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Put-Call-Futures Parity and Arbitrage Before and Amid Financial Turmoil: Evidence from South Korea

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ABSTRACT

This study aims to assess the magnitude and significance of arbitrage profit in a pre-crisis and a crisis context. Furthermore, the determinants of the arbitrage profit and how they impact arbitrage profit in a pre-crisis and a crisis period are inspected. To achieve this, I used data on KOSPI 200 Index calls, puts, and futures covering September 2007 to September 2009. Then, the analysis involved employing an OLS regression model to assess the relationship between the arbitrage profit and the determinants. Simultaneously, I utilized a t-test and an F-test to determine the significance and the structural change, respectively. The empirical results suggest that the determinants: intraday standard deviation, time to maturity, moneyness, futures volume, and the risk-free rate, have a positive and significant effect. In contrast, the variable strategy has no significant effect for the full sample. At the same time, the results present significant arbitrage profit and a structural change. Conclusively, the results presented are helpful for investors and financial policymakers.

Keywords: Derivatives, South Korea, Financial Crisis 2008

JEL codes: G13, G14

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CHAPTER 1 Introduction

Arbitrage is a trading strategy that professionals working for large financial institutions such as banks, hedge funds, asset management companies, and individuals exploit. Arbitrage involves simultaneously buying and selling an asset in different markets to profit from the price difference between those markets. This strategy may be exploited by trading different assets or instruments such as stocks, currencies, commodities, and financial derivatives, including calls, puts, and futures. The put-call-futures parity is widely used in academia and industry. It entails identifying a long or a short futures position given the theoretical difference between a call and a put option price. For instance, Fleming, Ostdiek, and Whaley (1996) indicate that market participants use the S&P 500 futures to price the S&P 100 index options. This underlines derivatives' importance for hedging and risk management, making arbitrage opportunities and the put-call-futures parity condition a scientifically relevant topic.

The thus generated academic output displays a many-sided relationship between arbitrage and the put-call-futures parity in terms of costs, arbitrage incentive, and volatility. For instance, Cheng et al. (1998) examine early unwinding strategies and find that arbitrage profit improves significantly under ex-post analysis, but the improvement is minimal under the ex-ante analysis. Furthermore, they suggest that the magnitude of the arbitrage profit is positively related to the stock market's volatility. Additionally, Brenan and Schwartz (1990) investigate the size of the mispricing to incentivize arbitrage. Consequently, they discover that even the smallest mispricing is enough for investors to engage in arbitrage. Choe et al. (1999) researched how foreign capital influenced the Korean stock market during the Asian financial crisis, accounting for the lenient regulation of the presence of foreign investors prior to the crisis.

The put-call-futures parity analysis can be replicated in other datasets. With this, a modified analysis of Cheng et al. (2000) will be replicated in a different context and country in this paper. Namely, instead of choosing the 1997 Asian financial crisis, I will analyse the 2008 global financial crisis and its effect on the derivatives market in South Korea. There are similarities and significant differences between the two crisis periods and the economies of both countries. To be precise, the Asian Financial crisis was particularly devastating for the growing economies of Southeast Asia. However, the 2008 crisis originating from the US had a global impact. Additionally, the economies of Hong Kong and South Korea are different. Hong Kong is a small and open economy focused on services. On the other hand, South Korea relies on heavy industry and automobiles. The similarities between the two crises are the magnitude of a macroeconomic shock as well as the policy response by the South Korean government, including different monetary and fiscal policies. As a result, I will explore how the violation of the put-call-futures parity will lead to arbitrage profits before and during financial turmoil.

The data for the analysis will be a set of time-stamped intraday trades on the Korea Stock Exchange, with one-minute intervals. The futures contracts will be matched with calls and puts based on the underlying asset (KOSPI 200 index), the date of expiration, and the trading time. The KOSPI 200 index is the leading index in South Korea, consisting of 200 stocks of blue-chip companies. Afterward, using the put-call-futures condition, arbitrage portfolios will be created. Furthermore, the significance of the arbitrage profit will be examined by utilizing a one-sample t-test. Moreover, I am going to employ a linear regression model with the arbitrage profit as the dependent variable and the following explanatory variables: intraday standard deviation of futures prices, the time to maturity of the simulated trio, a variable moneyness denoting the absolute difference between the close price of futures and the strike price of options divided by the strike price, the intraday futures volume, the risk free rate, a dummy variable S depending on the type of futures arbitrage, and the random error term. Additionally, this will be divided into two sets to inspect potential structural changes—the pre-crisis period from September 1st, 2007 to September 15th, 2008. Then, September 15th, 2008, to September 10th, 2009, will represent the crisis period. The crash of Lehman Brothers is the splitting event.

The expectations of this research are similar to the outcomes of Cheng et al. (2000). Nonetheless, they shall differ to a small extent. The derivatives market in 2008 in South Korea should be mature and efficient compared to the one in Hong Kong in 1997 due to the Asian Financial Crisis and the government's response. Namely, the crisis has improved regulation and thus contributed to more robust markets. With this, I anticipate the KOSPI 200 index and the respective puts, calls, and futures to be less volatile because the 2008 crisis was an external world crisis while the Asian Financial Crisis was a domestic one severely hitting the Korean market. Finally, I expect to find some arbitrage opportunities that are going to be significant and to find variables that significantly influence arbitrage profit.

The rest of the paper is organized in the following manner. Chapter 2 discusses the up-to-date scientific literature on arbitrage profit and its relationship with index futures and options. Furthermore, it explains the put-call-futures parity, its violations, and how it relates to arbitrage by summarizing academic papers on the topics mentioned earlier. Then, Chapter 3 gives insight into the data utilized for the conduct of research and Chapter 4 describes the methodology employed. Chapter 5 presents the results generated by the empirical analysis accounting for limitations, implications, relevance, and further research. Lastly, Chapter 6 contains final impressions and remarks concerning the study.

CHAPTER 2 Theoretical Framework

2.1 Arbitrage

The textbook definition delineates arbitrage as the intentional action of taking offsetting positions in different securities, generating an arbitrage profit. It concerns a transaction without a cash outlay, which guarantees a particular gain (Brennan & Schwarz, 1990). Nonetheless, arbitrage opportunities shall be minimal in a well-established market of rational agents. This is due to the profit-seeking behavior of rational agents and their attempt to exploit arbitrage once it is possible. For this reason, arbitrage opportunities are short-lived. In general, this is a by-product implication of the perfect market equilibrium definition, which entails that in a perfect market, there should be no opportunities for pure arbitrage (Brennan & Schwarz, 1990). Arbitrage is a type of trading strategy. The arbitrage process suggests an unobstructed market where agents instigate transactional activities whenever securities deviate from their fair price. Modern empirical evidence indicates that arbitrage is employed by both individual and institutional investors, such as algorithmic traders (Hendershott et al., 2011) as well as individual traders (Kelley & Tetlock, 2013) and market makers (Endor et al., 2006). Interestingly, the various arbitrageurs have contributed to better market liquidity in the sources above. Now, this study attempts to examine the arbitrage efficiency of the financial markets in times of crisis. Precisely, the mispricing of financial derivatives, their respective relationship, and potential arbitrage opportunities during the world financial crisis in 2008.

Arbitrage within the single stock market is familiar to the general public. Nevertheless, this practice assumes rather intricate dynamics in the derivatives landscape, owing to their unique and complex interplay, which demands sophisticated comprehension. Many studies delved into the pricing of stock index futures and the efficiency of the futures market. Logically, the inefficiency of the future markets creates arbitrage opportunities. Some of the earliest work on the points above includes the delivery of the future pricing model for a perfect market by Cornell and French (1983). The model was further extended by incorporating interest rates, taxes, and dividends. Moreover, Sundaresan and Modest (1983) contributed to the extension of the model by introducing transaction costs. Once again, Marcus and Modest (1984) further developed the model by integrating dividends' irregular and uneven distribution. Moreover, he also investigated the influence of the marking-to-market on the pricing model. The earliest empirical studies date back to Figlewski (1984), who studied the underpricing of futures. In his findings, he underlines that futures contracts are relatively underpriced compared to theoretical prices. Nonetheless, early underpricing disappeared as time passed, which eliminated potential arbitrage. Subsequently, Mackinlay and Ramaswamy (1988) presented that the futures mispricing decreased over time. To be precise, as the contract approaches its expiration date, the mispricing becomes smaller compared to the theoretical price. Merrick (1989) observed the effects on expiration day caused by the early unwinding and rollovers of stock index arbitrage positions. Finally, Brennan and Schwartz (1990) evaluated the most appropriate strategy for arbitrageurs under position limits and the option for an early close-out.

The literature on arbitrage concerning futures mispricing is extensive compared to the one on options. Some of the earliest work on index options and arbitrage became available a few years after introducing the first US index option contract, which commenced trading on March 11, 1983, on the Chicago Board of Options Exchange (CBOE). The underlying index is called the S&P100, designated to be the index for option trading. The index performance is deemed comparable to the S&P500. Hence, it was instantaneously popular among institutional investors. More than 50% of all listed stock option trades were attributed to the total daily volume in the S&P100 options. Less than two months later, the American Stock Exchange (AMEX), today known as NYSE American, introduced option contracts on a different index. The Major Market Index (MIM), consists of 20 significant stocks, engineered to be similar to the Dow Jones Industrial Average, (Evnine & Rudd, 1985). Similarly, this financial instrument garnered great favor among investors, coming only second after the S&P100 regarding trading volume. Hereby, the authors were motivated to examine these instruments' characteristics due to their novelty and immediate widespread appeal to market stakeholders.

Evnine and Rudd (1985) employed standardized derivative pricing methods concerning the browse for potential mispricing and arbitrage opportunities of the two indices mentioned above. Namely, they achieve this by using the tests of option lower boundary, put-call parity, and the binomial option pricing model. The results showcase significant violations of the arbitrage condition and the put-call parity. It is essential to note that the violations are significant even when accounting for the difficulty of gaining (almost) risk-free profits due to the complexity of constructing a proxy portfolio for the index or the absence of appropriate future contracts. Furthermore, the authors observe significant deviations between the theoretical prices derived from the binomial pricing model and the market prices of the derivatives. They emphasize that these deviations are even more severe during highly volatile financial periods.

2.2Put-Call-Futures Parity

Firstly, the stock index futures price stems from the underlying cash index via the cost-of-carry model (Cornell & French, 1983). On the contrary, the prices of the index call and put options contracts are associated with their underlying asset through the put-call parity condition (Stoll,1969). With this, the put-call-futures parity comes into place. The put-call-futures-parity is a financial concept that establishes a theoretical relationship between puts, calls, and futures contracts. To be precise, it denotes the principle that particular combinations of contracts should yield the same value at any time under the assumption of no arbitrage. Namely, buying a call and writing a put should lead to a riskless cash flow that is supposed to match the difference between the futures price and the exercise price of the options Tucker (1991). It is vital to make a notion that the put-call-futures parity holds valid only when the options contracts are of European-style and all contracts have the same underlying asset and a shared expiration date Lee and Nayar (1993).

$$C_0 - P_0 = (F_0 - X)(1 + \frac{r}{365})^{-(t_1 - t_0)} \quad (1)$$

Looking at equation (1), C_0, P_0, F_0 are the concurrent prices at the current date t_0 of the call and put options and the futures contract, respectively. All of the contracts expire at the same date, t_1. X is the common exercise for the put and call options and $(t_1 - t_0)$ is the holding period for all three contracts where t_1 and t_0 are in fractions of a year. Lastly, r represents the risk-free rate for the period. If we rearrange equation (1) we can get to the following equation.

$$F_0^* = X + (C_0 - P_0)\left(1 + \frac{r}{365}\right)^{-(t_1 - t_0)} \quad (2)$$

If the price of the futures F_0, happens to be above the F_0^*. Then the investor should short the overpriced futures at F_0, buy the call at C_0, and short the put at P_0. If the call is more expensive than the put, the investor has to borrow the difference to finance the options portfolio. If the call happens to be below the price of the put, the most rational choice for the investor would be to allocate the proceeds to the risk-free asset during the holding period. The process is described as short-futures arbitrage. Contrarily, if the future price F_0 is less than F_0^*, the investor should buy the underpriced futures, short the call and buy the put. If the call price is greater than the put price, then the investor should invest the proceeds in the risk-free asset. If the opposite holds true, the investor has to borrow at the risk-free rate and finance the options portfolio. This is scientifically termed as a long-futures arbitrage. In the end, both methods are supposed to generate a cashflow of $|F_0 - F_0^*|$.

Despite the extensive work concerning the put-call parity, a well-known concept within academia and industry, there is a notable shortage of research on the put-call-futures parity. However, this concept is widely practiced among investors and traders. Lee and Nayar (1993) have pioneered the generation of scientific knowledge on this topic. The authors noticed that there was a notable knowledge gap on this concept although index options and index futures were studied thoroughly either on a standalone basis or cross-compared to other derivatives. Hereby, there was intrinsic motivation to study the interrelationship of puts, calls, and futures sharing the same expiration date and underlying asset and how their relationship can be a signal for market efficiency. Lee and Nayar (1993) tested the violation of the parity by using data on the SPX option contracts and the S&P500 futures contract. Their findings show that after accounting for the transaction costs the mispricing is not of any significance. Additionally, their empirical analysis involves an ex-ante approach which shows that as time passes after the initial violation, the transactions generate losses. This indicates that mispricing is possible, however, it is of a rather short-lived nature.

Furthermore, Fleming, Ostdiek and Whaley (1996) utilize the put-call-futures parity concerning trading costs. Namely, for positions of similar risk and return profile, the direct trading costs in the S&P 100 options market tend to be 4 times the costs in the S&P 500 futures market. For this reason, S&P 500 futures prices appear to slightly lead the prices of both calls and puts with S&P 100 index as the underlying asset. Moreover, Fung and Fung (1997) use the parity condition to inspect the market efficiency of the HSI options and futures contracts. Consequently, the empirical evidence indicates that the trading strategies based on the violation of the put-call-futures parity do not yield significant profits when accounting for the trading costs. Nonetheless, one should make a notion that Fung and Fung (1997) employ a dataset of a stable financial period which decreases the likelihood of great mispricing occurring. Likewise, Fung et al. (1997) apply the put-call-futures parity condition to study the pricing efficiency of the HSI index derivatives. Their findings are in line with previous ones suggesting efficient and integrated markets with insignificant opportunities for arbitrage.

2.3 Relationship between the put-call-futures parity and arbitrage

Vipul (2008) studies the cross-market efficiency of the Indian derivatives market via the put-call and the put-call futures parity. For analysis, they utilize data on the Nifty index. The index constitutes the 50 largest and most liquid stocks on the National Stock Exchange (NSE), the biggest exchange in India. The data sample includes time-stamped transaction data for the value of Nifty, the options, and the futures on the index from January 1, 2002, to November 30, 2004. The author applies non-parametric tests to indicate the results' significance due to the mispricing's unknown distribution. Furthermore, they compare the magnitudes of the mispricing obtained via the violation of the put-call parity and the put-call-futures parity using Kruskal-Wallis's test. Additionally, the study examines the relevance of the results across different investor types. Namely, general or retail, institutional as well as exchange member investors accounting for the different transaction costs these investors may incur. Surprisingly, even a general investor has approximately 30 daily opportunities to earn more than 10% per annum return, above the risk-free rate, by exploiting the put-call-futures parity mispricing. Significant arbitrage opportunities are atypical for mature markets. Nonetheless, the opposite holds for younger markets, which aligns with previous research suggested by Evnine & Rudd (1985), studying early options in the US, and Mittnik & Rieken (2000), studying derivatives on the DAX index in Germany.

In terms of more mature markets, Zhang and Lai (2007) revisit the pricing efficiency of the Hong Kong market by examining violations of the put-call-futures parity and how they relate to arbitrage opportunities. Specifically, they analyzed this by utilizing data on Hang Seng Index options and futures contracts to compare it with previous literature. At the same time, they use a dataset on the Hang Seng Mini options and futures because of its popularity and accessibility to retail investors. The Hang Seng Mini derivatives are a shrunk version of the original, introduced in October 2002. Notably, the timeframe is divided into several sub-periods between December 2002 and February 2004 to cover turbulent events on the Hong Kong market, such as the breakout of the SARS virus in 2003 and the Closer Economic Partnership Agreement with mainland China. The authors employ regression and an ex-post, and ex-ante analyses to inspect the detected violations. The market price of the above derivatives deviates rather often compared to the theoretical prices. Nonetheless, the arbitrage profits are modest and only gained during turbulent times. This is nearly in line with previous empirical research delivered by Fung et al. (1997), suggesting the efficiency of the HSI derivatives and no real arbitrage opportunities. A similar study was produced by Li and Alfay (2006) on the SPI index in Australia. The results align with all previous literature on the put-call-futures parity and arbitrage profit.

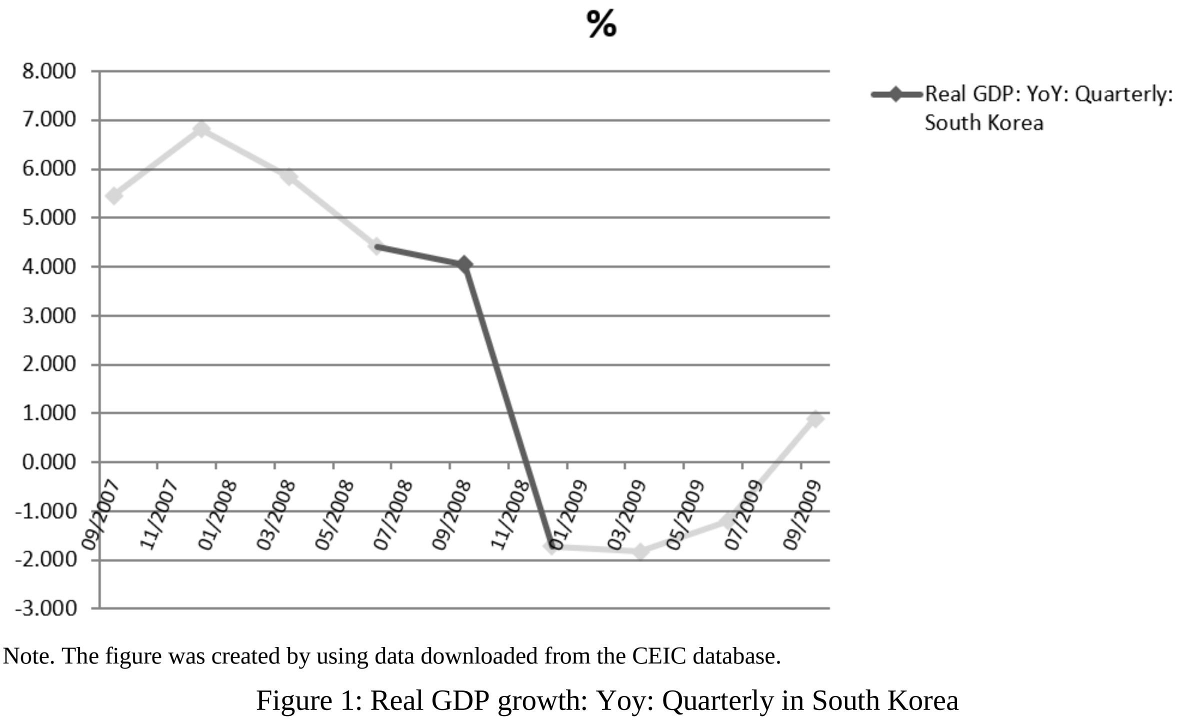
Furthermore, the put-call-futures parity framework can be extended to other financial assets. Followill and Helms (1990) have investigated violations and arbitrage opportunities for gold futures and futures options. They used COMEX futures, and their dataset encompassed May 14, 1984 to November 9, 1984. During this period, options were traded on the following gold futures contracts: August, October, December of 1984, and February and April of 1985. Expectedly, they employ a regression analysis. The empirical evidence concerning gold futures and the corresponding options does not differ significantly from the results related to index futures and options. When taking trading costs into account, the arbitrage profits are somewhat limited. Additionally, the conclusions are deemed comparable to earlier work on other assets. Jordan and Seale (1986) have applied the put-call-futures parity to Treasury bond futures. They conclude that floor traders typically garner the potential economic significance of the arbitrage profits and that arbitrage profits are somewhat restricted.

Given the knowledge generated on the relationship between put-call-futures parity and arbitrage opportunities, one should have different expectations concerning arbitrage profit incidence for younger and mature markets. There will likely be significant arbitrage profit. This expectation is attributed to one crucial factor. The most significant market participant in the derivatives market in South Korea is the retail investor. Namely, retail investors accounted for 50.6% of the KOSPI200 futures trading in 2001, which decreased to 44% in 2005; however, it remained the leading market participant Tang (2015). This does not apply to developed economies like the United States or the United Kingdom, where institutional investors dominate the derivatives market.

$H_{a(1)}$**:** *The arbitrage profit is statistically different than zero.*

2.4 Global Financial Crisis in 2008

The global financial crisis of 2008 was a catastrophe generated by years of industry malpractice and poor financial engineering of complex products. This was further intensified by having highly leveraged institutions engaging in risky behavior. The core problem was the NINJA (no income, job, or assets) loans to non-creditworthy parties. These loans were further securitized and sold on the financial markets. Furthermore, a lot of complex products associated with these loans were engineered. Finally, the credited parties could not meet their obligations, leading to a housing bubble and a financial crash. The outcomes of the crisis were first felt in the United States. Likewise, a lot of European countries faced huge financial distress. Iceland was the first victim, with its entire banking system collapsing in 2008. Moreover, the global financial crisis is assumed to be an underlying factor for the subsequent European sovereign debt crisis severely affecting Greece, Portugal, and Spain Chen et al. (2019). The bankruptcy of Lehman Brothers marked the beginning of the financial and foreign exchange market turbulence in South Korea. The Korean Won fell by 28.0% against the US dollar. Specifically, from KRW/USD 1,098.0 in late August to KRW/USD 1,513.0 on 24th of November, 2008. The KOSPI index decreased by 36.3% in two months. Additionally, the unemployment rate increased from 3.1% in August 2008 to 4.0% in March 2009, Chun Chung (2019).



Note. The figure was created by using data downloaded from the CEIC database.

Figure 1: Real GDP growth: Yoy: Quarterly in South Korea

Figure 1 presents the decrease in the quarterly GDP growth year over year. Evidently, there is a sharp decline in Q4 2008, and a consecutive negative growth up until the third quarter of 2009. This further indicates the slowdown of the overall economic activity due to the repercussions of the financial crisis.

Hereby, the dataset used for this study will cover the period from September 1st 2007 to September 10th, 2009, covering the 2008 world financial crisis as well. Therefore, I will attempt to examine possible structural changes in the dataset. There are 2 subsets. Namely, subset 1 covering the precrisis period from September 1st 2007 to September 15th, 2008. Then, subset 2 covering the crisis period from September 15th,2008 to September 10th, 2009. I expect significant changes given the different magnitude of market turbulence across the aforementioned periods. This periodization yields the following hypothesis.

$\boldsymbol{H_{a(2)}}$**:** *There is evidence for a structural change in the dataset after September 15th, 2008.*

CHAPTER 3 Data

3.1 Sample description

The dataset consists of futures and options sharing the KOSPI200 index as their common underlying asset. KOSPI 200 index futures were listed on May 3,1996. The size of one contract is the KOSPI200 Futures price times KRW 250,000. The KOSPI200 options contract was introduced on July 7, 1997. In the same fashion, the contract size is denoted by the KOSPI200 Options price times KRW 250,000. The options are European-style, thus avoiding complications associated with early exercise like American options. The dataset was constructed in the following way. Firstly, call and put options were matched conditioned on having the same trading date, trading time, delivery date and exercise price. Furthermore, the already paired calls and puts were matched with futures expiring on the same delivery date, traded on the same day and traded within a 1-minute window. The data covers the period from 1st of September 2007 up until 10th of September, 2009, the delivery date for the month of September in 2009 is the 10th , hence any contracts with later delivery dates were removed. For the analysis of structural change, the dataset was split into two subsets. Pre-crisis subset running from September 1st ,2007 up until September 15th 2008. The Lehman brothers' crash, the bankruptcy of one of the biggest investment banks is taken as the splitting event. Then, crisis subset presenting the period between September 16th 2008 up until September 10th 2009. Moreover, the dataset includes the daily bond yield of the short-term government 1-year bond, which when accounting for the holding period (number of days between trading and delivery date) is taken as the risk-free reference rate. The full sample counts 589, 759 matched trios. Importantly, all contracts are assumed to be hold to expiration with no early unwinding opportunities. Lastly, the data on the KOSPI200 derivatives was obtained upon request to the Korea Stock Exchange and the data on the daily bond yield was obtained from the CEIC data provider.

The literature on put-call-futures parity and arbitrage always takes trading costs into account. Cheng et al. (2000) factor in the associated trading costs when examining the pricing efficiency of the Hang Seng Index derivatives. Similarly, Draper et al. (1996) utilize the same approach on the FTSE-100 index in the United Kingdom. Nonetheless, previous studies pertinent to the KOSPI200 index derivatives do not take trading costs into consideration. The transaction costs for KOSPI200 index derivatives are low. Traders are exempt from commissions and brokerage fees, and members and exchange fees are also of a negligible amount. Furthermore, there is no tax on capital gains from KOSPI200 index derivatives trading. To attract more investors, KRX has been continuously lowering the margin required to be maintained in their accounts. This proved to be popular among all types and sizes of investors and increased foreign investor presence as well. Additionally, investors cannot buy or sell the stock index directly, they can only trade the index via derivatives products (Ryu, 2015).

Table 1: KOSPI200 futures contract trading volume by investor between September, 2007 and September, 2009

Investor type	**Sell**	**Buy**
Financial investment	46,569,086	46,579,037
Insurance	377,784	381,467
Investment trust	3,326,127	3,359,028
Bank	763,760	763,879
Other finances	72,160	72,302
Government, pension funds	340,292	342,335
Subtotal-Institutions	51,449,209	51,498,048
Other corporations	1,336,306	1,335,392
Individuals	51,153,258	51,161,893
Foreigners	34,896,445	34,839,885
Total	138,835,218	138,835,218

Note. the numbers are expressed in billions.

Table 2: KOSPI200 options contract trading volume by between September, 2007 and September, 2009

Investor type	**Sell**	**Buy**
Financial investment	1,848,112,816	46,579,037
Insurance	28,648,057	21,337,424
Investment trust	18,734,447	16,976,398
Bank	6,509,024	6,459,493
Other finances	1,354,493	1,323,584
Government, pension funds	22,681,798	16,447,922
Subtotal-Institutions	1,926,040,635	51,498,048
Other corporations	20,455,940	20,110,570
Individuals	1,887,999,497	1,933,925,138
Foreigners	1,521,403,928	1,535,030,085
Total	5,355,900,000	5,355,900,000

Note. the numbers are expressed in billions.

Table 3 and Table 4 present futures volume and options contracts traded by type of investor. Individuals are among the key market participants concerning KOSPI 200 Index derivatives in both instances. This further solidifies the argument, suggesting that the KOSPI 200 index derivatives are affordable and accessible to the retail investor, unlike on the exchanges of the developed countries' markets.

3.2 Variables

Arbitrage profit is the financial gain from taking the advantage of the mispricing. It is expressed in points and it denotes the cashflow represented by $|F_0 - F_0^*|$. Previously explained, F_0 represents the market close price of the futures contract. On the other hand, F_0^* denotes the theoretical price of the futures contract derived from the put-call-futures parity. For instance, the market close price is 238.45, the theoretical price is 239.25. In absolute terms, the difference between these two would be 0.8 points.

Intraday standard deviation is the deviation of the 5-minute returns of the KOSPI 200 Index futures contract.

Time to maturity was constructed by taking the number of days represented by the holding period and dividing it by 365. The time to maturity presents the number of days between the instigation of the simulated trade and the delivery date of the three contracts. For instance, if the time to maturity was 15 days, then it would be 15/365 as a fraction of a year.

The *moneyness* is the absolute difference between the market close price of the futures minus the exercise price divided by the exercise price of the options in the trio. This variable is constructed due to the fact that futures traders widely use options to hedge their positions.

$$moneyness = \left|\frac{futures\ price - exercise\ price}{exercise\ price}\right|$$

Futures trading volume, in the sample, represents the total amount of contracts traded within a single trading day. The data was obtained by the database of the Korea Stock Exchange. It is collected for futures with the KOSPI200 index as the underlying asset.

Risk free reference rate was constructed by taking the average daily short term government bond yield for the period between the initial trading date and the delivery date for a particular trio. The average was constructed by using daily bond yield data obtained from the CEIC database.

Strategy is a variable that takes a value of 0 for long futures strategy and 1 for a short futures strategy. If the actual price of the futures is greater than the theoretical price, then it is a long futures strategy if not, it is a short futures strategy.

3.3 Descriptive statistics

Table 3: Descriptive statistics for the full sample September 1st, 2007 to September 10th, 2009

	Mean	SD	Min	Max
Arbitrage profit	0.065	0.148	0	25.049
Intraday futures SD	0.0005	0.0004	0.0001	0.011
Time to maturity	0.045	0.035	0	0.496
Moneyness	0.039	0.046	0	0.6153
Futures trading volume	904.908	724.161	1	12051
Risk-free rate	0.043	0.012	0.024	0.056
Strategy	0.505	0.499	0	1
Observations	589,759			

Table 3 showcases the descriptive statistics concerning the listed variables. Arbitrage profit has a mean value of 0.06565. This indicates that over the 2-year period taken into consideration, the average arbitrage profit is positive. Further, the size of one contract is the KOSPI200 futures price multiplied by KRW 250,000. Hereby, the average monetary gain is 0.065*KRW 250,000 = KRW 16,412.5. The intraday standard deviation appears to be stable throughout the sample, indicating not overly fluctuating prices. Then, the small magnitude of the moneyness variable indicate that the futures market price of a matched put-call-futures trade does not differ greatly compared to the exercise price of the options. The risk-free rate throughout the sample oscillates from 2.361% to 5.606% which is expected given the size of the macroeconomic shock caused by the Financial Crisis. Another variable that seems to be varying is the futures trading volume, with its lowest value being 1 and highest being 12501. Given previous literature, trading volume tends to be more volatile during financially turbulent times.

CHAPTER 4 Methodology

To examine the collected data, I will employ the following approach. Firstly, a one-sample t-test will be used. This t-test will inspect whether the arbitrage profit is equal to zero throughout the sample. The test is a simple yet sophisticated statistical tool to assess if the mean of a sample significantly differs from a particular population mean, in this case, a 0. The null hypothesis assumes no difference, while the alternative hypothesis suggests a significant difference. The test presents a p-value, which will be compared to the significance level of 0.05. If the p-value is less than 0.05, the null hypothesis is rejected in favor of the alternative hypothesis. If not, the null cannot be rejected. Next, I will employ an ordinary least square regression model to analyze the different independent variables that might exhibit a causal effect on the magnitude of the arbitrage profit. The OLS is a popular statistical tool to estimate a relationship between variables. This method minimizes the sum of the squared differences between the observed and the predicted points. Consequently, the model provides insight into the significance and strength of the relationship between the independent and dependent variables. I will use a modified version of the model employed by Cheng et al. (2000) and borrow some ideas from Wagner et al. (1996). The model employed in this paper is the following:

$$\pi = \beta_0 + \beta_1\sigma + \beta_2 t + \beta_3 M + \beta_4 FVOL + \beta_5 R + \beta_6 S + \varepsilon \quad (3)$$

In the model, π is the arbitrage profit, σ is the is the intraday standard deviation of the 5-minute returns of the futures contract on the KOSPI200 index, t is the length of the holding period in a fraction of a year. M is the moneyness variable. FVOL is the futures trading volume, R is the risk-free rate, S represents the strategy used, and ε is the error term. In the original model of Cheng et al. (2000), the authors used the intraday trading volume of options as well. Nonetheless, due to inconsistencies of the data points concerning this variable, the options trading volume would not be included as an independent variable in the model.

Then, a test for restrictions will be utilized to examine possible structural changes. Namely, the model in equation (3) will be further altered with a dummy and interaction terms between the dummy and the coefficients of the variables. The dummy D equals zero if the observation occurred before 15^{th} of September, 2008, and it equals 1 if it occurred after. This date indicates the collapse of Lehman Brothers, one of the key banking institutions in the United States. It is considered a defining event of the World Financial Crisis in 2008.

$$\pi = \beta_0 + \beta_1 \sigma + \beta_2 t + \beta_3 M + \beta_4 FVOL + \beta_5 R + \beta_6 S + \beta_7 D + \beta_8 \sigma * D + \beta_9 t * D + \beta_{10} M * D + \beta_{11} FVOL * D + \beta_{12} R * D + \beta_{13} S * D + \varepsilon \quad (4)$$

Equation (3) presents the unrestricted model. A regression model and an F-test will be conducted to assess whether there is a structural change. If the coefficients of the dummy and the interaction terms are significant, there might be a structural change. This will be further examined with an F-test. The test will check if any of the coefficients of the dummy and the interaction terms are statistically different than zero; if they are, there is clear evidence for a structural change.

CHAPTER 5 Results & Discussion

5. Results & Discussion

In this chapter, I present the results for hypothesis 1 and hypothesis 2. A t-test was brought to use for the first hypothesis, and I review the appropriate statistics Then, for the second hypothesis, I present three regression models using model (3), one for the entire sample and two others for the pre-crisis and the crisis period, to get an intuition of the potential changes. Later, model (4) results are presented, and a test for restrictions is used to inspect a possible structural change. Finally, the results are compared with the scientific literature on mature and development markets. In the last section of this chapter, I present limitations to the research and further suggest potential research opportunities and how to possibly address the shortcomings of this study.

The Classical Linear Regression model assumptions are inspected to test the regression models' robustness. Since the OLS estimator is utilized when estimating the model, the model is assumed to satisfy the zero mean error assumption. Further, a white test was performed, and the null hypothesis of homoskedasticity was rejected. Considering academic practice, an appropriate approach for this was undertaken. Hence, using statistical software, the model was ensured to generate an appropriate regression and robust standard errors. Concerning the zero covariance terms, given the nature of the dataset, there is no room to include lags and test for autocorrelation. Lastly, there might be a correlation between the explanatory variables and the error term, which leads to endogeneity. The arbitrage profit is also prone to be affected by different variables and noise, which are difficult to determine and quantify.

5.1 Hypothesis 1

Firstly, to assess whether the arbitrage profit is significantly different than zero, a one-sample t-test was conducted. The t-value of the test is 339.292, and the p-value is 0.000. Hereby, the t-test results are significant at the 0.01 α-significance level. Consequently, we can reject the null hypothesis of no difference from zero in favor of the alternative hypothesis that the arbitrage profit is statistically different from zero.

Table 4: Determinants of the arbitrage profit from September 2007 to September 2009. Ordinary Least Squares regression model is employed to explain the relationship between the dependent variable, arbitrage profit, and several determinants: the intraday standard deviation of futures prices, time to maturity, moneyness, futures volume, risk-free-rate and strategy 0 for long, and 1 for short. The arbitrage profit is measured in points. For reference, 1 point is equal to KRW 250 000. The intraday standard deviation is expressed in Korean Wons, time to maturity is given in a fraction of a year, moneyness is an absolute ratio = |Futures Price-Strike Price/Strike Price| also expressed in dollars. Futures volume is the intraday number of traded contracts. The risk-free rate is expressed in basis points, and strategy is a dummy variable

	Dependent variable: Arbitrage profit		
Independent Variables	*Full Sample (Sep 08 to Sep 09)*	*Pre-crisis (Sep 07 to Sep 08)*	*Crisis (Sep 08 to Sep 09)*
Constant	-.073 (0.001)	-0.182 (0.005)	-0.0444 (0.00119)
Intraday std dev. of futures prices (*r*)	31.56*** (11.28)	6.884*** (1.003)	72.922*** (2.5349)
Time to maturity (T)	0.641*** (0.0114)	0.726*** (0.0169)	0.313*** (0.0102)
Moneyness (M)	0.766*** (0.1147)	1.202*** (0.018)	3.69** (1.24)
Futures volume (FVOL)	0.0000259*** (6.08e-07)	0.0000345*** (1.25e-06)	0.0000211*** (7.32e-07)
Risk-free rate	0.892*** (0.02)	2.796*** (0.10177)	0.359*** (0.0377)
Strategy (0 for long, 1 for short)	0.00054 (0.00036)	0.0014878** (0.000485)	-0.0002228 (0.000525)
R^2	0.1479	0.1448	0.1763
Number of Observations	589,752	296,839	292,913

Note. Significance levels indicated by * p < 0.1, ** p < 0.05, *** p <0.01.

5.2 Hypothesis 2

Table 4 presents the results of the linear regression model employed to determine the arbitrage profit's determinants. Firstly, the R^2 is 0.1479,0.1448, and 0.1763 for the full sample, pre-crisis, and crisis subsets. This means that the regressors can explain 14,79%, 14,47%, and 17,63% of the variation of the dependent variable. The R^2 is not exceptionally high, however, almost all of the coefficients of the factors are significant for the full sample and the two subsets. The lower R^2 may be due to the difficult-to-measure multifactorial relationship between the dependent and independent variables.

The coefficient of the intraday standard deviation is the biggest in magnitude and differs greatly across the different models. This is expected as, in more volatile times, greater deviations of the prices would be assumed. Nonetheless, an increase of 1 in the intraday standard deviation would increase arbitrage profit by 31.56 points. This is not likely since this variable's mean and standard deviation are low. Then, time-to-maturity varies across the models as well. This variable is expressed in a fraction of a year. Hereby, an increase of 1 is impossible since no contract has a time-to-maturity as long as one year. More realistically, if time-to-maturity increases by 0.05, then the arbitrage profit will increase by 0.032 points, on average. Moneyness also has a significant coefficient; if the coefficient of moneyness increases by 0.05, then arbitrage profit will increase by 0.038. Futures volume is significant for all three models. Nonetheless, the magnitude is minimal. Hereby, any change in this variable will not generate a meaningful increase in the arbitrage profit. The coefficient of the risk-free rate is significant as well. If the risk-free rate increases by 15 basis points or 0.0015, the arbitrage profit would increase by 0.00124, which is a relatively marginal improvement. Strategy is only significant for the second model. Hence, if the arbitrageur engages in a short futures arbitrage, then the arbitrage profit would increase by 0.00148, on average. Again, this is significant but would not be an outstanding increase in real life.

Moreover, there is a notable difference between the pre-crisis and crisis periods. This solidifies the argument, suggesting a structural change between the two periods. With this, one more regression analysis is employed, including a dummy and interaction terms. The dummy is set to take the value of 0 if the observations took place before the 15th of September 2008 and the value of 1 otherwise. This date marks the event of the Lehman Brothers collapse. Furthermore, the coefficients' effects and significance have been analysed and presented before. The regression model will solely serve as proof to materialize the argument that there is a structural change across different periods in the entire sample. For this reason, only the significance of the coefficients of the new terms is to be briefly commented on. Table 6 presents the output of the Ordinary Least Squares regression model corresponding to the one in Equation (4).

Table 6: Unrestricted model with a dummy and interaction terms for the full sample

Independent Variables	*Dependent variable: Arbitrage profit*
Constant	-0.182
	(0.005)
Intraday std dev. of futures prices (*r*)	6.884***
	(1.003)
Time to maturity (T)	0.7261***
	(0.0169)
Moneyness (M)	1.201***
	(0.0185)
Futures volume (FVOL)	0.0000345***
	(125e-06)
Risk-free rate	2.796***
	(0.1017)
Strategy (0 for long, 1 for short)	0.00148**
	(0.000484)
D	0.137***
	(0.0058)
Intraday std dev. of futures prices (*r*)*D	66.038***
	(2.726)
Time to maturity (T)*D	-0.414***
	(0.0198)
Moneyness (M)*D	-0.609***
	(0.0228)
Futures volume (FVOL)*D	-0.0000134***
	(1.45e-06)
Risk-free rate*D	-2.437***
	(0.10855)
Strategy (0 for long, 1 for short) *D	-0.00017**
	(0.0007146)
R^2	0.1619
Number of observations	589,752

Note. Significance levels indicated by * p < 0.1, ** p < 0.05, *** p <0.01.

The dummy and all of the interaction terms are significant, as shown in table 6. This signals a possible structural change. To further examine this, I employed an F-test. The F-statistic is 261.05, and the p-value is 0.000. Hereby, I reject the null hypothesis in favor of the alternative hypothesis that there is a structural change after the 15th of September 2008.

5.3 Discussion

My results present a significant arbitrage profit when the put-call-futures parity is violated. Namely, this is confirmed by rejecting the null hypothesis that the arbitrage profit is not significantly different than zero. Hereby, if there is a mispricing between the market price of the futures contract and the one derived by the put-call-futures, market participants could use that to their advantage and gain financially by exploiting a long or a short futures strategy. A long one if the theoretical price exceeds the market price and a short one if otherwise. The results pertinent to the arbitrage profit are on par with the previous literature. To be precise, literature on mature markets, such as Cheng et al. (2000), which examines the Hang Seng Index and the put-call-futures parity, suggest that arbitrage profits are significant; however, when trading costs are accounted for, they are often small. Likewise, Draper et al. (2002), who study the FTSE-100 options and contracts, have similar conclusions. Nonetheless, it is essential to note that Draper et al. (2002) extraordinarily studied this topic, including early-unwinding strategies due to the availability of American-style options with the FTSE-100 as an underlying asset.

On the other hand, Vipul (2008), who inspected the Indian derivatives market, has results that indicate significant arbitrage profit even when accounting for trading costs. Moreover, the author also points out the exploitability of arbitrage strategies by retail investors. This attribute is outstandingly crucial to the Korean derivatives market as well. As mentioned earlier, retail investors are central market participants in the derivatives landscape in South Korea, a practice uncommon for mature markets like Hong Kong, the United Kingdom, and the United States. Hence, it would be difficult to classify the Korean derivatives market as either mature or young due to its unique regulations and accessibility.

Concerning the determinants of the arbitrage profit, the results are similar to the model employed by Cheng et al. (2000). The magnitude of the intraday standard deviation in their results is more remarkable in magnitude but insignificant. The coefficient of the futures volume has a similar magnitude to our model but is insignificant. On that note, the rest of the coefficients are similar. Likewise, their models exhibit structural changes when dividing the data into pre-crisis and crisis periods.

A possible limitation of this paper could be the omission of the intraday trading volume concerning options. The options trading volume data obtained via the Korea Stock Exchange needed to be more consistent, and proper matching of the futures and options contracts was impractical primarily due to the dated nature of the data.

It would have been insightful to see how this variable impacted the arbitrage profit. For this reason, future researchers could exploit a more recent macroeconomic crisis where up-to-date data will be available. I suggest exploring the relationship between the put-call-futures parity and arbitrage profit during the COVID-19 crisis in 2020. Understandably, this event has caused a massive shock to the world economy and financial markets.

CHAPTER 6 Conclusion

In this paper, I have analyzed whether violating the put-call-futures parity and subsequently taking synthetic positions would generate an arbitrage profit. Furthermore, determinants of this arbitrage profit were explored. At the same time, arbitrage profit was analyzed in periods characterized by distinctive market turbulence to inspect possible structural changes. Previous research has shown both no significant arbitrage profit concerning mature markets and significant arbitrage profits concerning developing markets. However, none of the previous research reviews arbitrage and put-call-futures parity in a context where derivatives are easily accessible and traded by retail investors. Additionally, in terms of macroeconomic shocks, most of the papers examine domestic shocks, and none of them reflect global macroeconomic crises. Accordingly, I consider this topic relevant for the scientific community, and the question studied in my thesis was: "How does the violation of the put-call-futures parity lead to arbitrage profits before and during a financial crisis?".

In order to answer the question, data on puts, calls, and futures with the KOSPI 200 index as an underlying asset were matched into a simulated trade within the same one-minute window. The results and the analysis show that the arbitrage profit is significant and that there are structural changes between the pre-crisis and crisis periods.

This paper concludes that there is significant arbitrage profit when the put-call-futures parity is violated. Furthermore, the determinants of the arbitrage profit have different effects in regular market activity and volatile and turbulent market periods. Coupled with previous literature, there is evidence for potential financial gains if one utilizes an arbitrage strategy on the grounds of a violated put-call-futures parity, especially in unique markets like South Korea, where derivatives trading by retail investors is a common practice.

The implications of this paper are relevant for investors. Namely, investors can have monetary gains by exploiting arbitrage opportunities by using the violations of the put-call-futures parity. Furthermore, due to the favorable policy, they can achieve this without incurring significant costs and being exempt from taxes on financial gains.

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