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ARE DAILY STOCK PRICE INDICES IN THE MAJOR EUROPEAN EQUITY MARKETS COINTEGRATED? TESTS AND EVIDENCE

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Abstract

This study investigates short-run and long-run linkages among major West European equity markets in London (FTSE100), Frankfurt (DAX30), and Paris (CAC40). Long-run market co-movements of the three price indices are detected employing cointegration and vector error correction methodology. Empirical results of this study support the presence of one cointegrating vector and two common trends. CAC index is found to be weakly exogenous. The short-run dynamics indicate short-run causal links running both ways between FTSE and DAX.

I. Introduction

An understanding of the stochastic trends in the major equity markets is important for investors, portfolio managers, policy makers, for pricing derivatives and hedging portfolio risks. Cointegration analysis detects common stochastic trends in the price series and is useful for long-term investment analysis. Traditional money managers depended on correlation analysis of returns. Correlation analysis is conducted after differencing the original price series. Such differencing, while makes the series stationary, removes important long term information from the series. Granger and Hallman (1991) showed that as asset returns have short memory processes, investment decisions exclusively based on short-run asset returns is insufficient because the long-run relationship of asset prices is ignored. Further, correlation based hedging strategies require frequent rebalancing of portfolios whereas strictly cointegration based hedging does not require rebalancing.

Lucas (1997) and Alexander (1999) illustrate applications of cointegration analysis to portfolio asset allocation and trading strategies, such as, index tracking and arbitrage. Index tracking and portfolio optimization based on cointegration rather than correlation alone may result in higher asset returns.

Further, knowledge about the relationships among different national stock indices and asset returns is critical in designing and managing internationally diversified portfolios. The portfolio manager can determine country weights in an international equity portfolio and use cointegration analysis in selecting a basket of stocks from several markets in different countries that are cointegrated with the world index such as MSCI (Morgan Stanley Capital International) (Alexander 2001).

Duan and Pliska (1998) developed a theory of option valuation with cointegrated asset prices. Their Monte Carlo simulation results show that cointegration methodology can have a substantial influence on spread option price volatilities. Moreover, transmission of price movements in international equity markets is important for economic policy makers, especially during periods of high volatility. Appropriate policy action may be designed to mitigate the magnitude of financial crises. Thus studying stochastic trends in international equity markets is important. While correlation analysis is appropriate for short-term investment decisions, cointegration based strategies are

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required for long-term investment. Thus, cointegration technique complements correlation analysis.

This paper investigates the long-run equilibrium relationship among the three largest European equity markets: London, Frankfurt, and Paris, from late 1990 to mid-2002. Earlier studies focused on one or more of these markets and their linkages with the US and other equity markets (see literature survey in section II below) but did not exclusively examine the long-run relationship among these three equity markets. As such, we do not have any information, empirical or otherwise, regarding the relationship of these three major markets during the time period mentioned. This and significant institutional changes in Europe (specially the emergence of the Euro) during this time prompted us to undertake this research.

Our results obtained from the cointegration and error-correction methodology indicate that the price indices of the three markets are cointegrated, and that the CAC index is weakly exogenous during the sample period examined. Further, the burden of adjustment to restore equilibrium, following a shock, falls on DAX and FTSE indices. DAX and FTSE indices are found to be mutually causal.

The study is organized as follows. A brief survey of the literature is provided in section II. Information on sample period, data, frequency, and sources, including key descriptive statistics of the three equity markets is provided in Section III. Section IV gives an outline of the VAR model. Empirical results and inferences are provided in Section V, followed by some concluding remarks in Section VI.

II. Literature Survey

A large volume of empirical literature exists about correlations and volatility between international stock price indices and related aspects of stock market dynamics. The more recent empirical studies have employed time series econometric models to examine the short-run and long-run relationships of stock price indices worldwide. This literature can be classified into two groups. One focused on testing whether stock prices and returns of international stock markets share common time varying volatility structure, and also how shocks to price indices from one market are transmitted to other stock markets. A second group of studies can be sub-divided into two branches. The focus of the studies in the first branch of the second group is the short-run causal and lead-lag relationships between equity indices on world exchanges, and the work of the second branch is centered on the long-term equilibrium relationship and dynamic causal linkages among equity price indices and asset returns across nations. The long-run equilibrium studies mainly tested whether or not stock prices of different national markets share common stochastic trends. Studies in the second group have used temporal causality tests, bivariate or multivariate cointegration and error correction techniques proposed by Engle and Granger (1987) or the methodology of Johansen and Juselius (JJ, 1990) in testing the relationship between equity price indices of different stock markets. Our study follows this spirit and employs JJ cointegration and vector error correction (VEC) methodology to study the long-run relationship of the three major European equity market price indices.

Studies of correlations and pair-wise Granger causality tests to identify lead-lag relation of equity price indices in different countries include Granger and Morgenstern (1970) that used spectral analysis on weekly stock closing price data and reported very little or no relationship between stock markets around the world except for the U.S.-Holland, and Germany-Holland markets. In addition, Agmon (1972) found no significant lead-lag relation among the stock price indices of the U.K., U.S., and Germany using monthly data. Malliaris and Urrita (1992) conducted bivariate causality tests to find lead-lag relationships among six major world markets before and immediately following the October 1987 market crash. Their study reported no lead-lag relationship for the pre- or post-crash period. In contrast the study by Hilliard (1979), using daily closing prices of ten equity markets, reported close relationship among the ten markets. These studies did not employ multivariate cointegration methodology because cointegration between price indices is not a necessary condition for short-run temporal causation, although it is a sufficient condition.

Taylor and Tonks (TT, 1989) used monthly sterling deflated stock price indices from 1973 to mid-1986 and applied the two-step Engle-Granger (1987) cointegration technique to test whether the abandonment of U.K. exchange rate controls signaled any change in the long-run relationship of the U.K. stock market with markets in the U.S., Japan, the Netherlands, and Germany. Their study reported one cointegrating relationship between the U.K. market and each of the five markets. TT argued that the existence of cointegration implied a violation of the market efficiency. However, Fraser and Oyefeso (2005) suggest that the evidence of cointegration need not necessarily imply market inefficiency. In their view, if fundamentals in these markets are cointegrated their prices will also be cointegrated. Byers and Peel (1993) examined the interdependence of the same equity market price indices (1979–1989) used in TT and employed cointegration methodology to find no cointegration either for the group of five countries or for the pairs of markets.

Kasa (1992) reported one cointegrating relationship between the U.S. market and four European markets. Likewise, Corhay et al (1993) found evidence of cointegration among most European markets during 1970s and 1980s. Roca (1999), Roca et al (1998) investigated the co-movement of price indices of eight countries using weekly prices and found no cointegration between Australia, and the other seven markets. The Granger causality test indicated that Australia is significantly linked with the U.K. and the U.S. (cointegration is not necessary for short-run Granger causation). Dickinson (2000) reported cointegration of European stock markets only after the 1987 stock market crash, but not before 1987. The study by Chan et al (1997) did not find any evidence of cointegration among several European stock markets and also among those countries that are members of the European Economic Commission (EEC) particularly after the1987 stock market crash.

Gerritis and Yuce (1999) found that the long-run relationship among major European markets has weakened during 1990–1994. Pynnonen and Knif (1998) reported negligible interaction between two Scandinavian stock markets, but Knif and Pynnonen (1999) documented some positive evidence of cointegration in the relatively small European stock markets. Syriopoulos (2003) examined the emerging central European stock markets, Poland, Czech Republic, Hungary, and Slovakia, and their relationship with the U.S. and German markets. Empirical findings of the study support the presence of one cointegrating vector among these markets. However, in the bivariate context, individual central European countries displayed stronger linkages with Germany and the U.S. markets rather than their neighboring markets.

Chan et al (1992) used Engle-Granger methodology to examine Asian stock markets and reported no cointegration. However, in their 1997 study Chan et al, using a longer sample period and eighteen countries, tested for the weak-form market efficiency. Since each of the monthly stock price series has a unit root, they reported that each market is individually efficient, and only a small number of, not all, markets showed cointegration. Corhay et al (1995) reported evidence of one cointegrating vector among five major Pacific-Basin markets. However, the study by Pan et al (1999) did not find evidence of cointegration among the same countries examined by the Corhay study, namely, Australia, Hong Kong, Japan, Malaysia, and Singapore.

The studies reviewed above reported contradictory as well as ambiguous results regarding the world-wide integration of stock markets. Likewise, evidence of cointegration of European stock markets appears mixed, too. For this reason, we believe that further investigation of the behavior of stock price indices in the three largest stock markets is warranted and worthwhile.

III. Sample Data and Descriptive Statistics

The sample consists of daily closing index prices of FTSE 100, DAX, and CAC40 from November 26th, 1990 through June 3rd, 2002. The daily closing price data of the three indices are obtained from (www.finance.yahoo.com). This is a secondary source of data. Information on the indices is obtained from TradingLab investment firm of the UK. (www.tradinglab.co.uk).

FTSE100 index includes the 100 stocks selected on the basis of capitalization representing approximately 80% of the U.K. market, and the amount of freely-negotiated shares. CAC40 includes the 40 most significant stocks in terms of liquidity, and are selected in a way to represent the various sectors according to the weight that they assume within the French economy. DAX30 includes the top 30 stocks with reference to capitalization and trading volume. FTSE100 and CAC40 are value-weighted indices and dividends are not included, whereas DAX30 index includes dividends. DAX30 index is referred to as 'performance index', while FTSE and CAC are 'price indices'. The composition of the indices

TABLE 1a. Daily closing price indices in natural logs

	LDAX30	LFTSE100	LCAC40
Mean	8.040939	8.302140	7.949377
Std. Dev.	0.526631	0.341168	0.440641
Skewness	0.139499	-0.069638	0.485392
Kurtosis	1.538295	1.610785	1.759090
Jarque-Bera(JB)	277.3565	244.1519	310.9053
Probability	0.000000	0.000000	0.000000

and the adjustment of weights due to variation of capitalization (due to corporate actions) of the market is carried out periodically, generally, 2, 6, or 12 months. Following different types of corporate actions, such as, stock-splits, mergers and acquisitions, and changes arising outside of corporation's events, the indices are corrected to neutralize the distorting effects of these events on the value of the index.

Consistent with earlier studies, we implicitly assume that dividends are not critical to our analysis. The basis for this assumption is that, in general, dividends do not exhibit the level of volatility that would be required to impact on the null hypothesis of 'no cointegration', among a set of stock price indices (see Dwayer and Wallace 1992)

We did not transform the three indices into a common currency as many of the earlier studies had done. Instead we use the nominal indices in domestic currency to avoid the problem associated with transformation due to fluctuations in cross-country exchange rates and also to avoid the restrictive assumption that relative purchasing power parity holds (see Kasa, 1992, 114). Alexander and Thillainathan (1995) had examined the Asian-Pacific equity markets and reported evidence of cointegration, but only when the indices were expressed in local currency and not in common currency.

TABLE 1b. Correlation matrix of daily closing price indices in logs

	LDAX	LFTSE	LCAC
LDAX	1		
LFTSE	0.9701	1	
LCAC	0.9674	0.9296	1

Alexander (2001) suggests that cointegration between equity markets should be examined using local currency indices.

The first four sample moments of the daily closing price indices in logs, daily returns in log first differences multiplied by 100, the contemporaneous correlations of price indices and daily returns in the three stock markets are reported in Tables 1a, 1b, 2a and 2b.

The averages of the indices are pretty close, although the DAX series exhibited slightly higher standard deviation relative to CAC and FTSE indices. The price indices CAC and DAX are positively skewed while the FTSE index is negatively skewed. None of the price series exhibited excess kurtosis. The daily closing stock price indices exhibited strong positive correlation during the sample period.

The Jarque-Bera (1987) test, an asymptotic test

TABLE 2a. Daily returns: DAX, FTSE, and CAC

	ΔLDAX	ΔLFTSE	ΔLCAC
Mean	0.0275	0.0214	0.0239
Std. Dev.	1.4289	1.05588	1.3827
Skewness	–0.2788	–0.1117	–0.1227
Kurtosis	7.1208	5.7518	5.5815
Excess Kurtosis*	4.1208	2.7518	2.5815
Jarque-Bera	2165.130	954.4010	841.9260
Probability	0.0000	0.0000	0.0000

* Excess kurtosis is (kurtosis- 3).

TABLE 2b. Correlation matrix of average daily returns on the three indices

	ΔLDAX	ΔLFTSE	ΔLCAC
ΔLDAX	1		
ΔLFTSE	–0.0625	1	
ΔLCAC	0.0971	–0.0192	1

of normality, indicates that none of the price indices is normally distributed. The test statistic is computed as $\frac{n}{6}[S^2 + \frac{(K-3)^2}{4}]$ where, S is skewness, and K is kurtosis. It has a χ^2 distribution with 2 degrees of freedom. For a normally distributed variable, skewness is zero and $K - 3 = 0$ so that the test statistic is zero. At 5% level of significance we reject the null of normal distribution if the test statistic is ≥ 5.9914.

During the sample period, DAX index has the highest average rate of return followed by the CAC. The standard deviation of returns on DAX are higher than the standard deviation of returns on CAC or FTSE. Daily returns on the indices are negatively skewed, and all the indices exhibit excess kurtosis. Returns are more leptokurtic for DAX than FTSE and CAC indices. None of the average returns series exhibit normal distribution as per the JB test. We also found, not reported here, that there is autocorrelation in the squared returns on the three indices. It is inconsistent with the efficient market models that assume no auto correlation in returns. In general, this autocorrelation is attributed to some key reasons, such as, non-synchronous trading, weekend and holiday effects, time varying risk premiums, and to some extent irrational over or underreaction of investors plus factors such as market opening and closing time differences (Lo, and MacKinlay 1990). In addition, squared daily returns in all markets (not reported) exhibit very high positive skewness and excess kurtosis. Volatility clustering and conditional non-normality are the usual reasons for the reported leptokurtic distribution of returns in the three markets.

The contemporaneous correlation of average returns on DAX and CAC indices with the average returns on FTSE is negative, while the correlation of average returns on DAX and CAC is positive. However, none of these correlation coefficients is significant at the conventional levels during the sample period.

IV. VEC MODEL OF PRICE INDICES AND RETURNS

The long-run equilibrium relationship as well as the short-run dynamics among the three equity markets is studied employing the Johansen and Juselius (1990) model. If the three stock price indices share a common stochastic trend, then, they are considered cointegrated. The presence of cointegration relation forms the basis of the Vector Error Correction (VEC) specification. Consider a vector autoregressive (VAR) model of order *p:*

$$X_t = \mu + \sum_{i=1}^{p} A_i X_{t-i} + \varepsilon_t. \qquad (3.1)$$

where, X_t is a column vector of variables, here, the log price indices, μ is a vector of constants, and ε_t is a vector of innovations, random errors usually assumed to be contemporaneously correlated but not autocorrelated, and p is the number of lags of variables in the system.

If the variables in the vector X_t are integrated of order, say one, I(1), and are also cointegrated, that cointegration restriction has to be incorporated in the VAR in (3.1). The Granger Representation Theorem (Engle and Granger, 1987) states that variables, individually driven by permanent shocks, are cointegrated, if and only if there exists a vector error correction representation of the time series data. A VAR model, with this restriction imposed, is referred to as VEC. Variables in the model enter the equation in their first differences, and the error correction terms are added to the model. So the VEC has cointegration relations built into the specification so that it restricts the long-run behavior of the endogenous variables to converge to their cointegrating relationships while allowing for short-run dynamics. Deviations from long-run equilibrium are corrected through a series of partial short-run adjustments.

The VEC representation of (3.1), following Johansen and Juselius is:

$$\Delta X_t = \mu + \sum_{i=1}^{p} \Gamma_i \Delta X_{t-i} + \alpha\beta' X_{t-i} + \varepsilon_t \qquad (3.2)$$

where, Γ_i are (m x m) coefficient matrices (i = 1, 2, ..., k), α, β are (m x r) matrices, so that $0 < r < m$, where r is the number of linear combinations of the elements in X_t that are affected only by transitory shocks. Matrix β is the cointegrating matrix of r cointegrating vectors, β_1, β_2,...., β_r. The β vectors represent estimates of the long-run cointegrating relationship between the variables in the system. The error correction terms, $\beta' X_{t-1}$, are the mean reverting weighted sums of cointegrating vectors. The matrix α is the matrix of error correction coefficients that measure the speed at which the variables adjust to their equilibrium values. It is obvious that the model in (3.2) is the standard VAR in the first differences of X_t, augmented by the error correction terms, $\alpha\ \beta' X_{t-1}$. The JJ method provides maximum likelihood estimates of α and β'.

V. Empirical Estimation and Results

The first step in the estimation process is determining the order of integration of the individual price index series in natural log levels. The logs of the indices, denoted as LDAX, LFTSE, and LCAC, are tested for unit roots using the augmented Dickey-Fuller (ADF) (1979) test employing the lag structure indicated by Schwarz Bayesian Information Criterion (SBIC). The *p*-values used for the tests are the MacKinnon (1996) one-sided *p*-values. The test results, presented in Table 3 indicate that the null hypothesis, the price index in log levels contains a unit root, cannot be rejected for each of the three price series. Then, unit root tests are performed on each of the price index series in log first differences. The null hypothesis of a unit root could be rejected for each of the time series, based on the reported *p*-values in Table 3. As each of the series is found to be stationary in log first differences no further tests are performed. This finding that each price series is non-stationary implies that each individual market is weakly efficient.

The second step involves testing the three market series for cointegration. The cointegration test is to determine whether or not the three non-stationary price indices share a common stochastic trend. The estimated cointegrating equation is:

$$Ldax_t = \alpha_0 + \alpha_1 Lftse_t + \alpha_2 Lcac_t + e_t \qquad (4.1)$$

In (4.1) the cointegrating relationship is normalized on the log of DAX index. If it is normalized, say, on the log of FTSE, then (4.1) becomes:

$$Lftse_t = -\frac{\alpha_0}{\alpha_1''} - \frac{1}{\alpha_1} Ldax_t - \frac{\alpha_2}{\alpha_1} Lcac_t - \frac{1}{\alpha_1} e_t \qquad (4.2)$$

Many of the earlier studies reported estimated cointegration results normalized on the largest stock market based on capitalization. We did not follow that practice. Instead, we reported results that are normalized on DAX30 that has the smallest market capitalization value among the three markets as of June 2002.

We employ the JJ estimation procedure that uses the maximum likelihood method. The cointegration tests assumed no deterministic trends in the series and used lag intervals 1 to 1 as suggested by the SBIC for appropriate lag lengths. However, it would not have made any difference even if we had chosen AIC (Akaike Information Criterion) because both the AIC and SBIC suggested the same lag length as well as the assumptions for the test. The assumptions of the test are that the indices in log levels have no deterministic trends and the cointegrating equation has an intercept but no intercept in the VAR. The results of cointegration tests are presented in Table 4. The trace test, which tests the null hypothesis of *r* cointegrating relations against *k* cointegrating relations, where *k* is the number of endogenous variables, for *r* = 0, 1, ... *k*. If there are *k* cointegrating relations it implies that there is no cointegration between the three series. The maximum eigen value test which tests the null of *r* cointegrating relations against the alternative of *r* + 1 cointegrating relations, results indicated one cointe-

TABLE 3. Augmented Dickey-Fuller (ADF) Unit Root Tests of the price indices

Daily Closing Price Indices	Lags Based on SBIC**	Intercept	Intercept & Trend	Test Statistic	Probability*	SBIC Values
LFTSE	3		√	–0.1295	0.9944	–6.2589
LDAX	1		√	–0.0971	0.9949	–5.6518
LCAC	1		√	–0.9733	09459	–5.7173
ΔLFTSE	2	√		–34. 9044	0.0000	–6.2627
ΔLDAX	1	√		–53.4975	0.0001	–5.6545
ΔLCAC	1	√		–53.4858	0.0001	–5.7195

* MacKinnon (1996) one-sided p-values; ** SBIC: Schwarz Bayesian Information Criterion

TABLE 4. Cointegration Test Results

Series: LDAX LFTSE LCAC. Assumptions: Intercept and no deterministic trend in cointegrating equation and no intercept in VAR. Lags interval: 1 to 1, based on the Schwartz Bayesian (Information) Criterion

Hypothesized No. of co-integrating equations	Eigenvalue	Trace Statistic	5% Critical Value	Probability*	Max-Eigen-value Statistic	5% Critical Value	Probability*
None	0.0229	87.4233	35.1927	0.0000	69.6762	22.2996	0.0000
At most 1	0.0039	17.7461	20.2618	0.1071	11.6906	15.8921	0.2047
At most 2	0.0020	6.0555	9.1645	0.1865	6.0555	9.1645	0.1865

Trace Test and Maximum Eigenvalue Test indicate 1 cointegrating equation at 5% level of significance.
Critical values are from Osterwald-Lenum(1992); * MacKinnon-Haug-Michelis (1999) p-values

Normalized cointegrating coefficients (std. err. in parentheses)

LDAX	LFTSE	LCAC	C	
1.0000	−1.0030	− 0.4372	3.7608	Log Likelihood: 26574.89
	(0.0643)	(0.0499)	(0.2211)	AIC: −17.6824
				SBIC: −17.6504

grating equation at the 5% percent level of significance. The critical values used from Osterwald-lenum (1992) are slightly different from those reported in JJ (1990). The cointegrating relationship is normalized on *ldax*. The normalized cointegrating coefficients and the standard errors are reported at the bottom row of Table 4. The cointegrating vector of the three daily price indices, DAX, FTSE, and CAC, normalized on DAX is: [1 −1.0 −0.44]. The cointegrating equation indicates that DAX and FTSE indices adjust one-to-one in the long-run, and a smaller adjustment occurs between DAX index and CAC index.

We tested for cointegration between DAX and FTSE, DAX and CAC, FTSE and CAC market indices. While DAX and FTSE, and DAX and CAC are cointegrated, FTSE and CAC indices are not cointegrated. Test results are not presented as our focus is the relationship between the three markets.

The finding that the stock price indices are cointegrated means that there is one linear combination of the three price series that forces these indices to have a long-run equilibrium relationship even though the indices may wander away from each other in the short-run. It also implies that the returns on the indices are correlated in the long-run. The message for long-term international investors is that it does not matter, in terms of portfolio returns, whether investors in the three countries hold a fully diversified portfolio of stocks contained in all the three indices or hold portfolios consisting of all stocks of only one index. Cointegration between the portfolio and the index is assured when there is at least one portfolio of stocks that has stationary tracking error, that is, the difference between the portfolio of stocks and the stock index is stationary, or to put it differently, the price spread between the two is mean-reverting. However, in the short-run, the two may deviate from each other with the potential for higher returns on the portfolio relative to the index. So, investors may still be able to earn excess returns in the short-run by holding a portfolio of stocks from the three markets.

The final step is the estimation of the three variable VEC model. In terms of our analysis, the estimated vector error-correction model of price indices has the following form:

$$\Delta ldax_t = \alpha_0 + \sum_{i=1}^{p}\beta_{1i}\Delta ldax_{t-1} + \sum_{i=1}^{p}\beta_{2i}\Delta lftse_{t-1} + \sum_{i=1}^{p}\beta_{3i}\Delta lcac_{t-1} + \lambda_1 z_{t-1} + \varepsilon_{t1} \qquad (4.3)$$

$$\Delta lftse_t = \alpha_1 + \sum_{i=1}^{p}\gamma_{1i}\Delta lftse_{t-1} + \sum_{i=1}^{p}\gamma_{2i}\Delta lcac_{t-1} + \sum_{i=1}^{p}\gamma_{3i}\Delta ldax_{t-1} + \lambda_2 z_{t-1} + \varepsilon_{t2} \qquad (4.4)$$

$$\Delta lcac_t = \alpha_2 + \sum_{i=1}^{p}\delta_{1i}\Delta lcac_{t-1} + \sum_{i=1}^{p}\delta_{2i}\Delta lftse_{t-1} + \sum_{i=1}^{p}\delta_{3i}\Delta ldax_{t-1} + \lambda_3 z_{t-1} + \varepsilon_{t3} \qquad (4.5)$$

where $\Delta ldax$, $\Delta lftse$, and $\Delta lcac$ are the first log differences of the three market indices lagged p periods, z_{t-1} are the equilibrium errors or the residuals of the cointegrating equations, lagged one period, and λ_i are the coefficients of the error-correction term.

The lag lengths for the series in the system are determined according to the SBIC. The suggested lag lengths are one to one. No restrictions are imposed in identifying the cointegrating vectors. The coefficients of the error correction terms are denoted by λ_i. Estimated results are presented in Table 5. The estimated coefficient values of the lagged variables along with the t-statistics are presented without the asymptotic standard errors corrected for degrees of freedom for want of space, and will be available from the authors. At the bottom of the output in Table 5 the log likelihood values, the AIC and SBIC are reported.

Three types of inference, concerning the dynamics of the three markets, can be drawn from the reported results of the VEC model in Table 5. The first one concerns whether the left hand side variable in each equation in the system is endogenous or weakly exogenous. The second type of inference is about the speed, magnitude, and direction of adjustment of the variables in the system to restore equilibrium following a shock to the system. The third type of inference is associated with the direction of short-run causal linkages between the three markets.

Adjustment to Shocks:

In general, a cursory look at the statistical significance of the reported coefficients of the error-correction terms (λ_i) of $\Delta ldax$, $\Delta lftse$, and $\Delta lcac$ equations give us an idea whether the left-hand side variable in each equation of the system is exogenous or endogenous. If the coefficient of the error-correction term is not significantly different from zero, it usually implies that that variable is weakly exogenous, otherwise, it is endogenous.

Looking at the results in Table 5, we see that the coefficient of the error correction term, λ_3, in the $\Delta lcac$ equation is not significantly different from zero implying that the CAC index is weakly exogenous to the system. The weak exogeniety of CAC index means that it is the initial receptor of external shocks, and it in turn, will transmit the shocks to the other markets in the system. As a result, the equilibrium relationship of the three markets is disturbed. The adjustment back to equilibrium can be inferred from the signs and magnitude of the coefficients, λ_1 ($\Delta ldax$ equation) and λ_2 ($\Delta lftse$ equation).The sign of λ_1 is negative and its magnitude, in absolute terms, is relatively large (–0.025), and the sign of λ_2 is positive and smaller (0.015). Following a shock, the DAX index will decrease by 2.5 percent and the FTSE will increase by 1.5 percent per time period to eliminate the discrepancy caused by the shock. It appears that the speed of adjustment back to equilibrium is relatively quick. Further, the two indices, DAX and FTSE are mutually causal and the burden of adjustment back to equilibrium completely rests on these two indices, although CAC index also declines by a very insignificant amount, 0.47 percent.

TABLE 5. VEC Estimated Results

Variables: Δldax $\Delta lftse$ $\Delta lcac$
t-statistics in [ ]

	Δldax	Δlftse	Δlcac
Error-correction term (λ_i)	–0.0253	0.0153	–0.0047
	[–6.6477]	[5.4020]	[–1.2731]
$\Delta ldax$ (–1)	0.0280	–0.0368	0.0178
	[1.5338]	[–2.7182]	[0.9998]
$\Delta lftse$ (–1)	–0.0195	0.0425	0.0191
	[–0.7945]	[2.3348]	[0.7971]
$\Delta lcac$ (–1)	0.0636	–0.0022	0.0207
	[3.3713]	[–0.1606]	[1.1261]
R-squared:	0.0200	0.0126	0.0013
F-statistic:	20.4846	12.7633	1.3319
	Log Likelihood: 26574.8900		
	AIC –17.6824		
	SBIC –17.6504		

Granger Causality

Inference on the direction of Granger causality depends on whether or not the sum of the coefficients of each of the lagged variable in the equations is statistically different from zero. Our estimated VEC model used one period lag on the variables. So, from the reported results in Table 5, the coefficient of the one period lagged $\Delta lcac$ is statistically significant meaning that the CAC index Granger causes the DAX index. In the $\Delta lftse$ equation, the coefficient of the lagged $\Delta ldax$ is statistically significant, and hence DAX causes the FTSE index. None of the coefficients of the lagged $\Delta ldax$ or $\Delta lftse$ are significant in the $\Delta lcac$ equation, at the conventional levels, and so no causal link exists between DAX and CAC or FTSE and CAC during our sample period.

VI. Summary and Conclusions

This paper investigates the long-run equilibrium relationship among the three largest European equity markets (London, Paris and Frankfurt) from late 1990 to mid-2002. Specifically we examine if equity index prices in these three equity markets are cointegrated. By employing cointegration and error-correction methodology we find that the price indices of the three markets are cointegrated and that the CAC index is weakly exogenous during the sample period examined. Further, the burden of adjustment to restore equilibrium, following a shock, falls on DAX and FTSE indices. DAX and FTSE indices are found to be mutually causal while there is less than significant evidence of causation between DAX and CAC indices for the sample period used in this study. The existence of a linear combination of the three indices that forces these indices to have a long-term equilibrium relationship implies that the indices are perfectly correlated in the long run and diversification among these three equity markets can not benefit international portfolio investors. However, there can be excess returns in the short run.

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