International Equity Market Integration in a Small Open Economy: Ireland January 1990 – December 2000

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Abstract

We examine the relationship between the Irish, German, UK and US equity markets. Our main finding is that the Irish equity market depends heavily on trading activity in the other markets but not *vice versa*. Significant return and volatility spillover effects occur in the direction of, but not from the Irish market. We also find that dual listing in the form of ADRs has an important role to play in these spillover effects. Our findings obtain throughout the sample, but are strongest for the period after the ERM crises and before the introduction of the euro.

JEL classification: G1; G10.
Keywords: Equity market linkages, return and volatility spillovers, dual trading.

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1. Introduction

Ireland is recognized as a small open economy with a heavy reliance on external trade that has been increasing over time (EUROSTAT, 2000). The nature of Ireland's capital flows is less clear, however, and this paper addresses this subject by describing the bivariate interactions between the Irish equity market and the markets in Germany, the UK and the US. Traditional strong interactions between the Irish and the UK markets for economic and political purposes may have been superseded by new relationships with the Eurozone-dominated German markets and the globally dominant US market.

The literature provides some insights into the areas of investigation. Capital markets in general have been characterised by increased integration (Claessen and Forbes, 2001).[1] Within this, the extent and speed of these interactions have also increased. Harmonisation of regulatory and market structures, and the removal of capital control barriers are driving forces in these increased market interactions. Market linkages are decomposed into short and long run components with strong support for the former and weaker evidence on the latter (Malliaris and Urrutia, 1992). These interactions have incorporated both return and volatility linkages in a time-varying fashion (Bae and Karolyi, 1994; King et al., 1995). Dual listing equities also have an important influence on the time varying interactions (Karolyi, 2002).

The Irish equity market is small by international standards, with the majority of companies thinly traded and dominated in size by a few organizations. These latter equities have a dual listing with the American Depositary Receipts (ADR) programme being a popular mechanism. Accounting for these features, this paper examines market interactions during the 1990s by focusing on four issues: *first*, the long run relationship between the markets; *second*, the dynamic relationship between them; *third*, the return and volatility transmission process between them; and *fourth*, the impact of dual listing with ADRs on the return and volatility linkages. We also break the full sample into a number of separate sub-periods to discern whether our findings change as a result of key political and economic events.

The paper proceeds as follows. In the next section, a discussion of related studies that model the Irish market is presented, coupled with an outline of the methodological framework. Section 3 describes the data and some preliminary findings. The main empirical results are discussed in section 4. Finally a summary and conclusions are given in section 5.

2. Prior related studies and methodological framework

From a vast literature that examines the relationship between international equity markets, a number have specifically modelled the Irish market. Hardouvelis *et al* (1999) examine the development of the euro and its impact on equity market integration from a European-wide context using weekly price data. In a time-varying process, each county's returns are linked to an EU benchmark index and currency returns, and they use the BEKK (1990) model to detail volatility spillovers. They find that the development of EMU led to increased integration due to a reduction in restrictions related to the currency composition of investors' portfolios. Integration increases with the likelihood of the country joining EMU and the closer the launch date of the euro. In contrast to this, Aggarwal, Lucey and Muckley (2003) use cointegration methods on daily European returns for 11 European markets. They provide a dynamic multivariate approach with a Kalman filter to determine whether markets are converging. They find a long run relationship between all markets that increased over the 1990s driven by the EMU project, and a convergence in returns towards London and Frankfurt that is more rapid for the latter market.

While this study's emphasis is on examining the trading relationships for the Irish equity market in a bivariate setting, there is some previous evidence addressing this subject explicitly. Gallagher (1995) examines interdependence between the Irish, UK and German markets at weekly intervals using Granger causality tests. This study finds that while increased short run linkages occur, no long run cointegrating relationship exists between the markets. Granger causality occurred from the UK and German markets to Ireland but not in reverse. However, using a non-overlapping timeframe, Kearney (1998) finds that a long run relationship does in fact exist between the Dublin and London markets using monthly observations. He examines the causes of volatility in Ireland with a univariate GARCH approach incorporating macroeconomic explanatory variables. He finds that volatility in the Irish equity market is impacted most by FTSE and exchange rate volatility. Using a bivariate GARCH specification Gallagher and Twomey (1998) examine return and volatility spillovers from the FTSE100 index and specific UK sector indexes to the 10 largest Dublin traded equities. They find weak evidence of return linkages from the UK, with stronger volatility effects from both industry specific and market indexes.

Our study examines the bivariate linkages between the Irish equity market and its main partners, and it deviates from previous studies in our modelling approaches, in our data, and in the hypotheses that we test. We use impulse response analysis to determine the speed of, and the variance decomposition to measure the magnitude of these interactions. Using a bivariate GARCH specification, the impact of the US, the largest world equity market, is investigated. We then examine the influence of dual trading by examining return and volatility spillovers of Irish ADR's. These relationships are analysed during the 1990s, which incorporates a period before, during and after the EMS crises.

Equity market relationships can be examined using the following framework in prices:

$$P_{ISEQ,t} = \beta_0 + \beta P_{f,t} + e_t \qquad (1)$$

Here, ISEQ is the Irish stock market index, f is the foreign index (FTSE, DAX30, and S&P500), and this notation can be extended to apply to returns and higher moments. A number of key issues arise here. *First*, what is the long run relationship between the Irish equity market and other markets? To address this, cross-correlations provide an average estimate of the linkage of markets for any time period. The long run relationship between the markets is examined using the cointegration techniques of Engle and Granger (1987) and Johansen and Juselius (1990). Following Engle and Granger an error correction model is estimated for the ISEQ:

$$\Delta P_{ISEQ,t} = \alpha_1 + \alpha_{ISEQ}\, \hat{e}_{t-1} + \sum \alpha_{11}(i)\, \Delta P_{ISEQ,t-i} + \sum \alpha_{12}(i) \Delta P_{f,t-i} + \epsilon_{ISEQt} \qquad (2)$$

In (2), i = 1 … n, and the error correction model shows the long run dynamics of the adjustment process between two national market indices. Johansen and Juselius (1990) extend Engle and Granger's cointegration to a multivariate framework using a VAR. Following Johansen and Juselius (1990), the following is estimated:

$$\Delta P_{ISEQ,t} = \sum_{i=1}^{p-1} \pi_i \Delta P_{ISEQ,t-i} + \pi P_{ISEQ,t-p} + \epsilon_t \quad (3)$$

The parameter matrix, π, indicates whether the vector of stock prices has a long run relationship or not. The rank of π equals the number of independent cointegrating vectors. The procedures adopted provide information on any deviations of the long run relationships for equity markets.

The *second* issue we focus on concerns the dynamic relationship between the Irish equity market and other markets. Using the VAR in (3), we examine innovation accounting using forecast variance decomposition and impulse response analysis. Following Eun and Shim (1989), this divides the dynamic relationship into two concerns. The variance decomposition uses the VAR's forecast error to determine the extent to which movements in one market can be explained by a shock in another. Impulse responses then determine the speed in which price movements are transmitted between markets. In estimating the VAR system, the dynamic responses of each national stock index to innovations in a particular market using simulated responses can be traced out. In addition, the innovation accounting technique allows us to measure the relative importance of a market in generating unexpected variations of returns in another market, and thus establishes a causal ordering among the national stock markets. The findings of the VAR analysis are thus expected to shed light on the interdependence structure of national stock markets, in general, and on the international transmission of stock market movements, in particular.

The *third* issue concerns the return and volatility linkages between the Irish equity market and other markets. Volatility linkages are examined with the BEKK (1990) multivariate GARCH (1, 1) model:

$$H_{i,t} = C_0^{*'} C_0^{*} + A_{11}^{*'} H_{i,t-1} A_{11}^{*} + B_{11}^{*'} \varepsilon_{i,t-1} \varepsilon_{i,t-1}^{'} B_{11}^{*} \qquad (4)$$

where $H_{i,t}$ is the conditional variance covariance matrix at t. Each matrix, C, A and B is 2 x 2 and C is restricted to be upper triangular with 11 free parameters in the model. Multivariate GARCH models are notoriously hard to estimate, and for practical purposes the BEKK specification can be used without detriment to the application. The BEKK parameterisation has the advantage of being parsimonious while capturing the interactions requiring estimation of only 11 parameters for a bivariate setting in the conditional variance-covariance structure. It also ensures that $H_{i,t}$ positive definite.

Our use of the bivariate setting allows us to explicitly examine country pair interactions, focusing on the respective linkage of each other market with the Dublin market. The mean linkages are examined with a first order VAR that also acts as a filter removing any covariation between the indexes arising from lead and lag relationships in returns themselves. Parameters describe the extent of return interaction between the respective indexes and directional causality. Volatility spillover effects are ascertained from the GARCH estimates. The BEKK model implies that only the magnitude of past return innovations is important in determining current time-varying variances and covariances irrespective of sign.

Fourth, do ADRs impact the return and volatility linkages for the Irish equity market? A number of Irish equities have obtained dual listing by trading on the Dublin equity market and in the US as an ADR. ADRs, the most attractive means of conferring dual listing status on the US market, are negotiable certificates that confer ownership of shares in the foreign company. Their attractiveness is due to the liquidity and transparency available to traders, and importantly for the companies themselves, minimizing the cost of capital by diversifying across the investor base. There are restrictions placed on the dual listed company, however, including necessary sponsorship of a US bank and meeting the trading and financial requirements as specified in the sponsoring programme.

Using a case study approach for dual listing on the US and Irish markets, we determine whether the return and volatility linkages carry through to individually quoted equities. The methodology remains unchanged in the analysis of pair-wise linkages where a VAR provides a description of the return spillover effects, and a bivariate GARCH (1, 1) model is fitted to determine the volatility spillover effects in terms of magnitude and causality. Overall a profile of return and volatility spillover effects is provided based on trading location detailing the role that ADRs provide in this process.

3. Data considerations

We use daily closing price data from Datastream over an 11-year period from 01/01/1990 to 29/12/2000.[2] The Irish ISEQ, the UK FTSE All Share, the German DAX30 and the US S&P500 indices are analysed. When national stock exchanges were closed due to trading restrictions such as national holidays, the index price is removed from analysis. The dual listed companies chosen are AIB, Elan and Jefferson Smurfit, representing a cross section of dominant companies traded on the Irish market. Returns are denoted as the first difference of the natural logarithm of prices. There is an element of non-synchronous data to be accounted for. Both the London and Dublin markets operate contemporaneously from 09.00-17.00 Greenwich Mean Time (GMT). In contrast, the Frankfurt bourse trades between 09.30-16.00, and in New York trading occurs between 09.30-16.00. A common GMT framework has the German market open between 08.30-15.00, and the US between 14.30-21.00. We assume that the Frankfurt times overlap perfectly with the Irish market and that the lead days closing price is used for measuring prices in New York.[3]

The dataset is divided into three time periods to capture the effects of changing financial and economic integration between Ireland and the other markets over time. These sub-periods are based on key economic and political events that have occurred and are as follows:

- ***Sub-period 1*** runs from 1 January 1990 to 31 July 1993 involving the period leading upto and including the ERM crises,

- ***Sub-period 2*** runs from 3 August 1993 to 31 December 1998 involving the period post ERM crises and pre Euro, and
- ***Sub-period 3*** runs from 1 January 1999 to 29 December 2000 involving the introduction of the Euro.

Some preliminary statistics are reported in Table 1. Positive daily returns averaged approximately 1 percent over the full period for the ISEQ with volatility of 0.5 percent. Turning to the sub-periods, volatility has increased as the decade progressed associated with a very strong equity market performance during the mid 1990's. There is evidence of excess skewness and kurtosis relative to the normal distribution. Cross-correlations provide a preliminary indicator of equity integration, with positive correlation exhibited for the full period of analysis. The markets are most closely linked with US equities, although this is weakest for the ISEQ, which has relatively strong links (and of equal magnitude) with the UK and German markets. This correlation structure changes over time with increased linkage from sub-period 1 to 2 reversing in sub-period 3.

Insert Table 1 about here

4. Empirical findings

The *first* key question to be addressed concerns the nature of the long run relationship between the Irish equity market and other markets. Several interesting findings emerge and these are given in Table 2. At a common significance levels there is a cointegrating relationship between the ISEQ and FTSE but not with the other markets. This drives the long run relationship that exists for the 4 markets together. Variations occur across the sub-periods with evidence supporting increased integration between 1993 and 1999 that surprisingly decreased since 1999. Possible explanations include increased integration associated with bull markets, and contagion effects from the fallout of the ERM and Asian crises with the reduction caused by noise inducement from using daily data.

Insert Table 2 about here

For the cointegration analysis, stationarity is first verified with estimates in Table 2. The results are consistent across markets and support previous studies. The hypothesis that each index contains a unit root is not rejected, the markets are integrated of order 1, I(1).[4] No qualitative deviations occur across the sub-periods. Augmented Dickey-Fuller test statistics provide weak support for no cointegration. Given this weak support for a long run relationship for the country pairs and the conflicting past evidence in the literature, the Johansen and Juselius procedure is applied in the bivariate setting. There is general support for the bivariate cointegrating regression results with a lack of cointegrating relationships between the ISEQ and other markets for the full period, although a long run relationship is not rejected for the ISEQ and FTSE at 10% significance levels. However, a long run bivariate relationship is documented for sub-period 2 suggesting that the findings might be dependent on time periods chosen. This lack of consistency over the full period suggests that the contradictory bivariate findings of Gallagher (1995) and Kearney (1998) may be explained by the respective timeframes chosen.

This brings us to our *second* issue about the dynamic relationship between the Irish equity market and the other markets. The dynamic relationship is broken into two areas of investigation. First, variance decomposition is examined with results presented in Table 3 indicating that the Irish market is not exogenous. Thus a substantial amount of the ISEQ's variance is a result of activity in other markets. The breakdown of influence indicates that the US is the most important player in the ISEQ's variance decomposition followed by the UK. This is not surprising. Movements in the ISEQ index have negligible influence on those of other markets again supporting evidence of a casual effect for, and not by, the Irish market.

Insert Table 3 about here

Turning to the impulse response estimates, Table 4 provides normalised responses for the ISEQ index for a typical shock to and from the Irish market. These responses represent unit shocks measured in standard deviations. As can be seen from the results, innovations in the international equity markets are rapidly transmitted to the ISEQ. For instance, the response to a US shock on day 0 is 5.92. As expected, the response to a US shock also lags by 1 day and is even stronger with an estimate of

10.31. Shocks in the other markets also impact the ISEQ rapidly with the UK having the largest influence. In contrast, unit shocks in the ISEQ have little influence over the other markets. In general, the speed of transmission is quick with impulse response estimates reducing dramatically from day 2 onwards. These results suggest that the ISEQ becomes informationally efficient rapidly regardless of which market it is responding to. We now focus on the third issue.

Insert Table 4 about here

We now consider the third question about the return and volatility linkages between the Irish equity market and other markets. To examine this issue a VAR(1)-GARCH(1, 1) model is applied and estimates are presented in Table 5. The model is well specified according to the Ljung-Box statistics and suggests the dependence in the returns and especially squared returns is much reduced for the residual series. The VAR examines the direction and magnitude of the return linkages. The BEKK specification determines the causality and extent of volatility linkages. Note that the return interactions suggest that the spillover effects are in general positive,[5] with significant spillover effects to, but not from, the ISEQ index. As expected, the mean spillover effects are dominated by causality in the direction of the Irish equity market. The UK and US markets dominate and have a similar impact on the ISEQ although statistically the latter has slightly stronger effects.

Insert table 5 about here

Considering the second moment, the main diagonal elements of the variance covariance matrix are typical of a GARCH process with autoregressive and time dependent volatility effects reported for each index. The volatility spillover effects provides similar conclusions to the return interactions. As with the mean, the off diagonal of the covariance matrix identifies volatility spillover effects in the direction of, but not from, the Irish equity market. The US market has the biggest impact in terms of past squared innovations, while the German market has the largest impact for spillover of past conditional variances. Time variation in the covariance relationship for the ISEQ and the other indexes is given in Figure 1.

Insert Figure 1 about here

Considering the sub-periods gives an indication of how the market interactions have changed during the 1990's. The VAR(1)-GARCH(1, 1) results are presented in Tables 6-8 for all three sub-periods. The findings reinforce the full-period results with some notable variations. Beginning with similarities, mean spillovers are uni-directional to, and not from, the ISEQ index, with the US market being dominant. For all markets, the returns linkage is strongest for sub-period 2 and of reasonably similar magnitude during the other sub-periods. Also, autoregressive and time dependent volatility is generally documented for each index across the sub-periods. The variations in the sub-period results are interesting. In sub-period 1, weak volatility spillover effects are recorded along with negligible spillover effects in terms of past squared innovations, except for the FTSE. In sub-period 2, the movement towards the introduction of the euro impacts on increased integration between the Irish and German markets. Analysis of the final sub-period supports this view with the strongest volatility spillover effects to Ireland coming from the German market.

Insert Tables 6 – 8 about here

We now use a case study of dual listed companies to examine the fourth issue about whether ADRs impact on the return and volatility linkages for the Irish equity market. As described earlier, dual listing via ADRs is popular for allowing Irish equities trade in the US. A few companies dominate trading on the Dublin market, and three of these are chosen for analysis.[6] A VAR(1)-GARCH(1, 1) model is estimated for AIB, Elan and Jefferson Smurfit with findings presented in Table 9. The estimation procedure follows the investigation into the return and volatility interactions to the equities traded in Dublin and to the ISEQ index. The results reinforce the findings for the interactions between the ISEQ and S&P indexes. Strong mean and volatility spillover effects occur and their direction is from the ADRs to the Dublin market.

Insert Table 9 about here

In fact, the return spillovers have an even greater impact based on trading location than between the indexes. For instance, mean spillovers indicate that a 1% increase on the Jefferson Smurfit ADR causes a 0.472% increase on this equity traded on the ISEQ. The comparable spillover effect for the ISEQ index is 0.096%. These findings are consistent across equities, with AIB ADRs having the strongest statistical effect. Once again, the mean spillover effect is not always bi-directional with the exception of Elan. However all spillover effects are dominated by causality in the direction of equities traded in Dublin. Turning to the volatility effects, evidence of strong autoregressive and dependent volatility are consistent with the index analysis. As in the analysis of US and Irish indexes, past return innovations spillovers are based on trading location of the individual equities with causality toward trading in Dublin. The past volatility interactions however are not as strong although again they spillover to Dublin for AIB and Smurfit, impacting both the equities themselves and the ISEQ index. The results presented here indicate that dual trading has an important role to play in explaining the interactions between the Irish and US markets, with causality coming from activity in the ADRs.

5. Summary and conclusions

This paper examines bivariate relations for the Irish equity market with the US, UK and German markets. The long run relation between the markets was first determined using correlation analysis and cointegration techniques. The dynamic relationship between the markets was then profiled using forecast variance decomposition and impulse response analysis. The linkages between the markets were then analysed using multivariate GARCH techniques. Finally, a case study approach was adopted to determine the role of dual listing with ADRs on the time varying return and volatility linkages. Throughout our analysis, the impact of key economic and political events, namely the period pre and post ERM crises and the period after the introduction of the euro was examined.

Our main findings are that return interactions for the Irish equity market were strongest during the mid 1990s with the UK market having the dominant relation, and they were relatively weak for the other sub-periods. Thus, overall support for a long run relation, using cointegration techniques might be tenuous, and this might explain the inconsistent findings of previous studies. Variance decomposition findings indicate that the Irish equity market is heavily dependent on the activity of other markets, especially the US market. In addition, impulse response analysis of innovations indicates a rapid speed of transmission for the ISEQ that tapers off quickly.

Multivariate GARCH analysis points to significant return and volatility spillover effects to, but not from, the Irish equity market. These are strongest for the period post ERM crises and before the introduction of the euro, with the US and UK markets having a notable influence. The influence of the German market has risen over time, supporting greater integration of Eurozone markets. The role of dual listing for the return and spillover effects for the Irish equity market indicates a strong impact from US traded ADRs. These impacts are more pronounced than those emanating from our analysis using the indexes. Overall, our analysis demonstrates significant interactions of a direction and magnitude that are expected in the context of a small open economy.

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Table 1: Summary statistics for equity index returns

Full period

Moments	ISEQ	FTSE	DAX30	S&P500	Correlation	ISEQ	FTSE	DAX30	S&P500
Mean	0.98	1.62	0.15	0.29	**ISEQ**	1.00			
Std Dev	0.53	1.01	0.12	0.15	**FTSE**	0.43	1.00		
Skew	-0.29*	-0.17*	-0.09*	-0.23*	**DAX30**	0.49	0.52	1.00	
Kurtosis	8.84*	4.26*	5.81*	9.01*	**S&P500**	0.23	0.40	0.34	1.00

Sub-period 1

					Correlation	ISEQ	FTSE	DAX30	S&P500
Mean	-0.18	0.67	-0.01	0.11	**ISEQ**	1.00			
Std Dev	0.41	0.85	0.10	0.10	**FTSE**	0.32	1.00		
Skew	-0.11	0.47*	-0.42*	-0.07	**DAX30**	0.41	0.40	1.00	
Kurtosis	3.52*	3.37*	7.19*	1.64*	**S&P500**	0.22	0.32	0.29	1.00

Sub-period 2

					Correlation	ISEQ	FTSE	DAX30	S&P500
Mean	2.02	2.58	0.26	0.38	**ISEQ**	1.00			
Std Dev	0.75	1.34	0.16	0.18	**FTSE**	0.53	1.00		
Skew	-0.60*	-0.11*	-0.62*	-0.89*	**DAX30**	0.57	0.55	1.00	
Kurtosis	13.14*	4.66*	5.89*	12.73*	**S&P500**	0.27	0.43	0.34	1.00

Sub-period 3

					Correlation	ISEQ	FTSE	DAX30	S&P500
Mean	0.17	0.67	0.16	0.35	**ISEQ**	1.00			
Std Dev	1.99	3.93	0.49	0.66	**FTSE**	0.40	1.00		
Skew	-0.02	0.16	0.17	-0.02	**DAX30**	0.47	0.60	1.00	
Kurtosis	0.76*	0.87*	0.85*	0.97*	**S&P500**	0.16	0.44	0.40	1.00

Notes: The first two moments are expressed in percentage form. The symbol * indicates significance at the 5 percent level. Cross-correlations for the indexes are reported in the right-hand columns.

Table 2: Unit root tests and cointegration analysis for equity indexes

	Unit root				Cointegration		
	Indices		Returns			Returns	
Full period	**ADF**	**PP**	**ADF**	**PP**		**ADF**	**JJ**
ISEQ	-2.84	-2.73	-49.32*	-49.32*	ISEQ-FTSE	-3.17*	13.76
FTSE	-2.93	-3.05	-33.89*	-49.82*	ISEQ-DAX30	-2.39	7.47
DAX30	-3.18	-3.18	-51.24*	-51.24*	ISEQ-S&P500	-2.09	5.57
S&P500	-2.44	-2.58	-33.96*	-51.64*	ISEQ-FTSE, DAX30,S&P500	-3.89*	
Sub-period 1							
ISEQ	-2.01	-1.41	-26.64*	-26.78*	ISEQ-FTSE	-2.59	11.14
FTSE	-2.78	-2.78	-29.23*	-29.23*	ISEQ-DAX30	-3.62*	15.16
DAX30	-1.89	-1.92	-29.27*	-29.30*	ISEQ-S&P500	-2.75	14.33
S&P500	-0.01	-2.26	-29.00*	-29.06*	ISEQ-FTSE, DAX30, S&P500	-3.98*	
Sub-period 2							
ISEQ	0.12	-1.79	-15.68*	-33.29*	ISEQ-FTSE	-4.42*	25.25*
FTSE	-2.47	-2.21	-26.74*	-33.27*	ISEQ-DAX30	-3.89*	23.80*
DAX30	-0.36	-2.64	-30.28*	-36.44*	ISEQ-S&P500	-3.63*	16.41*
S&P500	0.56	-2.49	-36.07*	-36.10*	ISEQ-FTSE, DAX30, S&P500	-5.09*	
Sub-period 3							
ISEQ	-1.95	-1.72	-22.13*	-22.18*	ISEQ-FTSE	-2.51	28.30*
FTSE	-3.08	-3.03	-21.99*	-21.99*	ISEQ-DAX30	-2.45	15.58*
DAX30	-1.68	-1.72	-21.83*	-21.80*	ISEQ-S&P500	-2.15	13.36
S&P500	-2.28	-2.99	-22.01*	-22.02*	ISEQ-FTSE, DAX30, S&P500	-2.74	

Notes: The critical values for the Augmented Dickey Fuller (ADF) and Phillips and Perron (PP) tests of the null hypothesis of a unit root are -3.12, -3.41 and -3.96 at the 10%, 5% and 1% levels of significance respectively. The critical values for the ADF test for the null hypothesis of no cointegration, are –2.5671 at the 10% level, -2.8621 and –3.4336 at the 5% and 1% levels respectively. The critical values for the Johansen and Juselius (JJ) trace and maximum maximum eigenvalue statistics are 13.33 at the 10% level, 15.41 and 20.04 at the 5% and 1% levels respectively. The symbol * indicates significance at the 5 percent level.

Table 3: Forecast variance decomposition analysis for equity markets

Horizon	S&P500	FTSE	DAX30	ISEQ
ISEQ				
1	17.53	11.15	6.81	64.51
5	17.71	11.09	7.07	64.13
10	17.71	11.09	7.07	64.12
Horizon	**S&P500**	**FTSE**	**DAX30**	**ISEQ**
FTSE				
1	21.60	15.44	61.63	1.33
5	21.68	15.55	61.27	1.50
10	21.68	15.55	61.27	1.50
Horizon	**S&P500**	**FTSE**	**DAX30**	**ISEQ**
DAX30				
1	25.94	73.00	0.57	0.49
5	25.92	72.44	1.15	0.50
10	25.92%	72.43	1.15	0.50
Horizon	**S&P500**	**FTSE**	**DAX30**	**ISEQ**
S&P500				
1	99.51	0.23	0.01	0.26
5	98.88	0.30	0.12	0.70
10	98.87	0.31	0.12	0.71

Notes: The forecast variance of each markets price is broken up into portions accounted for by price shocks coming from other markets represented in percentage form.

Table 4: Impulse responses for the ISEQ index

No. of days	S&P500	FTSE	DAX30	ISEQ
To ISEQ				
0	5.93	9.30	7.41	22.79
1	10.31	1.83	0.06	-0.90
2	0.50	0.56	-0.82	-1.47
3	1.44	-0.08	-0.61	0.84
4	-0.85	0.52	1.30	0.68
5	0.45	-0.31	0.26	-0.01
6	0.06	0.04	-0.03	0.01
7	0.16	-0.04	0.09	0.02
8	-0.05	0.14	-0.02	0.00
9	0.02	0.00	-0.03	0.02
10	0.00	0.00	0.00	0.02
No. of days	**S&P500**	**FTSE**	**DAX30**	**ISEQ**
From ISEQ				
0	0.00	0.00	0.00	22.79
1	-0.41	-3.73	-0.77	-0.90
2	-0.07	-0.30	-0.11	-1.47
3	0.49	0.65	0.24	0.84
4	0.22	0.26	0.11	0.68
5	-0.06	-0.07	0.00	-0.01
6	-0.05	-0.07	-0.01	0.01
7	0.01	0.09	-0.01	0.02
8	0.02	0.07	0.00	0.00
9	0.00	0.02	0.00	0.02
10	0.00	-0.01	0.00	0.02

Notes: The impulse response coefficients represent the normalised response of a particular market to a shock of one standard error in another market.

Table 5: GARCH estimates for daily returns of the ISEQ index

Full period	S&P500		FTSE		DAX30	
Conditional mean						
c_{11}	0.000	(0.561)	0.000	(1.659)	0.000	(0.941)
r_{11}	0.145	(8.014)	0.028	(1.348)	0.082	(3.919)
r_{21}	0.178	(9.904)	0.235	(9.899)	0.094	(5.631)
c_{22}	0.001	(3.018)	0.000	(2.229)	0.000	(1.549)
r_{22}	0.019	(0.988)	0.136	(6.295)	0.063	(2.983)
r_{12}	-0.020	(-1.079)	-0.076	(-3.972)	-0.090	(-3.379)
Conditional variance						
c_{11}	0.000	(0.837)	0.000	(0.389)	0.000	(-0.055)
c_{12}	0.000	(1.343)	-0.001	(-10.493)	0.000	(0.176)
c_{21}	0.000	(-0.232)	-0.001	(-7.993)	0.000	(0.112)
a_{11}	0.283	(7.055)	0.185	(3.781)	0.165	(4.482)
a_{12}	-0.047	(-1.772)	0.018	(0.553)	-0.002	(-0.034)
a_{21}	0.283	(5.232)	0.139	(1.756)	0.124	(4.627)
a_{22}	0.106	(3.140)	0.247	(5.474)	0.317	(12.351)
b_{11}	0.856	(78.024)	0.965	(153347.882)	0.975	(33643.644)
b_{12}	0.047	(3.140)	-0.001	(-0.196)	-0.007	(-7.341)
b_{21}	-0.041	(-4.533)	-0.055	(-5.419)	-0.046	(-11.115)
b_{22}	0.992	(153741.777)	0.949	(1378.691)	0.932	(433.596)
Diagnostics						
R^2	0.067		0.072		0.032	
AIC	-18.786		-19.367		-18.588	
SBC	-18.761		-19.342		-18.563	
$Q\ (24)_{ret} \sim \chi^2(24)$	70.988		48.697		46.337	
$Q^2\ (24)_{ret} \sim \chi^2(24)$	229.351		235.720		280.279	
$Q\ (24)_{res} \sim \chi^2(24)$	25.382		19.618		28.444	
$Q^2\ (24)_{res} \sim \chi^2(24)$	119.918		113.803		116.793	

Notes: Quasi-maximum likelihood estimation gives robust t-statistics for the BEKK model based on Bollerslev and Wooldridge (1992) standard errors. T-statistics for the model are given in (). Home (foreign) market effects are given by 11 (22). Cross market effects to (from) the home country are given by 21 (12). Ljung-Box statistics, Q (24) and Q^2 (24), are given for the home returns (ret) and residuals (res) series.

Figure 1: Plots of equity index conditional covariances

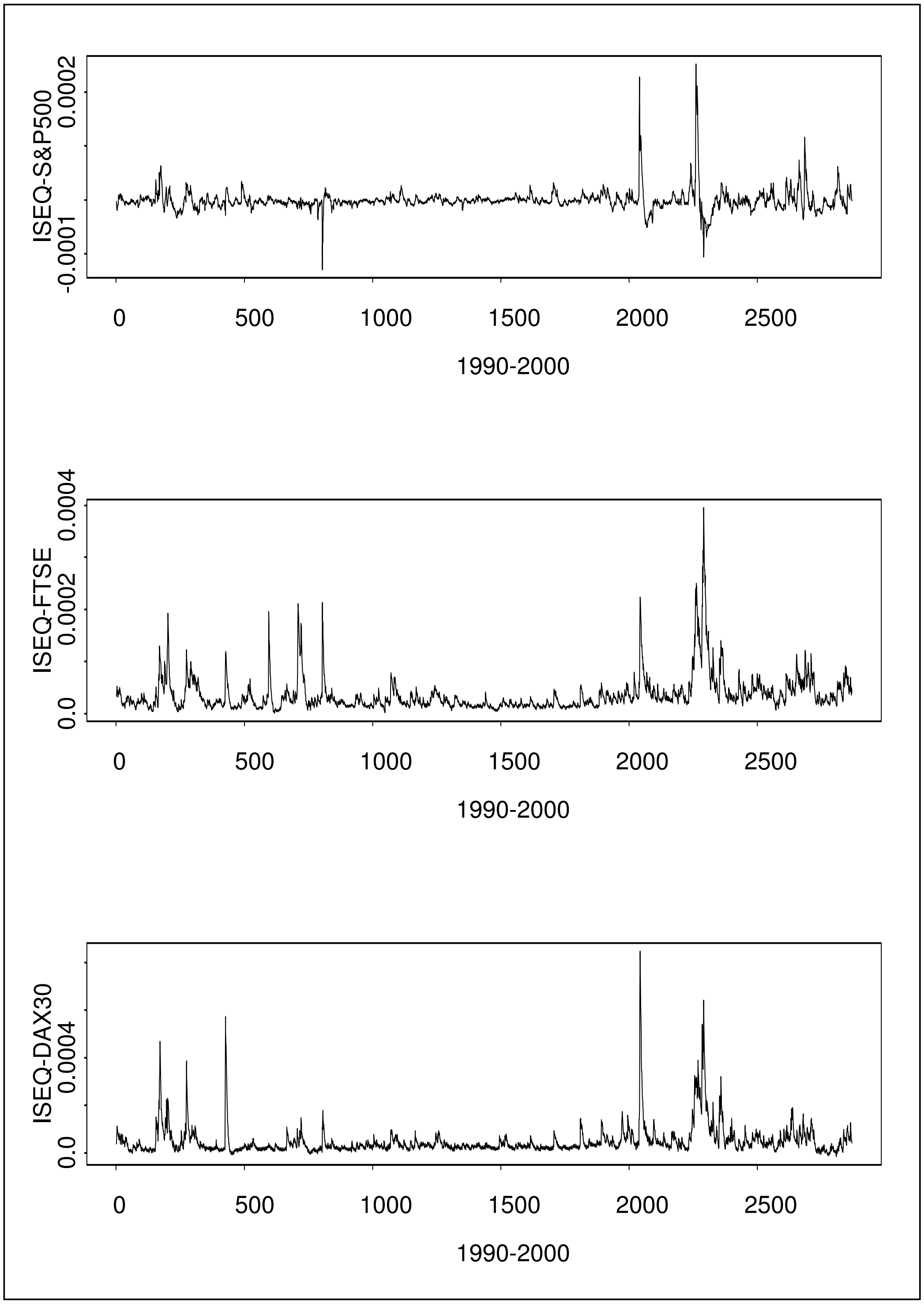

Table 6: Sub-period 1 GARCH estimates for daily returns of the ISEQ index

Sample 1	S&P500		FTSE		DAX30	
Conditional mean						
c_{11}	0.000	(0.253)	0.000	(-0.085)	0.000	(0.381)
r_{11}	0.144	(4.608)	0.123	(3.555)	0.168	(4.932)
r_{21}	0.314	(8.637)	0.185	(4.542)	0.049	(1.686)
c_{22}	0.000	(-0.153)	0.000	(1.095)	0.000	(0.944)
r_{22}	0.069	(2.066)	0.079	(2.192)	0.048	(1.344)
r_{12}	-0.052	(-1.800)	0.006	(0.202)	-0.002	(-0.048)
Conditional variance						
c_{11}	0.000	(-0.005)	0.000	(-0.007)	0.000	(-0.002)
c_{12}	0.000	(0.000)	-0.001	(-1.665)	0.000	(0.000)
c_{21}	0.000	(0.000)	-0.004	(-6.973)	0.000	(-0.006)
a_{11}	0.383	(10.740)	0.276	(5.516)	0.256	(5.433)
a_{12}	0.077	(1.578)	-0.106	(-1.263)	-0.027	(-0.241)
a_{21}	-0.135	(-1.774)	0.142	(2.351)	0.044	(0.768)
a_{22}	0.078	(0.715)	0.282	(3.077)	0.446	(6.473)
b_{11}	0.871	(82.848)	0.956	(29.283)	0.966	(276.081)
b_{12}	-0.033	(-1.041)	0.110	(1.053)	0.056	(1.178)
b_{21}	0.014	(0.189)	-0.194	(-1.595)	-0.050	(-1.495)
b_{22}	0.996	(5998.249)	0.647	(11.130)	0.790	(28.932)
Diagnostics						
R^2	0.125		0.088		0.078	
AIC	-19.144		-19.291		-18.594	
SBC	-19.081		-19.228		-18.532	
$Q\ (24)_{ret} \sim \chi^2(24)$	40.791		35.069		34.686	
$Q^2\ (24)_{ret} \sim \chi^2(24)$	192.217		133.648		148.430	
$Q\ (24)_{res} \sim \chi^2(24)$	34.628		21.754		33.879	
$Q^2\ (24)_{res} \sim \chi^2(24)$	48.371		43.068		40.473	

Notes: Quasi-maximum likelihood estimation gives robust t-statistics for the BEKK model based on Bollerslev and Wooldridge (1992) standard errors. T-statistics for the model are given in (). Home (foreign) market effects are given by 11 (22). Cross market effects to (from) the home country are given by 21 (12). Ljung-Box statistics, Q (24) and Q^2 (24), are given for the home returns (ret) and residuals (res) series.

Table 7: Sub-period 2 GARCH estimates for daily returns of the ISEQ index

Sample 2	S&P500		FTSE		DAX30	
Conditional mean						
c_{11}	0.000	(1.845)	0.001	(3.036)	0.001	(2.226)
r_{11}	0.039	(1.711)	-0.047	(-1.450)	0.041	(1.284)
r_{21}	0.515	(22.732)	0.355	(9.564)	0.139	(5.687)
c_{22}	0.000	(1.212)	0.000	(2.177)	0.000	(0.559)
r_{22}	-0.007	(-0.278)	0.221	(6.633)	0.084	(2.606)
r_{12}	-0.015	(-0.550)	-0.136	(-4.690)	-0.141	(-3.339)
Conditional variance						
c_{11}	0.000	(-0.069)	0.002	(6.615)	0.000	(-0.052)
c_{12}	0.001	(3.123)	0.000	(1.922)	0.000	(-0.147)
c_{21}	-0.001	(-2.575)	0.000	(0.103)	0.000	(-0.112)
a_{11}	0.182	(4.657)	0.398	(7.592)	-0.113	(-4.438)
a_{12}	0.115	(3.127)	0.094	(1.824)	-0.260	(-4.471)
a_{21}	-0.100	(-4.390)	-0.216	(-2.097)	0.209	(20.561)
a_{22}	0.279	(11.930)	0.089	(1.857)	0.350	(18.754)
b_{11}	0.960	(963.118)	0.855	(100.498)	0.978	(1977.510)
b_{12}	-0.012	(-1.316)	-0.044	(-4.910)	-0.042	(-26.288)
b_{21}	0.039	(2.874)	0.094	(4.378)	-0.010	(-20.694)
b_{22}	0.945	(327.737)	1.010	(65887.546)	0.969	(2001.192)
Diagnostics						
R^2	0.304		0.098		0.044	
AIC	-19.418		-19.866		-18.939	
SBC	-19.374		-19.821		-18.895	
$Q\ (24)_{ret} \sim \chi^2(24)$	71.553		71.419		61.250	
$Q^2\ (24)_{ret} \sim \chi^2(24)$	247.212		155.489		229.264	
$Q\ (24)_{res} \sim \chi^2(24)$	30.346		25.080		27.362	
$Q^2\ (24)_{res} \sim \chi^2(24)$	83.299		58.323		128.587	

Notes: Quasi-maximum likelihood estimation gives robust t-statistics for the BEKK model based on Bollerslev and Wooldridge (1992) standard errors. T-statistics for the model are given in (). Home (foreign) market effects are given by 11 (22). Cross market effects to (from) the home country are given by 21 (12). Ljung-Box statistics, Q (24) and Q^2 (24), are given for the home returns (ret) and residuals (res) series.

Table 8: Sub-period 3 GARCH estimates for daily returns of the ISEQ index

Sample 3	S&P500		FTSE		DAX30	
Conditional mean						
c_{11}	0.001	(1.125)	0.001	(1.321)	0.001	(1.069)
r_{11}	-0.020	(-0.470)	-0.028	(-0.577)	-0.012	(-0.239)
r_{21}	0.312	(8.951)	0.176	(3.484)	0.097	(2.566)
c_{22}	0.000	(0.235)	0.000	(0.540)	0.001	(1.092)
r_{22}	0.046	(1.049)	0.114	(2.297)	0.075	(1.553)
r_{12}	-0.082	(-1.576)	-0.128	(-2.686)	-0.145	(-2.351)
Conditional variance						
c_{11}	0.001	(0.097)	0.000	(-1.359)	0.000	(0.123)
c_{12}	-0.008	(-1.112)	0.002	(5.463)	0.007	(17.661)
c_{21}	-0.007	(-1.299)	-0.001	(-0.889)	-0.003	(-6.608)
a_{11}	0.296	(1.504)	-0.088	(-1.729)	-0.032	(-0.271)
a_{12}	-0.069	(-0.110)	-0.007	(-0.120)	0.092	(0.860)
a_{21}	0.059	(0.155)	0.094	(1.780)	0.258	(5.007)
a_{22}	0.183	(0.630)	0.210	(3.994)	0.057	(0.954)
b_{11}	0.368	(1.163)	0.983	(302.219)	0.620	(39.272)
b_{12}	-0.831	(-0.904)	0.094	(6.255)	0.349	(6.720)
b_{21}	-0.322	(-0.642)	-0.050	(-7.334)	0.120	(16.007)
b_{22}	0.392	(0.813)	0.928	(338.944)	0.824	(178.120)
Diagnostics						
R^2	0.142		0.054		0.017	
AIC	-18.044		-18.573		-17.909	
SBC	-17.946		-18.475		-17.811	
$Q\ (24)_{ret} \sim \chi^2(24)$	33.046		26.602		23.056	
$Q^2\ (24)_{ret} \sim \chi^2(24)$	51.117		40.608		37.846	
$Q\ (24)_{res} \sim \chi^2(24)$	35.838		30.651		30.273	
$Q^2\ (24)_{res} \sim \chi^2(24)$	37.322		37.538		38.709	

Notes: Quasi-maximum likelihood estimation gives robust t-statistics for the BEKK model based on Bollerslev and Wooldridge (1992) standard errors. T-statistics for the model are given in (). Home (foreign) market effects are given by 11 (22). Cross market effects to (from) the home country are given by 21 (12). Ljung-Box statistics, Q (24) and Q^2 (24), are given for the home returns (ret) and residuals (res) series.

Table 9: GARCH estimates for daily returns of ADRs

	AIB				SMURFIT				ELAN			
Conditional mean	ISEQ		AIB		ISEQ		SMURFIT		ISEQ		ELAN	
c_{11}	0.000	(2.377)	0.001	(1.533)	0.001	(2.445)	-0.001	(-1.090)	0.000	(1.781)	0.001	(2.448)
r_{11}	0.099	(5.530)	-0.005	(-0.304)	0.078	(3.076)	-0.142	(-5.773)	0.134	(7.462)	-0.039	(-2.242)
r_{21}	0.201	(20.374)	0.478	(28.466)	0.096	(8.934)	0.472	(16.192)	0.078	(11.780)	0.374	(19.871)
c_{22}	0.000	(0.354)	0.000	(0.294)	0.000	(0.326)	0.000	(0.376)	0.000	(-0.047)	0.000	(-0.033)
r_{22}	-0.021	(-1.063)	-0.024	(-1.208)	0.052	(1.952)	0.044	(1.634)	0.079	(4.271)	0.078	(4.205)
r_{12}	0.003	(0.092)	0.027	(1.361)	0.053	(0.852)	0.039	(1.733)	-0.153	(-3.037)	-0.050	(-2.915)
Conditional Variance												
c_{11}	0.000	(0.034)	0.000	(-0.033)	0.000	(0.004)	0.001	(0.136)	0.000	(-0.002)	0.000	(0.024)
c_{12}	0.000	(0.214)	-0.003	(-0.594)	0.000	(0.024)	-0.012	(-11.884)	0.000	(0.004)	-0.002	(-1.082)
c_{21}	0.000	(1.549)	0.000	(0.742)	0.000	(-0.030)	-0.001	(-0.526)	0.000	(0.041)	-0.002	(-0.439)
a_{11}	0.188	(3.837)	0.153	(2.673)	0.227	(4.790)	0.227	(3.912)	0.345	(10.807)	0.161	(2.383)
a_{12}	0.122	(2.973)	0.062	(2.025)	0.208	(2.178)	0.023	(0.500)	-0.103	(-0.653)	-0.006	(-0.156)
a_{21}	-0.163	(-10.283)	-0.267	(-5.522)	-0.071	(-2.435)	-0.503	(-13.040)	0.052	(1.241)	0.547	(9.049)
a_{22}	0.100	(10.932)	0.084	(5.628)	0.145	(2.053)	0.058	(1.376)	0.096	(5.160)	-0.044	(-0.552)
b_{11}	0.875	(236.005)	0.865	(118.742)	0.940	(228.506)	0.683	(30.616)	0.879	(36.029)	0.829	(28.324)
b_{12}	-0.004	(-0.201)	-0.016	(-0.794)	-0.203	(-8.688)	-0.066	(-2.641)	0.056	(0.540)	0.067	(1.927)
b_{21}	0.026	(6.103)	0.040	(2.849)	0.035	(8.866)	0.126	(2.472)	-0.007	(-1.436)	-0.038	(-1.367)
b_{22}	0.991	(363550.490)	0.995	(353008.136)	0.977	(268.086)	1.007	(58072.001)	0.994	(290935.741)	0.991	(14273.660)
Diagnostics												
R^2	0.166		0.245		0.081		0.172		0.080		0.136	
AIC	-17.798		-16.756		-16.803		-14.890		-16.828		-14.737	
SBC	-17.771		-16.729		-16.759		-14.846		-16.803		-14.712	
$Q(24)_{ret} \sim \chi^2(24)$	48.191		77.449		48.461		86.354		61.160		141.936	
$Q^2(24)_{ret} \sim \chi^2(24)$	162.727		155.832		115.297		106.583		254.556		51.030	
$Q(24)_{res} \sim \chi^2(24)$	30.043		74.640		29.285		140.661		26.426		121.493	
$Q^2(24)_{res} \sim \chi^2(24)$	124.085		129.766		61.303		85.447		114.316		87.199	

Notes: Quasi-maximum likelihood estimation gives robust t-statistics for the BEKK model based on Bollerslev and Wooldridge (1992) standard errors. T-statistics for the model are given in (). Home (foreign) market effects are given by 11 (22) where home represents trading on Dublin market. Cross market effects to (from) the home country are given by 21 (12). Ljung-Box statistics, Q (24) and Q^2 (24), are given for the home returns (ret) and residuals (res) series. For each ADR, spillovers to the ISEQ index are included in the first set of columns followed by the equity trading in Dublin. Reported findings based on data availability are given for Elan for the full period of analysis, AIB between 28 November 1990 and 29 December 2000 and Jefferson Smurfit between 17 January 1995 and 29 December 2000.

Endnotes

[1] This finding documented extensively has implications for equity pricing and asset allocation procedures (Longin and Solnik, 1995; DeSantis and Gerard, 1998; Ang and Bekaert, 2002). Traditional asset pricing models such as the Capital Asset Pricing Model (CAPM) need to incorpate the impact of international diversification and time-varying correlation features. Furthermore, asset allocation needs to be examined in the context of reduced benefits from international diversification.

[2] Daily data is used to capture potential interactions, for example impulse responses, since a month or even a week may be long enough to obscure interactions that may last only a few days.

[3] This is due to data availability and recognises that it does not make the time series fully synchronous.

[4] An exception occurs for the DAX30 at 10% significance levels.

[5] The S&P500 estimates presented use lead values to overcome non-synchronous trading. Results for the same trading day are qualitatively similar but not as pronounced and are available on request.

[6] The companies represent approximately 40% of the ISEQ's market capitalization (Irish Stock Exchange, 2001). The sub-period results support the overall findings and are available on request.