AN INVESTIGATION INTO THE CONSTITUENTS OF IRISH INVESTORS' EQUITY DEMAND FUNCTIONS

COLM FRIEL

Senior Sophister

While the determinants of demand for a stock are complex, financial economics seeks to find the elements of demand that are common to all economic agents. Colm Friel's analysis strives to improve our understanding of investor reactions to the stock market and consequently the movement of stock prices. He uses interest rates, oil prices, the dollar-euro exchange rate, the pound-euro exchange rate and daily volatility in an effort to explain some of the movements in Irish stock prices.

Introduction

What moves stock prices?[1]

The ostensibly enigmatic nature of stock price movements has been the subject of a multitude of studies by renowned financial economists for the last few decades. Stock prices are the result of the asset demands of a vast number of economic agents interacting across time. Their demand functions are complex and often contain as-yet-unquantifiable factors. However, in as much as every agent's demand function is different, it seems plausible several elements exist that are common to a majority. Financial economists aim to answer the above question by finding these elements. This paper takes a highly quantitative approach to ascertain the contribution of several recently formed daily series to the movement of stock prices in Ireland. Rather than trying to predict stock prices, the objective is to increase understanding of the nature and reactions of the aggregate investor, and, hence, contribute to the debate about why stock prices move as they do.

The General Linear Regression Model

The linear regression model in matrix-vector form is given by

[1] The title of a paper by Cutler, Poterba and Summers (1988)

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{u}$$

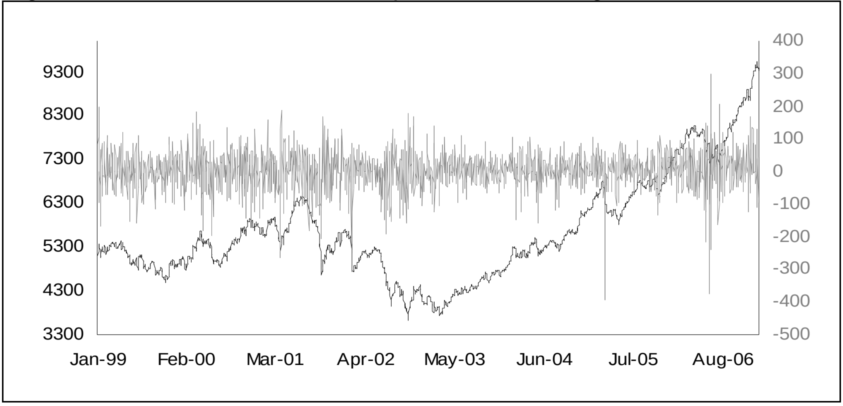
$$\begin{bmatrix} y_1 \\ : \\ : \\ : \\ : \\ y_T \end{bmatrix} = \begin{bmatrix} x_{11} & x_{12} & x_{13} & x_{14} & x_{15} \\ : & : & : & : & : \\ : & : & : & : & : \\ : & : & : & : & : \\ : & : & : & : & : \\ x_{T1} & x_{T2} & x_{T3} & x_{T4} & x_{T5} \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \end{bmatrix} + \begin{bmatrix} u_1 \\ : \\ : \\ : \\ : \\ u_T \end{bmatrix}$$

The parameter vector, $\boldsymbol{\beta}$, describes the nature of the relationship between **X** and **y**. It will be estimated using Ordinary Least Squares (hereafter OLS).

The Data

The column vector **y** comprises the daily price change of the ISEQ overall index since the introduction of the euro. The choice of this starting point is not arbitrary since three out of the four explanatory variables did not exist before this date. Figure 1 shows the daily price and return on the ISEQ.

Figure 1. ISEQ Overall Index Daily Price and Change Thereof[2]



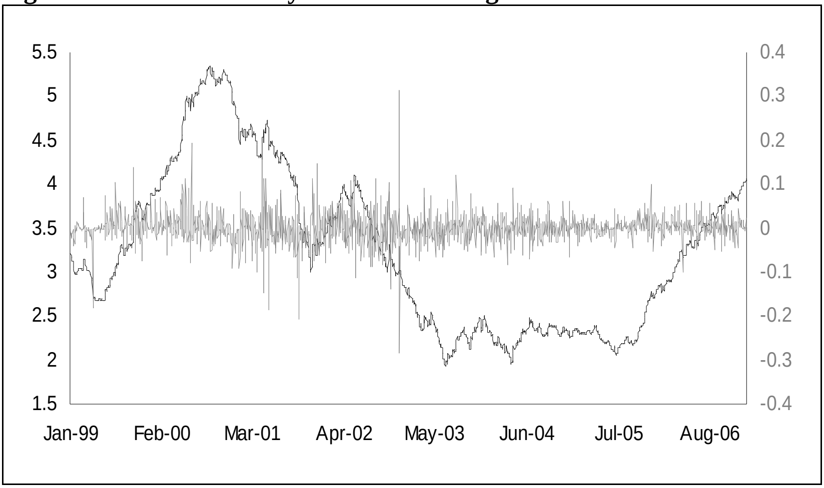
The **X** matrix contains the independent variables related to each contemporaneous observation of daily return on the ISEQ. The constant is

[2] Axes in Figures 1 to 5 measure levels of the original series on the left and first differences of the series on the right

suppressed for theoretical reasons. However, if it were included a column of 1s would appear in the matrix.

$\boldsymbol{x}_{12}$ is the daily change in the Euro Interbank Offered Rate (EURIBOR). This is the eurozone's equivalent to Britain's LIBOR[3] and represents an interest rate which moves freely and frequently to equate the supply and demand of liquidity. The daily change, rather than the original series, is used for reasons that will be revealed below. If this essentially risk-free rate increases, one would expect stock market returns to increase to maintain a constant risk premium. Figure 2 shows the daily interest rate and the daily change related to the EURIBOR.

Figure 2. EURIBOR Daily Price and Change Thereof



$\boldsymbol{x}_{13}$ is the daily change of the Pound-Euro sterling exchange rate. $\boldsymbol{x}_{14}$ is the daily change of the Dollar-Euro exchange rate. If either variable increases it makes Irish exports more expensive in two significant markets for export-oriented companies and should, *ceteris paribus*, reduce the value of the stocks of these companies, hence of the market as a whole. Figures 3 and 4 present the daily change in price of one Euro in terms of Pounds Sterling and US Dollars respectively.

[3] London Inter-bank Offered Rate

Figure 3. Price of €1 in Terms of £ and Daily Change Thereof

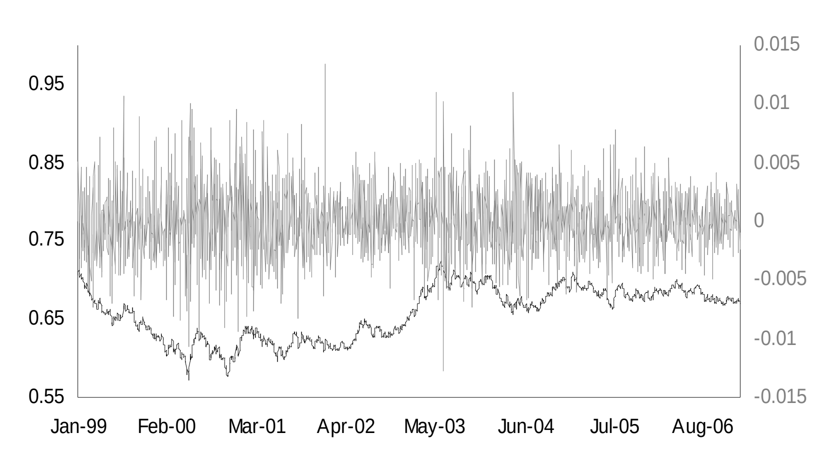
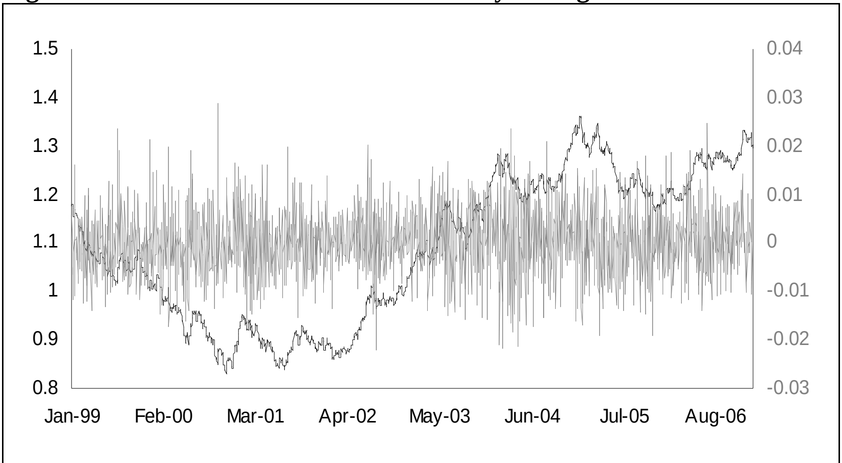
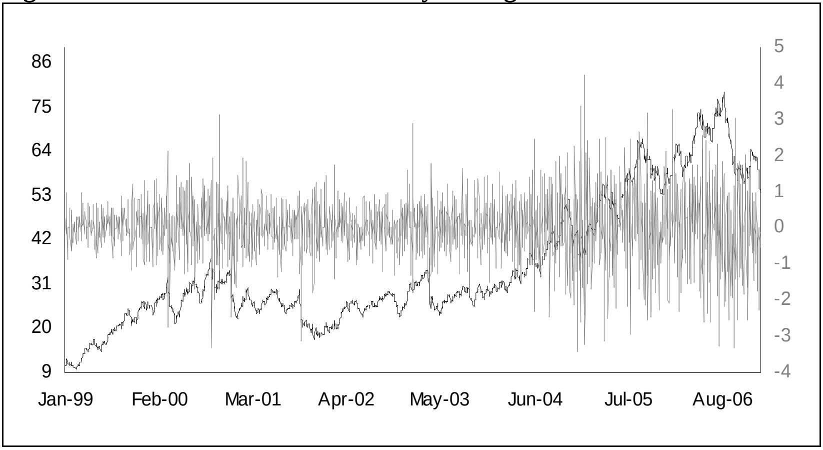


Figure 4. Price of €1 in Terms of $ and Daily Change Thereof



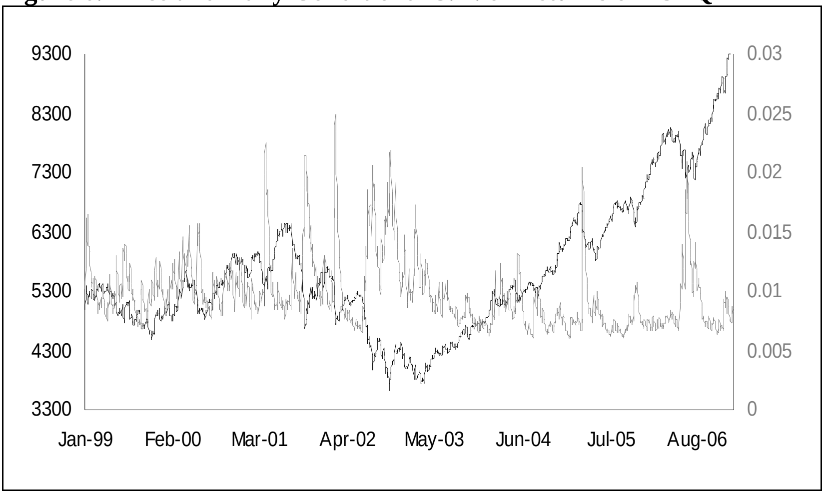
$\boldsymbol{x}_{15}$ is the daily change of the price of crude oil. There are contrasting sensitivities to oil prices. Firms that use oil face higher costs as the price increases so investors may expect lower profits thus lowering share prices. Conversely, companies involved in the energy sector may become more profitable and observe a share price increase. There may be additional effects of changing oil prices. The regression results below will indicate whether the net effect is positive, insignificant or negative.

Figure 5. Price of Crude Oil and Daily Change Thereof



$\boldsymbol{x}_{16}$ is a vector of estimated conditional standard deviations of returns. This variable captures the risk associated with stock returns. For a higher level of risk an investor will require a higher level of return so one expects a significant relationship between the two variables. Figure 6 shows the conditional standard deviation and the daily price of the ISEQ index.

Figure 6. Price and Daily Conditional S.D. of Returns on ISEQ



The following section outlines the procedure for calculating this variable.

Estimation of Conditional Standard Deviation
Engle (1982) proposed ARCH[4] as a solution to the problem of non-constant variance in time series. It models conditional variance as a function of past errors. Bollerslev (1986) extended the model to include past conditional variances. GARCH[5] (p,q) is given by the equation below; if the last term is omitted it gives ARCH(p).

$$\sigma_t^2 = \varpi + \sum_{j=1}^{p} \alpha_j \varepsilon_{t-j}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2$$

Through the process of Maximum Likelihood[6] (hereafter ML) this formula can be used to give variance estimates for each time period, t, conditional on p past errors and q past variances. Specifically, the Berndt-Hall-Hall-Hausman (1974) recursive algorithm estimates parameters that maximise the log-likelihood of the function. First, the orders of p and q are determined. Then, the parameters ω, α and β, are estimated.

Three specifications of the GARCH model were tested. Table 1 shows the results of running the ML procedure on each one.

Table 1. Results of three specifications of GARCH model

	GARCH(1,1)	**GARCH(1,2)**	**GARCH(2,1)**
$\boldsymbol{\omega}$	$3.67\text{x}10^{-6}$	$3.02\text{x}10^{-6}$	$3.95\text{x}10^{-6}$
S.E.	$4.82\text{x}10^{-7}$	$7.37\text{x}10^{-7}$	$5.08\text{x}10^{-7}$
P-value	0	0	0
$\boldsymbol{\alpha_1}$	0.0959333	0.0787445	0.0745398
S.E.	0.010181	0.0171913	0.0172947
P-value	0	0	0
$\boldsymbol{\alpha_2}$	-	-	0.028673
S.E.	-	-	0.0203786
P-value	-	-	0.159
$\boldsymbol{\beta_1}$	0.8705045	1.103471	0.8608325
S.E.	0.0121088	0.1939901	0.0135046
P-value	0	0	0
$\boldsymbol{\beta_2}$	-	-0.2096994	-

[4] Autoregressive Conditional Heteroscedasticity
[5] Generalised Autoregressive Conditional Heteroscedasticity
[6] ML is preferred to OLS on efficiency grounds since the errors are not independently distributed

S.E.	-	0.1727931	-
P-value	-	0.225	-

The p-values on the second lags of both the ARCH and GARCH components are not significant at the 5 per cent level. Thus, the GARCH(1,1) model is chosen as the best specification with which to estimate conditional standard deviation.

Testing for Unit Roots

With the exception of the conditional standard deviation of returns, each variable is the first difference of its underlying series. The reason for this lies with the fact that the original variables are non-stationary and the risk of spurious regression would be high if they weren't transformed. Table 2 shows the computed Dickey-Fuller test statistics for the original series and the first difference of the series. If the computed value exceeds the critical value in absolute terms the hypothesis of a unit root and hence non-stationarity can be rejected. The critical value is -2.8634.

Table 2. Computed Dickey-Fuller Statistics

Variable	**Level**	**First Difference**
ISEQ	1.1509	-43.39
EURIBOR	-0.52126	-44.3539
Brent[7]	-1.3996	-48.074
Pound-Euro	-2.2663	-44.4737
Dollar-Euro	-0.60439	-45.4719
Con S.D.	-6.608	n/a

Thus, the use of first differences is justified. It must be noted that all variables, with the exception of the conditional standard deviation, are integrated of order one and hence it is possible that a cointegrating relationship exists. This is a matter for ensuing investigative study.

Regression Results

[7] Used to measure the daily change in the price of oil, as described by the price of Brent crude oil; oil sourced from the North Sea.

The regression was run as set out above. Tables 3 and 4 below summarise the main results. This section will present and interpret these results.

The estimated contents of the **β** vector are given below.

$$\begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \end{bmatrix} = \begin{bmatrix} 213.11 \\ 3.43 \\ -587.03 \\ -1038.8 \\ 165.49 \end{bmatrix}$$

Table 3. Regression Results[8]

Regressor	Coefficient	Standard Error
FDEURIBOR	213.1131	38.1634
FDBRENT	3.4346	1.4522
FDUKEUR	-587.0341	501.3067
FDUSEUR	-1038.8	218.9947
CONSD	165.499	115.3733

Table 4. Relevant Statistics

Statistic	Value
R-Squared	0.039868
R-Bar-Squared	0.038029
F-Stat	21.6752
DW-statistic	1.8824
AIC[9]	-11321.5

The results indicate the following:

- Increasing interest rates by 1 percentage point will cause the price of the ISEQ index to rise by 213. This value is significant at both the 5% and 1% level. Intuitively, this seems plausible since a rise in the EURIBOR is akin to a rise in the risk-free rate and, according to asset pricing models, this should raise the return on risky assets such as stocks.

[8] Use Where FD implies the variables have been first differenced.
[9] Akiake Information Criterion

- A one euro increase in the price of oil causes the price of the ISEQ to rise by 3.4. This value is significant at the 5% level. Thus, the net effect of the conflicting theories outlined above is a positive one.

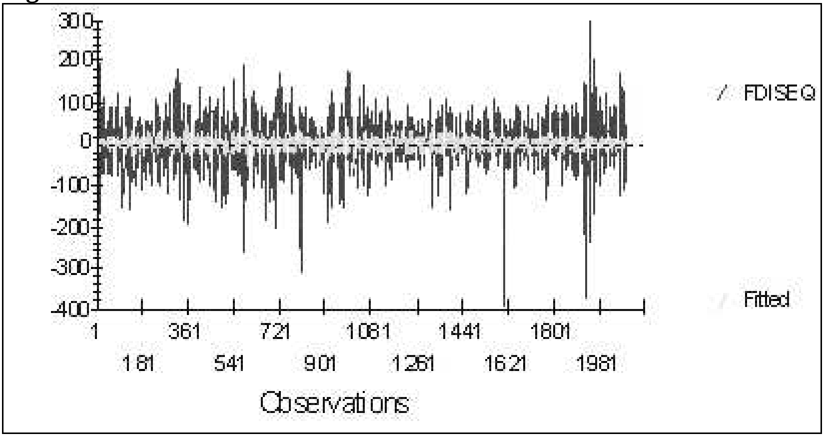
- The exchange rate coefficients are less straight-forward to interpret. If either exchange rate increases it is analogous to a terms-of-trade deterioration for Ireland relative to the United Kingdom or United States. The coefficient quoted for FDUKEUR, in a strict sense, means that if the exchange rate increases by 1 unit, the price of the ISEQ declines by 587 units. This interpretation is disjointed from any realistic situation. A more plausible interpretation is the following: If the exchange rate increases by .01, one would expect the ISEQ index to decline by 5.87 units. In the case of the FDUSEUR, an increase in the exchange rate of .01, will reduce the ISEQ index by 10.38 units. However, the coefficient on FDUKEUR is not significant at the 5% level. FDUSEUR, on the other hand, is significant at both the 5% and 1% levels.

- A one unit increase in the conditional standard deviation of returns should increase the price of the ISEQ by 165. This finding is consistent with the hypothesis that increased risk requires higher return. However, the coefficient is not significant at the 5% level so any inference based on this may be erroneous.

Table 3 above presents some relevant summary statistics. The R-squared value suggests that 96% of the movement in the price of the ISEQ has gone unexplained. This is not a cause for concern. In the introduction, the multitude of factors that enter investors' demand functions was alluded to; if a high R-squared value was obtained, the finding would be inconsistent with previous studies and perhaps point to a spurious regression (or, maybe, very narrow and simple minded investors).

Figure 7 graphs actual and fitted values of FDISEQ. The relatively small size of the fitted values when compared with realised values is testament to the low R-squared obtained in the regression.

Figure 7. Plot of Fitted and Actual Values



The F-statistic, with a P-value of 0.000, rejects the hypothesis that the **β** vector is zero.

Misspecification Testing

Parameter instability can be detected by plotting the residuals from the regression equation against time. The cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) are plotted in figures 8 and 9 respectively. Under the null hypothesis of parameter stability, the statistics follow a beta distribution which gives rise to the boundary lines used in the graphs. If the plots of residuals fail to cross these lines, one does not reject the hypothesis of parameter stability. The diagrams suggest that no structural breaks have occurred and that the parameters in the regression have remained stable over time. Brown et al. (1975:155) warn that this procedure is not strictly a formal test of significance but rather it acts as a "yardstick".

Figure 8: Plot of Cumulative Sum of Recursive Residuals

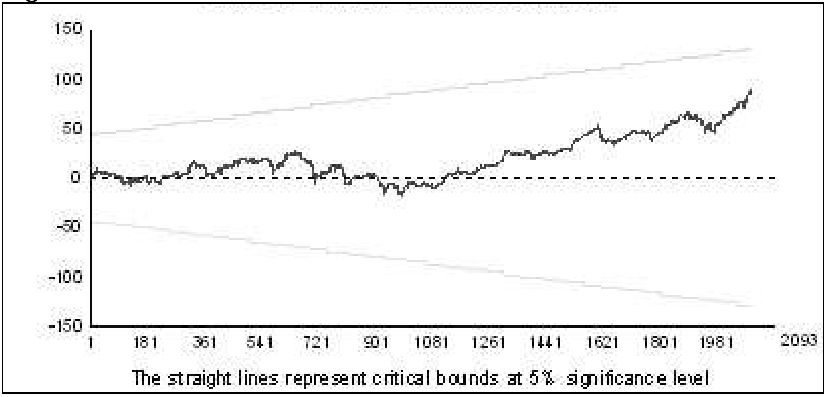
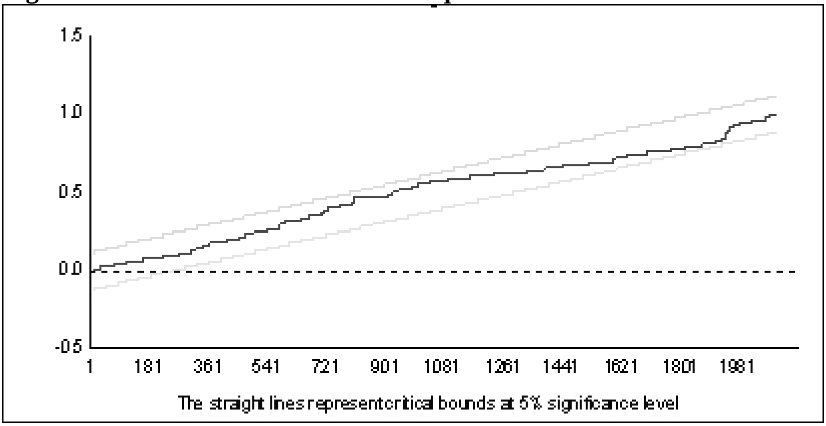


Figure 9: Plot of Cumulative Sum of Squares of Recursive Residuals



The Durbin-Watson (1951) test is principally a test for a serially or auto correlated error term but has applicability to other areas of misspecification such as incorrect functional form. The D-W test requires that an intercept be included in the model since the standard critical values are not strictly applicable otherwise. The D-W statistic in the regression with a constant, differed from the one reported above by .0035 (1.8859-1.8824). The critical *d*-statistics provide upper, d_U, and lower, d_L, bounds of 1.93049 and 1.92246, respectively[10]. The computed value lies marginally below the lower bound

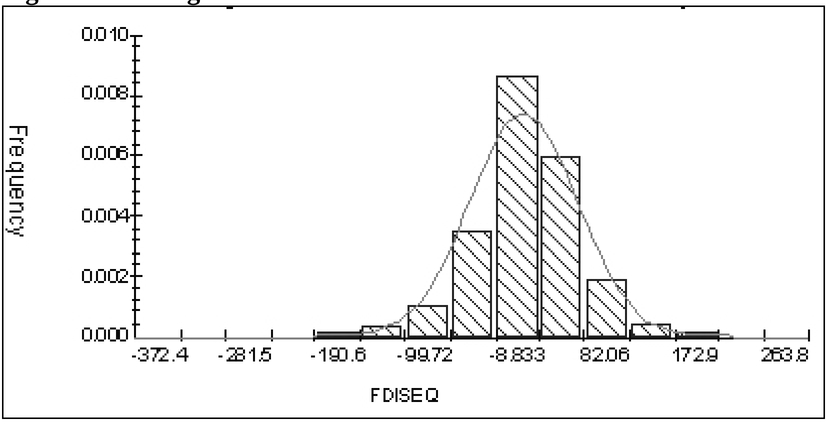
[10] These figures correspond to a sample size of 2000 rather than 2094 but would differ only in the 4th decimal place. In large samples, the DW statistic converges to the normal distribution.

thus we reject the null hypothesis of no positive autocorrelation. The correlation coefficient, ρ, is estimated to be approximately .06. The D-W test is strictly only valid under normality, which is evidently absent in this model.

A further test for autocorrelation of the error terms gives a chi-squared statistic of 6.99 with a corresponding p-value of .008. Thus, one rejects the null hypothesis of no serial correlation. Coupled with the D-W results, there is evidence of autocorrelation in the model. The implications of this are that the estimated $\boldsymbol{\beta}$ vector may be inefficient and its t-statistics may not be valid. Further discussion of this is issue will take place below.

Figure 10 compares a histogram of the regression residuals with a normal density function. At a glance, the residuals appear to be non-normal. The Jarque-Bera test is a more formal procedure for testing the normality of errors. The computed value is 1812.7 with a corresponding p-value of approximately zero. Thus, one fails to accept the null hypothesis of normality and the intuition from the graph is confirmed. Non-normality implies that t-tests and f-tests may be misleading. However, given the large sample size under consideration these statistics may have asymptotic validity.

Figure 10: Histogram of Residuals



Ramsey's (1969) RESET test for incorrect functional form computes a statistic of 1.5436 with a p-value of .214. Thus, one fails to reject the null hypothesis of correct functional form. The linear relationship imposed, it seems, is valid. Furthermore, the test for heteroscedasticity gives a statistic of 2.003 and a p-value of .157. Thus, one fails to reject the null hypothesis of homoscedasticity at the 5 percent significance level.

Cochrane and Orcutt Test Accounting for Autocorrelated Errors

Given the above finding of autocorrelation in the error terms, a generalised least squares approach is taken. The results of this regression are given in Table 4 below. The coefficients are not significantly different from those in the standard regression which is corroboration of the marginal rejection of non autocorrelated errors in the D-W test above. The model is specified with one autoregressive lag component since higher lags were not significant.

Table 5. Regression Results Accounting for Autocorrelated Errors

Regressor	Coefficient	Standard Error	T-Ratio	P-Value
FDEURIBOR	206.3051	38.0879	5.4166	0
FDBRENT	3.6075	1.4429	2.5002	0.012
FDUKEUR	-547.8212	501.0964	-1.0932	0.274
FDUSEUR	-1091.5	218.6797	-4.9912	0
CONSD	167.4418	122.3388	1.3687	0.171

These coefficients may be more reliable than those reported above. This procedure estimates the autocorrelation parameter to be .058, which is very close to the estimate derived from the D-W statistic above of .06. Furthermore, the R-squared statistic is marginally higher at 4.3 per cent.

Wald Test of Linear Restrictions

The Wald test for linear restrictions on variables is carried out. The null hypothesis that the coefficient on FDUSEUR is equal to .6 times that of FDUSEUR is tested. The restriction represents the average exchange rate between the US Dollar and UK Pound over the sample period. The Wald test returns a statistic of .0038680 with a p-value of .950. Thus, the null hypothesis is not rejected. This is merely an interesting aside but gives an added degree of intuitive credibility to the main test.

Conclusion

This investigation succeeded in explaining some of the movements of the ISEQ index using a general linear model. Each variable had theoretical justification but two were found not to be statistically significant. Interest rates and oil prices have a positive effect on the ISEQ index while the

Dollar-Euro exchange rate has a negative effect. The effect of Pound-Euro exchange rate and daily volatility are insignificantly negative and positive respectively. The results of the regression indicated marginally autocorrelated errors and severe non-normality. The Cochrane-Orcutt GLS regression was applied to account for the autocorrelation while the large sample size provides asymptotic validity to the results. Nevertheless, exactly what causes the entirety of movements in stock prices remains, as ever, an inscrutable phenomenon.

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