Index Futures Market Efficiency and Arbitrage Opportunities: Evidence from the Ukrainian Futures Market

by

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Abstract

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In this study the market efficiency of the Ukrainian index futures market is examined by testing the hypotheses of the absence of ex-post and ex-ante mispricings, rarity and transitoriness of arbitrage profits and the existence of the direct relationship between average absolute relative mispricing and the time to maturity. We find that the frequency of transaction boundary violations in the Ukrainian market is significantly lower than in the developing Polish market and is comparable to the matured MMI (American) market.

The analysis of the upper-bound violations does not allow us to reject the hypothesis of the absence of arbitrage opportunities. On the other hand, lower-bound violations, which are generally much more difficult to exploit by investors, led to frequent and persistent profits for the early contracts, however, violations almost totally ceased to exist for more recent futures. Overall, taking into account the current state of affair in the Ukrainian futures market the hypothesis of the market efficiency cannot be rejected.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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Chapter 1

INTRODUCTION

Financial derivatives, such as forwards, futures or options, perform a very important role in any economic system since they allow economic agents to hedge their risks and as a result enhance their welfare levels. Once the derivate markets open in an economy, both market participants and regulators raise the question of their efficiency, in particular with respect to fair market pricing and the existence of arbitrage opportunities. Loosely speaking, arbitrage opportunities imply that agents can make instant risk-free profits without investing any personal funds. An absence of the arbitrage opportunities is an important requirement for a market to be efficient.

While most modern asset pricing theories are based on the assumption of efficient markets, this assumption is often violated in the real world (Dimson and Mussavian, 2000). Underestimating the importance of financial market efficiency may have destructive consequences on the world economy. One striking example is the last financial crisis in 2008-2009 when assets were not priced fairly, market was not efficient that slowed down the world economic growth significantly.

This research is devoted to the investigation of the efficiency of stock index futures market in Ukraine. A futures contract is an agreement between two economic agents to buy or sell a certain asset (called underlying asset) for a certain price at a certain date in the future. An index futures contract is a particular type of a futures contract that has a stock exchange index (market portfolio) as an underlying asset.

The Ukrainian market of futures on index was launched on May 27, 2010. Each year 4 futures contracts are traded with maturity in March, June, September and December. Maturity time of each contract is a half of a year. There are about 250,000-300,000 trades for each futures contract or 4,000-5,000 transactions per day. For instance, these figures are slightly bigger than for Polish market in 2000-2002 (Bialkowski and Jakubowski, 2008).

Market efficiency of stock index futures markets and frequency of arbitrage opportunities have been tested in numerous studies. In plenty of works matured markets have been examined: USA (MacKinlay and Ramaswamy, 1988; Chung, 1991; Klemkiwski and Lee, 1991; Henker and Martins, 2005), UK (Yadev and Pope, 1990), Japanese (Brenner, Subrahmanyam and Uno, 1990), Finish (Puttonen, 1993) and other markets. Also, there are papers devoted to the analysis of new markets, including investigations of Polish (Bialkowski and Jakubowski, 2008), Greek (Floros and Vougas, 2008) and Indian markets (Hogue, Kim and Pyun, 2007; Mall, Pradhan and Mishra, 2011).

However, there have been no studies devoted to the Ukrainian index futures market. This market is of particular interest because it has several distinctive features that make the market unique compared to other markets.

First of all, the value of the underlying asset of Ukrainian futures contracts (the UX index) is highly volatile. During August-September 2011 there was a sharp decline in the UX index value: the index dropped from about 2500 points to 1300 points. We can expect that such turmoil on the market might deteriorate its efficiency.

Another distinctive attribute of the Ukrainian financial market is almost absolute absence of dividends paid. This feature may lead to more precise estimation of the market efficiency of the Ukrainian futures market. When computing the

theoretical price of a futures contract the expected discounted value of future dividends paid on the index should be subtracted from the price of a contract. The amount of future dividends is generally uncertain and its estimation by various investors may differ considerably leading to higher deviations of futures prices from corresponding fair prices.

Besides, the practical importance of this research comes from the fact that the Ukrainian index futures market is an experimental project for its organizers. Successful implementation of this project will hopefully lead to further development of the Ukrainian financial derivative markets. Thus, the organizers of the market as well as regulators and investors are interested in exploring its efficiency.

A standard approach to detecting pricing inefficiencies in a futures market consists in comparing the market futures price to the theoretical price that is based on a cost-of-carry model, which was developed by Cornell and French (1983). This model has been employed among others by MacKinlay and Ramaswamy (1988), Fieglewski (1984), Chung (1991), Klemkosly and Lee (1991) Bialkowski and Jakubowski (2008).

The hypothesis of market efficiency and impossibility of arbitrage operations requires deviation of the actual market price from the theoretically computed one to be less than transaction costs. We call these deviations 'pricing errors', and when these pricing errors in absolute value are larger than transaction costs then transaction boundaries are said to be violated. If there is a mispricing and a pricing error is positive then there is an upper bound violation or short arbitrage opportunity. In other words, investors can profit by shorting an overpriced futures contract. If deviation of the actual market price from the theoretical price is negative and it is larger in absolute value than the transaction costs, then there

is a lower bound violation or long arbitrage opportunity. In this case, investors benefit if they buy undervalued futures contract.

Following the literature, this research will focus on testing the efficiency of the Ukrainian futures market based on the following three hypotheses:

1. The absolute value of pricing errors lies within the transaction costs boundaries.

2. Arbitrage profits are rare and not persistent.

3. Deviation of actual price from the theoretical price is a declining function as time to maturity decreases.

Clearly, market efficiency hypothesis and impossibility of arbitrage opportunities does not require absolute absence of transaction boundaries violations. Rare and random price inefficiencies certainly do not contradict the main hypothesis of this study. The question is then how to estimate whether the frequency of mispricings is sufficiently large or not. One way to do it is to compare the empirical results of this study with corresponding indicators in other studies (particularly, Chung (1991) and Bialkowski and Jakubowski (2008) which used quite similar methodology). Another approach is to estimate whether exercising arbitrage opportunities leads to statistically significant profits. If such arbitrage profits are not statistically significant we can assert that arbitrage opportunities are rare and do not allow us to reject the market efficiency hypothesis.

Overall, general economic intuition suggests that a developing financial market (which is the case of Ukraine) is likely to be less efficient than an established market, and that there are likely to be large and persistent deviations of the actual market price from the arbitrage-free price opening opportunities for arbitrage

profits. Thus, the expected results are such that the first two out of the aforementioned hypotheses will be rejected.

The data used in this study consists of intraday data on the UX index futures contracts (at 1 minute frequency), intraday UX index values (at 1 minute frequency), daily data of interest rates KievPrime, as well as information on dividends transaction costs. However, as it has been mentioned, very few companies in Ukraine pay dividends on their stocks. Hence, we can simplify the model by excluding dividends from it. The information on transaction costs can be found on the UX official site. This data has been collected from the official site of UX and Cbonds and covers the period from January 2011 till May 2012.

The thesis has the following structure. The second chapter gives literature review regarding testing estimating market efficiency hypothesis and estimating frequency of arbitrage opportunities on other index futures markets. In the third chapter the data used in this research is described and discussed. In the fourth chapter the methodology used for the purposes of this study is presented. The fifth chapter is devoted to discussion of its empirical results and the sixth chapter contains the conclusion of the thesis.

Chapter 2

LITERATURE REVIEW

The most widespread approach to measuring arbitrage opportunities on index futures markets is the cost-of carry model developed by Cornell and French (1983). According to this model an opportunity of making an arbitrage profit arises if deviations of market prices from the corresponding theoretically computed ones do not stay within boundaries determined by transaction costs. The studies in the early 1980s (Cornell and French, 1983; Modest and Sundaresan, 1983; Figlewski, 1984; Stoll and Whaley, 1990; Brennan and Schwartz, 1990; Merrick, 1987; MacKinlay and Ramaswamy, 1988; Harris, 1989) reported significant mispricing questioning the market efficiency hypothesis.

Numerous studies try to explain why the inefficiencies occur. As far as Cornell and French asserted, the mispricing stems from different taxation of stocks and futures contracts. Fieglewski (1984) claimed that a source of the mispricing is a lack of knowledge about market's nature. Besides, mispricing can be caused by uncertainty of the future dividends payments (Peters, 1985), difference in lending and borrowing rates (Gould, 1988) and impossibility to perfectly replicate the underlying index (MacKinlay and Ramaswamy, 1988).

One important modification of the methodology was proposed by Chung (1991). Due to the fact that a trader cannot always execute his or her orders at the observed prices, Chung used execution lags in his work testing Major Market Index (MMI) futures market. As a result, Chung's paper revealed significantly lower arbitrage opportunities in comparison with other studies, including MacKinlay and Ramaswamy (1988), Fieglewski (1984) and Cornell (1983, 1985).

In addition, boundary violation frequency decreases sharply with time. Thus, according to this research the hypothesis of the efficient index futures market becomes more plausible.

Another suggestion with respect to the methodology was made by Bae, Chun and Cheung (1998). They argued that estimation of stock index futures profitability conducted in previous studies can be biased if it does not take into account ask-bid spreads. They assert that ignoring ask-bid spreads leads to overestimation of the size and the frequency of arbitrage opportunities. The authors show that using ask-bid boundaries instead of transaction boundaries to analyze stock index futures in Hong Kong leads to a significantly lower number of violations comparing to the classical approach.

Most recent studies investigating arbitrage opportunities on developed markets reported permanent decrease in mispricing frequency indicating maturing of the markets. For instance, Henker and Martens (2005) investigated the effect of a decline in the minimum change of a stock price in 1998 (from an eighth to a sixteenth) and found out that the market efficiency on S&P 500 increased.

However, most existing studies investigate mature markets, the group which obviously does not include Ukraine's stock index futures market. Recent investigations of the emerging markets include Bialkowski and Jakubowski (2008) and Floros and Vougas (2008), who study Polish and Greek stock index futures markets respectively, and Hogue, Kim and Pyun (2007), Mall, Pradhan and Mishra (2011) and other papers that focus on emerging Asian markets.

Bialkowski and Jakubowski (2008) studied the Polish market for period from December 2000 till December 2002 (future contract trading started on January, 1998) and found out that arbitrage opportunities were much more frequent and of much higher magnitude than on developed markets. However, this indicator

decreased significantly from March 2001 till December 2002, which is in line with the fact that arbitrage opportunities decline over time as markets mature.

In addition, the authors test whether there is a negative correlation between average absolute value of futures mispricing and their time to maturity. This relationship is explained by the decrease of uncertainty about interest rate as the time to maturity declines. Despite the fact that this hypothesis had been confirmed by studies of mature markets, there was no such evidence on Polish market.

Another distinctive feature of the Polish market is high persistence of arbitrage opportunities, i.e. long time span during which the market prices are misaligned relatively to their no-arbitrage counterparts. While the average persistence of pricing errors for the Polish market was 64 min, this indicator rarely exceeded 5 min for developed markets. Taking into consideration all these features of the Polish futures market, it is natural to expect that the Ukrainian futures market is quite inefficient at its early stage of development.

Chapter 3

METHODOLOGY

For this study we will use a long-established methodology in this research area. This will make our results directly comparable to the findings of previous studies. To test the first hypothesis that the absolute value of pricing errors lies within the transaction costs boundaries we should compare theoretical prices of index futures contracts with actual prices. The theoretical price of an index futures contract can be computed using the "cost-of-carry" model by Cornell and French (1983). Assuming that markets are efficient, there are no taxes and interest rates are nonstochastic, the stock index futures price is given by the formula:

$$F(t,T) = S(t) \cdot e^{r(T-t)} - D(t,T), \tag{1}$$

where *F(t,T)* is the price of the futures contract acquired at time t and maturing at time *T*, *S(t)* is the index value at time *t*, *r* is a risk-free interest rate, *D(t,T)* is the present value of the dividends at time *t*.

The hypothesis of market efficiency and impossibility of arbitrage operations requires deviation of the actual market price from the theoretically computed to be less than transaction costs:

$$\xi = \left| F(t,T) - (S(t) \cdot e^{r(T-t)} - D(t,T)) \right| \le b(t), \tag{2}$$

where *b(t)* is the present value of the sum of transaction costs at time *t*.

However, as it is stated in the previous works (Chung, 1991) traders cannot always execute their orders at observed prices. As a result, an ex post violation of

condition (2) would only be a signal for a trader to act, and would not necessarily mean that he can actually exploit this arbitrage opportunity to make profits.

Then, it is reasonable to investigate ex ante violations and corresponding arbitrage opportunities. Ex ante violations are ex post violations that led to profit in the next period of time. Thus, the formula for deviations has the following form:

$$\xi_{ante} = \left| F(t^+, T) - (S(t^+) \cdot e^{r(T-t)} - D(t^+, T)) \right| \leq b(t^+), \quad (3)$$

where t^+ corresponds to the time at which the next transaction took place.

Besides, it is important to investigate upper and lower bound violations separately. One of the features of a developing financial market is a restricted usage of short-sale trades. Despite the fact that short-selling is allowed on the Ukrainian Stock Exchange it may be the case that the market does not dispose of arbitrage opportunities due to unwillingness or inability of some investors to short-sell index.

To test the second hypothesis that arbitrage profits are rare and not persistent we have to compute arbitrage profit after each ex post mispricing. Since that there is mark-to-market accounting on the Ukrainian index futures market we should also take into account paid/received interest from changing variation margin.

For instance, if at time t an investor observes that a futures contract is overvalued. At time t^+ the investor can profit by borrowing funds, purchasing index, selling the futures contract and waiting till maturity. At the maturity the investor is obliged to sell the index for the price of the futures contract and to repay the borrowing. Assuming that no dividends are paid investor's arbitrage profit at the maturity can be calculated using the following formula:

$$\pi(t^+) = F(t^+,T) - S_t \cdot e^{r(T-t^+)} - b(t^+), \quad (4)$$

if $\xi > b(t) \Leftrightarrow F(t,T) - S_t \cdot e^{r(T-t)} > b(t)$

where $\pi(t^+)$ is arbitrage profit for the trades at time t^+, $\mu(t^+)$ is the sum of all interest paid or received due to the change in variation margin. The positive value implies that an investor that issues futures contract. The magnitude of this figure can be calculated using the following formula:

$$\mu(t^+) = (f_{end}(\tau,T) - f(t^+,T)) \cdot e^{r_\tau \cdot \Delta t_\tau} + \sum_{i=\tau}^{N} (f_{end}(i+1,T) - f_{end}(i,T)) \cdot e^{r_i \cdot \Delta t_i}, \quad (5)$$

where τ is the number of a trading day, N is total number of trading days for particular futures contract, $f(t^+,T)$ is an observed market price of a futures contract at time t^+, $f_{end}(i)$ is end-of-day price at day i, r_i is interest rate at trading day i, Δt_i is time to maturity for day i.

If at some point of time t a futures contract is undervalued it enables traders to get an arbitrage profit using the following strategy. At time t^+ the futures contract is bought, the index is shorted and received funds are invested till the maturity time. On the maturity day investor uses these funds to buy the index and return the index back to broker. The arbitrage profit in this case is

$$\pi(t^+) = S_t \cdot e^{r(T-t^+)} - F(t^+,T) - b(t^+), \quad (6)$$

if $\xi < -b(t) \Leftrightarrow S_t \cdot e^{r(T-t)} - F(t,T) > b(t)$

Regular and persistent arbitrage profits would imply that the transaction boundaries violations on the index futures market are sufficiently frequent to conclude that the market is inefficient.

According to the official site of the UX, registration and execution of an order on the UX index futures order amount to 0.6 UAH. It is equal to just 0.025%-0.05% of an index futures contract. Exchange duty on the stock exchange is equal to 0.01% of the amount of transaction. Besides, in this research we would like to take into account bid-ask spreads of the UX Index. The motivation comes from the reasoning that it is relatively more expensive to buy the index than to sell when an investor forms an arbitrage portfolio. The bid-ask spread is equal to approximately 0.5% of the UX Index, thus, we amount it as a part of transaction costs. Overall, it is assumed that transactions costs take one of the following three values 0.5%, 0.75%, 1.0% since different investors may face additional transaction costs (for example, brokerage fees etc).

Besides, there is a commission for the short-selling stocks that should be taken into account. The short-selling of stocks on the Ukrainian stock exchange is possible using repurchase agreement (repo). Investors, which short-sell stocks for more than one day, are typically obliged to make a repo contract with broker. Repurchase agreement is the sale of stocks with an agreement for the seller to buy back the securities at a certain date. Commission for repo agreements charged by two biggest brokers in Ukraine amounts to 20-25% per year. However, some reliable institutional investors may borrow for lower commission, for instance, 10%. Hence, to take into account additional transaction costs related to index short-selling we should use the asymmetric transaction boundaries. Moreover, the lower transaction boundary is time dependent. Thus, the following transaction costs are used in this study:

$$b(t) = \{0.005 \cdot F(t,T), \quad 0.0075 \cdot F(t,T), \quad 0.01 \cdot F(t,T)\} \text{ if } \xi(t) > 0,$$

$$b(t) = \{0.005 \cdot F(t,T) + 0.1 \cdot F(t,T) \cdot (T-t), \quad 0.0075 \cdot F(t,T) + 0.2 \cdot F(t,T) \cdot (T-t),$$

$$0.01 \cdot F(t,T) + 0.25 \cdot F(t,T) \cdot (T-t)\} \text{ if } \xi(t) < 0.$$

In order to test the third hypothesis that an average deviation of actual price from the theoretical price is a declining function as time to maturity decreases one should investigate the correlation between an average mispricing and the time to maturity of a contract. The methodology was proposed by MacKinlay and Ramaswamy (1988) and the model is as follows:

$$z(t,T) = \beta_0 + \beta_1 \cdot (T-t) + \varepsilon(t,T), \tag{7}$$

where *z(t, T)* is the average absolute deviation of actual index futures price with maturity date T from the theoretical price that is calculated using the formula:

$$z(t,T) = \sum_{i}^{N_t} \frac{abs(\xi_i^{post})}{N_t}, \tag{8}$$

where N_t is number of observations during day *t*.

The idea behind it is that the "uncertainty about interest rates and size of dividends in the cost-of-carry model becomes smaller as the time to maturity decreases" (Bialkowski and Jakubowski, 2008). In other words, as the time to maturity becomes smaller estimations of agents with respect to interest rates and dividends should converge to true values leading to lower deviation of index futures actual prices from theoretical prices. Thus, for an efficient market there should be a positive relationship between average mispricing and time to maturity or we expect that the coefficient β_1 will be statistically greater than zero.

Chapter 4

DATA DESCRIPTION

Index futures contracts trading on the UX exchange started on the 27th of May, 2010. During a year 4 index futures contracts are issued. The maturity of each contract is half of a year, thus, at each moment of time there 2 futures contracts traded simultaneously. Their expiration dates are on March 15th (these contracts are denoted by letter H), June 15th (M), September 15th (U) and December 15th (Z) respectively.

The data for this research comprise the information for six contracts: UX-3.11 (first trading day is 16.09.2010, the first day in data is 05.01.2011, last trading day is 15.03.2011), UX-6.11 (16.12.2010-15.06.2011), UX-9.11 (16.03.2011-15.09.2011), UX-12.11 (16.06.2011-15.12.2011), UX-3.12 (16.09.2011-15.03.2012) and UX-6.12 (16.12.2011-15.06.2012, last day available in data is 07.05.2012). Overall for the period from 05.01.2011 till 07.05.2012 there are 1,257,810 transactions. However, we should note that the trade volumes in the first 3 months of trading amount only 2.5% of the total number of transactions. It means that a contract with long maturity is highly illiquid and it is not reasonable to estimate its market efficiency. The scope of this research, however, is focused on futures contracts with short maturity that has 4,000-5,000 transactions per trading day.

Table 1 contains the descriptive statistics for 1 minute contract prices of futures contracts with short maturity. If at some minute there were no futures trading it means that the corresponding observation is missing.

Notice that the prices of September contracts (UXU1) have much higher standard error than other contracts. It can be explained by the fact that the UX Index, and therefore prices of traded futures, declined almost by half during August-September 2011. We can expect that such a drastic index decrease may deteriorate market efficiency. During periods of such high volatility arbitrage operations become less attractive due to risk that an investor will be unable to buy or short-sell index at a desirable price.

Table 1. Descriptive statistics of index futures contracts

Futures contract	Number of observations	Min	Max	Mean	Std. error
UXH1 (UX-3.11)	13584	2443.02	2944	2723.552	104.8228
UXM1 (UX-6.11)	21216	2347.75	2906	2606.618	155.5512
UXU1 (UX-9.11)	20792	1396	2383.5	2023.98	317.0773
UXZ1 (UX-12.11)	25673	1263.2	1638	1452.811	93.87295
UXH2 (UX-3.12)	21305	1371.05	1579.95	1479.973	46.4991
UXM2 (UX-6.12)	12406	1289	1456.9	1396.68	30.04748

The last three contracts (UXZ1, UXH2, UXM2) have a lower standard errors, however, it is due to lower mean. An average actual futures price is almost two times lower comparing to the mean of UXH1 and UXM1. Thus, the standard errors for these 5 contracts are relatively close and we should not expect that the difference in volatility will significantly affect market efficiency in the corresponding periods.

Besides, we should be cautious interpreting the results of the first and the last futures contracts (UXH1 and UXM2 respectively). The data available for these contracts is not complete: for UXH1 contract the first 12 trading days are missing, for UXM2 – last 25 days. If the third hypothesis is not rejected (there is a positive relationship between relative mispricing and time to maturity) we will obtain a lower frequency of transaction boundaries violation for UXH1 contract and a higher frequency for UXM2. Thus, the empirical results of these two contracts may be not directly comparable to other futures contracts.

In addition, the data on the UX Index price for this period with frequency of 1 min has been collected. UX Index tracks 15 most liquid and highly capitalized local shares and is widely recognized as the main benchmark for the Ukrainian securities market. In table 2 basic descriptive statistics of UX Index is presented. The main statistics is calculated for the whole period and separately for 6 periods that correspond to each futures contract.

Table 2. UX Index descriptive statistics

UX Index value	Number of observations	Min	Max	Mean	Std. error
UX	139357	1258.12	2962.58	1964.683	569.7068
UX (UXH1)	20058	2462.69	2962.58	2722.797	116.223
UX (UXM1)	25681	2338.71	2902.7	2635.716	149.691
UX (UXU1)	26718	1396.71	2393.29	2044.332	327.8634
UX (UXZ1)	27332	1258.12	1691.83	1457.415	99.33403
UX (UXH2)	25254	1366.34	1577.71	1469.421	44.60446
UX (UXM2)	14314	1285.95	1452.35	1392.159	28.01282

For the purposes of this study KievPrime index is used as an interest rate. KievPrime is an independent reference rate computed daily by Reuters based on offered inter-bank deposit rates in UAH as quoted by leading participants in the Ukrainian money market. Based on the reputation, expertise and credit standing eight local commercial banks were selected that contribute to the reference rate. They include Calyon Bank Ukraine, Citibank Ukraine, Erste Bank Ukraine, ING Bank Ukraine, Raiffeisen Bank Aval, Ukreximbank, UkrSibbank, and Ukrsotsbank. KievPrime is calculated for overnight, one week, 1-month, 2-month and 3-month tenors every day at 12.30pm.

Table 3. Descriptive statistics of interest rates used

Period	Number of observations	Min	Max	Mean	Std. error
05.01.11-15.03.11 (UXH1)	13584	3.72%	7.96%	4.93%	0.95%
16.03.11-15.06.11 (UXM1)	21216	3.70%	7.40%	4.99%	0.77%
16.06.11-15.09.11 (UXU1)	20792	5.75%	13.25%	8.17%	2.10%
16.09.11-15.12.11 (UXZ1)	25673	9.04%	33.17%	18.94%	6.73%
16.12.11-15.03.12 (UXH2)	21305	12.00%	21.83%	15.37%	2.91%
16.03.12-07.05.12 (UXM2)	12406	9.95%	15.25%	12.64%	1.87%

Ideally, to compute theoretical price of a futures contract for each observation we would like to have an interest rates that matches to the time to maturity of this futures contract. However, since this data is not available, the following algorithm is used to compute the interest rate for each observation: for maturity less or equal to one month one-month KievPrime index is used; for maturity of two month or less – two-month KievPrime index; for three month or less – three-

month KievPrime index. Besides, since that we use continiously-compounded interest rate in the model, KievPrime index should be correspondingly recalculated.

Table 3 contains descriptive statistics of interest rates that are actually used to compute the theoretical price of index futures contracts. This statistics is presented for each futures contract separately.

From this table we can infer that interest rates were very unstable during the analyzed period. The range of minimal and maximal interest rate is particularly high for UXZ1 contract (from 9.04% to 33.17%). For instance, 3-month WIBOR rate, the interest rate used for investigating Polish index futures market, was in the range of 6.88% and 19.62% for the whole period (Bialkowski and Jakubowski, 2003). We can expect that such an interest rate uncertainty may negatively affect the Ukrainian index futures market efficiency.

As it is mentioned in the introduction, Ukrainian companies pay dividends very rarely. No dividends were paid by the companies that constitute the UX Index during the period from 05.01.2011 till 07.05.2012.

Chapter 5

EMPIRICAL RESULTS

Tables 4, 5 and 6 contain the results for six index futures contracts regarding the number and frequency of ex post and ex-ante violations of no-arbitrage bounds, the total number of transaction boundaries crossings and the average time of a series for all, lower or upper bound violations.

The first inference about the Ukrainian index futures market is that the frequency of ex-post violations is not as large as one could expect based on the previous research of developing markets. The indicator magnitude for 0.5% transaction costs (and 10% repo commission for short-selling stocks) lies in the range from 13.81% to 52.88% (average is 34.3%); for 1.0% (and repo 25% commission for short-selling stocks) – from 0.0% to 28.31% (average is 9.43%) for 6 futures contracts. The frequencies are slightly higher than the corresponding indicators on the developed market. Particularly, Chung (1991) showed that during the period from 1984 to 1986 the frequency of ex-post violations at 0.5% decreased significantly from 33.12% till 8.73% for the Major Market Index futures market. The violation frequency at 1.0% transaction costs for the MMI market was almost insignificant – it dropped from 1.55% to 0.06%. However, the level of ex-post violation frequency for the Ukrainian index futures market is lower compared to other developing market. For instance, Bialkowski and Jakubowski (2008) in their paper revealed that the range of ex-post violation frequency for 0.3% transaction costs for Polish market is from 68.2% to 92.9% (average is 77.6%), for 0.9% – from 38.34% to 77.8% (average is 54.5%) for 8 futures that is significantly larger that the corresponding figures of the Ukrainian futures index market.

Second, the analysis of ex ante violations allows us to make a conclusion about persistency of ex-post violations. On one hand, the average number of crossings is 273 for ex-post violations and 179 for ex-ante violation at 0.5% transaction costs. Thus, we can conclude that about one third of all ex-post violations are temporal and disappear in the next period of time. On the other hand, however, the frequency of ex-post and ex-ante violations is almost the same. The average frequency of ex-ante transaction boundaries violation is equal to 32.93% and 9.01% for 0.5% and 1.0% transaction costs respectively (34.3% and 9.43% for ex-post violations). Thus, the major part of time market price of an index futures contract lies outside the transaction cost corridor that theoretically may lead to persistent arbitrage profits.

The third conclusion is that the frequency of lower-bound violations is very sensitive to the level of transaction costs, particularly, to the repo commission for short-selling stocks. For 20-25% commission (rates that are charged by two largest brokers from the major part of investors) the frequency of violations is quite insignificant. The average number of mispricings comprises 8.78% and 5.13% of the total number of observations respectively. These figures are in line compared to the corresponding indicators of the developed markets. Relatively high frequency of transaction boundaries violation for 10% repo commission may be due to the rarity of agreements with such generous contracts. It is likely that during the period of high and volatile interest rates (autumn-winter of 2011) brokers were unwilling to borrow securities at such low rates even to reliable financial institutions. It so it would not allow investors to earn on arbitrage opportunities, therefore, would not contradict the market efficiency hypothesis.

Another feature of the Ukrainian index futures market is virtually absent upper bound violations. For UXH1 the frequency of ex-post violations at 0.5% transaction costs is less than 4%, for UXM1, UXZ1, UXH2 and UXM2 futures

contracts the magnitude of this coefficient does not exceed 0.25%. The exception is UXU1 contract for which the corresponding figure equals to 30.85% and 25.59% at 0.5% and 1.0% transaction costs respectively. Such a high magnitudes can be explained by the sharp decrease in the UX index value. During August-September UX index was especially volatile that theoretically might have led to a higher risk of opening arbitrage positions. Besides, this period is characterized by a high and volatile interest rate.

The analogical picture was observed on the Polish index futures market (Bialkowski and Jakubowski, 2008). The frequency of lower-bound violations was about 4 times higher than of upper-bound violations. The authors explain such a difference by restrictions in stock short-selling. Besides, analogically to the Ukrainian index futures market, upper-bound violations are almost absent on the Polish market for majority of contracts while for two of them (out of eight) the corresponding frequencies were equal to 65.2% and 32.8% at 0.3% transaction costs. Despite the fact that the average frequency of ex-post violations on the Polish market was even higher than on the Ukrainian market (20.9% and 11.1% at 0.3% and 0.9% TC versus 5.85% and 4.3% at 0.5% and 1.0% TC respectively), we would not conclude that the Ukrainian futures market is more efficient that the Polish market. Persistent upper-bound violations are likely to appear due to some external shocks (such as volatile interest rate, sharp drop in index etc.), however, typically for most futures contracts these violations are very rare and, consequently, cannot lead to arbitrage profits.

Table 4. Summary statistics of ex-post and ex-ante violations

Contract	Total number of observations	TC	Ex post				Ex ante			
			Number of violations	Frequency	Number of crossings	Average time	Number of violatios	Frequency	Number of crossings	Average time
UXH1	13584	0.005	3813	28.07%	169	23	3644	26.83%	106	34
	13584	0.0075	1541	11.34%	112	14	1429	10.52%	63	23
	13584	0.01	885	6.52%	79	11	806	5.93%	57	14
UXM1	21216	0.005	10581	49.87%	329	32	10252	48.32%	224	46
	21216	0.0075	3325	15.67%	122	27	3203	15.10%	72	44
	21216	0.01	1813	8.55%	96	19	1717	8.09%	70	25
UXU1	20792	0.005	7316	35.19%	244	30	7072	34.01%	155	46
	20792	0.0075	6496	31.24%	191	34	6305	30.33%	127	50
	20792	0.01	5887	28.31%	176	33	5711	27.47%	106	54
UXZ1	25673	0.005	13577	52.88%	446	30	13131	51.15%	282	47
	25673	0.0075	5554	21.63%	238	23	5316	20.71%	149	36
	25673	0.01	3310	12.89%	147	23	3163	12.32%	83	38
UXH2	21305	0.005	5531	25.96%	248	22	5338	25.06%	168	32
	21305	0.0075	395	1.85%	311	1	345	1.62%	206	2
	21305	0.01	72	0.34%	234	0	54	0.25%	139	0
UXM2	12406	0.005	1713	13.81%	202	8	1511	12.18%	140	11
	12406	0.0075	0	0.00%	18	0	0	0.00%	14	0
	12406	0.01	0	0.00%	40	0	0	0.00%	31	0

Table 5. Summary statistics of ex-post and ex-ante lower-bound violations

Contract	Total number of observations	TC	Ex post				Ex ante			
			Number of violations	Frequency	Number of crossings	Average time	Number of violatios	Frequency	Number of crossings	Average time
UXH1	13584	0.005	3299	24.29%	100	33.0	3199	64	23.55%	50.0
	13584	0.0075	1414	10.41%	83	17.0	1331	47	9.80%	28.3
	13584	0.01	855	6.29%	66	13.0	789	51	5.81%	15.5
UXM1	21216	0.005	10529	49.63%	313	33.6	10216	215	48.15%	47.5
	21216	0.0075	3319	15.64%	116	28.6	3203	72	15.10%	44.5
	21216	0.01	1813	8.55%	96	18.9	1717	70	8.09%	24.5
UXU1	20792	0.005	901	4.33%	55	16.4	846	37	4.07%	22.9
	20792	0.0075	657	3.16%	25	26.3	632	15	3.04%	42.1
	20792	0.01	567	2.73%	35	16.2	532	22	2.56%	24.2
UXZ1	25673	0.005	13551	52.78%	434	31.2	13117	274	51.09%	47.9
	25673	0.0075	5548	21.61%	235	23.6	5313	147	20.70%	36.1
	25673	0.01	3309	12.89%	146	22.7	3163	83	12.32%	38.1
UXH2	21305	0.005	5511	25.87%	188	29.3	5323	121	24.99%	44.0
	21305	0.0075	390	1.83%	47	8.3	343	31	1.61%	11.1
	21305	0.01	69	0.32%	15	4.6	54	10	0.25%	5.4
UXM2	12406	0.005	1713	13.81%	202	8.5	1511	140	12.18%	10.8
	12406	0.0075	0	0.00%	0	-	0	0	0.00%	-
	12406	0.01	0	0.00%	0	-	0	0	0.00%	-

Table 6. Summary statistics of ex-post and ex-ante upper-bound violations

Contract	Total number of observations	TC	Ex post violations				Ex ante violations			
			Number of violations	Frequency	Number of crossings	Average time	Number of violatios	Frequency	Number of crossings	Average time
UXH1	13584	0.005	514	3.78%	69	7.4	445	3.28%	42	10.6
	13584	0.0075	127	0.93%	29	4.4	98	0.72%	16	6.1
	13584	0.01	30	0.22%	13	2.3	17	0.13%	6	2.8
UXM1	21216	0.005	52	0.25%	16	3.3	36	0.17%	9	4.0
	21216	0.0075	6	0.03%	6	1.0	0	0.00%	0	-
	21216	0.01	0	0.00%	0	-	0	0.00%	0	-
UXU1	20792	0.005	6415	30.85%	189	33.9	6226	29.95%	118	52.8
	20792	0.0075	5839	28.08%	166	35.2	5673	27.29%	112	50.7
	20792	0.01	5320	25.59%	141	37.7	5179	24.91%	84	61.7
UXZ1	25673	0.005	26	0.10%	12	2.2	14	0.05%	8	1.8
	25673	0.0075	6	0.02%	3	2.0	3	0.01%	2	1.5
	25673	0.01	1	0.00%	1	1.0	0	0.00%	0	-
UXH2	21305	0.005	20	0.09%	8	2.5	120	0.56%	4	30.0
	21305	0.0075	5	0.02%	3	1.7	20	0.09%	2	10.0
	21305	0.01	3	0.01%	3	1.0	0	0.00%	0	-
UXM2	12406	0.005	0	0.00%	0	-	0	0.00%	0	-
	12406	0.0075	0	0.00%	0	-	0	0.00%	0	-
	12406	0.01	0	0.00%	0	-	0	0.00%	0	-

The results of the model that estimates the correlation between average absolute relative mispricing and time to maturity are presented in table 7. The p-value shows the probability of rejecting the hypothesis that the regression coefficient is positive. The slope coefficients are statistically greater than zero for all contracts except UXH1 and UXU1 for which we have negative signs. The UXU1 contract can be considered as an exception since there was a drastic decline in the UX index that led to significant upper-bound violations (see graph 5 in Appendix). Thus, we can disregard the result for this contract. Overall, the conclusion may be drawn from the table that we would not reject the hypothesis about direct relationship between average mispricing and time to maturity. It implies that the market is more efficient when the time to maturity is closer.

Table 7. Results of the regression

Contract	Number of observations	Regression coefficient	Standard errors	P-value
UXH1	47	-0.0108	0.01465	0.7694
UXM1	58	0.052644	0.019466	0.0034
UXU1	62	-0.01891	0.016892	0.8685
UXZ1	64	0.04812	0.021397	0.0123
UXH2	58	0.141488	0.01109	0.0000
UXM2	33	0.125951	0.012865	0.0000

Tables 8, 9, 10 contain the summary statistics of total number of arbitrage trades, average value and standard deviation, minimal and maximal values of arbitrage profits, and share of profitable trades for all violations, lower-bound violations and upper-bound violations respectively. We count one arbitrage trade as purchase or issuance of one futures contract and short-selling of buying the index portfolio respectively.

Table 8. Summary statistics of arbitrage profits

Contract	Total number of obs.	TC	All violations					
			Total trades	Profitable trades	Average profit	St.D. of profits	Min	Max
UXH1	13584	0.50%	3813	94.8%	14.20	9.98	-22.31	43.58
	13584	0.75%	1541	92.7%	10.20	7.73	-18.42	33.84
	13584	1.00%	885	91.0%	6.972	6.03	-20.92	25.61
UXM1	21216	0.50%	10581	96.9%	25.76	19.25	-12.30	83.96
	21216	0.75%	3325	96.3%	18.63	13.27	-13.06	57.84
	21216	1.00%	1813	94.7%	12.97	9.43	-7.16	41.61
UXU1	20792	0.50%	7316	96.7%	28.66	19.78	-31.25	86.81
	20792	0.75%	6496	97.1%	27.76	18.48	-23.10	82.70
	20792	1.00%	5887	97.0%	26.23	17.34	-27.42	78.59
UXZ1	25673	0.50%	13577	96.7%	20.11	17.70	-10.3478	94.79
	25673	0.75%	5554	95.7%	20.81	18.97	-12.79	82.26
	25673	1.00%	3310	94.7%	24.05	17.11	-14.26	74.05
UXH2	21305	0.50%	5530	96.5%	8.46	6.60	-17.66	30.24
	21305	0.75%	394	87.6%	1.81	2.35	-17.57	10.83
	21305	1.00%	72	75.0%	0.80	3.32	-21.01	7.230
UXM2	12406	0.50%	1713	88.2%	2.24	2.21	-5.20	12.83
	12406	0.75%	0	-	-	-	-	-
	12406	1.00%	0	-	-	-	-	-

Table 9. Summary statistics of lower-bound arbitrage profits

Contract	Total number of obs.	TC	Lower-bound violations					
			Total trades	Profitable trades	Average profit	St.D. of profits	Min	Max
UXH1	13584	0.50%	3299	96.8%	15.84	9.55	-22.31	43.58
	13584	0.75%	1414	94.5%	10.88	7.53	-18.42	33.84
	13584	1.00%	855	92.3%	7.24	5.79	-13.69	25.61
UXM1	21216	0.50%	10529	97.0%	25.88	19.22	-12.30	83.96
	21216	0.75%	3319	96.5%	18.68	13.23	-7.21	57.84
	21216	1.00%	1813	94.7%	12.97	9.43	-7.16	41.61
UXU1	20792	0.50%	901	93.9%	11.60	8.36	-31.25	36.95
	20792	0.75%	657	96.2%	10.57	6.76	-18.37	32.43
	20792	1.00%	567	93.8%	7.84	6.11	-10.65	28.32
UXZ1	25673	0.50%	13551	96.8%	20.15	17.70	-10.35	94.79
	25673	0.75%	5548	95.8%	20.84	18.97	-12.78	82.26
	25673	1.00%	3309	95.6%	24.06	17.10	-14.26	74.05
UXH2	21305	0.50%	5510	96.6%	8.48	6.59	-17.66	30.24
	21305	0.75%	389	88.2%	1.86	2.10	-3.18	10.83
	21305	1.00%	69	78.3%	1.20	2.01	-3.51	7.30
UXM2	12406	0.50%	1713	88.2%	2.24	2.21	-5.20	12.83
	12406	0.75%	0	-	-	-	-	-
	12406	1.00%	0	-	-	-	-	-

Table 10. Summary statistics of upper-bound arbitrage profits

Contract	Total number of obs.	TC	Upper-bound violations					
			Total trades	Profitable trades	Average profit	St.D. of profits	Min	Max
UXH1	13584	0.50%	514	81.9%	3.62	4.95	-11.13	26.03
	13584	0.75%	127	72.4%	2.62	5.62	-16.31	19.35
	13584	1.00%	30	53.3%	-0.70	7.53	-20.92	12.66
UXM1	21216	0.50%	52	69.2%	1.12	3.69	-11.45	8.69
	21216	0.75%	6	0.0%	-6.70	4.40	-13.06	-2.02
	21216	1.00%	0	-	-	-	-	-
UXU1	20792	0.50%	6415	97.1%	31.06	19.74	-20.22	86.81
	20792	0.75%	5839	97.2%	29.69	18.38	-23.10	82.70
	20792	1.00%	5320	97.3%	28.19	17.00	-27.42	78.59
UXZ1	25673	0.50%	26	53.8%	0.59	3.34	-8.35	7.83
	25673	0.75%	6	50.0%	-0.85	4.22	-5.51	4.17
	25673	1.00%	1	0.0%	-9.18	-	-9.18	-9.18
UXH2	21305	0.50%	20	60.0%	1.43	6.29	-14.12	16.65
	21305	0.75%	5	60.0%	-1.82	10.00	-17.57	9.30
	21305	1.00%	3	0.0%	-8.38	11.03	-21.01	-0.65
UXM2	12406	0.50%	0	-	-	-	-	-
	12406	0.75%	0	-	-	-	-	-
	12406	1.00%	0	-	-	-	-	-

Overall, we can make a conclusion that the arbitrage profits are persistent for the majority of the futures contracts. On average, about 96% arbitrage trades are profitable (for both long and short arbitrage positions). For comparison, on Polish market the average profitability is in range 20.5%-26.8% for long arbitrage operations and 63.6%-83.3% for short arbitrage operations (for different levels of transaction costs). However, the results obtained by Chung (1991) are much closer to the case of the Ukrainian index futures market. Particularly, average frequency of profitable trades lie in the range 66%-88%.

Nonetheless, we should mention that for the case of upper-bound violations almost all violations and, as a consequence, almost all arbitrage profits occurred during a relatively short period of time of UX index sharp decrease. We indeed expected that the market efficiency could be deteriorated. If this period was not taken into account it would lead to almost absent upper-bound violations and rare and not persistent arbitrage profits. For the last three contracts (UXZ1, UZH2 and UXM2) these figures are particularly insignificant, thus, we cannot reject the hypothesis of market efficiency and absence of arbitrage opportunities analyzing the upper-bound violations.

For the lower-bound violations the arbitrage profits are persistent. The profitability of trades lies in the range from 78.3% to 97% (with mean 96%) and all the mean arbitrage profits are above zero.

Besides, as it has been mentioned, the number of arbitrage opportunities greatly depends on the level of transaction costs chosen. Particularly, there is an apparent gap between usage of 10% repo commission and 20-25% commission. Discussing usage of the 10% commission for short-selling stocks we should note again that this level of repo commission may be not available to investors on the regular basis. Moreover, during the Autumn-Winter 2011 (when interest rates were several times higher compared to the end and the beginning of the analyzed

period) brokers might be unwilling to borrow securities at such low rates implying that the actual level of transaction costs was higher while actual levels of arbitrage opportunity frequency and profitability were lower.

Thus, if we assume that 10% repo commission is quite rare and focus on 20-25% repo commission we would conclude that the arbitrage profits are quite rare. The relative persistency of the profits, in turn, can be explained by a lower activity of the stock exchange that may delay a formation of an arbitrage portfolio. Finally, we should note that the frequency and the profitability of arbitrage profits are decreasing that is a positive signal of the maturing of the market. For 20-25% repo commission levels arbitrage opportunities were virtually absent for the UXH2 contract and totally absent for the UXM2 contract (however, the data is not complete). An average arbitrage profit decreased significantly from 20-24 hryvnas per one trade to 1.2-1.9 hryvnas. Thus, we can conclude that for these levels of transaction costs we do observe arbitrage opportunities for past futures contracts, however, it looks like they faded out for UXH2 and UXM2 contracts.

Chapter 6

CONCLUSION

In this thesis the market efficiency of the Ukrainian index futures market has been examined by testing the hypotheses of the absence of ex-post and ex-ante mispricings, rarity and transitoriness of arbitrage profits and existence of the direct relationship between average relative mispricing and time to maturity. For the purposes of this study the standard methodology is slightly modified. Particularly, the bid-ask spreads and short-selling commission are introduced that leads to broader and asymmetric transaction boundaries. As a result, the frequency of transaction boundaries violations is considerably lower compared to the developing Polish market and is in line with the matured MMI market.

Our results indicate that we cannot reject the hypothesis of no arbitrage opportunities when the observed market price exceeds the theoretical price. The frequency of almost all such violations for almost all levels of transaction costs is far below 1% (the only exceptions are part of the UXU1 data, during which there was a sharp decline of the UX index, and the UXH1 contract at 0.5% transaction costs, which is the earliest contract that we analyze and therefore is likely to be suffer from market frictions arising at early stages of development).

The same conclusion can be drawn with respect to arbitrage profits that occur due to upper-bound violation of transaction bounds. Once more disregarding the UXU1 contract data, the number of arbitrage trades as well as the level of their profitability are low. The average profit is often below zero implying the impossibility of getting arbitrage profits by forming the corresponding arbitrage position.

The conclusions with respect to frequency, persistence and profitability of lower-bound arbitrage opportunities are less certain. On one hand, the aforementioned indicators (though mostly higher) are close to figures of the developed MMI market. Thus, we could infer that the market is close to be an efficient one. On the other hand, some figures are high enough to reject the hypotheses of this study. Particularly, the profitability of arbitrage trades amounts to 96%, an average profit is far above zero and the frequency of lower-bound violations using 10% short-selling commission is also much higher than that observed on the MMI market.

However, entering into repo contracts under such generous terms (10% commission) might be quite difficult even for the biggest investors, and, hence, the opportunities to benefit from index futures mispricings are rare, and it makes more sense to focus on 20-25% repo commission levels.

For these levels of commissions, we observe that arbitrage opportunities were more or less frequent and persistent for the first four contracts analyzed in this study. As to the last two contracts (UXH2, UXM2), the lower-bound arbitrage opportunities are almost absent. It implies that currently investors cannot profit on arbitrage operations.

Overall, there were periods of pricing inefficiency and there is no guarantee that persistent arbitrage opportunities will not appear in the future. Nonetheless, there is evidence that the pricing mechanism works properly on the Ukrainian index futures market in the latest period debarring arbitrage opportunities and leading to fair pricing. To sum it up, we cannot reject the hypothesis of the Ukrainian futures market efficiency.

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APPENDIX

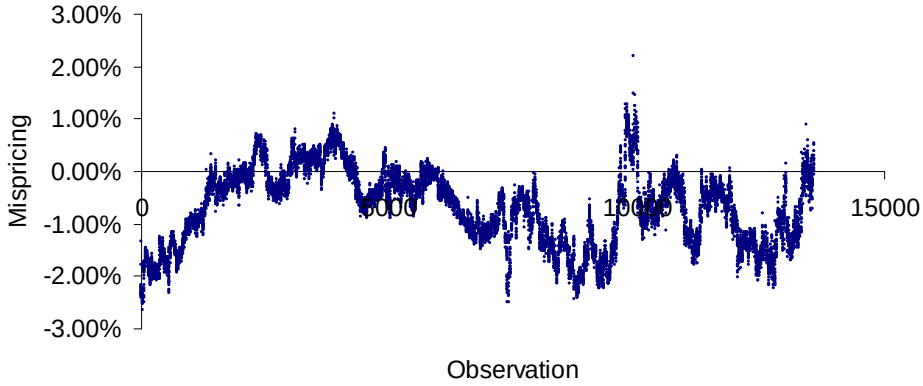

Figure 1. Relative mispricings of UX-3.11 contract

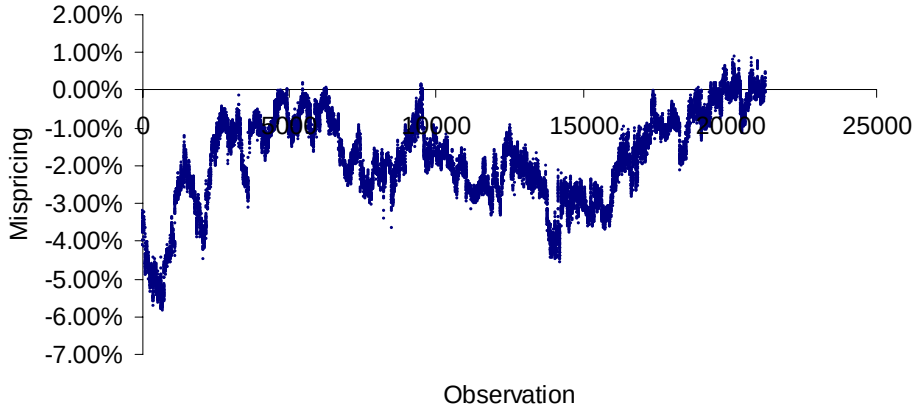

Figure 2. Relative mispricings of UX-6.11 contract

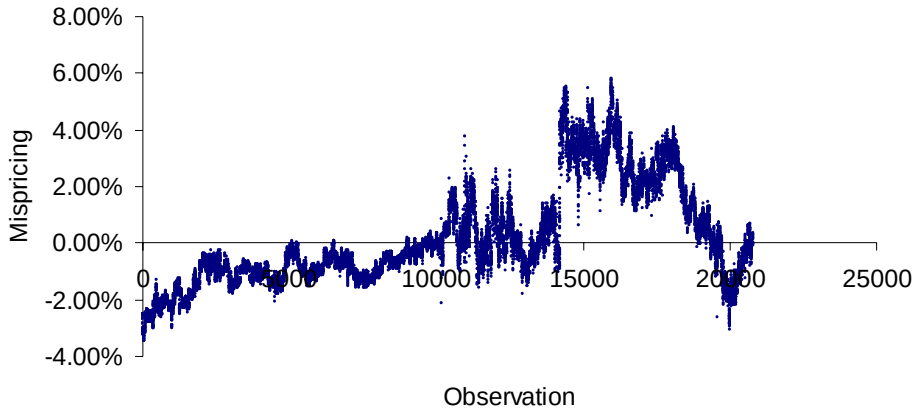

Figure 3. Relative mispricings of UX-9.11 contract

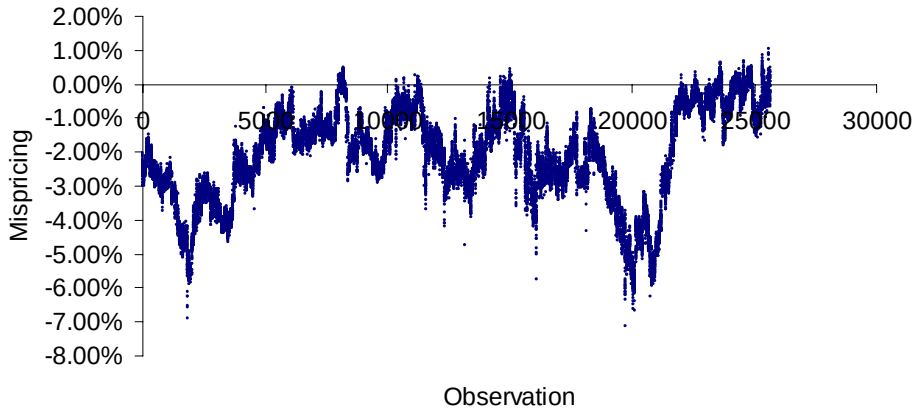

Figure 4. Relative mispricings of UX-12.11 contract

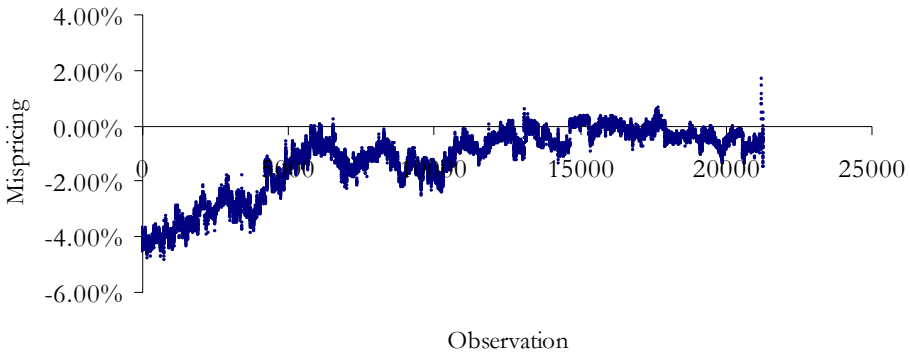

Figure 5. Relative mispricings of UX-3.12 contract

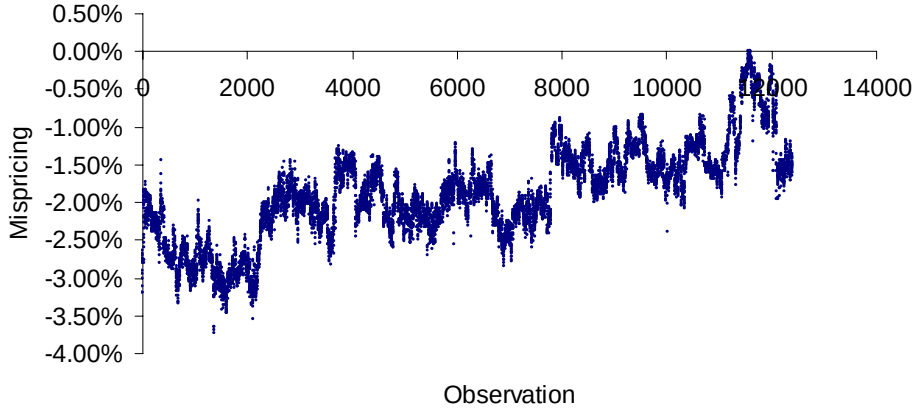

Figure 6. Relative mispricings of UX-6.12 contract