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# Identifying the Source of Mean and Volatility Spillovers in Irish Equities: A Multivariate GARCH Analysis*

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*Abstract:* This paper, using a multivariate VAR-GARCH analysis, examines the role of the UK stock market in the price behaviour of the ten largest Irish stocks. We identify the source of mean and volatility spillovers in Irish stocks by investigating interrelationships among industry sector, the overall UK and Irish markets, and individual Irish stock price movements. Significant mean and volatility spillovers exist from the UK to the individual Irish stocks. The relative size and significance of these spillovers from the UK indicate asymmetries in their effects on Irish stocks. Recent evidence of return spillovers from the UK to Ireland is not supported for all individual Irish stocks.

## I INTRODUCTION

The globalisation of financial markets has prompted a number of studies to examine the role of global news in explaining stock price movements and the integration of financial markets (see, for example, Theodossiou and Lee (1993), (1995); Karolyi (1995); Koutmos (1996); Darbar and Deb (1997)). Increased linkages in macroeconomic policy and information sharing among national markets have increased the speed of the international

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transmission of financial shocks across nations. That is to say, interdependencies between markets may exist, but such markets may not be integrated. Such interdependencies are clearly seen when markets with no cross-listed stocks and where capital controls remain, nevertheless, move together even in the absence of any fundamental news of international economic significance such as, for example, the October 1987 international crash (Bertero and Mayer, 1990).

Earlier studies of stock market interdependencies and contagion effects relied on Granger-causality testing of market indices. These studies suggested uni-directional mean (return) spillovers from the larger markets (in particular, the New York market) to smaller markets (see, for example, Eun and Shim (1989); Von Furstenberg and Jeon (1989)). However, these studies fail to capture the autoregressive second moment of the distribution of stock returns (i.e., the feature that the conditional variance of stock returns is time varying) which results in inconsistent estimates of the ordinary least squares estimation of mean spillovers (Bollerslev, Chou and Kroner, 1992).

More recently, contagion effects in stock price movements are captured by an autoregressive conditional heteroscedastic (ARCH) estimation of a vector autoregessive representation (VAR) of stock return indices. Empirical findings are similar to the earlier evidence, with the US being the primary influence on conditional means and conditional variances in other markets (see, for example, Hamao, Masulis and Ng (1990); Becker, Finnerty, and Tucker (1992); Poon and Taylor (1992); Theodossiou and Lee (1993); Karolyi and Stulz (1996); Koutmos (1996)). Given the rapidly changing environment of international capital markets, much of the earlier evidence is outdated.

This paper investigates return and volatility spillovers to the ten largest Irish stocks (see Table 1), accounting for over 70 per cent of the total Dublin stock market capitalisation. Motivated by the unique nature of the institutional relationship between the Dublin and London stock markets, whereby all listed Irish stocks are jointly (and simultaneously) traded — as well as the interdependencies between the two economies and the absence of capital controls — we test whether shocks in the London market are likely to be transmitted quickly to the price behaviour of Irish stocks. That is, additional to domestic shocks, we investigate whether Irish stock price movements are associated with shocks in the London stock market.

The ten Irish stocks are heterogeneous in nature — factors such as company size, international exposure and institutional configuration vary considerably.[1]

1. Studies of the characteristics of national stock market indices suggest that there are systematic differences in their underlying structure and volatility. A Herfindahl concentration index for the Irish market indicates that it is approximately five times less diversified than the UK market, and suggests that it is also likely to be more volatile (Roll, 1992).

Table 1: *Irish Shares and Associated UK Sector*

| *UK Sector* | *Irish Share Counterparts* |
|---|---|
| Banks (Retail) | AIB, Bank of Ireland |
| Building Materials and Merchants | CRH |
| Paper, Packaging and Printing | Smurfit |
| Pharmaceuticals | Elan |
| Household Goods | Waterford-Wedgewood |
| Food Producers | Kerry, Greencore |
| Life Assurance | Irish Life |
| Media | Independent |

Potential asymmetries in UK spillovers to Irish stocks congruent with these underlying differences are investigated.

Contagion effects between the UK stock market and individual Irish stocks are assessed by employing both the FTSE-100 national market index and the industry sector FTSE indices. This disaggregated approach allows for both industry-specific shocks and market shocks to be transmitted in the price behaviour of Irish stocks. Previous studies on the Irish stock market are limited as they examine interdependencies solely between national stock market indices Gallagher (1995). These studies fail to capture important contagion effects associated with small stock markets dominated by a few large stocks. In the Irish case, the ISEQ index is considerably more sensitive than the FTSE-100 index to shocks to a few industry sectors (principally the banking sector and, to less a degree, the building materials and merchants sector and the paper, packaging and printing sector).[2] Thus, as identified by Roll (1992) national stock market indices mask many of the dynamic linkages between markets.[3]

The source of mean and volatility spillovers in Irish stocks is of interest to individual investors allocating their portfolios between UK and Irish stocks. For example, investors are interested in examining the extent to which Irish stocks are exposed to UK shocks (either shocks in the overall market or the industry sector).

Advanced econometric time series modelling techniques are used to examine a number of hypotheses. First, in contrast with previous studies on Irish stocks

2. The sectors are comprised of a sufficient number and diversity of stocks that firm-specific risk is eliminated. Furthermore, global industrial trends and "fads", for instance, could be captured by the use of these FTSE sectors which corresponds broadly to industry categories.

3. The use of aggregate national stock market indices is also likely to mask supply-side innovations having implications for the earnings potential and contingencies of different industries (Von Furstenberg and Jeon, 1989).

which focused solely on national stock market indices, we identify the source of the mean and volatility spillovers by investigating the interrelationship between industry sector price movements in the UK and Irish stock price movements. This sectoral approach coincides with that of those investment firms who emphasise portfolio investment on a "thematic" basis, focusing on industry-related global trends (consumer franchises, information technology, etc.) rather than national markets.

Second, in estimating a vector autoregressive representation (VAR) of Irish stock returns in a generalised autoregressive conditional heteroscedastic (GARCH) framework, we obtain estimates of time-varying conditional volatilities of Irish stock returns. Furthermore, in the multivariate approach, we quantify the mean and volatility spillovers from the UK (industry and market) and overall Irish market to individual Irish stocks. Third, we examine whether lagged spill-overs are significant (and substantial), thereby implying that Irish stocks are relatively inefficiently priced and, to some degree, predictable.

The remainder of the paper is set out as follows. The econometric method used to estimate the mean and volatility spillovers is outlined in Section II. Section III describes the data, while Section IV discusses the empirical results. Section V concludes the study.

## II ECONOMETRIC TECHNIQUE

We employ a VAR of order q with multivariate GARCH errors. The ARCH family of models developed by Engle (1982) and generalised by Bollerslev (1986) has been shown to model the time-varying volatility in daily stock returns reasonably well (Bollerslev, Chou and Kroner, 1992). Moreover, we use a multivariate analysis to study the transmission mechanism of returns and volatility (conditional mean and conditional volatility of return spillovers) from one financial series to another. The general model is given by:

$$R(t) = \alpha + \sum_{k=1}^{q} \beta R(t-k) + u(t) \tag{1}$$

$$u(t) = N(0,\ H(t)^2) \tag{2}$$

$$H(t)^2 = C'C + B'u(t-1)u(t-1)'B + A'H(t-1)^2 A \tag{3}$$

where **R(t)** is the vector of returns, $\alpha$ is a vector of constants, and $\beta$ is a matrix of parameters. The residual vector is given by **u(t)** and the time-varying conditional variance is given by the positive definite matrix $\mathbf{H(t)^2}$. **C, B,** and **A** are all matrices of parameters.

In order to reduce the number of computations we impose the restriction that $\mathbf{H(t)}^2$, $\mathbf{A}$ and $\mathbf{C}$ are diagonal matrices.[4] The estimated model is given by:

$$\begin{aligned} R_j(t) = \alpha_j + \sum_{k=1}^{q} \beta_{jj,k} R_j(t-k) + \sum_{k=1}^{q} \beta_{ji,k} R_i(t-k) \\ + \sum_{k=1}^{q} \beta_{jf,k} R_f(t-k) + \sum_{k=1}^{q} \beta_{js,k} R_s(t-k) + u_j(t) \end{aligned} \tag{4}$$

$$\begin{aligned} R_i(t) = \alpha_i + \sum_{k=1}^{q} \beta_{ij,k} R_j(t-k) + \sum_{k=1}^{q} \beta_{ii,k} R_i(t-k) \\ + \sum_{k=1}^{q} \beta_{if,k} R_f(t-k) + \sum_{k=1}^{q} \beta_{is,k} R_s(t-k) + u_i(t) \end{aligned} \tag{5}$$

$$\begin{aligned} R_f(t) = \alpha_f + \sum_{k=1}^{q} \beta_{fj,k} R_j(t-k) + \sum_{k=1}^{q} \beta_{fi,k} R_i(t-k) \\ + \sum_{k=1}^{q} \beta_{ff,k} R_f(t-k) + \sum_{k=1}^{q} \beta_{fs,k} R_s(t-k) + u_f(t) \end{aligned} \tag{6}$$

$$\begin{aligned} R_s(t) = \alpha_s + \sum_{k=1}^{q} \beta_{sj,k} R_j(t-k) + \sum_{k=1}^{q} \beta_{si,k} R_i(t-k) \\ + \sum_{k=1}^{q} \beta_{sf,k} R_f(t-k) + \sum_{k=1}^{q} \beta_{ss,k} R_s(t-k) + u_s(t) \end{aligned} \tag{7}$$

$$\begin{aligned} h_{jj}(t)^2 = c_{jj} + b_{jj}u_j(t-1)^2 + b_{ji}u_j(t-1)u_i(t-1) + b_{jf}u_j(t-1)u_f(t-1) \\ + b_{js}u_j(t-1)u_s(t-1) + a_{jj}h_{jj}(t-1)^2 \end{aligned} \tag{8}$$

$$\begin{aligned} h_{ii}(t)^2 = c_{ii} + b_{ii}u_i(t-1)^2 + b_{ij}u_i(t-1)u_j(t-1) + b_{if}u_i(t-1)u_f(t-1) \\ + b_{is}u_i(t-1)u_s(t-1) + a_{ii}h_{ii}(t-1)^2 \end{aligned} \tag{9}$$

4. That is, we assume that the cross conditional covariances, $h_{ij}(t)=h_i(t)h_j(t)\rho_{ij}(t)$, between markets i and j are not time varying. The correlation coefficient $\rho_{ij}(t)$ is bounded by $-1\le\rho_{ij}(t)\le 1$. Specifying the cross conditional covariances as time varying enormously increases the computational parameters needed to be estimated (Bollerslev, 1990).

$$h_{ff}(t)^2 = c_{ff} + b_{ff}u_f(t-1)^2 + b_{fj}u_f(t-1)u_j(t-1) + b_{fi}u_f(t-1)u_i(t-1) + b_{fs}u_f(t-1)u_s(t-1) + a_{ff}h_{ff}(t-1)^2 \tag{10}$$

$$h_{ss}(t)^2 = c_{ss} + b_{ss}u_s(t-1)^2 + b_{sj}u_s(t-1)u_j(t-1) + b_{si}u_s(t-1)u_i(t-1) + b_{sf}u_s(t-1)u_f(t-1) + a_{ss}h_{ss}(t-1)^2 \tag{11}$$

where the vector of returns $\mathbf{R(t)} = [R_j(t)\ R_i(t)\ R_f(t)\ R_s(t)]'$, denoting daily returns of an individual Irish stock j, the overall Irish stock market index (ISEQ index), *The Financial Times* 100 index (FTSE-100), and *The Financial Times* sector market index (associated with stock j), respectively. The conditional variances are given by the diagonal of the covariance matrix $\mathbf{H(t)^2} = [h_{jj}(t)^2, h_{ii}(t)^2, h_{ff}(t)^2, h_{ss}(t)^2]$, and the residuals from the VAR are $\mathbf{u(t)} = [u_j(t), u_i(t), u_f(t), u_s(t)]$. To ensure that the conditional variances are never negative, all the parameters in the conditional variance equations ((8)-(11) are non-negative.

The multivariate structure permits measurement of the effects of the innovations in the stock returns of one series on its own lagged returns and those of other series (Theodossiou and Lee (1993); Karolyi (1995)). A $\chi^2(q)$ statistic of the $\Sigma(\beta)$ measures the significance of own- and cross-mean spillovers, where q is the number of restrictions. Similarly, own- and cross-volatility spillovers are estimated from the **B** matrix and the estimated parameters given in the **A** matrix measure persistence in conditional volatility. Significant parameters in the **A** matrix are evidence of the stock market exhibiting volatility patterns of stable (low levels of volatility) periods and unstable (high levels of volatility) periods.

The parameters of the multivariate system are estimated by computing the conditional log-likelihood function $\mathbf{L}(\theta)$, with

$$L(t)(\Theta) = -\log 2\pi - 0.5\log|H(t)^2| - 0.5u(t)'(\Theta)H(t-1)^2(\Theta)u(t)(\Theta) \tag{12}$$

$$L(\Theta) = \sum_{t=1}^{T} L(t)(\Theta) \tag{13}$$

where $\theta$ is the vector of all parameters. Numerical maximisation of the log-likelihood function following the Berndt, Hall, Hall, and Hausman (1974) algorithm yields the maximum likelihood estimates and associated asymptotic standard errors.

## III DATA AND PRELIMINARY ANALYSIS

Daily closing prices for the 4/1/1988 to 19/12/1996 period, a total of 2,339 daily price observations, are obtained from Datastream. The starting date was chosen to avoid the October 1987 international stock market crash.[5] The ten Irish shares are the ten largest by market capitalisation (as of 31/12/96) and account for around 74 per cent of the overall value of the Irish stock market. The overall Irish stock market index is taken to be the ISEQ index, the FTSE-100 is taken as the overall UK market index, and the UK stock market sector indices are the FTSE sector indices (as defined by the FTSE-350 Actuaries index), see Table 1.

Returns are given by the first difference of the natural logarithms of stock prices. The sample autocorrelations of the log price series reveal some degree of persistence in each series as they tend to die off slowly. The first-order autocorrelation values close to one suggest that the series are non-stationary. Preliminary unit root testing (not reported, and available on request from the authors) confirms that all the log price series are I(1) processes.

Table 2 reports summary statistics on the series of interest. The sample moments for the unconditional return distributions indicate empirical distributions with heavy tails relative to the normal distribution. The majority of the series exhibit non-normality and are strongly leptokurtic. This finding is consistent with previous studies on the Irish stock market (Lucey (1994); Gallagher (1995)). Furthermore, the Lagrange Multiplier test (Engle, 1982) of ARCH(1) effects indicates non-linear dependencies in the return distribution in all Irish stock return series, except the Elan series.[6]

The linear dependencies highlighted by the Ljung-Box statistics for the returns series may indicate some delay in information processing. This suggests that the return generating process is not strict white noise in the sense of two data points being independent (Cochran and Mansur, 1993) and, therefore, some form of market inefficiency exists (Koutmos, 1996).

5. The constant conditional correlation restriction is likely to be violated if pre- and post-October 1987 crash periods are included in the estimation procedure (see Von Furstenberg and Jeon, 1989).

6. The small ARCH(1) and $LB^2$ values for Elan Corporation may reflect the idiosyncratic nature of this stock which recorded only 17 bargains for 1996. ARCH in daily return data has been related to the time dependence in the process generating information flow to the market (Chelley-Steeley and Steeley, 1995). Using a sample of high-volume individual stocks, ARCH effects disappear when volume is included in the conditional variance equation (Lamoureux and Lastrapes, 1990). Engle's (1982) ARCH(1) test is not powerful in testing for the presence of significant ARCH effects when the data generating process is multivariate. Therefore, testing Elan Corporation in a VAR(q)-GARCH(1,1) process is more appropriate.

Table 2: *Summary Statistics*

| *Irish Stocks* | *Mean* | *Std D* | *Skew* | *K-3* | *LB(5)* | *LB(10)* | *LB²(5)* | *LB²(10)* | *χ²(1)* |
|---|---|---|---|---|---|---|---|---|---|
| AIB | 0.058 | 1.514 | 0.021 | 7.931* | 15.34* | 17.46 | 388.98* | 431.60* | 142.34* |
| Bank of Ireland | 0.062* | 1.500 | 0.037 | 7.367* | 39.05* | 43.39* | 249.05* | 288.32* | 169.57* |
| Independent Newspapers | 0.071* | 1.488 | -0.442* | 14.496* | 10.66* | 17.36 | 45.81* | 57.00* | 9.25* |
| Smurfit | 0.033 | 1.719 | 0.678* | 23.185* | 5.78 | 8.03 | 37.05* | 38.15* | 13.13* |
| CRH | 0.069* | 1.407 | 0.149* | 4.681* | 4.73 | 8.76 | 113.41* | 126.03* | 189.89* |
| Kerry | 0.092* | 1.332 | 0.463* | 12.533* | 6.81 | 17.48 | 27.41 | 45.27* | 27.57* |
| Waterford-Wedgwood | 0.005 | 2.501 | -0.813* | 19.816* | 20.33* | 25.50* | 16.91* | 25.15* | 14.51* |
| Greencore | 0.074* | 1.067 | -0.517* | 11.124* | 5.87 | 10.99 | 32.58* | 39.19* | 11.23* |
| Elan Corporation | 0.116* | 2.238 | 2.495* | 87.000* | 1.88 | 3.32 | 0.69 | 1.17 | 0.07 |
| Irish Life | 0.039 | 1.190 | 0.351* | 9.167* | 11.08 | 24.16* | 10.52 | 12.65 | 35.05* |
| *Indices* | *Mean* | *Std D* | *Skew* | *K-3* | *LB(5)* | *LB(10)* | *LB²(5)* | *LB²(10)* | *χ²(1)* |
| ISEQ | 0.042* | 0.818 | -0.075 | 7.748* | 92.92* | 102.77* | 139.51* | 165.17* | 107.09* |
| FTSE-100 | 0.036* | 0.783 | 0.098 | 2.336* | 8.51 | 15.35 | 64.60* | 96.92* | 29.15* |
| Banks (Retail) | 0.063* | 1.195 | 0.412* | 4.735* | 15.94* | 32.57* | 92.71* | 108.62* | 59.39* |
| Building Materials and Merchants | 0.006 | 1.090 | 0.588* | 7.207* | 109.58* | 120.61* | 306.19* | 427.92* | 38.58* |
| Paper, Packging & Printing | 0.023 | 0.835 | -0.558* | 8.615* | 106.85* | 120.33* | 154.62* | 160.15* | 64.27* |
| Pharmaceuticals | 0.059 | 1.170 | 0.119* | 1.001* | 18.56* | 21.24* | 72.66* | 123.79* | 32.82* |
| Household Goods | 0.030 | 0.891 | 0.303* | 4.059* | 59.30* | 64.13* | 27.57* | 31.27* | 11.34* |
| Food Producers | 0.025 | 0.732 | 0.222* | 3.894* | 34.70* | 39.64* | 68.77* | 119.97* | 22.63* |
| Life Assurance | 0.050* | 1.158 | 0.384* | 4.118* | 28.80* | 45.02* | 73.48* | 100.69* | 45.64* |
| Media | 0.041* | 0.769 | -0.351* | 8.615* | 52.98* | 73.15* | 58.65* | 110.01* | 16.27* |

*Notes:* (1) The first observation for the last 3 Irish stocks are as follows: Greencore (25/4/91), Elan Corp (4/9/89), and Irish Life (22/7/91), giving 1,474, 1,904, and 1,414 observations, respectively.

(2) Mean indicates the average daily return (in per cent), Std D the standard deviation, Skew the skewness coefficient, K-3 the excess kurtosis coefficient, LB and LB² the Ljung-Box Q-statistics for the returns and squared returns series, respectively, and $\chi^2(1)$ the Lagrange Multiplier test coefficient of ARCH(1) effects.

(3) Skewness is the third moment in a normal distribution, $E(x - \mu)^3$, and refers to a lack of symmetry with respect to the vertical axis. Kurtosis is the fourth moment, $E(x - \mu)^4$, and measures the degree to which a distribution has a "taller" or "flatter" curvature with respect to the normal (mesokurtic) distribution, which has a kurtosis value of 3. A distribution with a kurtosis value greater than 3 is leptokurtic (long-tailed). The standard errors for skewness and excess kurtosis are given by the $\sqrt{(6/N)}$ and $\sqrt{(24/N)}$, respectively, where N equals the number of observations.

(4) The portmanteau Ljung-Box Q statistic (LB) tests the null that the autocorrelation coefficients are jointly equal to zero. It is distributed as a $\chi^2(k)$ statistic with degrees of freedom, k, equal to the number of autocorrelations calculated (Ljung and Box, 1978). It is given by $Q(k) = T(T+2) \sum_{i=1}^{k} (1 / n - i) \rho_i^2$, where $\rho_i$ is the $i^{th}$ autocorrelation coefficient.
Q statistics for the returns and squared returns were calculated at 5 and 10 lags, thereby picking up weekly and fortnightly dependencies (a week corresponds to five trading days). Significant LB statistics for the returns series indicate linear dependencies, whereas significant LB statistics for the squared returns series indicate non-linear dependencies in the returns distribution which can be attributed to strong conditional heteroscedasticity (Hsieh, 1989).

(5) The $\chi^2(1)$ statistic is based on an LM test, where $NR^2 \sim \chi^2(1)$, developed by Engle (1982) to detect the presence of ARCH(1) effects.

(6) * indicates a significance at 5 per cent level.

## IV EMPIRICAL RESULTS

In order to identify the mean (return) and volatility spillovers to individual Irish share prices, we model the series employing the VAR(q)-GARCH(1,1) model as outlined in Equations (4)-(11). The multivariate model is estimated by maximum likelihood. The lag length q for the VAR was chosen as follows. First, using the Akaike Information Criterion (AIC), the initial lag length was determined. Second, using the Ljung-Box Q-statistic we tested for the whiteness of the residuals, increasing the lag depth (if necessary) until they were approximately white noise. The chosen lag depth is given in the final column of Table 3(a).

*Mean Spillovers*

Table 3(a) reports the results from the conditional mean equations for the Irish stocks (the mean and volatility equations for the ISEQ, FTSE-100, and the FTSE sectors are not reported, and are available on request from the authors). There is a significant mean spillover from the overall UK market and the industry sector only to a minority of Irish stocks.[7] This finding contradicts the earlier aggregate index findings that the UK market Granger-causes movements in the Irish stock market (Gallagher, 1995). Moreover, the results underpin the argument for using a more disaggregated approach to identify mean spillovers in Irish stocks rather than estimating interdependencies between the two national stock market indices.

The mean spillovers from the UK to Irish stocks are not homogeneous across the ten stocks. For example, only three stocks (Smurfit, CRH, and Irish Life) exhibit significant mean spillovers from the UK. Furthermore, it is the overall UK market (FTSE-100) rather than the industry sector indices that tends to explain movements in the future stocks prices of these three Irish stocks. The exception is Irish Life, where the return on this stock is significantly affected in future periods by a UK-industry return shock today.

The three significant UK mean spillovers that exist are positive and large, ranging from 0.18 (Irish Life) to 0.28 (Smurfit). For example, a 1 per cent increase in the FTSE-100 index will Granger-cause Smurfit stock to increase by 0.28 per cent over the following three days. Furthermore, the coefficient value of the industry-sector mean spillover for Irish Life is 0.19.

The finding of a significant own- and ISEQ-mean spillover is evidence against the martingale hypothesis for Irish stock prices and, therefore, market efficiency.

7. As the UK and Irish stock markets trade simultaneously, the measures reported for return and volatility spillovers between the markets are not affected by measurement problems due to nonsynchronous trading hours.

Table 3: *Multivariate GARCH Estimates*

(a) Conditional Mean Equation:
*Coefficient Values, Chi-Squared Values and Significance Levels*

| | $\Sigma\beta_{jj,k}$ | $\Sigma\beta_{ji,k}$ | $\Sigma\beta_{jf,k}$ | $\Sigma\beta_{js,k}$ | $q$ |
|---|---|---|---|---|---|
| AIB | 0.0102 | –0.0160 | 0.1988 | 0.0567 | 4 |
| | 11.2951 | 8.7512 | 9.3060 | 0.7467 | |
| | (0.0234)* | (0.0676) | (0.0539) | (0.9454) | |
| Bank of Ireland | 0.0004 | –0.0111 | 0.2718 | 0.0068 | 4 |
| | 15.6574 | 12.0518 | 7.2413 | 2.2924 | |
| | (0.0035)* | (0.0170)* | (0.1237) | (0.6822) | |
| Independent | –0.0838 | 0.6230 | –0.0586 | 0.2176 | 5 |
| | 11.4913 | 53.0780 | 6.8870 | 4.8878 | |
| | (0.0425)* | (0.0000)* | (0.2292) | (0.4297) | |
| Smurfit | –0.0074 | 0.0624 | 0.2799 | 0.0257 | 3 |
| | 2.2909 | 0.9119 | 19.1289 | 0.1280 | |
| | (0.5143) | (0.8225) | (0.0003)* | (0.9883) | |
| CRH | –0.1234 | 0.3766 | 0.2650 | 0.0944 | 1 |
| | 13.3610 | 31.8964 | 17.5689 | 3.5199 | |
| | (0.0003)* | (0.0000)* | (0.0000)* | (0.0606) | |
| Kerry | –0.1753 | 0.8176 | 0.1413 | –0.0960 | 3 |
| | 18.9185 | 117.6009 | 5.6276 | 4.7368 | |
| | (0.0003)* | (0.0000)* | (0.1312) | (0.1921) | |
| Waterford-Wedgewood | –0.0158 | –0.1586 | 0.1816 | 0.0672 | 5 |
| | 15.2069 | 9.9189 | 7.4288 | 1.3109 | |
| | (0.0095)* | (0.0776)* | (0.1907) | (0.9338) | |
| Greencore | –0.1590 | 0.4790 | –0.0265 | 0.0868 | 2 |
| | 14.7033 | 61.3791 | 5.0110 | 4.2123 | |
| | (0.0006)* | (0.0000)* | (0.0816) | (0.1217) | |
| Elan | 0.0175 | 0.4782 | -0.0451 | 0.1711 | 5 |
| | 22.4908 | 11.9779 | 1.4597 | 3.1550 | |
| | (0.0004)* | (0.0351)* | (0.9177) | (0.6761) | |
| Irish Life | –0.1458 | 0.3784 | 0.1761 | 0.1876 | 1 |
| | 15.2633 | 31.6034 | 10.4370 | 44.5432 | |
| | (0.0001)* | (0.0000)* | (0.0012)* | (0.0000)* | |

(b) Conditional Variance Equation:
*Coefficient Values and Significance Levels*

| | $c_{jj}$ | $b_{jj}$ | $b_{ji}$ | $b_{jf}$ | $b_{js}$ | $a_{jj}$ |
|---|---|---|---|---|---|---|
| AIB | 0.0590<br>(0.0000)* | 0.0525<br>(0.0000)* | 0.1089<br>(0.0000)* | | 0.0340<br>(0.0000)* | 0.8692<br>(0.0000)* |
| Bank of Ireland | 0.0040<br>(0.0422)* | 0.0273<br>(0.0000)* | | 0.0208<br>(0.0005)* | 0.0003<br>(0.8911) | 0.9660<br>(0.0000)* |
| Independent | 0.1131<br>(0.0000)* | 0.0412<br>(0.0000)* | 0.1061<br>(0.0000)* | | 0.0818<br>(0.0000)* | 0.8427<br>(0.0000)* |
| Smurfit | 0.3554<br>(0.0000)* | 0.0938<br>(0.0000)* | 0.0005<br>(0.9815) | 0.0003<br>(0.9904) | 0.2906<br>(0.0000)* | 0.7405<br>(0.0000)* |
| CRH | 0.2684<br>(0.0000)* | 0.0760<br>(0.0000)* | 0.2612<br>(0.0000)* | 0.0111<br>(0.6584) | 0.1406<br>(0.0000)* | 0.6021<br>(0.0000)* |
| Kerry | 0.0979<br>(0.0000)* | 0.0407<br>(0.0000)* | 0.3263<br>(0.0000)* | | 0.4111<br>(0.0000)* | 0.6898<br>(0.0000)* |
| Waterford-Wedgewood | 0.1879<br>(0.0000)* | 0.0711<br>(0.0000)* | 0.1694<br>(0.0000)* | | 0.1407<br>(0.0000)* | 0.8569<br>(0.0000)* |
| Greencore | 0.0110<br>(0.0001)* | 0.0805<br>(0.0000)* | 0.1297<br>(0.0000)* | | | 0.8598<br>(0.0000)* |
| Elan | 0.2472<br>(0.0000)* | | 0.0303<br>(0.0395)* | 0.3255<br>(0.0000)* | 0.1656<br>(0.0000)* | 0.9148<br>(0.0000)* |
| Irish Life | 0.1069<br>(0.0000)* | 0.0662<br>(0.0000)* | 0.1811<br>(0.0000)* | 0.1077<br>(0.0000)* | | 0.7686<br>(0.0000)* |

Notes: (1) The significance levels are in parentheses.
(2) Zero values for parameters due to the non-negativity constraints of the conditional variance are not reported.
(3) *indicates a significance at the 5 per cent level.

However, the explanatory power of these lagged variables is low and, in the presence of transaction costs and thin trading, profitable trading strategies are unlikely. All stocks (except Smurfit) exhibit a significant own- and ISEQ-mean spillover. The magnitude of the domestic spillovers are large and predominantly positive, ranging from 0.38 (CRH and Irish Life) to 0.82 (Kerry).[8] In contrast to

8. Positive correlation in the return distribution is usually evident in short investment horizons (Fama and French, 1988).

the general findings, the estimated coefficient of the ISEQ mean spillover to Waterford-Wedgewood is –0.16, indicating that a 1 per cent increase in the ISEQ index today will on average result in (Granger-cause) Waterford-Wedgewood stock price to fall by 0.16 per cent over the next five days.

Overall, the conditional mean equations only partly supports earlier findings that the Irish stock market in general — indicated by three of the ten largest stocks — lags behind the overall UK market. Therefore, innovations in the UK market get incorporated into certain Irish stocks with a lag. Furthermore, for only one of the ten stocks is there an industry-specific return spillover that significantly explains the return generating process, i.e., its stocks returns are strongly influenced by UK industry sector shocks. It is notable that the two largest industrial stocks (CRH and Smurfit) exhibit significant mean spillovers from the UK. This finding may be due in part to the exposure of these stocks to UK (and international) economic events and also the interest shown by UK investors in holding these stocks in their portfolios. Stocks with high internationally diversified shareholdings are likely to reflect innovations in other markets to a greater extent than stocks with primarily Irish-based shareholders.

*Volatility Spillovers*

In taking a multivariate GARCH approach this paper captures the origin and nature of volatility spillovers not previously considered by earlier studies (for example, Gallagher, 1995).[9] Table 3(b) reports the results for the conditional variance equations for the ten Irish equities. The results show the presence of significant conditional heteroscedasticity in the return series of all stocks.

Significant own- and cross-volatility spillovers to the individual Irish equities exist for all stocks. Own-volatility spillovers are large and significant for all stocks (except Elan — see footnote 7), indicating the presence of strong ARCH effects. The own-volatility spillover coefficients range from 0.03 (Bank of Ireland) to 0.09 (Smurfit). Thus, past volatility shocks in Smurfit have a greater effect on future Smurfit volatility than past volatility shocks in other Irish stocks.

Consistent with previous studies (for example, Hamao *et al.*, 1990), all coefficient values for the one-lag conditional variances are large and highly significant, indicating high volatility persistence. Persistence of stock market volatility is highest for Bank of Ireland and lowest for CRH.

Cross-volatility spillovers from the ISEQ index are generally quite large and significant, indicating that shocks in the overall Irish market are translated into individual domestic stocks. Volatility shocks from the ISEQ index spill over

9. These earlier studies that estimate mean equations without accounting for ARCH effects produce inconsistent estimates.

to eight of the ten stocks. This finding may reflect the high percentage of trading on the Dublin market for these stocks. The importance of the domestic market for a number of stocks (AIB; Independent; CRH; Waterford-Wedgewood; Greencore; and Irish Life) is indicated by the finding that the magnitude of the volatility spillovers from the ISEQ index are greater than the cross-volatility spillovers from the UK market. CRH and Kerry report values of cross-volatility spillovers from the ISEQ index in excess of 0.2.

Volatility spillovers from the UK are significant for all stocks, except Greencore. This result lends support to the international finding that volatility innovations in one market (usually the larger market) are transmitted to the volatility of returns in another market (Theodossiou and Lee (1993); Karolyi (1995); Brailsford (1996)). Furthermore, it implies that volatility linkages are not limited to national indices, but can also spill over to individual stocks in the smaller market.

The results of the cross-volatility spillovers from the UK industry sector (represented by the $b_{js}$ coefficients), reported in column six of Table 3(b), support the disaggregated sectoral approach adopted in this paper. The conditional variance of returns of Irish equities are time-varying and for seven of the ten equities are significantly explained by past industry-specific volatility shocks. Moreover, the magnitude of the significant industry-volatility spillovers ranging from 0.03 (AIB) to 0.41 (Kerry) exceeds the spillovers from the FTSE-100 index, with Elan as the exception.

*Summary*

The relative size of mean and volatility spillovers from the UK indicates asymmetries in their effects on Irish stocks. Mean UK spillovers to the Paper, Packaging and Printing (Smurfit); Building Materials and Merchants (CRH); and Life Assurance (Irish Life) sectors are quite large, while spillovers to the Banks (AIB and Bank of Ireland) are generally small.

The source of volatility spillovers to Irish stocks is not homogeneous. Smurfit; Elan; Independent; Kerry; CRH and Waterford-Wedgewood all exhibit significant and large industry volatility spillovers. Each of these (except Smurfit), together with AIB, Greencore and Irish Life exhibit significant and large domestic market (ISEQ) volatility spillovers. The large sectoral spillovers of 0.41 for Kerry and 0.29 for Smurfit are likely to reflect their international trading position, and the widely-held view that Smurfit's fortunes are linked explicitly to the outlook for the paper and packaging industry.

## V CONCLUSION

This paper has investigated the price behaviour of Irish stocks and, through a multivariate VAR-GARCH analysis, has identified the role of the UK stock market in the pricing of individual Irish stocks.

Significant return and volatility spillovers exist from the UK to a majority of individual Irish stocks. Large and significant own-volatility spillovers exist for all stocks indicating, as expected, the strong ARCH effect typically found with high-frequency financial data. A strong GARCH effect (a persistent volatility effect) is present as evidenced by the uniformly high one-lag conditional volatilities.

The institutional feature that a high proportion of trading in certain stocks occurs in the Dublin market is evident from the significant cross-volatility spillovers from the ISEQ index. Nevertheless, the importance of the UK market to its Irish counterpart is manifested by the fact that volatility spillovers from the UK market exist for all Irish stocks, except Greencore. Moreover, the innovation in employing a disaggregated sectoral approach is upheld by the findings that UK sectoral spillovers dominate cross-volatility spillovers from the overall UK market.

The results indicate that stocks do not behave homogeneously to return and volatility shocks (either domestic, foreign or industry). Therefore, aggregate results such as those presented by Gallagher (1995) should be cautiously interpreted when appied to individual stocks. Following Roll's (1992) argument, this conclusion especially applies to small stock markets where there are limits to holding diversified portfolios.

With the marked increase in the degree of global cross-listings, the joint trading of Irish stocks suggests that the current framework could usefully be extended to other environments with similar institutional and economic linkages, for example, American Depository Receipts (ADRs) and jointly traded stocks on the Canadian and American stock markets (Webb, Officer and Boyd (1995); Karolyi and Stulz (1996)). Previous Irish studies have ignored the strong temporal dependence in the conditional variance of stock returns evident in this paper for the Dublin market. Therefore, it is incumbent on future Irish studies in financial economics to incorporate this important role of time-varying conditional variances.

The significant lagged parameters in the mean equation suggest that individual Irish stocks are inefficient in processing information. This evidence supports earlier findings against the martingale hypothesis for Irish stock prices (Gallagher, 1995). Since the individual Irish stocks clearly violate the random walk hypothesis, it is important to explore more fully the return properties of Irish stocks in order to use such information to develop and modify existing models (that rely on the random walk hypothesis) in order to model a better approximation of reality.

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