When Does a New Market Become Efficient? Evidence from an Emerging Index Futures Market

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This paper tests how efficiency developed in a new exchange. The analysis shows how market efficiency evolved in the China Shanghai Shenzhen CSI 300 futures index market over time. The profitability of two well-known pairs trading arbitrage strategies were used to measure the degree of market efficiency. In the first year after the launch of the index future, the arbitrage strategies were profitable and short-term returns were predictable. The efficiency improved substantially in the second year as seen by progressively unprofitable strategies and unpredictable returns. Trading volume did not exhibit an upward trend, suggesting that the inefficiency during the nascent period cannot be explained by the lack of liquidity. It is unclear why it took as long as one year in a market with low transaction costs and a relatively sophisticated investor pool to reach a state of efficiency.

INRODUCTION

Market efficiency, which has its roots in a dissertation written in 1900 (Bachelier, 1900), is among the most fundamental topics in financial economics. It is generally accepted that stock prices are efficient in the long run but short term predictability may exist to create opportunities for profits (Fama, 1998). Researchers such as Cushing and Madhavan (2000) and Chordia, Roll, and Subrahmanyam (2008) document that short-term returns are predictable from past order flows. Girma and Mougoue (2002) analyzed the relationship of petroleum futures spread variability, trading volume and open interest in order to uncover the source of variability in futures spreads and found a degree of market inefficiency. Research supports the conventional wisdom that emerging markets are less efficient than developed ones and that efficiency does not improve with time (Foye, Mramor, & Pahor, 2013). This is important to traders because prices that deviate from a random walk create opportunities for profitable trading strategies (Chen, Wong, & Susai, 2016). However, Griffin, Kelly, and Nardari (2010) argue that it is not always the case, especially when considering the higher transaction cost in emerging markets. We add to the understanding of market efficiency and trading strategies by examining a unique situation in an emerging market.

Using the high frequency data containing intraday tick-by-tick transactions, this study documents that two simple arbitrage strategies were highly profitable (annualized 16%) in the China CSI 300 index futures market[1] in the first year after its launch in 2010. The market became efficient after the first year and the profitability of the strategies vanished. The first strategy examined in this paper is the well-known stock index futures arbitrage (Cornell & French, 1983; Yadav & Pope, 1990). This strategy shorts the index futures and at the same time longs the corresponding stock portfolio if futures price and spot price have enough deviation, and close the positions when the prices converge. If prices do not converge before the delivery day, positions are closed on the delivery day. Since shorting stocks is difficult in China, only the arbitrage by longing the stocks and shorting the futures is feasible (Sharif, Anderson, & Marshall, 2014).

The second strategy is the index futures calendar arbitrage (Gatev, Goetzmann, & Rouwenhorst, 2006) where an arbitrage occurs between two index future contracts with different delivery dates. The strategy longs the relatively cheaper contract and shorts the other, expecting to profit from their price convergence. Unlike stock pairs trading strategies, futures pairs are likely to have a limited divergence because their prices are both determined with the same underlying stock portfolio. However, it is still possible that the spread between two contracts become temporally wider than the arbitrage-free band. For example, if one particular contract is longed or shorted with a large amount of capital within a short period when the other contract has low trading volume, the price of the former contract will change more than the latter's and the spread will grow. Arbitragers with a fast reaction could possibly catch this opportunity and gain profit before the prices converge.

Two trading strategies were back tested using historic data and both perform well in the first year after the China CSI 300 index futures was launched. However, the profit gained from the arbitrage strategies dropped dramatically in the second year after the launch. In order to show that the first year's inefficiency is not explained by the reason given by Chordia et al. (2008), who suggested that potential arbitragers remaining on the sideline due to the lack of liquidity, we show that neither the trading volume nor the bid-ask spread exhibited clear trend during the first two years. Specifically, the bid-ask spread was fairly stable over our test period from April 16, 2010, the date of index future launch, to May 9, 2012 while the trading volume was more volatile.

The research documents that new China CSI 300 index futures market remained inefficient for nearly one year after its launch. With widely available internet access, low transaction costs, and relatively sophisticated investor pool[2], this long-lasting inefficiency is a surprise to those who believe in the market efficient hypothesis. While the findings support prior research related to the efficiency of a new market, it does not explain why the inefficiency lasted as long as one year. Prior research suggests that anomalies are largely due to (a) behavior bias such as *disposition effect* (Frazzini, 2006; Grinblatt & Han, 2002) or noise trader sentiment (Baker & Wurgler, 2006); (b) market regulation such as short selling impediments (Stambaugh, Yu, &Yuan, 2012); (c) exogenous change of minimum tick size (Chordia et al., 2008); and (d) inadequate liquidity (Chung & Hrazdil, 2010).

Our finding that a new market takes nearly one year to become arbitrage-free for simple strategies is an important unexpected finding. The unique circumstances of the launch of the CSI 300 index futures makes it difficult to replicate this paper's finding by using data of other countries. The CSI 300 index future, which was launched in 2010, accumulated 201 million contracts valued at 160.68 trillion yuan (USD 25.83 trillion) and became the fifth largest among index futures by the end of 2012 (Zhang, 2013). Many countries' index futures markets are not large enough to be efficient quickly. Even if the same results were produced in other emerging markets, critics could argue that the slow evolution to efficiency is due to the lack of enough market participants. In addition, the launch of other large market index futures occurred before the availability of the internet and high frequency trading techniques that would make it possible to replicate this paper's results. Electronic trading and quantitative trading, including electronic market making and algorithm trading, became popular after 2000. The Kansas City Board of

Trade began trading the world's first stock index futures contract, Value Line Index (VLI) future, in February 1982 (Herbst & Ordway, 2006). The S&P 500 index futures and NYSE composite index futures were created the same year by CME and NYSE, respectively. The largest index future in the UK, FTSE 100 index future, was created by London International Financial Futures Exchange (LIFFE) in 1984. Because these markets did not benefit from the current advances in trading strategies using current technology, the relative inefficiency these markets is not surprising (Draper & Fung, 2002; Herbst & Ordway, 2006). The real puzzle is the extended time of inefficiency of the China CSI 300 index futures given the use of electronic trading and sophisticated investor pool. The results of this study suggest a research question that is not explained by prior research, namely: Why was there an extended time of inefficiency of the China CSI 300 index futures given the use of electronic trading and a pool of sophisticated investors?

The rest of the paper is organized as follows: Section 2 reviews literature. Section 3 describes the background of China CSI 300 future. Section 4 provides a description of data. Section 5 discusses the details of strategies, performances and implications, and Section 6 concludes.

LITERATURE REVIEW

The research is based on several concepts that form the theoretical framework of our study. The first one is the market efficiency hypothesis. There is a large amount of research providing evidence that supports both the efficiency and inefficiency of the market. Those who support the argument of market efficiency including Fama (1998) and Fama and French (1997) who claim that most evidences of market anomaly can be explained by methodological biases in research. They argue that the anomalies tend to disappear with reasonable methodological changes, such as using value-weighted three-factor time series regressions. However, others insist the existence of profitable strategies that consistently beat the market. Loughran and Ritter (2000) show that the Fama and French (1997) three-factor model tends to underestimate abnormal returns when the event of interest is a managerial choice variable. Moreover, these researchers argue that if abnormal returns do exist, there should be predictable differences in abnormal return estimates across different methodologies because of the differences in predictability of various models. According to Chordia et al. (2008) who analyze the predictability of returns using daily data of NYSE stocks that are traded from 1993 to 2002, the mid-quote return predictability is diminished when bid-ask spread is narrower. Chordia et al. suggest that outsiders provide greater assistance in absorbing order flows when the market has a high level of liquidity. Moreover, the predictability of return is lower in the middle of a trading day and the predictability declines over time with the minimum tick size.

This study used two pairs trading strategies, including the stock index futures arbitrage and index futures calendar arbitrage. Pairs trading is a market neutral strategy where investors simultaneously trade long and short position (Huck, 2013). Pairs trading originated as a strategy developed at Morgan Stanley in the late 1980s, now is widely used in the financial industry (Larsson, Lindberg, & Warfheimer, 2013). Prior researchers used pairs trading strategies to test market efficiency[3]. Elliott, van der Hoek, and Malcolm (2005) and Larsson et al. (2013) used a mean reverting Gaussian Markov chain model for the spread, which they considered to be observed in Gaussian noise. Elliott et al. (2005) compared predictors to subsequent observations of the spread to determine appropriate investment decisions and as the spread narrows to an equilibrium value, a profit results. Using data from 1962 through 2002, Gatev et al. (2006) found that a simple pairs trading rule strategy yielded an average annualized return up to 11% in self-financing portfolios. The investment strategy used by Gatev et al. was to match stocks into pairs with minimum distance between normalized historical prices.

Stock index futures arbitrage research, with most of the seminal work published in the 1980s and 1990s, is a crucial component of our literature review. Stock index futures allow traders to expose to or hedge market risk with substantially lower transaction costs and establish larger position than in the stock market. Mackinlay and Ramaswamy (1988) and Merrick (1987) show substantial and sustained deviations between actual stock index futures prices and theoretical values. Based on their findings, Merrick (1989) and Finnerty and Park (1988) attempted to demonstrate the profitability of arbitrage trading strategies. Saunders and Mahajan (1988) adopted an alternative approach and concluded that stock index futures were priced efficiently. An important component of arbitrage strategies is transaction costs. Yadav and Pope (1990) considered transaction costs in their analysis. They study the UK FTSE-100 stock index futures traded on the LIFFE and found that the forward pricing formula tends to provide an upward biased estimate of actual futures prices. Furthermore, the authors showed that the mispricing series had high positive autocorrelation and tended to be an auto regression (AR1) process. However, while the average level of mispricing is significantly different from zero for most contracts, Yadav and Pope (1990) found that the average mispricing "return" was essentially zero, with mispricing constrained to a window by the actions of arbitragers.

MARKET BACKGROUND

The China CSI 300 index futures market opened on April 16, 2010 and the index futures quickly became the most liquid and actively traded financial instrument in China (Zhang, 2013). The delivery date is set at the third Friday of each month. The trading hours are from 9:15 to 11:30 and from 13:00 to 15:15, with a noon break. Compared with stock trading hours, the index futures market opens 15 minutes earlier and closes 15 minutes later (China Financial Futures Exchange, 2013). During the period of our review, the average daily trading volume was about 180 billion yuan (about 30 billion US dollars). A one-point change in the CSI 300 index equals 300 Chinese yuan (about 50 US dollars). On the day of January 2, 2014, the closing price of the index was 2331.8 points; therefore, the full price of one index futures contract was 699,540 yuan.

Requirements to trade on the exchange excluded most nonprofessional traders. The margin requirement was 12.5% (and leverage ratio is accordingly 8), so an investor must have at least 87,442.5 yuan to buy one contract. An investor was required to deposit at least 500,000 yuan in a futures trading account before trading. In 2010, 500,000 yuan was about 10 times of China's GDP per capita and 90% of the A Share market's trading accounts have deposits lower than this required number (National Bureau of Statistics China, 2010). Moreover, a trader must pass a financial test organized by brokerage firms before opening an account. Experiences of mock trading or commodity futures trading were also required. These requirements prevent retail investors from trading index futures to some extent and ensure the sophistication of investors.

Four index futures contracts with different expiration dates are traded, labeled as IF01, IF02, IF03 and IF04. The four contracts are delivered at the end of the current month, next month, next quarter and the quarter after next quarter, respectively. More than 99% of the trading volume is attributed to the IF01, the contract with closest delivery date. To replicate the index future calendar arbitrage, we used IF01and IF02, the two most liquid contracts. The transaction cost of index futures is much lower than that of stocks and other Chinese financial instruments. The exchange fee was 0.5 basis-points (bp) before June 1st, 2012 and has changed to 0.35 bp since after. In contrast, the A-share stock commission fee and stamp tax usually total about 8 -10 bp for one-side trade.

Shorting individual stocks was prohibited until March 2010 (Sharif et al., 2014). After this date, short selling, while legal, is costly and difficult; thus, the introduction of index futures is more important to investors in China compared to other developed financial market. As a result, irrational overpricing of stocks cannot be corrected by shorting them easily except for the investors who already hold overpriced stocks. Therefore, overpricing is more prevalent than underpricing in Chinese stock market. The introduction of index futures provides a convenient instrument for short selling.

DATA DESCRIPTION AND STATISTICS SUMMARY

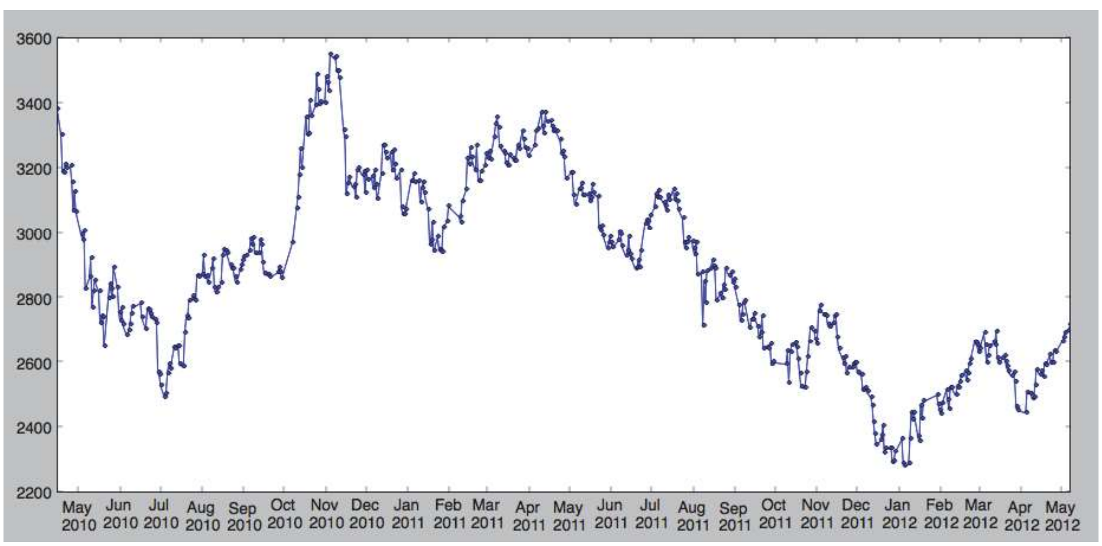
The Chinese CSI 300 index futures dataset records tick-by-tick transactions and ranges from April 16th, 2010, the date of market opening, to May 9th, 2012, totaling 498 trading days. The dataset contains all four contracts' bid, ask and close prices, open interests and trading volumes. Pricing of all tradable financial securities has a fixed standardized updating frequency. For stocks, the frequency is once every 3 seconds. For CSI 300 index futures it is twice per second. The actual price is continuously changing but investors can only take a snapshot of the prices every 0.5 second (China Financial Futures Exchange, 2013). The dataset collects all orders. Buying and selling orders are matched together and new bid, ask, close prices are updated every 0.5 second. For simplicity, we compress the tick-by-tick dataset to form minute-level data to perform the back tests of the arbitrage strategies. Details are introduced in Section 5. We also obtained another minute-level underlying index price dataset from Tinysoft, a well-known commercial financial database in China, to check the validity and consistency of tick-by-tick dataset.

The rest of this section presents summary statistics of the data, including historical price chart, trading volume and its distribution over four contracts, bid-ask spread, and lead-lag relation of futures and underlying index.

Index price trend

Figure 1 provides a summary of the daily price of the CSI 300 Index for the period of our investigation.

FIGURE 1
DAILY PRICE OF CSI 300 INDEX



Bid-ask spread

Three measures of spread are presented in Table 1. Not surprisingly, spread of the most liquid contract IF01 is the smallest and spread of the least liquid contract IF04 is the greatest.

The first measure, presented in the first column of Table 1, is a simple measure of bid-ask spread, which is

$$\frac{2(P_{ask} - P_{bid})}{P_{ask} + P_{bid}}$$

The second measure, presented in the second column of Table 1, is based on Roll (1984). Unlike common tick-by-tick price, the dataset actually contains the information that whether a transaction is buyer-initiated or seller-initiated. Therefore, Roll's measure could be presented as

$$E(\Delta P_t | transaction\ direction\ changed)$$

The third measure, presented in the third column of Table 1, is defined as

$$\frac{2(\tilde{P}_{ask} - \tilde{P}_{bid})}{\tilde{P}_{ask} + \tilde{P}_{bid}}$$

$\tilde{P}_{ask}$ and $\tilde{P}_{bid}$ are recovered bid and ask prices before the transaction is made. The recovered bid and ask prices are using the close price to replace the ask price if it is a buyer initiates the order or using close price to replace the bid price if it is a seller initiates the order.

Both the second and third measures are significantly larger than the first one, which is consistent with the claim that the bid-ask spread is overstated with the first measure. Bid-ask spreads are computed from tick-by-tick data for all four contracts by three methods. The three methods yield similar bid-ask spreads for IF01 contract, which is with the largest trading volume. Other contracts with less trading frequency and larger bid-ask spreads may have temporally enlarged spread when a large market order is submitted.

TABLE 1
BID-ASK SPREADS OF FOUR CONTRACTS (BASIS POINT)

Contract	Raw BAS	Roll's BAS	Recover BAS
IF01	0.96	0.99	0.943
IF02	1.939	1.292	1.282
IF03	4.813	2.744	2.671
IF04	8.258	5.061	4.565

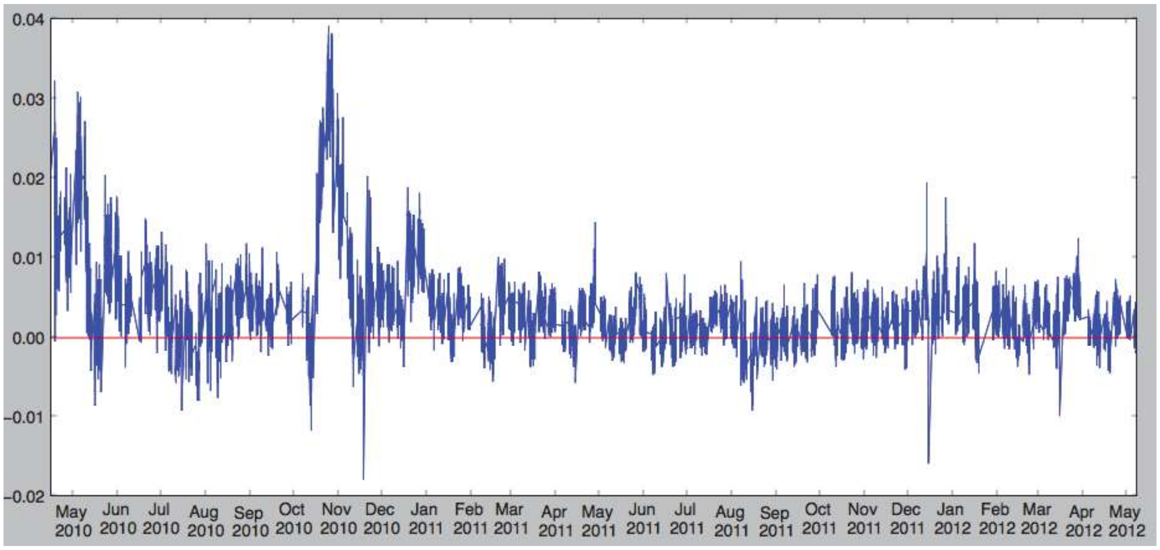
Index futures-stock premium

The theoretical no-arbitrage price, or the fair price, of the index futures should be

$$F_t = P_t e^{(r-d)(T-t)}$$

where r and d are the risk-free rate and dividend rate, respectively. $T - t$ is the time before the futures delivery. We use the interest rate of China's Central Bank Bills, an equivalent of U.S. Treasury Bills, as a proxy of risk-free rate. Estimating expected dividend rate is difficult. We use realized variable dividend as a proxy of dividend rate but this adjustment was made only for the test of stock index futures arbitrage. For index futures calendar arbitrage, the original data is applied since we could de-trend the calendar spread in other ways. Futures contracts in China more often are traded at premium instead of at discount, as Figure 2 shows. However, trading in premium is unlikely in developed markets because overpricing of futures is comparatively more easily corrected than underpricing, due to lower short selling costs in the index futures market.

FIGURE 2
INDEX FUTURES-STOCK PREMIUM

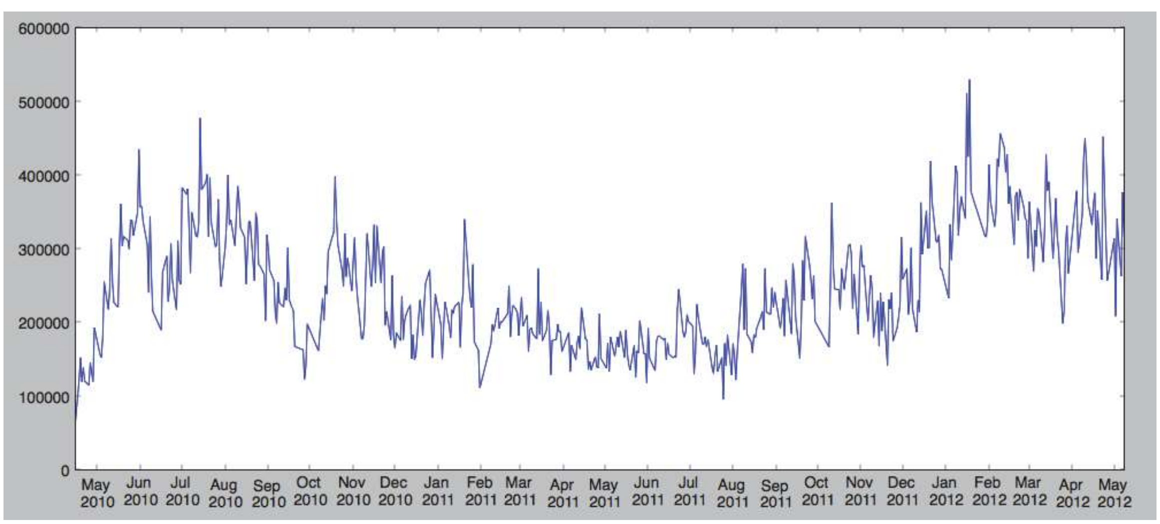


Note: This figure shows Index futures-stock premium between April 16, 2010 and May 9, 2012, defined as $(P_{Futures} - P_{Index})/P_{Index}$

Trading volume and distribution

Figure 3 shows the evolution of trading volume over time. When it was launched in 2010, the trading volume was below 100 million contracts; but the volume increased to an average of over 300 million contracts in 2011 and reached over 500 million contracts in January 2012.

FIGURE 3
DAILY TRADING VOLUME



Note: The unit of vertical axis is number of contracts. Price of one futures contract is (300 * Index Price) yuan

Not surprisingly, the majority of trading volume is concentrated on the IF01 contract with the closest delivery date. As the delivery date approaches, investors and speculators roll over by closing position on the expiring contract and open position on the next contract. As shown in Table 2, this roll-over procedure takes 4-6 days to complete. Table 2 presents the trading volume distribution of index futures. The numbers are computed by averaging daily trading volume across each month. Each month has around 22 trading days and in most of the days, trading volume is concentrated on IF01, the contract with closest delivery day. In the last week before delivery, the trading volume begin to shift from IF01 to the next contract IF02, and only 5% trading volume is left on IF01 on the last day of the month. Trading volume on IF03 and IF04 is always small, usually less than 1% of total trading volume.

TABLE 2
TRADING VOLUME DISTRIBUTION OF CSI 300 INDEX FUTURES

N days before delivery	IF01	IF02	IF03	IF04
0	0.052	0.929	0.015	0.004
1	0.142	0.842	0.012	0.003
2	0.401	0.584	0.011	0.003
3	0.685	0.303	0.010	0.003
4	0.820	0.167	0.010	0.003
5	0.872	0.116	0.009	0.002
6	0.905	0.084	0.009	0.002
7	0.926	0.063	0.008	0.002
8	0.939	0.050	0.008	0.003
9	0.946	0.043	0.008	0.002
10	0.954	0.036	0.007	0.002
11	0.959	0.032	0.007	0.002
12	0.925	0.066	0.007	0.002
13	0.922	0.068	0.008	0.002
14	0.955	0.036	0.007	0.002

Lead-lag correlation

Prior literature has documented that index futures markets lead the spot markets in the United States and many other international markets (Kawaller, Koch, & Koch, 1987; Min & Najand, 1999) because the futures market has lower transaction cost and higher leverage. Here we computed the correlation coefficient between lagged futures and stock index spot return. The lag ranges from 1 to 4 minutes. The lead-lag result is quite similar to the developed markets, where futures price leads the index. However, index futures return itself looks like a random walk and not predictable by historical index futures return. Table 3 presents the lead-lag effect. Minute-level middle price return of index futures and price return of the CSI 300 index are computed. F_{-i} and I_{-i} are index futures and CSI 300 index return with i minutes lag, respectively. We determine that (a) index futures and CSI 300 index have strong contemporaneous correlation; (b) CSI 300 index price is highly positive auto-correlated but index futures price is not, which is consistent with the intuition that index futures price is more efficient than CSI 300 index price, and much less predictable by its historical prices; (c) lagged index futures return has strong predictability on CSI 300 index return and the predictability lasts at least 3 minutes; (d) lagged CSI 300 index return has nearly no predictability on index futures return.

TABLE 3
LEAD-LAG EFFECT

The Lead-lag Correlation								
	I_{-3}	I_{-2}	I_{-1}	I_0	F_{-3}	F_{-2}	F_{-1}	F_0
I_{-3}	1.000							
I_{-2}	0.568	1.000						
I_{-1}	0.295	0.569	1.000					
I_0	0.077	0.297	0.569	1.000				
F_{-3}	0.333	0.569	0.369	0.221	1.000			
F_{-2}	0.009	0.333	0.570	0.370	0.041	1.000		
F_{-1}	-0.016	0.010	0.334	0.570	0.007	0.041	1.000	
F_0	-0.025	-0.015	0.011	0.335	0.011	0.007	0.041	1.000

BACKTEST RESULTS

In this section, the back test results of two strategies are presented. For stock index futures arbitrage and index futures calendar arbitrage, we compressed the tick-by-tick data to minute-level data. For both strategies, we only consider the situation when only one contract is traded, so the market depth and impact cost are not a concern. This assumption is made for two reasons. First, if trading one contract is not profitable, then larger trades will perform even worse due to the impact cost. Second, it is normal for large institutional traders to split large orders into small ones before submitted to avoid impact cost. Unlike many literature papers which do not consider transaction costs when computing profitability, our computation takes a comprehensive consideration of different levels of transaction costs.

Stock index futures arbitrage

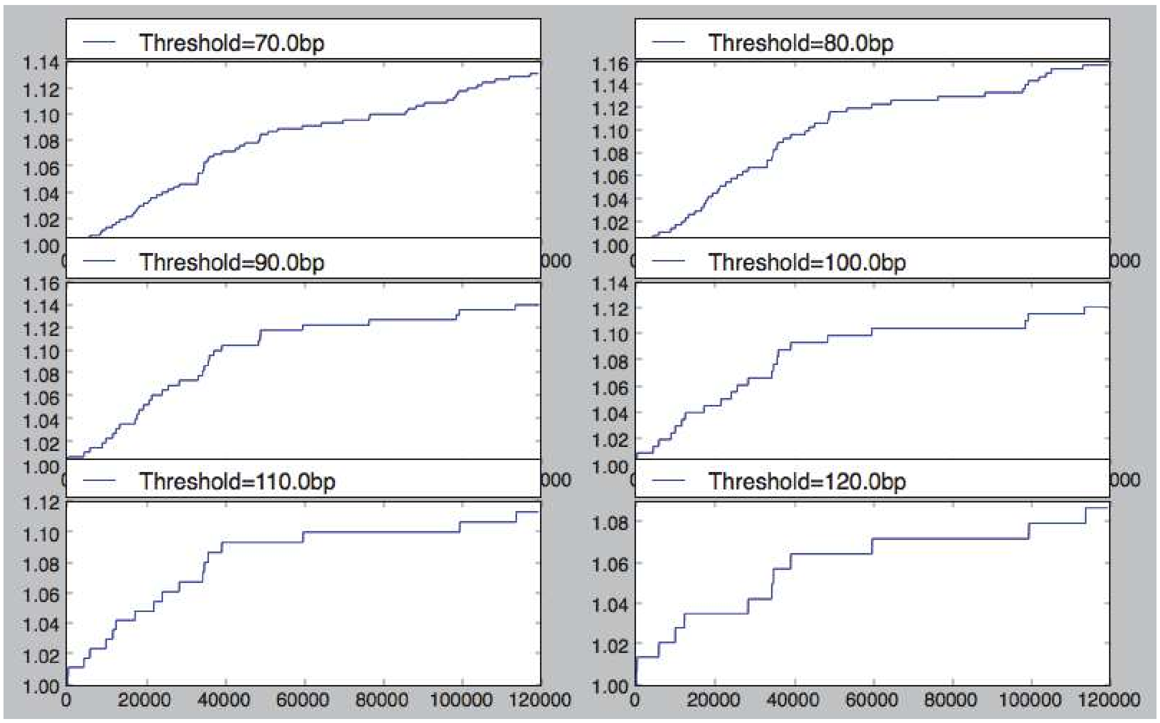
The process of stock index futures arbitrage is as follows. Once the futures price exceeds the index price and meets a pre-established threshold, we long the stocks portfolio and short the futures. We hold the position until the premium converges to zero, or negative if the futures are traded at a discount; or hold until delivery when the prices are guaranteed to converge and the premium is guaranteed to disappear. Given the short selling restrictions of stocks, arbitrager could generate profit only when the futures are overpriced, not the stocks. This overpricing did happen quite often at least in the first year.

The stock index futures arbitrage strategy is theoretically simple but not trivial in practice. An arbitrager needs to be able to trade 300 stocks simultaneously, and get orders executed in relatively short interval. Failing to execute orders in time will add tracking error risk, thus increasing the transaction cost due to possible adverse market conditions or temporary trading suspension. This risk or related cost is not taken into account in this study. The assumption of the one-side transaction cost, including transaction cost in futures and spot market, is 25 bp.

Figure 4 shows the results of profit and loss with threshold ranging from 60 bp to 120 bp. The profitability is obvious even after deducting transaction costs. The annualized profit rate is from 9% to 16%. At the time, the risk-free rate in China in 2010 was around 3%. However, the level of profitability was not sustained after the first year. The second year profit is only about 3% after deducting transaction cost, which is less than one third of the first year profit rate and close to the risk-free rate. This indicates that more arbitragers using the same strategy entered the market in the first year, making the market close to a competitive and efficient level.

In addition, we can see from Figure 4 that as time passed by, the arbitrage strategies were less frequently triggered, which is consistent with our results. Beside temporary market inefficiency, another explanation of our results is the inability to leverage. Though leveraging the index futures market is relatively easy, obtaining leverage in the Chinese stock market is difficult. Margin trading of stocks was strictly restricted in China and loan interest rates were around 8% - 10% for institutional investors. Therefore, an arbitrager with limited capital available could not eliminate this inefficiency because of the cost of borrowing.

FIGURE 4
PROFIT AND LOSS OF STOCK INDEX FUTURES ARBITRAGE OVER TIME



Note: The unit of horizontal axis is minutes past launch. The vertical axis is return.

Table 4 presents the annualized return and annualized Sharpe ratio of stock index futures arbitrage strategy in different periods after deducting transaction cost. The whole sample is equally divided into four following periods: from 2010-04-16 to 2010-10-16 (Period 1), from 2010-10-16 to 2011-04-16 (Period 2), from 2011-04-16 to 2011-10-16 (Period 3) and from 2011-10-16 to 2012-05-09 (Period 4). A loss is not possible with this strategy. In the worst case situation, the futures premium is below the threshold and no trade is ever triggered, thus there is a zero gain.

TABLE 4
STOCK INDEX FUTURES ARBITRAGE RETURN BY PERIOD

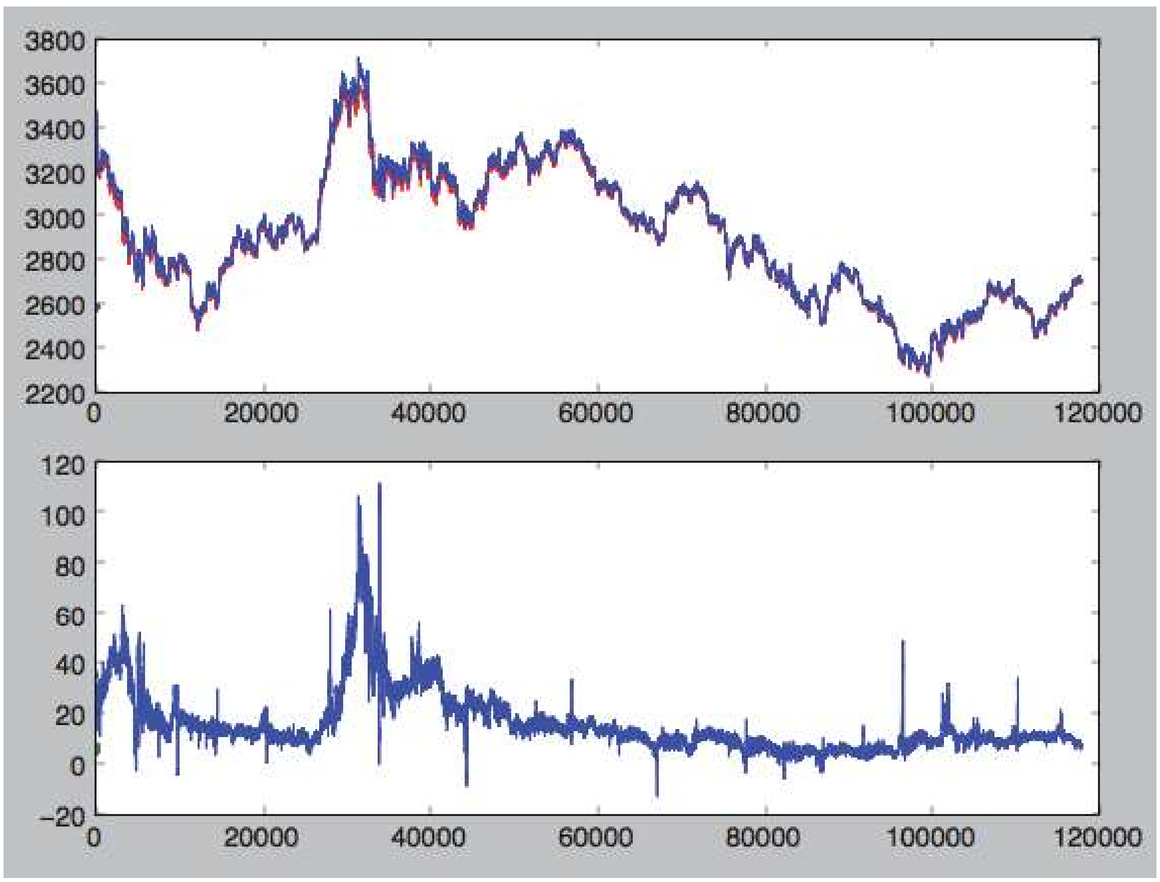
Threshold	Period 1	Period 2	Period 3	Period 4
70bp	9.19%	8.75%	2.83%	2.40%
80bp	13.40%	10.70%	1.81%	2.42%
90bp	14.50%	9.18%	1.61%	1.20%
100bp	12.70%	7.23%	1.00%	1.50%
110bp	12.70%	6.16%	1.20%	1.20%
120bp	7.22%	5.74%	1.40%	1.40%

Index futures calendar arbitrage

Index futures calendar arbitrage is conceptually simple and its profitability can be a measure of market efficiency. Given four tradable contracts, there are $C_4^2 = 6$ potential pairs. But we only consider the pair of the first two contracts (IF01 and IF02) and the price difference or spread between the two contracts because they are the most liquid and with less impact cost and greater market depth. Figures 5 - 7 show the spread between IF01 and IF02 over time.

In the top graph of Figure 5, the two contracts' prices are colored with red and blue. The bottom graph shows the spread over time, which is the difference between the two contracts' prices. The spread is computed without adjustment of interest rate and dividend. The spread could be modeled as a mean reversion process with a drift. It has some "spike" points but they only appear when there is a significant price change.

FIGURE 5
PRICES AND SPREAD BETWEEN IF01 AND IF02 OVER TIME



Note: The unit of horizontal axis is minutes past launch

Figure 6 shows the prices of two contracts moved together, the spread tended to revert to a certain mean and the spread process could be predicted. Figure 7 shows the price of IF01 contracts changed significantly but IF02 lagged for some time, leading to a large spike on the spread.

The goal of index futures calendar arbitrage is to forecast the price difference of the two contracts, or their spread. As proposed by Elliott et al. (2005) model pairs trading based on Gaussian mean-reversion process. In this case, however, the spread is hardly a mean zero or constant mean process. Rather, the spread has a strong trend, and tends to revert to the trend. The time-varying trend may reflect the non-stationary interest rate and expected dividend rate. Temporary deviation from the trend may be explained by the transaction impacts of large orders: short-term speculators who trade on only one particular contract, not four contracts simultaneously, for liquidity concern. The intuition of the strategy is that the deviation filtered from the trend ultimately converges to zero. Hence, we apply the simple exponential moving average (EMA) based strategy to identify the trend. EMA filter is a standard method in high frequency trading. Basically, we use the EMA of spread process as its trend, and define the difference between spread and EMA as deviation. Specifically, denote the spread process as $S_t = P_{1t} - P_{2t}$, and the EMA trend will be

$$E_t = \sigma E_{t-1} + (1 - \sigma) S_t$$

E_0 is initialized as mean of first day spread. The first day is discarded in backtest. The upper, middle, and bottom graphs of Figure 8 illustrate the original spread, EMA trend, and the de-trended spread series, respectively. In this strategy, the one side transaction cost is assumed as 1 bp and 1.5 bp for IF01 and IF02, respectively, based on the fact that transaction cost equals exchange fee plus one half of bid-ask spread, which is estimated in Table 1. Each transaction involves reversing both contracts' position (except for the initial opening position), so the total two-side transaction cost is 2*(1+1.5) = 5 bp. The trading rule is to long IF01 and short IF02 when $S_t - E_t > \bar{S}$; and to short IF01 and long IF02 when $S_t - E_t < \bar{S}$. $\bar{S}$ is the threshold. Thus, we have two parameters to set, α and $\bar{S}$. We demonstrate the result of profit and loss in Figure 9 and Table 5. Figure 9 shows profit and loss of index futures calendar arbitrage strategy over time after deducting transaction costs. The results are robust by testing under a range of parameters.

FIGURE 6
PRICES AND SPREAD BETWEEN IF01 AND IF02 OF 1000 RANDOM OBSERVATION

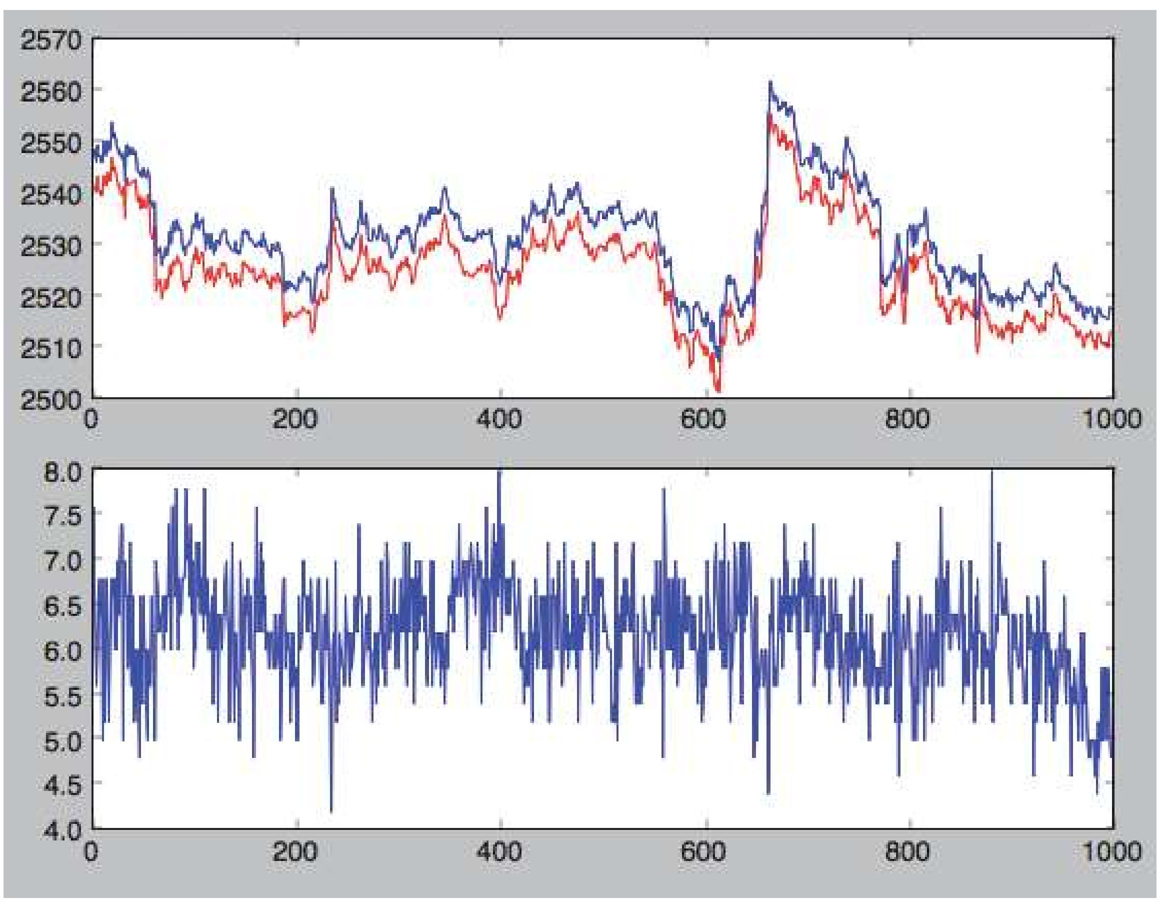


FIGURE 7
PRICES AND SPREAD BETWEEN IF01 OF ANOTHER 1000 RANDOM OBSERVATIONS

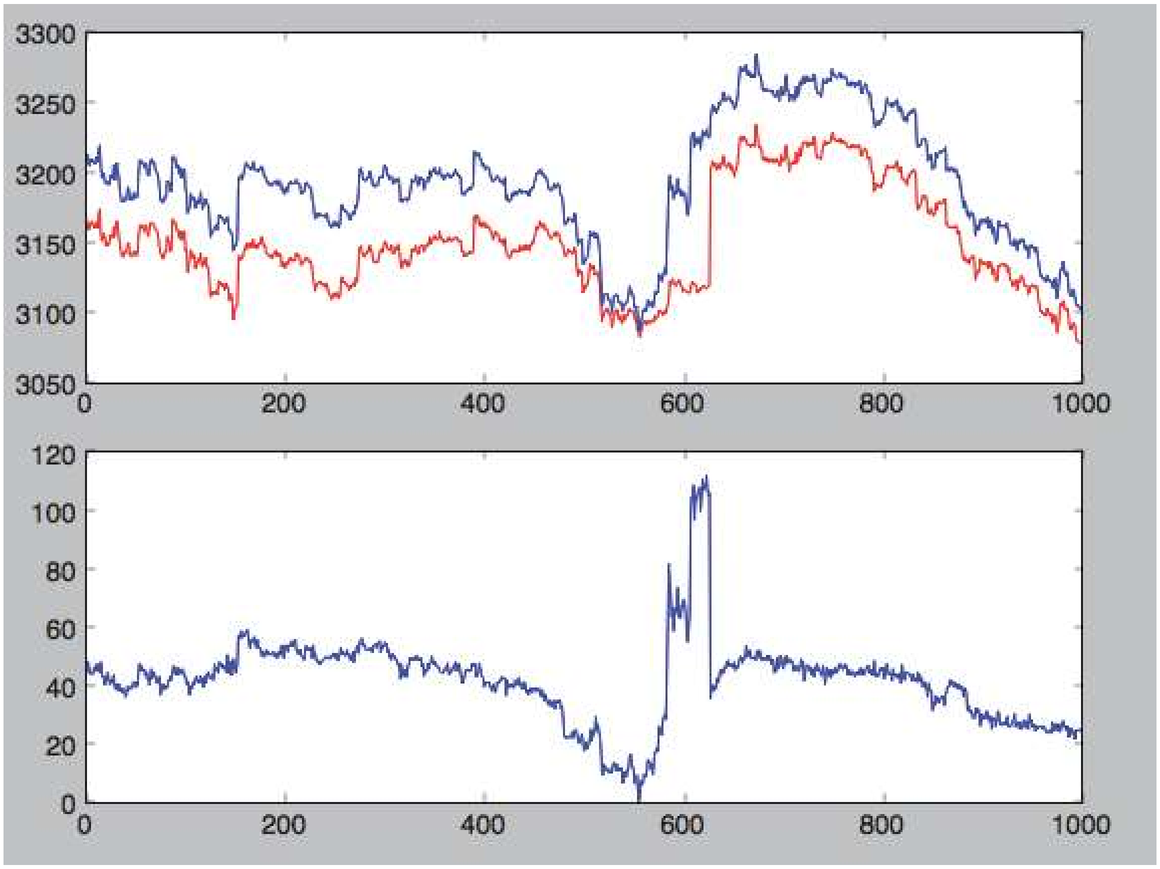


FIGURE 8
ORIGINAL SPREAD, EMA TREND, AND THE DE-TRENDED SPREAD SERIES

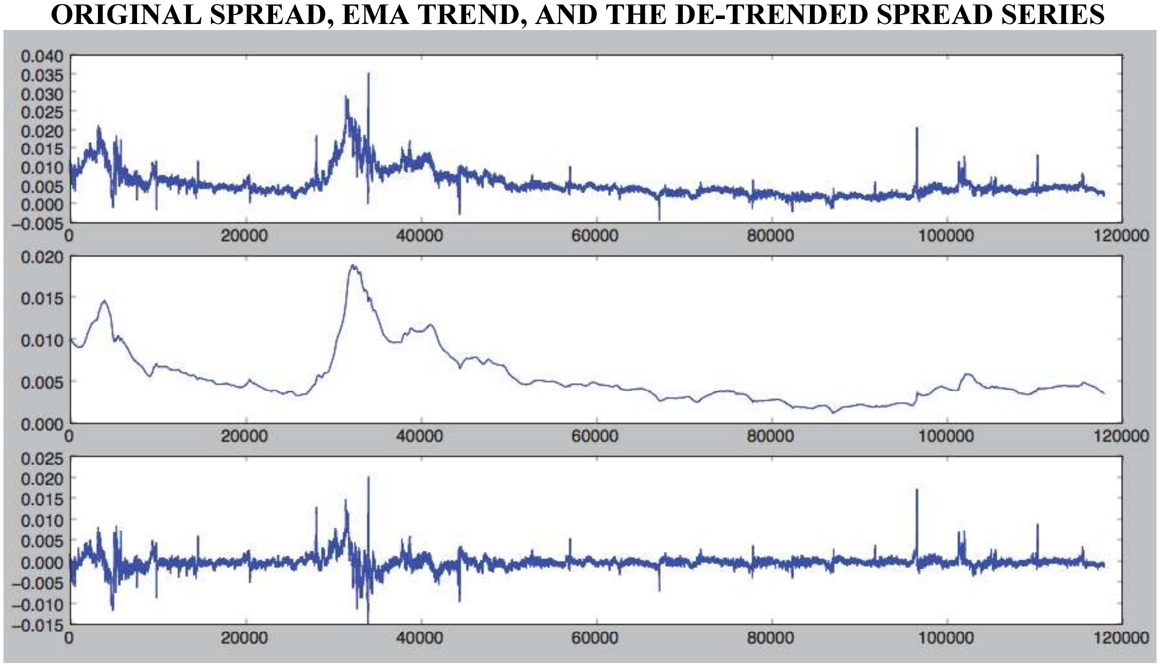


FIGURE 9
PROFIT AND LOSS OF INDEX FUTURES CALENDAR ARBITRAGE STRATEGY

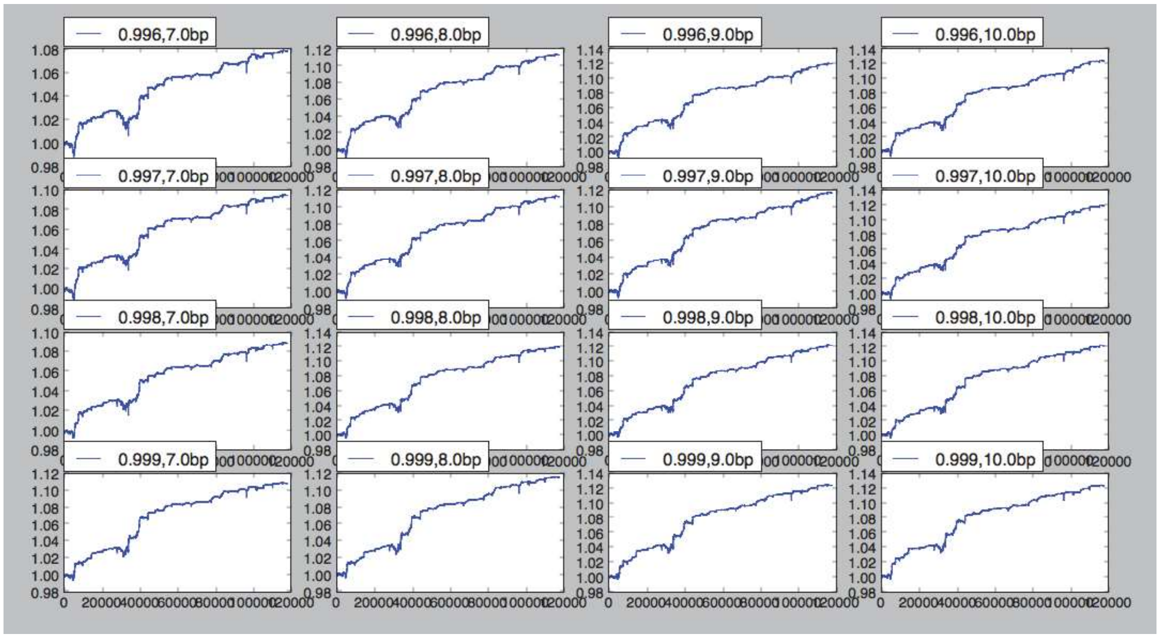


Table 5 presents the annualized return and annualized Sharpe ratio of index futures calendar arbitrage strategy in different periods after deducting transaction cost. The whole sample is equally divided into four following periods: from 2010-04-16 to 2010-10-16 (Period 1), from 2010-10-16 to 2011-04-16 (Period 2), from 2011-04-16 to 2011-10-16 (Period 3) and from 2011-10-16 to 2012-05-09 (Period 4). The Sharpe ratio is computed by $\sqrt{N} r_{daily}/std(r_{daily})$, while N equals 250, the number of trading days in a year and r_daily is the daily return. std(r_daily) is the standard deviation of the daily return. The annualized Sharpe ratio is high and stable.

TABLE 5
INDEX FUTURES CALENDAR ARBITRAGE RETURN BY PERIOD

σ	Threshold	Period 1	Period 2	Period 3	Period 4
0.996	7.0bp	5.2%	5.8%	2.0%	1.8%
		2.895	2.865	2.951	2.505
0.996	8.0bp	8.0%	7.8%	3.2%	2.3%
		4.076	4.128	4.28	3.23
0.996	9.0bp	8.9%	8.3%	2.6%	2.9%
		4.503	4.37	3.397	3.796
0.996	10.0bp	8.2%	8.9%	3.1%	3.1%
		4.278	4.434	3.828	3.608
0.997	7.0bp	6.8%	7.1%	2.2%	1.8%
		3.419	3.393	3.091	2.387
0.997	8.0bp	7.8%	8.0%	3.3%	2.1%
		4.099	4.227	4.09	2.956
0.997	9.0bp	7.7%	9.0%	2.5%	2.8%
		4.025	4.785	3.223	3.648
0.997	10.0bp	7.8%	9.0%	2.9%	2.7%
		4.136	4.718	3.584	3.104
0.998	7.0bp	6.3%	6.3%	2.4%	1.8%
		3.257	3.203	3.21	2.391
0.998	8.0bp	8.7%	8.7%	3.1%	2.1%
		4.448	3.581	3.843	2.817
0.998	9.0bp	8.1%	8.9%	3.4%	2.5%
		4.558	3.735	4.144	3.269
0.998	10.0bp	7.8%	9.3%	3.3%	2.4%
		4.242	3.827	4.175	2.834
0.999	7.0bp	6.4%	9.9%	2.7%	1.5%
		3.368	3.668	3.59	2.198
0.999	8.0bp	7.0%	9.5%	3.5%	1.8%
		3.713	3.54	4.277	2.684
0.999	9.0bp	8.7%	9.0%	3.6%	2.0%
		4.172	3.36	4.468	3.012
0.999	10.0bp	8.7%	9.2%	3.3%	2.1%
		4.017	3.645	4.059	2.998

Similar to stock index futures arbitrage, the calendar arbitrage strategy was profitable and created opportunities for traders, but profitable strategies diminished after one year (demonstrated in Table 5). Notice that in stock index futures arbitrage, an arbitrager's lowest possible profit is zero if there is no trading opportunities being triggered, while in index futures calendar arbitrage, loss is possible. Loss is realized when a "trend" is mistakenly considered as a "deviation". In this situation, the deviation gets larger after the transaction is made and will not converge to zero (and the spread process will not converge to the EMA trend) before IF01 is expired, and the arbitrager will be forced to close his position and realize loss. The abnormal return is more sensitive to transaction cost (computation not shown in Table 5), thus its capacity of profitability is more limited than stock index futures arbitrage.

CONCLUSION

This paper documented that the 2010-launched China CSI 300 index futures market took nearly one year to reach a state of efficiency. With widely available internet access, low transaction costs, and a relatively sophisticated investor pool, this long-lasting inefficiency is a surprise to those who believe in the market efficient hypothesis.

The results are important and unexpected. Given the unique circumstances of the study, it is difficult to replicate our paper's findings. First, many countries' index futures markets are not large enough to be efficient quickly. Even if the same results were produced in other emerging markets, critics could argue that the slow evolution to efficiency is due to the lack of enough market participants. Though China's index futures market was launched in 2010, its average daily trading volume during the period of our review was about 180 billion yuan (about 30 billion USD). Its trading volume tripled and became the fifth largest among index futures in 2012.

Second, other index futures of large market size were created too early to make it possible to replicate this paper's results. These index futures in the U.S. and the UK were created prior to the internet and before the development of modern sophisticated trading strategies. Electronic and quantitative trading were not invented in the 1980s. Therefore, it is not surprising to see inefficiency in the US index futures market in the 1980s (Herbst & Ordway, 2006). The real puzzle is even in 2010's China, the inefficiency existed for as long as one year given the popularity of electronic trading and the sophisticated investor pool.

Emerging equity and derivatives markets are widely considered to have weak- and semi-strong-form market inefficiencies and potential trading profits. This paper documents evidences that partially supports this belief. Even simple and well-known arbitrage strategies could be highly profitable at the beginning when a new market opened. Though profitability diminished over time, it lasted for nearly one year. A broad range of parameter combinations of both strategies were tested to ensure the robustness of the profitability. For practitioners, the results suggest that seeking profits through simple strategies based on past return may still be possible when a new market is launched.

As for future research, analyzing the microstructure of the index futures market, like decomposing the bid-ask spread into components attributed to adverse selection and order processing, may shed light on the profitability of market making strategies. In addition, modeling the spread series in the index futures calendar arbitrage strategy with a regime switching state space model could potentially improve the strategy's profitability. Pursuit of these topics appears to be a worthwhile agenda for future research.

ENDNOTES

1. Like the S&P 500 in the United States, the CSI 300 index is the most representative stock index in China, containing 300 large stocks traded in the Shanghai Stock Exchange and Shenzhen Stock Exchange. The aggregated market value of CSI 300 stocks is about 60% of the total market capitalization.
2. The index futures trading was only open to investors with experience of commodity futures trading and the exchange required investors to pass a financial test before opening trading account (Paget, TieCheng, & Phua, 2010).
3. For a brief history and summaries, see Gatev et al. (2006) and Vidyamurthy (2004).

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