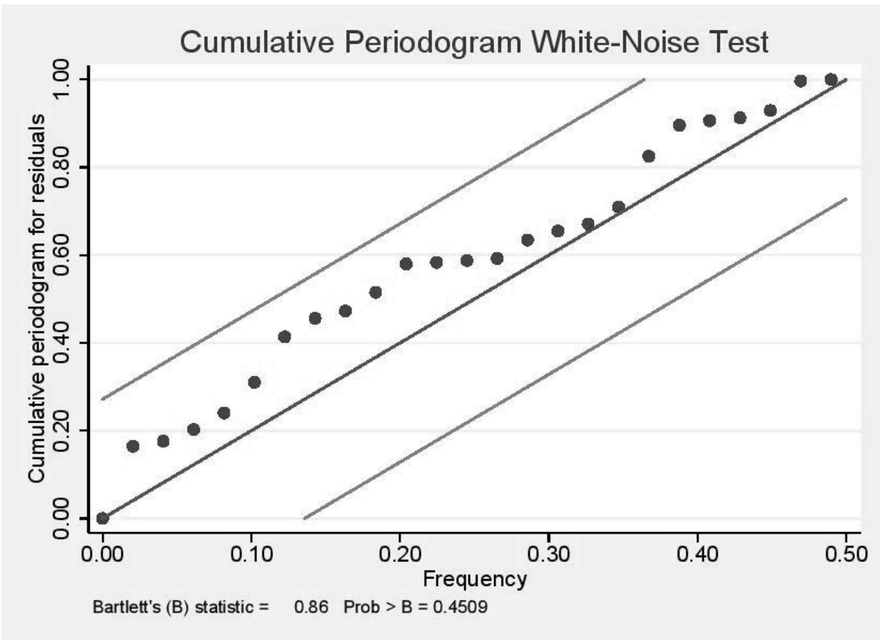
Note: The Table shows the correlation matrix between the explanatory variables in the OLS regression of the CCC(1,1) modeled quarterly correlations.

Graph 7: Bartlett's Correlogram



Note: The Bartlett's correlogram shows the level of autocorrelation for different lags of the residuals from the OLS regression of the CCC(1,1) modeled quarterly correlations.

Graph 8: Bartlett's Periodogram



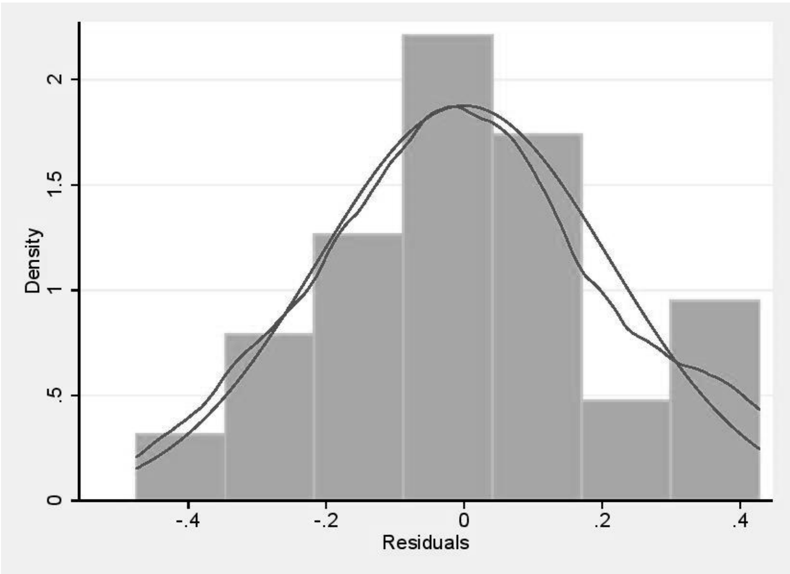
Note: The Bartlett's periodogram shows distribution of residuals from the OLS regression of the CCC(1,1) modeled quarterly correlations.

Table 10: Bartlett's and Portmanteau (Q) test

Test	Statistic	P-value
Portmanteau (Q) statistic	27.1572	0.2053
Bartlett's (B) statistic	0.8569	0.4509

Note: The Table shows P-values for Bartlett's test and the Portmanteau (Q) test for the residuals from the OLS regression of the CCC(1,1) modeled quarterly correlations. Both tests use a null hypothesis of the residuals being a white-noise process of uncorrelated, random variables, having a constant mean and constant variance.

Chart 1: Residual distribution



Note: The chart shows the distribution and a Kernel density estimation curve for the residuals in the OLS regression of the CCC(1,1) modeled quarterly correlations, compared to a normal distribution curve.

Table 11: Jarque-Bera test and D'Agostini's Skewness & Kurtosis test

Test for Residuals	X2-statistic	P-value
Jarque-Bera	0.3012	0.8602
Skewness & Kurtosis	0.11	0.9451

Note: The table shows P-values for a Jarque-Bera test and D'Agostino's Skewness & Kurtosis for the residuals from the OLS regression of the CCC(1,1) modeled quarterly correlations. Both tests use a null hypothesis of the residuals being normally distributed

Table 12: Ramsey's RESET Test

Test results	
F-statistic	1.11
P-value	0.3557

Note: The table shows P-values for Ramsey's regression equation specification error test (RESET) using the variables used in the OLS regression of the CCC(1,1) modeled quarterly correlations. The test uses a null hypothesis of that the relationship of between the response variable and the explanatory variable is best fitted when using the current linear relationships