Estudios de Administración, vol. 2, N° 2, 1995

Price and Variance Transmission from the U.S. Capital Market to Foreign Capital Markets; Evidence in the Financial Times Actuaries World Indices from 1991 to 1993

Franco Parisi
Universidad de Chile

Extracto

El impacto del mercado de capitales norteamericano, tanto en precio como en varianza, en los más importantes centros comerciales del mundo es significativo. En particular, el impacto en precio es significativo en todos y cada uno de los índices contenidos en el *Financial Times Actuaries World Indices* (FTAWIS), en tanto que el impacto de innovaciones del índice accionario norteamericano en la varianza de dichos índices es significativo en 18 oportunidades sobre un total de 22 países. Se concluye que los FTAWIS incorporan la información generad en el mercado norteamericano en el precio y la varianza de los primeros.

Abstract

The U.S. impact on the *Financial Times Actuaries World Indices* (FTAWIS) is significant, in both pricing and variance. The pricing effect from the U.S. to the FTAWIS is significant in all cases. The U.S. spillover

The author thanks L. Campbell and W. Megginson; an anonymous referee, and the workshop participants from the Departamento de Administración, Universidad de Chile and the Escuela de Economía y Administración, Pontificia Universidad Católica de Chile.

effect is significant in 18 cases over a total of 22 countries considered in the sample. This leads to the conclusion that the FTAWIS incorporate the information generated in the U.S. capital market in both pricing and variance.

Introducción

This paper presents evidence of the spillover effect from the U.S. market to foreign capital markets. This empirical investigation supports the hypothesis of price and variance transmission from the U.S. market to foreign capital markets, observed by King and Wadhwani 1990; Eun and Shim 1989; King, Sentana and Wadhwani 1994; Becker, Finnerty and Gupta 1990; Campbell and Hamao 1992; Harvey 1989, 1991, and Hamao, Masulis and Ng 1990.

The hypothesis of price and variance transmission from the U.S. market to other markets is based on two facts. The first is the evidence of volatility spillover from the New York Stock Exchange to the London and Tokyo Stock Exchanges (Hamao, Masulis and Ng 1990). Second, the price mistakes from the foreign stock exchange are transmitted to other markets in a contagion fashion (King and Wadhwani 1990).

To test the hypothesis, the standard GARCH(1,1) model is implemented to quantify: i) how much of the movement in the foreign index variances can be explained by innovations in the U.S. market return, and ii) how rapidly the price movements in the U.S. market are transmitted to the foreign markets.

This paper is comprised of seven parts. First, the time-varying transmission literature is presented. The second part reviews the trading hours in the different stock markets in the sample, to identify overlapping. The third section gives statistical information about the sample return. Fourth, the model, results and conclusions from the AR(1) model are presented in order to test for autocorrelation in the country sample. The fifth section contains the estimation of the GARCH(1,1) autoregressive model for each country in the sample. Next, the spillover effect from the U.S. market to other countries is tested by incorporating in the model the U.S. innovation effect. Finally, the conclusions are presented.

LITERATURE REVIEW

This section presents the literature regarding international transmission in variance and price. The evidence suggests that major capital markets are integrated, especially the Japanese, the U.K. and the U.S. capital markets. In particular, Dwyer and Hafer 1988 examine the short-term relationships among four big markets. They suggest that correlation among markets had not increased during the 1980's, except for the period immediately around the crash. In the long-term case, they find a small increase in international co-movements. Errunza and Losq 1985 estimate the relations among volatilities across countries and the relation between countries' volatility, from one country to another, in a contemporaneous and lagged fashion. They conclude that daily return volatility tends to be significantly positively related across countries, where high volatility is associated with a high degree of intercountry correlation. Arshanapalli and Doukas 1993 posit that return correlations across geographical regions increased during the period around the crash. They suggest that the degree of intercorrelation between two markets is related to the trading of overseas securities on the domestic market.

Heston and Rouwenhorst 1994, contrary to Roll 1992, suggest that industrial structure explains very little of the cross-sectional difference in country return volatility, and the low correlation between indices is almost completely due to country-specific sources of return variation.

Bollerslev, Engle and Wooldridge 1988 (BEW hereafter) find that the conditional variance is quite variable over time and a significant determinant of the time-varying risk premia. This implies that betas are also time-varying and forecastable. Under the assumptions of BEW 1988, the CAPM is stated in terms of conditional moments, since these reflect the information set available to agents at the time the portfolio decisions are made, where any explanation of time-varying expected excess holding yields should be built around a structure with a time-varying conditional covariance matrix.[1] In econometric terms this model is called multivariate[2] GARCH(1,1).

BEW 1988 use three portfolios to test the model. The first is composed of 6-month T-bills. The second is based on 20-year T-bonds, and the third is

[1]Since the covariance matrix of returns varies over time, the mean returns and betas will also be time-varying.

[2]GARCH stands for generalized autorregresive conditional heteroscedastic.

formed with stocks. The sample covers from the first quarter of 1959 to the second quarter of 1984. They use the 3-Month T-bill as the risk free rate. The results indicate that the conditional covariance matrix of the asset returns is strongly autoregressive. The data clearly reject the assumption that this matrix is constant over time. There is evidence that the risk premiums are better represented by covariances with the implied market than by their own variances. The expected returns or risk premiums for the assets are significantly influenced by the conditional second moment of returns.

French and Roll 1986, Ferson and Harvey 1991, and French, Schwert and Stambaugh 1987 (hereafter FSS) analyze expected stock returns and volatility. They find evidence that the expected market risk premium is positively related to the predictable volatility of stock returns. FSS 1987 obtain monthly volatility from daily returns. They decompose volatility into predictable and nonpredictable components using univariate autoregressive-integrated-moving average (ARIMA) models and generalized autoregressive conditional heteroscedasticity (GARCH) models. The composite portfolio estimating the monthly standard deviation of the stock returns is the S&P 500, from January 1928 through December 1984.

FSS 1987 suggest that the ARCH model is attractive since the return and variance are estimated jointly. They obtain ARCH estimators using as dependent variables the S&P 500 index minus the daily yield on one-month T-bills. They construct two equations to measure the variance. The first considers the average of the previous twenty-two squared errors to predict the variance of errors. In the second, the standard GARCH model is applied. Their results indicate that there is a reliable positive relation between expected risk premium and predicted volatility. The variability of realized stock returns is so large that it is difficult to discriminate among alternate GARCH(1,1) specifications.

Chan, Karolyi and Stulz 1992 (CKS hereafter) model the daily excess returns for the S&P 500 and a non-U.S. asset portfolio, using a bivariate GARCH in mean (GARCH-M) model. They find that the conditional expected excess returns on the U.S. market portfolio are significantly related to the conditional covariance of the S&P 500 and Japan's Nikkei 225 index, but not significantly related to the conditional variance of the S&P 500. The results are robust to different econometric approaches and different intervals for the data.

The authors' hypothesis is that the foreign returns can be predicted using the previous close-to-close U.S. returns. This predictability is spurious, since it cannot be exploited through a portfolio strategy if the foreign market is efficient.

CKS 1992 use three indices for non-U.S. assets. The first is the Nikkei 225 Stock Average, from January 3, 1978 to December 31, 1989. The second is Morgan Stanley's Japan Index in yens, from January 3, 1980 to December 31, 1989. The third is the Morgan Stanley EAFE Index in dollars, during the same period. The authors use the indexes only in calendar days when they are available in both countries and make no distinction between single and multiple-day returns. The results for the U.S. returns indicate the Japanese effect is significant. However, the conditional variance of the U.S. returns have no effect on the foreign market.

Hamao, Masulis and Ng 1990 (HMN hereafter) study the correlation in price changes and volatility across international stock markets. They state that there is evidence of a price spillover from New York to Tokyo, London to Tokyo, and New York to London, but not of a price volatility spillover effect in the other directions. HMN 1990 use open and close data to test the volatility transmission between the major world capital markets. The sample encompasses a three-year period, from April 1, 1985 to March 31, 1988. The selected Japanese index is the Nikkei 225.[3] The English index tested is the Financial Times 100 Shares (FTSE) index. The American index selected is the S&P 500 Composite Index.

The nonsynchronous holidays and twice monthly Saturday trading in Japan are managed by HMN 1990 with two different strategies.[4] As the first, the authors substitute the most recent "volatility surprise" available for the foreign exchange that was closed.[5] As the second, they drop out domestic returns for any days where at least one of the two foreign markets were closed. HMN 1990 estimate the model using a nonlinear optimization technique to calculate the maximum likelihood, based on the Berndt-Hall-Hall-Hausman 1974 algorithm.

HMN's final GARCH (1,1) model (1990) estimates the spillover effect in the stock return of one market on the conditional means as well as on the conditional variance in the next market to trade. The evidence indicates that the

[3]This index is share price weighted, and has no dividend reinvestment.

[4]Both strategies give similar spillover effects.

[5]Volatility surprise was obtained from the squared residuals derived from the MA(1)-Garch(1,1) models.

conditional mean return exhibits a positive spillover effect from the prior market. This model was estimated using close-to-close prices, and the results are similar. HMN 1990 conclude that daily stock returns are approximated by a GARCH(1,1)-M model, that the spillover effect exists only for the Japanese market, and that the volatility spillover effect on the other two markets is weak.[6]

THE DATA

In this section we present the data used in this research and its main statistics, as well as a description of the hours that the different stock markets are open, with respect to noon, Eastern Standard Time, to identify overlapping. The sample is the *Financial Times Actuaries World Indices* (FTAWI), in U.S. currency, published daily in the *Financial Times* and calculated by Financial Times Limited, Goldman, Sachs & Co., and Country NatWest/Wood Mackenzie in conjunction with the Institute of Actuaries and Faculty of Actuaries. The selected period for this study covers from December 28, 1990 to December 31, 1993.

TRADING HOURS IN THE SAMPLE STOCK EXCHANGE

The information in Table 1 is based on the trading hours in each of the stock markets.[7] The hours are taken at noon, Eastern Standard Time.

Australia, Austria, Belgium, Germany, Hong Kong, Italy, Japan, Malaysia, New Zealand, Singapore and South Africa close before the New York Stock Exchange (NYSE) opening. Only Denmark's closing is simultaneous with the NYSE opening.

The rest of the countries close before the NYSE closing. These countries are Finland, France, Ireland, the Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom. However, Ireland closes just five minutes after the New York opening. The Mexican and Canadian cases are special, since they are in the same time zone.

[6]The main results were not affected if returns were converted into a single currency.
[7]Based on Fry (1994) and *The Almanac* (1994).

Table 1

Standard Time and Trading Hours

COUNTRY	HOUR w/r/t 12:00 ET	OPENING TRADING	CLOSING TRADING	DIFFERENCE NY/c-L/c
Australia	03:00*†	19:00	02:00	10:00
Austria	18:00	04:30	07:30	15:00
Belgium	18:00	04:30	08:30	16:00
Canada	12:00	09:30	04:00	00:00
Denmark	18:00	04:00	09:30	17:30
Finland	17:00	04:00	12:30	21:30
France	18:00	03:00	11:00	12:00
Germany	18:00	04:30	07:30	15:30
Hong Kong	01:00*	21:00	04:30	12:30
Ireland	17:00	04:30	09:35	17:35
Italy	18:00	04:00	07:45	15:45
Japan	02:00*	19:00	03:00	11:00
Malaysia	01:00*	20:30	04:00	12:00
Mexico	11:00	09:30	14:00	-2:00
Netherlands	18:00	04:30	10:00	19:00
New Zealand	05:00*	16:30	22:30	06:30
Norway	18:00	03:30	11:00	20:00
Singapore	01:00*	20:30	04:00	12:00
South Africa	19:00	02:30	09:00	17:00
Spain	18:00	05:00	11:00	20:00
Sweden	18:00	04:00	10:00	19:00
Switzerland	18:00	04:00	10:00	19:00
U.K.	17:00	04:30	11:30	20:30
U.S.	12:00	09:30	16:00	00:00

†Indicates a new day, in relation to NYSE time.

THE SAMPLE BASIC STATISTICS

In this section we present the sample statistics. The basic statistics are mean, standard deviation, minimum, maximum, skewness, kurtosis and variance of each country's return. The country's daily returns, in U.S. currency, were obtained from the *Financial Times Actuaries World Indices*, from December 28, 1990 to December 31, 1993.

During the sample period, only eight indices present a positive absolute daily mean (see Table 2). From those, only the Mexican and the Hong Kong means are statistically significantly different from zero, at the levels of 1% and 5%, respectively. The rest of the countries with a positive mean are France, Hong Kong, Malaysia, the Netherlands, Singapore, Switzerland, the United Kingdom and the United States. Only Austria presents a statistically significant negative mean, at the 6% level.

The maximum and minimum stock return for each country is presented in Table 2. The highest negative return corresponds to Germany[8] (-12.62%), followed by South Africa (-11.33) and Norway (-11.061%). The maximum daily return for the sample is Switzerland's (12.88%), followed by Mexico (11.92%) and Norway (11.25%).

Table 2 shows two other statistics for each country's index: skewness and kurtosis. Skewness is a measure of the asymmetry of the distribution.[9] Kurtosis is a measure of the thickness of the distribution tails.[10]

Fifteen countries in the sample evidence negative skewness. Hong Kong presents the most negative skewness coefficient (-0.95), followed by Germany (-0.649) and Italy (-0.522). The kurtosis coefficients indicate that only four countries show tails approximate to the normal distribution; namely: Australia (1.248), Canada (3.704), the United Kingdom (3.540), and the United States (1.887). In the rest of the sample, the kurtosis coefficients oscillate from 4.64 (Finland) to 16.10 (Switzerland). The U.S. and the U.K. returns have a positive daily mean return, with an almost symmetric maximum and minimum, and their skewness and kurtosis coefficients are close to the normal coefficients. The

[8]September 28, 1991.

[9]For symmetric distributions, skewness is equal to zero. For asymmetric distributions the skewness will be positive when the "long-tail" is in the positive direction.

[10]In the normal distribution case, the kurtosis coefficient is equal to three.

most volatile markets are South Africa (3.63) and Japan (3.03). The lesser ones are Canada (0.28) and the U.S. returns (0.69).

Table 2

Basic Statistics of the Sample[†]

COUNTRY	MEAN	MINIMUM	MAXIMUM	SKEWNESS	KURTOSIS	VARIANCE
Australia	-0.0208	-4.693	4.048	-0.106	1.248	0.976
	(0.275)			(0.225)	(0.00)	
Austria	-0.0240	-10.53	7.823	0.077	5.246	2.434
	(0.056)			(0.376)	(0.00)	
Belgium	-0.0118	-8.204	7.475	-0.115	9.212	1.105
	(0.754)			(0.190)	(0.00)	
Canada	-0.0334	-3.726	3.703	-0.150	3.704	0.380
	(0.131)			(0.086)	(0.00)	
Denmark	-0.0234	-8.286	7.355	-0.264	6.360	1.336
	(0.573)			(0.002)	(0.00)	
Finland	-0.0742	-8.903	6.714	-0.334	4.641	2.189
	(0.162)			(0.00)	(0.00)	
France	0.0023	-9.497	8.051	-0.261	6.935	1.769
	(0.961)			(0.00)	(0.00)	
Germany	-0.011	-12.621	7.483	-0.649	10.265	1.986
	(0.812)			(0.00)	(0.00)	
Hong Kong	0.0909	-8.441	5.601	-0.950	8.631	1.551
	(0.042)			(0.00)	(0.00)	
Ireland	-0.0253	-9.778	8.105	-0.115	5.991	2.069
	(0.624)			(0.189)	(0.00)	
Italy	-0.0621	-10.217	9.253	-0.522	8.296	2.555
	(0.279)			(0.00)	(0.00)	
Japan	-0.0645	-8.191	10.761	0.504	4.035	3.038
	(0.302)			(0.00)	(0.00)	
Malaysia	0.0259	-6.954	9.280	0.221	9.227	1.473
	(0.552)			(0.01)	(0.00)	
Mexico	0.223	-10.127	11.920	0.251	6.349	2.661
	(0.714)			(0.846)	(0.00)	
Netherlands	0.0130	-6.473	6.559	-0.017	6.140	0.990
	(0.714)			(0.846)	(0.00)	
New Zealand	-0.058	-10.064	11.536	0.554	9.791	2.010
	(0.249)			(0.00)	(0.00)	

(Continues)

[†]The level of significance is shown in parentheses.

Norway	-0.0349 (0.541)	-11.061	11.257	0.194 (0.02)	6.785 (0.00)	2.536
Singapore	0.0309 (0.501)	-8.027	7.428	-0.087 (0.318)	6.605 (0.00)	1.646
South Africa	-0.0195 (0.774)	-11.337	8.765	-0.407 (0.00)	5.248 (0.00)	3.631
Spain	-0.0321 (0.518)	-10.387	9.725	-0.253 (0.00)	8.818 (0.00)	1.918
Sweden	-0.007 (0.896)	-9.311	8.155	0.367 (0.00)	5.047 (0.00)	2.278
Switzerland	0.0336 (0.493)	-10.814	12.882	0.398 (0.00)	16.6103 (0.00)	1.876
U.K.	0.0163 (0.691)	-5.581	5.545	-0.054 (0.537)	3.540 (0.00)	1.314
U.S.	0.032 (0.275)	-3.562	3.665	0.018 (0.837)	1.887 (0.00)	0.693

The intermarket effects can be observed in the covariance matrix. In Table 3, the U.S. and the U.S.$_{(t-1)}$ covariances[11] with the foreign countries are presented.[12] In this table, the U.S.$_{(t-1)}$ covariance with respect to other countries shows a great variation in values. The highest correlation between the U.S.$_{(t-1)}$ returns and foreign returns is with New Zealand (0.366), which coincides with the least difference in time between the NYSE closing and the foreign closing. Also, the New Zealand opening is at the same time as the NYSE closing. The second highest U.S.$_{(t-1)}$ correlation with a foreign country is with Australia (0.364), for which there are only 10 hours of difference between its closing and the closing of NYSE. The Australian stock market opens three hours after the NYSE closing. The third highest correlation with the U.S.$_{(t-1)}$ returns is with Singapore (0.357), with 12 hours of difference between closing times. Another country that has the same time difference with the NYSE closing is Malaysia, with a correlation of 0.336. The rest of the correlations between the U.S.$_{(t-1)}$ returns and other countries oscillate between 0.275 and 0.030.

[11]Where (*t*-1) denotes the observation of the day previous to the day *t*.

[12]Because the correlation matrix is 26x25, it was divided into two parts.

Table 3

Correlation Matrix

Part a

	AUS	AUU	BE	CA	DE	US{1}	FI	FR	GE	HO	IR	IT	JA	MA
AUS	1.000	0.258	0.292	0.197	0.167	0.364	0.126	0.227	0.248	0.271	0.197	0.192	0.330	0.257
AUU	0.258	1.000	0.639	0.153	0.541	0.301	0.349	0.522	0.674	0.333	0.466	0.484	0.352	0.345
BE	0.292	0.639	1.000	0.202	0.648	0.263	0.392	0.603	0.688	0.298	0.582	0.535	0.414	0.354
CA	0.197	0.153	0.202	1.000	0.148	0.184	0.136	0.233	0.200	0.090	0.217	0.150	0.230	0.166
DE	0.167	0.541	0.648	0.148	1.000	0.174	0.402	0.550	0.635	0.230	0.544	0.524	0.329	0.262
US{1}	0.364	0.301	0.263	0.184	0.174	1.000	0.139	0.186	0.247	0.279	0.211	0.246	0.253	0.336
FI	0.126	0.349	0.392	0.136	0.402	0.139	1.000	0.326	0.345	0.157	0.325	0.278	0.161	0.216
FR	0.227	0.522	0.603	0.233	0.550	0.186	0.326	1.000	0.693	0.254	0.515	0.497	0.374	0.250
GE	0.248	0.674	0.688	0.209	0.635	0.247	0.345	0.693	1.000	0.287	0.571	0.559	0.373	0.334
HO	0.271	0.333	0.298	0.090	0.230	0.279	0.157	0.254	0.287	1.000	0.235	0.227	0.340	0.400
IR	0.197	0.466	0.582	0.217	0.544	0.211	0.325	0.515	0.571	0.235	1.000	0.450	0.363	0.310
IT	0.192	0.484	0.535	0.150	0.524	0.246	0.278	0.497	0.559	0.227	0.458	1.000	0.310	0.271
JA	0.336	0.352	0.414	0.230	0.329	0.253	0.161	0.374	0.373	0.340	0.363	0.310	1.000	0.391
MA	0.257	0.345	0.354	0.166	0.262	0.336	0.216	0.250	0.334	0.400	0.310	0.271	0.391	1.000

(Continues)

	AUS	AUU	BE	CA	DE	US{1}	FI	FR	GE	HO	IR	IT	JA	MA
ME	0.112	0.128	0.112	0.050	0.083	0.323	0.130	0.052	0.055	0.162	0.076	0.072	0.099	0.133
NE	0.251	0.499	0.598	0.220	0.564	0.275	0.298	0.689	0.705	0.206	0.525	0.490	0.385	0.262
NZ	0.430	0.247	0.223	0.175	0.167	0.366	0.119	0.140	0.193	0.125	0.147	0.157	0.254	0.176
NO	0.274	0.358	0.425	0.223	0.479	0.212	0.274	0.429	0.484	0.154	0.391	0.315	0.268	0.231
SI	0.327	0.437	0.419	0.165	0.335	0.357	0.200	0.344	0.389	0.445	0.315	0.331	0.449	0.617
SO	0.143	0.125	0.161	0.172	0.165	0.030	0.159	0.122	0.166	0.069	0.112	0.146	0.071	0.136
SP	0.281	0.542	0.571	0.201	0.529	0.218	0.283	0.648	0.633	0.300	0.479	0.471	0.445	0.316
SW	0.298	0.484	0.529	0.238	0.523	0.300	0.337	0.561	0.605	0.267	0.470	0.464	0.361	0.340
ST	0.222	0.487	0.554	0.217	0.511	0.214	0.269	0.626	0.666	0.256	0.467	0.431	0.384	0.288
U.K.	0.259	0.404	0.466	0.235	0.455	0.218	0.313	0.618	0.537	0.190	0.490	0.421	0.382	0.223

Part b

	ME	NE	NZ	NO	SI	SO	SP	SW	ST	UK	US
AUS	0.112	0.251	0.430	0.274	0.327	0.143	0.281	0.298	0.222	0.259	0.115
AUU	0.128	0.499	0.247	0.358	0.437	0.125	0.542	0.484	0.487	0.404	0.204
BE	0.112	0.598	0.223	0.425	0.419	0.161	0.571	0.529	0.554	0.466	0.220
CA	0.050	0.220	0.175	0.223	0.165	0.172	0.201	0.238	0.217	0.235	0.515
DE	0.083	0.564	0.167	0.479	0.335	0.165	0.529	0.523	0.511	0.455	0.181
US{1}	0.323	0.275	0.360	0.212	0.357	0.030	0.218	0.300	0.214	0.218	1.000

(Continues)

	ME	NE	NZ	NO	SI	SO	SP	SW	ST	UK	US
FI	0.130	0.298	0.119	0.274	0.200	0.159	0.283	0.337	0.269	0.313	0.172
FR	0.052	0.689	0.140	0.429	0.344	0.122	0.648	0.561	0.626	0.618	0.297
GE	0.055	0.705	0.193	0.484	0.389	0.166	0.633	0.605	0.666	0.537	0.253
HO	0.162	0.206	0.125	0.154	0.445	0.069	0.300	0.267	0.256	0.190	0.142
IR	0.076	0.525	0.147	0.391	0.315	0.112	0.479	0.470	0.467	0.490	0.173
IT	0.072	0.490	0.157	0.315	0.331	0.146	0.471	0.464	0.431	0.421	0.164
JA	0.099	0.385	0.254	0.268	0.449	0.071	0.445	0.361	0.384	0.382	0.206
MA	0.133	0.262	0.176	0.231	0.617	0.136	0.316	0.340	0.288	0.223	0.223
ME	1.000	0.060	0.181	0.063	0.143	-0.01	0.080	0.116	0.008	0.025	0.020
NE	0.067	1.000	0.169	0.495	0.296	0.114	0.560	0.515	0.659	0.620	0.264
NZ	0.181	0.169	1.000	0.155	0.234	0.083	0.204	0.171	0.139	0.195	0.107
NO	0.063	0.495	0.155	1.000	0.246	0.191	0.379	0.498	0.442	0.433	0.195
SI	0.143	0.296	0.234	0.246	1.000	0.102	0.403	0.384	0.331	0.285	0.202
SO	-0.01	0.114	0.083	0.191	0.102	1.000	0.136	0.178	0.153	0.110	0.087
SP	0.080	0.560	0.204	0.379	0.403	0.136	1.000	0.525	0.576	0.532	0.297
SW	0.116	0.515	0.171	0.498	0.384	0.178	0.525	1.000	0.546	0.481	0.269
ST	0.008	0.659	0.139	0.442	0.331	0.153	0.576	0.546	1.000	0.503	0.260
U.K.	0.025	0.620	0.195	0.433	0.285	0.110	0.532	0.481	0.503	1.000	0.281

King and Wadhwani 1990; Eun and Shim 1989; King, Sentana and Wadhwani 1994, and Hamao, Masulis and Ng 1990 focus their attention on the relationship between the $U.S._{(t-1)}$, Japan and the U.K. returns. They observe a spillover or contagion effect from the U.S. market to the Japanese and U.K. markets. The covariance between the $U.S._{(t-1)}$ returns and Japanese returns is 0.253, and between the $U.S._{(t-1)}$ returns and the U.K. returns is 0.218. The difference between the Japanese and U.K. closing times with respect to the NYSE is 11 and 20.5 hours, respectively.

Focusing on Japan, the Japanese-Hong Kong variance is 0.340, and the difference in the closing time is 1.5 hr. The covariance between Japan and Malaysia is 0.391, with one hour of difference in closing time. The Japanese-Singapore correlation is 0.449, with a difference of one hour in closing time. The Japanese covariance with other European countries is surprisingly high. For instance, the Japan-Belgium covariance is 0.414, Japan-Spain is 0.445, Japan-Switzerland is 0.384, and Japan-U.K. is 0.382.[13]

Another major market from the sample is Germany, whose covariance with the $U.S._{(t-1)}$ returns is 0.247. We consider the German index important, since its correlation with different European indices is high. For instance, the Germany-France variance is 0.693, Germany-Austria is 0.674, Germany-Spain is 0.633, Germany-Sweden is 0.605, Germany-Switzerland is 0.666, and so on. Due to such results, the correlation between European countries is presumed to be significantly high. In our appraisal, the German index is the leader in Europe, since it is the largest economy in the continent.

THE MODEL

In this section we describe the econometric specification of the model used to test the hypothesis of price and variance transmission from the U.S. market to the rest of the countries in the sample. Hamao, Masulis and Ng 1990; Chan, Karolyi and Stulz 1992; King, Sentana and Wadhwani 1994, and French, Schwert and Stambaugh 1987 analyze the conditional variance and spillover effect in financial indices and portfolios using GARCH or GARCH-M models, as defined by Bollerslev 1986.

The GARCH(p,q) suggested by Bollerslev 1986 may be written as:

[13]The closing time difference between Japan and the U.K. markets is 8.5 hours.

$$y_t = x_t(\beta) + u_t, \tag{1}$$

$$u_t = \sigma_t \epsilon_t, \tag{2}$$

$$\sigma_t^2 = \alpha + A(L,\gamma)u_t^2 + \beta(L,\delta)\sigma_t^2, \tag{3}$$

$$\epsilon_t \sim NID\,(0,1). \tag{4}$$

Equation (1) is the conditional mean formulation, where y_t is a variable depending on x_t and u_t. The errors of the conditional mean depend on the conditional variance times an independent normally distributed white noise (see equations (2) and (4)). Equation (3) is called conditional variance; γ and δ are parameter vectors with elements γ_i and δ_i, respectively; $A(L, \gamma)$ and $\beta(L, \delta)$ are polynomials in the lag operator L. Under this formulation, σ_t effectively depends on its own past values as well as on lagged values of u_t.

There are three principal ways to estimate regression models with GARCH: feasible GLS, one-step efficient estimation and maximum likelihood. The last one is the most popular. If the model to be estimated is a nonlinear regression model with GARCH(p,q) errors that are conditionally normal, the loglikelihood function is:

$$C - \frac{1}{2}\sum_{t=1}^{n} \log\left(\sigma_t^2(\alpha,\gamma,\delta,\beta)\right) - \frac{1}{2}\sum_{t=1}^{n} \frac{(y_t - x_t(\beta))^2}{(\sigma_t^2(\alpha,\gamma,\delta,\beta)}, \tag{5}$$

where C is a constant, and

$$\sigma_t^2(\alpha,\gamma,\delta,\beta) \equiv \alpha + A(L,\gamma)(y_t - x_t(\beta))^2 + \beta(L,\delta)\sigma_t^2. \tag{6}$$

Because this is a GARCH model, one must solve (5) recursively for σ_t to evaluate (6).

To test the spillover effect in variance and price from the U.S. market to the rest of the *Financial Times Actuaries World Indices*, we will estimate a GARCH(1,1) model, following the general model defined by Bollerslev 1986. The first step in the testing procedure is to obtain the AR(1) model for each of the countries in the sample. These results will be used to identify the conditional mean of the model, where the results will indicate if the U.S. market impacts the pricing of the foreign index. To test the spillover effect from the U.S.$_{(t-1)}$ market, we will include a new variable, $FUS_{(t-1)}$,in the conditional variance. The spillover effect proxy is the errors from the U.S.-GARCH(1,1) model. Also, a dummy variable will be added to account for the Monday and after-holiday effects. The estimation process will be the nonlinear maximum likelihood with the BHHH (1974) iteration process.

Autocorrelation of the Indices in Lag One and the U.S. Direct Effect

Scholes and Williams 1977 suggest that daily returns are highly autoregressive. To validate this hypothesis we estimate

$$y_{i,t} = \alpha_i + \beta_1 y_{i,t-1} + \epsilon, \tag{7}$$

where $y_{i,t}$ represents the market return for the $^{-ith}$ country at time t. The estimation procedure used here is the typical OLS (ordinary least squared), where the common assumption about the errors and the estimators are held to be true. The results and main test statistics are presented in Table 4, where the sample period covers from December 28, 1990 to December 28, 1993, using the *Financial Times Actuaries World Indices* for that market as proxy of the country's returns.

The results suggest that twelve countries exhibit autocorrelation in lag one, at the five percent level of significance or less. These countries are Australia, Austria, Belgium, Canada, Denmark, Italy, Japan, Malaysia, Mexico, Norway, Singapore and Sweden. In these cases test F is significant at the one percent level, suggesting that the model is correct for those particular indexes. Relaxing the level of significance to ten percent for beta one, Finland, the Netherlands, Switzerland and the United Kingdom are correlated in lag one, with a significant F test at the five percent level. In the rest of the indices, neither beta one t tests nor F tests are significant at conventional levels. However, only Hong Kong presents the alpha estimator significant at the 10% level, though the F test is insignificant.

Table 4

AR(1) Model for each Country

COUNTRY	ALPHA†	BETA†	R**2	D-W	F(1,775)††
Australia	-0.01814	0.13484	0.0169	1.977	14.297
	(-0.514)	(3.780)			(0.000)
Austria	-0.02550	0.27152	0.0739	1.976	62.73
	(-0.477)	(7.920)*			(0.000)
Belgium	-0.01093	0.0881	0.0064	1.999	6.039
	(-0.290)	(2.457)*			(0.014)
Canada	-0.02944	0.1544	0.0226	2.017	18.915
	(-1.341)	(4.349)			(0.000)
Denmark	-0.0176	0.1414	0.0188	1.983	15.814
	(-0.041)	(3.976)			(0.000)
Finland	-0.0652	0.0991	0.008	2.007	7.664
	(-1.229)	(2.768)***			(0.0050)
France	0.0039	0.0033	-0.001	2.000	0.008
	(0.082)	(0.093)			(0.925)
Germany	-0.0105	0.0283	-0.000	1.989	0.619
	(-0.207)	(0.786)			(0.431)
Hong Kong	0.0860	0.0539	0.001	2.005	2.248
	(1.91)***	(1.499)			(0.134)
Ireland	-0.0253	0.0301	-0.000	1.994	0.700
	(-0.489)	(0.837)			(0.402)
Italy	-0.054	0.1099	0.010	1.981	9.438
	(-0.945)	(3.072)*			(0.002)
Japan	-0.052	0.1636	0.025	1.962	21.178
	(-0.849)	(4.602)*			(0.000)
Malaysia	0.0198	0.1635	0.025	2.028	21.249
	(0.461)	(4.609)*			(0.000)
Mexico	0.200	0.1009	0.008	1.998	7.957
	(3.396)*	(2.820)*			(0.004)
Netherlands	0.0144	-0.066	0.003	2.002	3.467
	(0.401)	(1.86)**			(0.062)
New Zealand	-0.0588	-0.0013	-0.001	1.986	0.001
	(1.152)	(0.037)			(0.9669)
Norway	-0.0325	0.1321	0.0161	1.976	13.670
	(-.572)	(3.697)*			(0.000)

(Continues)

Singapore	0.0249	0.1431	0.019	2.009	16.158
	(0.545)	(4.019)*			(0.000)
South Africa	-0.0187	0.0264	-0.000	1.997	0.539
	(-0.273)	(0.734)			(0.462)
Spain	-0.0304	0.0495	0.001	1.997	1.893
	(-0.611)	(1.376)			(0.169)
Sweden	-0.0047	0.1219	0.0136	1.975	11.66
	(-0.088)	(3.414)			(0.000)
Switzerland	0.03866	-0.076	0.004	2.003	4.518
	(0.787)	(-2.12)**			(0.033)
U.K.	0.0145	0.068	0.003	1.989	3.665
	(0.353)	(1.914)**			(0.055)

†The *t*-statistic is shown in parentheses.

††The level of significance is shown as a percentage, where 0.00 means significant at the 0% level of significance.

The Godfrey test (Godfrey 1978) over equation (7) for each country in the sample indicates that the presence of autocorrelation in the errors is significant at the five percent level in seven cases (see Table 5). However, most of the autocorrelation in the errors is solved when the $U.S._{(t-1)}$ and a dummy variable that takes a value of one on Mondays and after a holiday and zero otherwise are added in equation (7), as the following equation shows

$$y_t = \alpha_i + \beta_1 y_{t-1} + \beta_2 US_{t-1} + \beta_3 dmon + \epsilon. \qquad \textbf{(8)}$$

The Godfrey test in equation 8 indicates that the errors do not present autocorelation in the sample return (see Table 5). The explanatory equation (8) for the FTAWIs is used as the conditional mean in the next section. In the Canadian and Mexican cases the direct effect from the U.S. returns is valuated at moment t, rather than at t-1.

Finally, in order to test the stationality of the FTAWIs, the augmented Dickey-Fuller test was implemented (Dickey and Fuller 1981), under the null hypothesis of unit root in the sample.[14] The results indicate that the country returns are not $I(1)$. See Table 5.

[14]If a variable is truly $I(1)$, shocks to it will have permanent effects.

Table 5

ADF *Test for the Return Sample and Godfrey Tests for:*

$$y_{i,t}=\alpha_i+\beta_i y_{t-1}+\epsilon_i \quad \textbf{(a)}$$

$$y_{i,t}=\alpha_i+\beta_{i,1} y_{t-1}+\beta_{i,2} R_{us,t-1}+\beta_{i,3} dom+\epsilon_i \quad \textbf{(b)}$$

COUNTRY	ADF[†]	GODFREY TEST FOR a[††]	GODFREY TEST FOR b[††]
Australia	-6.642	3.410 (0.06)**	2.209 (0.13)
Austria	-4.876	3.450 (0.06)**	2.346 (0.11)
Belgium	-3.896	0.013 (0.90)	1.023 (0.31)
Canada	-4.219	14.858 (0.00)*	1.749 (0.18)
Denmark	-12.492	2.102 (0.14)	1.071 (0.30)
Finland	-4.342	4.523 (0.03)*	0.652 (0.41)
France	-10.815	3.456 (0.06)**	2.777 (0.10)**
Germany	-8.751	3.108 (0.07)**	1.538 (0.21)
Hong Kong	-5.772	4.139 (0.04)*	3.212 (0.07)**
Ireland	-6.548	0.932 (0.33)	0.030 (0.86)
Italy	-8.190	5.494 (0.01)*	3.456 (0.08)**
Japan	-10.266	6.656 (0.01)*	2.663 (0.10)**
Malaysia	-6.921	0.575 (0.44)	0.360 (0.54)
Mexico	-3.740	3.609 (0.06)**	0.225 (0.63)
Netherlands	-10.065	0.617 (0.43)	0.074 (0.78)

(Continues)

New Zealand	-3.520	0.293	0.073
		(0.58)	(0.78)
Norway	-5.743	4.438	2.677
		(0.03)*	(0.10)*
Singapore	-5.213	0.642	0.247
		(0.42)	(0.61)
South Africa	-4.558	0.261	0.648
		(0.60)	(0.42)
Spain	-13.630	1.006	0.601
		(0.31)	(0.43)
Sweden	-10.579	6.937	0.938
		(0.01)	(0.33)
Switzerland	-5.383	2.621	0.219
		(0.10)**	(0.63)
U.K.	-11.038	2.995	1.570
		(0.08)*	(0.21)
U.S.	-4.142	0.203	0.126
		(0.65)	(0.72)

†In the ADF test, the critical t-statistic is -3.17 (Dickey-Fuller 1981).
††This test is distributed as chi-squared (1).

GARCH(1,1) *in the Financial Times Actuaries World Indices*

Bollerslev 1986; Bollerslev, Engle and Wooldridge 1988; Bollerslev, Chou and Kroner 1992, and French, Schwert and Stambaugh 1987 suggest that stock returns and risk premiums are positively related to the predictable volatility of stock returns. In particular, French, Schwert and Stambaugh 1987 suggest that there is a strong correlation between the daily variances.

Combining the results of the previous section and the evidence suggested by the researchers, we estimate the GARCH(1,1) model, as the following equations show:

$$R_t = \beta_0 + \beta_1 R_{t-1} + \beta_2 R_{US,t-1} + \beta_3 Dmon + \varepsilon_t \ , \quad (9)$$

$$h_t = a_0 + a_1 h_{t-1} + a_2 e_{t-1}^2 + a_3 Dmon \ , \quad (10)$$

where, in equation (9), R_t is the foreign index return at time *t*. $R_{us,t-1}$ is the lagged U.S. returns,[15] *Dmon* is a dummy variable that takes one for Mondays and days after holidays, and zero otherwise. The conditional variance, equation (10), depends on its own lag one, the squared lagged errors, and the *Dmon* variable, described above. The dummy variable was included based on the so-called weekend effect. Jaffe and Westerfield 1985, Kiem and Stambaugh 1984, and Jaffe, Westerfield and Ma 1988 posit that the weekend effect is an international phenomenon independent of the U.S. returns.

The empirical results from the FTAWIs are shown in Table 6. Table 7 contains some statistics about econometric results from the GARCH(1,1) model. The results indicate that the conditional variance is significantly different from zero in all cases. In particular, the conditional lagged variance coefficient (a_1) is significant in 23 countries at the five percent level. The squared lagged error (e^2(t-1)) in the conditional variance equation is significant at the five percent level in all cases. In the conditional variance equation, the dummy variable is significant in most of the FTAWI country samples. For instance, 21 coefficients are significant at the one percent level, one is significant at the five percent level, and there are only two cases where the dummy variable is not different from zero (see Table 6).

The explanatory power of the lagged dependent variable ($R_{(t-1)}$) in the conditional mean equation can be observed in the B_1 coefficient. From the previous model we expect that this coefficient would be significant among the countries. The results indicate that 15 FTAWIs present a significant autocorrelation in lag one at the 1% level. Ireland's returns and the U.S. returns are autocorrelated at the five percent level of significance. The returns from Belgium, France, Germany, New Zealand, South Africa, Sweden and the United Kingdom are not autoregressive, according to the GARCH(1,1) model. The direct impact from the $U.S._{(t-1)}$ returns in each of the FTAWIs can be analyzed in the significance of B_3. In all cases, the $U.S._{(t-1)}$ returns are a significant explanatory variable in each foreign index, with the exception of South Africa, where its B_3 coefficient is positive but not significant at conventional levels (see Table 6).

[15]In the Canadian and Mexican cases, the direct impact from the U.S. market in the conditional mean is evaluated at time *t*.

Table 6

GARCH (1,1) *in an Autoregressive Model*

COUNTRY	b0	b1	b2	b3	a0	a1	a2	a3	MAXIMUM LIKELIHOOD
Austria	-0.067	0.228	0.070	0.370	0.849	0.159	0.229	2.065	-610.90
	(1.315)	(6.466)*	(0.453)	(6.996)	(7.069)*	(2.815)*	(3.657)*	(10.07)*	
Australia	-0.025	0.099	0.007	0.419	0.054	0.811	0.074	0.207	-307.17
	(0.731)	(2.932)*	(0.089)	(10.88)*	(1.149)	(12.40)*	(3.216)*	(2.268)*	
Belgium	0.001	0.057	-0.023	0.336	0.860	-0.129	0.167	0.661	-369.38
	(0.040)	(1.456)	(0.220)	(8.360)*	(13.64)*	(1.966)*	(3.874)*	(7.484)*	
Canada	-0.032	0.128	0.042	0.098	0.016	0.739	0.095	0.210	31.919
	(1.422)	(2.888)*	(0.702)	(3.807)*	(0.767)	(13.19)*	(5.339)*	(5.401)*	
Denmark	0.025	0.164	-0.065	0.195	0.079	0.776	0.122	0.299	-454.58
	(0.579)	(3.746)*	(0.631)	(4.193)*	(1.93)**	(26.52)*	(4.623)*	(2.815)*	
Finland	-0.063	0.099	0.045	0.171	-0.070	0.964	0.032	0.406	-637.77
	(1.176)	(3.061)*	(0.369)	(3.311)*	(2.216)*	(17.26)*	(6.108)*	(2.484)*	
France	0.078	-0.011	-0.200	0.326	0.456	0.458	0.220	0.447	-549.08
	(1.597)	(-0.246)	(1.71)**	(6.305)*	(6.825)*	(10.54)*	(4.819)*	(3.035)*	
Germany	-0.008	-0.004	0.147	0.369	0.494	0.396	0.202	1.360	-584.96
	(0.179)	(0.105)	(0.996)	(6.860)*	(4.447)*	(6.675)*	(4.138)*	(7.388)*	
Hong Kong	0.183	0.094	-0.299	0.344	0.223	0.483	0.258	0.736	-447.80
	(5.024)*	(2.565)*	(2.700)*	(8.361)*	(3.697)*	(8.341)*	(6.656)*	(8.373)*	
Italy	0.024	0.165	-0.201	0.433	0.653	0.450	0.175	0.967	-667.82
	(0.429)	(3.770)*	(1.409)	(6.988)*	(6.171)*	(7.074)*	(4.913)*	(5.935)*	

(Continues)

COUNTRY	b0	b1	b2	b3	a0	a1	a2	a3	MAXIMUM LIKELIHOOD
Ireland	-0.004	0.071	0.023	0.324	0.255	0.660	0.224	0.111	-600.98
	(0.077)	(1.79)**	(0.192)	(5.796)*	(4.615)*	(16.18)*	(5.748)*	(0.784)	
Japan	0.021	0.119	-0.303	0.389	0.083	0.754	0.181	0.622	-718.98
	(0.388)	(3.551)*	(2.404)*	(5.932)*	(1.229)	(21.77)*	(6.688)*	(2.542)*	
Malaysia	0.070	0.274	-0.160	0.357	0.454	0.1549	0.476	0.391	-393.55
	(2.045)*	(8.039)*	(1.72)**	(8.955)*	(8.394)*	(2.400)*	(7.580)*	(3.475)*	
Mexico	0.171	0.193	0.093	0.600	0.962	0.331	0.145	1.051	-678.57
	(3.055)*	(5.078)*	(0.533)	(11.04)*	(4.205)*	(2.957)*	(3.790)*	(6.169)*	
Netherlands	0.012	-0.102	-0.002	0.380	0.057	0.771	0.115	0.222	-303.66
	(0.368)	(2.452)*	(0.026)	(9.539)*	(2.194)*	(19.77)*	(4.320)*	(3.328)*	
New Zealand	-0.046	0.036	-0.105	0.599*	0.146	0.721	0.112	0.653	-548.95
	(0.908)	(0.924)	(-0.760)	(11.70)*	(1.501)	(11.94)*	(4.301)*	(4.954)*	
Norway	0.003	0.140	-0.220	0.408	0.516	0.453	0.272	0.918	-674.65
	(0.069)	(3.361)*	(1.55)**	(7.202)*	(3.791)*	(7.191)*	(6.794)*	(4.739)*	
Singapore	0.020	0.174	0.093	0.421	0.146	0.595	0.237	0.486	-449.01
	(0.524)	(4.787)*	(1.05)	(9.409)*	(2.850)*	(10.84)*	(6.613)*	(4.280)*	
South Africa	0.121	0.11	-0.357	0.114	0.741	0.547	0.238	0.493	-837.60
	(2.276)*	(0.269)	(2.411)*	(1.529)	(6.579)*	(11.16)*	(6.021)*	(1.68)**	
Spain	-0.055	0.109	0.253	0.286	0.185	0.605	0.259	0.562	-554.20
	(1.280)	(2.802)*	(2.157)*	(5.346)*	(4.038)*	(16.82)*	(5.341)*	(4.125)*	
Sweden	-0.025	0.068	-0.083	0.450	-0.026	0.826	0.161	0.518	-598.06
	(0.627)	(2.163)*	(0.735)	(7.703)*	(1.053)	(9.927)*	(10.78)*	(4.786)*	
Switzerland	0.061	0.000	-0.084	0.309	0.164	0.609	0.212	0.653	-513.90
	(1.472)	(0.025)	(0.732)	(5.874)*	(3.370)*	(14.86)*	(5.062)*	(4.201)*	
U.K.	0.027	-0.015	-0.114	0.296	0.677	0.184	0.209	0.319	-440.14
	(0.665)	(0.356)	(1.162)	(6.229)*	(5.777)*	(1.89)**	(5.509)*	(2.555)*	
U.S.	0.075	0.065	0.1338		-0.005	0.972	0.022	0.403	-208.97
	(0.231)	(1.67)**	(1.983)*		(0.476)	(146.8)*	(4.112)*	(0.648)	

Table 7

Complementary Tests for the GARCH(1,1) *Model*

COUNTRY	SKEWNESS	KURTOSIS	LJUNG-BOX	LJUNG-BOX2
Australia	-5.431	49.230	23.811	4.944
Austria	-9.255	123.89	18.0324	0.3987
Belgium	-14.209	262.42	6.610	0.082
Canada	-7.894	112.97	34.43*	7.97
Denmark	-12.1619	195.02	15.45	0.145
Finland	-6.061	51.84	65.47*	6.563
France	-6.216	67.03	39.36*	0.73
Germany	-12.020	198.501	13.130	0.113
Hong Kong	-9.889	149.962	40.769*	0.410
Ireland	-10.182	146.17	30.72*	0.214
Italy	-11.328	176.44	19.95	0.453
Japan	-4.507	31.166	129.07*	6.494
Malaysia	-18.398	430.38	17.419	0.033
Mexico	-13.313	266.41	19.378	0.609
Netherlands	-10.869	182.74	33.005*	0.112
New Zealand	-14.318	281.42	31.109*	1.833
Norway	-9.742	146.70	34.915*	0.371
Singapore	-6.202	57.185	84.110*	7.840
South Africa	-5.813	44.94	46.153*	4.376
Spain	-13.009	233.95	32.777*	0.115
Sweden	-8.166	91.379	70.766*	1.236
Switzerland	-7.521	80.258	61.667*	4.486
U.K.	-6.325	58.667	30.135*	2.062
U.S.	-6.216	67.038	39.364*	0.730

In the conditional mean equation, the Monday and after holiday effect is not clear, since in most of cases it is not significant and the sign is not definite. Seven FTAWIs present significant dummy coefficients at the 1% level of significance. The constant coefficient of the main equation is not significant in almost all the FTAWIs. In the conditional mean equation, four countries present significant constant coefficients: Hong Kong, Malaysia, Mexico and South Africa (see Table 6).

Based on these results, we can argue that the FTAWIs are autoregressive and that the direct impact of the lagged U.S. returns is an important explanatory variable. The generalized autoregressive conditional heteroscedastic model improves the explanatory power of the model with respect to the AR(1) model in the previous section.

Table 6 presents a complementary set of statistics. In particular, the skewness and the kurtosis for normalized errors[16] are shown. Most of the skewness coefficients are extremely different from zero. The same but more critical situation is evidenced by the kurtosis coefficients of the normalized errors. The extremely high values can be explained by the low number of stocks in some FTAWIs (see Table 7).

The Ljung-Box test was used to test the autocorrelation of both the normalized errors and the squared normalized errors. However, Davidson and Mackinnon 1991 comment that "the Ljung-Box test is not generally valid when the residuals are from linear or nonlinear regression models that include both exogenous variables and lagged dependent variables in the regression functions" (pp. 364), as in the case that we are analyzing. The results for the Ljung-Box test for normalized residuals indicate that 15 countries present no residual autocorrelations at any level of significance (see Table 7).

Spillover Effect from the U.S. Market on the Financial Times Actuaries World Indices

The spillover effect from the U.S.$_{(t-1)}$ on foreign markets[17] is studied in this section, through the following equations:

$$R_t = \beta_0 + \beta_1 R_{t-1} + \beta_2 R_{US,t-1} + \beta_3 D_{mt} + \varepsilon_t \,, \tag{11}$$

$$h_t = a_0 + a_1 h_{t-1} + a_2 e_{t-1}^2 + a_3 D_{mt} + a_4 FUS_{t-1}, \tag{12}$$

where, in equation (12), $FUS_{(t-1)}$ is the innovation effect from the U.S. GARCH(1,1) squared errors, suggested by HMN 1990, Engle and Ng 1993, and Giovannini and Jorion 1989. The independent variable $FUS_{(t-1)}$ captures the

[16]The estimate h_t is used to normalize the errors.

[17]In the Canadian and Mexican cases, the U.S effect is valuated at time t.

spillover effect from the U.S. market on other countries.[18] The spillover effect from the U.S.$_{(t-1)}$ returns[19] to other countries can be observed in the conditional variance, where a_4 is the estimated coefficient of this effect (see Table 8). In fact, 18 FTAWIs evidence a significant spillover effect from the U.S.$_{(t-1)}$ returns at the 1% level. These countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Hong Kong, Japan, Malaysia, the Netherlands, Singapore, Spain, Sweden, Switzerland and the United Kingdom. It is interesting that the major foreign indices present a strictly significant spillover effect from the U.S.$_{(t-1)}$ returns and do so in a positive pattern. The countries with an insignificant U.S.$_{(t-1)}$ spillover effect are Ireland (0.04), Italy (0.01), Mexico (0.061), New Zealand (0.014), and South Africa (0.037), as shown in Table 8.

In the conditional variance equation (12) the estimator coefficient for the lagged conditional variance (a_1) is significant at the 1% level in 15 cases (see Table 8). The lagged squared residual coefficient (a_2) is significant in all cases. The dummy variable coefficient (a_2) does not present a constant pattern among the FTAWIs, neither in sign nor in significance.

The results indicate that the U.S.$_{(t-1)}$ impact on the conditional variance is important, with the exception of the South African returns. The impact of the lagged dependent variable in the current FTAWI is significant in 13 instances. The effect of the dummy variable is not clear, neither on significance nor on sign.

The likelihood ratio for each country indicates that the inclusion of the U.S.$_{(t-1)}$ innovation in the conditional variance equation for the GARCH(1,1) model significantly increases explanatory power in 21 cases (see Table 8). Only two cases are not improved in their specifications with respect to the GARCH(1,1) models.

Statistics for the normalized errors show that the skewness and kurtosis measures are improved in 15 cases (see Table 8). However, these results are far from the normal skewness and kurtosis. The Ljung-Box(12) tests of the normalized squared errors and normalized errors present an improvement with respect to the previous model, both in the significance and in the number of countries (see Table 9). The same statistics for the squared normalized residuals with the U.S.$_{(t-1)}$ spillover effect are better than those of the previous model.

[18]Other authors call this variable the volatility surprise.

[19]In the Canadian and Mexican cases the U.S. spillover effect is evaluated at time t, rather than at t-1.

Table 8

Estimation of the U.S. Spillover Effect

COUNTRY	b0	b1	b2	b3	a0	a1	a2	a3	a4	MAXIMUM LIKELIHOOD
Australia	-0.035	0.118	0.032	0.402	0.199	0.581	0.141	-0.001	0.042	-299.7
	(1.02)	(3.19)*	(0.42)	(9.92)*	(3.06)*	(6.19)*	(3.27)*	(0.01)	(3.70)*	
Austria	-0.068	0.202	0.068	0.355	0.745	0.116	0.197	1.290	0.414	-573.4
	(1.46)	(5.7)*	(0.52)	(6.4)*	(7.0)*	(1.60)	(3.7)*	(4.9)*	(4.1)*	
Belgium	-0.127	0.515	-0.017	0.289*	0.553	0.038	0.180	0.162	0.178	-316
	(0.35)	(1.30)	(0.208)	(7.3)*	(9.31)*	(0.64)	(4.12)*	(1.462)	(5.25)*	
Canada	-0.039	0.165	0.453	0.092	0.159	0.118	0.112	0.147	0.155	54.9
	(1.8)**	(3.5)*	(0.70)	(3.0)*	(7.8)*	(2.4)*	(4.8)*	(5.3)*	(3.8)*	
Demnark	-0.001	0.146	-0.03	0.199	0.320	0.455	0.200	0.134	0.089*	-421
	(0.03)	(3.4)*	(0.36)	(4.0)*	(4.1)*	(5.7)*	(4.3)*	(1.37)	(6.2)*	
Finland	-0.05	0.101	0.014	0.173	-0.088	0.927	0.055	0.574	0.013	-633
	(1.10)	(2.8)*	(0.11)	(3.1)*	(2.6)*	(76)*	(6.1)*	(3.3)*	(2.5)*	
France	0.154	0.126	-0.225	0.328	0.266	0.455	0.234	0.152	0.127	-419
	(4.0)*	(3.3)*	(2.6)*	(7.5)*	(5.2)*	(8.1)*	(6.1)*	(1.26)	(6.0)*	
Germany	-0.063	-0.018	0.159	0.363	0.162	0.0879	0.573	0.573	0.4822	-535
	(1.35)	(0.47)	(1.32)	(6.5)*	(2.34)*	(2.10)*	(2.86)*	(2.86)*	(5.29)*	
Hong Kong	0.1544	0.1269	-0.225	0.328	0.266	0.455	0.234	0.152	0.127	-419
	(4.09)*	(3.38)*	(2.61)*	(7.55)*	(0.51)*	(8.17)*	(6.14)*	(1.26)	(6.08)*	
Ireland	-0.010	0.050	0.037	0.317	0.233	0.670	0.233	0.167	-0.004	-597
	(0.19)	(1.18)	(0.29)	(5.9)*	(4.3)*	(16)*	(5.7)*	(1.16)	(0.08)	

(Continues)

COUNTRY	b0	b1	b2	b3	a0	a1	a2	a3	a4	MAXIMUM LIKELIHOOD
Italy	0.017	0.164	-0.194	0.439	0.594	0.474	0.177	0.964	0.001	-663
	(0.31)	(3.7)*	(1.34)	(7.0)*	(5.8)*	(7.5)*	(4.8)*	(5.6)*	(0.08)	
Japan	0.019	0.125	-0.337	0.404	0.041	0.766	0.174	0.799	-0.007	-711
	(0.36)	(3.8)*	(2.7)*	(11)*	(0.71)	(24.5)	(6.8)*	(3.3)*	(5.5)*	
Malaysia	0.056	0.293	-0.114	0.343	0.492	0.092	0.421	0.305	0.090	-383
	(1.62)	(7.3)*	(1.23)	(8.2)*	(7.6)*	(1.30)	(6.9)*	(2.8)*	(2.5)*	
Mexico	0.168	0.191	0.102	0.563	0.717	0.430	0.133	1.036	0.061	-675
	(2.9)*	(5.0)*	(0.59)	(8.1)*	(3.3)*	(3.8)*	(3.9)*	(6.1)*	(1.56)	
Netherlands	0.000	-0.096	0.017	0.388	0.077	0.725	0.127	0.036	0.054	-282
	(0.25)	(2.4)*	(0.24)	(8.9)*	(3.8)*	(26)*	(5.6)*	(0.46)	(6.9)*	
New Zealand	-0.047	0.0427	-0.116	0.579	0.166	0.680	0.122	0.732	0.014	-547
	(0.93)	(1.06)	(0.83)	(9.9)*	(1.6)	(10)*	(5.1)*	(5.6)*	(1.45)	
Norway	-0.014	0.128	-0.172	0.413	0.378	0.515	0.254	0.350	0.157	-657
	(0.26)	(3.0)*	(1.48)	(6.7)*	(3.7)*	(9.7)*	(6.9)*	(1.53)	(5.9)*	
Singapore	-0.032	0.196	0.173	0.391	0.141	0.599	0.157	0.409	0.096	-423
	(0.82)	(5.2)*	1.9**	(7.9)*	(3.4)*	(12)*	(4.8)*	(3.4)*	(4.9)*	
South Africa	0.127	0.0122	-0.343	0.117	0.742	0.535	0.251	0.366	0.037	-836
	(2.4)*	(0.27)	(2.3)*	(1.48)	(6.8)*	(11)*	(6.0)*	(1.25)	(1.46)	
Spain	-0.110	0.058	0.295	0.296	0.371	0.418	0.202	0.219	0.268	-509
	(2.6)*	(1.46)	(2.9)*	(5.1)*	(5.4)*	(8.2)*	(4.9)*	(1.43)	(5.9)*	
Sweden	-0.031	0.089	-0.050	0.428	0.0433	0.810	0.162	0.093	0.045	-584
	(0.73)	(2.3)*	(0.49)	(6.7)*	(1.36)	97*	(10)*	(0.64)	(5.1)*	
Switzerland	0.028	-0.022	-0.040	0.325	0.188	0.602	0.1404	0.302	0.161	-483
	(0.68)	(0.57)	(0.39)	(5.3)*	(5.4)*	(19)*	(4.7)*	(2.0)*	(4.4)*	
U.K.	0.011	-0.018	-0.078	0.288	0.692	0.130	0.180	0.229	0.107	-430
	(0.26)	(0.42)	(0.78)	(5.5)*	(5.7)*	(1.29)	(4.8)*	(2.0)*	(2.5)*	

Table 9

Complementary Statitstics with U.S. Spillover Effect

COUNTRY	LR(1)	SKEWNESS	KURTOSIS	LJUNG-BOX	LJUNG-BOX^2	ERRORS
Australia	16.34*	-3.725	19.390	32.99*	1.73	-0.427
Austria	74.86*	-3.434	18.377	35.633	2.949	-0.742
Belgium	106.34*	-3.716	19.238	33.691*	6.547*	-0.429
Canada	45.96*	-8.453	130.23	31.53	6.153	0.0711
Denmark	65.62*	-4.607	29.881	53.678*	14.132	-0.546*
Finland	9.3*	-6.694	65.792	58.281*	2.286	-0.820*
France	259.3*	-4.612	31.734	120.08*	74.73*	-0.543*
Germany	99.92*	-3.264	15.181	47.74*	21.42**	-0.694*
Hong Kong	57.6*	-4.612	31.734	120.08*	74.73*	-0.543*
Italy	9.38*	-11.75	188.58	19.587	0.397	-0.858
Ireland	7.92*	-10.196	145.89	31.126*	0.2105	-0.773
Japan	14.08*	-4.266	30.070	141.597*	6.435	-0.922
Malaysia	20.62*	-19.671	476.48	14.483	0.0302	-0.4964
Mexico	5.6**	-13.657	277.33	20.495	0.6539	-0.875
Netherlands	42.44*	-5.207	42.884	101.89*	35.82*	-0.365
New Zealand	2.22	-14.150	274.96	29.918*	1.566	-0.709
Norway	33.78*	-5.185	43.418	78.89*	7.77	-0.852
Singapore	50.22*	-3.508	17.697	100.88*	13.252	-0.549
South Africa	2.46	-5.829	45.03	46.769	4.437	-1.083
Spain	88.44*	-3.676	18.360	107.32*	67.375*	-0.660
Sweden	27.92*	-8.969	117.74	80.509*	1.241	-0.756
Switzerland	61.48*	-6.757	88.00	81.49	10.40	-0.625
U.K.	18.37*	-6.906	70.855	26.952	1.4203	-0.558

Conclusions

The economical conclusion is addressed to the fact that most of the *Financial Times Actuaries World Indices* incorporate the information generated in the U.S. market in a contagion or spillover effect, as was described by King and Wadhwani 1990; Hamao, Masulis and Ng 1990, and Chang, Karolyi and Stulz 1992.

The models tested indicate that the *Financial Times Actuaries World Indices* present heteroscedastic behavior (Schwert 1989, and Schwert and Segin 1990). The GARCH(1,1) procedure partially fixes the heteroscedasticity in the equation, which is improved in all of its coefficients and tests by the inclusion of the U.S.$_{(t-1)}$ spillover effect in the conditional variance. The results in the conditional mean suggest that the direct effect from the U.S.$_{(t-1)}$ returns is significant in most of the cases. This is not surprising, since the *Financial Times Actuaries World Indices* comprise only the most liquid stocks in each foreign stock exchange, where the greater the proportion of liquidity trading, the smaller the informativeness of prices (Chowdhry and Nanda 1991).

References

ARSHANAPALLI, B. and J.DOUKAS (1993). "International Stock Market Linkages: Evidence from the Pre- and Post-October 1987 Period", *Journal of Banking and Finance* 17, pp.193-208.

BECKER, K., J.FINNERTY and M.GUPTA (1990). "The Intertemporal Relation Between the U.S. and Japanese Stock Markets", *Journal of Finance* 45, pp.1.297-1.306.

BERNDT, E. et al (1974). "Estimation and Inference in Nonlinear Structural Models", *Annals of Economic and Social Measurement* 3/4, pp.653-665.

BOLLERSLEV, T. (1986). "Generalized Autoregressive Conditional Heteroscedasticity", *Journal of Econometrics* 31, pp.307-327.

BOLLERSLEV, T., R.CHOU and K.KRONER (1988). "*ARCH* Modeling in Finance: a Review of the Theory and Empirical Evidence", *Journal of Political Economy* 96, pp.116-131.

BOLLERSLEV, T., R.ENGLE and J.WOOLDRIDGE (1992). "A Capital Asset Pricing Model with Time-Varying Covariances", *Journal of Econometrics* 52, pp.201-224.

CAMPBELL, J. and YASUSHI HAMAO (1992). "Predictable Stock Returns in the U.S. and Japan: a Study of Long-Term Capital Market Integration", *Journal of Finance* 47, pp.43-69.

CHOWDHRY, B. and V.NANDA (1991). "Multimarket Trading and Market Liquidity", *Review of Financial Studies* 4, pp.483-511.

DAVIDSON, R. and J.MACKINNON (1993). *Estimation and Inference in Econometrics*. N.York: Oxford University Press.

DICKEY, D. and W.FULLER (1981). "Likelihood Ratio Tests for Autoregressive Time Series with a Unit Root", *Econometrica* 49, pp.1.057-1.072.

DWYER, G. and R.W.HAFER (1988). "Are National Stock Markets Linked?", *Federal Reserve Bank of St. Louis Review*, November-December, pp.3-14.

ENGLE, R. and V.NG (1993). "Measuring and Testing the Impact of News on Volatility", *Journal of Finance* 48, pp.1.749-1.788.

ERRUNZA, V. and E. LOSQ (1985). "International Asset Pricing under Mild Segmentation: Theory and Test", *Journal of Finance* 40, pp.105-124.

EUN, CH. and S. SHIM (1989). "International Transmission of Stock Market Movements", *Journal of Finance and Quantitative Analysis* 24, pp.241-56.

FERSON, W. and H.CAMPBELL (1991). "The Variation of Economic Risk Premiums", *Journal of Political Economy* 99, pp.385-415.

FRENCH, K., W.SCHWERT and R.STAMBAUGH (1987). "Expected Stock Returns and Volatility", *Journal of Financial Economics* 18, pp.3-29.

FRENCH, K. and R.ROLL (1986). "Stock Return Variances", *Journal of Financial Economics* 17, pp.5-26.

GIOVANNINI, A. and PH.JORION (1989). "The Time Variation of Risk and Return in the Foreign Exchange and Stock Markets", *Journal of Finance* 44, pp.307-325.

GODFREY, L. (1978). "Testing Against General Autoregressive and Moving Average Error Models when the Regressors Include Lagged Dependent Variables", *Econometrica* 46, pp.1.293-1.302.

HAMAO, Y., R.MASULIS and V.NG (1990). "Correlations in Price Changes and Volatility Across International Stock Markets", *Review of Financial Studies* 3, pp.281-307.

HARVEY, C. (1989). "Time-Varying Conditional Expected Market Returns", *Journal of Financial Economics* 24, pp.289-317.

---------- (1991). "The World Price of Covariance Risk", *Journal of Finance* 46, pp.111-157.

HESTON, S. and H.G.ROUWENHORST (1994). "Does Industrial Structure Explain the Benefits of International Diversification?", *Journal of Financial Economics* 36, pp.3-27.

JAFFE, J. and R.WESTERFIELD (1985). "The Weekend Effect in Common Stock Returns: the International Evidence", *Journal of Finance* 40, pp.433-454.

JAFFE, J. and C.MA (1989). "A Twist on the Monday Effect in Stock Prices: Evidence from the U.S. and Foreign Stock Markets", *Journal of Banking and Finance* 13, pp.641-650.

KIEM, ... and ... STAMBAUGH (1984). "A Further Investigation of the Weekend Effect in Stock Returns", *Journal of Finance* 39, pp.819-34.

KING, M. and S.WADHWANI (1990). "Transmission of Volatility between Stock Markets", *Review of Financial Studies* 3, pp.5-35.

KING, M., E.SENTANA and S.WADHWANI (1994). "Volatility and Links between National Stock Markets", *Econometrica* 62, pp.901-933.

ROLL, R. (1992). "Industrial Structure and Comparative Behavior of International Stock Market Indices", *Journal of Finance* 47, pp.3-41.

SCHWERT, W. (1989). "Why Does Stock Market Volatility Change over Time?", *Journal of Finance* 44, pp.1.115-1.153.

SCHWERT, W. and P.SEGUIN (1990). "Heteroskedasticity in Stock Returns", *Journal of Finance* 45, pp.1.129-1.155.

SHOLES, M. and J.WILLIAMS (1977). "Estimating Betas from Nonsynchronous Data", *Journal of Financial Economics* 5, pp.309-327.