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Re-assessing Co-movements among G7 Equity Markets: Evidence from iShares

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ABSTRACT

iShares funds are products designed to mimic the movements of MSCI stock market indices. Being devoid of problems associated with trading restrictions, exchange-rate fluctuations and non-synchronous trading, iShares data are better suited for measuring, firstly, equity-market co-movements and, secondly, diversification potential than national indices data; the latter data are used by most of the studies in the area. Applying recent time-varying methodology for the analysis of short- and long-term co-movements, a detailed analysis of the dynamics of the equity market linkages over the period 1996-2005 is provided. Evidence is found of increasing conditional correlations and significant time-varying long-run relationships between the US and the majority of other G7 markets since 2001, as measured by iShares. However, the extent of both short-term and long-term linkages between the G7 equity markets is lower for national indices data. Our findings suggest that (i) the results of earlier studies that are based on stock market indices should be interpreted with caution, since using these may overestimate the extent of available diversification benefits; and (ii) iShares funds do not represent perfect diversification products. These results appear to be robust to alternative model specifications, data frequency and conditioning bias.

Keywords: Stock Market Co-movements, ETFs, Correlation, G7 Stock markets, Cointegration, GARCH

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1. Introduction

Since the 1970s, international asset-market co-movements have been widely studied in order, firstly, to measure the potential for international diversification (Goetzmann *et al.*, 2005), secondly, to construct efficient portfolios (Ang and Bekaert, 2002) and, finally, to assess the vulnerability of capital markets to international financial shocks (Forbes and Rigobon, 1999). The need for accurate estimates of the extent of asset market co-movements is therefore stipulated by the importance of these issues for modelling securities returns. The strand of the literature that is particularly relevant for this study is the one that focuses on identifying the diversification benefits available to international investors (Longn and Solnik, 1995, 2001; Goetzmann *et al.*, 2005).

Until the middle of the 1990s, international diversification occurred either via well-diversified MNCs or via international index funds, which provided exposure to a basket of countries, or via closed-end single-country funds. In 1996, a new family of financial products, iShares funds, was introduced that provided investors with easy access to a well-diversified indexed portfolio at low cost (Khorana *et al.*, 1998). iShares, formerly World Equity Benchmark Shares (WEBS), are organized as exchange-traded funds (ETFs) and are designed to track Morgan Stanley Capital International (MSCI) indices. They provide a product which tracks a portfolio designed explicitly to allow internationally comparable benchmark performances and can be easily traded on an organized exchange. iShares funds thus combine the diversification benefits of an index fund with the flexibility of a common stock. Furthermore, iShares are created or redeemed only in kind and the resulting arbitrage opportunities ensure that their prices, unlike those of closed-end country funds (CECF), do not significantly diverge from the underlying net asset value (NAV) of the constituent shares. Thus iShares present the US-based investor with an opportunity to replicate the market portfolio of a foreign country without the risk of selling it at a discount. Moreover, iShares products can be managed at a low cost.

Therefore, it is not surprising that iShares have rapidly become an attractive alternative for investors seeking international equity exposure (Business Wire (2005)).

In view of the growing popularity of international iShares, the purpose of the present study is to use iShares prices to measure the extent of equity-market co-movements. While numerous empirical studies have analyzed this issue (Baele *et al.*, 2004; Kearney and Lucey, 2004), they tend to rely on broad national stock-market indices as market proxies. However, stock market indices may not represent easily investable assets due to the high costs of maintaining equivalent portfolios and due to the entry and trading barriers that exist for foreign investors in some markets (Li *et al.*, 2003). ETFs, therefore, appear to be more suitable for examining market linkages since their exposure to entire markets and their ease of trade make them accessible to investors with varying degrees of sophistication. Finally, iShares price data are devoid of problems such as non-synchronous trading, exchange-rate fluctuations and trading restrictions.

Despite the advantages of using iShares over national stock market indices, only a handful of studies have used iShares as proxies for foreign equity markets; this reflects, in part, the relative novelty of these financial products. (See Miffre (2004), Phengpis and Swanson (2004), Durand and Scott (2003), Pennathur *et al.* (2002), Schwebach *et al.*, (2002), and Olienyk *et al.*, (1999) for a selection of the few papers that have used these securities.) These studies mainly focused on measuring the international diversification benefits from holding iShares funds compared to those of respective closed-end country funds.

Longin and Solnik (1995) and Ang and Bekaert (2002), among others, point out the time-varying nature of international correlations, attributing it to the time-varying risk-premium. Ang and Bekaert (2002) analyzed the implications of this for international asset allocation. Specification of long-term relationships can also be subject to change due to possible structural breaks that are likely to occur over longer time spans (Gregory and Hansen, 1996). These two observations suggest that a dynamic framework may be preferable over a static one since the former accounts for potential instabilities in the time-series relationships.

Against this backdrop, the present study adds to the existing literature in a number of ways. Firstly, this paper extends the work of Olienyk *et al.* (1999), by performing a detailed analysis of the dynamics of the long-term and short-term interdependencies between iShares price series; this analysis relies on the most recent econometric techniques. In particular, the dynamics of the long-run relationships are investigated using the Hansen and Johansen (1999) recursive cointegration procedure. Secondly, the recently developed dynamic conditional correlation specification of multivariate GARCH models developed by Engle (2002) (DCC-GARCH) is used to allow for explicit time variation in the conditional correlation matrix of iShares returns. Thirdly, all analyses are performed using national indices data, which are more commonly used in the literature; this is done in order to compare the findings with those based on iShares data. Finally, data from a recent time period – March 1996 to January 2005 – are used. This comprises the longest time series of iShares prices analyzed in the literature so far.

Taking the perspective of US-based investors, this paper measures the status of co-movements between the US and the remaining Group of Seven (G7) markets: Canada, France, Germany, Italy, Japan and United Kingdom. The reasons for using G7 markets are manifold. Firstly, by using G7 markets, well in excess of 60 per cent of world equity-market capitalization (www.world-exchanges.org/) is covered. Secondly, G7 markets capture over 50 per cent of US foreign equity holdings (US Department of Treasury, 2003). Thirdly, over 80 per cent of investment in iShares is concentrated in the iShares of G7 countries (http://indexfunds.com/).

Our findings provide evidence in favour of time-varying multivariate long-run relationships between the G7 markets. The pattern of the long-run relationships appears to be affected during periods of high market volatility. These periods of disruption of the long-run equilibrium are longer when national indices data are used. However, there is strong evidence that the extent of the long-run linkages stabilised after 2001. The short-term co-movements between the USA and the individual G7 markets have also, when measured by iShares returns, increased since 2001. At the same time, in line with findings for long-term dependencies, estimates of the conditional correlations based on broad stock-market indices data seem to significantly overestimate potential diversification benefits. The discrepancy in the correlation patterns for iShares and market indices suggest that the returns from iShares may be prone to the influence of factors other than information from the underlying markets. These findings suggest that limited diversification opportunities are available to the US-based investor interested in acquiring iShares of the G7 markets.

The rest of the paper is structured as follows. Section 2 reviews recent findings in relation to equity market co-movements. Section 3 provides an overview of exchange-traded funds with a particular focus on Standard & Poor's Depositary Receipts (SPDRs) and iShares. The data and methodology are described in Sections 4 and 5. Section 6 provides empirical results and Section 7 concludes.

2. Literature Review

2.1 Studies of Asset Market Co-movements: Correlation and Cointegration Analyses of Stock Market Indices

An extensive literature on the evolution of equity-market correlations and the presence of common stochastic trends exists. Since the seminal work by Grubel (1968), analyses of correlations between international asset markets has become a cornerstone for inferences regarding short-term market interdependencies and the presence of diversification benefits. The evidence for developed markets, based on correlation analysis, strongly supports an increase in equity-market co-movements (Maldonado and Saunders (1981); Meric and Meric (1989); Longin and Solnik (1995); Longin and Solnik (2001)). This finding is associated with increasing real economic linkages between countries (Arshanapalli and Doukas (1993); Bachman *et al*. (1996); Campbell and Diebold (2005); Roll (1992); Bracker and Koch (1999); Bracker *et al.* (1999); Johnson and Soenen (2003)).

Parallel to these contributions is a literature that uses cointegration measures to assess the degree of long-term co-movements between international equity markets. Kasa (1992) examines the major equity markets over the 1974-1990 period, and finds a single cointegration vector indicating low levels of convergence. However, the analysis performed in Kasa (1992) is subject to criticism by Richards (1995) due to potential small sample bias. Similar results for major world markets are found by Arshanapalli and Doukas (1993). In contrast, Chou *et al*. (1994) find no evidence of cointegration for the G7 countries. However, Hung and Cheung (1995) for the Asian markets, Cotter (2004) for Irish-European markets, Gilmore and McManus (2002) for US and Central European markets, and Ratanapakorn and Sharma (2002) and Manning (2002) for south east Asian, European and US markets find limited evidence of long-run co-movements.

This evidence of convergence is also found for major markets including the G7 in Masih and Masih (2002), and also in the context of G7 multinational companies in Rowland and Tesar (2004). Evidence for NAFTA markets is found in Atteberry and Swanson (1997), Gilmore and McManus (2004) and Aggarwal and Kyaw (2006), while Kearney and Poti (2006) and Hasan and Schmiedel (2004) arrive at similar results using firm-level data and network models respectively. An explicit examination of the time variation in these results has been undertaken by Koch and Koch (1991) who use a simultaneous equation model estimated over a number of contiguous sub-periods to find significant and increased linkages among world equity markets. A similar result is the finding of increased co-movements from Longin and Solnik (1995) who use correlation and covariance matrix estimates. Rangvid (2001), Rangvid and Sorensen (2001) and Aggarwal *et al.* (2003) use dynamic cointegration methodologies, and find that there has been a significant increase in convergence among European financial markets. More recently, Kim (2005) concludes from multivariate E-GARCH models that the EMU process has been associated with increased integration among European equity markets, while Vinh Vo and Daly (2005) note the implications for portfolio diversification of this increased integration. This finding of increased and strong integration is not, however, unanimous: Kanas (1988), Sentana (2000), Fratzscher (2001), Garcia Pascual (2003) and Phengpis and Apilado (2004) find indications that amongst developed markets integration is partial, slow and incomplete. It should, however, be noted that the purpose of this paper is to assess the extent of co-movements rather than to measure stock-market integration. This paper focuses on the former issue without making inferences about the latter. See Baele *et al.* (2004) for a discussion of the definitions of integration and co-movements.

2.2 International Diversification and Long-Run Relationships between Equity Markets: Evidence from ETFs

One of the first studies that considered ETFs as diversification instruments was Olienyk *et al.*, (1999). They tested for cointegration and Granger causality between SPDR and seventeen World Equity Benchmark Securities (WEBS) and twelve respective country funds during 1996-1998. The authors made a consistent finding: SPDR is pair-wise cointegrated with every WEBS. Cointegration is also found for WEBS and the respective CECFs. Furthermore, all 17 WEBS are found to Granger cause SPDR, thus indicating the presence of short-term pricing inefficiencies. Hence, Olienyk *et al.*'s (1999) findings suggest that it is possible to earn short-run arbitrage profits using WEBS and SPDRS; however, there appears to be only a limited potential for diversification benefits from index-linked securities in the long run.

The diversification benefits of iShares are also analysed in Pennathur, Delcoure and Anderson (2002), Durand and Scott (2003), Miffre (2004), Schwebach, *et al*. (2002). Pennathur *et al.* (2002) apply single and two-factor asset-pricing models to the iShares prices for the 1996-1999 period. The two-factor model, which includes both home and US-market index returns, indicates that iShares maintain a considerable exposure to the US market. The authors, thus, conclude that iShares do not represent a perfect international diversification vehicle. In a later study, Zhong and Yang (2005), using a three-factor model, arrive at a similar finding. Durand and Scott (2003), drawing on Australian iShares data, also reach a comparable conclusion. Durand and Scott (2003) use a VAR framework to explain the dynamics of Australian iShares returns and volume due to movements in US returns, volumes and exchange rates. Their findings suggest that US-based investors in the Australian market tend to overreact to contemporaneous and past information from the US equity market, exchange rates and past iShares returns.

Despite their limitations, iShares appear to offer a diversification potential superior to that of investment in US securities only (Miffre, 2004). Relying on the analysis of optimal portfolios constructed on the basis of Sharpe ratios, Miffre (2004) argues that a typical investor would benefit from investing on average half of his or her wealth in the S&P500 and the rest in iShares of developed non-US markets (Canada, France, Italy, Spain, Sweden, and the UK). To date, Miffre (2004) is the only study to consider time-varying correlations between S&P500 and iShares returns. While acknowledging that these are not stable over time, the author does not discuss the dynamics of time-varying correlations or the implications for optimal asset allocation.

In a related paper, Schwebach *et al.* (2002) draw attention to the impact of increased volatility on the efficacy of diversification. They evaluate the performance and diversification benefits of both WEBS and CECF before and after the Asian crisis. Having analyzed simple correlations, they argue that both the performance and extent of diversification benefits changed drastically after the Asian crisis; the latter change is reflected in increased correlations. As suggested by the results of the correlation analysis, since the Asian crisis, WEBS, compared to CECF, may have offered better diversification opportunities.

Phengpis and Swanson (2004), on the other hand, discuss the construction of optimal portfolios. In this context, they use results from cointegration analysis to investigate whether or not incorporating information about long-run relationships, instead of relying exclusively on short-term information, can help to improve diversification gains. The authors conclude that relying on national indices (as opposed to iShares) to evaluate diversification gains may overstate the actual benefits. Moreover, they note that the inclusion of long-term information as an additional input to portfolio construction can improve diversification benefits.

Olienyk *et al.*'s (1999) paper is the starting point of the present study. This paper extends their study to investigate the existence of multivariate cointegration relationships between G7 markets. Subsequently, this paper focuses on the time-varying dynamics of both long-term and short-term cointegration relationships by using the recursive cointegration procedure of Hansen and Johansen (1999), and the dynamic conditional correlation GARCH (DCC-GARCH) model of Engle (2000). The resulting graphs present a detailed pattern of the time-varying nature of short-term equity-market linkages.

3. Background on ETFs, iShares and SPDR

Exchange-traded funds are considered to be one of the major financial innovations of the past decade. ETFs are organized as funds or unit investment trusts that seek to track price and yield performance of the underlying sector, domestic or international indices (www.amex.com). ETFs allow investors to track a benchmark; they, thus, enable investors to gain exposure to segments or entire domestic or foreign markets with relative ease. Purchasing and selling ETFs for both retail and institutional investors is easy due to their similarities with equity stocks. Buying on margin and short selling (even on a downtick) are allowed; this enhances liquidity. In the secondary market, ETFs are traded intra-daily, as are the stocks or shares of close-end funds. In the primary market, when the fund itself is the party of the trade, transactions take the form of an in-kind creation (redemption) process through market specialists. This process involves depositing (receiving) a stock portfolio to receive (redeem) a pre-specified amount of ETF shares. The in-kind transfer process underlies some of the unique features of ETFs: one of the lowest expense ratios in the industry (Fuhr, 2001; Gastineau, 2002; Gastineau, 2004a) and tax efficiency (Poterba and Shoven, 2002; Gastineau, 2004b). The typical expense ratios on an ETF range between 0.35 and 0.50 per cent, which compares favourably with the 0.73 per cent charged by index funds (Sills, 2001; Simon, 2004). Such low expenses are explained by the absence of active management and shareholder-level accounting. Furthermore, in-kind creation (redemption) gives rise to arbitrage opportunities and precludes significant deviations between ETF net asset value and market price. All these features render ETFs an attractive investment vehicle.

Thus, ETFs have aided the development of ETF-based portfolio management where ETFs are used as portfolio components for the purposes of tax management, sector rotation strategies, hedging strategies, the maintenance of equity exposure during manager transition *etc*. (Chamberlain and Jordan, 2004)). The disadvantages of ETFs lie in the risk of offsetting potential gains by brokerage commissions paid on every trade, and the sensitivity of the ETF's price to a price of a single security; the latter may arise because particular ETFs may have a high portfolio concentration (Simon, 2004).

In the US, the first ETFs were introduced on AMEX in 1993 in the form of SPDRs (Standard & Poor's Depository Receipts). Since their introduction, ETFs have seen remarkable growth: their assets have almost doubled every year since 1995 (see Table 1). Nowadays, a large number of ETFs exist in the US. They comprise a variety of financial products, such as SPDRs, iShares, QQQs, Vanguard Index Participation Equity Receipt shares (VIPERs), that are traded on AMEX, NYSE and CBOE (Ross, 2005; Gastineau, 2002; Chamberlain and Jordan, 2004). In December 2004, the combined assets of US exchange-traded funds amounted to $226 billion, having increased by almost 50 per cent over the previous year. Among them, the assets of International Equity Funds surged by almost 140 per cent during the last year from $13.9 billion to $33.6 billion (http://www.ici.org/). The two different types of ETFs, SPDRs and iShares, analysed in the present study are discussed below.

Table 1 Assets and Number of ETFs by Type of Fund

Year	Total	Domestic Equity	Global/International Equity	Bond
Panel A: Assets, million of dollars, end of the year				
1993	464	464	–	–
1994	424	424	–	–
1995	1,052	1,052	–	–
1996	2,411	2,159	252	–
1997	6,707	6,200	506	–
1998	15,568	14,542	1,026	–
1999	33,873	31,881	1,992	–
2000	65,585	63,544	2,041	–
2001	82,993	79,977	3,016	–
2002	102,143	92,904	5,324	3,915
2003	150,983	132,332	13,984	4,667
2004	226,205	184,045	33,644	8516
Panel B: Number of Funds, end of the year				
1993	1	1	–	–
1994	1	1	–	–
1995	2	2	–	–
1996	19	2	17	–
1997	19	2	17	–
1998	29	12	17	–
1999	30	13	17	–
2000	80	55	25	–
2001	102	68	34	–
2002	113	66	39	8
2003	119	72	41	6
2004	151	102	43	6

Source: Investment Company Institute Fact Book 2004.

3.1 SPDRs

SPDRs were launched by State Street Global Advisors in 1993. SPDRs are exchange-traded funds that aim to track the performance of various indices compiled by Standard & Poor's. They include SPDR Trust Series 1 (referred to as Spiders) and Select Industry SPDRs. The former is designed as a unit investment trust that follows the S&P500 index. The latter is constructed as an open-end fund that tracks the performance of specific industry groups within the S&P500 index (www.amex.com). SPDRs are the largest ETFs. Since 2004, they have attracted almost $56 billion of assets and their average daily trading amounts to $5 billion (Ross (2005)).

3.2. iShares

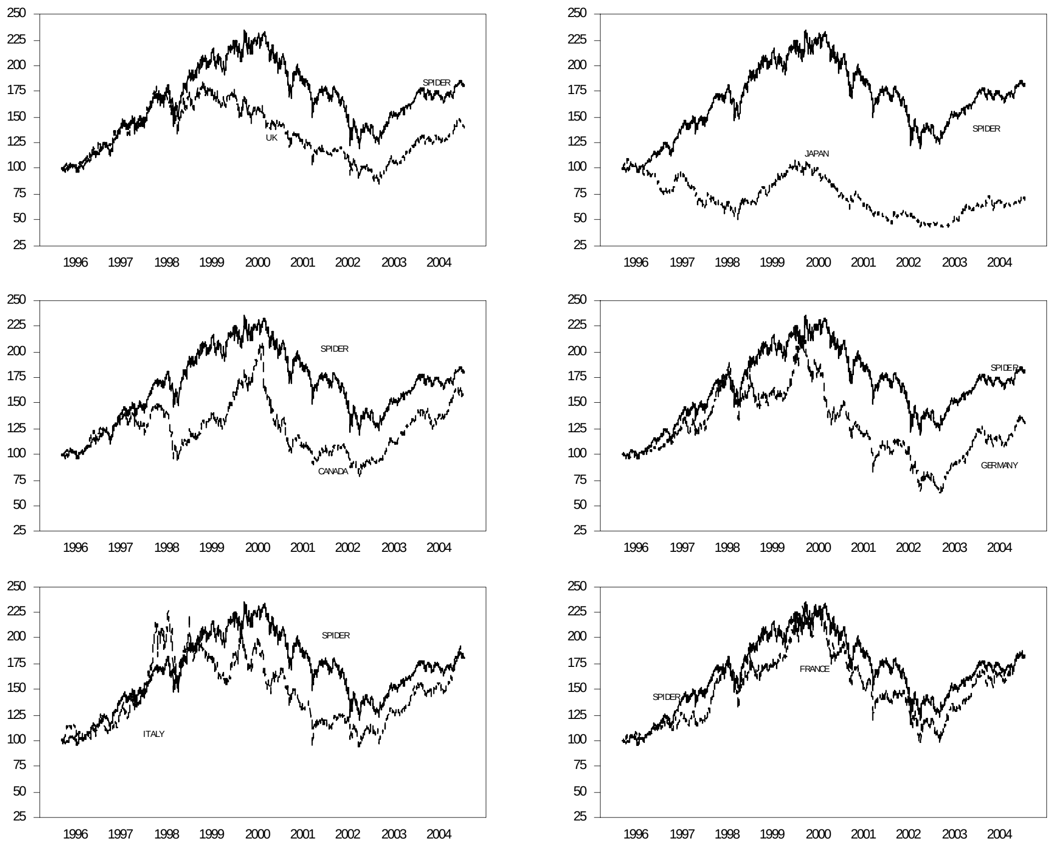
iShares, initially known as WEBS (World Equity Benchmark Securities), were launched by Morgan Stanley in May 1996 and re-branded as iShares MSCI Index Funds by Barclays Global Investors in May 2000. iShares have provided investors with access to markets that otherwise would have remained beyond their reach. Accounting for 42 per cent of the ETF market, iShares belong to one of the most popular ETFs today (Ross, 2002). As from January 2005, 21 series of iShares exist. They cover individual foreign equity markets; namely, Australia, Austria, Belgium, Brazil, Canada, France, Germany, Hong Kong, Italy, Japan, Malaysia, Mexico, Netherlands, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, and the United Kingdom. iShares do not invest in every security in the market, but in a basket of securities closely representing the market. Developed (emerging) markets index funds would normally invest at least 95 per cent (60 per cent) of their assets in securities from the underlying index and in American Depository Receipts (Chamberlain and Jordan, 2004).

4. Data

Our dataset consists of daily closing prices for SPDR for the US market and six MSCI iShares Series for the remaining G7 stock markets; namely, Canada, France, Germany, Italy, Japan, and the UK. This paper concentrates on the iShares covering G7 countries as these represent the largest equity markets, covering in excess of 60 per cent of market capitalization of all world markets over the period (www.world-exchanges.org/). This paper also uses data on representative national stock market indices for the G7 countries for the same period. These are the TSX (Canada), the CAC40 (France), the DAX30 (Germany), COMIT (Italy), the Nikkei225

(Japan), the FTSE100 (UK), and the DJIA (USA). The sample period spans almost ten years, from 18 March 1996 to 20 January 2005 and includes 2309 observations. The entire dataset has been obtained from DataStream. The beginning of the sample period coincides with the start of trading of iShares, then WEBS. It is thus the longest time series of iShares prices analyzed so far in the literature. Such a long dataset is especially suited to applying cointegration analysis to characterize the long-term dependencies between markets. Figure 1 presents a graph of SPDR and iShares prices over the sample period.

Figure 1. MSCI iShares Indices for G7 Countries, 18 March 1996 to 20 January 2005



This paper presents descriptive statistics of the SPDR, iShares, and the MSCI national indices sample daily returns in Table 2. The returns were calculated as continuously compounded returns, $R_t = \log P_t - \log P_{t-1}$, where P_t is the daily closing price. With the exception of Japan, even allowing for the bear market of the early 2000s, all securities displayed a positive return. The returns on iShares are leptokurtic for all G7 countries and, with the exception of Japan, negatively skewed.

Table 2. Descriptive Statistics for SPDR and iShares Returns, 18/03/1996-20/01/2005

Panel A: National Indices							
	TSX	**CAC40**	**DAX**	**COMIT**	**NIKKEI225**	**FTSE100**	**DJIA**
Mean	0.00031	0.00029	0.00022	0.00042	-0.00024	0.00020	0.00026
Maximum	0.05	0.06	0.07	0.06	0.13	0.06	0.06
Minimum	-0.09	-0.07	-0.08	-0.08	-0.08	-0.05	-0.07
Std. Deviation	0.01	0.01	0.02	0.01	0.02	0.01	0.01
Skewness	-0.76	-0.13	-0.16	-0.38	0.26	-0.13	-0.21
Kurtosis	8.26	5.01	5.06	5.79	5.89	5.07	3.87
Jarque-Bera	2884.09	393.77	417.30	803.05	830.69	417.21	1458.27
Prob (Jarque-Bera)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Observations	2309	2309	2309	2309	2309	2309	2309
Panel B: iShares and SPDR							
	Canada	**France**	**Germany**	**Italy**	**Japan**	**UK**	**USA**
Mean	0.00031	0.00025	0.00011	0.00026	-0.00016	0.00015	0.00025
Maximum	0.056	0.065	0.084	0.085	0.123	0.058	0.065
Minimum	-0.087	-0.090	-0.111	-0.093	-0.069	-0.075	-0.064
Std. Deviation	0.014	0.015	0.017	0.016	0.017	0.012	0.014
Skewness	-0.356	-0.160	-0.265	-0.336	0.390	-0.066	-0.058
Kurtosis	5.879	5.117	6.358	6.076	6.554	5.822	4.851
Jarque-Bera	845.988	440.90	1111.35	953.26	1273.12	767.64	330.68
Prob (Jarque-Bera)	0.00	00.00	0.00	0.00	0.00	0.00	0.00
Observations	2308	2308	2308	2308	2308	2308	2308

Prior to testing for the presence of cointegration, price series data were checked for non-stationarity using conventional unit root tests; namely, Augmented Dickey-Fuller (ADF; Said and Dickey, 1984) and Phillips-Perron (PP; Phillips and Perron, 1988). All series were found to be non-stationary in levels and stationary in differences. The critical values are from

MacKinnon (1991). For brevity, tables are not reported here, but they are available upon request.

5. Methodology

5.1 Johansen and Juselius Multivariate Cointegration Tests

Multivariate cointegration tests suggested by Johansen (1988) and developed in Johansen and Juselius (1990) have been widely used in the empirical analysis of the long run co-movements between asset markets. The tests determine cointegration rank (the number of common stochastic trends) in a multivariate system containing non-stationary variables. Two tests have been suggested: the trace test and the maximum eigenvalue tests. Due to the extreme popularity of these tests, only a brief description will be offered here. The trace statistics which tests the null hypothesis of *r* cointegration relationships against the hypothesis of *n* cointegration relationships are given by:

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} \log(1-\hat{\lambda}_i), \qquad (1)$$

where r = 0, 1, 2, …, n-2, n-1; $\hat{\lambda}_i$ represents the estimated i^{th} eigenvalue from the eigenvalue problem:

$$|\lambda S_{kk} - S_{k0} S_{00}^{-1} S_{0k}| = 0, \qquad (2)$$

The maximum eigenvalue test assesses the null hypothesis of *r* cointegration vectors against the alternative of $r+1$ cointegration vectors: $H_0(r)$ against $H_1(r+1)$. The maximum eigenvalue statistics are given by:

$$\lambda_{\max} = -T \log(1-\hat{\lambda}_{r+1}), \qquad (3)$$

Critical values for the two tests have been tabulated by Osterwald and Lenum (1992). Monte Carlo experiments reported by Cheung and Lai (1995) suggest that the trace statistic is more robust to skewness and excess kurtosis (in the residuals) than the maximum eigenvalue test. Therefore, when interpreting results, more weight is given to the outcomes of the former test.

5.2 Recursive Cointegration Tests

Hansen and Johansen (1993) provide a method to analyze not only the extent, but also the dynamics of the long-run relationships. Their recursive cointegration approach relies on the Johansen and Juselius (1990) cointegration test. The analysis is performed for an initial period and thereafter updated as new data are added to the initial sample. The test statistic of interest, here the trace, is calculated over the chosen sample, t_0 to t_n. This sample is then extended by j periods and the statistic is re-estimated for the period from t_0 to t_{n+j}. Eventually, the estimation procedure reaches the end of the data, producing the test statistic results; these are equivalent to the standard static Johansen and Juselius (1990) estimation over the entire time period. The relevant statistic is then plotted and examined for interpretation. For ease of interpretation, the calculated statistic is rescaled by 90 per cent of the asymptotic distribution for a model without exogenous variables or dummies. Rescaled values above 1 provide evidence against the null hypothesis. An upward trend indicates an increased extent of co-movements; a downward trend indicates a decreased extent of co-movements.

5.3 Dynamic Conditional Correlations GARCH (DCC-GARCH)

Earlier studies of international correlations relied on the analysis of simple correlation coefficients (see for example Panton *et al.*, 1976, and Watson, 1980), whereas later studies utilized rolling correlation coefficients and correlation coefficients adjusted for the presence of different volatility regimes (Forbes and Rigobon, 1999). This paper builds on this work by analyzing time-varying conditional correlations between international stock markets. In doing so, it utilizes the recent methodology proposed by Engle (2002). This methodology is a multivariate GARCH dynamic conditional correlation analysis (DCC-GARCH).

The DCC-GARCH class of models encompasses the parsimony of univariate GARCH models of individual assets volatility with GARCH-like time-varying correlations. The estimation of the DCC-GARCH model is a two-step procedure. In the first step, univariate GARCH models are estimated for each time series; in the second step, the transformed residuals from the first stage are used to obtain a conditional correlation estimator. The model assumes that returns from the *k* series are multivariate normally distributed with zero mean value and covariance matrix H_t:

$$r_t | F_{t-1} \sim N(0, H_t) \tag{4}$$

$$H_t \equiv D_t R_t D_t \tag{5}$$

where D_t is a *kxk* matrix of time-varying standard deviations from univariate GARCH models with $\sqrt{h_{it}}$ on the i^{th} diagonal, following a univariate GARCH model. The proposed dynamic correlation structure is:

$$R_t = (Q_t^*)^{-1} Q_t (Q_t^*)^{-1}, \tag{6}$$

where Q_t^* is a diagonal matrix composed of the square root of the diagonal elements of the Q_t and Q_t follows a GARCH type of process:

$$Q_t = (1 - \sum_{m=1}^{M} \alpha_m - \sum_{n=1}^{N} \beta_n)\overline{Q} + \sum_{m=1}^{M} \alpha_m (\varepsilon_t^{'} \varepsilon_t) + \sum_{n=1}^{N} \beta_n Q_{t-n}, \tag{7}$$

where $\overline{Q}$ is an unconditional covariance matrix of the standardized residuals from the first-stage estimation.

This paper uses a parsimonious approach, modelling data as a DCC-GARCH (1,1) process, within a bivariate system of each iShare return in relation to that of the US stock market. An asymmetric GARCH process of Glosten *et al.* (1993) with *t*-distribution is assumed. The extraction of the conditional time-varying correlations allows us to examine the short-run dynamics of the series. It also allows us to monitor the effects attributed to the sequence of crisis events that took place throughout the sample. A conventional GARCH specification, which assumed a normal symmetric distribution, was also estimated. Although the results are very similar, the less strict specification was chosen by likelihood ratio tests. The results are not reported here, but are available on request.

6. Empirical Findings

6.1. Findings using iShares Data

6.1.1 Multivariate cointegration test results

This paper first uses Johansen and Juselius cointegration tests to obtain preliminary evidence on the presence of cointegration relationships in the system of G7 markets. The results for the VAR specification with a linear trend in the data and in a cointegrating vector are reported in Table 3. The lag length was chosen by AIC to be 2. These cointegration tests provide evidence in favour of one cointegration relationship between the iShares prices of the G7 markets over the total sample period, between March 1996 and January 2005.

Table 3 Johansen-Juselius (1990) Cointegration Test Results for iShares Data, 18 March 1996 to 10 January 2005

Eigenvalue	L-max	Trace	H_0: r	p-r	L-max90%	Trace90%
0.0393	91.98	159.81	0	7	28.36	117.73
0.0095	21.92	67.82	1	6	24.63	89.37
0.0088	20.29	45.90	2	5	20.90	64.74
0.0050	11.43	25.61	3	4	17.14	43.84
0.0028	6.52	14.19	4	3	13.39	26.70
0.0021	4.76	7.67	5	2	10.60	13.31
0.0013	2.90	2.90	6	1	2.71	2.71

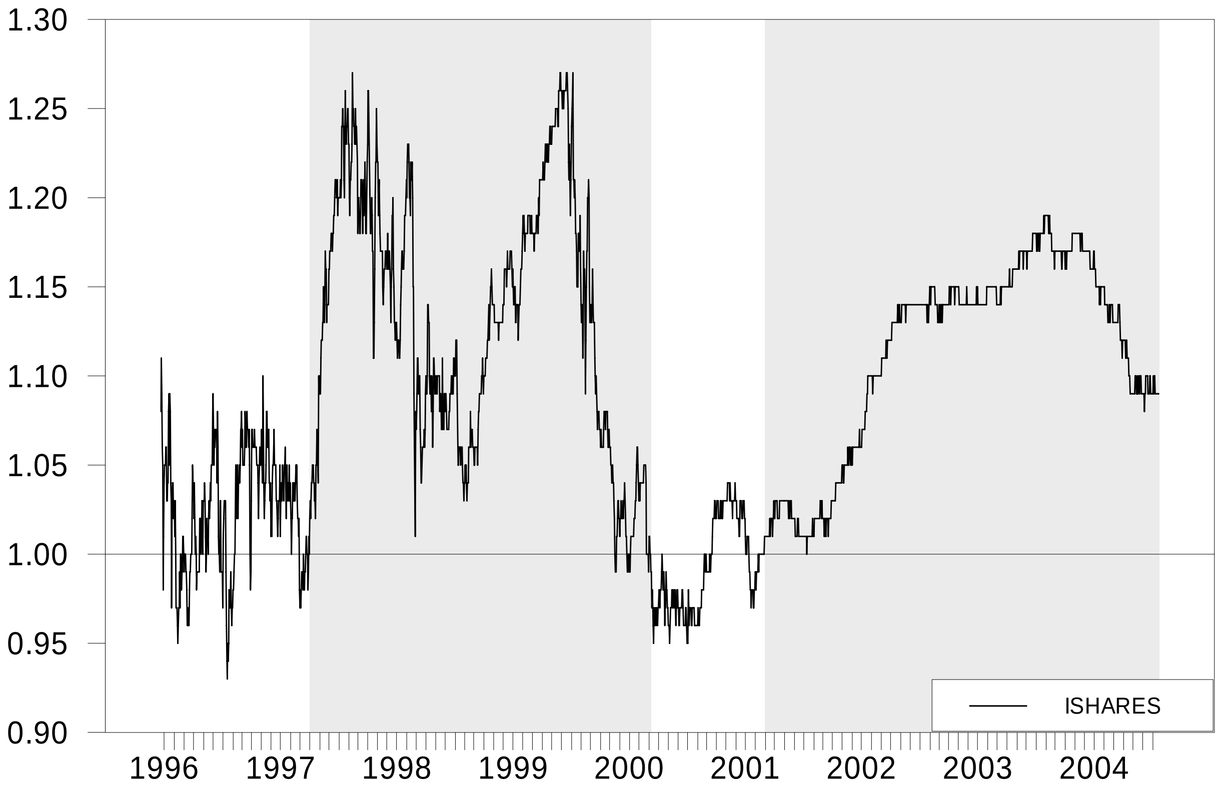
Notes: VAR Specification includes unrestricted constant and two lags.

However, this result does not provide any evidence regarding the temporal stability of the parameters of the relationship. Therefore, attention is now turned to tests that are designed to provide more information on the dynamics of the system.

6.1.2 Recursive cointegration test results

To explore the dynamics of the equilibrium relationship in further detail, this paper now turns to the multivariate recursive cointegration methodology developed by Hansen and Johansen (1999). Figure 2 presents the rescaled recursive trace statistics for the null hypothesis of no cointegration (*r*=0) for the iShares prices of the G7 markets (see Section 5.2 for details). The results are presented for the whole sample period.

Figure 2. Recursive Normalized Trace Statistic for iShares Data for the G7 Countries, 18 March 1996 to 20 January 2005



Notes: The figure shows values of the rescaled recursive trace statistic of Hansen and Johansen (1993) for H_o: r=0 (no cointegration) against H_1: r=1 (one cointegration relation in the system), rescaled by the 10 per cent critical value. The values of the statistic above one (above the horizontal line) indicate presence of a cointegration relationship.

The estimations were performed using RATS6.0 software. The initial sample period t_0 was set to three, six and twelve months and the initial sample size was increased by one observation in the recursive estimation. The estimation results remained unchanged.

Figure 2 suggests that the group dynamics are unstable; this is reflected in the large variations of the trace statistic. Based on a visual inspection of the graph, four distinct periods can be discerned; these are indicated on the graph by shading. The first period ranges from March 1996 to September 1997, characterised by the instability of the trace statistics, with the total number of cointegration relationships ranging from 3 to 1. In the second period, from October 1997 until September 2000, stabilized convergence can be discerned. The second period may, in turn, be further divided into two sub-periods: before and after September 1998. The number of cointegration relationships between October 1997 and September 1998 fluctuates between 1 and 2. This finding is not surprising given the strong performance demonstrated by all the mature markets throughout 1997 and the first part of 1998, with the peck of performance in July 1998 (IMF, 1998). Interestingly, after this period the convergence processes appears to slow down between the second half of 1998 and 1999, with the number of cointegration vectors declining to 1. This slowdown appears to reflect events that adversely affected various G7 markets to a differing extent, such as the August 1998 financial crisis in Russia, liquidation of the Long-Term Capital Management (LTCM) hedge fund in the US, and continuous deterioration of the domestic economy in Japan (IMF, 1998).

It is also worth noting that during the 1996-1998 period there were several common trends in the sample. This was the period analyzed in Olienyk *et al.* (1999) study. They discovered a number of cointegration relationships in their sample. The dynamics of the relationship, shown by the recursive cointegration test, suggest, however, that Olienyk *et al.*'s (1999) findings may have been driven by their choice of sample period.

The third period ranges from October 2000 to March 2001 and indicates a disruption to the long-run equilibrium with no cointegration relations evident. The beginning of the period coincides with a decline in equity prices, led by the technology sector; the end of the period, by a slow recovery in the major market indices (IMF, 2000, 2001). The long-run equilibrium was restored after August 2001 to January 2005 (the fourth period covering the end of our sample);

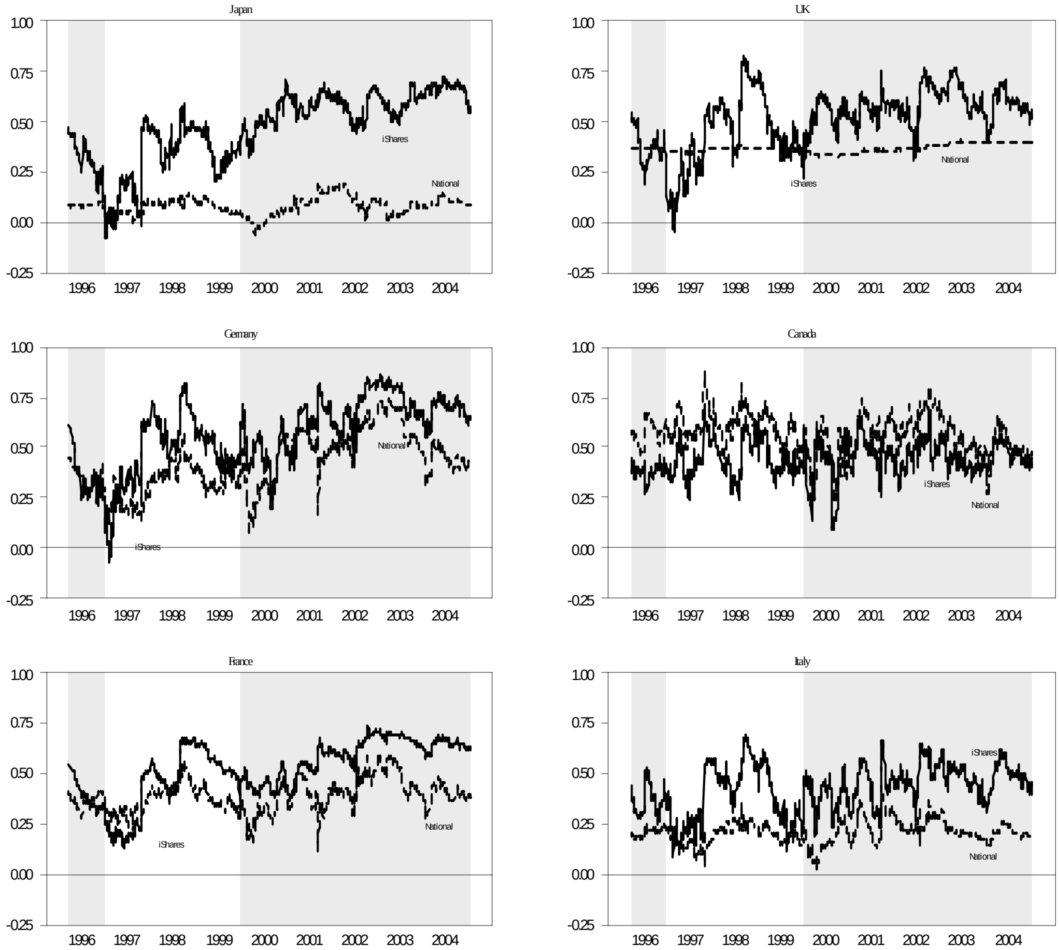
this reflects increasing convergence with the number of cointegration relationships rising back to two.

The plots based on recursive cointegration tests suggest a trend towards increasing market co-movements since 2001. In an earlier study, Rangvid (2001) analyzed dynamics of integration between the major European equity markets using quarterly data from IFS indices from 1960 to 1999 and found single cointegration relationship. Having applied Hansen and Johansen's (1999) recursive cointegration test, Rangvid (2001) also pointed to an increasing degree of European financial markets' convergence as reflected in the upward trend of recursive lambda trace statistics, though in his sample the first signs of convergence appeared in 1982.

6.1.3 Dynamic conditional correlations (DCC-GARCH) analysis results

Dynamic conditional correlations between SPDR and iShares returns, calculated as described in Section 5.3, are presented in Figure 3. The shaded areas highlight distinct regimes, which are discussed below. It can be seen that the correlations between iShares and SPDR returns tend to be higher than those for the national indices (apart from the case of Canada). These correlations also demonstrate less volatility. The impacts of the Asian (1997), LTCM and Russian (1998) financial crises, are clearly discernible in most of the graphs: during these years the conditional correlations display a clear upward trend. Although there is no pronounced upward trend in the correlations for the iShares data throughout the sample period, it becomes more marked in the last part of the sample; that is, since 2001 (except for Canada). This trend is especially strong in the data for Germany, France and Japan.

Figure 3. Dynamic Conditional Correlations: iShares and National Stock Indices Returns, 18 March 1996 to 20 January 2005



Notes: The solid line indicates dynamic conditional correlations between SPDR and iShares returns. The dashed line shows conditional correlation coefficients between DJIA returns and respective national indices returns (DAX, CAC, FTSE, TOPIX, TSE). Both sets of the dynamic conditional correlations were computed from the DCC-GARCH (1,1) specification (Engle (2002), with *t*-distributed errors. See Section 5.3 for the details of the model.

6.2 Findings using National Indices Data

6.2.1 Multivariate cointegration test results

The results of the Johansen and Juselius (1990) cointegration tests for the national indices are reported in Table 4. The VAR model specification includes a linear trend in the data and in the cointegration vector; the number of lags selected was again two.

Table 4. Johansen and Juselius (1990) Cointegration Test Results, National Indices Data, 18 March 1996 to 10 January 2005

Eigenvalue	L-max	Trace	H_0: r	p-r	L-max90%	Trace90%
0.0227	53.01	115.37	0	7	28.36	117.73
0.0078	18.10	62.36	1	6	24.63	89.37
0.0074	17.17	44.27	2	5	20.90	64.74
0.0055	12.68	27.10	3	4	17.14	43.84
0.0045	10.30	14.42	4	3	13.39	26.70
0.0016	3.72	4.12	5	2	10.60	13.31
0.0002	0.39	0.39	6	1	2.71	2.71

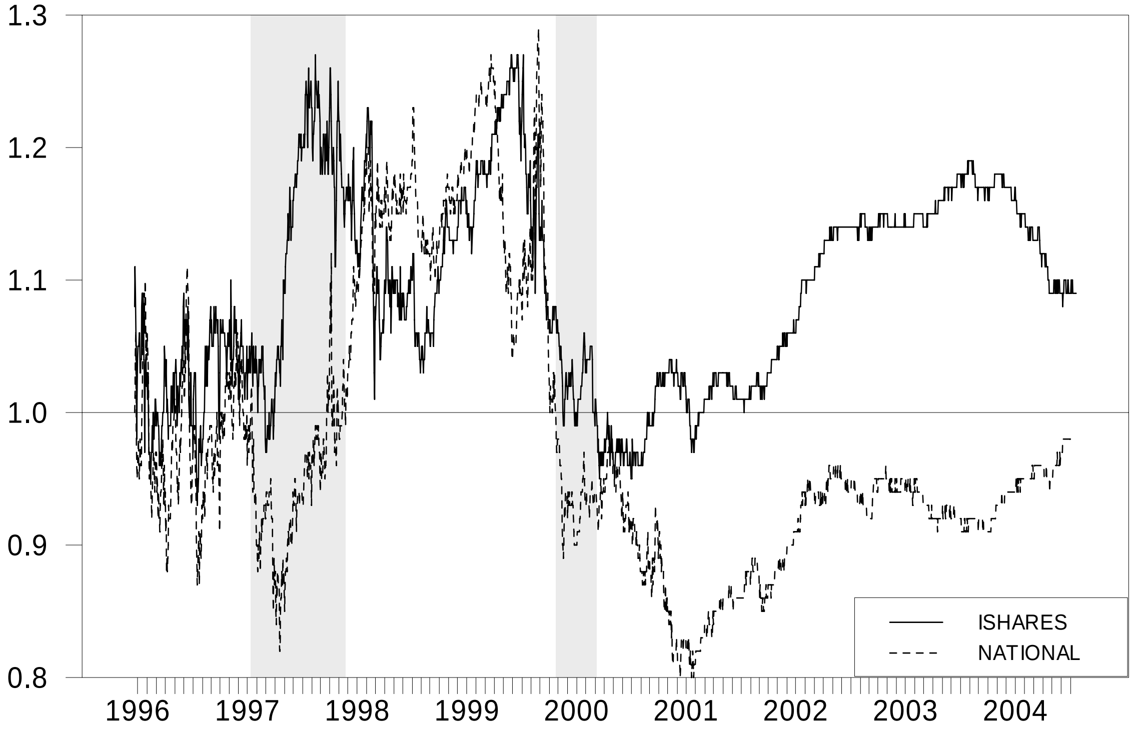
Notes: VAR Specification includes unrestricted constant and two lags.

The results in Table 4 indicate that the null hypothesis of no cointegration relationship in the system of G7 markets is rejected at the 10 per-cent level by the maximum eigenvalue test, but not by the trace test. As mentioned above, Cheung and Lai (1995) show that the trace test is more robust to excess kurtosis and skewness. It cannot, therefore, be stated that there is strong evidence in favour of the presence of long-term convergence. This finding suggests that the result of cointegration studies should be interpreted with caution, since the conclusions regarding the extent of long-run market co-movements inferred from national indices data and from data based on investable assets, such as iShares, seem to differ, at least in our sample.

6.2.2 Recursive cointegration test results

Figure 4 represent the results of Hansen and Johansen's recursive cointegration test for the national indices data (dashed line). To facilitate the comparison, the Figure also contains results of the test for the iShares data (solid line).

Figure 4. Recursive Normalized Trace Statistic for National Indices and iShares Data for the G7 Countries, 18/03/1996-20/01/2005



Notes. The figure shows values of the rescaled recursive trace statistic of Hansen and Johansen (1993) for H_0: r=0 (no cointegration) against H_1: r=1 (one cointegration relation in the system), rescaled by the 10 per cent critical value. The values of the statistic above one (above the horizontal line) indicate presence of a cointegration relationship. The dashed line shows values for the system of national indices; solid line shows the values for the system of iShares indices.

A number of interesting results follow from a visual inspection of Figure 4. Firstly, the normalized trace statistics that have been computed and that are based on the iShares and the national indices data follow similar paths. However, the values of calculated statistics based on the iShares data clearly lag those based on the national data. Secondly, statistics based on the national indices data display more variation as reflected in higher (lower) values for the maximum (minimum) statistics in several periods. Thirdly, a divergence between the two statistics occurred during the turbulent 1997-1998 period, whereas the two statistics follow each other more closely after that. Remarkably, starting from the end of the 2000 and continuing until the end of the sample, the two statistics suggest opposing results: while that based on the national indices data indicates an absence of cointegration relationships and thus indicates the presence of long-term diversification opportunities, that based on iShares data suggests that such opportunities may be limited to the presence of at least one long-run relationship in the system of G7 iShares. Finally, the periods of absence of long-run relationships, between 1997-1998 and 1999-2000 are somewhat longer in the case of national indices. This echoes earlier results by Phengpis and Swanson (2004), who find that relying on national data may overstate the actual extent of diversification benefits.

6.2.3 Dynamic conditional correlations (DCC-GARCH) analysis results

The dynamic conditional correlations, computed as described in Section 5.3, for the national data are presented on the Figure 3 (see above). A number of observations regarding the pattern of the dynamics of the short-term dependencies between the US and other developed stock markets can be inferred from it.

As noted above, several periods, which are characterized by different average conditional correlations, can be distinguished. In the first, prior to 1997, conditional correlations are found to be declining. This regime is indicated by the first shaded area on the graph. The second regime that coincides with the financial instability during 1997-1999 is characterized by a drastic increase in the value of the conditional correlations (with the exception of the correlation between the US and Canada). This finding is in line with Longin and Solnik's (1995) result; they demonstrated that co-movements between markets increase during volatile periods. Our findings also support the relevant results in Schwebach *et al.*'s (2002) study that found an increase in correlation and volatility after the Asian crisis for eleven foreign markets that included five of the G7 markets. Another peak in correlations follows in the middle of 1998. The third regime (the second shaded area) is characterized by volatile correlations, more so for some series than others. This regime, starting in the 2001, is characterized by rising conditional correlations between the ETF returns of the G7 countries.

Comparing findings for the iShares and national indices, a number of stylised facts can be noted. First, similar patterns of bivariate conditional correlations are observed for the returns of iShares and national indices, except for the correlations between the US and the UK, and between the US and Japan. Secondly, there is an upward trend, observed after 2000, in correlations for both the national indices and the iShares data. On average, conditional correlations between indices returns have increased from 0.32 before 2000 to 0.35 after 2000 and from 0.41 to 0.55 for iShares returns. Thirdly, all iShares bivariate correlations, apart from that between the US and Canada, are higher than correlations between national indices returns. This result is probably not surprising given the findings by Pennathur *et al.* (2002) and Zhong and Yang (2005) of significant risk exposure of iShares returns to US market factors. This paper does not, however, attempt to analyse the reasons behind this discrepancy. Goetzman *et al.* (2005) point to a problem of conditioning bias that arises from conditional correlations that are found to be higher than unconditional correlations due to large observations or time-varying volatility. To address this potential criticism, unconditional rolling correlation coefficients for various windows were calculated. The results are not reported here, but are available upon request. These unconditional correlations confirm this paper's two main findings: correlations computed using iShares data are significantly higher than those computed using national indices data, and correlations between iShares returns have been increasing since 2000.

From the findings above, it can be concluded, firstly, that short-term co-movements between the returns securities representative of G7 equity markets have been increasing for several years; this is in line with earlier findings from Meric and Meric (1989), Wahab and Lashagari (1993) and Longin and Solnik (1995). Secondly, the findings based on the non-investable indices tend to overestimate the extent of the diversification potential; this may have important consequences for optimal asset allocation.

7. Conclusions

This study examines the extent of long- and short-term interdependencies between the US and other G7 equity markets. Contrary to most published studies on international financial convergence that use broad stock-market indices data, this study utilizes price series from ETFS in the G7 to provide empirical evidence on the actual extent of diversification opportunities available to US-based investors. This study provides an in-depth analysis of co-movements in G7 equity markets by drawing on econometric techniques that allow the time-varying nature of short-term and long-term market relationships to be illustrated. The findings, based on ETFs data, suggest that the extent of short-term interdependencies has been increasing since 2001; this is shown in the increased conditional correlation between daily international returns. Our time-varying analysis of long-term interdependencies suggest that the evidence of cointegration or the lack thereof is sensitive to the time period chosen and, as a result, the long-term diversification benefits may vary with time. The multivariate recursive cointegration test shows an increase in the number of common equilibrium relationships since 2001; this number appears to have stabilized at two for the G7 markets. It can, therefore, be concluded that there are limited diversification opportunities available to US-based investors who invest in the ETFs of the large equity markets over the long run.

The extent to which iShares track the existing market indices may provide some evidence as to the real portfolio diversification benefits from holding these funds. When compared with the findings based on the data from national stock-market indices, there is strong evidence that the extent of short-term and long-term linkages is underestimated by the latter, at least in the case of sample used here. The results based on the analysis of the conditional correlations support earlier findings from the asset-pricing studies that iShares prices reflect information from both the US and the tracked market; they, therefore, do not represent a perfect diversification instrument. It can, hence, be suggested that relying on data for non-investable assets may overestimate the actual extent of diversification benefits available to investors in these markets.

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