Identifying the evolution of stock markets stochastic structure after the euro

Caiado, Jorge and Crato, Nuno

January 2008

Identifying the evolution of stock markets stochastic structure after the euro

Jorge Caiado[a] Nuno Crato[b]

[a]Department of Economics and Management, Escola Superior de Ciências Empresariais, Polytechnic Institute of Setúbal and CEMAPRE, Campus do IPS, Estefanilha, 2914-503 Setúbal, Portugal. Tel.: +351 265 709 438. Fax: +351 265 709 301. E-mail: jcaiado@esce.ips.pt

[b]Department of Mathematics, Instituto Superior de Economia e Gestão, Technical University of Lisbon and CEMAPRE, Rua do Quelhas 6, 1200-781 Lisboa, Portugal. Tel.: +351 213 925 846. E-mail: ncrato@iseg.utl.pt

Abstract: Previous studies have investigated the comovements of international equity markets by using correlation, cointegration, common factor analysis, and other approaches. In this paper, we investigate the stochastic structure of major euro and non-euro area stock market series from 1994 to 2006, by using cluster analysis techniques for time series. We use an interpolated-periodogram based metric for level and squared returns in order to compute distances between the stock markets. This method captures the stochastic dependence structure of the time series and solves the shortcoming of unequal sample sizes found for different countries. The clusters of countries are formed by the dendrogram and the principal coordinates associated with the sample spectrum for both the series of returns and volatilities. The empirical results suggest that the cross-country groups have become considerably more homogeneous with the introduction of the euro as an electronic currency. For reference, we also explore the pairwise correlations among the series.

Keywords: Cluster analysis; Euro area; International stock markets; Periodogram; Stock returns; Volatility.

1. Introduction

The comparative analysis of the international equity markets has become one of the most important research areas in macroeconomics and international finance for several reasons. Investors are interested in international equity market relationships for portfolio diversification and risk management purposes. Economists and finance analysts are interested in international equity market relationships to investigate the comovement structure of countries and to identify groups of countries with similar comovement characteristics.

Cross-country stock returns correlation has been extensively studied in the economic and financial literature (Lin et al., 1994, Longin and Solnik, 1995, Karolyi and Stulz, 1996, Bessler and Yang, 2003, Morana and Beltratti, 2007). Many studies have found small international stock-markets correlations in periods of low volatility (small absolute returns), and much higher correlations in periods of high volatility (large absolute returns). International equity market comovements and euro area market integration have been also widely studied using vector error correction and cointegration approaches (Bessler and Yang, 2003, Syriopoulos, 2004, Tahai et al., 2004, Voronkova, 2004, Rita and Costantini, 2006), and factor model approaches (Engle and Susmel, 1993, Hui, 2005). For a review of measures of equity market integration in the euro area, see the survey by Baele et al. (2004).

The identification of similarities (or dissimilarities) in international stock returns by using cluster analysis needs further research. Some studies, as Mantegna (1999) and Bonanno et al. (2001), used the Pearson correlation coefficient as similarity measure of a pair of stock returns. Although this can be useful to ascertain the structure of stock returns comovements, it does not take into account the information about the stochastic behavior of returns and volatilities and it cannot be directly used for comparison and grouping stocks with unequal sample sizes.

In this paper, we investigate whether the structure of stock markets change over time from before to after the introduction of the euro as an electronic currency. In addressing this issue we also attempt to analyze some important questions:

1) Is there a financial integration in the euro area markets?
2) How this financial integration changes over time?
3) Which stock markets and countries have become more integrated?
4) What is the degree of affinity among euro and non-euro area financial markets?
5) Are the cross-country affinities similar for returns and squared returns?

In order to compare the series, our method groups the asset return series into clusters, with the property that series in the same cluster have similar stochastic dependence structure and series in other clusters are quite distinct. The clusters are formed by looking to the dendrogram and the principal coordinates associated with the log normalized periodogram ordinates for both returns and squared returns.

In order to obtain overlapping data researchers usually delete part of the series, which has the disadvantage of using less than available information. Our method overcomes this problem by constructing interpolated periodograms where needed.

The remainder of the paper is organized as follows. Section 2 presents the distance-based methods for time series classification and clustering. Section 3 describes the data set used in this paper. Section 4 presents the cluster analysis evidence for the empirical results. Section 5 explores correlations for returns and squared returns. Conclusions are summarized in the final section.

2. Comparing financial time series

In order to compare different time series and to perform their cluster analysis, we have to define a relevant distance measure. Previous studies have used the contemporaneous correlation between time series data to analyze their interdependence.

We complement this approach with the study of the stochastic structure of each series. For doing this analysis, we use a spectral distance measure. This way, we measure the stochastic dynamics similarity of each pair of series, independently of their contemporaneous cross-correlations.

With this spectral distance measure we perform a cluster analysis of the series. This way we form groups and assess in what measure they are defined according to euro-area boundaries. We use both return series and volatility series.

2.1. Periodogram-based distance

The periodogram is a useful tool to describe the cyclical behavior of an observed time series. It is common practice to normalize the periodogram, dividing it by the sample variance so that it captures only the autocorrelation structure. The Euclidean distance between the log normalized periodogram ordinates provides a recently developed frequency domain method for time series classification (Caiado et al., 2006).

Let $P_t, t = 1, ..., n$ be the price index of a given country series. We compute the returns as the difference of log prices, $r_t = \log P_t - \log\ P_{t-1}$. Volatility is taken as the squared returns, r_t^2. Let $P_x(\omega_j) = n^{-1}|\sum_{t=1}^{n} r_{t,x}e^{-it\omega_j}|^2$ be the periodogram of the return series $r_{t,x}$ for country x at frequencies $\omega_j = 2\pi j/n$, $j = 1, ..., m$ (with $m = [n/2]$ the largest integer less or equal to $n/2$), and let $NP_x(\omega_j) = P_x(\omega_j)/\widehat{\gamma}_{0,x}$ be the normalized periodogram of $r_{t,x}$, where $\widehat{\gamma}_{0,x}$ is the sample variance of $r_{t,x}$. Similar expression is defined for $NP_y(\omega_j)$.

A log normalized periodogram (LNP) distance measure between the returns series of countries x and y is given by

$$d_{LNP}(x, y) = \sqrt{\sum_{j=1}^{m} \left[\log NP_x(\omega_j) - \log NP_y(\omega_j)\right]^2}, \tag{1}$$

This distance fulfills the usual properties of a metric, except the triangle inequality: (i) $d(x, y) = 0$ if $NP_x(\omega_j) = NP_y(\omega_j)$; (ii) $d(x, y) \geq 0$; and (iii) $d(x, y) = d(y, x)$. We construct similar expression for the volatilities, substituting r_t^2 for r_t. The advantages of the above measures over other distance-based methods are that they additionally convey all the stochastic structure of the processes and they are easy to implement and computational fast.

For two return series $\{r_{t,x}, t = 1, ..., n_x\}$ and $\{r_{t,y}, t = 1, ..., n_y\}$ with unequal sizes $n_x \neq n_y$, we can use the periodogram interpolation method proposed by Caiado et al. (2007). This method consist of a linear interpolation of the individual periodogram ordinates at Fourier frequencies so that we estimate the periodogram ordinates of the series with longer (shorter) length from the series with the shorter (longer) length.

Without loss of generality, let $m_y < m_x$ and $k = [p\frac{m_x}{m_y}]$ be the largest integer less or equal to $p\frac{m_x}{m_y}$ for $p = 1, ..., m_y$. The interpolated periodogram ordinates for country x are given by

$$P_x'(\omega_p) = P_x(\omega_k) + (P_x(\omega_{k+1}) - P_x(\omega_k)) \times \frac{\omega_{p,y} - \omega_{k,x}}{\omega_{k+1,x} - \omega_{k,x}}. \tag{2}$$

We then use the following distance measure between the interpolated log normalized periodogram (ILNP) ordinates of the two series,

$$d_{ILNP}(x, y) = \sqrt{\sum_{p=1}^{m_y} \left[\log NP_x'(\omega_p) - \log NP_y(\omega_p)\right]^2}, \tag{3}$$

where $NP'_x(\omega_p)$ is the interpolated normalized periodogram of the longer series and $NP_y(\omega_p)$ is the normalized periodogram of the shorter series. This approach can be quite useful since the usual metrics based on the Euclidean distances and pairwise correlations cannot be directly used for comparison of financial time series with unequal length.

2.2. Cluster analysis

For each data set, we compute a distance matrix with $c(c-1)/2$ different pairs (where c is the number of countries) using the ILNP metric (3) for both returns and squared returns. We group the time series using the hierarchical clustering tree (or dendrogram) by complete linkage method (see for instance, Johnson and Wichern, 1992) which minimizes the maximum distance between time series features in the same group in such a way that series in the same group are similar to one another and series in different groups are as distinct as possible. We consider also the useful technique of multidimensional scaling, which creates a configuration of c points in a map of p dimensions (in this case, two dimensions) with the Euclidean distances among stock markets using the information about the time series stochastic features.

3. Data description

We consider data of daily index returns for 27 international stock markets from the Americas, Asia and Pacific, Europe and Middle East. Data are reported in Table 1 and cover the period from 1994 to 2006. Data correspond to closing prices adjusted for dividends and splits (http://finance.yahoo.com).

Table 2 reports summary statistics (mean, standard deviations, skewness, and kurtosis coefficients, and Ljung-Box test for the k-th autocorrelations) of the indices returns for the sample periods previous (1994-1998) and subsequent (1999-2006) to the introduction of the euro as an electronic currency. Before euro, we found negative skewness coefficients for all markets except Brazil, Hong-Kong, Indonesia, Japan, Korea, Malaysia and Singapore, which show small positive skewness coefficients. After euro, Belgium and the non-euro countries Argentina, Brazil, Mexico and U.S. exhibit a positive skewness. The return series for all the markets are highly leptokurtic except France, India, Korea and Taiwan (before euro), and Japan (after euro), which have moderate (less than 5) excess of kurtosis. In general, the euro area markets show lower excess of kurtosis than the non-euro area markets for both sample periods. There are significant autocorrelations up to order 20 in the returns for all markets but Australia, India, Switzerland and Taiwan (before euro), and Australia, Hong-Kong, Japan, Korea, Norway and Singapore (after euro), which do not reject the null hypothesis of no autocorrelation at the 5% significance level.

4. Stochastic structure analysis

Figure 1 shows the relative average distances among euro, non-euro and euro versus non-euro stock markets using the periodogram-based metric defined in (3). These plots clearly suggest that the euro area countries tend to become more homogeneous over time and their relative distance increased with respect to the non-euro area countries. Results are similar for both returns and squared returns.

To further investigate the affinity among stock markets, we performed a cluster analysis

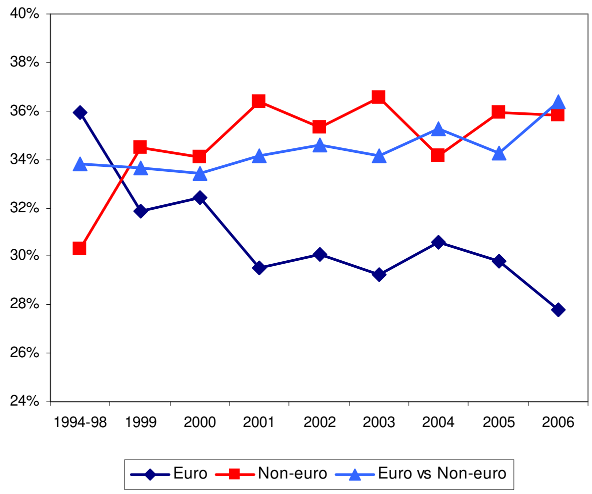
Table 1
Daily indices of 27 international stock markets

Stock market	Country	Code	Period	Sample size
Americas				
New York Stock Exchange	United States	US	01:94 - 10:06	3201
TXS Venture Exchange	Canada	CAN	01:00 - 10:06	1716
Sao Paolo Stock Exchange	Brazil	BRA	01:94 - 10:06	3151
Buenos Aires Stock Exchange	Argentina	ARG	10:96 - 10:06	2473
Mexico Stock Exchange	Mexico	MEX	01:94 - 10:06	3198
Asia/Pacific				
Bombay Stock Exchange	India	IND	07:97 - 10:06	2293
Hong Kong Stock Exchange	Hong-Kong	HK	01:94 - 10:06	3147
Jakarta Stock Exchange	Indonesia	INDO	07:97 - 10:06	2233
Kuala Lumpur Stock Exchange	Malaysia	MAL	01:94 - 10:06	3134
Korea Stock Exchange	Korea	KOR	07:97 - 10:06	2277
Japan Stock Exchange	Japan	JAP	01:94 - 10:06	3133
Singapore Stock Exchange	Singapore	SING	01:94 - 10:06	3213
Taiwan Stock Exchange	Taiwan	TAI	07:97 - 10:06	2277
Australian Stock Exchange	Australia	AUST	01:94 - 10:06	3206
Europe				
Amsterdam Stock Exchange	Netherlands	NET	01:94 - 10:06	3256
Vienna Stock Exchange	Austria	AUS	01:94 - 10:06	3148
Brussels Stock Exchange	Belgium	BEL	01:94 - 10:06	3242
Paris Stock Exchange	France	FRA	01:94 - 10:06	3241
Xetra Stock Exchange	Germany	GER	01:94 - 10:06	3239
London Stock Exchange	United Kingdom	UK	01:94 - 10:06	3214
Madrid Stock Exchange	Spain	SPA	01:94 - 10:06	3201
Milan Stock Exchange	Italy	ITA	01:00 - 10:06	1752
Stockholm Stock Exchange	Sweden	SWE	01:01 - 10:06	1452
Oslo Stock Exchange	Norway	NOR	02:01 - 10:06	1429
Swiss Stock Exchange	Switzerland	SWI	01:94 - 10:06	3211
Middle East				
Egypt Stock Exchange	Egypt	EGY	07:97 - 10:06	1815
Tel Aviv Stock Exchange	Israel	ISR	07:97 - 10:06	1853

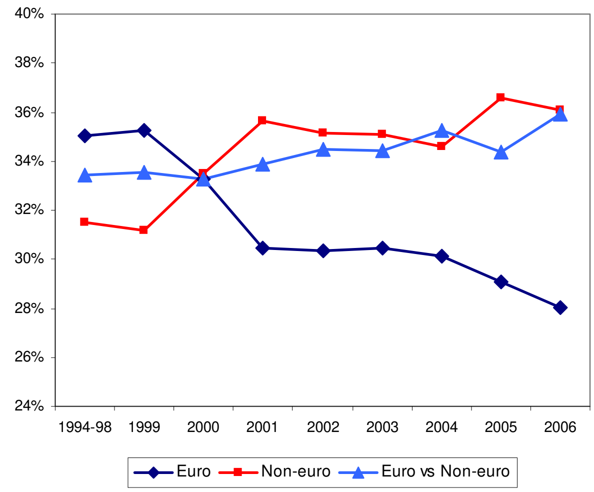
Table 2
Summary statistics for daily euro area and non-euro area stock-market returns

	Mean×100		Std.dev.×100		Skewness		Kurtosis		Q(20)	
Market	Before	After	Before	After	Before	After	Before	After	Before	After
Euro										
AUS	-0.002	0.027	0.48	0.42	-0.88	-0.65	9.11	7.27	43.5*	35.7**
BEL	0.031	0.002	0.38	0.51	-0.15	0.29	5.87	8.69	68.0*	88.2*
FRA	0.020	0.005	0.54	0.62	-0.14	-0.09	4.92	5.74	34.4**	50.2*
GER	0.029	0.003	0.55	0.70	-0.54	-0.03	6.01	5.37	76.6*	43.0*
ITA	—	-0.002	—	0.55	—	-0.22	—	6.82	—	40.3*
NET	0.038	-0.003	0.51	0.65	-0.29	-0.04	6.85	7.23	58.6*	77.9*
SPA	0.035	0.005	0.57	0.58	-0.37	-0.08	6.74	5.02	51.7*	45.4*
Average	0.025	0.005	0.51	0.58	-0.40	-0.12	6.58	6.59		
Non-euro										
ARG	-0.025	0.003	1.04	0.98	-1.12	0.20	9.76	7.67	47.7*	33.1**
AUST	0.007	0.013	0.37	0.31	-0.43	-0.66	10.20	7.60	18.1	31.0
BRA	0.092	0.013	1.41	0.87	0.19	1.34	7.91	24.74	65.7*	32.4**
CAN	—	0.001	—	0.45	—	-0.74	—	10.24	—	31.8**
EGY	—	0.050	—	0.44	—	-0.17	—	13.85	—	126.3*
HK	-0.004	0.013	0.87	0.60	0.27	-0.26	13.40	6.22	57.0*	30.5
IND	-0.041	0.031	0.75	0.69	-0.07	-0.39	4.42	7.06	21.6	68.2*
INDO	-0.071	0.032	1.30	0.66	0.24	-0.05	5.83	8.05	37.5*	67.8*
ISR	—	0.029	—	0.62	—	-0.22	—	5.50	—	43.8*
JAP	-0.011	0.004	0.62	0.61	0.19	-0.10	6.05	4.54	41.1*	17.8
KOR	-0.035	0.019	1.42	0.87	0.27	-0.35	3.91	5.90	49.6*	27.4
MAL	-0.023	0.012	0.96	0.45	0.63	-0.13	31.83	8.82	45.9*	99.0*
MEX	0.015	0.039	0.84	0.65	-0.03	0.10	9.61	5.51	39.4*	52.9*
NOR	—	0.023	—	0.53	—	-0.48	—	6.66	—	19.0
SING	-0.017	0.014	0.64	0.52	0.56	-0.36	13.83	7.50	84.4*	24.5
SWE	—	0.005	—	0.59	—	-0.09	—	6.35	—	39.7*
SWI	0.030	0.002	0.50	0.52	-0.26	-0.05	6.91	7.07	27.7	49.5*
TAI	-0.040	0.003	0.73	0.72	-0.09	-0.05	4.32	5.57	14.7	35.0**
UK	0.019	0.000	0.40	0.50	-0.13	-0.15	5.09	5.58	53.6*	63.7*
US	0.028	0.007	0.36	0.44	-0.86	0.01	12.06	5.31	44.5*	35.4**
Average	-0.005	0.016	0.81	0.60	-0.04	-0.13	9.68	7.99		

* (**) Significant at the 1% (5%) level; $Q(20)$ is the Ljung-Box statistic with 20 lags.



(a) Returns



(b) Squared returns

Figure 1. Evolution of relative average distances among stock-market stochastic features for (a) returns and (b) squared returns

of the time series of daily stock-market indices using all available data in the sample periods 1994-1998 (for all countries except Egypt, Canada, Italy, Sweden, Norway and Israel) and 1999-2006 with the introduction of the euro (for all countries). For better visualizing the clusters, on the plots we dropped the outlier countries Australia and Mexico for mean and squared return analysis, respectively.

Figure 2 focus on the multidimensional scaling approach (also known as principal coordinates analysis) associated with the log normalized periodogram ordinates in sample periods 1994-1998 and 1999-2006.

On the period previous to the introduction of the euro, all the markets seem to be close for level returns, except Hong-Kong, Austria, Mexico and France. Looking at the map for squared returns, we see that some current euro area markets are at different locations; for instance, Austria and Belgium are close to the major Asian markets, Germany is close to Brazil in a distinct cluster, and France seems to be an outlier.

After euro, we found that the euro area countries (with the exception of Austria for mean returns) are close together and close to United States, United Kingdom, Switzerland and Sweden. The South/Middle American, the Asian/Pacific and the Middle East markets tend to cluster together. Austria and Norway markets are clear outliers for mean and squared returns, respectively.

These maps suggest that the euro area countries become much more homogenous in returns and volatilities since the beginning of third stage of the European Monetary Union. Similar patterns are found in the dendrograms presented in Figure 3.

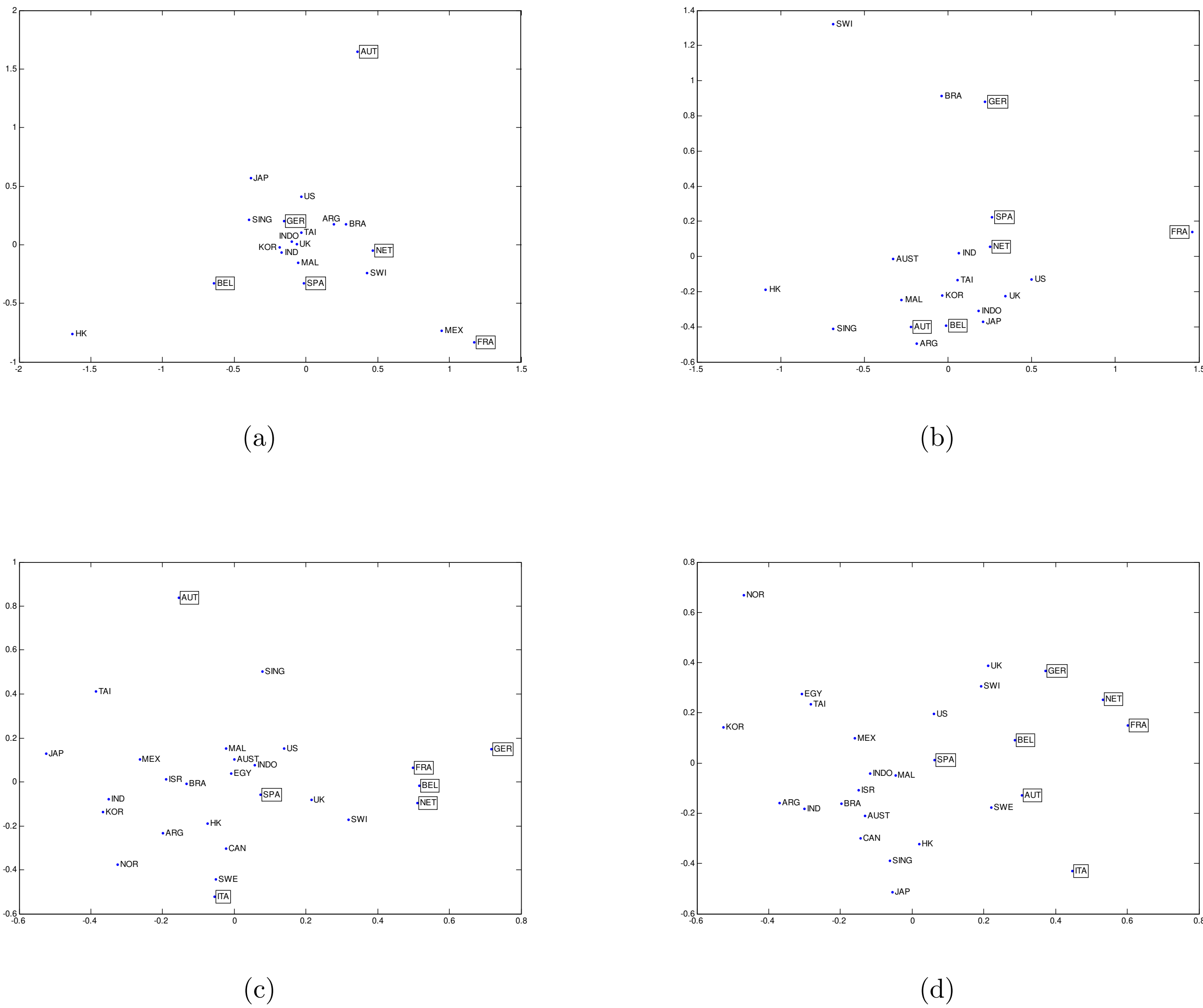
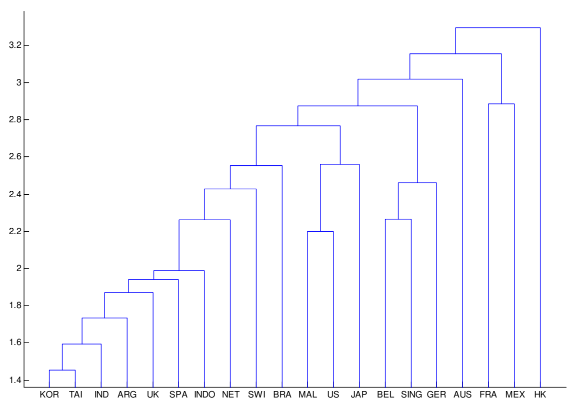
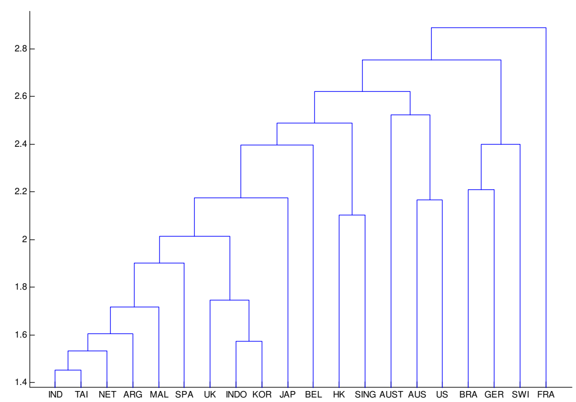


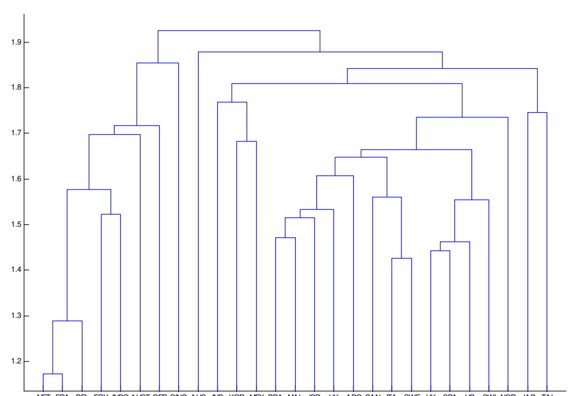
Figure 2. Maps of euro and non-euro area stock markets using the periodogram-based method for (a) returns before euro, (b) squared returns before euro, (c) returns after euro, and (d) squared returns after euro. Euro area countries are within boxes



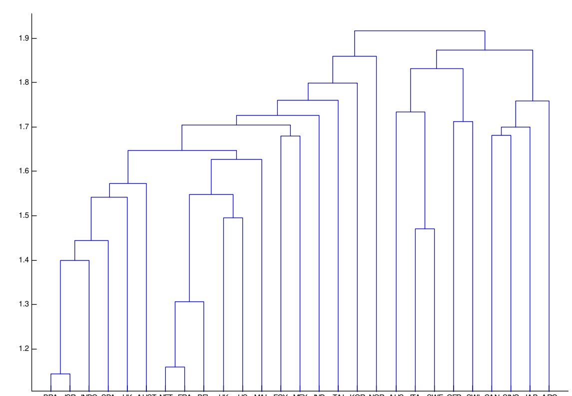
(a)



(b)



(c)



(d)

Figure 3. Dendrogram by complete linkage of euro and non-euro area stock markets using the periodogram-based method for: (a) returns before euro, (b) squared returns before euro, (c) returns after euro, and (d) squared returns after euro

5. Cross-correlation analysis

To complement the previous analysis, we studied the pairwise correlation between data for all countries It is not possible to do so directly with the available data Non-trading days and holidays are not the same in different countries. To make data corrections is difficult and subject to too many errors. As it is usually done (e.g., Engle and Susmel, 1993), we used weekly series constructed by aggregation. We got a total of 678 weekly observations for the period 1994-2006.

Tables 3 and 4 show the correlation matrices for the weekly returns and squared returns in both sample periods under study. For simplicity, we present in the tables the euro area markets Netherlands, Austria, Belgium, France, Germany and Spain, and only the non-euro area markets for United Kingdom, Switzerland, United States, Australia and Japan.

Before euro, it can be seen that correlations among current euro area market returns and squared returns are high (i.e., more than 0.6) except for Austria. As expected, there are very high correlations between neighboring countries Netherlands, France and Germany, and relatively high correlations among all euro area countries. For squared returns, there are 3 correlations higher than 0.7 among euro area markets Belgium, Germany, Netherlands and Spain, and 4 correlations higher than 0.7 between these euro area markets and Switzerland. After euro, there are 8 mean correlations and 5 squared correlations higher than 0.7 among euro area markets (with the exception of Austria), and 9 mean correlations and 6 squared correlations higher than 0.7 between euro area markets (except Austria) and non-euro area markets Switzerland and United Kingdom.

Before 1999, no euro area country shows mean and squared correlations higher than 0.1 with United States nor higher than 0.2 with Japan. After euro, such correlations are much higher with the United States (the lowest mean and squared correlations are 0.34 and 0.17 with Austria) but do not increase with the Japan. In contrast, the squared correlations between Switzerland and Austria, and between Austria and Germany decrease from 0.67 to 0.13 and from 0.61 to 0.19 before to after the euro.

In general, mean correlations are slightly higher than squared correlations. These results are in agreement with some existing findings in international stock-market comovements literature. For instance, Engle and Susmel (1993) have found lower squared correlations among European stock markets than in level returns.

6. Concluding remarks

In this paper, we investigated the evolution of similarities among major euro and non-euro area stock markets in the period 1994-2006.

We performed a cluster analysis using a sample-spectrum based metric for daily stock indices returns and squared returns. This approach provides useful information about the time series behavior in terms of the stochastic dependence and volatility effects, and solves the shortcoming of unequal sample sizes found for different countries.

Data were divided into two sample periods: previous and subsequent to the introduction of the euro as an electronic currency. Before euro, there is a weak linkage among euro area countries both in returns and in volatilities. After euro, returns display some identity formed by the neighboring euro area countries France, Belgium, Germany and Netherlands that is close to the non-euro European countries United Kingdom and Switzerland.

Table 3
Correlation matrices for the period before euro (1994-1998)

(a) Weekly returns

	AUS	BEL	FRA	GER	NET	SPA	AUST	JAP	SWI	UK	US
Euro											
AUS	1.00										
BEL	0.57	1.00									
FRA	0.53	0.69	1.00								
GER	0.62	0.69	0.74	1.00							
NET	0.61	0.73	0.75	0.79	1.00						
SPA	0.55	0.65	0.72	0.71	0.74	1.00					
Non-euro											
AUST	0.39	0.42	0.37	0.42	0.46	0.48	1.00				
JAP	0.13	0.05	0.09	0.06	0.10	0.10	0.06	1.00			
SWI	0.58	0.64	0.69	0.76	0.76	0.69	0.41	0.06	1.00		
UK	0.53	0.61	0.68	0.67	0.73	0.65	0.45	0.13	0.65	1.00	
US	0.09	-0.07	-0.11	-0.04	0.02	0.01	0.19	-0.01	0.00	-0.05	1.00

(b) Weekly squared returns

	AUS	BEL	FRA	GER	NET	SPA	AUST	JAP	SWI	UK	US
Euro											
AUS	1.00										
BEL	0.55	1.00									
FRA	0.41	0.61	1.00								
GER	0.61	0.74	0.70	1.00							
NET	0.51	0.71	0.64	0.79	1.00						
SPA	0.52	0.71	0.69	0.69	0.69	1.00					
Non-euro											
AUST	0.13	0.09	0.05	0.03	0.08	0.17	1.00				
JAP	0.00	0.05	0.01	0.04	0.06	0.11	0.03	1.00			
SWI	0.67	0.75	0.69	0.86	0.78	0.77	0.11	0.03	1.00		
UK	0.37	0.53	0.54	0.54	0.51	0.51	0.22	0.19	0.50	1.00	
US	0.09	0.02	-0.08	0.01	0.04	0.04	-0.04	0.04	-0.01	0.03	1.00

Table 4
Correlation matrices for the period after euro (1999-2006)

(a) Weekly returns											
	AUS	BEL	FRA	GER	NET	SPA	AUST	JAP	SWI	UK	US
Euro											
AUS	1.00										
BEL	0.39	1.00									
FRA	0.34	0.71	1.00								
GER	0.39	0.69	0.88	1.00							
NET	0.38	0.79	0.89	0.87	1.00						
SPA	0.40	0.64	0.80	0.80	0.78	1.00					
Non-euro											
AUST	0.39	0.47	0.54	0.53	0.52	0.54	1.00				
JAP	0.21	0.05	0.12	0.16	0.15	0.10	0.12	1.00			
SWI	0.39	0.75	0.77	0.76	0.80	0.71	0.45	0.10	1.00		
UK	0.40	0.68	0.83	0.78	0.81	0.72	0.53	0.11	0.76	1.00	
US	0.34	0.40	0.45	0.51	0.49	0.44	0.41	0.14	0.51	0.48	1.00

(b) Weekly squared returns											
	AUS	BEL	FRA	GER	NET	SPA	AUST	JAP	SWI	UK	US
Euro											
AUS	1.00										
BEL	0.17	1.00									
FRA	0.24	0.70	1.00								
GER	0.19	0.63	0.81	1.00							
NET	0.14	0.81	0.83	0.79	1.00						
SPA	0.23	0.64	0.75	0.75	0.70	1.00					
Non-euro											
AUST	0.25	0.28	0.38	0.39	0.32	0.36	1.00				
JAP	0.09	0.06	0.08	0.10	0.10	0.11	0.10	1.00			
SWI	0.13	0.71	0.66	0.73	0.72	0.70	0.36	0.08	1.00		
UK	0.15	0.69	0.76	0.71	0.74	0.65	0.40	0.10	0.73	1.00	
US	0.17	0.43	0.43	0.44	0.41	0.38	0.36	0.01	0.60	0.50	1.00

Volatilities show a more clear grouping of euro area countries in a distinct cluster.

In contrast, from correlation analysis, we found that the correlations of returns and volatilities among euro area countries do not change significantly from before to after the introduction of the euro.

Acknowledgment: This research was supported by a grant from the Fundação para a Ciência e Tecnologia (FEDER/POCI 2010). Comments from participants in the 11th International Conference on Macroeconomic Analysis and International Finance and 26th International Symposium on Forecasting are gratefully acknowledged.

REFERENCES

1. Baele, L., Ferrando, A., Hördahl, P., Krylova, E. and Monnet, C. (2004). "Measuring financial integration in the euro area", Occasional Paper Series No. 14, European Central Bank.
2. Bessler, D. and Yang, J. (2003). "The structure of interdependence in international stock markets", *Journal of International Money and Finance*, 22, 261-287.
3. Bonanno G., Lillo F., and Mantegna, R. N. (2001). "High-frequency cross-correlation in a set of stocks", *Quantitative Finance*, 1, 96-104.
4. Caiado, J., Crato, N. and Peña, D. (2006). "A periodogram-based metric for time series classification", *Computational Statistics & Data Analysis*, 50, 2668-2684.
5. Caiado, J., Crato, N. and Peña, D. (2007). "Comparison of time series with unequal length", manuscript.
6. Engle, R. and Susmel, R. (1993). "Common volatility in international equity markets", *Journal of Business & Economic Statistics*, 11, 167-176.
7. Hui, T. (2005). "Portfolio diversification: a factor analysis approach", *Applied Financial Economics*, 15, 821-834.
8. Johnson, R. A. and Wichern, D. W. (1992). *Applied Multivariate Statistical Analysis.* 3rd Ed., Englewood Cliffs, Prentice-Hall.
9. Karolyi, G. and Stulz, R. (1996). "Why do markets move together? An investigation of U.S.-Japan return comovements", *The Journal of Finance*, 51, 951-986.
10. Lin, W., Engle, R. and Ito, T. (1994). "Do bulls and bears move across borders? International transmission of stock returns and volatility", *The Review of Financial Studies*, 7, 507-538.
11. Longin, F. and Solnik, B. (1995). "Is the correlation in international equity returns constant: 1960-1990?", *Journal of International Money and Finance*, 14, 3-26.
12. Mantegna, R. N. (1999). "Hierarchical structure in financial markets", *The European Physical Journal B*, 11, 193-197.
13. Morana, C. and Beltratti, A. (2007). "Comovements in international stock markets", *Journal of International Financial Markets, Institutions and Money*, in press.
14. Rita, D. and Costantini, M. (2006). "Comovements and correlations in international stock markets", *The European Journal of Finance*, 12, 567-582.
15. Syriopoulos, T. (2004). "International portfolio diversification to Central European stock markets", *Applied Financial Economics*, 14, 1253-1268.
16. Tahai, A., Rutledge, R. and Karim, K. (2004). "An examination of financial integra-

tion for the group of seven (G7) industrialized countries using an I(2) cointegration model", *Applied Financial Economics*, 14, 327-335.

17. Voronkova, S. (2004). "Equity market integration in Central European emerging markets: A cointegration analysis with shifting regimes", *International Review of Financial Analysis*, 13, 633-647.