Conditional Correlations in the Returns on Oil Companies Stock Prices and Their Determinants

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Summary

The identification of the forces that drive stock returns and the dynamics of their associated volatilities is a major concern in empirical economics and finance. This analysis is particularly relevant for determining optimal hedging strategies based on whether shocks to the volatilities of returns of oil companies stock prices, relevant stock market indexes and oil spot and futures prices are high or low, and positively or negatively correlated. This paper investigates the correlations of volatilities in the stock price returns and their determinants for the most important integrated oil companies, namely Bp (BP), Chevron-Texaco (CVX), Eni (ENI), Exxon-Mobil (XOM), Royal Dutch (RD) and Total-Fina Elf (TFE). We measure the actual co-risk in stock returns and their determinants "within" and "between" the different oil companies, using multivariate cointegration techniques in modelling the conditional mean, as well as multivariate GARCH models for the conditional variances. We focus first on the determinants of the market value of each company using the cointegrated VAR/VECM methodology. Then we specifiy the conditional variances of VECM residuals with the Constant Conditional Correlation (CCC) multivariate GARCH model of Bollerslev (1990) and the Dynamic Conditional Correlation (DCC) multivariate GARCH model of Engle (2002). The "within" and "between" DCC indicate low to high/extreme interdependence between the volatilities of companies' stock returns and the relevant stock market indexes or Brent oil prices.

Keywords: Constant conditional correlations, Dynamic conditional correlations, Multivariate GARCH models, Stock price indexes, Brent oil prices, Spot and futures prices, Multivariate cointegration, VECM

JEL Classification: C32, G10, Q40

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1. Introduction

The identification of the forces that drive stock returns and the dynamics of their associated volatilities is a major concern in empirical economics and finance. The assessment of the volatility of stock price returns and their determinants is particularly important in the Oil & Gas sector (O&G), since O&G is one of the largest industries in the world, involving different companies and business in the different chains of production, distillation and distribution.

This paper extends the study of Lanza et al. (2004) and investigates the correlations of volatilities in the stock price returns and their determinants for the most important integrated oil companies, a broad class which ideally include the super majors, regional companies (US, Europe) and national companies. This analysis is particularly relevant for determining optimal hedging strategies based on whether shocks to the volatilities of returns of oil companies stock prices, relevant stock market indexes and oil spot and futures prices are high or low, and positively or negatively correlated.

We measure the actual co-risk in stock returns and their determinants within and across different oil companies, using multivariate cointegration techniques in modelling the conditional mean, as well as multivariate GARCH models for the conditional variance of the errors in the system of conditional means.

We analyze time series data on stock prices of several oil companies of different dimensions and from different countries, together with relevant stock market indexes, exchange rates and crude oil prices. We first focus on the determinants of the market value of each company using the cointegrated VAR/VECM methodology of Johansen and Juselius (1990). Then we specify the conditional variances of VECM residuals with the Constant Conditional Correlation (CCC) multivariate GARCH model of Bollerslev (1990) and the Dynamic Conditional Correlation (DCC) multivariate GARCH model of Engle (2002).

The paper is organized as follows. Section 2 contains a brief review of the relevant literature. The data set is discussed in Section 3. Section 4 is dedicated to modelling the determinants of the stock price returns of different oil companies, as well as their associated volatilities. In Section 5 the main empirical results are presented and discussed. Section 6 concludes.

2. Previous work

Several studies on stock exposures and their determinants are available in the literature. A tentative classification can be based on the types of risk factors and industries which are analyzed. It is possible to identify three broad groups of contributions. The first strand of literature evaluates the risk exposure to exhaustible resources prices for gold mining firms and oil companies. A second group of papers investigates the returns of financial institutions in relation with interest rate changes. The last group of studies considers the sensitivity of multinational corporations stocks to exchange rate risk.

Blose and Shieh (1995) examine the impact of gold price changes on the returns of gold mining stock. The authors derive a model where the gold price elasticity is related to the level of gold prices, the quantity of reserves, the cost of production and the amount of nongold activities, and the gold price sensitivity of a mining stock is grater than one. This hypothesis is not rejected using monthly data over the period 1981-1990 for a sample of commonly traded companies.

Tufano (1998) studies gold price exposures of North American gold mining firms and their determinants. Data from January 1990 to March 1994 show that gold mining stocks respond more than proportionally to gold price changes, and the exposures vary considerably over time and across firms.

Strong (1991) analyses the ability of oil equities portfolios to hedge oil price risk. In addition to the estimation of exposure coefficients of oil companies, the author constructs portfolios aimed at maximizing sensitivity to oil price changes and at diversifying away other risk. Using monthly data over the period 1975-1987, the oil price sensitivity of firms returns appears to be low or not significant, and on average the percentage of oil price changes offset by the returns of the hedge portfolio is only about one-third.

Flannery and James (1984) analyse the effect of interest rate changes on common stock returns of financial institutions. Using a sample of commercial banks and stock savings and loan associations from January 1976 to November 1980, common stock returns are found to be correlated with interest rate changes. Cross-sectional differences in the results arise from differences in the maturity composition of nominal assets: the longer the maturity of bank's nominal assets, the larger the interest rate sensibility.

Elyasani and Mansur (1998) analyse the sensitivity of banks stock returns to changes in interest rate. A GARCH-M specification is employed to investigate whether volatility is a significant factor in determining risk premia; the GARCH-M specification is extended to include the interest rate volatility effect on bank stock volatility and risk premia and to allow for shifts in the stochastic process due to changes in monetary policy regimes. This model seems to be statistically adequate on monthly data for the period 1970-1992. In particular, the degree of persistence in shocks and the effect of interest rate volatility are substantial and depend on the nature of bank portfolio and on the prevailing monetary policy regime.

Jorion (1990) estimates exchange rate exposure of US multinationals over the period from January 1971 to December 1987. Statistical tests are performed to determine whether the exposure coefficients differ across firms. The hypothesis of equal coefficients is strongly rejected for multinationals, but not for domestic firms without foreign operations. The determinant of exchange rate exposure are therefore analysed and a direct relation between exchange rate sensitivity and the percentage of foreign operations is assessed.

Bartov et al. (1996) consider two five-year periods around the 1973 switch from fixed to floating exchange-rates to examine the relation between exchange rate variability and stock returns volatility. A significant generalised increase in the volatility of equity returns during the second period is found. Moreover, this increase is significantly larger for US multinationals than for other US firms, and only multinationals show a significant increase in market risk corresponding to the increase in exchange rate volatility.

He and Ng (1998) examine the effect of exchange rate fluctuations on stock's returns and the determining factors for Japanese multinationals. About 25 percent of the considered multinationals show positive exposure over the period from January 1979 to December 1993. The level of export ratio as well as variables that are proxies of the firm's hedging policies are found to affect exchange rate sensitivity. Exposure coefficients are smaller for firms with low liquidity or high financial leverage, and for small Japanese multinationals. Moreover, evidence is provided that industrial grouping is likely to affect hedging needs and exchange rate exposure of firms.

In summary, all the surveyed studies refer to US, except Strong (1991), who considers the world's major oil companies, and He and Ng (1998), who concentrate on Japanese multinational firms. From a methodological viewpoint, all authors estimate the exposure coefficients (betas) and analyse the estimated betas against their determinants. Elyasiani and Mansur (1998) extend this approach by relating bank stock returns to their conditional variance, while Strong (1991) uses the estimated betas as a first step for constructing portfolios aimed at hedging oil price risk.

3. Data Description

We investigate companies from several countries and with different business volumes and targeted markets (global or regional), namely: Bp (BP, UK), Chevron-Texaco (CVX, US), Eni (ENI, Italy), Exxon-Mobil (XOM, US), Royal Dutch (RD, The Netherlands), and Total-Fina-Elf (TFE, France). The stock price series (STOCK) for each company is the closing price quoted in the stock market of the company's country of origin.[1] For the six selected oil companies the relevant stock indexes (INDEX) are: FTSE (UK), Dow Jones (DJ, US), MIB30 (Italy), AEX (The Netherlands) and CAC40 (France).

Moreover, given the presence of companies from UK and countries belonging to the European Monetary Union, we consider the closing quotations of the exchange rates (ER) of the US dollar (USD) against the Euro (EUR) and British pound (GBP).[2]

The selected crude oil prices are dated Brent for the spot series and futures Brent prices with twelve-month maturities.[3]

The sample period ranges from 23 January 1998 to 4 April 2003, and the frequency of observations is weekly. All prices are log-transformed and expressed in

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[1] For RD the relevant stock market is the Dutch market.

[2] Reuters is the main source for company stock values, market indexes and exchange rates

[3] Spot and futures prices of Brent are from Platt's.

local currencies, with the only exception of crude prices, which are denominated in USD per barrel.

Augmented Dickey-Fuller statistics are used to investigate the time series properties of the data. All variables are integrated of order one, or I(1), most of them with intercept but no trend.[4]

4. Modelling Oil Company Stock Returns and Volatility

We consider each company separately and analyze, using a VAR/VECM, the existence of long-run relations and short-run effects among the market value of the company, the difference between twelve-month futures price and spot price on Brent (SPREAD), and the relevant stock market index and exchange rate, the latter being only for non-US companies.

Although individually I(1), these series may still form one or more linear combinations which are stationary, or I(0). In this case, there are one or more long-run equilibrium relationships among the variables entering the VAR specification, which are said to be cointegrated.

The Maximum Likelihood method proposed by Johansen (1991) tests the presence of cointegration among the variables in the mx1 vector X_t by determining the rank of the long-run matrix, P. If $rank(P) = r$, with $0<r<m$, the matrix P can be decomposed as $\Pi = l b'$, where l is a mxr matrix of adjustment parameters and b is a mxr matrix containing the r cointegrating relations among the variables X_t. The Johansen approach enables estimation of the b parameters, and to test for the number of I(0) linear combinations among the X_t variables.

With the number r of cointegrating relationships determined, the following VECM can be estimated by OLS:

[4] Results from Augmented Dickey-Fuller tests, although not reported to save space, are available from the authors upon request.

$$\Delta X_t = m_0 + m_1 t + l\, ecm_{t-P} + \sum_{p=1}^{P-1} A_p \Delta X_{t-p} + e_t \qquad (1)$$

where m_0 is a mx1 vector of constants, t = 1,…,n is a deterministic trend, m_1 is a mx1 vector of deterministic linear trend coefficients, e_t is a mx1 error vector, and $ecm_{t-p} \equiv \hat{b}' X_{t-p}$ is the $rx1$ vector of long-run equilibria among the X_t variables.

Testing the significance of the estimated l parameters in system (1) determines which variables can be considered as (weakly) exogenous (see Urbain, 1992). Specifically, the dependent variables of equations where the estimates of the l are not statistically significant can be treated as exogenous. This enables estimation of a parsimonious conditional VECM formed from the equations of the remaining endogenous variables. Each equation is augmented by the full set of exogenous variables in terms of first-differences.

Next, we look for the presence of ARCH effects in the errors of the conditional VECM equations, using univariate GARCH(1,1) models of the type:

$$h_{it} = w_i + a_i e_{it-1}^2 + b_i h_{it-1}, \qquad (2)$$

where i = 1,…,m, indicates the i-th equation in the VECM, and h_{it} is the conditional variance of e_{it}, the error term of the i-th equation. If a_i or a_i and b_i are significant, then ARCH or GARCH effects are present. In order for this test to be meaningful, the necessary and sufficient condition for the existence of the second moments of e_{it}, namely $a_i + b_i < 1$, should be satisfied, since this condition is also sufficient for the Quasi-Maximum Likelihood Estimator (QMLE) to be consistent and asymptotically normal. Jeantheau (1998) showed that the log-moment condition, $E\left(\log\left(a_i h_{it}^2 + b_i\right)\right) < 0$, $h_{it} = e_{it} \big/ \sqrt{h_{it}}$, is sufficient for the QMLE to be consistent for GARCH(1,1).

If conditional heteroskedasticity is found at the single-equation level, a system approach to the analysis of non-constant conditional error variances can be used.

The time-varying behaviour of the conditional covariance matrix of the VECM errors, $e_t = (e_{1t},...,e_{mt})'$, can be described using a a multivariate GARCH model. A general expression for heteroskedastic system error terms is:

$$e_t = H_t h_t \qquad (3)$$

where H_t is the square root of a mxm symmetric matrix of conditional variances and covariances, and h_t is an $mx1$ vector of i.i.d. standardized errors. From expression (3), it follows that $E(e_t \mid \Omega_{t-1}) = 0$ and $E(e_t e_t^{'} \mid \Omega_{t-1}) = H_t$, with W_{t-1} denoting the information set at time t-1.

A GARCH-type parameterization of the covariance matrix of e_t should allow H_t to depend on lagged shocks e_{t-q}, q=1,..,Q, and on its own past H_{t-p}, $p=1,..,P$. However, in this case the number of parameters to be estimated is too large and conditions for H_t to be positive definite can be complicated to impose.

A model which drastically solves these problems is the CCC multivariate GARCH model of Bollerslev (1990). In the CCC specification, $H_t = diag\left(h_{1t}^{1/2},...,h_{mt}^{1/2}\right)$ and, setting Q=P=1, the conditional variance for each return is assumed to follow the univariate GARCH process (2), that is the conditional variance of the i-th return is assumed to be independent of the conditional variance of the j-th return, i,j = 1,…,m. In order to calculate the constant conditional correlation matrix Γ, whose typical element is r_{ij}, i,j = 1,…,m, m univariate GARCH(1,1) models should be estimated with QMLE, the m standardized residuals $\hat{h}_{it}$ calculated, and the m correlation coefficients obtained as $\hat{r}_{ij} = \sum_{t=1}^{n} \hat{h}_{it}\hat{h}_{jt} \Big/ n$, i,j = 1,…,m.

If h_t is not a sequence of i.i.d. random error, the assumption of constant conditional correlation is no longer valid. In order to model the time-varying behaviour of the conditional correlation matrix Γ_t, Engle (2002) introduced the DCC multivariate GARCH:

$$\Gamma_t = (1 - q_1 - q_2)\Gamma + q_1 h_t h_t' + q_2 \Gamma_{t-1}, \qquad (4)$$

where q_1 and q_2 are scalar parameters to capture the effects of previous standardized shocks and dynamic conditional correlations on current dynamic conditional correlations, respectively.

5. Empirical Results

According to the Johansen cointegration procedure outlined in Section 4, there is one cointegrating relation among the variables STOCK, SPREAD, INDEX and ER for each of the six oil companies under analysis (see Tables 1a-6a).

The estimated adjustment coefficients in the VECM representations are reported in Tables 1b-6b. In all models, the significance of the estimated parameters l (that is the coefficients of the variables ECT(-1)) indicates that one or two variables can be considered to be weakly exogenous in the VECM, and that the number of equations can be reduced to form a parsimonious VECM. In particular, the market index seems to be endogenous for those companies (ENI, RD, TFE) whose capitalization is large, compared with the size of the relevant stock market. The spread variable is found to be endogenous for BP, XOM, CVX and RD. Estimates of the loading coefficients which correspond to the exchange rate equations are never significant, confirming the expected exogeneity of ER. The autoregressive structure of the estimated models seems to be statistically adequate, since the null hypothesis of no residual autocorrelation is never rejected by the system LM tests reported on the bottom of Tables 1b-6b.

The univariate estimates of the conditional volatilities in the residuals of each parsimonious VECM system are given in Tables 7a-7f. The three entries for each parameter are their respective estimates, asymptotic t-ratios and Bollerslev-Wooldridge (1992) robust t-ratios. Four companies of six have significant ARCH(1) or GARCH(1,1) effects in the residuals of all equations forming the parsimonious VECM. Oil company CVX has significant GARCH(1,1) effects in the STOCK equation only (Table 7b), whereas oil company BP does not exhibit significant ARCH(1) or GARCH(1,1) effects in either the STOCK or the SPREAD equation. Both second moment and log moment conditions are satisfied, so that the QMLE are consistent and asymptotically normal.

The standardized residuals from each of the estimated univariate GARCH(1,1) models are used to compute the constant conditional correlations reported in Tables 8a-8b.

The CCC presented in Table 8a are calculated on the VECM standardized residuals “within” each company. Four are the companies for which the STOCK and SPREAD variables are endogenous according to the VECM specification, namely BP, CVX, RD and XOM. Shocks to volatilities in the returns of STOCK and SPREAD are significantly correlated for RD and BP only. The variable INDEX is endogenous for oil companies ENI, RD and TFE. In this case, the shocks to volatilities in STOCK and INDEX are significantly correlated for all companies. Moreover, the corresponding CCC are the highest, and vary between 0.481 (ENI) and 0.553 (TFE). The only company with three endogenous variables, i.e. STOCK, INDEX and SPREAD, is RD. The CCC in the shocks to the volatilities of SPREAD and INDEX for RD is low and statistically insignificant.

Table 8b reports the constant conditional correlations “between” the volatilities of the STOCK equations of different companies. These correlations are the highest for the pairs BP-RD, BP-TFE and CVX-XOM, being 0.744, 0.680 and 0.632 respectively, whereas the CCC are the lowest for companies TFE-XOM, ENI-XOM and ENI-CVX, (i.e. 0.259, 0.262, 0.280 respectively), although they are all statistically significant.

Finally, the DCC-GARCH(1,1) estimates are given in Tables 9a-9b. As the estimates “within” companies are concerned, at least one of the two DCC parameters is statistically significant for four of six companies, which makes it clear that the assumption of CCC is not, in general, empirically supported. For oil companies BP and CVX the parameters q_1 and q_2 are not statistically significant, which is not surprising since in both cases the CCC were low (-0.120 and 0.070, respectively) and insignificant. The parameters of the DCC-GARCH(1,1) model applied to the STOCK equation “between” companies show even stronger results against the assumption of constant conditional correlations. In this case, q_2 is always highly significant, while q_1 is insignificant only for three pairs of eight.

The significant DCC for oil companies ENI, RD, TFE and XOM, as well as for the pairs of equations STOCK-SPREAD, STOCK-INDEX and SPREAD-INDEX are plotted against time and presented in Figures 1-4. The DCC with the highest range of variation are related to the pair STOCK-INDEX. The range of variation of the DCC for ENI is (0.028, 0.912), (0.120, 0.792) for RD, and (0.323, 0.728) for TFE, indicating, whithin each oil company, low to high/extreme interdependence between the volatilities of the companies' stock returns and the relevant stock market indexes. Figures 5-12 report the plots against time of the "between" DCC for the pairs of companies with the eight highest CCC. Among the eight pairs of companies, the DCC characterized by the larger range of variation are for the pairs BP-ENI (0.187, 0.800), CVX-XOM (0.258, 0.808), ENI-TFE (0.216, 0.840) and RD-TFE (0.337, 9.38). As in the case of the "within" DCC, the wide ranges of variation suggest that the volatilities associated with stock price returns of different oil companies go from low to high/extreme interdependence. These results are particularly relevant for determining optimal hedging strategies based on the sign, size, and temporal variation of the correlation of shocks to the returns of oil companies stock prices, relevant stock market indexes and oil spot and futures prices.

6. Conclusion

This paper has investigated the correlations in the stock price returns and their determinants for the most important integrated oil companies, namely Bp (BP), Chevron-Texaco (CVX), Eni (ENI), Exxon-Mobil (XOM), Royal Dutch (RD) and Total-Fina Elf (TFE).

We have measured the actual co-risk in stock returns and their determinants within and between different oil companies, using multivariate cointegration techniques in modelling the conditional mean, as well as multivariate GARCH for the conditional variances in the system of conditional means.

We have analyzed time series data on stock prices of six oil companies of different dimensions and from different countries, together with relevant stock market indexes, exchange rates and crude oil prices. We have focussed on the determinants of the market value of each company using the cointegrated VAR/VECM methodology. Then we have specified the conditional variances of VECM residuals with the Constant Conditional Correlation (CCC) multivariate GARCH model of Bollerslev

(1990) and the Dynamic Conditional Correlation (DCC) multivariate GARCH model of Engle (2002).

The CCC are calculated on pairs of VECM standardized residuals “within” each company. Four are the companies for which the STOCK and SPREAD variables are endogenous according to the VECM specification, namely BP, CVX, RD and XOM. Shocks to volatilities in the returns of STOCK and SPREAD are significantly correlated for RD and BP only. The variable INDEX is endogenous for oil companies ENI, RD and TFE. In this case, the shocks to volatilities in STOCK and INDEX are significantly correlated for all companies. Moreover, the corresponding CCC are the highest.

We have also calculated the constant conditional correlations “between” the STOCK equations of different companies. The correlations of shocks to volatilities in the STOCK equations are the highest for the pairs BP-RD, BP-TFE and CVX-XOM, whereas the CCC are the lowest for companies TFE-XOM, ENI-XOM and ENI-CVX, although they are all statistically significant.

As the estimates “within” companies are concerned, at least one of the two DCC-GARCH(1,1) parameters are statistically significant for four of six companies, which makes it clear that the assumption of CCC is not, in general, empirically supported. The parameters of the DCC-GARCH(1,1) model applied to the STOCK equation “between” companies show even stronger results against the assumption of constant conditional correlations.

The significant DCC for oil companies ENI, RD, TFE and XOM, as well as for the pairs of equations STOCK-SPREAD, STOCK-INDEX and SPREAD-INDEX are plotted against time, indicating, whithin each oil company, low to high/extreme interdependence between the volatilities of companies’ stock returns and the relevant stock market indexes. We have also reported the plots against time of the “between” DCC for the pairs of companies with the eight highest CCC. As in the case of the “within” DCC, the wide ranges of variation suggest that the volatilities associated with stock price returns of different oil companies go from low to high/extreme interdependence.

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Table 1a: Unrestricted cointegration rank tests – Oil company BP

N° of coint. vects. Tests	None	At most 1	At most 2	At most 3
Trace	43.042 47.21	15.083 29.68	6.472 15.41	1.319 3.76
Max-eigenvalue	27.959 27.07	8.611 20.97	5.153 14.07	1.319 3.76

Note: Each pair of entries is the calculated statistic and the five percent critical value.

Table 1b: VECM estimates and diagnostics – Oil company BP

Equations Variables	STOCK	SPREAD	INDEX	ER
ECT(-1)	-0.115 -3.168	-0.127 -3.326	-0.006 -0.234	-0.004 -0.387
C	0.0004 0.164	-0.0009 -0.347	-0.001 -0.699	-0.0003 -0.380
LM autocorrelation test	10.762 0.824			

Notes: Each pair of entries is the estimated coefficient of a specific variable in a specific equation, and its asymptotic t-ratios. Entries for the Lagrange Multiplier (LM) autocorrelation test, reported at the bottom of the table, are the calculated value of the system test for residual serial correlation of order 2, and the corresponding p-value. Under the null of no serial correlation, this statistic is distributed as χ^2 with m^2 degree of freedom (where m is the number of equations).

Table 2a: Unrestricted cointegration rank tests – Oil company CVX

N° of coint. vects. Tests	None	At most 1	At most 2
Trace	34.114 29.68	8.760 15.41	3.691 3.76
Max-eigenvalue	25.354 20.97	5.069 14.07	3.691 3.76

Note: Each pair of entries is the calculated statistic and the five percent critical value.

Table 2b: VECM estimates and diagnostics – Oil company CVX

Equations Variables	STOCK	SPREAD	INDEX
ECT(-1)	-0.105 -3.424	0.107 2.698	0.018 0.706
ΔSTOCK(-1)	-0.071 -1.074	-0.286 -3.354	0.082 1.461
ΔSPREAD(-1)	-0.021 -0.445	0.055 0.918	0.071 1.792
ΔINDEX(-1)	0.008 0.108	-0.008 -0.077	-0.103 -1.524
C	-0.0006 -0.287	-0.0009 -0.352	0.0003 0.174
LM autocorrelation test		5.558 0.783	

Notes: Each pair of entries is the estimated coefficient of a specific variable in a specific equation, and its asymptotic t-ratios. Entries for the Lagrange Multiplier (LM) autocorrelation test, reported at the bottom of the table, are the calculated value of the system test for residual serial correlation of order 2, and the corresponding p-value. Under the null of no serial correlation, this statistic is distributed as χ^2 with m^2 degree of freedom (where m is the number of equations).

Table 3a: Unrestricted cointegration rank tests – Oil company ENI

N° of coint. vects. Tests	None	At most 1	At most 2	At most 3
Trace	49.510 47.21	20.334 29.68	10.188 15.41	4.455 3.76
Max-eigenvalue	29.176 27.07	10.146 20.97	5.733 14.07	4.455 3.76

Note: Each pair of entries is the calculated statistic and the five percent critical value.

Table 3b: VECM estimates and diagnostics – Oil company ENI

Equations Variables	STOCK	SPREAD	INDEX	ER
ECT(-1)	-0.134 -4.723	-0.020 -0.614	-0.118 -4.636	0.005 0.459
ΔSTOCK(-1)	-0.157 -2.113	-0.054 -0.651	-0.132 -1.981	0.045 1.679
ΔSPREAD(-1)	0.015 0.280	0.002 0.029	-0.017 -0.344	0.012 0.584
ΔINDEX(-1)	0.121 1.475	-0.167 -1.804	0.222 3.012	-0.027 -0.914
ΔER(-1)	0.131 0.733	0.146 0.726	-0.009 -0.055	-0.016 -0.240
C	0.001 0.407	-0.001 -0.333	-0.0005 -0.226	-5.54E-05 -0.065
LM autocorrelation test	20.280 0.208			

Notes: Each pair of entries is the estimated coefficient of a specific variable in a specific equation, and its asymptotic t-ratios. Entries for the Lagrange Multiplier (LM) autocorrelation test, reported at the bottom of the table, are the calculated value of the system test for residual serial correlation of order 2, and the corresponding p-value. Under the null of no serial correlation, this statistic is distributed as χ^2 with m^2 degree of freedom (where m is the number of equations).

Table 4a: Unrestricted cointegration rank tests – Oil company RD

N° of coint. vects. Tests	None	At most 1	At most 2	At most 3
Trace	70.819 62.99	33.904 42.44	13.664 25.32	4.975 12.25
Max-eigenvalue	36.915 31.46	20.240 25.54	8.690 18.96	4.975 12.25

Note: Each pair of entries is the calculated statistic and the five percent critical value.

Table 4b: VECM estimates and diagnostics – Oil company RD

Equations Variables	STOCK	SPREAD	INDEX	ER
ECT(-1)	-0.090 -3.436	-0.093 -3.454	-0.059 -2.597	-0.016 -1.864
C	-0.0008 -0.0.316	-0.0008 -0.320	-0.002 -0.789	-1.58E-05 -0.019
LM autocorrelation test	12.162 0.733			

Notes: Each pair of entries is the estimated coefficient of a specific variable in a specific equation, and its asymptotic t-ratios. Entries for the Lagrange Multiplier (LM) autocorrelation test, reported at the bottom of the table, are the calculated value of the system test for residual serial correlation of order 2, and the corresponding p-value. Under the null of no serial correlation, this statistic is distributed as χ^2 with m^2 degree of freedom (where m is the number of equations).

Table 5a: Unrestricted cointegration rank tests – Oil company TFE

N° of coint. vects. / Tests	None	At most 1	At most 2	At most 3
Trace	60.801 47.21	19.646 29.68	10.026 15.41	3.167 3.76
Max-eigenvalue	41.155 27.07	9.621 20.97	6.859 14.07	3.167 3.76

Note: Each pair of entries is the calculated statistic and the five percent critical value.

Table 5b: VECM estimates and diagnostics – Oil company TFE

Equations / Variables	STOCK	SPREAD	INDEX	ER
ECT(-1)	-0.215 -5.254	-0.078 -1.930	-0.098 -3.111	-0.011 -0.854
C	0.001 0.447	-0.0009 -0.343	-0.0002 -0.078	-0.0001 -0.138
LM autocorrelation test	19.476 0.245			

Notes: Each pair of entries is the estimated coefficient of a specific variable in a specific equation, and its asymptotic t-ratios. Entries for the Lagrange Multiplier (LM) autocorrelation test, reported at the bottom of the table, are the calculated value of the system test for residual serial correlation of order 2, and the corresponding p-value. Under the null of no serial correlation, this statistic is distributed as χ^2 with m^2 degree of freedom (where m is the number of equations).

Table 6a: Unrestricted cointegration rank tests – Oil company XOM

N° of coint. vects. / Tests	None	At most 1	At most 2
Trace	47.635 42.44	20.110 25.32	5.411 12.25
Max-eigenvalue	27.524 25.54	14.700 18.96	5.411 12.25

Note: Each pair of entries is the calculated statistic and the five percent critical value.

Table 6b: VECM estimates and diagnostics – Oil company XOM

Equations / Variables	STOCK	SPREAD	INDEX
ECT(-1)	-0.115 -2.793	0.178 3.410	0.025 0.710
ΔSTOCK(-1)	-0.199 -2.719	-0.295 -3.175	-0.050 -0.811
ΔSPREAD(-1)	0.022 0.467	0.042 0.709	0.073 1.848
ΔINDEX(-1)	-0.048 -0.534	0.053 0.467	-0.034 -0.458
C	0.0008 0.412	-0.0006 -0.228	0.0003 0.165
LM autocorrelation test		7.245 0.612	

Notes: Each pair of entries is the estimated coefficient of a specific variable in a specific equation, and its asymptotic t-ratios. Entries for the Lagrange Multiplier (LM) autocorrelation test, reported at the bottom of the table, are the calculated value of the system test for residual serial correlation of order 2, and the corresponding p-value. Under the null of no serial correlation, this statistic is distributed as χ^2 with m^2 degree of freedom (where m is the number of equations).

Table 7a: Univariate GARCH(1,1) estimates – Oil company BP

Residuals of VECM equations:	ω	α	β	Log-moment	Second moment
STOCK	0.0005 0.804 0.897	0.066 0.941 1.093	0.616 1.455 1.605	-0.389	0.683
SPREAD	0.0005 0.649 0.472	0.033 0.663 0.598	0.693 1.512 1.144	-0.323	0.726

Note: The three entries for each parameter are their respective estimates, asymptotic t-ratios and Bollerslev-Wooldridge (1992) robust t-ratios.

Table 7b: Univariate GARCH(1,1) estimates – Oil company CVX

Residuals of VECM equations:	ω	α	β	Log-moment	Second moment
STOCK	4.51E-05 0.914 1.015	0.052 1.365 1.524	0.897 10.705 13.051	-0.054	0.950
SPREAD	0.001 0.769 0.963	0.070 1.066 0.863	0.321 0.385 0.503	-0.966	0.391

Note: The three entries for each parameter are their respective estimates, asymptotic t-ratios and Bollerslev-Wooldridge (1992) robust t-ratios.

Table 7c: Univariate GARCH(1,1) estimates – Oil company ENI

Residuals of VECM equations:	ω	α	β	Log-moment	Second moment
STOCK	0.0004 1.705 0.895	0.113 2.566 0.917	0.611 3.417 1.540	-0.343	0.724
INDEX	0.0005 2.594 4.017	0.305 3.658 2.308	0.193 0.861 1.475	-0.948	0.498

Note: The three entries for each parameter are their respective estimates, asymptotic t-ratios and Bollerslev-Wooldridge (1992) robust t-ratios.

Table 7d: Univariate GARCH(1,1) estimates – Oil company RD

Residuals of VECM equations:	ω	α	β	Log-moment	Second moment
STOCK	0.0008 2.112 3.052	0.276 3.524 1.969	0.241 0.975 1.158	-0.837	0.517
SPREAD	0.0005 0.803 0.426	0.028 0.589 0.572	0.709 1.964 1.116	-0.306	0.738
INDEX	9.64E-05 1.632 2.009	0.247 3.666 2.474	0.698 7.281 7.217	-0.106	0.945

Note: The three entries for each parameter are their respective estimates, asymptotic t-ratios and Bollerslev-Wooldridge (1992) robust t-ratios.

Table 7e: Univariate GARCH(1,1) estimates – Oil company TFE

Residuals of VECM equations:	ω	α	β	Log-moment	Second moment
STOCK	0.0002 1.167 0.605	0.064 1.091 1.153	0.790 5.218 2.775	-0.162	0.855
INDEX	0.0001 1.189 1.317	0.110 2.031 1.673	0.777 6.140 5.823	-0.132	0.887

Note: The three entries for each parameter are their respective estimates, asymptotic t-ratios and Bollerslev-Wooldridge (1992) robust t-ratios.

Table 7f: Univariate GARCH(1,1) estimates – Oil company XOM

Residuals of VECM equations:	ω	α	β	Log-moment	Second moment
STOCK	0.0001 0.915 1.037	0.055 1.238 1.085	0.784 4.028 4.037	-0.181	0.839
SPREAD	4.71E-05 0.531 0.602	0.028 1.093 1.109	0.943 13.487 15.466	-0.029	0.971

Note: The three entries for each parameter are their respective estimates, asymptotic t-ratios and Bollerslev-Wooldridge (1992) robust t-ratios.

Table 8a: Constant conditional correlations (CCC) – “within”

Oil companies	Standardized residuals of VECM equations:	CCC
BP	STOCK,SPREAD	-0.120 -2.054
CVX	STOCK,SPREAD	0.070 1.206
ENI	STOCK,INDEX	0.481 10.421
RD	STOCK,SPREAD	-0.143 -2.351
	STOCK,INDEX	0.508 11.372
	SPREAD,INDEX	-0.046 -0.727
TFE	STOCK,INDEX	0.553 15.619
XOM	STOCK,SPREAD	0.053 0.922

Note: The two entries for each CCC are their respective estimates and asymptotic t-ratios.

Table 8b: Constant conditional correlations (CCC) – “between”

Std. res. of VECM eq. STOCK for oil companies	BP	CVX	ENI	RD	TFE	XOM
BP	1.000					
CVX	0.509 11.876	1.000				
ENI	0.464 9.595	0.280 5.435	1.000			
RD	0.744 28.993	0.404 7.718	0.546 16.045	1.000		
TFE	0.680 20.819	0.346 6.464	0.543 15.756	0.732 26.161	1.000	
XOM	0.363 7.565	0.632 19.547	0.262 4.627	0.287 5.567	0.259 5.051	1.000

Note: The two entries for each CCC are their respective estimates and asymptotic t-ratios.

Table 9a: DCC-GARCH(1,1) estimates – “within”

Oil companies	Standardized residuals of VECM equations:	θ_1	θ_2
BP	STOCK, SPREAD	0.010 0.217	0.633 0.643
CVX	STOCK, SPREAD	0.126 1.584	-0.069 -0.211
ENI	STOCK, INDEX	0.198 2.502	0.106 0.430
RD	STOCK, SPREAD	0.006 0.491	0.973 18.721
	STOCK, INDEX	0.032 2.620	0.964 57.423
	SPREAD, INDEX	0.033 0.575	0.758 3.128
TFE	STOCK, INDEX	0.054 0.695	0.841 2.314
XOM	STOCK, SPREAD	-0.008 -1.247	0.976 49.480

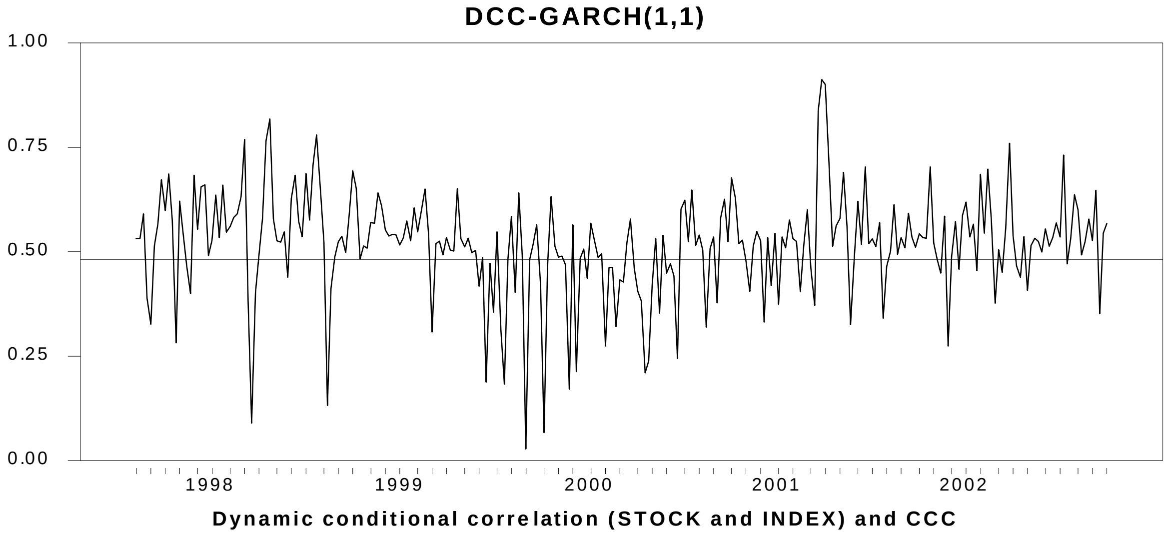
Notes: The model is $\Gamma_t = (1 - q_1 - q_2)\Gamma + q_1 h_{t-1} h'_{t-1} + q_2 \Gamma_{t-1}$. The two entries for each parameter are their respective estimates and asymptotic t-ratios.

Table 9b: DCC-GARCH(1,1) estimates – “between”

Std. res. of VECM eq. STOCK for oil companies	θ_1	θ_2
BP, CVX	0.066 1.215	0.586 2.455
BP, ENI	0.046 2.131	0.931 27.340
BP, RD	0.032 2.444	0.963 47.977
BP, TFE	0.028 1.406	0.951 27.021
CVX, XOM	-0.026 -7.757	0.993 139.836
ENI, RD	0.028 1.751	0.946 31.084
ENI, TFE	0.042 2.965	0.948 49.447
RD, TFE	0.065 2.827	0.925 33.890

Notes: The model is $\Gamma_t = (1 - q_1 - q_2)\Gamma + q_1 h_{t-1} h'_{t-1} + q_2 \Gamma_{t-1}$. The two entries for each parameter are their respective estimates and asymptotic t-ratios.

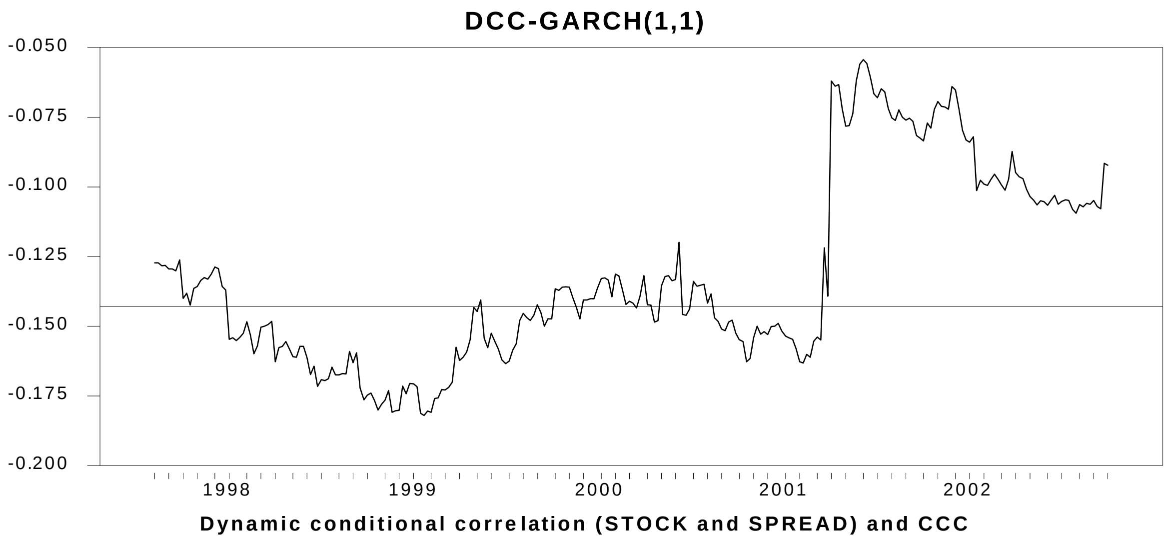
Figure 1: Dynamic conditional correlation between STOCK and INDEX – Oil Company ENI



Descriptive statistics on DCC – Oil company ENI

MEAN	0.519
MINIMUM	0.028
MAXIMUM	0.912
STANDARD DEVIATION	0.124
SKEWNESS	-0.680
EXCESS KURTOSIS	2.628

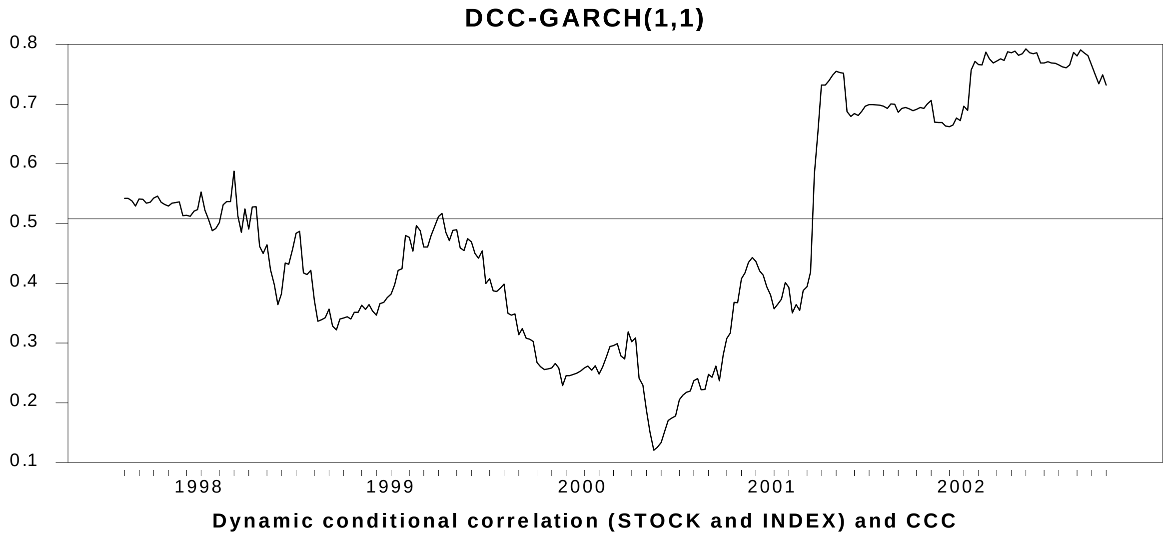
Figure 2a: Dynamic conditional correlation between STOCK and SPREAD – Oil Company RD



Descriptive statistics on DCC – Oil company RD (STOCK and SPREAD)

MEAN	-0.132
MINIMUM	-0.182
MAXIMUM	-0.054
STANDARD DEVIATION	0.034
SKEWNESS	0.705
EXCESS KURTOSIS	-0.607

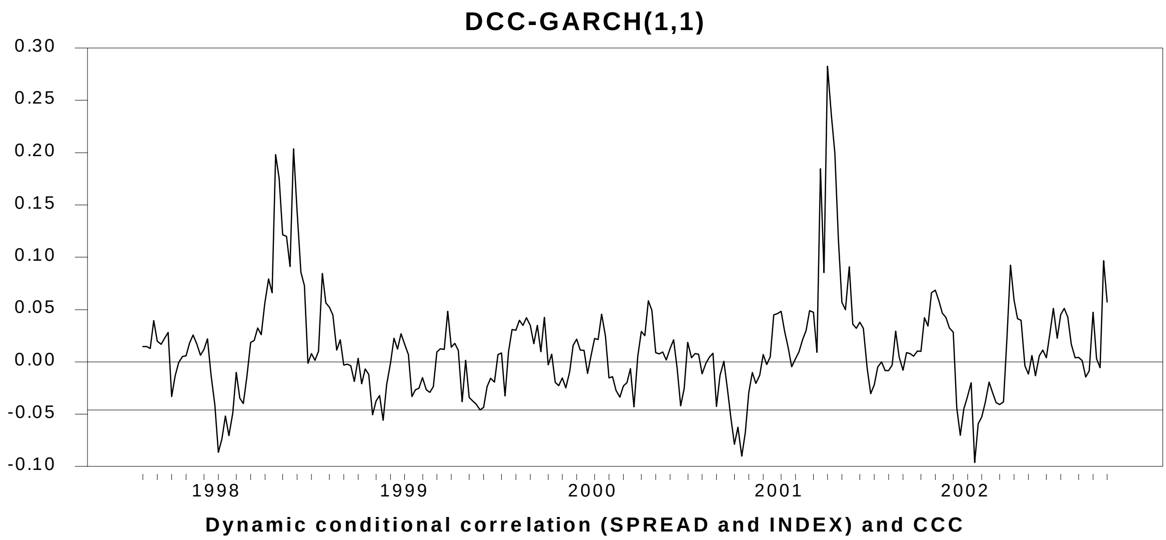
Figure 2b: Dynamic conditional correlation between STOCK and INDEX – Oil Company RD



Descriptive statistics on DCC – Oil company RD (STOCK and INDEX)

MEAN	0.486
MINIMUM	0.120
MAXIMUM	0.792
STANDARD DEVIATION	0.187
SKEWNESS	0.171
EXCESS KURTOSIS	-1.141

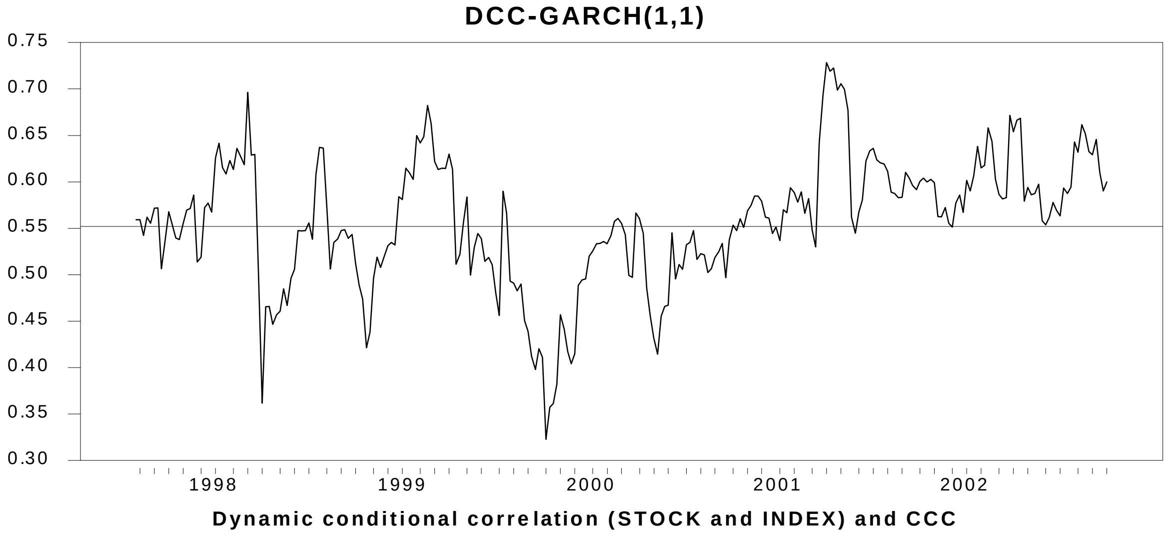
Figure 2c: Dynamic conditional correlation between SPREAD and INDEX – Oil Company RD



Descriptive statistics on DCC – Oil company RD (SPREAD and INDEX)

MEAN	0.012
MINIMUM	-0.096
MAXIMUM	0.282
STANDARD DEVIATION	0.050
SKEWNESS	1.795
EXCESS KURTOSIS	6.374

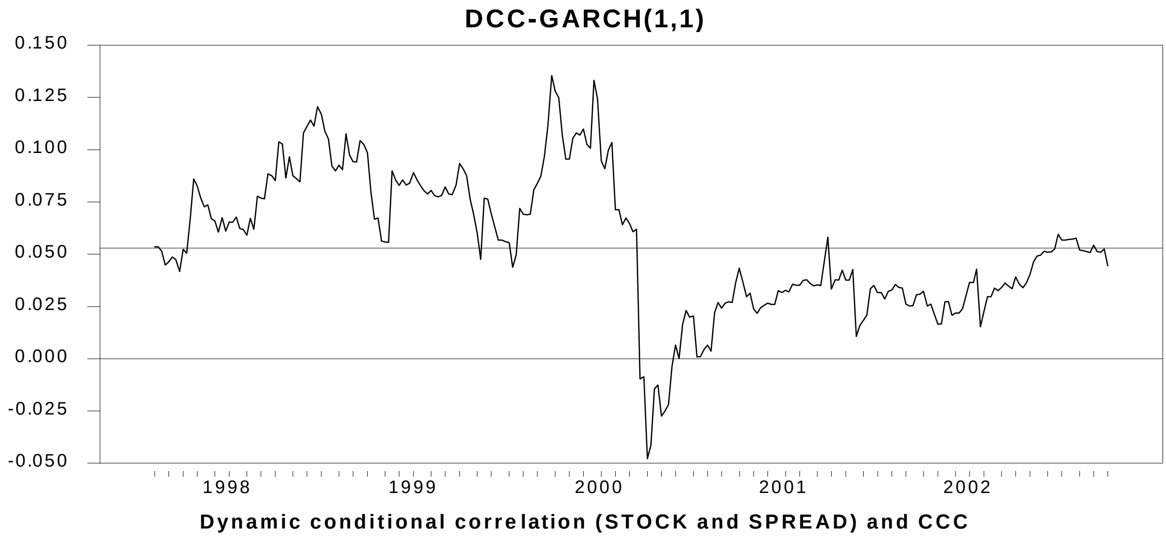
Figure 3: Dynamic conditional correlation between STOCK and INDEX – Oil Company TFE



Descriptive statistics on DCC – Oil company TFE

MEAN	0.557
MINIMUM	0.323
MAXIMUM	0.728
STANDARD DEVIATION	0.069
SKEWNESS	-0.422
EXCESS KURTOSIS	0.600

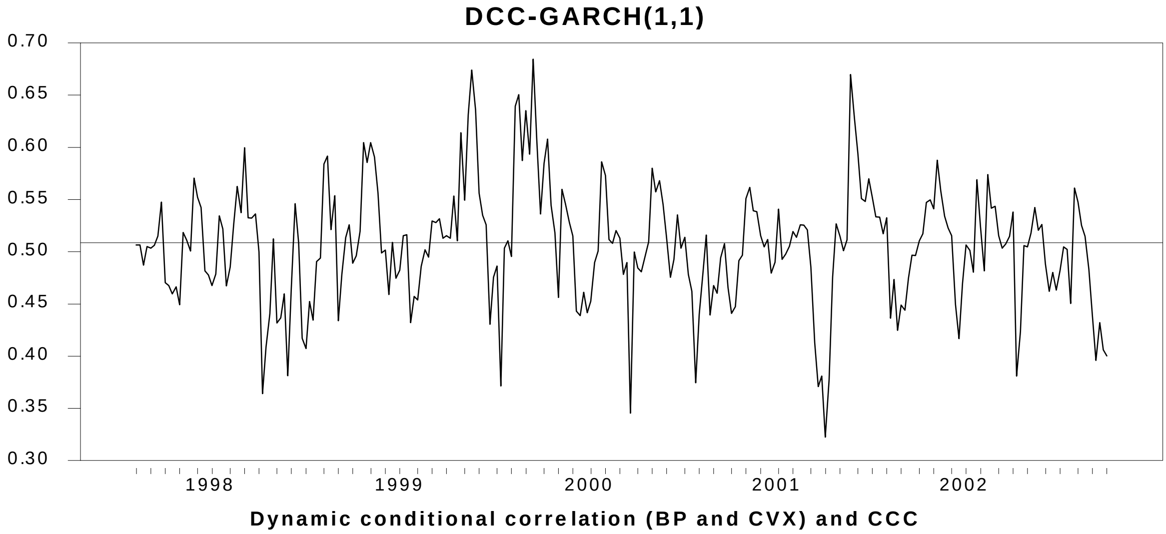
Figure 4: Dynamic conditional correlation between STOCK and SPREAD – Oil Company XOM



Descriptive statistics on DCC – Oil company XOM

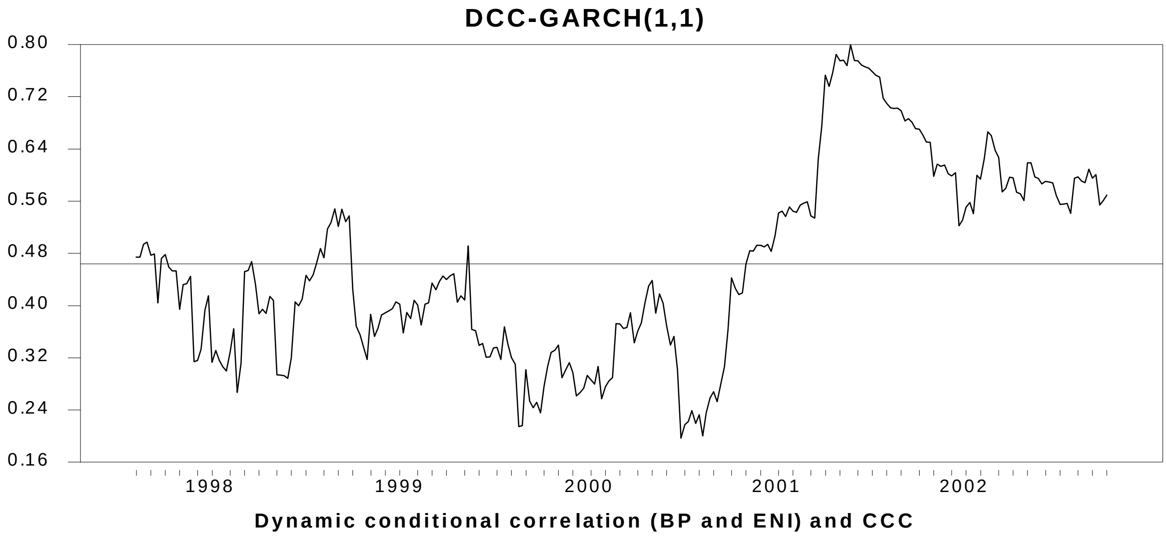
MEAN	0.055
MINIMUM	-0.047
MAXIMUM	0.136
STANDARD DEVIATION	0.033
SKEWNESS	-0.063
EXCESS KURTOSIS	-0.096

Figure 5: Dynamic conditional correlation between STOCK of oil companies BP and CVX



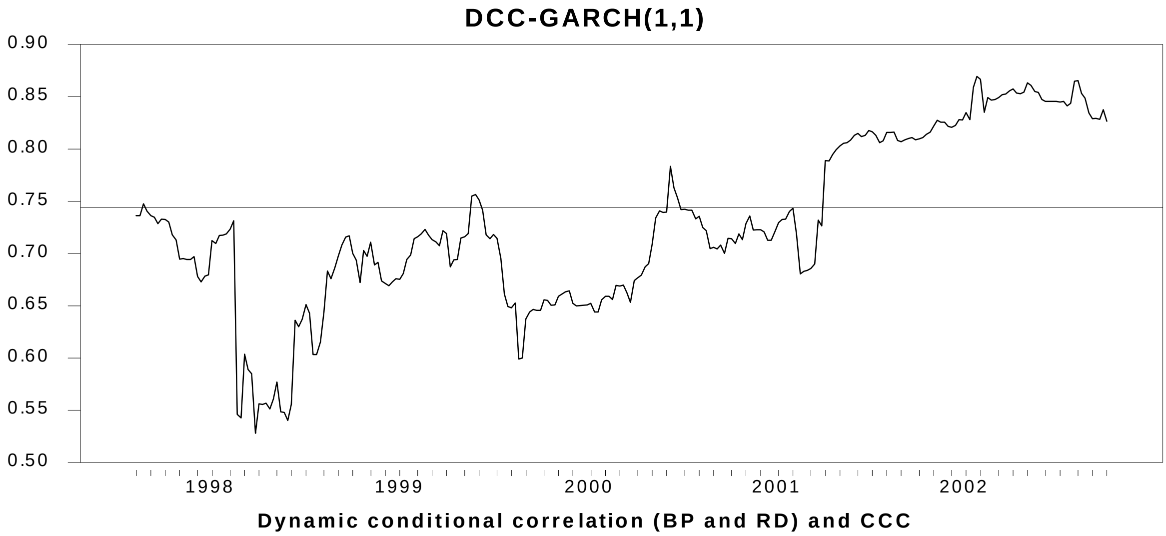
Descriptive statistics on DCC – Oil companies BP and CVX	
MEAN	0.506
MINIMUM	0.323
MAXIMUM	0.684
STANDARD DEVIATION	0.057
SKEWNESS	0.017
EXCESS KURTOSIS	0.954

Figure 6: Dynamic conditional correlation between STOCK of oil companies BP and ENI



Descriptive statistics on DCC – Oil companies BP and ENI	
MEAN	0.461
MINIMUM	0.187
MAXIMUM	0.800
STANDARD DEVIATION	0.146
SKEWNESS	0.386
EXCESS KURTOSIS	-0.681

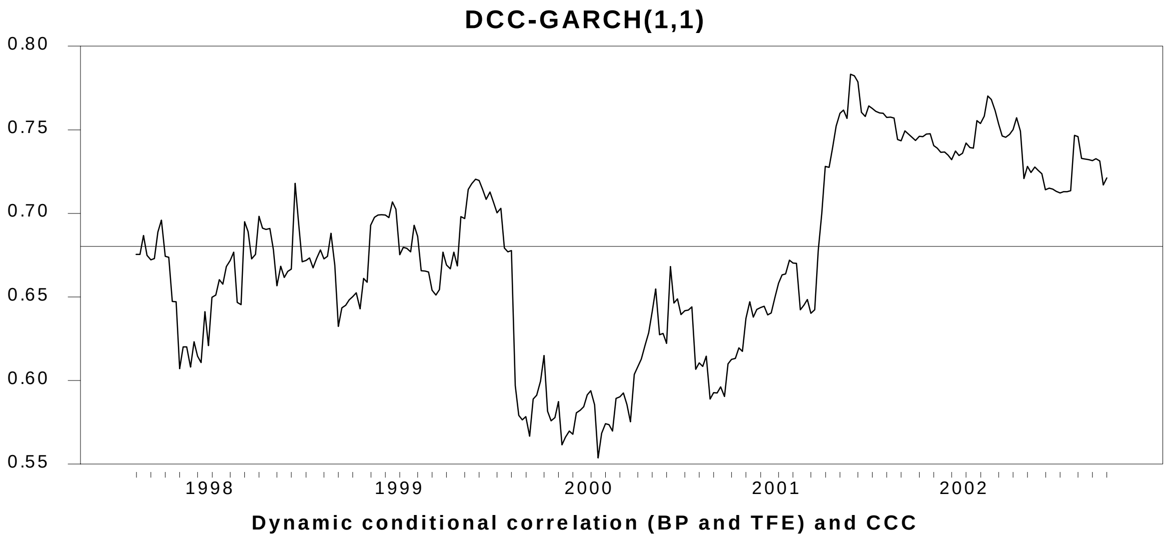
Figure 7: Dynamic conditional correlation between STOCK of oil companies BP and RD



Descriptive statistics on DCC – Oil companies BP and RD

MEAN	0.727
MINIMUM	0.528
MAXIMUM	0.869
STANDARD DEVIATION	0.080
SKEWNESS	-0.080
EXCESS KURTOSIS	-0.511

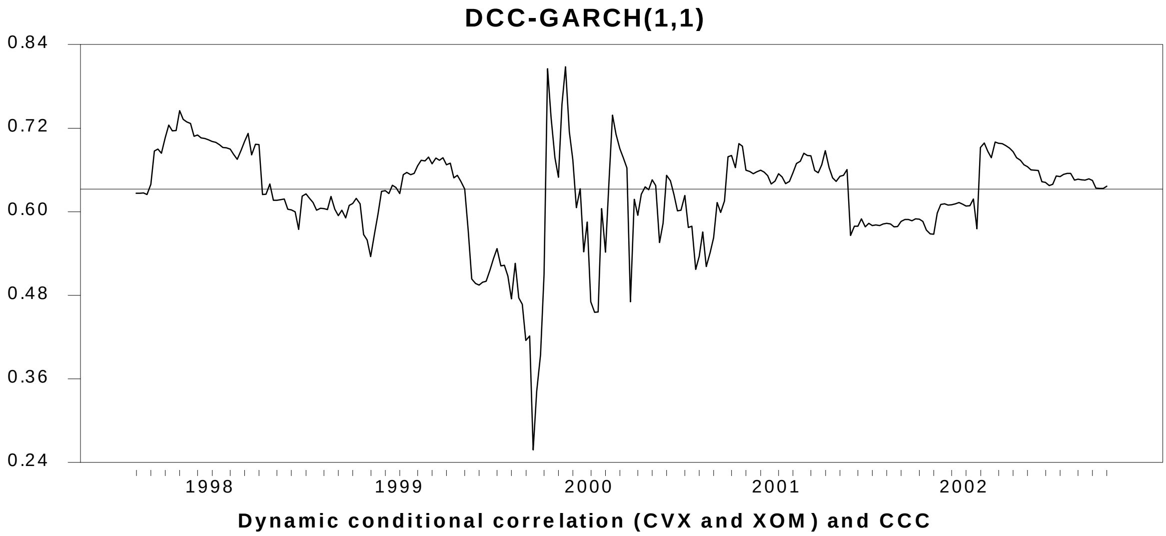
Figure 8: Dynamic conditional correlation between STOCK of oil companies BP and TFE



Descriptive statistics on DCC – Oil companies BP and TFE

MEAN	0.674
MINIMUM	0.554
MAXIMUM	0.783
STANDARD DEVIATION	0.057
SKEWNESS	-0.135
EXCESS KURTOSIS	-0.937

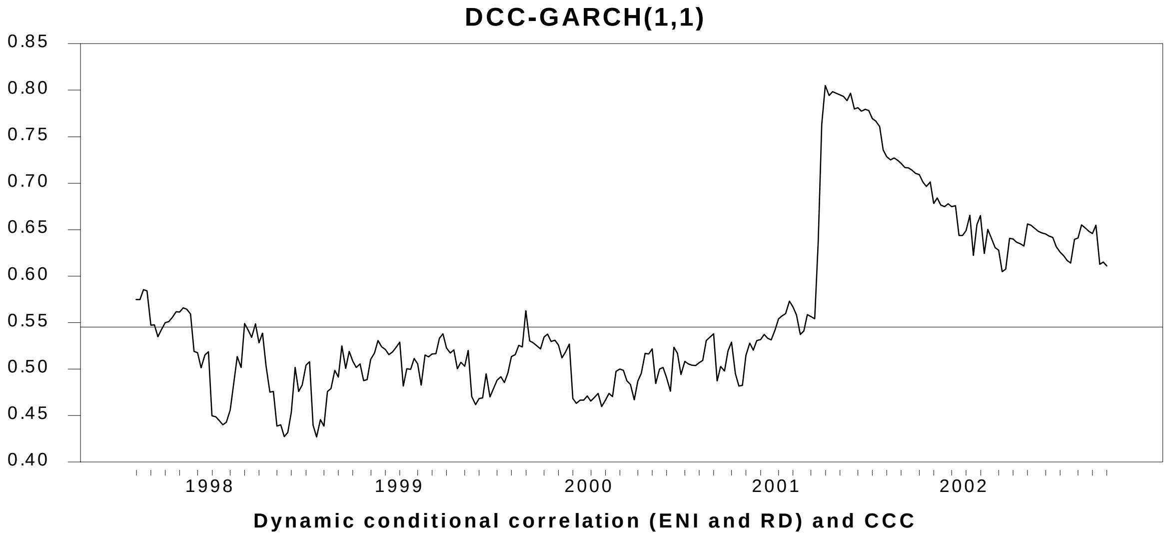
Figure 9: Dynamic conditional correlation between STOCK of oil companies CVX and XOM



Descriptive statistics on DCC – Oil companies CVX and XOM

MEAN	0.625
MINIMUM	0.258
MAXIMUM	0.808
STANDARD DEVIATION	0.070
SKEWNESS	-1.243
EXCESS KURTOSIS	3.665

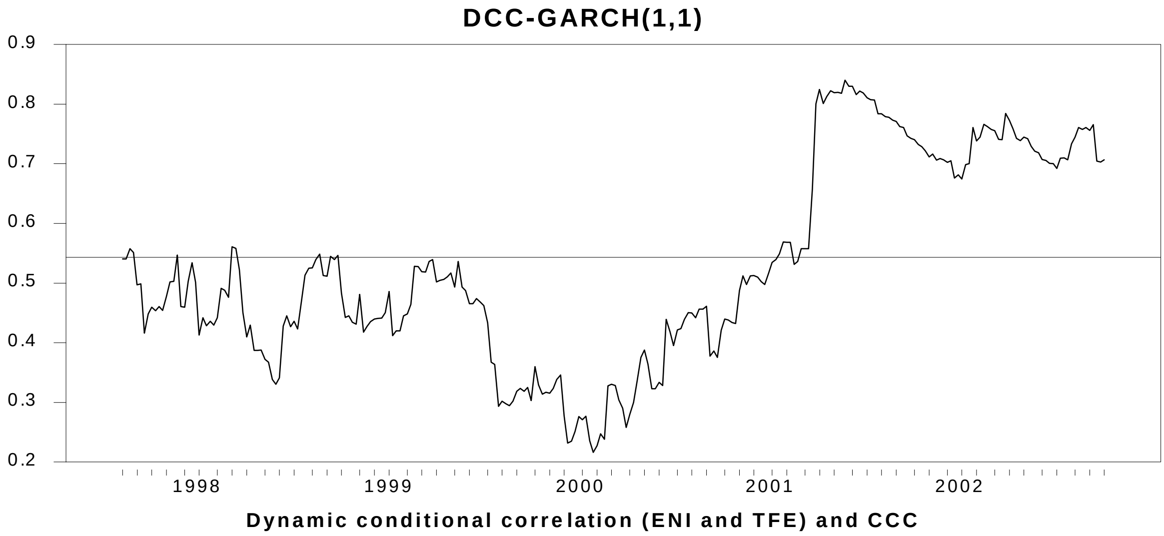
Figure 10: Dynamic conditional correlation between STOCK of oil companies ENI and RD



Descriptive statistics on DCC – Oil companies ENI and RD

MEAN	0.561
MINIMUM	0.427
MAXIMUM	0.805
STANDARD DEVIATION	0.092
SKEWNESS	1.004
EXCESS KURTOSIS	0.120

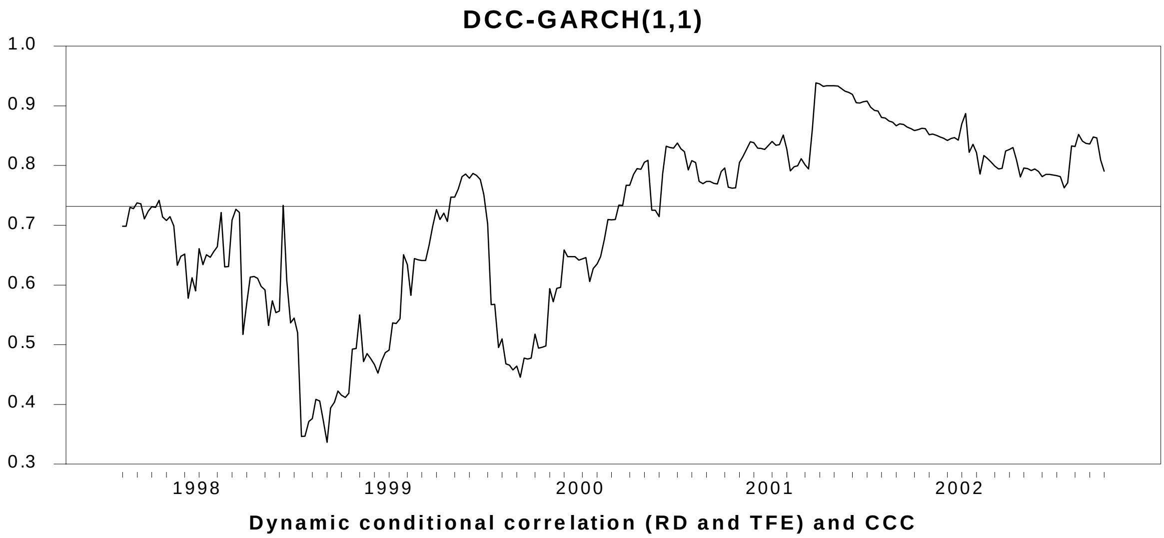
Figure 11: Dynamic conditional correlation between STOCK of oil companies ENI and TFE



Descriptive statistics on DCC – Oil companies ENI and TFE

MEAN	0.526
MINIMUM	0.216
MAXIMUM	0.840
STANDARD DEVIATION	0.167
SKEWNESS	0.282
EXCESS KURTOSIS	-1.030

Figure 12: Dynamic conditional correlation between STOCK of oil companies RD and TFE



Descriptive statistics on DCC – Oil companies RD and TFE

MEAN	0.713
MINIMUM	0.337
MAXIMUM	0.938
STANDARD DEVIATION	0.146
SKEWNESS	-0.686
EXCESS KURTOSIS	-0.447

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