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Departamento de Economía de la Empresa
Universidad Carlos III de Madrid
Calle Madrid, 126
28903 Getafe (Spain)
Fax (341) 6249608

**ON THE EFFECTIVENESS OF SEVERAL MARKET
INTEGRATION MEASURES. AN EMPIRICAL ANALYSIS ¹**

Ángel Pardo*, Alejandro Balbás** and Vicente Meneu*

Abstract

Many market integration measures are operationalized to compute their numerical values during a period characterized by the lack of stability and market turmoil. The results of the tests give their degree of effectiveness, and reveal that the measures based on the principles of asset valuation, versus statistical measures, more clearly yield the level of integration of financial markets. Besides, cross market arbitrage-linked measures and equilibrium models-linked measures provide complementary information and reflect different properties, and consequently, both types of measures may be useful in practice.

Keywords: Market integration, measures of integration, statistical techniques, principles of asset valuation, law of one price, arbitrage, IBEX-35, future contract.

*Universidad de Valencia, Dept. de Economía Financiera y Matemática, Facultad de Ciencias Económicas y Empresariales, Campus Naranjos, Edificio Departamental Oriental, 46071 Valencia, España. Phone: 34-96-3828377, Fax: 34-96-3828370, E-mail: Angel.Pardo@uv.es, Vicente.Meneu@uv.es

** Universidad Carlos III de Madrid, Dept. Economía de la Empresa, C/ Madrid, 126, 28903 Getafe (Madrid), Phone: 34-91-6249636, Fax: 34-91-6249608, E-mail: balbas@emp.uc3m.es

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I- INTRODUCTION.

The integration of financial markets is an usual issue of special interest that has been the objective of numerous papers comparing share markets, bond markets, foreign exchange markets, commodity markets and derivative markets. A high degree of integration among markets indicates that prices are formed in a correct way and, therefore, agents interested in well-diversified portfolios and appropriate risk-return ratios will concentrate on the available assets without taking into account the concrete markets. Furthermore, if derivative markets are involved, low cost operations can be carried out possibly helping to attract more investors to hedged or deferred positions, increasing market liquidity.

Conversely, a low degree of integration implies quite different pricing rules with the subsequent effect on the diversification process. It also can dissuade hedged positions and leads to arbitrage strategies that generate risk-less profits derived from discrepancies in prices. Finally, some agents can implement speculation strategies that take profits from greater predictive power of one market over another.

In spite of this, a rigorous definition of what is understood by integrated markets does not exist in the financial literature and it is only commonly accepted an intuitive but imprecise idea: two financial markets are integrated when they evolve in a combined way. Many authors try to formalize the concept and provide numerical and analytic integration measures. Several questions arise. For instance, under which conditions are they equivalent? Is any of them superior to the rest? Do the responses to these questions depend on the concrete setting?

Theoretical and empirical approaches may be applied to answer these questions. This paper presents an empirical test that analyzes the effectiveness of a large number of measures in a situation of clear disintegration. To do that, the measures have been classified into two major categories accordingly to their nature. The first group contains those measures introduced by statistical and econometric methods, while the second focuses on the asset pricing theory.

It should be pointed out that this type of classification has never been previously proposed. The purpose is to analyze the convenience of considering the financial theory to

introduce an integration measure. In short, twelve integration measures are revised; four based on statistical techniques and eight on the basic principles of asset valuation.

In order to guarantee the lack of integration, the Spanish index IBEX-35 and its derivative market have been chosen during a period characterized by market turmoil. These markets have shown a high degree of efficiency, as pointed out by Lee and Mathur (1999), but a large number of cross-market arbitrage opportunities were available during the Asian crash of October, 1997 (Balbás *et al.* 1997).

The applied procedure guarantees the maximal precision since perfectly synchronized high frequency data have been used to compute the value of the market integration measures.

Two main results are reached. First, measures based on the principles of asset valuation provide minute-by-minute an absolutely similar degree of integration during the tested period, while the rest of measures contradict each other. This seems to imply a serious objection for the statistical measures that are not able to give an unified conclusion and, consequently, asset-pricing models could yield a more successful way to measure the level of market integration.

Second, the measures based on theoretical approaches may be subdivided in measures based on cross-market arbitrage and measures based on equilibrium models. Cross-market arbitrage-linked measures seem to be more adequate when derivatives are involved and hedging or deferred strategies are the focus of the analysis. Besides, equilibrium-linked measures are useful when studying very incomplete markets and seeking for well-diversified portfolios, although the data of long periods are required in order to compute some of these measures. Thus, arbitrage and equilibrium arguments apply in different settings and reflect different properties, what justifies that both sorts of measures may be considered to analyze integration levels.

The outline of the paper is as follows: section II is devoted to summarize some integration measures based on statistical and econometric techniques. Section III studies the measures based on cross-market arbitrage. Section IV reviews equilibrium-linked measures. Section V describes the data and the trading conditions on Spanish Financial Markets during

the first days of the Asian *crash* (October 1997). In Section VI the measures are applied to the IBEX-35 futures market. Section VII concludes the paper.

II - MEASURES BASED ON STATISTICAL AND ECONOMETRIC TECHNIQUES.

The first set of measures is based on statistical and econometric methods. The most used and intuitive is the cross correlation of contemporary returns of the compared markets. The first measure of economic integration can be stated as:

Measure 1. "The spot-future market integration can be measured by the correlation coefficient between simultaneous returns in the markets. The higher the correlation coefficient, the stronger the market integration is." Kempf and Korn (1996, p. 1713).

A correlation coefficient near to one would indicate perfect integration between both markets since they incorporate the information in the same way. A zero or negative correlation coefficient would imply segmentation. This measure is usually accompanied by the cross-correlation coefficient analysis of the non-contemporary returns of both markets. The purpose is to check if they are not autocorrelated. Through this analysis, another measure of the degree of market integration is defined.

Measure 2. Spot-future market integration can be measured by the cross-correlation coefficient between simultaneous returns and the cross-correlation coefficients for the spot return with the futures return at different lags. The higher the contemporaneous coefficient and the minor lagged correlation coefficient, the stronger the market integration is.

We would like to emphasize that cash market frictions grant some comparative advantages to the futures market, which have led to some authors to analyze if prices in the futures market lead or lag those in the spot market. Consequently, different works studied the dynamics between the price returns of market indexes and their future contracts applying either the causality of Granger (1969)¹ or the causality of Sims (1972)². For this last case, the regression equation is:

¹ Kawaller *et al.* (1987) and Ng (1987).

$$c_t = \alpha + \sum_{k=-p}^p \beta_k f_{t-k} + u_t \quad [1]$$

where c_t and f_t indicate the returns of the cash and of the derivative assets at the date t , respectively, and k the number of lags. The coefficients with negative (positive) subscripts indicate lag (lead) coefficients. The degree of market integration is deduced, in this case, from the β_k values:

Measure 3. The markets are integrated if the contemporary variable coefficient β_k is greater than zero. Significant values for the coefficients at lags k would indicate that the returns in the futures markets tend to lead those in the spot market, and significant values for the coefficients at leads k would indicate that the futures market tends to lag the spot market.

It should be pointed out that measures 1, 2 and 3 are characterized for the use of returns (first differences in prices). This causes some inconvenience when spot and futures prices form a cointegrating vector.³ For this reason, the development of cointegration techniques at the end of the eighties resulted in a new integration measure based on prices and not on returns.

Measure 4. Two markets are integrated if a cointegrating structure between them exists.

The study of the integration between the derivative market and its underlying asset through cointegration analysis rests on the relationship between arbitrage and cointegration. Pricing based on arbitrage must duplicate one asset with another (or a combination of other asset(s)). Hence, if the derivative asset follows a certain trend, the arbitrage activity should cause the underlying asset to share the same trend. Consequently, as Arshanapalli and Doukas

² Stoll and Whaley (1990), Chan (1992) and Abhyankar (1995).

³ The components (price series) of the vector x_t are said to be cointegrated of order d, b , if all components of x_t are integrated of order $d, I(d)$, and there exists a vector $\alpha \neq 0$ such that linear combination is integrated of order $d-b, I(d-b)$, where $b > 0$. The vector α that allows a linear combination of variables $I(d)$ with a integration order smaller than d is called a cointegration vector. If α exists a bivariate model that uses only first differences will be misspecified [see Engle and Granger, 1987].

(1997, pp. 258-259) pointed out, "cointegration [...] would imply that the deviation from the common equilibrium path should cause price realignments, restoring the original equilibrium. On the other hand, lack of cointegration between the index futures and the underlying cash market would suggest that the underlying forces which are required to integrate the two markets into one market are rather weak".

The Granger Representation Theorem establishes that if the price series of the two comparative markets are cointegrated, the short-run adjustments of the series with regard to the equilibrium level are included in an error correction model. If spot and derivative asset prices are cointegrated, then either spot prices lead derivative prices, or derivative prices lead spot prices or a combination of the two effects exists. For this reason, measure 4, together with measures 2 and 3, have been applied to measure the integration between markets and to check a possible lead-lag relationship.⁴

All the measures based on statistical and econometric techniques study the integration between two concrete markets in a time interval and require a wide sample period. However, they do not provide information on the strategy to develop to take advantage of the lack of integration, nor do they consider the transaction costs that would be incurred when carrying it out. We should stress that all they are characterized to reflect exclusively movements in returns or in market prices of the comparative assets, without taking into account any valuation model. As a result, measures based on the principles of asset valuation are of a particular interest since they can be applied at any moment in time and, in some cases, they provide an optimum arbitrage strategy.

III. - MEASURES BASED ON CROSS-MARKET ARBITRAGE.

The first studies to outline the integration between derivative markets and their underlying assets following the basic principles of asset valuation placed great emphasis on checking the fulfillment of the Law of One Price (LOP).⁵ Consequently, the derivative asset

⁴ See Sutcliffe (1997, pp. 162-172) for a complete survey of the empirical studies of leads and lags between spot and futures prices and Stephen and Whaley (1990) and De Jong and Donders (1998) for the case of relationships between options and stock markets.

⁵ See Protapapadakis and Stoll (1983), Cornell and French (1983a and 1983b), Modest and Sundaresan (1983) and Modest (1984).

has to be duplicated (or the underlying asset from the market price of the derivative asset) and the theoretical price has to be compared with its market price. Since the asset and its replica must offer the same payoffs, the equality between these prices indicates the fulfillment of the LOP. On the other hand, the mismatches of the market prices with the theoretical ones allow a risk-less benefit to be obtained through the purchase of the cheap asset and the sale of the expensive one. Of the above-mentioned, an integration measure p that compares the deviation between the theoretical spot price (C'_t) and the spot price (C_t) can be defined as:

$$p = \frac{C'_t}{C_t}. \quad [2]$$

In this case, the presence (absence) of market integration is studied by means of fulfillment (or not) of the Law of One Price.

Measure 5. If p is equal to one, the LOP is fulfilled and the markets are integrated. Conversely, if p is bigger (smaller) than one the cash index is undervalued (overvalued) with regard to its replica obtained from the derivative contract and the risk-less bond.

This measure allows the incorporation of the transaction costs involved in arbitrage strategy. It also permits the study of market integration between the futures market and the underlying market, between the options market and the cash market and between the futures and the options markets if these last two have a future contract as an underlying asset.

Recently, Chen and Knez (1995) have introduced a new approach to analyze the degree of market integration. They define the concepts of market integration in a weak and a strong sense and establish the corresponding measures. Two markets are integrated in a weak sense if the LOP is fulfilled between them.

Measure 6. Consider two markets A and B in which the LOP holds separately. The weak integration measure $g(A,B)$ is defined as the smallest difference between each market's family of state prices and it is calculated as

$$g(A,B) = \min_{d_A \in D_A, d_B \in D_B} \|d_A - d_B\|^2 \quad [3]$$

where D_A and D_B are the sets of state prices for each market and $\| \cdot \|$ is the Euclidean norm. If $g(A,B)=0$, the markets are integrated in a weak sense, while if $g(A,B)>0$ the markets are not integrated and arbitrage opportunities exist. Since the fulfillment of the LOP does not imply the absence of arbitrage opportunities (AAO),⁶ Chen and Knez restrict the concept of integration and establish that two markets are integrated in a strong sense if cross-market arbitrage opportunities do not exist between them. They define a new integration measure:

Measure 7. Consider two markets A and B in which there are not arbitrage opportunities in either market. The integration measure in a strong sense is defined as the smallest difference between the positive state prices and it is calculated as

$$a(A,B) = \min_{d_A \in D_A^+, d_B \in D_B^+} \|d_A - d_B\|^2 \quad [4]$$

where D_A^+ and D_B^+ are the sets of positive state prices for each market. If $a(A,B)=0$, the markets are integrated in a strong sense, while markets are not integrated and arbitrage opportunities exist as long as $a(A,B)>0$.

Measures g and a represent an important advance on the measures based on statistical and econometric techniques and on measure p , since they inform of market integration by considering all the possible arbitrage portfolios and they are not based on concrete strategies. Nevertheless, the two integration measures proposed by Chen and Knez are based on differences in state prices and, therefore, they do not allow the transaction costs to be discounted.

Balbás and Muñoz (1998), following the approach by Chen and Knez, propose a new integration measure (m) based on monetary terms. They use the benefits that can be obtained from the optimal arbitrage strategy, if it exists. To obtain this measure, they consider a two

period model, t and T , and a unique market that incorporates all the markets that they compare. n assets are negotiated at a price p_i with $i = 1, 2, \dots, n$, at the date t . A portfolio x is defined as $x = (x_1, x_2, \dots, x_n)$ where the x_i indicates the bought (positive sign) or sold (negative sign) units of the asset i . Any market portfolio has a price at t given by:

$$P(x) = \sum_{i=1}^n x_i p_i.$$

All the assets take prices that are known at the moment T assuming a discrete source of uncertainty K . If the states of nature are H , only one of them can occur at T . The price of the portfolio x at the moment T is given by:

$$\alpha_x(k) = \sum_{i=1}^n x_i \alpha_i(k)$$

where $\alpha_i(k)$ indicates the pay-off of the asset i in the state of the nature k . Theorem 3 of Balbás and Muñoz (*op.cit.* p. 163) proves that when LOP fails, then exists a solution x^* for the following optimization problem:

$$\text{Maximize } f(x) = \frac{-\sum_{i=1}^n x_i p_i}{-\sum_{i \in S_x} x_i p_i}$$

$$\text{subject to } \begin{cases} \sum_{i=1}^n x_i \alpha_i(k) = 0 \text{ for every } k \in K \\ \sum_{i=1}^n x_i p_i < 0 \end{cases}$$

where S_x represents the set of the sold assets of the portfolio x , (i.e. $x_i < 0$). The numerator of the objective function is the value of the arbitrage portfolio and the denominator is the aggregate amount of the sales, both expressed in monetary units at the moment t . The quotient can be interpreted as the ratio between the benefit obtained from the arbitrage strategy x^* and

⁶ The absence of arbitrage opportunities implies the fulfillment of the LOP. In general, the reciprocal is not true. See Ingersoll (1987, p.59).

the value of the sold assets. The first constraint implies that at the moment T the portfolio has a pay-off equal to zero in all states of nature. The second constraint looks for portfolios that provide an income at the moment t . Notice that the opportunities set of the problem is the set of possible arbitrage portfolios.

If the solution is reached at x^* , the integration measure is defined by $m=f(x^*)$ and takes values between 0 and 1. As a result, the new integration measure is:

Measure 8. If m is equal to zero, the LOP holds and the markets are integrated. If m takes values greater than zero, arbitrage opportunities exist and the markets are not integrated.

It is possible that arbitrage opportunities exist even when m is equal to zero. To detect them, it is only necessary to modify the sign of the first constraint of the previous problem, imposing the search for a portfolio whose payoffs at T are bigger than or equal to zero in all the states of nature. In this case, the optimal value will be denoted by M . Therefore, following the terminology of Chen and Knez (1995), m and M could be considered the weak and strong integration measures proposed by Balbás and Muñoz (1998). Thus, we have a new integration measure:

Measure 9. If M is equal to zero, the markets are integrated in a strong sense. If M takes a value greater than zero, arbitrage opportunities exist and the markets are not integrated.

The measures m and M denote the integration of the market in a global sense, since they consider all the possible arbitrage strategies and they choose the optimal one. Moreover, these measures do not need to make assumptions about the fulfillment of the LOP or about the AAO on each market, because all the analyzed assets are included in only one market.

The use of integration measures based on profits instead of state prices facilitates the consideration of the transactions costs paid when carrying out an arbitrage strategy. If, l is defined as the quotient between the profit of the arbitrage portfolio and the total value of the exchanged assets, a relationship between l and m [Balbás and Muñoz (*op.cit*, p. 165)] can be stated:

$$l = \frac{m}{2 - m}$$

Assume that the total transactions costs (T) incurred in arbitrage related strategies are proportional to the sum of the purchase (P) and sold (S) quantities and define the ratio TC as the ratio $T/(P+S)$. The difference between l and TC indicates the unitary profit obtained from the arbitrage once the transaction costs have been discounted. The consideration of the transaction cost is a fundamental aspect when determining if the markets are integrated or not. Arbitrage opportunities can exist, indicating that the markets are not integrated ($m > l > 0$), but they cannot be exploited since the profit would not compensate the transaction costs ($TC > l$). It is interesting to highlight that if l is equal to TC we have:

$$m' = \frac{2(TC)}{1 + TC}$$

where m' is an implicit measure of integration that indicates the minimum value that m must take so that arbitrage opportunity exists. Or, in an alternative sense, the maximum value that m can take so that the market is integrated.

Therefore, significant results are obtained with the Balbás and Muñoz integration measures: the composition of the optimal portfolio and the possibility to discount the transaction cost.

IV. – MEASURES BASED ON EQUILIBRIUM MODELS.

The third group of measures is based on the principles of asset valuation but they rest on equilibrium models. Garbade and Silber (1983) collected this feature in the measure they suggested for testing the integration level between the cash and futures markets. These authors specified a dynamic equilibrium model and they established that the degree of market integration is a function of the elasticity of supply of arbitrage services that can be measured from the following model:

$$C'_t - C_t = \alpha + \delta(C'_{t-1} - C_{t-1}) + \varepsilon_t \quad [5]$$

where C'_t is the natural logarithm of the theoretical spot price, C_t is the natural logarithm of the observed spot price and δ is an inverse measure of the elasticity of supply of arbitrage services. "In the context of equation [...] δ measures the rate of convergence of cash and futures prices" (*op.cit.* p. 294) and is the measure of integration 10:

Measure 10. If δ is small, both markets are integrated and prices will converge quickly. If δ is equal to one, both markets are not linked and the futures and spot prices will follow uncoupled random walks.

It is important to note that "although Garbade and Silber have provided a model to estimate the rate of convergence of cash and futures prices which reflects the corresponding level of index arbitrage activities, they do not furnish a statistical test for the significance of the estimated coefficients, [...] which has profound implications in the testing for market linkage" [Wang and Yau, 1994, p. 461]. Hence, Wang and Yau (*op.cit.*), Yadav (1992) and Kempf and Korn (1996) have outlined the estimation of δ testing for the presence of a unit root in the mispricing series, defined as the difference between theoretical and market prices. Thus, we have a new measure of integration derived from the previous one that would be obtained by testing for the presence of a unit root in the following model:

$$\Delta M_t = \alpha_0 + \gamma M_{t-1} + \sum_{i=1}^p \gamma_p \Delta M_{t-p} + \xi_t \quad [6]$$

where $M_t = C'_t - C_t$ and γ shows the mean reversion in mispricing. Its value is the integration measure 11:

Measure 11. If there is not a unit root in the mispricing series (*i.e.* $\gamma < 0$), markets are linked. If there is a unit root (*i.e.* $\gamma = 0$), spot and futures price series are not related and the markets are not linked. The higher the mean reversion parameter (γ), the stronger the market integration is.

In this case, the integration is again wholly related to the existence of arbitrage opportunities. If the previous mispricing was positive (the spot price was underpriced), arbitrage activity would force the change in the mispricing to be negative (the underpricing would decline) and vice versa.⁷

Yadav (1992) and Dwyer *et al.* (1996) have generalized the mean reversion analysis by applying a cost of carry model with nonzero transaction costs to motivate estimation of threshold models between futures and cash indexes. Their results suggest that the speed of convergence of the basis to its equilibrium value depends on the level of mispricing.

Bessembinder (1992) proposed the latest measure we review. This author establishes that assets and futures markets are integrated if expected returns on portfolios consisting of asset and futures positions are identical to expected returns on asset-only portfolios of identical systematic risk.

The relationship between the expected next period return on i asset, $E_{t-1}(R_{it}^a)$, and its systematic risk is stated as

$$E_{t-1}(R_{it}^a) = \gamma_{0t} + \beta_{it-1}^a \gamma_{1t} \quad [7]$$

where γ_{0t} is a cross sectional constant, $\beta_{it-1}^a \gamma_{1t}$ is a $1 \times n$ vector of conditional sensitivities of i asset to each of n economic variable and γ_{1t} is a $n \times 1$ vector of risk premiums at time t .

The behavior of futures prices in a model of capital market equilibrium obeys the relation

$$E_{t-1}(R_{it}^f) = \beta_{it-1}^f \gamma_{1t} \quad [8]$$

where $\beta_{it-1}^f \gamma_{1t}$ is a $1 \times n$ vector of conditional sensitivities of percentage change in futures prices j to the n economic variable.

⁷ In perfectly integrated markets this measure is not defined since the mispricing series takes a zero value for all t [see Kempf and Korn, 1998].

Since [7] holds for spot prices and [8] holds for futures, expected returns of portfolios composed of assets and futures are also given by [7]. Thus, market integration implies that the futures premium and the expected excess return on the spot asset differ only if the systematic risk of the spot and the future differ. To evaluate this, conditional betas are estimated and are used to make cross sectional regressions of the form

$$R_{pt} = \gamma_{0t} + \gamma_{0t}^* d_p + \sum_{i=1}^n [\gamma_{it} \hat{\beta}_{ipt} + \gamma_{it}^* \hat{\beta}_{ipt} d_p] + \varepsilon_{pt}$$

where R_{pt} is the return on equity portfolio or futures contract p , $\hat{\beta}_{ipt}$ is the estimated beta for portfolio p with respect to the i th economic variable, and d_p is a dummy variable equal to zero for spot assets and equal to unity for futures contracts.

The hypothesis that futures markets are fully integrated with assets markets is checked by testing that the intercept for futures contract is zero and that risk premiums are uniform across assets and futures markets.

Measure 12. The markets are integrated if we cannot reject that the estimates of γ_{0t}^* and the estimates of $\gamma_{0t}^f \equiv \gamma_{0t} + \gamma_{0t}^*$ are equal to zero.

In short, measures 10, 11 and 12 only study the integration between the spot and futures markets. They have similar characteristics to the measures based on econometric techniques but, unlike them, they have to take into account some equilibrium model.

Table I shows the different financial integration measures described in Sections II, III and IV and a summary of some of their characteristics.

V.- DATA AND TRADING CONDITIONS.

The IBEX-35 futures market (MEFF-RV) began to trade in January 1992 and since then it has consolidated itself as one of the most important in Europe.⁸ The stock and futures markets open at 10.00 a.m. and close at 5.00 p.m. and 5.15 p.m. respectively. Both markets are electronic and the priority for crossing a transaction is determined by price. If prices are equal, priority is given to the arrival time of the order.

The data used in this study make reference to the period between the 22nd and 30th of October 1997 (7 market sessions). The minute to minute prices of the IBEX-35 index and the midquote of the bid and ask price of the futures contract on IBEX-35, with expiration on the 21st of November 1997, have been obtained from the Market Information System (MIS) of MEFF-RV. The Sociedad de Bolsas provided the dividends distributed from the IBEX-35 index shares and the interest rates have been obtained from the *Servicio de Series Temporales del Banco de España*.⁹

On Thursday, October 23rd, 1997, the Hang Seng index of the Hong Kong Stock Exchange, suffered a fall of 10.41%, which in turn caused a generalized drop in the European markets. The IBEX-35 index fell 2.49% and 0.79% on the 23rd and 24th, respectively (see the third line of Table II).

On the 27th of October the Hong Kong, the Indonesian and the Taiwanese Stock Exchanges received a large number of sale orders, which caused an important fall in market prices. Its effect was reflected, again, in the Spanish market, first, through increments in the trading volumes and in the intraday volatility of the markets and, second, through a decline in the IBEX-35 of 4.40% (fifth column of Table II).

⁸ MEFF-RV, in 1994 and 1995, was the stock index futures market with the biggest number of futures contracts negotiated worldwide (Sutcliffe, 1997, p.59, Table 3.4.).

⁹ Because intraday data were not available for interest rates, the daily middle rate corresponding to the repo operations carried out with Spanish Treasury Bonds has been chosen for all the minutes of the same day.

The convulsions in the financial shares markets and in their underlying assets continued during the market session of the 28th of October. The Spanish stock market stopped trading from 4.46 p.m. to 5.30 p.m. due to the spectacular increase in prices in New York (at 4.40 p.m., Spanish time). For the first time in the history of the Spanish electronic market, an adjusting period was instigated from 5.30 p.m. to 6.00 p.m. in order to allow adjustments in the shares market. At 6.00 p.m. the open session began again and concluded a half an hour later. However, the derivatives market was closed from the 5.04 p.m. to 6.43 p.m., at which time trading began once more and continued uninterruptedly until 7.40 p.m. The results of a session with so many incidents can be summed up under three points: firstly, the stock and the derivative markets on IBEX-35 registered record maximum daily volumes; second, the size of the relative bid-ask spread of the futures contract took values that duplicated the bid-ask spread in stable periods; and, lastly, the intraday volatility of the minute by minute IBEX-35 index was 0.125%, while the volatility of the IBEX-35 future was 0.235% (sixth column of Table II).

Market instability continued on the 29th of October. The shares market began trading 39 minutes late, due to the excessive volume of orders that had been placed during the adjusting period. The diffusers of prices stopped giving information about the spot index from 0.22 p.m. until the 0.49 p.m. Finally, the Spanish Stock Exchange rose by 5.66%, the biggest daily rise in the last six years, with an intraday volatility of over than 0.07% (seventh column of Table II).

To sum up, the beginning of the crisis of the Asian financial markets at the end of October, 1997 caused large variations in the closing prices, high intraday volatilities and unprecedented trading volumes in the spot and futures markets. All this justify the choice of this period for the study of the financial integration between the two markets, comparing a stable subperiod (the 22nd, 23rd and 24th of October) with an unstable subperiod (the 27th, 28th, 29th and 30th of October).¹⁰ The delays, stops and extensions of the trading session in several

¹⁰ The integration between the derivative markets of the S&P 500 market index and their underlying asset in stable and volatile periods has been studied in various works in which the sample period is centered around the *crash* of October of 1987. Harris (1989) studies the behavior of the base; Kleidon (1992) and Kleidon and Whaley (1992) carry out a cross correlation analysis of the series of returns of the cash and derivative markets; Wang and Yau (1994) analyze the mean reverting of the residuals of the cointegration equation while Arshanapalli and Doukas (1997) study the integration using cointegration and error correction models.

market sessions have led to the adjustment of the sample period for the seven days. Consequently, the degree of financial integration between stocks and stock index futures has been determined daily.

VI.- RESULTS.

Measures based on statistical and econometric techniques.

The cross correlation analysis of the minute-by-minute returns for IBEX-35 spot and IBEX-35 futures is presented in Table III. The contemporary correlation coefficients (measure 1) are significant at the 1% level every day, except the 29th of October. For this day we cannot reject the segmentation hypothesis between markets ($H_0: \rho_{spot,fut}=0$) at the 1% level.

In the non-contemporary cross correlation analysis (measure 2) we observe that, firstly, every day presents a cross correlation between spot price changes and one-minute lagged futures price changes ($\rho_{spot,fut (-1)}$) significant at the 1% level and higher than the contemporary correlation. Secondly, the coefficients with $k>0$ are significant only starting from the 28th. These results suggest that new information tends to be reflected first in futures market in stable periods, while during the Asian crisis a bi-directional effect is observed. According to the second measure, therefore, the 22nd, 23rd and 24th show the highest degree of integration.

Before estimating a bivariate model to determine the degree of market integration that measure 3 proposes, it is important to remind that this measure uses returns as variables (first differences in prices). If the cash and futures series were cointegrated, a bivariate model expressed in first differences would not be well-specified (Engle and Granger (1987)). Hence, we are going to analyze if a cointegration relationship exists between the cash and futures prices on the IBEX-35 index.

The null hypothesis of a single unit root is tested for each of the IBEX-35 spot and futures prices using the non-parametric test of Phillips and Perron (1988).¹¹ Although the null hypothesis is not rejected for the price series at the 5% level, it is for the series in differences at the 1% level.

Once proven that both series are integrated of the same order, we have tested for the existence of a stationary linear combination of them (measure 4) by applying the multivariate methodology proposed by Johansen (1988 and 1991) and by Johansen and Juselius (1990). Table V reports the cointegration results. The null hypothesis of no cointegration is rejected at 10% level and, therefore, we cannot reject the existence of at least one cointegration vector. These results dissuade the use of integration measure number 3. We highlight in Table V the fact that the null hypothesis is rejected at the 10% level on the 29th of October and at 5% level on the 27th and 28th, while the remaining days it is rejected at the 1% level. Therefore markets appear to have been highly integrated under normal trading conditions.

After detecting the existence of a cointegration vector, an error correction model has been estimated for each day.¹² The model that has finally been constructed, according to the Johansen procedure (1988 and 1991) is as follows:

$$\begin{aligned}\Delta lpc_t &= c_1 + \gamma_1 z_{t-1} + \sum_{i=1}^p a_{1i} \Delta lpc_{t-i} + \sum_{i=1}^p a_{2i} \Delta lpf_{t-i} + u_{1t} \\ \Delta lpf_t &= c_2 + \gamma_2 z_{t-1} + \sum_{i=1}^p b_{1i} \Delta lpc_{t-i} + \sum_{i=1}^p b_{2i} \Delta lpf_{t-i} + u_{2t}\end{aligned}$$

where lpc_t and lpf_t indicate the natural logarithm of the prices of the last transaction of the series of the IBEX-35 and the midquote of the futures contract; c_1 and c_2 are constant; p

¹¹ In this section, the term integration is used in an econometric sense. A series is integrated of order one if it contains a unit root. A series of this type becomes stationary or integrated of order zero when taking first differences.

¹² The Schwartz Bayesian Criterion has been used to determine the number of lags of the error correction models. Subsequently, we proved the presence of serial correlation. If correlation did not appear, the chosen number of lags was that proposed for the criterion. Conversely, if serial correlation problems were detected, the number of lags was increased until eliminating the correlation. We should also point out that the number of lags proposed was the same for the both equations and both variables.

indicates the number of lags and z_{t-1} is the term of error correction that is obtained from the following expression

$$z_{t-1} = \alpha_1 \times lpc_{t-1} - c - \alpha_2 \times lpf_{t-1}$$

where α_1 and α_2 indicate the parameters of the cointegrating vector.¹³

The estimates of error correction coefficients in the spot (γ_1) and the futures (γ_2) equations are presented in Table VI. γ_1 is significant, negative and higher than γ_2 in absolute value for every day, while γ_2 is only significant on the 27th of October. These results suggest that the spot market responds to the deviation from long-run equilibrium in (t-1) for every day except for the 27th, where a simultaneous adjustment is observed in the spot and futures markets. Furthermore, the absolute value of γ_1 diminishes strongly on the 28th and 29th. This indicates a smaller response of the spot market to the disequilibrium between spot and futures prices during the Asian crisis.¹⁴

In short, the measures based on statistical and econometric techniques contradict each other when determining the absence or presence of market integration. For example, according to measure 1 ($\rho_{spot-fut}$) the markets are more integrated on the 28th than the 29th (Table II) while, according to measure 4, the markets are not integrated on the 28th and they are on the 29th at the 5% level (Table VI).

Measures based on cross-market arbitrage

The study of financial integration measures based on the basic principles of assets valuation traditionally starts by measuring the degree of fulfillment of the LOP. Although the absence of arbitrage opportunities (AAO) is stronger than LOP (AAO implies LOP but the converse fails in a general framework), they are equivalent conditions in the particular case of

¹³ The models have been estimated for each day and they do not include intercept in the cointegration equation on the 29th and 30th, while the rest of the days include intercept in the cointegrating equation and in the error correction vector.

¹⁴ The effects of infrequent trading in stocks are modeled through the methodology proposed by Jokivuolle (1995) to proxy for the true index prices. The results do not differ significantly from those obtained without carrying out this adjustment and they are available upon request.

a stock index and its replica.¹⁵ Consequently, the study of the fulfillment of the LOP between the futures market on IBEX-35 and its underlying asset (and the risk-less asset) in fact embraces the study of all the possible arbitrage opportunities. Furthermore, Pardo (1998) proved the equalities $g=a$ and $m=M$ in this particular context.

Measures p , g and m have been calculated for each minute of the days considered and are summarized in Table VII (second, third, fourth and fifth lines). If we do not consider the transaction costs all the measures indicate market disintegration. The maximum disintegration is observed during the 28th, 29th and 30th. On the 28th measure p takes the maximum and the minimum values of the period and, also, measures g and m reach their highest values. The greatest integration level is detected on the 22nd, 23rd and 24th. We also highlight the fact that the minutes with overvaluations of spot prices with regard to the futures prices ($C_t > C'_t$) are greater than those of the undervaluations ($C'_t > C_t$) on both the Asian *crash* days and the other days (sixth and seventh line).

As has been explained, measures p and m allow the transaction costs to be discounted. Therefore, we can analyze if disparities in prices of the asset and its replica are or not explained by them. The transaction costs have been considered for each day taking into account market fees, commissions and market impact costs in the spot and futures markets.¹⁶ Having carried out this correction, the measures p and m lead to similar results.

Complementarily, in the eight and ninth lines of Table VII we present the number of detected opportunities of direct and reverse cash-and-carry arbitrage strategies. In the days prior to the *crash*, all (except one) of the deviations between cash and futures prices are explained by the transaction cost (arbitrage opportunities do not exist and markets are integrated). However, during the 28th and 29th, most of the deviations are not explained by transaction costs (arbitrage opportunities exist and markets are not integrated). In these circumstances, we still detect the prevalence of inverse arbitrage opportunities except on October 30th when the number of direct arbitrage opportunities is greater.

¹⁵ See Appendix.

¹⁶ The estimated transaction costs oscillate between 19 and 22 basic points, on the 22nd and 28th of October, which implies a m' value of 0.0038 and 0.0043, respectively.

To sum up, the level of integration shown by the integration measures based on cross-market arbitrage coincides as much in stable periods as in volatile periods:

Measures based on equilibrium models

Finally, we have calculated the difference between the natural logarithms of the theoretical spot price and of the observed spot price and we have tested whether the mispricings follow a mean reversion process (measure 11).¹⁷

We used the Augmented Dickey-Fuller (ADF) test [Dickey and Fuller (1981)] to check the presence of mean reversion in the mispricings. The results are reported in Table VIII. The estimated ADF values support the absence of a unit root, with the exception of October 27th and 28th. Hence, the mispricing series for both days are non-stationary and, according to measure 11, the markets are not integrated. The remaining days, the mispricing series behaves as a stationary series and, therefore, the spot and futures markets are integrated.

Note that the parameter γ is bigger in absolute value the days outside the Asian crisis period. This indicates a bigger convergence from prices to the equilibrium level during those days and the presence of certain disintegration during the Asian *crash*.

The integration measure of Bessembinder (measure 12) has not been calculated for two reasons. First, because this measure needs long time series with low frequency and, second, because our empirical application includes only one futures markets and “inference with regard to asset pricing models can be sensitive to the exclusion of securities from the cross-sectional analysis” [Bessembinder, 1992, p.639-640].

If we compare these results with those obtained with the measures based on statistical and econometric techniques, we can conclude that spot and futures markets were integrated in

¹⁷ Miller *et al.* (1994) indicate that the mean reversion of the changes in the base is a *statistical illusion*, caused by the infrequent trading of stocks within the index. The empirical evidence obtained by Neal (1996) contradicts the previous results. This author analyses 837 arbitrage operations and he observes a relationship between arbitrage and mean reversion of the mispricing series.

the stable subperiod (the 22nd, 23rd and 24th). Nevertheless, the results on market integration are partially contradicted in the volatile subperiod (the 27th, 28th, 29th and 30th). See the values of $\rho_{spot-fut}$ and γ in Tables II and VIII.

The comparison with the results achieved when applying the measures based on cross-market arbitrage shows that the lower the mean reversion parameter (γ), the greater the existence of arbitrage opportunities is.

VII. - CONCLUSIONS.

The paper empirically tests the effectiveness of a large number of market integration measures, and the analysis justifies the convenience of classifying them into two major categories: statistical measures, and measures related to the theory of asset pricing.

A large number of measures are operationalized and their values are computed during a period characterized by disintegration and the effect of the Asian Crisis of October 1997. The results clearly reveal that the statistical measures contradict each other. On the contrary, the second group of measures solves this caveat, which confirms that pricing models must be taken into account when a measure of market integration is being developed.

The reason explaining the contradiction among statistical and econometric techniques lies in the fact that these techniques are very sensitive to the high volatility shown by some financial time series.

The measures based on theoretical approaches may be defined by arbitrage methods or by equilibrium arguments. The first group is appropriate if derivative markets are involved or hedging strategies are the main purpose of the analysis. Instead, the second is useful to study well-diversified portfolios in incomplete markets. Anyway, there exist some measures γ that could be applied in both types of settings.

APPENDIX

The fulfillment of the Law of One Price (LOP) and the absence of arbitrage opportunities are equivalent properties in some restricted contexts.

Let us consider two dates $t < T$ and three securities denoted by S_1 , S_2 and S_3 . S_1 will be a risk-less asset, S_2 a risky one and S_3 a futures contract on S_2 with T maturity. Suppose that S_2 does not pay any dividend between t and T and denote its price by $I(t) > 0$ at t and by $I(T) \geq 0$ at T . It is clear that $I(t)$ must be a concrete numerical value while $I(T)$ must be a random variable. As usual, $r > 0$ will represent the interest rate between t and T and, consequently, $I/(1+r)$ and I are the prices of S_1 at t and T respectively. Finally, denote by $F(t, T)$ the future (at T) price of S_2 that can be guaranteed by S_3 .

Lemma. *Under latter assumptions, there are no arbitrage opportunities in the model if and only if the Law of One Price holds.*

Proof. Assume that LOP holds. Then,

$$I(t) = \frac{F(t, T)}{(1+r)} \quad \text{or} \quad I(t) \times (1+r) = F(t, T) \quad [1]$$

Let $x = (x_1, x_2, x_3)$ be an arbitrary portfolio composed by x_i units of S_i ($i=1,2,3$) and denote by $P(t)$ and $P(T)$ its numerical and random prices at t and T respectively. If x were an arbitrage portfolio, then $P(t) \leq 0$ and $P(T) \geq 0$ should hold. Hence, the proof will be finished if we show that the fulfillment of the LOP and latter inequalities lead to $P(t) = P(T) = 0$.

Obviously

$$P(t) = \frac{x_1}{(1+r)} + x_2 \times I(t) \leq 0 \quad [2]$$

and

$$P(T) = x_1 + x_2 \times I(T) + x_3 \times (I(T) - F(t, T)) = x_1 - (x_3 \times F(t, T)) + I(T) \times (x_2 + x_3)$$

Since $P(T) \geq 0$ must hold for any final value of the random variable $I(T) \geq 0$, future price (or payoff) of S_2 , the following inequalities have to be fulfilled.

$$x_1 - (x_3 \times F(t, T)) \geq 0 \quad [3]$$

$$x_3 \geq -x_2 \quad [4]$$

[1] and [3] lead to

$$x_1 \geq x_3 \times I(t) \times (1 + r) \quad [5]$$

We obtain from [2] that

$$x_1 \leq -x_2 \times I(t) \times (1 + r). \quad [6]$$

and, thus, bearing in mind [4],

$$x_1 \leq -x_2 \times I(t) \times (1 + r) \leq x_3 \times I(t) \times (1 + r) \quad [7]$$

Therefore, [5], [7], [3] and [4] must be equalities and $P(t) = P(T) = 0$.

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TABLE I
INTEGRATION MEASURES BETWEEN A FINANCIAL MARKET AND ITS DERIVATIVES MARKETS

Measures based on statistics and econometric techniques		Measures based on the asset pricing theory		
		Measures based on cross-market arbitrage		Measures based on equilibrium models
Series in differences	Series in levels	Fulfillment of the Law of One Price	Fulfillment of the Law of One Price and Absence of Arbitrage Opportunities	Garbade and Silber's model (1983)
Cross-correlation technique Granger causality (1969) Sims causality (1972)	Engle-Granger test for cointegration (1987) Cointegration procedure proposed by Johansen (1988 and 1991) and Johansen and Juselius (1990)	Relationship between future contract and its underlying asset Put-call parity	Measures of weak and strong integration of Chen and Knez (1995) Measures of weak and strong integration of Balbás and Muñoz (1998)	
Characteristics		Characteristics		Characteristics
Integration for one period		Integration level for a fixed date		Integration for one period
Lead-lag relationships can be established		Lead-lag relationships cannot be established		Lead-lag relationships cannot be established
Medium, last transaction or closing prices		Bid and ask, medium, last transaction or closing prices		Medium, last transaction or closing prices
Transaction costs cannot be accounted for		Transaction costs can be taken into account	Transaction costs cannot (resp., can) be taken into account by measures of Chen and Knez (resp., Balbás and Muñoz)	Transaction costs cannot be taken into account
Relationships between concrete markets		Concrete strategies	Non-predetermined strategies	Concrete strategies

TABLE II
STATISTICS FOR THE IBEX-35 CASH INDEX AND THE IBEX-35 FUTURES CONTRACT

The first column shows the variables and the remaining columns give the results for the corresponding day. The second row shows the number of observed returns. The third row gives the close to close variation of the IBEX-35 stock index. The fourth (fifth) row gives the IBEX-35 stock index (IBEX-35 futures contract) volatility obtained as the standard deviation of the minute to minute returns. The sixth row gives the spot returns autocorrelation coefficient (ρ_{spot}) and its p -value appears in parenthesis. The seventh row gives the autocorrelation coefficient of the futures returns (ρ_{fut}) and its p -value appears in parenthesis. The eighth row shows the relative bid-ask spread of the futures contract (S_{fut}). The ninth and tenth rows give the transaction volume on the spot and futures market in millions of pesetas and number of contracts, respectively.

VARIABLE	Asian crisis						
	22	23	24	27	28	29	30
Observations	415	415	415	415	401	379	407
Variation	-0.40%	-2.49%	-0.79%	-4.40%	-4.18%	5.66%	1.12%
σ_{spot}	0.046%	0.063%	0.056%	0.074%	0.125%	0.078%	0.090%
σ_{fut}	0.049%	0.069%	0.047%	0.084%	0.235%	0.117%	0.118%
ρ_{spot}	0.077 (0.115)	0.085 (0.083)	0.197 (0)	0.192 (0)	0.147 (0.003)	0.233 (0)	0.327 (0)
ρ_{fut}	0.115 (0.019)	0.037 (0.455)	0.007 (0.88)	0.139 (0.004)	0.175 (0)	0.131 (0.01)	0.245 (0)
S_{fut}	0.05	0.05	0.05	0.06	0.11	0.07	0.06
Vol_{spot}	138433.35	124031.96	82628.55	102194.46	218310.71	151003.4	148770.57
Vol_{fut}	21525	30179	22351	38374	93130	54816	61231

TABLE III
CROSS-CORRELATION OF MINUTE-TO-MINUTE INTRADAY RETURNS

Cross-correlation of minute-to-minute intraday returns for stock index and stock index futures. The first and last columns show the number of lags (k). The rest of the columns gives the cross correlation $\rho_{spot,fut(k)}$ for the corresponding day. The t -statistic appears in parenthesis. The numbers in bold are significant at the 1% level.

k	Asian crisis							k
	22	23	24	27	28	29	30	
-5	-0.001 (-0.024)	0.036 (0.735)	-0.001 (-0.014)	0.083 (1.691)	0.189 (3.789)	0.012 (0.232)	0.057 (1.156)	-5
-4	0.138 (2.809)	0.027 (0.548)	0.051 (1.037)	0.064 (1.306)	0.168 (3.368)	0.123 (2.389)	0.077 (1.547)	-4
-3	0.154 (3.127)	0.047 (0.947)	0.023 (0.477)	0.123 (2.512)	0.177 (3.548)	0.164 (3.199)	0.208 (4.190)	-3
-2	0.210 (4.276)	0.110 (2.231)	0.229 (4.667)	0.249 (5.081)	0.211 (4.223)	0.277 (5.395)	0.408 (8.233)	-2
-1	0.360 (7.338)	0.448 (9.126)	0.478 (9.729)	0.476 (9.701)	0.224 (4.492)	0.235 (4.579)	0.512 (10.323)	-1
0	0.246 (5.005)	0.333 (6.782)	0.334 (6.800)	0.297 (6.052)	0.136 (2.723)	0.116 (2.266)	0.430 (8.669)	0
1	0.091 (1.852)	-0.008 (-0.163)	0.007 (0.147)	0.125 (2.544)	0.193 (3.859)	0.101 (1.972)	0.193 (3.900)	1
2	0.060 (1.220)	-0.011 (-0.230)	0.096 (1.954)	0.070 (1.428)	0.116 (2.315)	0.074 (1.439)	0.002 (0.042)	2
3	-0.023 (-0.477)	-0.013 (-0.261)	0.046 (0.937)	0.024 (0.493)	0.120 (2.403)	-0.154 (3.004)	0.004 (0.073)	3
4	0.031 (0.623)	0.085 (1.734)	-0.054 (-1.106)	0.018 (0.261)	0.018 (0.364)	0.110 (2.134)	-0.015 (-0.305)	4
5	-0.045 (-0.921)	0.001 (0.014)	-0.017 (-0.336)	-0.075 (-1.536)	-0.020 (-0.398)	-0.060 (-1.166)	-0.179 (-3.607)	5

TABLE IV
PHILLIPS-PERRON TEST FOR UNIT ROOTS IN STOCK INDEX AND STOCK INDEX FUTURES PRICES

Z_L is the Phillips-Perron statistic of the series in levels and Z_D is the Phillips-Perron statistic of the series in first differences. For a model with intercept the MacKinnon (1991) critical values are -2.868 and -3.448 at the 1% and 5% levels, respectively.

		Panel A: lpc _t						
		22	23	24	27	28	29	30
Z_L		-1.348	-1.296	1.820	-1.898	-2.319	-0.872	0.147
Z_D		-18.880	-18.725	-16.390	-17.096	-17.964	-16.080	-14.894

		Panel B: lpf _t						
		22	23	24	27	28	29	30
Z_L		-1.186	-1.236	2.332	-0.601	-0.605	-0.484	-0.393
Z_D		-18.160	-19.525	-20.300	-17.742	-16.754	-16.731	-15.612

TABLE V
JOHANSEN COINTEGRATION TEST RESULTS FOR STOCK INDEX AND STOCK INDEX FUTURES PRICES

The first column shows the corresponding day and the number of observations and lags are in parenthesis. $\hat{\lambda}_i$ ($i=1,2$) is the estimated value of the characteristic root (eigenvalue). The last column gives the statistic $\hat{\lambda}_{trace}$ that tests the null hypothesis, which, versus a more general alternative, considers that the number of distinct cointegration vectors is lower or equal to r . Each day has an intercept in a cointegration equation. October 24th and October 30th have intercept and deterministic trend. *, **, and *** denote significance at the 1%, 5% and 10% level. Critical values of the λ_{trace} statistic are obtained from Osterwald-Lenum (1992).

Day	H_0	$\hat{\lambda}_i$	$\hat{\lambda}_{trace}$
22	$r=0$	0.058	28.153*
(416,6)	$r \leq 1$	0.009	3.657
23	$r=0$	0.116	52.992*
(416,3)	$r \leq 1$	0.006	2.301
24	$r=0$	0.078	33.943*
(416,4)	$r \leq 1$	0.001	0.578
27	$r=0$	0.052	24.361**
(416,4)	$r \leq 1$	0.006	2.286
28	$r=0$	0.052	22.556***
(402,9)	$r \leq 1$	0.004	1.600
29	$r=0$	0.029	13.229**
(380,7)	$r \leq 1$	0.006	2.341
30	$r=0$	0.062	26.625*
(408,7)	$r \leq 1$	0.003	1.082

TABLE VI
ERROR CORRECTIONS MODEL AND MEAN REVERSION

Parameter estimates of the error correction model for the IBEX-35 spot and futures prices. γ_1 (γ_2) give the coefficient of the error correction term in a spot (future) equation and the *t*-statistic is in parentheses.

	22	23	24	Asian crisis			30
				27	28	29	
γ_1	-0.152	-0.299	-0.269	-0.150	-0.076	-0.057	-0.158
<i>t</i> -stat.	(-4.221)	(-6.960)	(-5.677)	(-4.562)	(-4.519)	(-3.201)	(-5.008)
γ_2	0.066	-0.053	-0.039	-0.103	-0.011	0.003	-0.098
<i>t</i> -stat.	(1.464)	(-0.943)	(-0.756)	(-2.309)	(-0.289)	(0.084)	(-1.911)

TABLE VII
MEASURES BASED ON CROSS-MARKET ARBITRAGE

The first column shows all the measures. The rest of the columns give the results for the corresponding day. The second (third) row gives the maximum (minimum) value of *p*. The fourth (fifth) row shows the maximum values of *g* and *m*. The sixth (seventh) row gives the number of minutes in which the contemporaneous spot price (C_t) is lower (higher) than the theoretical spot price (C_t'). The eighth row shows the number of cash-and-carry (C.C.) arbitrage opportunities. The ninth row shows the number of reverse cash-and-carry (R.C.C.) arbitrage opportunities. The transaction costs have been computed for the corresponding day.

VARIABLE	22	23	24	Asian crisis			30
				27	28	29	
Maximum <i>p</i>	1.002382	1.002769	1.002459	1.003566	1.038149	1.004643	1.010057
Minimum <i>p</i>	0.997282	0.997058	0.995792	0.989183	0.970087	0.986578	0.995893
Maximum <i>g</i>	0.001547	0.001653	0.002358	0.005674	0.017762	0.007035	0.005316
Maximum <i>m</i>	0.002718	0.002942	0.004208	0.010817	0.036747	0.013422	0.009957
$C_t' > C_t$	148	100	53	202	31	53	224
$C_t > C_t'$	268	316	363	214	371	327	184
C.C.	0	0	0	0	27	4	20
R.C.C.	0	0	1	8	322	125	1

TABLE VIII
MEAN REVERSION IN MISPRICING SERIES

Test of unit roots in mispricing series. The variable ADF represents the Augmented Dickey-Fuller test of a single unit root in the mispricing series. The critical value of ADF at 1% level is -3.449. γ is the mean reversion parameter of the mispricing process and its *p*-value appears in parentheses.

	22	23	24	Asian crisis			30
				27	28	29	
ADF	-8.278	-4.645	-8.717	-7.785	-0.920	-3.549	-3.714
γ	-0.276	-0.241	-0.351	-0.079	-0.011	-0.091	-0.146
<i>p</i> -value	(0.000)	(0.000)	(0.000)	(0.075)	(0.858)	(0.000)	(0.000)