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Andreou, P. C. and Pierides, Y. (2008). Empirical investigation of stock index futures market efficiency: the case of the Athens Derivatives Exchange. **European Journal of Finance 14**, 211-223.

http://dx.doi.org/10.1080/13518470801890768

Empirical Investigation of Stock Index Futures Market Efficiency: The Case of the Athens Derivatives Exchange

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This Version: October 2007

Abstract

Pricing and trading practices in the Athens Derivatives Exchange, a newly established derivatives market, result in significant futures arbitrage profit opportunities for low costs traders. We find that a large part of the mispricing is due to transaction costs but additional factors, such as anticipated volatility and time to maturity contribute too. Ex-ante tests reveal significant arbitrage opportunities that could have been exploited up to 30 minutes after they had been identified. All different tests employed indicate that the derivatives market was inefficient during its early trading history because arbitrage opportunities persisted even after other market impact costs were taken into consideration.

JEL classification: G13; G14

Keywords: Market Efficiency, Market Frictions, Cost of Carry Model

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1. Introduction

Theory maintains that the mispricing of futures contracts cannot be sustained in the presence of arbitrage trading by market participants. There is an abundant of empirical evidence regarding the efficiency of well established derivatives markets that operate in developed countries (Modest and Sundaresan, 1983, Figlewski, 1984, MacKinlay and Ramaswamy, 1988, Yadav and Pope, 1990, Bühler and Kemph, 1995, Dwyer, et al., 1996, Neal, 1996, Tse, 2001). However, the empirical evidence from emerging or newly established derivatives markets is less frequent.

As in the case of other developed European derivatives exchanges (see for example Bühler and Kempf, 1995, who study arbitrage and mispricing for the DAX index futures), market conditions in the Athens Derivatives Exchange (ADEX) should not allow for large and long-lasting arbitrage opportunities. Sophisticated low cost traders (like market makers and large institutional traders) should be in the best position to exploit arbitrage opportunities. First, arbitrageurs can avoid tracking error because both index futures contracts traded are written on indices that are narrow and liquid (especially the FTSE/ASE-20 index). Second, they can replicate the index at favourable levels of transaction costs and within a reasonable span of time, minimizing at the same time execution risk in the spot market (see also Tse, 2001, who examines futures index arbitrage for the Dow Jones industrial average). Finally, ADEX is operating a fully automated electronic trading system eliminating in this way the execution risk in the futures market.

The purpose of this study is to examine the profitability of index futures arbitrage in order to provide novel empirical evidence about the efficiency of the recently established ADEX. The establishment of a well functioning derivatives exchange is very important for the Greek capital market since it can improve the overall efficiency and information dissemination process; it can complete the market, contribute in price discovery and can also attract foreign investors that can benefit from the (emerging) characteristics of this market (see Alexakis et. al., 2007).

Many issues that are addressed in this study contribute to our knowledge. First it is important to investigate whether the relationship between the index futures prices and the underlying stock indices can be described by the cost-of-carry model (Cornell and French, 1983). It is also of great importance to examine whether futures mispricings can result to profitable arbitrage trading in the presence of market frictions. To the best of our knowledge, this is the first study that directly validates (under market frictions) the index futures market efficiency of ADEX using high-frequency data for the period 2002-2004. Specifically, market efficiency is examined by analysing the FTSE/ASE-20 index futures contract, the most liquid of the traded contracts; for completeness we have also consider the FTSE/ASE Mid-40 index futures which is the second most liquid contract.

Prior research has documented that derivative markets are less efficient at their early trading history and that the frequency and the magnitude of mispricings are diminishing over time (see Bühler and Kempf, 1995, Dwyer, et al, 1996, and references therein). Thus a second interesting issue is to examine whether the price discrepancy between the cost-of-carry model and the market futures prices becomes less prevalent as time passes (indicating that the market becomes more mature over time).

Third, the efficiency of the derivatives market can have implications on the lead-lag relationship, on the hedging effectiveness (risk management) and on the price discovery mechanism. For example Lafuente and Novales (2003) discuss the estimation of optimal hedge ratios when there is discrepancy between the futures market price and its theoretical valuation according to the cost-of-carry model. So the investigation of the market efficiency can be informative and beneficial for market participants in the ADEX.

Finally, the interest on the properties and behavior of the ADEX is growing (i.e. Alexakis et al., 2007, Kavussanos and Visvikis, 2007, Kenourgios, 2005, and other related references therein). These empirical studies concentrate on other issues of interest and employ different methodologies. Our study contributes to this line of research using a new dataset and derives results that are over and above of what has been already seen in the extant literature regarding the ADEX[1].

Our primary results lead to the conclusion that index futures contracts offer profitable arbitrage opportunities, especially to low cost traders (like market makers and large institutional traders). The futures contracts present similar mispricing rates with transactions and closing data and they also exhibit cyclical mispricing patterns[2], evidence that complies with the findings of Evnine and Rudd (1985). We show that the frequency and magnitude of the futures mispricings remain the same even when stock index trading is delayed for at least 30 minutes[3]. We also extend the Gay and Jung (1999) theoretical model to account for the cost of borrowing stocks and for index tracking error. Despite introducing additional market frictions, we can still observe profitable arbitrage opportunities. At the end, using regression analysis, we identify additional factors that can explain the mispricing rates, such as time to maturity and market anticipated and unanticipated volatility.

The ADEX development is in accordance to other developed European markets (Kenourgios, 2005). In addition, investors in Greece have become more aware of derivatives trading as evidenced from the increase in the volume of futures contracts. Despite this, arbitrage opportunities are still very large and persistent indicating that the market does not exhibit a maturation effect like other European derivatives markets (see Bühler and Kempf, 1995). Our results indicate that for the period under investigation the ADEX has not attracted the attention of highly specialist and sophisticated traders that can act as arbitrageurs. We conjecture that most probably the market is dominated by the trading activities of hedgers[4] (similar conclusions are conjectured by Kavussanos and Visvikis, 2007, and Alexakis et al., 2007). As suggested by Shleifer and Vishny (1997) this might happen because specialized arbitrageurs (like large investment banks and hedge funds) avoid extremely volatile markets when they are risk averse and prefer large bond and foreign exchange markets where arbitrage opportunities are better exploited. Nevertheless, actions have to be taken in order to attract more investors that can act as arbitragers since as shown by Basak and Croitoru (2006) this can improve the risk sharing among investors and it can enhance the liquidity of the market.

2. Market Structure and Frictions for ADEX and ASE

The FTSE/ASE-20 index futures contract (namely FTASE) was first launched in late 1999. Its underlying asset comprises twenty blue chip stocks that are traded on the Athens Stock Exchange (ASE); these stocks account for more than 50% of the total market capitalization. A second stock index futures contract was introduced in early 2000 (namely FT40M). The underlying asset is the medium capitalization FTSE/ASE Mid-40 index and it comprises about 15% of the total market capitalization. At any time, there are six futures contracts listed for trading: their maturities correspond to the three nearest consecutive months and to the three nearest months from the March, June, September and December quarterly cycle. The futures contracts expire on the third Friday of the expiration month and all positions are cash settled. For the period under investigation, trading hours for the ADEX are between 10:45 – 16:15 and for the ASE between 11:00 – 16:00 (so closing data is non-synchronous). The futures are quoted in index points and the multiplier is 5 Euros. For further details about the ADEX and ASE please refer to Kavussanos and Visvikis (2007) and also to the ADEX website: www.adex.ase.gr.

Market participants can be classified in three categories: *non-exchange/individual members*, *large institutional investors* and *market makers*. Market makers are close related with large banks or brokerage houses and are obliged to adhere to many trading rules. Their prime responsibility is to enhance market liquidity by providing continuous bid and offer quotes for the two closest to maturity contracts. ADEX officers allow them to trade at significantly low transaction cost levels. Large institutional investors such as insurance companies and mutual funds, can also trade at favourable transaction costs because of their financial status and their close collaboration with an exchange member-agent. On the other hand, individuals trade at significantly higher costs than large institutional investors.

Both contracts under investigation bear similar transaction cost for taking a long or short position in the futures contract: 15 Euros for individuals, 5 Euros for large institutional traders and 0.22 Euros for market makers[5]. The transaction cost for taking a long (short) position in a comparable stock portfolio that replicates the FTSE/ASE-20 index is assumed to be 0.06% (0.36%) of the index level for market makers, 0.36% (0.66%) of the index level for institutional traders, and 0.66% (0.96%) of the index level for individuals[6]. As shown in Table 1, for the FTSE/ASE Mid-40 we assume smaller transaction costs because its level is much higher[7] than the one of FTSE/ASE-20. For long (short) positions in the futures contracts the initial margin requirement is set to 12% (14%) of the value of the contract[8]. In addition profits realized by derivatives are tax free.

[Table 1, here]

After June 2001, ADEX introduced stock repos (stock lending contracts) and stock reverse repos (stocks borrowing contracts) in an attempt to make short selling available to all investors. The contract size is fixed at 100 shares, the time period of the stock loan is limited to six months and any position in stock reverse repos bears a small non-fixed interest rate. Short sale proceeds from the stock reverse repos plus 50% of this amount is needed as an insurance deposit.

For the needs for our analysis we assume that all market participants can benefit from quasi-arbitrage trading (Gay and Jung, 1999, Fung and Draper, 1999), so we assume that the rate of availability of short sales proceeds equals unity. For the first part of our analysis we assume zero tracking error for taking a position in a comparable stock portfolio that replicates the index and we also ignore the cost of borrowing stocks. We examine the alternative assumption at a later stage by extending the Gay and Jung (1999) model.

3. Theoretical Model Prices and Bounds for the Futures Contracts

The cost-of-carry (*CoC*) model used to find the theoretical value of a futures contact, F_t, at time t is defined as (Cornell and French, 1983):

$$F_t = S_t e^{(r_t - \delta_t)T_t} , \tag{1}$$

where S_t is the current stock index level, T_t is the time to maturity of the contract, and r_t and δ_t represent the annual risk-free rate and dividend yield over the period T_t. Gay and Jung (1999) have shown that in the presence of transaction costs and short sales restrictions, the no arbitrage price must lie within the following lower (F_t^L) and upper (F_t^U) bounds:

$$F_t^L = \frac{S_t\{e^{r_tT_t}(m - k_{SS}) + ((1-m)(1-k_{br}) - k_{SL} - k_{FS} - k_{trc})\} - \delta(T)}{1 + e^{r_tT_t}k_{FL} + \{e^{r_tT_t} - 1\}q_S}, \qquad (2.a)$$

and,

$$F_t^U = \frac{S_t\{e^{r_tT_t}(1 + k_{SL}) + (k_{SS} + k_{FL} + k_{trc})\} - \delta(T)}{1 - e^{r_tT_t}k_{FS} - (e^{r_tT_t} - 1\}q_L}, \qquad (2.b)$$

Gay and Jung (1999) derived the above model without taking into consideration: *i)* the cost of borrowing stocks (k_{br}) when taking short positions in the comparable stock portfolio using the stocks borrowing mechanism (stock reverse repos), and *ii)* other market impact costs that can result to tracking error (k_{trc}). Following their rationale, Eqs (2.a) and (2.b) present the extended model that accounts for these market frictions. These new market frictions (parameters) mostly affect the lower bound that is related to futures underpricing. The other parameters of the pricing model are: k_{FL} (k_{FS}) is the percentage transaction cost of a long (short) position in the futures contract; k_{SL} (k_{SS}) is the percentage transaction cost of a long (short) position in a comparable stock portfolio that replicates the index[9]; m is the rate of availability of short sales proceeds (it lies in [0,1]); q_L (q_S) is the futures margin rate for a long (short) index position; and finally, $\delta(T)$ represents the future value of dividends until the futures expiration date.

4. Data Description and Analysis of the Mispricing Rates

We use intraday data to reduce any non-synchronous issues[10] for the period January 2002 to December 2004. For the FTASE (FT40M) contract we examine 721 (670) trading days corresponding to 37 expiration dates. We examine the futures mispricing rates by using three different datasets. First, we use futures transaction prices that are as close as possible to 15:30, i.e. 30 minutes before the close of the underlying market. Second, we use futures observations that are closest to 15:59. For both previous cases the futures data are matched with the underlying index within 30 seconds of the futures transaction. The basic dataset is the one that uses intraday data closest to 15:30 and any reference takes this dataset into consideration unless stated otherwise. Third, we use index closing prices with futures closing prices that are non-synchronous. It is of interest to see whether the same results can be obtained with or without synchronous data and if mispricings persist within the same day. Future prices are always those of the nearest and the second nearest expiration months (volume and open interest details are available from the authors upon request). Other months are excluded to eliminate any potential bias arising from thin trading. An appropriate dividend yield is computed from the sum of dividends paid out by stocks divided by the per year average market capitalization. We assign a constant dividend yield only during the period that dividends were paid out by companies (from April to August); this is a practice that is actually adopted by ADEX practitioners. Finally, the one and two month to expiration EURIBOR Euro rates collected from DATASTREAM® are used as an approximation of the risk free rate associated with the nearest and the upcoming futures contracts[11].

As a starting point, mispricing rates are evaluated under four different scenarios. In the first scenario the simple *CoC* as exhibited in Eq. (1) is used[12]. In the other three scenarios the upper and lower bounds are calculated according to Eqs. (2.a) and (2.b) using the transaction costs of individuals (*Ind*), large institutional investors (*Ins*) and market makers (*MM*). At this stage of the analysis we ignore the cost of borrowing stocks and tracking error.

Table 2 tabulates the futures mispricing results from the three different datasets for the FTASE contract. The overall mispricing results are in agreement with international evidence from other markets (Bailey, 1989, Figlewski, 1984, Modest and Sundaresan, 1983, Brailsford and Cusack, 1997, Gay and Jung, 1999). One (the nearest) and two (the upcoming) months to expiration contracts exhibit a tendency of underpricing relative to the theoretical *CoC* price.

Underpricing is observed in about 58% (69%) of the days for the nearest (upcoming) contract whereas overpricing is observed in only 35% (26%) of the days examined (significant underpricing is also reported by Bühler and Kempf, 1995, for the DAX futures market). Under market frictions, the maximum percentage of fairly priced contracts is observed for non-exchange members and the minimum percentage for market makers. For every dataset considered, the mispricing levels are bigger for the longer maturity contracts. In percentage terms the average underpricing of the nearest (upcoming) futures contract is between 0.78%-0.97% (1.35%-1.38%) of the index level. The mispricing rates for the FT40M contract (available upon request), in general coincide with those of the FTASE. From unreported per maturity mispricing statistics concerning the FTASE contract (available upon request) we observe significant underpricing during October 2002 to August 2003 and April 2004 to June 2004. Overpricing clustering is more prominent during the last months of 2004. This evidence is in contrast to European and other international evidence that report that index futures markets become more mature and mispricing rates diminish over time (see Bühler and Kempf, 1995, Dwyer et al., 1996, and Brailsfort and Cusack, 1997). Finally, from Table 2 is obvious that similar mispricing results are obtained regardless of the dataset considered. Arbitrage opportunities observed with the 15:30-dataset also persist with the closing prices dataset (see Evnine and Rudd, 1985, who document similar patterns for put-call parity violations).

[Table 2, here]

We continue to check the economic significance of the arbitrage violations for low cost traders (market makers and large institutional investors) with ex-ante tests. In accordance to previous studies (Bühler and Kempf, 1995, Neal, 1996, Fung and Draper, 1999, Tse, 2001), we assume that upon the identification of a significant mispricing, low cost traders can immediately trade the futures contract and take a position in the spot market with a time delay. Using evidence from previous studies (i.e. Bühler and Kempf, 1995, and Dwyer, et al., 1996), two different time delay assumptions are made: *i)* one (1m) to five (5m) minutes after taking the futures transaction, and *ii)* use of same day's index closing prices (C).

[Table 3, here]

As shown in the Table 3, profitable futures arbitrage opportunities persist in both frequency and level for the one (1m) to five (5m) minute cases. In the case of the nearest FTASE contract, when index trade execution is done with the closing price (C), there is a minor decrease in the number of futures overpricing and (especially) underpricing cases for both category of traders. This is in contrast to Bühler and Kempf (1995) who observe a large number of economically significant mispricings that disappear quickly because of arbitrage trading (see also Fung and Draper, 1999, and Tse, 2001). In addition, Dwyer et al. (1996) report for the S&P 500 futures that as the market becomes more mature (exchange trading history becomes larger) mispricing rates are exploited in a shorter amount of time. From unreported statistics we do not observe something similar in our case. This evidence is not necessarily striking but it can reveal a market that reacts slowly to profitable arbitrage signals.

To make the analysis more realistic we use the extended version of Gay and Jung (1999) model. First, and only for the market makers, we introduce the cost of borrowing stocks (k_{br}). When market makers sell short stocks that were borrowed, 150% of the proceeds should be deposited in a margin account and as a result the short sales proceeds parameter is always zero (m = 0). The cost of borrowing stocks is set equal to $1.5(e^{r_t T_t} - 1)$ of the index value in order to reflect the opportunity cost of having 150% of the proceeds in a margin account earning no interest (see Ackert and Tian, 2001, for a similar approach). For large institutional traders we use $k_{br} = 0$ since they can always engage into (quasi) arbitrage trading with stocks that they already hold (a similar assumption is used by Bühler and Kempf, 1995).

Second, for market makers and large institutional traders, we introduce k_{trc} with values between 0 and 1% of the index level in order to approximate for other market impact costs that can result to tracking error. As suggested by Evnine and Rudd (1985) tracking error can exist even when index replication is performed with all stocks comprising the index (see also Bühler and Kempf, 1995, and Gay and Jung, 1999).

Table 4 presents the results under the additional market frictions. The first column of figures (when k_{trc}=0) refers to the case where there is no tracking error but stock borrowing is costly (applies only for market makers); as a result, overpricing frequency and magnitude is as before. It can be seen that k_{br} is significant for market makers because there is an obvious decrease in the futures underpricing cases. This evidence coincides with the assessment of Modest and Sundaresan (1983) that futures underpricing can be also related to the loss of full use of short sales proceeds.

[Table 4, here]

When tracking error is introduced, there is an additional decline in the number of futures mispricing cases for both categories of traders. For 1% tracking error, all overpricing opportunities disappear and there is a significant reduction in the underpriced cases. Nevertheless, for relatively reasonable levels of market impact cost of around 0.4%[13], futures underpricing cases are large in number and still economically significant.

5. Other Factors that Affect the Pricing of the FTASE Contracts

In this section regression analysis is employed to identify other factors related with the mispricing rates. As in Gay and Jung (1999), (see also Brailsford and Cusack, 1997, Fung and Draper, 1999) the linear regression models include variables that are related with the futures time to maturity, market trend, and volatility. The analysis is done on a daily basis with the 15:30-data based on the *CoC* model using the regression model given below:

$$P_t = a_0 + \sum_{j=1}^{\upsilon} a_{1j} P_{t-j} + a_2 T_t^* + a_3 MACD_t + \sum_{j=1}^{\lambda} a_{4j} \sigma_{t-j+1}^{a} + a_5 \sigma_t^{u} + u_t \qquad (3)$$

In the above, P_t is the mispricing rate for day *t* and T_t^* is set equal to 0 if the time to maturity of the nearest (upcoming) futures contract is less than 14 (44) calendar days and to 1 otherwise (these values correspond to the average maturity of each contract class). $MACD_t$ is the Moving Average Convergence Divergence technical indicator and it is defined as the difference between a 26-day and a 12-day exponential moving average indicator. Moreover, σ_t^a (σ_t^u) is the maturity adjusted ARMA(2,1)-GARCH(1,1) anticipated (unanticipated) volatility of the FTSE/ASE-20 index. Regression results for the nearest and upcoming FTASE contract are presented in Table 5. All regression models are checked for serial correlation[14] up to the fifth residual lag based on the Breusch-Godfrey LM statistic (Godfrey, 1988). The coefficient standard errors are estimated with White's (1980) heteroskedasticity consistent covariance matrix.

Daily market volatility is decomposed into *anticipated* and *unanticipated* using a two-step approach (see Zhang et al., 2005). In the first step, an ARMA(2,1)-GARCH(1,1) specification (results are available upon request) is estimated using the FTASE/ASE-20 returns for the period 23/9/1997 to 31/12/2004 (call this Spec. #1). This is used to compute the daily market volatility via the fitted conditional standard deviation values of the model. In the second step, a volatility value is re-estimated daily using the above model specification based on prices beginning on 29/9/1997 and ending on the day prior to the day of each mispricing observation (call this Spec. #2). Using Spec. #2 we compute daily standard deviation return forecasts to estimate next day's *anticipated* market volatility (σ_t^a). In addition the difference between Spec. #1 and Spec. #2 is used to estimate next day's *unanticipated* market volatility (σ_t^u).

[Tables 5, here]

From the results of Table 5, the coefficients on the lagged mispricing rates are positive and significant. This indicates persistence of the mispricing and complies with evidence by MacKinlay and Ramaswamy (1988). For the nearest and upcoming contracts the time to maturity coefficient is positive[15] most probably because the time to maturity effect is captured by the maturity adjusted volatility variables. Regarding the market trend variable, $MACD_t$, it is marginally significant at 10% only for the nearest contract. This possibly indicates that futures mispricings are not affected by speculative trading that is related with the direction of the spot market. The anticipated volatility estimates are negative and statistically significant at 1% in both maturity contracts. In addition, the coefficient of the unanticipated volatility is negative and significant at 5% for the nearest to maturity contract and marginally insignificant at 10% for the upcoming contract. The latter evidence is probably induced by the emerging characteristics of the underlying market that may not at all time reacting rationally and thus reflecting all available information.

10. Conclusions

The results allow us to study the efficiency evolution of this new market. If we accept that the cost-of-carry model is a true approximation of the correct futures price, then we must consider the Athens Derivatives Exchange to be inefficient, at least during its early trading history. Even under more general assumptions about the prevailing market frictions, one can still observe economically significant mispricing cases.

The above analysis has different implications. First and most importantly, a significant dependence of the futures mispricings with volatility related variables has been identified by the regression analysis. This might imply that the futures market is dominated by the activities of hedgers (a similar conclusion is also reached by Kavussanos and Visvikis, 2007) who mainly wish to sell futures contracts in order to hedge their stock portfolio positions against volatility changes. Low cost traders like market makers and large institutional investors do not seem to actively engage in arbitrage trading in order to bring prices back to fundamental values. This might happen for various reasons like for example because of capital constrains (Tse, 2001, Basak and Croitoru, 2006), because specialized performance based arbitrage is ineffective in the presence of different agency relationships between arbitrageurs and investors (Shleifer and Vishny, 1997), or because low cost traders in ADEX require extremely high risk premia in order to exploit the arbitrage opportunities (Bühler and Kempf, 1995). Moreover other market conditions that might have prevailed during this period – like the maturity, the size of the derivatives market and the limited number of derivatives products – did not help in attracting the attention of large (and foreign) arbitrage specialist.

Second, our results complement and support other empirical evidence documented for the Athens Derivatives Exchange. For example, Alexakis et al. (2007) find that informed investors are not indifferent between trading in the futures and the cash market since only information that is released by the cash market has as an effect on the futures behavior (the reverse does not hold); thus giving birth to exploitable arbitrage and hedging opportunities (see also Kenourgios, 2005). Moreover, Lafuente and Novales (2003) show that when there is a systematic mispricing between the futures and the spot market the hedging effectiveness is optimized when using a lower number of futures contracts compared to the position taken to the stock index portfolio. Then our findings can offer an additional explanation why in the study of Kavussanos and Visvikis (2007) the minimum variance hedge ratio is significantly below unity.

The results indicate that actions should be taken that will eventually help increase the futures market efficiency by allowing additional investors (local and foreign) to participate in the market. In addition, the Athens Stock Exchange sometimes behaves as an emerging market with periods of aggressive rises and falls; so policy makers should find ways to further enhance liquidity and stabilize the spot market. Finally, the stocks borrowing mechanism seems to be under used by market participants; for the period we consider, the number of contracts that investors could trade was small and the number of stocks available for index short selling was limited. Therefore, any arbitrage trade could have been done only with a small number of contracts resulting to limited profits.

Acknowledgements

We would like to thank Andreas Papanayotopoulos for all his helpful comments and useful insights related to the Athens Derivatives Exchange trading mechanisms. We, as well, gratefully acknowledge the comments of Kostas Petsas and Andreas Georgopoulos.

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Tables

Table 1. Parameters related to the trading of the index and the futures contracts

		Non-Exchange Members	**Institutional Investors**	**Market Makers**
m	FTASE	1	1	1
	FT40M	1	1	1
$q_L\,(q_S)$ %	FTASE	12 (14)	12 (14)	12 (14)
	FT40M	12 (14)	12 (14)	12 (14)
$k_{SL}\ (k_{SS})$ %	FTASE	0.66 (0.96)	0.36 (0.66)	0.06 (0.36)
	FT40M	0.46 (0.76)	0.21 (0.51)	0.06 (0.36)
$k_{FL} = k_{FS}$ %	FTASE	15 e.p.c.	5 e.p.c	0.22 e.p.c.
	FT40M	15 e.p.c.	5 e.p.c	0.22 e.p.c.

FTASE (FT40M) are the tickers for the FTSE/ASE-20 (FTSE/ASE Mid-40) index futures contracts. k_{SL} (k_{SS}) is the cost for taking a long (short) position in a comparable stock portfolio that replicates the index without any tracking error. k_{FL} (k_{FS}) is the cost for taking a long (short) position in the futures contract. q_L (q_S) is the margin requirement for a long (short) futures position and m represents the availability rate of short sales proceeds The abbreviation “e.p.c.” stands for *euros per contract*.

Table 2: Mispricing rates for the FTASE contracts

	One Month to Expiration				**Two Months to Expiration**			
	CoC	***Ind***	***Ins***	***MM***	***CoC***	***Ind***	***Ins***	***MM***
Panel A: Futures mispricing statistics with data closest to 15:30								
Frequency of the mispricing (number of cases)								
Overpricing	254	0	1	88	190	0	0	72
Fair Pricing	52	701	633	387	34	629	521	283
Underpricing	415	20	87	246	497	92	200	366
Descriptive statistics of the mispricing levels (in index points except * that are in %)								
Mean Overpricing	3.94	0.00	1.81	2.75	4.46	0.00	0.00	2.82
Mean Overpricing*	0.32%	0.00%	0.12%	0.22%	0.36%	0.00%	0.00%	0.23%
Mean Underpricing	7.53	8.01	6.59	7.27	13.11	11.39	12.10	12.52
Mean Underpricing*	0.78%	0.97%	0.77%	0.79%	1.36%	1.37%	1.38%	1.35%
Panel B: Futures mispricing statistics with data closest to 16:00								
Frequency of the mispricing (number of cases)								
Overpricing	237	0	2	83	180	0	3	69
Fair Pricing	59	697	617	383	26	621	494	280
Underpricing	425	24	102	255	515	100	224	372
Descriptive statistics of the mispricing levels (in index points except * that are in %)								
Mean Overpricing	4.03	0.00	1.64	2.96	4.72	0.00	2.84	3.25
Mean Overpricing*	0.33%	0.00%	0.12%	0.24%	0.39%	0.00%	0.23%	0.26%
Mean Underpricing	7.97	7.60	6.65	7.78	13.33	11.17	11.57	13.02
Mean Underpricing*	0.82%	0.92%	0.77%	0.84%	1.38%	1.34%	1.32%	1.40%
Panel C: Futures mispricing statistics with closing index and futures data								
Frequency of the mispricing (number of cases)								
Overpricing	198	0	1	84	162	0	3	69
Fair Pricing	106	694	605	355	49	622	495	259
Underpricing	417	27	115	282	510	99	223	393
Descriptive statistics of the mispricing levels (in index points except * that are in %)								
Mean Overpricing	4.29	0.00	1.60	3.37	4.52	0.00	1.46	3.28
Mean Overpricing*	0.35%	0.00%	0.14%	0.27%	0.37%	0.00%	0.13%	0.27%
Mean Underpricing	8.28	8.21	6.78	7.83	13.51	12.24	12.18	12.94
Mean Underpricing*	0.85%	0.99%	0.78%	0.84%	1.39%	1.47%	1.39%	1.38%

The mispricing statistics concern 721 trading days for the two nearest to maturity future contracts of the FTSE/ASE-20 index. *CoC* represents the cost-of-carry model (under no transaction costs). In addition, *Ind*, *Ins* and *MM* refer to the mispricing rates for individuals (non-exchange members), large institutional investors and market makers (under transaction costs shown in Table 1). The upper part of each panel presents the frequency of mispricing rates and the lower tabulates the mean values of the mispricing rates.

Table 3: Ex-ante arbitrage tests regarding the FTASE contracts for market makers (and large institutional traders)

	1m	**2m**	**3m**	**4m**	**5m**	**C**
Panel A: Ex-ante arbitrage statistics for the nearest futures contract						
	Frequency of the mispricing (number of cases)					
Overpricing	83 (1)	81 (1)	78 (1)	75 (1)	72 (1)	71 (1)
Fair Pricing	394 (634)	400 (637)	409 (636)	413 (638)	419 (638)	430 (647)
Underpricing	244 (86)	240 (83)	234 (84)	233 (82)	230 (82)	220 (73)
	Descriptive statistics of the mispricing levels in index points					
Mean Overpric.	2.61 (2.03)	2.60 (2.14)	2.57 (2.29)	2.59 (2.28)	2.53 (2.60)	3.31(6.22)
Mean Underpric.	7.28 (6.56)	7.25 (6.59)	7.25 (6.64)	7.25 (6.61)	7.24 (6.59)	7.42 (6.58)
Panel B: Ex-ante arbitrage statistics for the upcoming futures contract						
	Frequency of the mispricing (number of cases)					
Overpricing	68 (0)	66 (0)	64 (0)	63 (0)	63 (0)	58 (0)
Fair Pricing	291 (522)	295 (522)	300 (522)	301 (523)	298 (523)	322 (528)
Underpricing	362 (199)	360 (199)	357 (199)	357 (198)	360 (198)	341 (193)
	Descriptive statistics of the mispricing levels in index points					
Mean Overpric.	2.66 (0.00)	2.64 (0.00)	2.70 (0.00)	2.71 (0.00)	2.65 (0.00)	3.37 (0.00)
Mean Underpric.	12.5 (12.1)	12.5 (12.1)	12.5 (12.1)	12.5 (12.2)	12.6 (12.2)	12.7 (12.2)

Ex-ante arbitrage profits under market frictions and transaction costs incurred by market makers and large institutional investors (low cost traders). The tabulated statistics concern 721 trading days for the two nearest to maturity future contracts of the FTSE/ASE-20 index. In each case, results for large institutional investors are reported in parenthesis. The results are computed by assuming an instantaneous futures trading and time delay for the index position. The time delays for the index trading are for one (1m) to five (5m) minutes and for same day's closing prices (C). The upper part of each panel presents the frequency of mispricing rates and the lower tabulates the mean mispricing values in index points.

Table 4: Mispricing statistics for market makers (and large institutional traders) for the FTASE contracts under costs for borrowing stocks and tracking error

	Tracking Error (k_{trc})					
	0%	0.2%	0.4%	0.6%	0.8%	1.0%
Panel A: Futures mispricing statistics for the nearest futures contract						
Frequency of the mispricing (number of cases)						
Overpricing	88 (1)	40 (0)	15 (0)	6 (0)	1 (0)	0 (0)
Fair Pricing	445 (633)	540 (654)	610 (673)	640 (682)	665 (693)	678 (701)
Underpricing	188 (87)	141 (67)	96 (48)	75 (39)	55 (28)	43 (20)
Descriptive statistics of the mispricing levels (in index points except * that are in %)						
Mean Overpricing	2.75 (1.81)	2.26 (0.00)	1.91 (0.00)	1.33 (0.00)	0.62 (0.00)	0.00 (0.00)
Mean Overpricing (%)*	0.22 (0.12)	0.18 (0.00)	0.15 (0.00)	0.10 (0.00)	0.04 (0.00)	0.00 (0.00)
Mean Underpricing	6.14 (6.59)	6.05 (6.56)	6.68 (7.17)	6.49 (6.90)	6.75 (7.62)	6.70 (8.67)
Mean Underpricing (%)*	0.69 (0.77)	0.70 (0.78)	0.78 (0.86)	0.77 (0.83)	0.81 (0.92)	0.81 (1.05)
Panel B: Futures mispricing statistics for the upcoming futures contract						
Frequency of the mispricing (number of cases)						
Overpricing	72 (0)	34 (0)	11 (0)	7 (0)	0 (0)	0 (0)
Fair Pricing	446 (521)	499 (538)	545 (565)	576 (597)	600 (618)	625 (625)
Underpricing	203 (200)	188 (183)	165 (156)	138 (124)	121 (103)	96 (96)
Descriptive statistics of the mispricing levels (in index points except * that are in %)						
Mean Overpricing	2.82 (0.00)	2.28 (0.00)	2.51 (0.00)	0.87 (0.00)	0.00 (0.00)	0.00 (0.00)
Mean Overpricing (%)*	0.23 (0.00)	0.19 (0.00)	0.21 (0.00)	0.07 (0.00)	0.00 (0.00)	0.00 (0.00)
Mean Underpricing	12.48 (12.1)	11.48 (11.2)	11.05 (11.1)	11.16 (12.0)	10.84 (12.4)	11.62 (11.5)
Mean Underpricing (%)*	1.42 (1.38)	1.32 (1.30)	1.29 (1.31)	1.32 (1.43)	1.30 (1.49)	1.41 (1.39)

The mispricing statistics concern 721 trading days for the two nearest to maturity future contracts of the FTSE/ASE-20 index. In each case, results for large institutional investors are reported in parenthesis. The results refer to theoretical futures bounds under additional transaction costs that account for the cost of borrowing stocks (k_{br}) and tracking error (k_{trc}). When k_{trc} = 0% only the cost of borrowing stocks is considered. The upper part of each panel presents the frequency of mispricing rates and the lower tabulates the mean values of the mispricing rates.

Table 5: Regression analysis for the FTASE mispricing rates

	a_0*	a_{11}	a_{12}	a_{13}	a_2*	a_3*	a_{41}	a_{42}	a_5	R^2_{adj}	$x^2(5)$
1M	0.18 [0.65]	0.80 [0.00]	---	---	0.84 [0.09]	0.01 [0.10]	-2.47 [0.00]	1.75 [0.00]	-2.08 [0.03]	0.697	6.857
2M	0.43 [0.65]	0.79 [0.00]	0.06 [0.36]	0.10 [0.05]	0.27 [0.50]	0.01 [0.35]	-1.54 [0.00]	1.23 [0.02]	-0.83 [0.12]	0.877	5.52

Regression results for the near (1M) and upcoming (2M) maturity futures contracts. Mispricing rates are based on the cost of carry model for the period 2002-2004 for 721 observations. The regression model is based on the following definition:

$$P_t = a_0 + \sum_{j=1}^{\upsilon} a_{1j} P_{t-j} + a_2 T_t^* + a_3 MACD_t + \sum_{j=1}^{\lambda} a_{4j} \sigma_{t-j+1}^{a} + a_5 \sigma_t^u + u_t$$

where P_t is the futures mispricing rate, T_t^* is a dummy variable related with the futures time to maturity, $MACD_t$ is the Moving Average Convergence Divergence technical indicator and σ_t^a (σ_t^u) is the maturity adjusted ARMA(2,1)-GARCH(1,1) anticipated (unanticipated) volatility of the FTSE/ASE-20 index. All regression results are based on the White (1980) heteroskedasticity consistent standard errors and covariance matrix. The Chi-Square test refers to the Breusch-Godfrey serial correlation LM statistic for serial correlation up to the fifth lag (the critical value at 5% significance level for five lags is 11.10). To avoid autocorrelation in the residuals, one (three) lagged values of the futures mispricing rates is (are) included for the nearest (upcoming) futures contracts. For the same reason we include one lag value of the anticipated volatility. Figures with (*) are multiplied by 1,000.

Endnotes

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[1] To our knowledge, Kenourgios (2005) uses minute-by-minute prices to examine the joint hypothesis of market efficiency and unbiasedness (only) for the FTSE/ASE-20 index futures contracts using cointegration analysis for the period March 2000 to March 2002.

[2] We examined the existence of cycles with a regression analysis in which we have used three yearly dummies to represent the trading years under investigation and we observed a clear **U** shape in the estimated dummy coefficients and their corresponding p-values (results not reported for brevity).

[3] Shleifer and Vishny (1997) and Basak and Croitoru (2006) show that under capital constrains arbitrageurs (e.g. low cost traders) limit the size of their trades and never fully “arbitrage away” the mispricing rates.

[4] Basak and Croitoru (2006) develop a model where arbitrage opportunities arise endogenously in equilibrium in the presence heterogeneous rational investors that are subject to investment restrictions.

[5] These Euro values are transformed to represent percentage values of the index level by dividing them with the level of the index times the index multiplier.

[6] The transaction costs used here seem on average to be higher compared to the ones used as benchmark in Dwyer et al. (1996) which is 0.25% of the index value for exchange members and 0.38% for institutional investors. Also in Bühler and Kempf (1995) for low cost traders the total transaction cost of a long arbitrage position is about 0.125% of the value of the stock portfolio and on average around 0.50% for a short arbitrage (including the cost of borrowing the stocks).

[7] For the period 2002-2004, the average index value for FTSE/ASE-20 is about 1,128 whereas for FTSE/ASE Mid-40 is about 2,201.

[8] The differential margin for the short and long futures positions is not significant and does not change our results.

[9] k_{SL} and k_{SS} refer to transaction costs paid under the assumption that tracking error does not exist when taking a long (short) position to a comparable stock portfolio that replicates the underlying index. We have introduced k_{trc} as an additional transaction cost proportional to the index level to mitigate this market friction.

[10] Tick futures and index transactions data were obtained from the AGFN database (ADEX official data vendor). Closing prices, volumes and open interest for the FTASE futures contract were obtained from the ADEX research department and closing index prices from the ASE research department.

[11] Our results are robust to the levels of dividend yields and risk-free rates used.

[12] It is rare for the market value of the futures to be exactly the same with the *CoC* estimate. A transaction is considered to be mispriced if it deviates by more than -/+0.05% for intraday data or by more than 0.1% for closing data.

[13] This value is even higher compared to the levels of other studies. Gay and Jung (1999) assume that the market impact cost from trading a 50-stock portfolio that replicates an index comprised by 200 stocks is about 0.4% of the index value. Bühler and Kempf (1994) document that DAX futures index arbitrager are willing to trade only if, in addition to transaction costs, a required risk premium equal to 4 index points is covered by the mispricing.

[14] To avoid autocorrelation in the residuals, lagged values of the futures mispricing rates and of the anticipated volatility are included.

[15] Using a regression model where volatility related variables are excluded we find that the coefficient of time to maturity is negative for both maturities and statistically significant for the nearest contract. This evidence complies with previous research (i.e. MacKinlay and Ramaswamy, 1988 and Bühler and Kempf, 1995).