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## ARBITRAGE IN EQUITY MARKETS

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**Abstract:** This paper tackles the problem of equity arbitrage on London Stock Exchange in years 1985–2012. The relationship between spot and future prices (the mispricing) has been analysed on the basis of FTSE100 index. Recently, the spread between spot prices and present value of the future prices has increased. This increase in mispricing can be perceived as evidence that could lead to an arbitrage opportunity. At the same time one could argue that none such opportunity exists as the mispricing merely reflects the change in the risk free rate proxy used by market participants. Furthermore the paper identifies the impact of the day-of-the-week effect on mispricing.

**Keywords:** arbitrage, equity markets, futures, derivatives.

### 1. Introduction

Efficient market hypothesis assumes that one cannot obtain sustainable abnormal returns, and that all information is already incorporated in the asset prices. In efficient market asset prices follow random walk (with a drift) and no pattern describing the behaviour of the prices can be identified. Moreover all new information should be immediately absorbed by the market, which should lead to immediate price adjustment following news release. In efficient market any arbitrage opportunity should vanish instantly, as such opportunity should be immediately taken advantage of. The no-arbitrage assumption is a basis for risk neutral valuation models used in derivative pricing. Yet one can wonder whether making no-arbitrage assumption can be justified and whether arbitrage opportunities exist in the financial markets.

There is a broad empirical literature that is providing evidence for mispricing in equity markets and suggesting that such mispricing could lead to arbitrage opportunities [Cornell, French 1983; MacKinlay, Ramaswamy 1988; Bilson et al. 2005; Bembenik 2007]. At the same time there are factors such as, for example: transaction costs, short-selling constrains or low liquidity of underlying asset that

could affect (reduce) the possibility of profiting from such arbitrage opportunity [Fung, Draper 1999; Richie et al., 2008; and Szyszka, Zaremba 2010]. Yet as much as those market frictions prevent arbitrageurs from keeping the mispricing at zero level, arbitrageurs still have some impact on the mispricing [Cooper, Mello 1990; Kumar, Seppi 1994; Kempf 1998].

This paper aims to investigate the arbitrage opportunities, and in particular the magnitude of mispricing in equity market. The focus is on British equity market, as it is the most liquid European market. The study is based on FTSE100 index and is conducted for years 1985–2012. The novelty of the research is that not only it focuses on the most recent data that covers also the current economic crisis, but it incorporates the study of the impact of the day-of-the-week effect on the mispricing and thus on the arbitrage opportunities. The paper intends to answer two research questions: (1) was the level of mispricing affected by the crisis and therefore is mispricing changing in time; (2) are there any evidence of the day-of-the-week pattern in the mispricing.

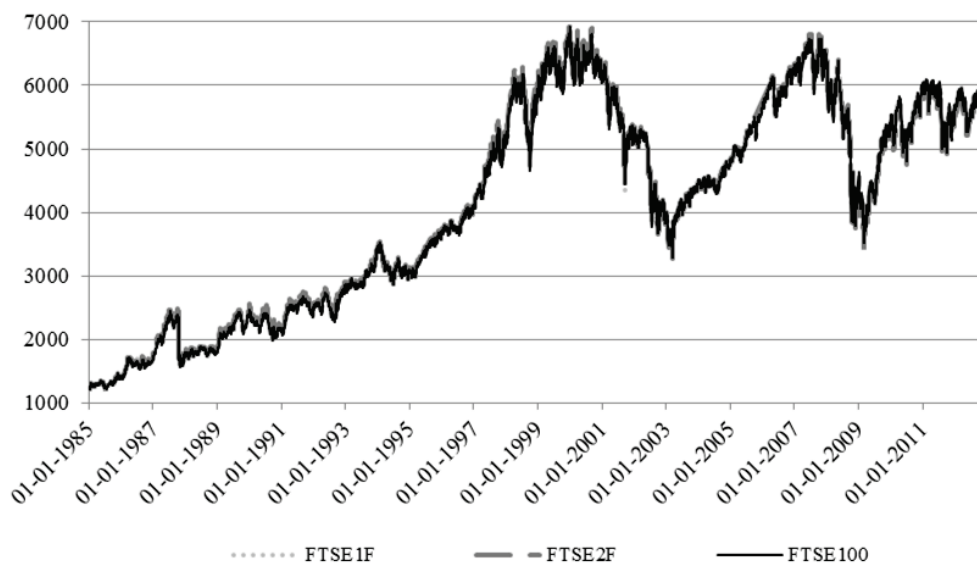
The paper is organized as follows, first the trend in FTSE100 and FTSE100 futures is analysed. Following that the level of mispricing of FTSE100 futures is identified. Next the study investigates (1) whether mispricing is stable over time, and (2) whether there are any signs of the day-of-the-week patterns in mispricing. Finally conclusions summarize the main results of the research.

## 2. FTSE100 and FTSE100 futures

The paper aims to investigate possible mispricing on the London Stock Exchange. FTSE100 index has been chosen as the proxy of the London market, due to its high liquidity and also relatively high liquidity of its trading futures.<sup>1</sup> Figure 1 presents how the value of FTSE100 and its 1- and 2-position futures was changing over time. The diagram reveals that there were two major stock market crashes in years 1987–2012. First one was related to the bust of the IT bubble, second to the current economic crisis (that had its origin on the bust of the U.S. real estate market bubble and more precisely in the problems resulting from excessive use of mortgage backed securities). It is apparent that although changes in both futures follow the changes in the underlying asset, still mispricing might be taking place. The following section investigates whether such mispricing exists and if so, is it stable over time.

---

<sup>1</sup> FTSE1F refers to FTSE100 1-position futures, i.e. outstanding contract closest to maturity. FTSE2F is the FTSE100 2-position futures, i.e. outstanding contract 2<sup>nd</sup> closest to maturity. FTSE3F is FTSE100 futures that is 3<sup>rd</sup> closest to maturity and FTSE4F is 4<sup>th</sup> closest to maturity.



**Figure 1.** FTSE100 and 1- and 2-position futures

Source: own calculations based on data obtained from EcoWin.

### 3. Mispricing: change in time

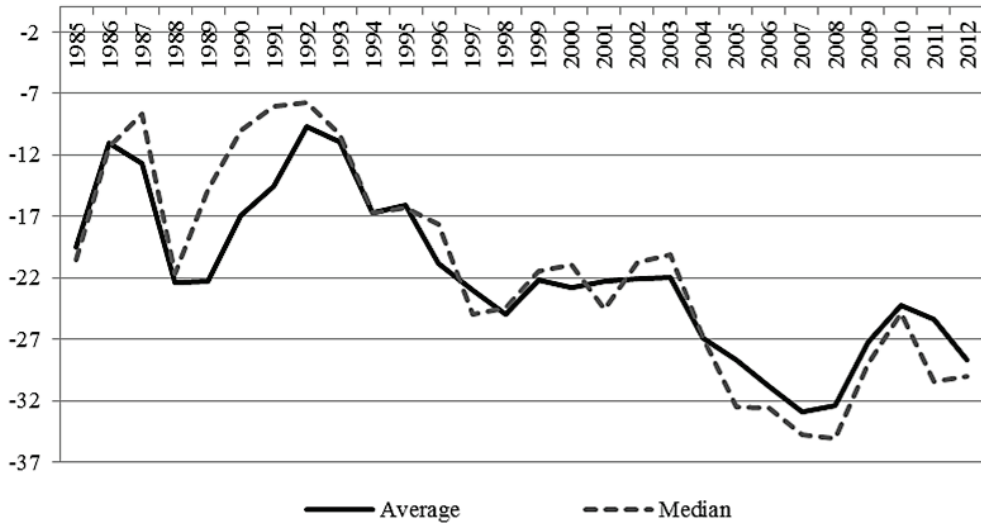
Figure 2 outlines the difference between the actual and the artificial value of the FTSE100 1-position futures contract.<sup>2</sup> Both the daily average values and daily median values of the mispricing are reported. It is clear that since 1993, excluding short period following the IT bubble bust, mispricing has been increasing. Mispricing continued to increase until the start of the current crisis, and after a brief decrease it is increasing yet again.

This increase in the mispricing could be originating from the fact that the standard measures of the proxy of the risk-free rate do not reflect any more what market believes to be a fair risk-free rate. Moreover changes in mispricing could be coming from government intervention [Naranjo, Nimalendran 2000; Chaboud, LeBaron,

<sup>2</sup> Later referred to as mispricing. In the perfect and frictionless market, the futures price should be equal to the future value of the current spot price, thus the artificial FTSE100 futures ( $F_t$ ) is calculated as [Black 1976; Merton 1977; Harrison, Kreps 1979]:

$$F_t = S_t e^{rt},$$

where  $S_t$  is the spot value, i.e. the FTSE100 price index on day  $t$ ,  $r$  – is the risk free rate (proxied by 1- and 3-month TBills) and  $t$  is the time to maturity of the futures contract (expressed as fraction of a year). The study has been limited to FTSE100 1-position as those contracts are characterized by the highest liquidity, thus one would expect them to provide relatively limited arbitrage opportunities that are yet to be explored.



**Figure 2.** Average and median of the daily difference between actual and artificial rate of FTSE100 1-position futures

Source: own calculations based on data obtained from EcoWin.

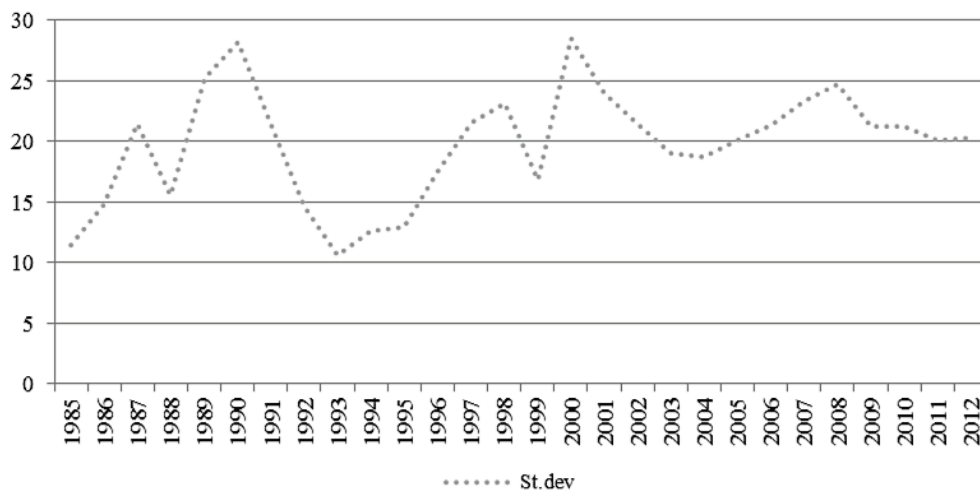
2001]. To help the economy overcome the crisis U.K. government did impose low interest rates. This resulted in initial decrease of mispricing. Yet at present the government policy is not sufficient to keep the belief in the market that the fair value of the risk-free rate is in-line with traditional proxies (such as T-bills). Therefore one can witness yet another increase in mispricing while using those traditional proxies in valuation.

One would expect that times of high volatility should be calling for higher risk compensation of fair risk-free rate (as opposed to proxy rate), leading to possible increase in mispricing. This is apparently the case during the current crisis. Yet it seems rather puzzling that during the IT bubble bust mispricing stabilized instead of increasing (at least in terms of the mean mispricing). At the same time both crisis brought increase in the risk as measured by the standard deviation of the level of mispricing (see Figure 3). What is interesting is that since 1996 the level of the standard deviation was relatively stable. The change in level of the standard deviation resulting from IT and current crisis was relatively low (in range of 20% only).<sup>3</sup>

The puzzle of the lack of increase in the average level of mispricing following IT bubble bust (as seen on Figure 2) could be tackled by looking at relative values.

<sup>3</sup> This is not entirely in line with previous studies that indicate positive relationship between volatility and mispricing [Merrick 1987; Hill et al. 1988; Draper, Fung 2003].





**Figure 3.** Standard deviation of the daily difference between actual and artificial rate of FTSE100 1-position futures

Source: own calculations based on data obtained from EcoWin.

When talking about the level of mispricing it seems relevant to look at relative figures and compare the change in the level of mispricing to the (absolute) changes in the value of the underlying asset. Both Table 1 and Figure 4 show that in comparison to the absolute daily changes in FTSE the daily mispricing of the FTSE1F seem to be of high importance.<sup>4</sup> In years 1987–2012 the average ratio of the mispricing to the changes in FTSE ( $M^s$ ) was equal to 0.85. Yet during the crisis the mispricing became relatively less important, with the ratio dropping down to 0.39 for both periods during the IT bubble and during current crisis. This could have been expected as the crisis brought high volatility in the underlying asset, whereas as noted earlier volatility in mispricing was relatively low (i.e. stable in time standard deviation).

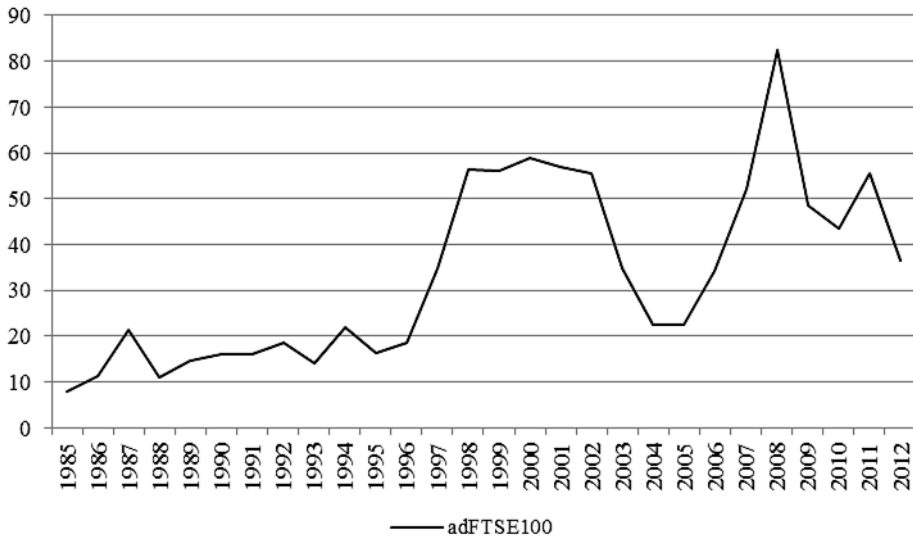
To sum up, this section outlined not only the increasing trend in mispricing but also the high relative importance of mispricing. The following section will investigate whether the day-of-the-week effect exists in mispricing.

<sup>4</sup> Some other papers use the level of the index and not changes in the index as a benchmark [MacKinlay, Ramaswamy 1988 Yadav, Pope 1994].

<sup>5</sup>  $M$  (at time  $i$ ) is calculated as:

$$M_i = \frac{F_{\text{FTSE1F}_i}}{\text{adFTSE100}_i},$$

where  $\text{adFTSE100}_i$  is the absolute value of the change in the FTSE100 index between day  $i - 1$  and  $i$ .



**Figure 4.** Average absolute value of the daily change in the FTSE100

Source: own calculations based on data obtained from EcoWin.

**Table 1.** Ratio of FTSE 1-position futures daily mispricing to the absolute daily changes in FTSE100

Year	<i>M</i>	Year	<i>M</i>	Year	<i>M</i>	Year	<i>M</i>
1985	2.472	1992	0.524	1999	0.395	2006	0.897
1986	0.987	1993	0.771	2000	0.387	2007	0.631
1987	0.594	1994	0.763	2001	0.392	2008	0.393
1988	2.026	1995	0.981	2002	0.398	2009	0.56
1989	1.534	1996	1.124	2003	0.632	2010	0.557
1990	1.053	1997	0.66	2004	1.196	2011	0.456
1991	0.909	1998	0.443	2005	1.278	2012	0.788

Source: own calculations based on data obtained from EcoWin.

#### 4. Mispricing: day-of-the-week effect

Monday effect is one of the most widely acknowledged time patterns in equity prices. The evidence of this pattern leads to rejection of the weak form of the market efficiency hypothesis. This section investigates the day-of-the-week pattern in the mispricing.

Table 2 presents average and median mispricing of 1-, 2-, 3- and 4-position contracts on FTSE100. The longer the maturity of the contract, the higher is the mispricing. This seems to be well expected as the contracts with longer maturities are characterized by low liquidity (due to the majority of trades being conducted in

the nearest outstanding contracts), thus leaving more chances for arbitrage opportunity [Yavad, Pope 1994].

**Table 2.** Average, median and standard deviation of the difference between artificial and actual forward rates for 1-, 2-, 3- and 4-position contracts on FTSE100

		FTSE1F	FTSE2F	FTSE3F	FTSE4F
Monday	Average	-22.2	-50.68	-90.3	-145.32
	Median	-19.95	-48.36	-83.06	-146.21
	St.dev	20.43	26.08	85.68	29.59
Tuesday	Average	-21.26	-49.8	-88.18	-143.32
	Median	-18.91	-47.75	-82.72	-143.6
	St.dev	20.31	26	74.57	29.68
Wednesday	Average	-21	-49.61	-89.65	-143.47
	Median	-18.44	-47.09	-81.58	-142.69
	St.dev	19.96	25.74	97.65	29.38
Thursday	Average	-20.68	-49.71	-88.12	-144.46
	Median	-18.63	-46.56	-82.1	-142.51
	St.dev	23.62	26.65	75.52	30.02
Friday	Average	-23.52	-52.04	-93.02	-146.37
	Median	-20.77	-50.41	-86.56	-147.77
	St.dev	21.35	26.21	85.69	29.38
Average	Average	-21.71	-50.34	-89.79	-144.56
	Median	-19.33	-48.04	-83.27	-144.14
	St.dev	21.18	26.14	84.23	29.61

Source: own calculations based on data obtained from EcoWin.

When comparing the value of the average mispricing on various days of the week, it is clear that in the sample period the largest mispricing occurs on Fridays, while the smallest mispricing is identified on Thursdays. Table 3 displays the results of the Welch's  $t$  test that investigates the day-of-the-week effect in mispricing.<sup>6</sup>

For the nearest outstanding contract Table 3 shows that the expected Friday mispricing is statistically significantly higher than expected mispricing on other days of the week (as confirmed by the  $t$ -stat of the Welch's test). The largest expected difference in mispricing occurs between Thursday and Friday. At the same time as compared with Monday, Thursday has the smallest expected mispricing.

<sup>6</sup> Welch's  $t$  test has been chosen, as it compares the expected values of two series with different standard deviations. Welch's  $t$  statistics is calculated as:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}}$$

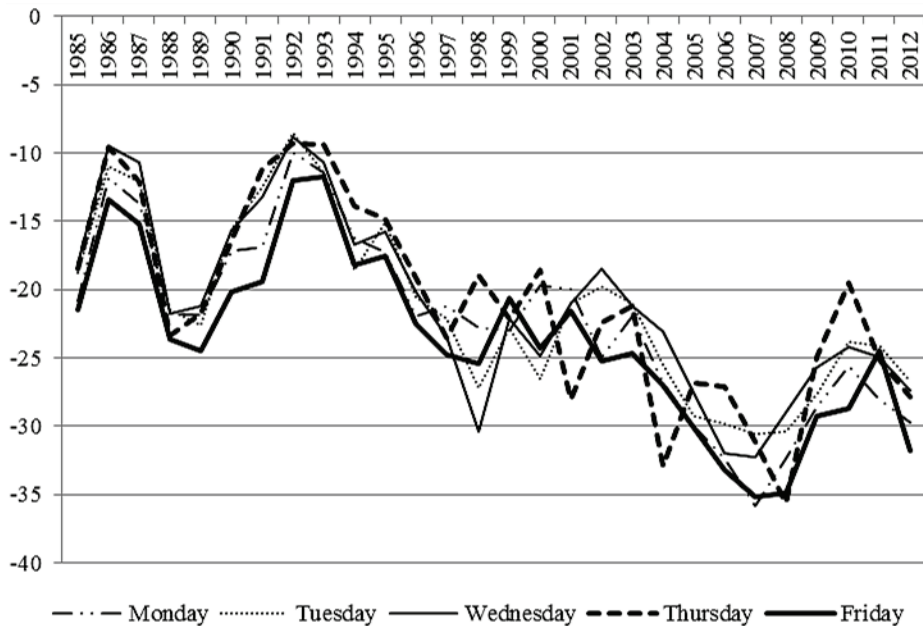
where  $\bar{x}_i$  is the average mispricing on  $i$ -th day-of-the-week,  $s_i$  is the standard deviation of the mispricing on  $i$ -th day-of-the-week and  $N_i$  is the number of observations of  $i$ -th day-of-the-week mispricing.

**Table 3.** Welch's *t*-test for the similarity of the expected difference between artificial and actual forward rates for 1-, 2-, 3- and 4-position contracts on FTSE 100 for various days of the week

	FTSE1F	FTSE2F	FTSE3F	FTSE4F
Mon Fri	1.711**	1.398*	0.856	0.963
Mon Tue	-1.251	-0.913	-0.715	-1.823**
Mon Wed	-1.599*	-1.123	-0.193	-1.694**
Mon Thr	-1.863**	-0.999	-0.73	-0.78
Tue Wed	-0.338	-0.206	0.457	0.138
Tue Thr	-0.71	-0.097	-0.021	1.031
Tue Fri	2.94***	2.311***	1.628*	2.792***
Wed Thr	-0.404	0.106	-0.473	0.899
Wed Fri	3.293***	2.528***	0.991	2.667***
Thr Fri	3.415***	2.38***	1.638*	1.739**

Asterisks indicate the level of significance.

Source: own calculations based on data obtained from EcoWin.



**Figure 5.** Average difference between artificial and actual forward rates for 1-position contracts on FTSE100 at various days of the week

Source: own calculations based on data obtained from EcoWin.

Figure 5 indicates that mispricing on various days of the week has been changing in time. There are apparent patterns in the relative level of mispricing, with Friday's mispricing being the largest. This provides yet another evidence of the day-of-the-week effect in mispricing.

The Friday effect identified above could be explained by the unwillingness of market participants (on average) to be holding open position through the weekend. This could result in increased trading on Fridays, which in turn could lead to mispricing (as perhaps more market participants want to clear the positions versus explore arbitrage opportunities). This explanation would need further empirical investigation (by for example focusing on intraday data<sup>7</sup>). Moreover it would be also interesting to investigate what could be the possible explanation of the relatively low mispricing on Thursdays, in particular during the recent crisis.

## 5. Conclusions

The paper investigates the arbitrage opportunities, and in particular the mispricing in equity markets based on FTSE100 index and FTSE100 futures. There is an evidence of mispricing in years 1985–2012, with the recent years characterized by increasing spread between actual and artificial futures prices (thus providing evidence that mispricing is changing in time). The possible explanation for this increase in mispricing is the technical default of derivative pricing model that relies on traditional proxy of “risk-free” rate, which apparently are not what the markets believes to be the fair value of the risk-free rate anymore. Furthermore the study conducted in the paper revealed the presence of the day-of-the-week pattern in mispricing. The largest mispricing occurs on Fridays, the smallest on Thursdays.

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<sup>7</sup> Particularly high mispricing is to be expected at the end of the session. It would be interesting to compare the end of session mispricing on various days of the week.

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## ARBITRAŻ NA RYNKU AKCJI

**Streszczenie:** Praca ta porusza problem występowania możliwości arbitrażu na rynku akcji na giełdzie londyńskiej w latach 1985–2012. W szczególności przedmiotem badania jest stosunek między wartością obecną a wartością wynikającą z kontraktów terminowych na indeks FTSE 100. Badanie ukazuje, iż można zaobserwować wzrost różnicy między tymi wartościami, a tym samym należy się spodziewać możliwości występowania arbitrażu. Niemniej jednak należy się zastanowić, czy możliwość arbitrażu rzeczywiście istnieje, a wzrost nie jest tylko odzwierciedleniem zmiany w mierniku stopy wolnej od ryzyka używanej przez uczestników rynku do wyceny instrumentów finansowych. Ponadto w pracy ukazano wpływ efektu dni tygodnia na możliwości arbitrażu.

**Słowa kluczowe:** arbitraż, rynek akcji, kontrakty terminowe.