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Common volatility in the industrial structure of global capital markets

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This paper investigates the nature of the volatility process among security prices for US, Europe and the Pacific Rim capital markets using a new data set that removes the problem of disparate index composition associated with aggregate stock market index series. We use the common ARCH-feature testing methodology, recently developed by Engle and Kozicki (*Journal of Business Economics* **11**, pp. 369–380, 1993), to examine the issue of a common volatility process among asset prices of nine industry groups from three economic regions of the world economy. It is found that industry-return series exhibit intra-industry common time-varying volatility process. The evidence is consistent with the view that world capital markets are related through their second moments implying that a world common time-varying variance specification seems to be appropriate in modeling asset prices. While our empirical evidence suggests that investors can form constant-variance portfolios by investing within an industry across regions, they will be better off if they invest across regions and industries rather than diversify within an industry across different geographical regions. That is, the industrial mix of global investment portfolios accounts for a substantial proportion of the international diversification benefits. Finally, our results appear to be consistent with Roll (*Journal of Finance*, **47**, pp. 3–41, 1992) view that the industrial structure of national stock exchange indices is important for explaining cross-sectional return volatility differences. (JEL G14, G11). © 1997 Elsevier Science Ltd.

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With growing interest in international asset allocation, a number of studies have provided evidence of significant international linkages among aggregate price indices of national exchanges. Recent studies include Eun and Shim (1989), Hamao et al. (1990), Barclay et al. (1990), and Arshanapalli and Doukas (1993). Earlier studies, however, on share price comovements across exchanges by Grubel (1968), Levy and Sarnat (1970), Agnon (1972), Ripley (1973), Solnik (1974), Lessard (1976), Panton et al. (1976) and Hilliard (1979), using either correlation or variance-covariance or spectral analysis, found low correlation between changes in international stock price indices.[1] Cross-market correlations are generally much larger in periods of high volatility while they appear to subside to modest or even negligible associations during periods of more normal trading activity. Furthermore, volatility is systematically higher in some national equity markets than in others. Since the constituent stock of national exchange indices are not identical, the episodic increases in correlated movements of the indices can be attributed simply to the technical procedures of index construction (i.e. some indices have a small number of stocks while others have a larger number), their industrial composition (i.e. some have industries that are inherently more or less volatile) (see Roll, 1992) and to changes in actual or perceived relative importance of common factors in periods of unusual volatility. Roll (1992) provides a detailed empirical study on the industrial structure and the comparative behavior of international stock market indices in an attempt to explain why stock price indices exhibit disparate behavior. He finds that stock market indices reflect the idiosyncrasies of each country's industrial structure which explains why aggregate equity market and correlation structure of country index returns differ across countries. Heston and Rouwenhorst (1994), however, attribute the cross-sectional differences in return volatility between country indices to country-specific sources of return variation rather than the industrial composition of country indices. Specifically, they report that the industrial structure of 12 European countries over the 1978–1992 period explains only a small fraction of the cross-sectional differences in return volatility. Hence, they argue that because industry effects are so small, country diversification rather than industry diversification must be pursued by investors for effective portfolio risk reduction.

The thrust of this paper is to investigate the nature of the volatility process among security prices, in the absence of the disparate composition of the price indices of national exchanges, by examining the behavior of a set of nine industry groups as they are valued in US, Europe and Pacific Rim capital markets. Specifically, the industry groups are organized within nine sectors, such as basic materials, utilities, consumer cyclical, and financial (see, Dow Jones World Stock Index) that allow investors to measure how an individual industry performs against its peer industry group on a regional and global basis. Dow Jones and Company Inc., introduced the World Stock Index on January 5, 1993 to provide a comprehensive measure of stock performance with two comparative views: geographic and industrial. The same criteria in selecting stocks for the nine industry groups are used across different regions of the world to assure comparability when investors assess one group of stocks in US and the same group in Europe and the Pacific Rim. Using this disaggregated set of data we are interested in the extent to which security prices across the three major regions of the world have the same volatility process. If industry indices across different regions of the world are shown to have common time-varying volatility, then regional stock market volatility will not be confounded by industry effects. That is, the industrial composition would have no role in explaining cross-regional market volatility. To ascertain the influence of industry effects on the typical stock's return behavior (i.e. in isolation of any other sources of return variation) requires the use of industry rather than aggregate stock market indices which are more likely to be under the influence of regional-specific components of return variation. This study builds on and extends the recent literature of stock market linkages by using (i) a new data set that overcomes the disparate composition problem associated with aggregate price indices of national exchanges and (ii) a recently developed methodology by Engle and Kozicki (1993) which takes advantage of the time-varying structure of security time series' variances to test for common volatility (features). As Engle and Kozicki (1993) note, it is quite possible for two stock markets to be dependent, because they might be related through their second moments, even though they exhibit small correlations in returns. For instance, while Roll (1992) reports low correlations for 24 countries, Engle and Susmel (1993) provide evidence which points out that national stock markets are linked through their second moments.

The objective of this study is two-fold. First, we search for a time-varying volatility process in nine industry groups for the US, Europe and Pacific Rim capital market regions. Second, we investigate whether a common factor is driving the intra-industry volatility across regions of the world economy. Our results indicate that there is a common factor in the industrial structure of US, European and Pacific Rim capital markets that has time-varying volatility. It is shown that this is a world factor and not a regional factor.

The outline of the paper is as follows. Section I describes the data and sample characteristic. The ARCH testing procedure and ARCH results are also reported. The concept of the common ARCH-feature and its methodology are introduced in Section II. In Section III the common ARCH evidence is presented and discussed. A summary and concluding remarks are provided in Section IV.

I. Data and methodology

I.A. Sample characteristics

The sample consists of daily index values, categorized by the Dow Jones World Stock Index in nine broad economic sectors (industries) (i.e. Basic Materials, Consumer/Cyclical, Consumer/Non-cyclical, Energy, Financial, Industrial, Technology, Utilities and Independent[2]) for the US, European and Pacific Rim regions. The countries included in the Pacific Rim region are: Australia, Hong Kong, Japan, Malaysia, New Zealand, and Singapore. Countries in the index that are grouped in three geographic regions (Americas, Europe and Pacific Rim), in turn, make up the world index. Each country's index is calculated in that country's own currency as well as the US dollar, British pound, German mark and Japanese yen. The index values used in this study are US dollar denominated. The Dow Jones World Stock Index was introduced January 5, 1993 and hence the sample of this study contains all daily values from January 5, 1993 to December 31, 1993. The industry index series are market capitalization weighted values and have been constructed not to double count those stocks multiple-listed on foreign stock exchanges (see WSJ; 1/15/93 for more details on the construction of the index series).

In Table 1 univariate statistics are reported for the nine industries in the sample. First-order autocorrelations and Ljung–Box (LB) test statistics for serial correlation are also reported. The results show that the unconditional distribution for all industries is not normal. Furthermore, the autocorrelations appear to be fairly small, and the LB statistic values seem to be statistically insignificant at the 5% level.[3]

Table 2 reports the results of correlation analysis. The correlation matrix is estimated for the index (Panel A) and the squared index (Panel B) series. The rationale for the estimation of squared correlations is basically the same as the rationale for the ARCH tests. That is, while industry index series across different regions might be uncorrelated through their first moments they might be correlated through their second moments (volatilities). The results listed in Panel A show that correlations between the three regions of the world economy (i.e. results reported in the first three columns), for all nine industries, are very low. All 27 correlation coefficients are well below 0.25. However, there is a pattern of higher correlations between the three regions and the world index (i.e. results reported in the last three columns). Eight correlation coefficients out of 27 appear to be higher than 0.50. Three US industries (i.e. consumer/cyclical, consumer/non-cyclical and technology) have correlation coefficients greater than 0.63 while four Pacific Rim industries (i.e. Basic materials, consumer/cyclical, industrial and technology) have correlation coefficients greater than 0.58 with the corresponding world industry indices. European industries, with the exception of utilities, appear to have correlation coefficients lower than 0.40. Overall, the correlation results for the nine different industries examined here seem to favor weak linkages across the major regions of the world economy. These results are consistent with Roll (1992), and Engle and Susmel (1993) evidence that documents low correlations across countries, using aggregate stock exchange index series. Based on these low industry intercorrelation results across the three regions of the world economy, someone might be tempted to attribute the benefits of international diversification, documented by earlier studies, to the industrial-specific sources of return variation. This, however, may not be true if industries across different geographical regions have the same volatility structure (i.e. they are correlated through their second moments).

TABLE 1. Univariate statistics for industry returns: January 5 to December 31, 1993

Industry	US						Europe					
	Mean	SD.	Skew	Kurt	Rho(1)	LB(6)	Mean	S.D.	Skew	Kurt	Rho(1)	LB(6)
Basic materials	0.0002	0.0074	0.14	5.24	0.12	7.08.	0.0009	0.2344	0.08	99.23	0.50	50.85*
Consumer/cyclical	0.0006	0.0081	−0.24	4.59	0.19	4.00	0.0010	0.2279	−0.09	99.21	−0.51	50.00*
Consumer/non-cyclical	−0.0004	0.0081	−0.12	4.88	0.20	16.90*	−9.09E−06	0.0159	0.50	25.40	−0.58	62.28*
Energy	0.0008	0.0616	−0.08	35.00	−0.48	46.33*	0.0011	0.0282	−0.46	53.92	0.01	91.64*
Financial	0.0006	0.0085	−6.44	4.92	0.20	15.66*	0.0010	0.0112	−2.66	27.06	0.04	4.56
Industrial	0.0002	0.2331	0.19	96.62	−0.50	6.20	0.0012	0.0330	−0.05	49.28	−0.50	50.64*
Technology	0.0005	0.0083	0.08	3.66	0.01	12.02*	0.0012	0.0086	0.09	3.22	0.02	3.37
Utilities	−0.0006	0.0224	−12.42	67.90	0.00	6.52	0.0011	0.0105	−1.02	7.29	−0.01	5.23
Independent	0.0007	0.0081	0.41	8.37	0.00	1.50	0.0005	0.0089	−0.22	3.34	−0.67	5.84

Industry	Pacific Rim						World					
	Mean	S.D.	Skew	Kurt	Rho(1)	LB(6)	Mean	S.D.	Skew	Kurt	Rho(1)	LB(6)
Basic materials	0.0016	0.0128	0.71	7.08	0.36	9.14	0.0009	0.0063	0.61	5.24	0.15	7.24
Consumer/cyclical	0.2279	0.0018	0.69	19.53	0.17	9.18	0.0011	0.0062	0.23	4.65	0.03	6.43
Consumer/non-cyclical	0.0159	0.0015	0.39	5.67	0.30	6.27	1.09E−05	0.0062	0.09	4.62	0.13	14.57*
Energy	0.0282	0.0016	−0.07	5.07	0.04	7.48	0.0010	0.0066	0.25	4.11	0.15	6.06
Financial	0.0112	0.0021	−0.58	6.05	0.16	11.67*	0.0016	0.0217	−0.37	69.41	0.43	37.86*
Industrial	0.0330	0.0019	0.02	5.53	0.08	4.20	0.0013	0.0070	0.05	5.22	0.05	4.26
Technology	0.0086	0.0025	0.21	8.60	0.05	3.00	0.0012	0.0076	0.28	4.92	0.42	4.29
Utilities	0.0105	0.0022	0.61	96.17	−0.52	55.44*	0.0010	0.0055	0.58	3.71	0.02	4.17
Independent	0.0089	0.0020	0.16	5.21	−0.02	2.52	0.0013	0.0126	−1.11	63.55	0.47	47.18*

*Significant at the 5% level.

TABLE 2. Correlation analysis: January 5 to December 31, 1993

Industry	Pacific Rim	US/Europe	Europe/Pacific Rim	US/World	Europe/World	Pacific Rim/World
			Panel A: Correlation matrix for industry returns			
Basic materials	0.07	0.17	0.18	0.49	0.19	0.82
Consumer/cyclical	0.02	−0.02	0.04	0.63	0.08	0.58
Consumer/non-cyclical	−0.03	0.15	0.14	0.82	0.38	0.31
Energy	−0.08	−0.43	0.12	0.03	0.28	0.33
Financial	0.08	0.11	0.20	0.21	0.13	0.35
Industrial	−0.02	0.00	−0.07	−0.04	−0.07	0.93
Technology	0.12	0.04	0.02	0.66	−0.24	0.71
Utilities	0.02	−0.09	0.02	0.17	0.54	−0.03
Independent	0.00	0.07	0.25	0.24	0.20	0.32

Industry	US/Pacific Rim	US/Europe	Europe/Pacific Rim	US/World	Europe/World	Pacific Rim/World
			Panel B: Correlation Matrix for Squared Industry Returns			
Basic materials	0.21	0.24	0.33	0.46	0.73	0.82
Consumer/cyclical	0.01	0.00	−0.02	0.39	0.01	0.26
Consumer/non-cyclical	0.00	−0.01	−0.04	0.43	0.03	0.14
Energy	−0.01	0.42	−0.02	0.02	0.00	0.11
Financial	0.12	−0.02	0.00	0.00	0.02	0.04
Industrial	−0.04	−0.01	0.00	0.01	0.01	0.92
Technology	0.06	0.02	0.15	0.37	−0.03	0.58
Utilities	−0.01	0.11	0.04	−0.03	0.13	0.20
Independent	0.07	0.01	0.11	−0.03	−0.04	0.01

I.B. ARCH testing procedure

Testing for common volatility across the nine industry index series for different geographical regions of the world economy, requires that each series displays an ARCH effect (i.e. time-varying volatility).[4] To test for ARCH effects in the time series the following regression is estimated[5]

$$\hat{\epsilon}_{it}^2 = a_{io} + \sum_{j=1}^{n} a_{ij}\hat{\epsilon}_{it-j}^2 + v_{it}$$

where a_{io} represents a constant parameter, ϵ_{it} identifies the autoregression residuals and v_{it} is an error term. The residuals, ϵ_{it}, were obtained by first regressing log index changes (i.e. industry returns) on a constant term, four own lags and an indicator variable to account for the day-of-the-week effect in the return series. The test statistic is obtained by multiplying the regression R^2 to the sample size (T). Engle (1982) shows that the $T \times R^2$ test has an asymptotic chi-squared distribution with degrees of freedom equal to the number of lagged squared residuals.

Table 3 reports univariate and multivariate information-based ARCH results. The ARCH (1) test indicates univariate ARCH with one lag while ARCH (4) reveals univariate ARCH with four lags. The MARCH test is an ARCH test with a multivariate information set. MARCH (1) signifies one lag while MARCH (4) a four lag structure. This test is obtained by using not only own lagged squared residuals but also lagged squared residuals of the other series as well as lagged cross-products of the other two residual series. For US, European and Pacific Rim series we used their own lagged squared residuals and lagged squared residuals series of the World and their respective cross-products. For the World series, in addition to its own lagged series we have used lagged US series and the cross-product of US and World series.[6] The distribution of this test is chi-squared as well. The purpose of using a multivariate information set is to check whether we would find ARCH in the series if no ARCH is found in the univariate ARCH tests. The critical values for univariate and multivariate ARCH tests are as follows. For ARCH (1), at the 5(1) percent level, is 3.84(6.63). For ARCH (4), at the 5(1) percent level, is 9.49(13.3). For MARCH (1), at the 5(1) percent level, is 7.81(11.34) and for MARCH (4) 19.30(24.70), respectively.

In the US, all industry groups with the exception of energy and industrial industries show evidence of ARCH effects. In Europe, three industry groups (i.e. basic materials, consumer/cyclical and industrial) exhibit no time-varying variance while the other six display ARCH effects. This might reflect the influence of regulatory constraints and/or price controls still in place among many European countries. In the Pacific Rim, all industry groups except the group of utilities do provide evidence of ARCH effects. ARCH effects are also present in all industry groups for the entire world economy. The $T \times R^2$ estimated values are significant for all industry groups at the 1% level of significance. The critical values for ARCH (1) and ARCH (4), at the 1% level, are 6.63 and 13.3, respectively, well below the estimated $T \times R^2$ statistics

TABLE 3. ARCH tests: January 5 to December 31, 1993

Industry	$T \times R^2$ statistics[a]							
	US				Europe			
	ARCH		MARCH		ARCH		MARCH	
	(1)	(4)	(1)	(4)	(1)	(4)	(1)	(4)
Basic materials	41.30	41.58	50.51	56.54	1.78	2.44	2.05	3.82
Consumer/cyclical	44.54	45.56	44.65	47.54	1.72	2.30	2.45	3.26
Consumer/non cyclical	43.23	44.81	44.12	48.05	15.15	15.45	15.72	19.98
Energy	3.56	3.51	18.40	35.29	87.64	83.83	93.10	92.43
Financial	42.64	44.47	42.71	52.86	44.57	45.42	45.61	47.90
Industrial	1.86	2.57	2.72	3.81	3.03	3.39	3.29	4.14
Technology	50.05	50.85	58.42	55.58	64.24	63.73	65.00	70.73
Utilities	33.82	35.97	33.83	37.89	27.21	27.35	27.26	30.13
Independent	58.58	64.34	58.59	65.14	60.65	60.93	60.87	64.80

Industry	Pacific Rim				World			
	ARCH		MARCH		ARCH		MARCH	
	(1)	(4)	(1)	(4)	(1)	(4)	(1)	(4)
Basic materials	30.71	30.63	30.81	33.23	35.92	36.60	36.10	39.88
Consumer/cyclical	35.00	37.74	37.86	43.20	40.48	44.50	41.30	47.40
Consumer/non-cyclical	36.89	38.24	60.16	69.15	43.25	44.12	44.68	48.14
Energy	42.11	43.00	42.86	49.24	48.21	48.49	52.38	53.60
Financial	38.80	40.67	41.73	46.94	16.75	16.76	16.81	17.52
Industrial	40.83	41.81	42.56	46.50	37.61	38.97	38.22	40.40
Technology	35.43	37.89	40.50	50.31	39.43	39.94	39.60	41.91
Utilities	1.42	1.57	1.57	54.00	52.02	54.75	52.95	59.14
Independent	39.09	41.90	43.31	57.09	44.04	45.93	45.30	55.38

[a]Daily log index-estimated returns are first regressed against a constant, four own lags and an indicator variable to account for the day-of-the-week effect in the series. Then, the estimated errors are used to obtain the R^2 by regressing the squared errors against a constant and own lags. The $T \times R^2$ statistic is obtained by multiplying the R^2 times the sample size. The distribution of this test is chi-squared with n (regressors) degrees of freedom. Its critical value for ARCH(I), at the 5(1) percent level, is 3.84(6.63). For ARCH(4), the critical value at 5(1) percent level, is 9.49(13.3). The MARCH test is an ARCH test with a multivariate information set. This test is obtained by using not only own lagged squared residuals but also lagged squared residuals of the other series as well as lagged cross-products of the other two residuals series. Its critical value for MARCH(1), at the 5(1) percent level, is 7.81 (11.34). For MARCH(4), the critical value at 5(1) percent level, is 19.30 (24.70).

sufficient to reject the no-ARCH null hypothesis. The MARCH based results confirm the presence of ARCH effects in most index series. Although MARCH results confirm the presence of ARCH in most industry-return series, it should be noted that the multivariate information set did not add new information to find ARCH in those series that were found to have no ARCH. For example, the Basic Material series for the European region had no ARCH based on univariate or multivariate ARCH tests. It should be noted that this is the case for all the other return series. These results also suggest that it may not be prudent to omit a time-varying risk premium in modeling stock return volatility.

II. Testing for common features

II.A. Common ARCH-feature

The common ARCH feature test was introduced recently by Engle and Kozicki (1993). The intuition of this test, which builds on the statistical idea of cointegration (Granger, 1983; Engle and Granger, 1987)[7], is that linear combinations of autoregressive conditional heteroskedasticity (ARCH) time series can generate time series that do not display a time-varying variance (i.e. linear combinations of time series that do not exhibit ARCH effects). What makes the common ARCH feature methodology appealing is that the linear combination identifies a portfolio that has a constant variance that is in conformity with a simple one factor or an APT-like model. Furthermore, the common ARCH feature framework is attractive because it does not suffer from the statistical limitations of first moment analysis (see Engle and Susmel, 1993).

Engle and Kozicki (1993) have shown that a feature will be common in two series if a linear combination of two data series fails to have the feature even though each of the series individually exhibits the feature (i.e. ARCH). We briefly describe, next, how the linear combination of two series may not have the feature (i.e. no ARCH). Suppose that the x_t, and y_t series can be written without loss of generality as

$$x_t = \delta p_t + e_{xt}, \tag{1a}$$

$$y_t = w_t + e_{yt}, \tag{1b}$$

where $x_t(y_t)$ represents the daily observed industry index series, $w_t(p_t)$ is the time-varying risk premium and $e_{xt},(e_{yt})$ is the unexpected component of the series.

with

$$e_{xt}|I_{t-1} - D(0,\sigma_x^2), \qquad e_{yt}|I_{t-1} - D(0,\sigma_y^2),$$

$$p_t|I_{t-1} - D(0,h_{pt}), \qquad w_t|I_{t-1} - D(0,h_{wt}),$$

$$h_{pt} = \alpha_{po} + \alpha_{p1} p_{t-1}^2, \qquad h_{wt} = \alpha_{wo} + \alpha_{w1} w_{t-1}^2$$

$$E(p_t e_{xt}|I_{t-1}) = 0, \qquad E(w_t e_{yt}|I_{t-1}) = 0.$$

where I_{t-1}, is the information set on which agents condition their decisions at time t that includes all past information while σ_x^2 (σ_y^2) is constant variance, $h_{pt}(h_{wt})$ is a time varying variance that follows an ARCH process, and $D(a,b)$ an arbitrary distribution with mean a and variance b.

The variance of x_t, and y_t are equal to

⟨2a⟩ $$V(x_t) = \delta^2 h_{pt} \sigma_x^2,$$

⟨2b⟩ $$V(y_t) = h_{wt} + \sigma_y^2,$$

which are both time varying. A feature that is present in each of the two series is said to be common to those series if there exists a non-zero linear combination of the series ($u_t = x_t - \tau y_t$) that does not have the feature. This result is obtained when $w_t = p_t$ and $\tau = \delta$ since u_t has a constant variance,[8] (i.e. $u_t^2 = \sigma_x^2 + \tau^2 \sigma_y^2$). Alternatively, the null hypothesis (i.e. no ARCH in the linear combination between the two series) of a common factor can be designed by setting $w_t = p_t$ and $\tau = \delta$.

II.B. Common ARCH-feature methodology

The common ARCH-feature test, addresses the question whether ARCH-features observed in single time series are shared in common. An ARCH feature is said to be common if a linear combination of two time series does not have the feature even though each of the series individually has the feature. In the context of this study, we use the common ARCH-feature test to investigate whether a common component is driving the volatility of the nine industries across the three regions of the world economy (i.e. US, Europe and Pacific Rim). The common ARCH-feature test is based on the estimation of the $T \times R^2$ statistic. The $T \times R^2$ is obtained from regressing $x_t - \tau y_t$ on a constant, lagged y_t and lagged x_t, and the lagged cross products of y_t and x_t. More generally, the common ARCH testing procedure involves a search for a τ such that minimizes a test of this form

⟨3a⟩ $$\min_\tau T \times R^2(\tau),$$

⟨3b⟩ $$u_t^2(\tau) = (x_t - \tau y_t)^2,$$

⟨3c⟩ $$R^2 = u_t^2(\tau)' Z_t (Z_t' Z_t)^{-1} Z_t' u_t^2(\tau) / \sigma^2,$$

where Z_t is the larger information set composed of y_{t-1}^2, x_{t-1}^2, y_{t-2}^2, $x_{t-2}^2, \ldots$, y_{t-p}^2, x_{t-p}^2, and lagged cross-products $y_{t-1}\ x_{t-1}$, $y_{t-2}\ x_{t-2}, \ldots$, $y_{t-p}\ x_{t-p}$, y_t is $T \times 1$, x_t is a $T \times 1$ vector, τ is the cofeature parameter and σ^2 is a consistent estimator of the variance of u^2. This test is a general method-of-moments-type test. That is, the objective is to identify a portfolio that is not correlated in the squares with any information included in Z. Put it differently, if two industry index series are individually characterized by ARCH effects, there might be a portfolio (i.e. a linear combination) between them for which there is no evidence against the null hypothesis of no ARCH. This, then, would provide evidence that would favor the presence of a common volatility process in the two industries. Engle and Kozicki (1993) have shown that, under the assumptions of Hansen (1982), $\min_\tau T \times R^2(\tau)$ follows a chi-squared distribution with the degrees of freedom given by the number of overidentifying restrictions (i.e. number of instruments included in the information set Z_t minus $K-1$; where K indicates the number of variables used). To minimize ⟨3⟩ we use a non-linear simplex search method.

III. Common ARCH-feature results

From the previous evidence reported in Table 3, it is clear that the ARCH feature is found in most industry-return series. Furthermore, the use of ARCH and MARCH tests, with different lags, show that all industries require only one lag. Therefore, common ARCH tests are conducted based on one lag specification.

Table 4 reports intra-industry common ARCH-feature results across regions. The analysis was restricted to those industries that their time series produced evidence in favor of ARCH effects. The parameter (τ) that minimizes the linear combination of two series is shown in the first column while the $T \times R^2$ statistics are reported in the second column for all different regional combinations across industries. The distribution of this test is chi-squared with 2 d.f. and its critical value, at the 5(1) percent level, is 5.99(9.21). As Panel A shows, the results do not favor the presence of ARCH effects for all possible intra-industry combinations across regions in all industries. These results imply that there is strong evidence of intra-industry common time-varying volatility between the main geographic regions of the world economy. For instance, the results for the consumer/non-cyclical industry shows that US, Europe and Pacific Rim have similar volatility processes (i.e. common feature). More specifically, for the consumer/non-cyclical industry a portfolio can be formed between US and -1.39 times Pacific Rim that exhibits no time-varying volatility. This implies that such a portfolio can be formed by going one unit long in the consumer/non-cyclical US industry and 1.39 units long in the Pacific Rim. Since the parameter τ that minimizes the $T \times R^2$ of the linear combination of the two series is always squared (see equation ⟨3⟩), it does not establish direction and therefore the same outcome can be obtained by going one unit short in the US and 1.39 units short in Pacific Rim consumer/non-cyclical industry for the formation of a constant-variance portfolio between the two regions. Furthermore, there is evidence of a constant-variance portfolio formed by US and 6.98 times Europe. This result, however, would require to go one unit long in US and 6.98 units short in Europe. Similarly, a portfolio formed by Europe and 0.13 times Pacific Rim shows no time-varying volatility. For the Europe/Pacific Rim portfolio in the energy sector, we observe the cofeature parameter to be -1.01, which could also imply that we can form a portfolio between the two regions by going approximately 50% long (short) in Europe and 50% long (short) in the Pacific Rim since the value of the parameter is close to one. This also implies that the energy industries in Europe and in the Pacific Rim have the same volatility. Therefore, when the cofeature parameter is different from 1 the formation of a constant-variance

TABLE 4. Intra-industry common ARCH feature tests: January 5 to December 3, 1993

	Panel A: Intra-region analysis											
	US/Pacific Rim				US/Europe				Europe/Pacific Rim			
	Param[a]	Min-test[b]	MARCH[c]		Param	Min-test	MARCH		Param	Min-test	MARCH	
Industry			(1)	(2)			(1)	(2)			(1)	(2)
Basic materials	−0.32*	1.39	48.60	30.30	—	—	—	—	—	—	—	—
Consumer (cyclical)	−3.66	0.83	43.48	39.16	—	—	—	—	—	—	—	—
Consumer (non-cyclical)	−1.39**	0.78	42.76	43.46	6.98	0.26	42.77	15.72	0.13	6.04	15.94	40.90
Energy	−0.03**	2.58	12.93	42.38	−0.01**	7.48	52.46	66.43	−1.01**	1.33	66.09	42.33
Financial	−1.38**	1.02	46.60	37.94	−0.02*	2.68	46.55	40.29	−4.10**	2.80	40.41	38.95
Industrial	—	—	—	—	—	—	—	—	—	—	—	—
Technology	−6.95**	1.64	52.58	37.31	3.49*	0.25	50.32	59.63	4.52*	1.79	61.11	61.72
Utilities	—	—	—	—	15.26*	0.24	35.66	29.06	—	—	—	—
Independent	0.68*	0.65	59.40	39.60	0.29*	0.43	58.44	60.01	−0.20*	3.72	60.13	40.74

Panel B: Region–World Analysis

Industry	US/World				Europe/World				Pacific Rim/World			
	Param[a]	Min-test[b]	MARCH[c]		Param	Min-test	MARCH		Param	Min-test	MARCH	
			(1)	(2)			(1)	(2)			(1)	(2)
Basic materials	0.06*	0.49	51.54	37.71	—	—	—	—	−1.50**	0.29	29.48	39.55
Consumer (cyclical)	1.90*	0.33	43.22	41.95	—	—	—	—	−0.28**	0.63	38.43	42.03
Consumer (non-cyclical)	1.96*	0.71	43.28	42.56	0.04*	0.85	15.44	42.14	0.26*	2.31	61.30	42.89
Energy	0.06	6.97	18.64	51.36	0.03*	0.72	66.68	48.00	−0.43*	0.02	42.33	47.77
Financial	−4.18	3.49	46.82	15.60	6.77	0.58	40.25	20.46	2.31*	2.38	40.45	16.10
Industrial	—	—	—	—	—	—	—	—	0.24*	1.45	42.49	40.52
Technology	0.21*	0.07	55.02	41.16	−0.91*	1.07	60.13	43.00	−0.18*	0.72	40.66	41.83
Utilities	−0.21*	1.41	35.49	53.22	−0.25*	0.93	27.94	52.70	—	—	—	—
Independent	−0.88*	0.02	58.31	46.76	−6.95*	0.49	59.62	54.11	−0.34*	3.21	43.45	47.48

[a]The parameter that minimizes the $T \times R^2$ of the linear combination of the intra-industry return series between two geographic regions. (i.e., region and world).
[b]The Min-test is a $T \times R^2$ test. The distribution of this test is chi-squared with d.f. $(z-(k-1))$ where z is the number of instruments used and k is the number of variables used. The critical value for 2 d.f. at the 5(1) percent level is 5.99 (9.21).
[c]MARCH-1 is an ARCH test for the first series with a multivariate information set. This multivariate information set consists of the own lag, one lag of the other series and their cross-product. MARCH-2 is a MARCH-1 test but for the second series.
*Significant at the 5% level.
**Significant at the 1% level.

portfolio between two industries across regions would require different investment positions (weights) as we saw above. For instance, the cofeature parameter for the technology industry between Europe and Pacific Rim is 4.52 indicating that a portfolio of technology stocks can be formed between the two regions by going 1 unit long in Europe and 4.52 units short in the Pacific Rim. The reason for this is that the technology industries across these two regions have different underlying volatility structures. This, in turn, explains why different investment weights are required to create a constant-variance portfolio that would consist of European and Pacific Rim technology stocks. This further implies that intra-industry portfolio investments across different economic regions may result in portfolio risk-reduction benefits. Similar results (i.e. portfolios with constant variance) were obtained for the financial, technology and independent industries across all three regions.

The financial industry across regions exhibits no ARCH effects. For the US the minimization procedure gives a weight of -1.38 to Pacific Rim and -0.02 to Europe. Therefore, the portfolio weights appear to be different from the Pacific Rim and the European financial markets since they do not have the same degree of similarity with the US financial market. The low weight of -0.02 to Europe implies that the portfolio is very similar to the US and this is evidence in favor of a higher degree of financial integration between these two regions of the world economy than between US and Pacific Rim. The degree of integration between the European and Pacific Rim financial industries appears to be quite low as the minimization procedure requires a weight of -4.10 to Pacific Rim indicating that the portfolio is not similar to the European. In brief, while the evidence favors the existence of a common factor that has a time-varying volatility in the financial industry of the three regions the underlying volatility of each financial industry is not uniform across regions. This can be attributed to the varying degree of integration across the financial industries of the three regions. This may also be due to differences in local monetary and fiscal policies, and differences in institutional and legal structures that are more pronounced between the Pacific Rim and the US or European regions than they are between the US and Europe.

It is interesting to note, however, that the cofeature parameter estimates, listed in Table 4, are different from one for most industries. Consequently, investment diversification across regions within an industry can produce desirable risk-reduction results for many industries (i.e. those industries with a cofeature parameter that is not equal to one) because of the non-existence of a uniform intra-industry volatility structure across regions. This intra-industry factor seems to be consistent with the low cross-regional intra-industry return correlations observed in Table 2.

These results appear to be inconsistent with the evidence reported in Heston and Rouwenhorst (1994) who find that the industrial structure explains very little of the cross-sectional difference in European return volatility over the 1978–1992 period. They show, instead, that the low intercorrelations of European equity markets is mainly due to large country-specific components of return variation. However, they were not able to identify these country-specific effects. Their findings, which are in sharp contrast with those reported by Roll

(1992), also imply that intra-industry volatility is basically uniform across countries and therefore the benefits of international diversification (i.e. risk reduction) are largely attributed to country-specific and not industry-specific sources of return variation. The findings of this study, however, point out that cross-regional intra-industry volatilities are not similar and consequently intra-industry diversification across regions appears to be an effective strategy for portfolio risk reduction because of the existence of industry-specific sources of return variation rather than region-specific factors as shown below. Furthermore, our analysis suggests, these results are not reported here, that inter-industry volatility structure is not the same across the three regions of the world economy and that the τ parameter estimates are greater than one and substantially larger than those reported in Table 4. According to Heston and Rouwenhorst (1994), this is not what you would expect if industrial structure does not explain much of the cross-sectional difference in country (or region) return volatility. Therefore, investors are likely to reap higher international diversification benefits as they invest across economic regions (or countries) and industries rather than diversify within an industry across different geographical regions.

More interesting, perhaps, results are presented in Panel B of Table 4. These results present evidence of common volatility between each region's-industry return series and the corresponding world return series. The evidence for the US suggests that seven out of nine industries share a common volatility process with the world return series; for Europe six out of nine industries and for the Pacific Rim eight out of nine industries have similar volatility processes with the world industry return series. Furthermore, the reported common-ARCH results for almost all industries appear to be essentially the same. These results clearly suggest a common time-varying volatility across industries and regions of the world economy irrespective of the lag structure of the series. The results favor the existence of a common volatility feature in the groups formed by US, Europe, Pacific Rim and the corresponding world industry return series. In brief, these findings suggest that the common factor that has time-varying volatility is a world factor and not a regional factor. It is interesting to note, however, that our evidence is not consistent with the results reported in Engle and Susmel (1993) which favor regional rather than world common time-varying volatility. This could be attributed to the fact that Engle and Susmel (1993) used the Morgan Stanley Capital International Perspective aggregate country stock return series that fail to distinguish between country effects and industry-driven sources of volatility (see, Roll, 1992; and Heston and Rouwenhorst, 1994) while we used DJIA index series. However, the industry-return series used in this study do not suffer from the well known index construction problems associated with typical aggregate stock market indices used in previous studies.

Furthermore, it is worth pointing out that the no-ARCH combinations (portfolios) reported in Table 4 appear with a substantially lower value of the MARCH test relative to the MARCH test for the individual series listed in Table 3.

We have also examined the robustness of our results by testing whether the

TABLE 5. ARCH tests for optimal combination

Industry	Estimated model $(X-\tau y)_t^2 = a + b(x-\tau y)_{t-1}^2 + v_t$					
	US/Pacific Rim	US/Europe	Europe/Pacific Rim	US/World	Europe/World	Pacific Rim/World
Basic materials	0.03	—	—	−0.03	—	0.02
	(0.50)			(−0.54)		(0.35)
Consumer/cyclical	0.01	—	—	−0.06	—	0.21
	(0.19)			(−0.76)		(1.14)
Consumer/non-cyclical	0.09	−0.00	0.16	−0.02	0.00	0.06
	(0.96)	(−0.05)	(2.30)*	(−0.33)	(0.03)	(0.81)
Energy	0.10	−0.01	0.01	0.13	−0.00	−0.01
	(1.40)	(−1.23)	(0.16)	(1.76)	(−0.64)	(−0.76)
Financial	0.09	−0.09	−0.10	0.17	−0.02	0.28
	(1.34)	(−1.31)	(−1.41)	(2.33)*	(−0.35)	(4.01)
Industrial						0.07
						(0.99)
Technology	−0.08	−0.08	0.18	−0.03	−0.00	0.01
	(−0.19)	(−1.08)	(2.59)*	(−0.47)	(−0.06)	(0.16)
Utilities		−0.02		0.15	0.10	
		(0.22)		(2.08)	(1.47)	
Independent	0.05	−0.08	0.08	0.10	−0.06	0.25
	(0.69)	(−1.14)	(1.18)	(1.41)	(−0.87)	(0.56)

Values in parentheses are t-statistics.
*Significant at the 5% level.

TABLE 6. Intra-industry common ARCH feature tests

	Panel A: January 1 to June 1, 1993					
	(Parameter (τ) values)[a]/[Minimum TxR^2 statistics][b]					
Industry	US/Pacific Rim	US/Europe	Europe/Pacific Rim	US/World	Europe/World	Pacific Rim/World
Basic materials	(−0.32)	—	—	(0.05)	—	(−0.67)
	[1.09]			[0.93]		[0.65]
Consumer/cyclical	(2.70)	—	—	(0.42)	—	(−0.17)
	[0.64]			[0.39]		[1.05]
Consumer/non-cyclical	(15.86)	(−1.90)	(−0.15)	(−0.35)	(0.06)	(−0.28)
	[2.18]	[1.73]	[10.75]	[3.23]	[1.13]	[1.18]
Energy	(−0.11)	(−0.03)	−0.93	−0.09	(0.02)	(−1.05)
	[4.74]	[26.48]	[1.64]	[1.06]	[4.30]	[0.94]
Financial	(−1.06)	(−1.40)	(−6.68)	(−29.79)	(9.60)	(2.36)
	[3.91]	[3.63]	[4.26]	[6.44]	[3.32]	[1.68]
Industrial	—	—	—	—	—	(0.23)
						[2.68]
Technology	(−6.97)	(1.74)	(−5.21)	(0.25)	(−1.02)	(−0.17)
	[4.65]	[0.62]	[3.26]	[1.96]	[0.59]	[3.92]
Utilities	—	(0.54)	—	(−0.01)	(−0.80)	—
		[1.16]		[3.20]	[1.90]	
Independent	(0.55)	(−0.04)	(0.43)	(−0.92)	(−2.16)	(−0.99)
	[1.02]	[1.64]	[3.51]	[1.89]	[0.35]	[1.20]

— *continued*

Panel B: June 2 to December 31, 1993						
Basic materials	(−4.80)	—	—	(−0.05)	—	(0.16)
	[1.13]			[0.16]		[1.09]
Consumer/cyclical	(17.29)	—	—	(0.49)	—	(−0.05)
	[0.22]			[0.97]		[1.25]
Consumer/non-cyclical	(−5.74)	(−3.73)	(−0.67)	(4.45)	(−0.15)	(0.17)
	[4.16]	[18.36]	[17.02]	[8.67]	[2.47]	[5.43]
Energy	(−0.02)	(0.02)	(−1.17)	(0.04)	(−0.00)	(0.23)
	[3.21]	[5.86]	[1.38]	[1.69]	[5.08]	[4.95]
Financial	(−6.28)	(0.34)	(−3.77)	(−6.70)	(−4.55)	(−1.79)
	[2.15]	[2.09]	[4.39]	[2.04]	[7.03]	[14.23]
Industrial	—	—	—	—	—	(0.47)
						[3.04]
Technology	(−2.84)	(0.55)	(−3.09)	(−0.43)	(−0.94)	(0.20)
	[2.08]	[0.64]	[0.40]	[1.87]	[3.60]	[2.04]
Utilities	—	(3.21)	—	(−6.82)	−0.11	—
		[0.60]		[0.47]	[1.20]	
Independent	(1.32)	(0.40)	(1.94)	(−0.29)	(1.19)	(0.35)
	[1.27]	[1.46]	[1.14]	[3.95]	[0.15]	[0.43]

[a]The parameter that minimizes the linear combination of the intra-industry index series between two geographic regions.
[b]The distribution of this test is chi-squared with 2 d.f. $(z - (k - 1))$ where z is the number of instruments used and k is the number of variables used. Its critical value for 2 d.f., at the 5(1) percent level is 6.99 (9.21).

no-ARCH portfolios (i.e. the portfolios that do not exhibit time-varying volatility) show any ARCH effects using the τ values reported in Table 4. The results are listed in Table 5 and do confirm the previous findings. That is, when the no-ARCH industry portfolios are regressed against a broader information set, they fail to show evidence of ARCH effects.

Finally, we partitioned the sample into two sub-samples in order to investigate whether our results were driven by outliers or any other time-dependent factors. Table 6 reports the results of common ARCH feature tests for January 1–June 1, 1993 (Panel A) and June 2–December 31, 1993 (Panel B). These results do confirm the evidence reported in Table 4. Similar results were obtained when common feature tests were run using multivariate information sets.[9]

IV. Conclusion

The focus of this study has been to investigate the nature of the volatility process among security prices in the US, European and Pacific Rim capital markets. This study builds on and extends the recent literature of stock market integration by using a new data set that removes the problem of disparate index composition associated with aggregate stock market indices of national exchanges. The analysis employed the common ARCH-feature testing methodology recently developed by Engle and Kozicki (1993) to address the issue of common volatility process among asset prices of nine industry groups. First, we document that the majority of industry-return series for the US, Europe, Pacific Rim and the World show time-varying volatility. Second, application of the Engle and Kozicki (1993) common ARCH-feature test produced results in favor of intra-industry common volatility (feature) among the three major geographic regions of the world economy. This result suggests a relatively high degree of intra-industry integration across different economic regions implying that investors are likely to reap greater international diversification benefits if they invest across regions and industries rather than diversify within an industry across different geographical regions. That is, the industrial mix of global investment portfolios accounts for a substantial proportion of the international diversification benefits. Hence, our analysis appears to be consistent with Roll's (1992) view that industrial structure of national stock exchange indices is important for explaining cross-sectional return volatility. While the results of our study suggest that the capital markets of the US, Europe and the Pacific Rim are related through their second moments, investigation of whether the nine industries of each economic region have similar time-varying volatility with the corresponding world industry-return series produced convincing evidence in support of the existence of a single common volatility process (i.e. common ARCH-feature). In sum, our results favor one common time-varying variance specification in modeling asset prices.

Notes

1. One possible reason for the low correlations among countries would be time zone differences (see Roll, 1992).

2. Very large companies whose activities cut across industries and other economic sectors.
3. Our six lag length is similar to the Engle and Susmel (1993), LB lag structure.
4. The statistic is obtained by multiplying the R^2 times the sample size. This statistic, developed by Engle (1982), has a chi-squared distribution with degrees of freedom equal to the number of variables used.
5. The lag length of the ARCH models is determined by employing Akaike (1973) final prediction error criterion.
6. The results did not change significantly for different information set combinations.
7. The statistical idea behind cointegration is that linear combinations of nonstationary time series can, under certain circumstances, produce a stationary time series.
8. Substituting equations (la) and (lb) into $u_t = x_t \times \tau y_t$ we obtain

   $$u_t = \delta p_t + e_{xt} - \tau w_t - \tau e_{yt}.$$

   Empirically we are looking for a value of τ such that $\delta = \tau$ and $p_t = w_t$ which yields.

   $$u_t = e_{xt} - \tau e_{yt}.$$

   The variance of u_t, then, will be $v(u_t) = \sigma_x^2 + \tau^2\sigma_y^2$.
9. These results are not reported here but are available from the authors upon request.

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