Reassessing co-movements among G7 equity markets: evidence from iShares†

M. Bararia, Brian Luceyb,* and S. Voronkovab

aDept of Economics, Missouri State University, 901 South National Avenue, Springfield, Missouri 65897
bSchool of Business and Institute for International Integration Studies, Trinity College Dublin, Dublin 2, Ireland

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 equity-market co-movements and the diversification potential than national indices data that have been used by most of the existing studies in the area. Applying recent time-varying methodology for the analysis of short and long-term co-movements, we provide detailed analysis of the dynamics of the equity market linkages over the period 1996–2005. We find evidence 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. By contrast, the extent of both short-term and long-term linkages between the US and G7 equity markets is found to be much lower for national indices data. Our findings suggest that (i) the results of the earlier studies based on national stock market indices should be interpreted with caution, since use of national indices data may overestimate the extent of available diversification benefits; (ii) iShares funds do not represent perfect diversification products.

I. Introduction

Since 1970s international asset-market co-movements have been widely studied for purposes of measuring international diversifications potential (Goetzmann et al. (2005)), construction of efficient portfolios (Ang and Bekaert (2002)) and assessing capital market vulnerabilities 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 particularly relevant for the present study is the one that focuses on identifying the diversification benefits available to international investors (Longin and Solnik (1995), Goetzmann et al. (2005)).

Until middle of 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 new family of financial

*Corresponding author. E-mail: blucey@tcd.ie
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products, iShares funds, was introduced that provided investors with an easy access to a well-diversified indexed portfolio at low cost (Khorana et al. (1998)). The iShares, formerly World Equity Benchmark Shares (WEBS), are organized as exchange-traded funds (ETFs) and 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 any 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 do not significantly diverge from the underlying net asset value (NAV) of constituent shares, unlike those of closed-end country funds (CECF).1,2 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. Given low costs of managing iShares products, 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 investible assets due to high costs of maintaining equivalent portfolios and due to entry and trading barriers for foreign investors existing 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 ease of trade make them accessible to investors with varying degrees of sophistication. Finally, iShares price data are devoid of problems such as nonsynchronous 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, reflecting in part the relative novelty of these financial products. See Khorana et al. (1998), Olienyk et al. (1999), Schwebach et al. (2002), Pennathur et al. (2002), Durand and Scott (2003), Miffre (2004), Phengpis and Swanson (2004) for a selection of the few articles that have used these securities. These studies mainly focused on measuring 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 its implications for international asset allocation. Specification of long-term relationships can also be subject to a 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. First, we extend 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 relying on the most recent econometric techniques. In particular, we investigate the dynamics of the long-run relationships by using the Hansen and Johansen (1999) recursive cointegration procedure. Secondly, we use the recently developed dynamic conditional correlation specification of multivariate GARCH models by Engle (2002) (DCC-GARCH) to allow for explicit time variation in the conditional correlation matrix of iShares returns. Thirdly, we repeat all of our analyses using national indices data that are widely used in the literature in order to provide a comparison of our findings based on iShares data with that of broad based national indices. Finally, we consider a recent time period from the inception of iShares in March 1996 to January 2005. This comprises the longest time series of iShares prices analyzed in the literature so far.

Taking the US-based investor’s perspective, we measure the status of co-movements between the US and the remaining Group of Seven (G7) markets:

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1 For a review of the literature on closed-end fund discount puzzle see Dimson and Minio-Kozerski (1999).
2 Using cointegration methodology, Delcourage and Zhong (2006) documented that while many iShares may have traded at statistically significant premiums, the deviations of iShares prices from their underlying benchmark values were only transitory. A majority of iShares prices were found to be cointegrated with their NAVs as well as the corresponding MSCI country indexes thereby ruling out persistent mispricing.
Canada, France, Germany, Italy, Japan and United Kingdom. The reasons for using G7 markets are manifold. First, by using G7 markets, we cover well in excess of 60% of world equity-market capitalization (www.worldexchanges.org/). Secondly, G7 markets capture over 50% of US foreign equity holdings (US Department of Treasury (2003)). Thirdly, over 80% 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 US and the remaining G7 markets. The pattern of long-run relationships appears to be affected by 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 have stabilized after 2001. Our iShares findings in this regard present a stark contrast to the benchmark case based on national indices data which indicate lack of long-term relationships since 2000. As regards short-term comovements, there is an upward trend in conditional correlations since 2000 for both iShares and national indices data, although the increase is more pronounced for iShares data.

Overall, our findings suggest that broad national indices data typically underestimate short-term and long-term market linkages when compared to iShares data and therefore, may overestimate potential diversification benefits.

The rest of the article is structured as follows. Section II reviews recent findings in relation to equity market co-movements. Section III provides an overview of exchange-traded funds with a particular focus on Standard & Poor’s Depositary Receipts (SPDRs) and iShares. Data and methodology are described in Sections IV and V. Section VI provides empirical results and Section VII provides conclusions.

II. Literature Review

Studies of asset market co-movements: correlation and cointegration analyses of stock market indices

There is an extensive literature on the evolution of equity-market correlations and presence of common stochastic trend. 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, is strongly in favour of increased equity market co-movements (Maldonado and Saunders (1981), Meric and Meric (1989), Longin and Solnik (1995)). This finding is associated with increasing real economic linkages between countries (Roll (1992), Arshanapalli and Doukas (1993), Bachman et al (1996), Bracker and Koch (1999), Bracker et al (1999), Johnson and Soenen (2003), Campbell and Diebold (2005)).


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 by Longin and Solnik (1995) who use correlation and covariance matrix estimates. Rangvid (2001), Rangvid and Sorensen (2002) 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

3 However, the analysis performed in Kasa (1992) is subject to criticism by Richards (1995) due to potential small sample bias.
impact that this increased integration would have for portfolio diversification.

However, this finding of increased and strong integration is not unanimous. Chou et al. (1994) finds no evidence of cointegration for the G7 countries. 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. We note however, that the purpose of this article is assessing the extent of co-movements rather than measuring stock market integration. We focus on the former issue without making inferences with regard to the latter one. See Buele et al. (2004) for a discussion of the definitions of integration and co-movements.

**International diversification and long-run relationships between equity markets: evidence from ETFs**

The first evidence on the performance and indexing efficiency of World Equity Benchmark Securities (WEBS) is provided by Khorana et al. (1998). Over the six-month period following the introduction of WEBS between April 1996 and October 1996, Khorana et al. find that WEBS to closely track the underlying MSCI country index and exhibit low correlations with S&P500, thereby suggesting useful diversification opportunities. Olienyk et al. (1999) test for cointegration and Granger causality between SPDR, 17 WEBS and 12 respective country funds during 1996–1998. The authors find that most of the 17 WEBS and the US SPDR are pairwise cointegrated with each other for this time period. In addition, substantial cointegration also exist between individual closed-end country funds and their respective own country WEBS. Furthermore 13 of the 17 WEBS are found to Granger-cause the SPDR. Thus Olienyk et al.’s findings suggest that it is possible to earn short-run arbitrage profits using WEBS and SPDRS, though 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 et al. (2002), Schwebach et al. (2002), Durand and Scott (2003), Miffre (2004). Pennathur et al. (2002) apply single and two-factor asset-pricing models to the iShares prices for the 1996 to 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 (2006) arrive at a similar conclusion using a three-factor model. Similar results are reported by Durand and Scott (2003) for Australian iShares. Durand and Scott 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, Miffre (2004) demonstrates that iShares appear to offer a diversification potential superior to that of investment in US securities only. Relying on the analysis of optimal portfolios constructed on the basis of Sharpe ratios, the article argues that a typical investor would benefit from investing on average half of her wealth in the S&EP500 and the rest in iShares of developed non-US markets (Spain, Italy, the UK, Sweden, Canada and France). 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 the optimal asset allocation.

In a related article, Schwebach et al. (2002) draw attention to the impact of increased volatility on the efficacy of diversification. They evaluate 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 have changed drastically after the Asian crisis, the latter being reflected in increased correlations. As suggested by the results of the correlation analysis, WEBS offer better diversification opportunities after the Asian crisis than CECF.

Phengpis and Swanson (2004) 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 data (as opposed to iShares data) to evaluate diversification gains may overstate the actual benefits and, moreover, including long-term information as an additional input to portfolio construction can improve diversification benefits.
The article by Olienyk et al. (1999) is the starting point of the present study. We extend their pairwise cointegration study to investigate the existence of multivariate cointegration relationships between the G7 markets. Subsequently, we focus on the time-varying dynamics of both long-term and short-term cointegration relationship by using the recursive cointegration procedure of Hansen and Johansen (1999), and the dynamic conditional correlation GARCH (DCC-GARCH) model of Engle (2000) respectively. The resulting graphs present a detailed pattern of the time-varying nature of equity-market linkages.

III. 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 thus gaining an exposure to segments or entire domestic or foreign markets with relative ease. Buying on margin and short selling (even on a downtick) are allowed, enhancing liquidity. In the secondary market ETFs are traded intra-daily, like 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 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 (2004b)) and tax-efficiency (Poterba and Shoven (2002), Gastineau (2004a)). The typical expense ratios on an ETF range between 0.35 and 0.50%, which compares favourably with 0.73% 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 in 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, maintaining equity exposure during manager transition etc (Chamberlain and Jordan (2004)). The disadvantages of the ETFs lie in the risk of offsetting potential gains by brokerage commissions paid on every trade, and sensitivity of the ETF’s price to a price of a single security due to the possibility of high portfolio concentration of particular ETFs (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 a 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, VIPERs that are traded on AMEX, NYSE and CBOE (Gastineau (2002) and Chamberlain and Jordan (2004), Ross (2005)). In December 2004 the combined assets of US exchange-traded funds amounted to $226 billion, having increased by almost 50% over the previous year. Among them, assets of International Equity Funds surged by almost 140% during the last year, from $13.9 billion to $33.6 billion (http://www.ici.org/). Two different types of ETFs, namely SPDRs and iShares, are analyzed in the present study and hence discussed below.

SPDRs

SPDRs were launched by State Street Global Advisors in 1993. SPDRs are exchange-traded funds that aim to track the performance of various Standard & Poor’s indices. 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 of the S&P500 index (www.amex.com). SPDRs are the largest ETFs. As of 2004 they have attracted almost $56 billion of assets and their average daily trading amounts to $5 billion (Ross (2005)).

iShares

iShares, initially known as WEBS, 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

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4 For a brief review of the history of ETFs’ antecedents (portfolio trading, IPS, TIPS, Supershares) see Gastineau (2002).
5 For information about non-US ETFs see Fuhr (2001).
investors with access to markets that otherwise would have remained beyond their reach. Accounting for 42% of the ETF market, iShares belong to one of the most popular ETFs today (Ross (2005)). As of 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% (60%) of their assets in the securities from the underlying index and American Depository Receipts (Chamberlain and Jordan (2004)).

IV. 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 the UK, Germany, France, Italy, Japan and Canada. We concentrated on the iShares covering G7 countries as these represent the largest equity markets, covering in excess of 60% of market capitalization of all world markets over the period (www.world-exchanges.org/). We also use data on representative national stock market indices for the G7 countries for the same period. These are the CAC40 (France), the TSX (Canada), the DAX (Germany), the Nikkei225 (Japan), the FTSE100 (UK), COMIT (Italy) and the DJIA (USA). The sample period spans almost 10 years, from 18th March 1996 to 20th January 2005 and includes 2309 observations. The entire dataset is obtained from DataStream. The beginning of the sample period coincides with the start date of trading of iShares, then WEBS. It is thus the longest time series of iShares prices analyzed in the literature so far. Such a long dataset is especially suitable for applying cointegration analysis to characterize the long-term dependencies between the markets.

We present 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. Descriptive statistics are qualitatively similar for
national indices and ETFs. With the exception of Japan, even allowing for the bear market of the early 2000s, all securities displayed a positive return. Both national indices and iShares’ returns are leptokurtic for all G7 countries and mostly negatively skewed, except for Japan.

Prior to testing for the presence of cointegration, price series data were checked for nonstationarity 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 nonstationary in levels and stationary in differences.6

V. Methodology

Multivariate cointegration tests

Multivariate cointegration tests suggested by Johansen and developed in Johansen and Juselius 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 nonstationary variables. Two tests have been suggested: the trace test and the maximum eigenvalue tests. Due to the extreme popularity of these tests we limit ourselves to a brief description. The trace statistics which tests the null hypothesis of $r$ cointegration relationships against the hypothesis of $n$ cointegration relationships are given by

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

(1)

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

$$|\lambda S_{hk} - S_{hh} S_{00}^{-1} S_{0k}| = 0$$

(2)

The maximum eigenvalue test tests 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:

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

(3)

Critical values for the two tests have been tabulated by Osterwald-Lenum (1992). Monte Carlo experiments reported by Cheung and Lai (1995) suggest that the trace statistic is more robust to skewness and

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Table 2. Descriptive statistics for SPDR and iShares returns, 18 March 1996 to 20 January 2005

<table>
<thead>
<tr>
<th></th>
<th>TSX</th>
<th>CAC40</th>
<th>DAX</th>
<th>COMIT</th>
<th>NIKKEI225</th>
<th>FTSE100</th>
<th>DJIA</th>
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<tbody>
<tr>
<td>Panel A: National indices</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.00031</td>
<td>0.00029</td>
<td>0.00022</td>
<td>0.00042</td>
<td>−0.00024</td>
<td>0.00020</td>
<td>0.00026</td>
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<tr>
<td>Maximum</td>
<td>0.05</td>
<td>0.06</td>
<td>0.07</td>
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<td>0.06</td>
<td>0.06</td>
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<tr>
<td>Minimum</td>
<td>−0.09</td>
<td>−0.07</td>
<td>−0.08</td>
<td>−0.08</td>
<td>−0.08</td>
<td>−0.05</td>
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<tr>
<td>SD</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
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<tr>
<td>Skewness</td>
<td>−0.76</td>
<td>−0.13</td>
<td>−0.16</td>
<td>−0.38</td>
<td>0.26</td>
<td>−0.13</td>
<td>−0.21</td>
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<tr>
<td>Kurtosis</td>
<td>8.26</td>
<td>5.01</td>
<td>5.06</td>
<td>5.79</td>
<td>5.89</td>
<td>5.07</td>
<td>3.87</td>
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<tr>
<td>Jarque-Bera</td>
<td>2884.09</td>
<td>393.77</td>
<td>417.30</td>
<td>803.05</td>
<td>830.69</td>
<td>417.21</td>
<td>1458.27</td>
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<tr>
<td>Prob. (Jarque-Bera)</td>
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<td>0.00</td>
<td>0.00</td>
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<td>Panel B: iShares and SPDR</td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>Mean</td>
<td>0.00031</td>
<td>0.00025</td>
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<td>0.00026</td>
<td>−0.00016</td>
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<td>Maximum</td>
<td>0.056</td>
<td>0.065</td>
<td>0.084</td>
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<td>0.065</td>
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<tr>
<td>Minimum</td>
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<td>−0.090</td>
<td>−0.111</td>
<td>−0.093</td>
<td>−0.069</td>
<td>−0.075</td>
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<tr>
<td>SD</td>
<td>0.014</td>
<td>0.015</td>
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<td>0.016</td>
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<tr>
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<td>−0.160</td>
<td>−0.265</td>
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<td>Kurtosis</td>
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<td>5.117</td>
<td>6.358</td>
<td>6.076</td>
<td>6.554</td>
<td>5.822</td>
<td>4.851</td>
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<tr>
<td>Jarque-Bera</td>
<td>845.988</td>
<td>440.90</td>
<td>1111.35</td>
<td>953.26</td>
<td>1273.12</td>
<td>767.64</td>
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<td>0.00</td>
<td>0.00</td>
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</tbody>
</table>

Note: Table shows the descriptive statistics for iShares (panel b) and respective national indices (panel a) of the G7 countries.

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6 The critical values are from MacKinnon (1994). For brevity tables are not reported here, but they are available upon request.
excess kurtosis (in the residuals) than the maximum eigenvalue test. Therefore when interpreting results we give more weight to the outcomes of the former test.

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 test statistic results 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 the 90% of the asymptotic distribution for a model without exogenous variables or dummies. Rescaled values above one indicate against the null hypothesis of no cointegration. An upward trend indicates an increased extent of co-movements while a downward trend indicates decreased extent of co-movements.

Dynamic conditional correlations GARCH (DCC-GARCH)

Earlier studies of international correlations relied on the analysis of simple correlation coefficients (see for example Panton and Lessig (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 article makes a step forward and suggests to analyze time-varying conditional correlation between international stock markets by utilizing the recent methodology proposed by Engle (2002), namely 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 \( H_t \):

\[
r_t | F_{t-1} \sim N(0, H_t)
\]

\[
H_t \equiv D_t R_t D_t
\]

where \( D_t \) is a \( k \times k \) matrix of time varying SDs from univariate GARCH models with \( \sqrt{h_{it}} \) on the \( i \)th diagonal, following a univariate GARCH model. The proposed dynamic correlation structure is:

\[
R_t = (Q_t^2)^{-1} Q_t (Q_t^2)^{-1}
\]

where \( Q_t \) is a diagonal composed of the square root of the diagonal elements of the \( Q_t \) and \( Q_t \), follows a GARCH type of process:

\[
Q_t = (1 - \sum_{m=1}^{M} \alpha_m - \sum_{n=1}^{N} \beta_n) \tilde{Q} + \sum_{m=1}^{M} \alpha_m (e_t^\prime e_t) + \sum_{n=1}^{N} \beta_n Q_{t-n}
\]

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

We use a parsimonious approach, modelling data as a DCC-GARCH (1,1) process, within a bivariate system of each of the other G7 iShare returns vs. the US SPDR. 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

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7 Brada et al. (2005) have recently applied a rolling version of the Johansen and Juselius cointegration test for analysis of the real and monetary convergence in the EU.

8 In a related article, Barari and Sengupta (2002a, b) analyzed the time varying nature of cointegration using a group of nine emerging markets by proposing two windowing strategies – global and local plots. While global plots are conceptually analogous to recursive cointegration procedure mentioned above, local plots pertain to a rolling time period and hence capture short-run fluctuations.
VI. Empirical Findings

Findings using iShares data

Multivariate cointegration test results. We first use Johansen and Juselius cointegration tests to obtain preliminary evidence on the presence of cointegration relationships in the system of G7 markets. We report results for the VAR specification with a linear trend in the data and in a cointegrating vector (Table 3). The lag length was chosen by AIC to be two. These cointegration tests provide evidence in favour of at least one cointegration relationship between the iShares prices of the G7 markets over the total sample period, between March 1996 and January 2005.

However, this result does not provide any evidence regarding the temporal stability of the parameters of the relationship. We thus turn our attention to tests designed to provide more information about the dynamics of the system.

Recursive cointegration test results

To explore the dynamics of the equilibrium relationship in further detail, we turn to the multivariate recursive cointegration methodology by Hansen and Johansen (1999). Figure 1 presents the rescaled recursive trace statistics for the null hypothesis of no cointegration \( (r=0) \) for the iShares prices of the G7 markets plus the US SPDR (see section Recursive cointegration tests, for details). The results are presented for the whole sample period.

Figure 1 suggests that there is instability in the group dynamics, reflected in large variations of the trace statistic. Based on visual inspection of the graph, four distinct periods can be separated out, and these are indicated on the graph by shading. The first period ranges from March 1996 to September 1997, characterized by the instability of the trace statistics. In the second period, from October 1997 to September 2000, we notice stabilized convergence. The second period in turn may be further divided into two sub-periods, before and after September 1998. This finding is not surprising given a strong performance demonstrated by all the mature markets throughout 1997 and the first part of 1998, with the peak of performance in July 1998 (IMF (1998)). Interestingly, after this period the convergence processes appears to slowdown between the second half of 1998 and 1999. 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 noteworthy that during the period of 1996–1998 there were several common trends in the sample and this was the period analyzed in Olienyk et al. (1999) study that discovered a number of...
cointegration relations in their sample. The dynamics of the relationship, showed by the recursive cointegration test, suggests however that Olienyk et al. (1999) findings may have been driven by their choice of the 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 of 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).

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

Dynamic conditional correlations (DCC-GARCH) analysis results

Dynamic conditional correlations between US SPDR and remaining G7 iShares returns, calculated as described in section ‘Dynamic conditional correlations (DCC-GARCH)’, are presented in Fig. 2. Several periods characterized by different average conditional correlations can be distinguished. In the first regime, 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 (1995) result demonstrating that co-movements between markets increase during volatile periods. Our findings also support the relevant results in Schwebach et al. (2002) study.

Note: 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% critical value. The values of the statistic above one (above the horizontal line) indicate presence of a cointegration relationship.

All the calculations were repeated using weekly price data, to avoid possible bias due to nonoverlapping trading hours. The results, available from the authors upon request, remain qualitatively the same. However, it should be pointed out that using lower frequency data may result in loss of a part of information and even potential loss of estimation efficiency (Schotman and Zalevska (2006)).
that found increase in correlation and volatility after the Asian crisis for 11 foreign markets that included five of the G7 markets. Another peak in correlations follows in the mid of 1998. The third regime (the second shaded area) is characterized by volatile correlations, more so for some series than others. 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, except for the case of Canada. This regime, starting in the year 2001, is characterized by rising conditional correlations between the ETF returns of the G7 countries and is especially strong in case of Germany, France and Japan.

Findings using national indices data

Multivariate cointegration test results. The results of the Johansen and Juselius 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.

The results in Table 4 indicate that the null hypothesis of no cointegration relationship in the system of G7 market is rejected at a 10% level by the maximum eigenvalue test but not by the trace test. As was mentioned above, Cheung and Lai (1995) show that the trace test is more robust to excess kurtosis and skewness. We therefore cannot state that there is strong evidence in favour of the presence of the 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 the national indices data and data based on investible assets, such as iShares, seem to differ, at least in our sample.

Recursive cointegration test results

Figure 3 represent the results of the recursive cointegration test of Hansen and Johansen 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).

A number of interesting results follow from visual inspection of Fig. 3. First, the normalized trace statistics computed based on the iShares and the national indices data follow a similar path only for the first part of the sample period. However, the values of statistics calculated based on the iShares data generally 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 periods of 1997–1998, whereas the two statistics follow each other more closely in the aftermath. Remarkably, starting with the end of the year 2000 and continuing until the end of the sample the two statistics suggest opposing results: while that based on national indices data indicates an absence of cointegration relationships and thus indicates presence of long-term diversification opportunities, that which is based on iShares data suggest that such opportunities may be limited due 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 also find that relying on national indices data may overstate the actual extent of diversification benefits.

### Dynamic conditional correlations (DCC-GARCH) analysis results

The dynamic conditional correlations, computed as described in section ‘Dynamic conditional correlations GARCH (DCC-GARCH)’, for the national data are also presented in Fig. 2 (see above) discussed earlier. 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.

Comparing findings for the iShares and national indices, we note a number of stylized facts. First, similar patterns of bivariate conditional correlations are observed for the returns of iShares and national indices, except for correlations between the US and the UK, and the US and Japan. Secondly, there is an upward trend in correlations for both national indices and iShares data, observed after 2000. On average, conditional correlations between indices returns have

<table>
<thead>
<tr>
<th>$\lambda$-max</th>
<th>Trace</th>
<th>$H_0$: $r$</th>
<th>$H_0$: $p - r$</th>
<th>L-max</th>
<th>Trace</th>
</tr>
</thead>
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<td>28.36</td>
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</tr>
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<td>62.36</td>
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<td>6</td>
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<tr>
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<td>44.27</td>
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<td>5</td>
<td>20.90</td>
<td>64.74</td>
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<td>4</td>
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<td>1</td>
<td>2.71</td>
<td>2.71</td>
</tr>
</tbody>
</table>

Notes: VAR specification includes unrestricted constant and two lags. Column 1 shows the $\lambda$-max statistic and column 2 the trace statistic of Johansen and Juselius (1990). Columns 3 and 4 show the null hypotheses for the number of cointegrating vectors and the number of common stochastic trends and Columns 5 and 6 the 90% critical values for these hypotheses.
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 (2006) of significant risk exposure of iShares returns to the US market factors.12

From the findings above we can conclude that first, short-term co-movements between the US and the remaining G7 equity markets have been increasing during the last several years using both iShares and national indices data, which is in line with the earlier findings of Meric and Meric (1989), Wahab and Lashagari (1993) and Longin and Solnik (1995). Secondly, higher conditional correlations using iShares data suggest that findings based on non-investable national indices data should be interpreted with caution, as they may overestimate the extent of the diversification potential and thus may have important consequences for optimal asset allocation.

VII. Conclusions

Our study examines the extent of long and short-term interdependencies between the US and other G7 equity markets. Contrary to most of the published studies of international financial convergence that use broad stock market indices data, our study utilizes price series of G7 ETFs and US SPDR to provide empirical evidence on the actual extent of diversification opportunities available to US-based investors. Our study provides an in-depth analysis of G7 equity markets co-movements by drawing on econometric techniques that allow illustrating the time-varying nature of short-term and long-term market relationships. Our findings based on the ETFs data suggest that the extent of short-term interdependencies has been increasing since 2001, as reflected in the increased conditional correlation between daily international returns. Our time-varying analysis of long-term interdependencies suggests 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. We thus conclude that there are limited diversification opportunities available to US-based investors interested in investing 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 findings based on national stock market indices data, we find strong evidence that the extent of short-term and long-term linkages is underestimated by the latter, at least in case of our sample. Our results based on the analysis of conditional correlations lend support to the earlier findings by the asset-pricing studies that iShares prices reflect information from both the US and tracked market and therefore do not represent a perfect diversification instrument. This allows us to suggest that relying on the data for non-investable assets may overestimate the actual extent of diversification benefits available to investors in these markets.

References


12Goetzman et al. (2005) point to a problem of conditioning bias in finding conditional correlations to be higher than unconditional correlations due to large observations or time-varying volatility. To address this potential criticism, we also calculate unconditional rolling correlation coefficients for various windows. The results are not reported here, but are available upon request. These unconditional correlations confirm our 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 after 2000.


Reassessing co-movements among G7 equity markets


