Market Performance Effects on Pairs Trading Strategies:

Evidences on Banks' Equity Shares in Germany and Greece

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Abstract:

In this project, our research pertains to examination of market performance effects on pair-wise long-run relations between banks' shares trading in the German and Greek stock markets. In order to leave out any structural effects coming from the introduction of euro as a common currency, we choose to examine a seven years period of 2001:01:05-2007:12:28. The examined data contains one bust phase followed by a mild bullish period. Employing cointegration analysis, reported results initially indicate that, changes in market performance affect stability of long-run relations hence, suggesting that arbitrageurs should perform rebalancing between the examined stocks, in each pair, when a change in market trend is evident. In particular, extreme market performance harms the mean-reverting properties of the long-run relations while, moderate market performance points to one cointegrating vector which retains the characteristics implied in full-sample analysis. Applicability of our conclusions is important since; cointegration approach has recently received considerable attention from hedge funds' managers, adopting statistical arbitrage strategies, in order to determine the weights in their portfolios.

Keywords Cointegration • Pairs Trading Strategies

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I. Introduction and Literature Review

Present study pertains to examination of a market efficiency issue, considering pair-wise long-run relations between banks' shares trading in the German and Greek stock markets, under different market conditions, and their implications on the implementation of Statistical Arbitrage (SA) strategies. There is an enormous literature in financial economics concerning the validity of various forms of the Efficient Market Hypothesis (EMH), Cuthbertson (1996) provides a thorough review. EMH implies that in liquid markets, where asset prices will be the result of unconstrained demand and supply equilibria, the current price should accurately reflect all the information that is available to the players in the market. In other words, the price today is just yesterday's price plus a random term. This is why the model that is most commonly assumed for stock price movement is a log-normal process; that is, the logarithm of the stock price is assumed to exhibit a random walk. However, because the random walk is a martingale, the mean value of the predicted increment is zero. Therefore, knowing the past history of a random walk is not much help in predicting the forward-looking increments. The situation is very different for stationary processes. Armed with the knowledge that stationary processes are mean reverting, one can predict the increment to be greater than or equal to the difference between the current value and the mean. The prediction is guaranteed to hold true at some point in the future realizations of the time series.

Given that stock prices' predictability may lead to abnormal returns, testing mean reversion has been the objective of many researchers since 1960. While initial studies (Fama, 1965; Samuelson, 1965; Working, 1960) could not reject the random walk hypothesis however, posterior findings are mixed. There are studies suggesting stock prices are either mean reverting (Chaudhuri and Wu, 2004 and 2003; Balvers et al., 2000; Grieb and Reyes, 1999; Urrutia, 1995; Fama and French, 1988; Lo and MacKinlay, 1988; Poterba and Summers, 1988) or random walk (unit root) processes (Narayan and Narayan, 2007; Narayan and Smyth 2007 and 2004; Kawakatsu and Morey, 1999; Zhu, 1998; Choudhry, 1997; Huber, 1997; Liu et al., 1997).

Although there is no consensus as to whether stock prices are mean reverting or unit root processes, assuming that the joint hypothesis of risk neutrality and market efficiency holds (and thus lack of stock prices' mean-reversion property), we cannot apply trading strategies that rely upon unconditional variance in order to realize excess returns. However, previous researches suggest the existence of stationary linear relations among log data of share prices. Based on the latter result, prior literature suggests the construction of SA strategies exploiting the mean-reverting properties of linear relations among financial data (Jacobsen, 2008; Canjels et al., 2004; Hogan et al., 2004; Bondarenko, 2003; Laopodis and Sawhney, 2002; Tatom, 2002; Harasty and Roulet, 2000; Forbes et al., 1999; Wang and Yau, 1994).

Reviewing relevant literature, Gori (2009), Gatev et al. (2006) and Vidyamurthy (2004) mention that SA is attributed to Nunzio Tartaglia, a Wall Street quant who was at Morgan Stanley in the mid 1980s. Tartaglia's group of former academics used statistical methods to develop trading programs, executable through automated trading systems, which replaced traders' intuitions and skills with disciplined, consistent filter rules. SA is widely used by hedge funds, Wall Street companies, and even sophisticated independent investors trying to profit from temporary deviations of equity prices from their fundamental value. In academic literature, SA is opposed to (deterministic) arbitrage. In deterministic arbitrage a sure profit can be obtained from being long some securities and short others. In SA there is a statistical mispricing of one or more assets based on the expected value of these assets. In other words, SA conjectures statistical mispricings or price relationships that are true in expectation, in the long run when repeating a trading strategy. One of the most popular trading strategies is Pairs Trading (PT). PT is a very simple technique, "find two stocks whose prices nave historically moved together, when the spread between the two widens, short the winner and buy the loser: if history repeats itself, prices will converge and the arbitrageur will profit" (Pole, 2007). PT is a trading strategy which aims to exploit temporal deviations from an equilibrium price relationship between two securities. It is given by a long position in one security and a short position in another security in such a way that the resulting portfolio is market neutral (which typically translates in having a beta equal to zero). This portfolio is often called a spread. According to Gori (2009), considering spread modelling, among the more recent techniques we find cointegration as probably the most popular approach in quantitative trading strategies adopted by hedge funds and a reasonable amount of literature has been spent on it.

Main objective of the present study is to relate pair-wise cointegrating relations between banks' shares, trading in the German and Greek stock markets, with the implementation of SA strategies exploiting the mean-reversion property of the implied long-run relations. Bondarenko (2003) and Hogan et al. (2004) defined SA as an attempt to exploit the long-horizon trading opportunities revealed by cointegration relationships. Furthermore, according to Alexander and Dimitriu (2005), compared to other conventional methods, cointegration performs better as a way of applying SA strategies. Overall, cointegration methodology is a powerful tool for long-term investment analysis. A number of asset management firms are now basing allocations on cointegration analysis. In addition, when portfolios are constructed on the basis of returns analysis, frequent rebalancing will be necessary. However, as suggested by Alexander (2001), the power of cointegration analysis is that optimal portfolios may be constructed on the basis of common long-run trends between asset prices, and they will not require so much rebalancing.

Compared with previous research, present work extends existing literature by considering if changes in market performance, alternate the mean-reverting properties of long-run relations between equities and as a result, affects implementation of SA strategies on the variables under consideration. The examined data contains a bust phase followed by a mild bullish period. Employing cointegration analysis, reported results initially indicate that, changes in market performance affect stability of long-run relations hence, suggesting that arbitrageurs should perform rebalancing among the examined shares when a change in market trend is evident.

In particular, extreme market performance harms the mean-reverting properties of the long-run relations, which have been identified in full-sample analysis, while, moderate market performance points to cointegration between the examined stocks in each pair. However, absence of a stationary spread does not suggest, in any case, the potential of abnormal returns realization, in the short-run, through exploitation of deviations from its mean value. Since cointegration approach is widely used by hedge funds adopting SA or PT strategies, our results are of great importance suggesting that when a change in market performance is evident then fund managers should have in mind the necessity of rebalancing.

The structure of the rest of this paper includes a description of the examined data, in Section II, and research organization along with the employed methodology, in section III, followed by model specification and results on cointegration rank tests as well as tested hypotheses, in Section IV. Finally, section V provides summary and conclusions.

II. Data Description

Data employed in this paper includes closing prices with weekly frequency of banks' shares trading in Deutsche Boerse and Athens Stock Exchange. In order to leave out any structural effects coming from the introduction of euro, we choose to examine a seven years period of *2001:01:05-2007:12:28*. The examined stocks are Deutsche Bank and Commerzbank from the German market and National Bank, Alpha Bank, Cyprus Bank, EFG Eurobank Ergasias, Piraeus Bank and Marfin Bank from the Greek market. Our choice of stock variables relies on our objective to examine all shares constituting the sector indices in each of the two markets as well as on data availability for the examined seven years period. Apart from the local sector indices the examined shares are constituents of two popular market performance indices namely, DAX 30 for the German market and FTSE/ASE 20 for the Greek market.

In order to examine cointegrating relations between pairs of the examined shares, under different market conditions, we have split the sample into two sub-samples. In Figure 1, we can visually examine the performance of FTSE/ASE 20 and DAX 30 indices, for the examined seven years period. Although structural change is obvious, from visual inspection of data in Figure 1, in order to further justify our choice to split the sample, we apply a breakpoint test, suggested by Chow (1960), on a linear regression of the relationship between pairs of stocks that appear to be cointegrated in the first part of our econometric analysis, employing data for the whole sample.[1] According to the results of Chow test, reported in Table 1, with a zero p-value, we reject in all cases the null of no breaks at the starting point of the second sub-sample. In addition to the latter documentation of the two sub-samples, in order to reveal market performance, we define positive (negative) weekly index returns as Up (Down) market returns. Furthermore, following Fabozzi and Francis (1977), we redefine Up (Down) market returns as Substantially Up (Substantially Down) market returns when the weekly return of an index is larger (lower) than the sum (difference) between average market return and half of one standard deviation measured over the full sample.

Considering market performance of the German DAX 30 index, in the first sub-sample there are 48 Up and 67 Down market returns while 79.10% of the latter returns are also Substantially Down market returns. In second sub-sample there are 154 Up and 96 Down market returns while 48.70% of the former returns are also Substantially Up market returns.

Examining market performance of the Greek FTSE/ASE 20 100 index, in the first sub-sample there are 47 Up and 68 Down market returns while 73.53% of the latter returns are also Substantially Down market returns. In second sub-sample there are

[1] Our choice to apply Chow breakpoint test, on four bivariate linear regressions between log data of the examined shares, is justified by the results of our analysis in Section III where, employing full-sample data, Tables 2a-g indicate four existing pair-wise cointegrating relations among the examined variables.

149 Up and 101 Down market returns while 53.69% of the former returns are also Substantially Up market returns.

While there is no commonly agreed-upon definition for a “bear” market, broadly defined, a “bear” market represents a substantial decline of at least 20% in stock prices over a period of several months. This characteristic is met in market performance of both examined indices in the first sub-sample. Furthermore, examining each stock market index, in the first sub-period, we find that the number of Down returns characterized as Substantially Down returns is sufficiently higher than 50% thus, we identify first sub-sample as “extreme downtrend period”.

According to market analysts, a “bull” market is a prolonged period in which share prices raise faster than their historical average. Considering individual market performance of each stock market index, in the second sub-period, we find that the number of Up returns characterized as Substantially Up returns is 48.70% and 53.69% for DAX 30 and FTSE/ASE 20, respectively. That is, only for FTSE/ASE 20 the number of Up returns characterized as Substantially Up returns is slightly higher than 50% thus, we identify second sub-sample as a “Non-extreme uptrend period”.

Overall, the sample under consideration contains “extreme downtrend period” followed by “non-extreme uptrend period”. “Non-extreme uptrend period” is characterized as a period of moderate market performance and “extreme downtrend period” is thought to be a period of extreme market performance. “Extreme downtrend period” falls within the sub-sample of *2001:01:05-2003:03:14* and the data include 115 observations. “Non-extreme uptrend period” falls within the sub-sample of *2003:03:21-2007:12:28* and the data comprises of 250 observations.

III. Methodology and Research Organization

The empirical section has three parts. First, employing full-sample data we investigate the existence of cointegrated pairs among all possible pairs of the examined shares. In the second part of our analysis, splitting the sample into two sub-periods we examine if market performance affects evidences about cointegrating relations indicated by the results of the first empirical part. Finally, as indicated by the results of the second part, in the third empirical part we shed more light on the second sub-sample, characterized as “non-extreme uptrend period”, in order to reveal differences between cointegrating relations from full-sample and second sub-sample data.

We apply the Johansen (1988 and 1996) and Johansen and Juselius (1990) methodology of the Cointegrated VAR Model. As noted by Gonzalo (1994) and Kremers et al. (1992), the Johansen and Juselius approach performs better or at least as well as the Dickey-Fuller cointegration test of Engle and Granger (1987). In addition, the selected procedure is invariant to different normalizations (Hamilton, 1994) and thus the test outcome does not depend on the chosen normalization. Our results were obtained using CATS in RATS version 2 (Dennis et al., 2005).

The error correction form of the examined unrestricted VAR model is described below:

$$\Delta x_t = \Pi x_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta x_{t-i} + \phi D_t + \varepsilon_t, \qquad \varepsilon_t \sim iid\ N_p(0,\Omega), \qquad t = 1,\dots,T \tag{1}$$

where, x_t is a vector of two variables: $[li_t,\ \ lj_t] \sim I(1)$, (2)

and D_t is a vector of deterministic variables such as a constant and intervention dummies.

The set of variables is defined by:

li_t: weakly closing prices (in logs) of bank i,

lj_t: weakly closing prices (in logs) of bank j.

Notation of the examined banks' shares is: lge_{1t} for Deutsche Bank, lge_{2t} for Commerzbank, lgr_{1t} for National Bank, lgr_{2t} for Alpha Bank, lgr_{3t} for Cyprus Bank, lgr_{4t} for EFG Eurobank Ergasias, lgr_{5t} for Piraeus Bank and lgr_{6t} for Marfin Bank.

We do not think appropriate to include a linear trend in our model, because then it would be like assuming that stock prices are predictable which is highly unlikely. In the main part of our analysis we choose to restrict the constant term to lie in the cointegrating space and in addition, when proper, we include dummy variables, as unrestricted to the cointegrating space.

Performing model specification, we choose the optimal number of lags using Schwarz, Hannan-Quinn and Akaike Information Criteria along with a Likelihood Ratio (LR) test. Following Juselius and MacDonald (2003), in order to secure valid statistical inference we need to control for the largest of observations by dummy variables or leave out the most volatile periods from our sample. Since the volatile periods could potentially be very informative we choose the former alternative. The dummy variables used in our models are permanent impulse dummies $Dyyyy.mm.dd_t$ (are equal to one at *yyyy:mm:dd*, and equal to zero otherwise).

Performing cointegration tests our main objective is to investigate if there is a long-run relation, with a non-zero intercept, between the examined banks' shares in each pair. Applying Johansen (1988 and 1996) and Johansen and Juselius (1990) methodology of the cointegrated VAR model, we examine the existence of a long-run relation with a non-zero intercept based upon the estimated eigenvalues, $\hat{\lambda}_i$, and the trace test, τ_{p-r}.

In addition, we perform hypotheses testing regarding multivariate stationarity, univariate normality and variable exclusion. In the presence of I(1) series, Johansen and Juselius (1990) developed a multivariate stationarity test which has become the standard tool for determining the order of integration of the series within the multivariate context. Multivariate stationarity test is a LR test distributed as chi-square with (p-r) degrees of freedom, [$\chi^2(1)_{95\%}$=3.841]. Testing univariate normality we apply Doornik and Hansen (2008) test, distributed as $\chi^2(2)$, [$\chi^2(2)_{95\%}$=5.991]. In order to test variable exclusion we apply a LR test distributed as chi-square with r degrees of freedom.

Furthermore, focusing on the cointegrated pairs of banks' shares, we perform long-run identification of the existent cointegrating relations through testing the validity of over-identifying restrictions. First, we test the null hypothesis of long-run weak exogeneity for each stock constituting the examined pair. According to Juselius (2006), the hypothesis that a variable has influenced the long-run stochastic path of the other variables of the system, while at the same time has not been influenced by them, is called the hypothesis of "no levels feedback" or long-run weak exogeneity. Long-run weak exogeneity test is a LR test distributed as chi-square with r degrees of freedom. Second, testing if cumulating shocks driving the system have exactly the same influence on both variables (li_t and lj_t) we examine if the hypothesis of long-run homogeneity holds. That is, we examine if the cointegrating vector is (1, -1) implying stationarity of the spread calculated as the difference (li_t-lj_t) between the log-price series of banks' shares in each cointegrated pair. In addition, in cases where results, of long-run weak exogeneity test, point to the identification of the common stochastic trend, we apply a joint test of long-run weak exogeneity and long-run homogeneity hypotheses.

Finally, in order to further justify our suggestions, we apply the Augmented Dickey-Fuller (ADF) technique (Dickey and Fuller, 1981) testing the null hypothesis that the spread has a unit root.

IV. Model Specification and Results on Cointegration Rank and Tested Hypotheses

As already mentioned, performing model specification, we choose the optimal number of lags using Schwarz, Hannan-Quinn and Akaike Information Criteria along with a LR test while; in order to secure valid statistical inference, we choose to control for the largest of observations by dummy variables.

In the first part of our analysis, examining full-sample data, for twenty eight pairs of banks' shares, we have employed a model, with one or two lags, described in eq. (3).

$$\Delta x_t = \alpha\left(\beta', \rho'\right)\begin{pmatrix} x_{t-1} \\ 1 \end{pmatrix} + \sum_{i=1}^{k-1}\Gamma_i \Delta x_{t-i} + \phi D_t + \varepsilon_t \tag{3}$$

where, *k* equals the number of lags minus 1.

Being confident enough about the specification of our model, we shall try to determine the rank. Reported results, in Tables 2a-g, suggest that, in four cases, the null hypothesis of r=0 is rejected while a cointegration rank equal to one is accepted, with 95% significance. Overall, for the pairs of lge_{1t}-lgr_{6t}, lge_{2t}-lgr_{6t}, lgr_{3t}-lgr_{4t} and lgr_{3t}-lgr_{5t}, we have evidence that, our system contains one cointegrating relation and as a result one common trend.

Considering results reported in Tables 2a-g, further analyzing the four cointegrated pairs (lge_{1t}-lgr_{6t}, lge_{2t}-lgr_{6t}, lgr_{3t}-lgr_{4t} and lgr_{3t}-lgr_{5t}), with rank=1, we cannot accept the exclusion of any of the variables of the system. Overall, in each of the four cases, we have a system where the employed variables are non-stationary and significant hence, they cannot be excluded. Univariate normality test outcomes suggest that residuals properties are in acceptable levels. The rest of our analysis, in this part, is focused on the four cointegrated pairs. That is, as described below, performing detailed long run identification, we shall test the validity of over-identifying restrictions on the implied cointegrated vectors.

Examining the dynamics of each system, we perform hypotheses testing. In Tables 3a-d, we begin our analysis with the unrestricted model $\mathcal{H}_1$, normalizing the β vector to lgr_{6t}, in the first two cases (Tables 3a and 3b), to lgr_{4t}, in the second case (Table 3c), and to lgr_{5t}, in the fourth case (Table 3d). Although, normalization of each cointegrated vector leads to identified cointegrating relations, we choose to impose over-identifying restrictions.

First, given the importance of a zero error correction term, employing models $\mathcal{H}_2$ and $\mathcal{H}_3$, we test the validity of long-run weak exogeneity hypothesis, for both shares constituting each pair. Estimated coefficients of the error correction terms represent the short-run speed of adjustment; their magnitude and significance are of great importance regarding the results of our study. If the coefficient of either term is zero, then the error correction comes from only one variable. Reported results, in Table 3a, indicate rejection of the hypothesis of long-run weak exogeneity for both shares constituting the first pair (lge_{1t}-lgr_{6t}). That is, in the first case, we cannot distinguish between the pushing force (common stochastic trend) and the adjusting process of the system. Considering the rest three pairs (lge_{2t}-lgr_{6t}, lgr_{3t}-lgr_{4t} and lgr_{3t}-lgr_{5t}), results reported, in Tables 3b, 3c and 3d, indicate that, we cannot reject the hypothesis of long-run weak exogeneity for Commerzbank, EFG Eurobank Ergasias and Marfin Bank, respectively. Overall, Marfin Bank from the Greek market is cointegrated with each one of examined German banks' shares. However, only in the cointegrated relation between Marfin Bank and Commerzbank we have evidence of a well established system where, Commerzbank is the pushing variable while, Marfin Bank is purely adjusting. Cyprus Bank is identified as the adjusting variable in the rest two cases where, we identify EFG Eurobank Ergasias and Marfin Bank as the pushing variable of the third and fourth pair, respectively.

Regarding the second over-identifying restriction, employing model $\mathcal{H}_4$, we test the null hypothesis of long-run homogeneity between share prices in each pair. Reported results, considering model $\mathcal{H}_4$ (in Tables 3a-d), indicate rejection of long-run homogeneity hypothesis in three pairs (lge_{1t}-lgr_{6t}, lgr_{3t}-lgr_{4t} and lgr_{3t}-lgr_{5t}). Therefore, the hypothesis of long-run homogeneity holds just in the second case. That is, cumulating shocks driving the system have exactly the same influence on both variables (lge_{2t} and lgr_{6t}) hence; considering the second pair, constituted by the log-price series of Commerzbank and Marfin Bank, the cointegrating vector is (1, -1). Moreover, examining model $\mathcal{H}_5$, we accept the null joint hypothesis of long-run weak exogeneity and long-run homogeneity, just in the second case.

Overall, apart from the first pair where we could not distinguish between the stochastic trend and the adjusting process of the system; considering the rest cases, we detect three well established cointegrating relations. Summing up, cointegrating relation β_2, implied by model $\mathcal{H}_5$ (Table 3b), and long-run relations β_3 and β_4, implied by model $\mathcal{H}_3$ (Tables 3c and 3d, respectively), are:

$$\beta_2: \quad lgr_{6t} = \underset{(-34.656)}{-1.729} + lge_{2t} + stat.error. \tag{4}$$

$$\beta_3: \quad lgr_{3t} = \underset{(-6.383)}{-5.088} + \underset{(8.149)}{2.471} \times lgr_{4t} + stat.error. \tag{5}$$

$$\beta_4: \quad lgr_{3t} = \underset{(-6.039)}{-1.518} + \underset{(11.803)}{1.249} \times lgr_{5t} + stat.error. \tag{6}$$

The above described cointegrating relations (β_2, β_3 and β_4) seem to be stable in the short run as well, as we can infer from the negative sign and significance of the coefficient corresponding to Δlgr_{6t} (model $\mathcal{H}_5$, in Table 3b) and Δlgr_{3t}, (model $\mathcal{H}_3$, in Tables 3c and 3d, respectively) reported in α matrix. In other words, the share prices of banks identified as the adjusting processes seem to adjust very well to the long-run relations.

Cointegrating vector β_2 suggests a positive long-run relation between the share prices of Commerzbank and Marfin Bank which cancels the common trend identified by Commerzbank while; given statistical significance and sign of the constant term (restricted to the cointegrating space), the presence of a nonzero but mean-reverting spread is verified. That is, eq. (4) suggests that, any shock coming from Commerzbank will have the same effect to each of banks' share prices (long-run homogeneity hypothesis), implying that the share prices of Marfin Bank truly reflect the performance of Commerzbank. Moreover, we should note here that, acceptance of long-run homogeneity hypothesis points to the identification of the spread as an I(0) process. Performing ADF unit root tests on the spread (calculated as the difference between lge_{2t} and lgr_{6t}), choice of lag structure relies upon results from Akaike and Bayesian Information Criteria. However, results, reported in Table 4, indicate acceptance of the null hypothesis (with 95% and 99% significance) that the discount is I(1) and do not support our latter suggestion.

In the second empirical part, our analysis is focused on the three pairs (lge_{2t}-lgr_{6t}, lgr_{3t}-lgr_{4t} and lgr_{3t}-lgr_{5t}) where well established cointegrating relations have been detected. Splitting the examined sample in two sub-periods, we perform cointegration tests and hypotheses testing in each subsample. We have employed a model with one lag in the first sub-period and a model with one or two lags in the second sub-period. In order to secure valid statistical inference, we choose to control for the largest of observations by dummy variables. Equation (3) describes the model employed in the two sub-periods.

Reported results, in Table 5, suggest the acceptance of a cointegration rank equal to zero regarding all examined pairs, in the first sub-period. On the other hand, as indicated by the results in Table 6, considering the second sub-period, with 95% significance, the null hypothesis of r=0 is rejected while, a cointegration rank equal to one is accepted, in all cases.

Given the previously mentioned results of cointegration tests, in the third part of our analysis, we focus in the second sub-period in order to perform long-run identification of the three cointegrated pairs. Proceeding in the same line as in the first empirical part, we examine the dynamics of each system, performing hypotheses testing. In Tables 7a-c, we begin our analysis with the unrestricted model $\mathcal{H}_1$, normalizing the β vector to lge_{2t}, in the first case (Table 7a), to lgr_{4t}, in the second case (Table 7b), and to lgr_{5t}, in the third case (Table 7c). Although, normalization of each cointegrated vector leads to identified cointegrating relations, we choose to impose over-identifying restrictions.

First, given the importance of a zero error correction term, employing models $\mathcal{H}_2$ and $\mathcal{H}_3$, we test the validity of long-run weak exogeneity hypothesis, on both shares constituting each pair. Reported results, in Table 7a, indicate rejection of the hypothesis of long-run weak exogeneity for each of the shares of Commerzbank and Marfin Bank. That is, we cannot distinguish between the stochastic trend and the adjusting process of the system, in that case. Considering the next pair (lgr_{3t}-lgr_{4t}), results, reported in Table 7b, indicate that, we cannot reject the hypothesis of long-run weak exogeneity for either Cyprus Bank or EFG Eurobank Ergasias. Finally, in the last pair (lgr_{3t}-lgr_{5t}), results, reported in Table 7c, indicate that, we cannot reject the hypothesis of long-run weak exogeneity for Piraeus Bank. Overall, only in the cointegrated relation between Cyprus Bank and Piraeus Bank we have evidence of a well established system where, Piraeus Bank is the pushing variable while, Cyprus Bank is purely adjusting.

Regarding the second over-identifying restriction, employing model $\mathcal{H}_4$, we test the null hypothesis of long-run homogeneity between share prices in each pair. Reported results, considering model $\mathcal{H}_4$ (in Tables 7a-c), indicate rejection of long-run homogeneity hypothesis in all the examined pairs. Therefore, there is no evidence of a cointegrated vector (1, -1) in any case. Moreover, employing model $\mathcal{H}_5$, in the first and last case (Tables 7a and 7c, respectively) and examining models $\mathcal{H}_5$ and $\mathcal{H}_6$ in the second case (Table 7b) we reject the null joint hypothesis of long-run weak exogeneity and long-run homogeneity, in all the examined pairs. Results from Augmented Dickey-Fuller (Dickey and Fuller, 1981) unit root tests (Table 8) verify our evidence indicating, with 99% significance, acceptance of the null hypothesis that all the examined spreads are I(1).

Overall, considering all cases, we detect just one well established cointegrating relation. Summing up, cointegrating relation β_4, implied by model $\mathcal{H}_3$ (Tables 7c) is:

$$\beta_4 : \quad lgr_{3t} = \underset{(-6.367)}{-1.733} + \underset{(12.493)}{1.329} \times lgr_{5t} + stat.error. \tag{7}$$

The above described cointegrating relation, β_4, seems to be stable in the short run as well, as we can infer from the negative sign and significance of the coefficient corresponding to Δlgr_{3t} (model $\mathcal{H}_3$, in Table 7c), reported in α matrix. In other words, the share prices of Cyprus Bank, identified as the adjusting processes, seem to adjust very well to the long-run relation between Cyprus Bank and Piraeus Bank.

V. Summary and Conclusions

According to Alexander (2008), the prices (and log prices) of stocks are integrated, and integrated processes have infinite unconditional variance hence; there is little point in trying to use past prices to forecast future prices in a univariate time series model. However, when two or more shares are cointegrated, there is a multivariate model revealing information about the long-run equilibrium in the system.

Investigating pair-wise long-run relations between banks' shares, trading in the German and Greek stock markets, we have found three well established cointegrating relations. In addition, we have found that, in one of these pairs; the cointegrated vector is (1, -1) pointing to the mean-reversion of the spread between the prices series of the two examined banks' shares. Based on that finding, one could set up a SA strategy in order to exploit the mean reverting properties of the spread. However, an arbitrageur should be skeptic considering that, the results from unit root test indicate an I(1) process for the spread.

Compared with previous research, present work extends existing literature by considering pair-wise long-run relations between log-prices of stocks, under different market conditions, and their implications on the implementation of SA strategies. Applicability of our results is important since; cointegration approach has recently received considerable attention from hedge funds adopting SA or PT strategies.

Taking into account a structural change due to alternation in market performance, our results indicate that, one should be cautious about applying such strategies. That is, further investigating the long-run relations among the examined stocks, we have split the sample into two sub-periods in order to re-examine the suggested linear relations under different market conditions. The examined sub-samples contain a bust phase followed by a mild bullish period.

Employing cointegration analysis, reported results initially indicate that, changes in market performance affect stability of long-run relations hence, suggesting that arbitrageurs should perform rebalancing among the examined shares when a change in market trend is evident. In particular, extreme market performance harms the mean-reverting properties of the three long-run relations while, moderate market performance points to cointegration between the examined stocks in each pair. Furthermore, under moderate market performance, we have found that there is just one well established cointegrating relation that retains the same characteristics shown in the analysis of the full-sample. However, absence of a stationary spread does not suggest, in any case, the potential of abnormal returns realization, in the short-run, through exploitation of deviations from its mean value.

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Figures

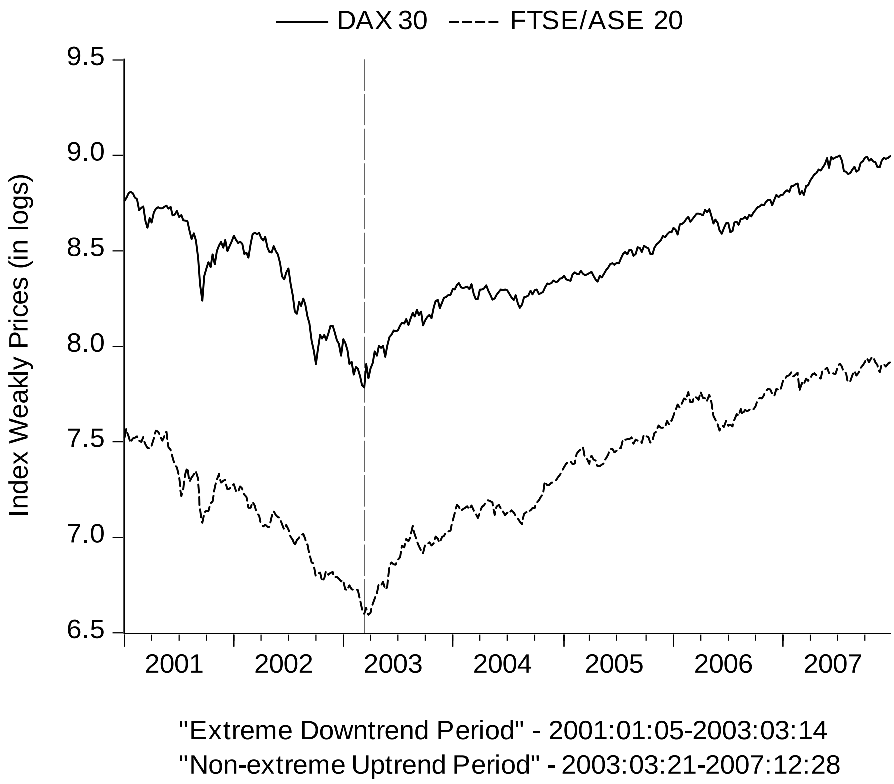

Figure 1 Plots of data (weakly index prices) in logs

Tables

Table 1 Chow's breakpoint test

Pairs of Stocks	*F-stats*	*p-values*
lge_{1t} , lgr_{6t}	53.697	(0.000)
lge_{2t} , lgr_{6t}	92.117	(0.000)
lgr_{3t} , lgr_{4t}	62.101	(0.000)
lgr_{3t} , lgr_{5t}	99.270	(0.000)

Table 2a Bivariate trace tests for cointegration rank and hypotheses testing (full sample)

# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lge_{1t}	lge_{2t}
2	0	2	1	0.038	15.308[b]	20.164	10.882[i,a]	12.712[i,a]
	1	1	2	0.003	1.151[b]	9.142	0.221[ii,b]	5.530[ii,b]
							12.712[iii,a]	10.882[iii,a]

# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lge_{1t}	lgr_{1t}
2	0	2	1	0.027	11.703[b]	20.164	6.389[i,a]	8.257[i,a]
	1	1	2	0.005	1.652[b]	9.142	0.229[ii,b]	1.812[ii,b]
							8.257[iii,a]	6.389[iii,a]

# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lge_{1t}	lgr_{2t}
1	0	2	1	0.034	12.957[b]	20.164	9.294[i,a]	11.771[i,a]
	1	1	2	0.002	0.551[b]	9.142	2.032[ii,b]	5.078[ii,b]
							11.771[iii,a]	9.294[iii,a]

# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lge_{1t}	lgr_{3t}
1	0	2	1	0.033	13.389[b]	20.164	4.095[i,a]	9.810[i,a]
	1	1	2	0.003	1.218[b]	9.142	0.754[ii,b]	5.317[ii,b]
							9.810[iii,a]	4.095[iii,a]

# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lge_{1t}	lgr_{4t}
1	0	2	1	0.019	7.717[b]	20.164	4.369[i,a]	5.954[i,a]
	1	1	2	0.002	0.881[b]	9.142	2.763[ii,b]	1.610[ii,b]
							5.954[iii,a]	4.369[iii,a]

# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lge_{1t}	lgr_{5t}
1	0	2	1	0.028	13.935[b]	20.164	5.677[i,a]	6.004[i,a]
	1	1	2	0.010	3.773[b]	9.142	0.272[ii,b]	4.803[ii,b]
							6.004[iii,a]	5.677[iii,a]

# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lge_{1t}	lgr_{6t}
1	0	2	1	0.070	28.457[a]	20.164	20.108[i,a]	21.126[i,a]
	1	1	2	0.005	1.865[b]	9.142	1.586[ii,b]	2.361[ii,b]
							21.126[iii,a]	20.108[iii,a]

[a] Rejection of the null with 95% significance
[b] Acceptance of the null with 95% significance
[i] Multivariate Stationarity test is a LR test, distributed as $\chi^2(1)$
[ii] Doornik and Hansen (2008) univariate normality test, distributed as $\chi^2(2)$
[iii] Variable Exclusion is a LR test, distributed as $\chi^2(1)$

Table 2b Bivariate trace tests for cointegration rank and hypotheses testing (full sample)

# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lge_{2t}	lgr_{1t}
1	0	2	1	0.023	10.092[b]	20.164	5.818[i,a]	6.724[i,a]
	1	1	2	0.004	1.513[b]	9.142	1.789[ii,b]	3.678[ii,b]
							6.724[iii,a]	5.818[iii,a]
# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lge_{2t}	lgr_{2t}
1	0	2	1	0.028	11.792[b]	20.164	8.566[i,a]	6.822[i,a]
	1	1	2	0.004	1.609[b]	9.142	4.048[ii,b]	4.698[ii,b]
							6.822[iii,a]	8.566[iii,a]
# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lge_{2t}	lgr_{3t}
1	0	2	1	0.010	3.775[b]	20.164	0.320[i,b]	1.751[i,b]
	1	1	2	0.000	0.105[b]	9.142	3.971[ii,b]	5.620[ii,b]
							1.751[iii,b]	0.320[iii,b]
# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lge_{2t}	lgr_{4t}
1	0	2	1	0.019	8.246[b]	20.164	4.648[i,a]	5.459[i,a]
	1	1	2	0.004	1.371[b]	9.142	3.621[ii,b]	1.357[ii,b]
							5.459[iii,a]	4.648[iii,a]
# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lge_{2t}	lgr_{5t}
1	0	2	1	0.015	9.150[b]	20.164	2.133[i,b]	2.155[i,b]
	1	1	2	0.009	3.466[b]	9.142	3.092[ii,b]	4.164[ii,b]
							2.155[iii,b]	2.133[iii,b]
# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lge_{2t}	lgr_{6t}
1	0	2	1	0.056	21.417[a]	20.164	13.969[i,a]	14.851[i,a]
	1	1	2	0.002	0.549[b]	9.142	1.150[ii,b]	1.845[ii,b]
							14.851[iii,a]	13.969[iii,a]

[a] Rejection of the null with 95% significance
[b] Acceptance of the null with 95% significance
[i] Multivariate Stationarity test is a LR test, distributed as $\chi^2(1)$
[ii] Doornik and Hansen (2008) univariate normality test, distributed as $\chi^2(2)$
[iii] Variable Exclusion is a LR test, distributed as $\chi^2(1)$

Table 2c Bivariate trace tests for cointegration rank and hypotheses testing (full sample)

# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{1t}	lgr_{2t}
1	0	2	1	0.042	16.144[b]	20.164	14.468[i,a]	13.013[i,a]
	1	1	2	0.001	0.368[b]	9.142	2.455[ii,b]	0.273[ii,b]
							13.013[iii,a]	14.468[iii,a]
# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{1t}	lgr_{3t}
1	0	2	1	0.049	18.783[b]	20.164	9.907[i,a]	17.319[i,a]
	1	1	2	0.002	0.603[b]	9.142	1.638[ii,b]	3.088[ii,b]
							17.319[iii,a]	9.907[iii,a]
# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{1t}	lgr_{4t}
1	0	2	1	0.026	10.963[b]	20.164	8.123[i,a]	7.692[i,a]
	1	1	2	0.003	1.263[b]	9.142	0.953[ii,b]	0.342[ii,b]
							7.692[iii,a]	8.123[iii,a]
# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{1t}	lgr_{5t}
2	0	2	1	0.014	7.060[b]	20.164	2.443[i,b]	2.083[i,b]
	1	1	2	0.005	1.975[b]	9.142	1.610[ii,b]	0.391[ii,b]
							2.083[iii,b]	2.443[iii,b]
# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{1t}	lgr_{6t}
2	0	2	1	0.026	12.496[b]	20.164	2.825[i,b]	2.469[i,b]
	1	1	2	0.008	2.902[b]	9.142	1.791[ii,b]	1.355[ii,b]
							2.469[iii,b]	2.825[iii,b]

[a] Rejection of the null with 95% significance
[b] Acceptance of the null with 95% significance
[i] Multivariate Stationarity test is a LR test, distributed as $\chi^2(1)$
[ii] Doornik and Hansen (2008) univariate normality test, distributed as $\chi^2(2)$
[iii] Variable Exclusion is a LR test, distributed as $\chi^2(1)$

Table 2d Bivariate trace tests for cointegration rank and hypotheses testing (full sample)

# lags	r	p-r	i	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{2t}	lgr_{3t}
2	0	2	1	0.052	19.285[b]	20.164	4.996[i,a]	15.786[i,a]
	1	1	2	0.000	0.051[b]	9.142	1.043[ii,b]	2.334[ii,b]
							15.786[iii,a]	4.996[iii,b]

# lags	r	p-r	i	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{2t}	lgr_{4t}
1	0	2	1	0.022	8.843[b]	20.164	7.491[i,a]	7.457[i,a]
	1	1	2	0.002	0.652[b]	9.142	0.644[ii,b]	1.532[ii,b]
							7.457[iii,a]	7.491[iii,a]

# lags	r	p-r	i	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{2t}	lgr_{5t}
1	0	2	1	0.023	9.697[b]	20.164	4.284[i,a]	5.600[i,a]
	1	1	2	0.003	1.185[b]	9.142	0.470[ii,b]	3.588[ii,b]
							5.600[iii,a]	4.284[iii,a]

# lags	r	p-r	i	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{2t}	lgr_{6t}
2	0	2	1	0.021	10.772[b]	20.164	2.149[i,b]	1.729[i,b]
	1	1	2	0.008	2.893[b]	9.142	0.658[ii,b]	2.274[ii,b]
							1.729[iii,b]	2.149[iii,b]

[a] Rejection of the null with 95% significance
[b] Acceptance of the null with 95% significance
[i] Multivariate Stationarity test is a LR test, distributed as $\chi^2(1)$
[ii] Doornik and Hansen (2008) univariate normality test, distributed as $\chi^2(2)$
[iii] Variable Exclusion is a LR test, distributed as $\chi^2(1)$

Table 2e Bivariate trace tests for cointegration rank and hypotheses testing (full sample)

# lags	r	p-r	i	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{3t}	lgr_{4t}
2	0	2	1	0.057	22.541[a]	20.164	17.567[i,a]	7.292[i,a]
	1	1	2	0.003	1.238[b]	9.142	1.187[ii,b]	1.276[ii,b]
							7.292[iii,a]	17.567[iii,a]

# lags	r	p-r	i	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{3t}	lgr_{5t}
1	0	2	1	0.056	22.368[a]	20.164	19.782[i,a]	15.310[i,a]
	1	1	2	0.003	1.219[b]	9.142	3.488[ii,b]	2.297[ii,b]
							15.310[iii,a]	19.782[iii,a]

# lags	r	p-r	i	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{3t}	lgr_{6t}
2	0	2	1	0.031	13.136[b]	20.164	0.760[i,b]	0.002[i,a]
	1	1	2	0.005	1.748[b]	9.142	2.296[ii,b]	0.636[ii,b]
							0.002[iii,a]	0.760[iii,b]

[a] Rejection of the null with 95% significance
[b] Acceptance of the null with 95% significance
[i] Multivariate Stationarity test is a LR test, distributed as $\chi^2(1)$
[ii] Doornik and Hansen (2008) univariate normality test, distributed as $\chi^2(2)$
[iii] Variable Exclusion is a LR test, distributed as $\chi^2(1)$

Table 2f Bivariate trace tests for cointegration rank and hypotheses testing (full sample)

# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{4t}	lgr_{5t}
1	0	2	1	0.025	9.747[b]	20.164	5.821[i,a]	7.057[i,a]
	1	1	2	0.002	0.632[b]	9.142	1.182[ii,b]	2.305[ii,b]
							7.057[iii,a]	5.821[iii,a]
# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{4t}	lgr_{6t}
2	0	2	1	0.027	12.252[b]	20.164	2.938[i,b]	2.804[i,b]
	1	1	2	0.006	2.316[b]	9.142	1.309[ii,b]	0.541[ii,b]
							2.804[iii,b]	2.938[iii,b]

[a] Rejection of the null with 95% significance
[b] Acceptance of the null with 95% significance
[i] Multivariate Stationarity test is a LR test, distributed as $\chi^2(1)$
[ii] Doornik and Hansen (2008) univariate normality test, distributed as $\chi^2(2)$
[iii] Variable Exclusion is a LR test, distributed as $\chi^2(1)$

Table 2g Bivariate trace tests for cointegration rank and hypotheses testing (full sample)

# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{5t}	lgr_{6t}
2	0	2	1	0.041	18.369[b]	20.164	0.532[i,b]	0.042[i,b]
	1	1	2	0.009	3.172[b]	9.142	3.936[ii,b]	0.216[ii,b]
							0.042[iii,a]	0.532[iii,b]

[a] Rejection of the null with 95% significance
[b] Acceptance of the null with 95% significance
[i] Multivariate Stationarity test is a LR test, distributed as $\chi^2(1)$
[ii] Doornik and Hansen (2008) univariate normality test, distributed as $\chi^2(2)$
[iii] Variable Exclusion is a LR test, distributed as $\chi^2(1)$

Table 3a Long run identification of cointegrated pair: lge_{1t} , lgr_{6t} (full sample)

	$\mathcal{H}_1$		$\mathcal{H}_2$		$\mathcal{H}_3$		$\mathcal{H}_4$	
	$\hat{\alpha}_1$	$\hat{\beta}_1$	$\hat{\alpha}_1$	$\hat{\beta}_1$	$\hat{\alpha}_1$	$\hat{\beta}_1$	$\hat{\alpha}_1$	$\hat{\beta}_1$
lge_{1t}	0.030	-1.703	0	-1.626	-0.073	1	-0.008	1
	(3.009)	(-12.522)		(-9.516)	(-4.044)		(-1.087)	
lgr_{6t}	-0.039	1	-0.047	1	0	-0.560	0.023	-1
	(-3.291)		(-4.232)			(-9.526)	(2.835)	
Constant		6.017		5.714		-3.550		-3.104
		(10.297)		(7.784)		(-42.654)		(-40.068)
Log-Likelihood	2438.652		2434.487		2433.681		2431.053	
LR statistic			8.331		9.942		15.198	
p-value			0.004		0.002		0.000	
			$\chi^2(1)$		$\chi^2(1)$		$\chi^2(1)$	

Numbers in brackets are t-ratios

Table 3b Long run identification of cointegrated pair: lge_{2t} , lgr_{6t} (full sample)

	$\mathcal{H}_1$		$\mathcal{H}_2$		$\mathcal{H}_3$		$\mathcal{H}_4$		$\mathcal{H}_5$	
	$\hat{\alpha}_2$	$\hat{\beta}_2$	$\hat{\alpha}_2$	$\hat{\beta}_2$	$\hat{\alpha}_2$	$\hat{\beta}_2$	$\hat{\alpha}_2$	$\hat{\beta}_2$	$\hat{\alpha}_2$	$\hat{\beta}_2$
lge_{2t}	0.001	-0.977	0	-0.974	-0.012	1	0.001	-1	0	-1
	(0.123)	(-8.560)		(-8.549)	(-1.369)		(0.154)			
lgr_{6t}	-0.041	1	-0.041	1	0	-0.722	-0.040	1	-0.040	1
	(-4.473)		(-4.504)			(-1.734)	(-4.461)		(-4.499)	
Constant		1.657		1.650		-2.092		1.728		1.729
		(4.832)		(4.816)		(-3.526)		(34.680)		(34.656)
Log-Likelihood	2402.761		2402.754		2393.277		2402.743		2402.731	
LR statistic			0.015		18.968		0.036		0.060	
p-value			0.903		0.000		0.849		0.971	
			$\chi^2(1)$		$\chi^2(1)$		$\chi^2(1)$		$\chi^2(2)$	

Numbers in brackets are t-ratios

Table 3c Long run identification of cointegrated pair: lgr_{3t} , lgr_{4t} (full sample)

	$\mathcal{H}_1$		$\mathcal{H}_2$		$\mathcal{H}_3$		$\mathcal{H}_4$		$\mathcal{H}_5$	
	$\hat{\alpha}_3$	$\hat{\beta}_3$	$\hat{\alpha}_3$	$\hat{\beta}_3$	$\hat{\alpha}_3$	$\hat{\beta}_3$	$\hat{\alpha}_3$	$\hat{\beta}_3$	$\hat{\alpha}_3$	$\hat{\beta}_3$
lgr_{3t}	0.038 (4.460)	-0.406 (-5.213)	0	-0.025 (-0.071)	-0.015 (-4.437)	1	-0.008 (-1.445)	1	-0.006 (-1.140)	1
lgr_{4t}	0.001 (0.068)	1	-0.008 (-1.690)	1	0	-2.471 (-8.149)	-0.005 (-1.062)	-1	0	-1
Constant		-2.057 (-17.750)		-2.650 (-5.034)		5.088 (6.383)		1.218 (5.438)		1.292 (4.346)
Log-Likelihood	2471.244		2462.123		2471.242		2461.842		2461.310	
LR statistic			18.244		0.004		18.806		19.870	
p-value			0.000		0.948		0.000		0.000	
			$\chi^2(1)$		$\chi^2(1)$		$\chi^2(1)$		$\chi^2(2)$	

Numbers in brackets are t-ratios

Table 3d Long run identification of cointegrated pair: lgr_{3t} , lgr_{5t} (full sample)

	$\mathcal{H}_1$		$\mathcal{H}_2$		$\mathcal{H}_3$		$\mathcal{H}_4$		$\mathcal{H}_5$	
	$\hat{\alpha}_4$	$\hat{\beta}_4$	$\hat{\alpha}_4$	$\hat{\beta}_4$	$\hat{\alpha}_4$	$\hat{\beta}_4$	$\hat{\alpha}_4$	$\hat{\beta}_4$	$\hat{\alpha}_4$	$\hat{\beta}_4$
lgr_{3t}	0.043 (4.659)	-0.801 (-10.877)	0	-0.793 (-0.752)	-0.029 (-3.947)	1	-0.034 (-3.896)	1	-0.029 (-3.296)	1
lgr_{5t}	0.014 (1.687)	1	-0.003 (-1.028)	1	0	-1.249 (-11.803)	-0.012 (-1.449)	-1	0	-1
Constant		-1.195 (-10.810)		-1.929 (-1.217)		1.518 (6.039)		0.919 (15.827)		0.944 (15.233)
Log-Likelihood	2475.173		2465.237		2473.835		2472.050		2471.087	
LR statistic			19.871		2.675		6.246		8.170	
p-value			0.000		0.102		0.012		0.017	
			$\chi^2(1)$		$\chi^2(1)$		$\chi^2(1)$		$\chi^2(2)$	

Numbers in brackets are t-ratios

Table 4 Augmented Dickey-Fuller unit root test on spreads (full sample)

Spread	*# lags*	*Significance Level* 99%	95%	90%	*T-statistic*
lge_{1t}-lgr_{6t}	0	-3.450	-2.870	-2.571	-2.923[b]
lge_{2t}-lgr_{6t}	0	-3.450	-2.870	-2.571	-2.706[b]
lgr_{3t}-lgr_{4t}	0	-3.450	-2.870	-2.571	-1.007[b]
lgr_{3t}-lgr_{5t}	0	-3.450	-2.870	-2.571	-2.017[b]

[b] *Acceptance of the null with 99% significance*

Table 5 Bivariate trace tests for cointegration rank and hypotheses testing (1st sub-sample)

# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lge_{2t}	lgr_{6t}
1	0	2	1	0.095	13.519[b]	20.164	0.077[i,b]	0.068[i,b]
	1	1	2	0.019	2.178[b]	9.142	2.872[ii,b]	4.185[ii,b]
							0.068[iii,b]	0.077[iii,b]
# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{3t}	lgr_{4t}
1	0	2	1	0.106	18.040[b]	20.164	0.744[i,b]	0.289[i,b]
	1	1	2	0.045	5.256[b]	9.142	0.474[ii,b]	1.124[ii,b]
							0.289[iii,b]	0.744[iii,b]
# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{3t}	lgr_{5t}
1	0	2	1	0.088	11.184[b]	20.164	1.159[i,b]	1.224[i,b]
	1	1	2	0.006	0.729[b]	9.142	1.203[ii,b]	0.095[ii,b]
							1.224[iii,b]	1.159[iii,b]

[a] Rejection of the null with 95% significance
[b] Acceptance of the null with 95% significance
[i] Multivariate Stationarity test is a LR test, distributed as $\chi^2(1)$
[ii] Doornik and Hansen (2008) univariate normality test, distributed as $\chi^2(2)$
[iii] Variable Exclusion is a LR test, distributed as $\chi^2(1)$

Table 6 Bivariate trace tests for cointegration rank and hypotheses testing (2nd sub-sample)

# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lge_{2t}	lgr_{6t}
1	0	2	1	0.084	25.615[a]	20.164	11.712[i,a]	15.806[i,a]
	1	1	2	0.015	3.785[b]	9.142	1.914[ii,b]	1.839[ii,b]
							15.806[iii,a]	11.712[iii,a]
# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{3t}	lgr_{4t}
1	0	2	1	0.055	22.886[a]	20.164	5.250[i,a]	4.480[i,a]
	1	1	2	0.035	8.779[b]	9.142	2.117[ii,b]	3.456[ii,b]
							4.480[iii,a]	5.250[iii,a]
# lags	*r*	*p-r*	*i*	$\hat{\lambda}_i$	τ_{p-r}	$C_{95\%(p-r)}$	lgr_{3t}	lgr_{5t}
2	0	2	1	0.061	24.202[a]	20.164	5.056[i,a]	5.082[i,a]
	1	1	2	0.034	8.656[b]	9.142	5.689[ii,b]	2.645[ii,b]
							5.082[iii,a]	5.056[iii,a]

[a] Rejection of the null with 95% significance
[b] Acceptance of the null with 95% significance
[i] Multivariate Stationarity test is a LR test, distributed as $\chi^2(1)$
[ii] Doornik and Hansen (2008) univariate normality test, distributed as $\chi^2(2)$
[iii] Variable Exclusion is a LR test, distributed as $\chi^2(1)$

Table 7a Long run identification of cointegrated pair: lge_{2t} , lgr_{6t} (2^{nd} sub-sample)

	$\mathcal{H}_1$		$\mathcal{H}_2$		$\mathcal{H}_3$		$\mathcal{H}_4$	
	$\hat{\alpha}_2$	$\hat{\beta}_2$	$\hat{\alpha}_2$	$\hat{\beta}_2$	$\hat{\alpha}_2$	$\hat{\beta}_2$	$\hat{\alpha}_2$	$\hat{\beta}_2$
lge_{2t}	-0.042	1	0	-1.183	-0.046	1	-0.020	1
	(-2.644)			(-10.729)	(-3.653)		(-1.432)	
lgr_{6t}	0.056	-0.768	-0.061	1	0	-0.630	0.050	-1
	(3.267)	(-10.327)	(-4.037)			(-5.339)	(3.315)	
Constant		-2.008		2.220		-2.241		-1.694
		(-18.512)		(6.616)		(-13.024)		(-38.596)
Log-Likelihood	1621.944		1619.078		1617.608		1618.665	
LR statistic			5.731		8.671		6.557	
p-value			0.017		0.003		0.010	
			$\chi^2(1)$		$\chi^2(1)$		$\chi^2(1)$	

Numbers in brackets are t-ratios

Table 7b Long run identification of cointegrated pair: lgr_{3t} , lgr_{4t} (2^{nd} sub-sample)

	$\mathcal{H}_1$		$\mathcal{H}_2$		$\mathcal{H}_3$		$\mathcal{H}_4$		$\mathcal{H}_5$		$\mathcal{H}_6$	
	$\hat{\alpha}_3$	$\hat{\beta}_3$	$\hat{\alpha}_3$	$\hat{\beta}_3$	$\hat{\alpha}_3$	$\hat{\beta}_3$	$\hat{\alpha}_3$	$\hat{\beta}_3$	$\hat{\alpha}_3$	$\hat{\beta}_3$	$\hat{\alpha}_3$	$\hat{\beta}_3$
lgr_{3t}	0.035	-0.367	0	-0.256	-0.016	1	-0.007	1	0	-1	-0.005	1
	(2.827)	(-5.009)		(-2.549)	(-3.520)		(-2.762)				(-2.195)	
lgr_{4t}	-0.018	1	-0.030	1	0	-2.388	-0.005	-1	0.004	1	0	-1
	(-1.549)		(-3.227)			(-6.189)	(-2.060)		(1.318)			
Constant		-2.159		-2.459		4.826		0.440		-0.673		0.287
		(-18.052)		(-15.024)		(4.492)		(1.446)		(-1.259)		(0.612)
Log-Likelihood	1677.398		1675.900		1676.940		1674.999		1671.260		1672.904	
LR statistic			2.995		0.915		4.798		12.276		8.987	
p-value			0.084		0.339		0.028		0.002		0.011	
			$\chi^2(1)$		$\chi^2(1)$		$\chi^2(1)$		$\chi^2(2)$		$\chi^2(2)$	

Numbers in brackets are t-ratios

Table 7c Long run identification of cointegrated pair: lgr_{3t} , lgr_{5t} (2nd sub-sample)

	$\mathcal{H}_1$		$\mathcal{H}_2$		$\mathcal{H}_3$		$\mathcal{H}_4$		$\mathcal{H}_5$	
	$\hat{\alpha}_4$	$\hat{\beta}_4$	$\hat{\alpha}_4$	$\hat{\beta}_4$	$\hat{\alpha}_4$	$\hat{\beta}_4$	$\hat{\alpha}_4$	$\hat{\beta}_4$	$\hat{\alpha}_4$	$\hat{\beta}_4$
lgr_{3t}	0.048 (3.967)	-0.757 (-10.891)	0	-0.719 (-5.989)	-0.036 (-3.667)	1	-0.013 (-3.063)	1	-0.023 (-2.605)	1
lgr_{5t}	0.010 (0.923)	1	-0.023 (-2.777)	1	0	-1.329 (-12.493)	-0.010 (-2.562)	-1	0	-1
Constant		-1.260 (-10.968)		-1.605 (-8.093)		1.733 (6.367)		0.485 (2.977)		0.859 (8.911)
Log-Likelihood	1697.594		1694.212		1697.402		1695.656		1693.667	
LR statistic			6.765		0.383		3.877		7.854	
p-value			0.009		0.536		0.049		0.020	
			$\chi^2(1)$		$\chi^2(1)$		$\chi^2(1)$		$\chi^2(2)$	

Numbers in brackets are t-ratios

Table 8 Augmented Dickey-Fuller unit root test on spreads (2nd sub-sample)

Spread	*# lags*	*Significance Level*			*T-statistic*
		99%	*95%*	*90%*	
lge_{2t}-lgr_{6t}	0	-3.458	-2.873	-2.573	-2.926[b]
lgr_{3t}-lgr_{4t}	0	-3.458	-2.873	-2.573	-0.190[b]
lgr_{3t}-lgr_{5t}	0	-3.458	-2.873	-2.573	-1.673[b]

[b] *Acceptance of the null with 99% significance*