A Study on Information Contents in the Volatility Spread in KOSPI market

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Abstract

This research examines information content and origin of the volatility spread of KOSPI200 index, which is the difference in implied volatility of call and put options of KOSPI200 having the same maturity and strike. Kim (2011) discovered that the volatility spreads of KOSPI200 options precedes KOSPI200 index return rate. Using a more recent data set of KOSPI200, this study shows that the volatility spread shows forecasting power on KOSPI200 return rate as in Kim (2011). Further, it reveals the fundamental cause of volatility spread is the basis between spot and futures of underlying asset. In addition it has been indicated that spread of spot and futures are the more reliable information in predicting KOSPI200 return than the volatility spread index return rate through VAR analysis and theoretical explanation respectively. This study differs to Kim(2011) mainly in considering futures as key role.

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Ⅰ. Introduction

The theories of financial asset valuation and pricing decision can provide the basis for analyzing financial structure and investor's portfolio selection. The valuation has been the main issue for estimation and prediction on pricing of financial instrument and its derivatives. Further, such method is currently being mainly used for arbitrage trading, establishing hedge strategy, developing model for evaluating credit of customers. The price of financial instrument varies depending on market frictions, completeness, concept and methodologies used for pricing. The concept of arbitrage proposed by Modigliani-Miller and equilibrium asset pricing, which has been used for capital asset pricing model (CAPM) of Sharp and Litner, are mainly utilized for pricing theory.

There have been numerous studies carried out on fair price for option. The studies of Black-Scholes(1973) and Merton(1973) are mainly referred by researchers in this field. According to such findings, the option price can be presented as the value of replicating portfolio excluding risks. Further, they revealed that profit can be made equal to the maturity yield payoff through continuous implementation of dynamic hedge. These results indicate that the value of derivatives, of which underlying asset is stock, can be replicated through linear combination of bond and underlying asset. That is to say, if the value of derivatives and replicating portfolio are traded in market, profit can be made by longing cheaper one and shorting more expensive one. Because profit can be realized at maturity date as the value of two assets are the same. If there is no arbitrage trading in the market, the value of non-risk portfolio becomes equal to the price of financial instrument and this pricing method is called ‘Risk-Neutral-Pricing’.

Many people can agree with the same price through the option pricing model developed by Black-Scholes(1973). However, such model cannot estimate population parameter required to price completely. Therefore, it can be seen that the price set based on the parameter in which the participants' opinions are reflected in the market. In a nutshell, the

Black-Scholes model cannot estimate volatility and appropriate dividend. In this sense, the market price depends on the perspectives of market participants on dividend and volatility.

After Black-Scholes-Merton (1973) has developed an option pricing model, Black (1976) has proposed option pricing model for future. Black(1976) sees that the fair price of option, of which underlying asset is future, can be set based on a logic which is similar to that of Black-Scholes-Merton(1973). Since market's perspectives on dividend of spot is reflected on future price, using Black (1976), one could avoid to estimate dividend.

Further, future converges to spot price as matured. Therefore, the price of option whose underlying is future and the price of option whose underlying is spot should be same if future has same maturity with the option and other condition is same. According to these features of above two models, there are two main ways to replicate index option in Korean financial market. One method is setting non-risky portfolio until expiration date through dynamic hedge which uses index itself. The other one is doing so by using index future market. That is to say, the two types of replication have the same payoff at expiration date therefore their price should be same although they use seemingly different evaluation methods.

At 1996 KOSPI200 Future and Option have been introduced in Korean financial market seeking finacial autonomy and patency. As a result, the era of derivatives has been held in domestic financial market. Initially, speculators have been the main agents of transaction. However, the market has become the world's largest market regarding the volume through continuous growth. This high level of liquidity allows the various strategies in KOSPI200 market as well as theories can be applied and observed appropriately in practice.

Since KOSPI 200 index option is traded in option market, it would be possible to inversely estimate how the market participants see volatility. This is called implied volatility and each implied volatility corresponds to option price. As earlier mentioned, the option prices set by the models of Black(1976) and Black-Scholes(1973) are equal to each other therefore, implied volatilities should be theoretically the same. If the two volatilities are not the same, they do not satisfy no-arbitrage-condition therefore arbitrage trading is available in the market. We can call this argument as Black and Black-Scholes no-arbitrage. This relation partly owes to interest rate parity.

According to Sol Kim and Guel Lee(2011), if we define volatility spread as the differences between implied volatility of put option and call option, the volatility spread in KOPSI200 precede thirty minutes than KOSPI200's rate of return. However, this spreads directly leads to violation of put-call parity and therefore the fact that spread exists in implied volatility means that arbitrage trading is available in the market. This research, in this light, has analyzed the reason why there is volatility spread which violates conditions of no-arbitrage-condition and attempted to find the source of information content of volatility spread through spot and future basis which refers to the difference between spot and future. Through the analysis we combine two main no arbitrage argument, which is put-call parity and Black(1977) and Black-Scholes(1973) arbitrage.

Ⅱ. Literature Review

Theoretically, volatility indicates stochastic term of Geometric Brownian Motion and this can be measured through various methods. The most popular one, among them, is historical volatility which sees the trend is the same in the past and future. Further, EWMA, ARCH (Engle,1982) and GARCH(Bollerslev, 1986) have been developed as the models for volatility to reflect clustering and regression towards the mean of volatility. As this shows, there are numerous ways of measuring volatility that each one has own characteristic.

Apart from this statistical method, one can calculate the volatility back from price of option using option pricing model. The volatility which has been calculated backward by using the market price is called implied volatility. This can be seen as population parameter which takes into account the opinions of market participants. There have been many of research carried out on this topic. Sol Kim and Geul Lee(2011) argue that the volatility spread, the differences between implied volatility of put option and call option, which have the same expiration date and striking price, precede KOSPI200 index return rate. Jongwon Park and Wook Jang (2002) have seen that program trade increases implied volatility temporarily. Further, Hyuk Choi and Seonheum Yoon (2007) argue that such trade has lead-lag relationship with KOSPI200 index and basis.

According to the advanced research, it can be seen that the volatility is closely related to market shock and gap that this article sees the differences between spot and future as the level of market gap. Through this, the information content resulted from the differences between spot and future has been analyzed. Further, the relationship between volatility spread and basis of spot and future has been explained.

Ⅲ. Analyzing and Data Selection Methods

Carrying out this research, KOSPI200 nearby contract data for option, futures and index has been collected per minute from 28th of June in 2011 to 10th of August in 2012 to analysis the cause of volatility spread which precedes return rate of KOSPI200 index. Sol Kim and Geul Lee (2011) have analyzed minutely data from 30th of September in 2009 to 3rd of January in 2007. In this paper, the methods from research carried out by Sol Kim and Geul Lee (2011) have been applied to data collected from other(recent) periods to find out same result can be repeated. Moreover, normal data, which have been collected after contretemps including economic crisis, has been utilized and this may have minimized error caused by market disturbance therefore analysis can be carried out according to recent market trend.

Various errors can occur analyzing minutely data. If the volume of trade is not enough, price can be distorted due to non-simultaneous trade. However, the KOSPI market ranks first in the world regarding volume of trade and especially nearby contract(current delivery)is feasible enough therefore such distortion can be neglected for analysis. Further, analysis has been carried out with at-the-money option only to increase the reliability of analysis. In addition, next nearby contract has been analyzed for the expiration date as error can occur due to very short expiration in case of nearby contract. 91 days CD interest rate has been used as risk-free interest rate. Such rate can attract many of criticisms. However, there are not much of differences in various interest rates and it does not affect measurement of implied volatility therefore the 91 days CD interest rate, which is generally used, has been used.

To calculate implied volatility, there are some considerations on underlying asset and model and it is crucial part of this research. Black(1976) and Black-Scholes(1973) use different types of underlying. As the model proposed by Black(1976) sets future as underlying asset, therefore, there are needs of verification on which type of futures is to be used to apply the model to get implied volatility. KOSPI200 futures can be seen as the best underlying asset when Black(1976)model is applied. This is because KOSPI200 futures are traded in the market with great liquidity therefore market price can be applied. However, KOSPI200 futures cannot be applied to option of whose maturity is not accord with the option. In KOSPI market, nearby futures contract and nearby option contract has different maturity. For this reason, synthesized futures are one of the available choices to eliminate errors occurring with unmatched maturity dates.

Stoll(1969) has argued that the below formula should be established for call, put options and underlying asset and this formula (1) is called put-call parity

$$C - P = S - Ke^{-(r-d)T} \tag{1}$$

S : Underlying Asset Price, K : Call Option Price, r : Risk-Free Rate of Return,

d : Dividend Rate, C : Call Option Price, P : Put Option Price

The put-call parity is a model-independent formula therefore the price formula proposed by Black-Scholes(1973) satisfies the above formula. Therefore, it can be said that such formula can be always applied to KOSPI200 option market which is very feasible. In this research, the virtual(synthetic) future price has been regarded as the price of underlying asset by utilizing put-call parity through the following method.

The put-call parity indicates that the expiration payoff of portfolio which longs and shorts an unit of call option and put option with same strike respectively should be equal to the payoff of future and so their current price should be same. Therefore, the portfolio price of synthesized position, suggested earlier, is appropriate for the underlying asset for applying the model of Black (1976). In this research, analysis has been carried out by using the price of future, which utilizes synthesized position, as underlying asset to eliminate error caused by dismatch of expiration date.

To calculate the price of synthesized future, we use minutely price data of call and put options with the same strike. If pair of prices are not available, corresponding strike is excluded. Yet the case was very small compared with entire sample.

The methodologies used to carry out this research are as follows.

Firstly, we examine the data of our choice has same characteristics to that of research carried out by Sol Kim and Geul Lee (2011). In other words, we checked that volatility spreads are really there since it means arbitrage. According to their research method, we calculate volatility spreads as difference between call and put volatility of KOSPI200 option. In doing so, we compare the implied volatility spreads obtained from Black and Black-Scholes respectively and checked summary statics and stylized facts.

Secondly, theoretical analysis has been carried out on the cause of volatility spread and its information. We suggest the level of gap between future and spot is one reason, and explain the reason why it has the same information content with that of volatility spread.

Thirdly, through VAR analysis, we show empirically the basis of future and spot and implied divident have same strength of information with the volatility spreads Further, the research examine which one has more fundamental information content on predicting KOSPI index return.

Fourthly, conclusion of this research has been suggested based on these results and there has been contemplation on direction of further research.

Ⅳ. Volatility Spread by Underlying Asset

1. Implied Volatility Affected by KOSPI200 Index

To calculate implied volatility of KOSPI200 index option, its configuration is need to be analyzed and the consideration regarding calculation method also need to be discussed. KOSPI 200 is stock price index, which has been developed as trading subject for future and index option, consists of 200 items which have been selected taking into account market, field typicality and liquidity to be appropriate for future and option trading. KOSPI 200 has set 3rd of January as 100p then calculated and reported it from 15th of June in 1994. In doing so, such figure has been calculated as increase in aggregate value of listed. Further, it has been calculated as half the non-current asset + current asset from 15th of June in 2007. Then it has started to be calculated by using current stocks only since 14th of December in 2007. Currently, the KOSPI200 index is being reported every two seconds and the indexes before after occurrence of factors when it comes to decrease in stocks including ex-rights and ex-dividend for continuity. Further, the accorded total market value is reflected.

The KOSPI 200 index option is underlying asset which does not have the content of dividend. Therefore, implied volatility can be calculated back through market price of the option and other parameters by using a pricing model without taking into account dividend. That is to say, it is appropriate to calculates implied volatility with dividend rate as 0, for an option which sets KOSPI 200 index as underlying asset. Therefore, if the implied volatility is calculated inverse using KOSPI200 index as underlying, the volatility is free of error due to measuring dividend.

To calculate implied volatility, closed-form inverse solution of Black or Black-Scholes formula does not exist. So, it should be calculated numerically. Newton-Rapson methd, which is the most popular one, has been used in this research.

Table 1, Figure 1,Figure 2 and Figure3 shows summary statistics of KOSPI200 index and historical trends of implied volatility and volatility spread. Imp_Call and Imp_Put refer to implied volatilities of call and put options of KOSPI200 respectively. The implied volatilities of call option and put option have been 20.2% and 22% respectively on average. The volatility spread, which refers to the difference between implied volatilities of option and put option, has been –1.8%.

<Insert Table 1 here>

<Insert Figure 1 here>

<Insert Figure 2 here>

If we look at the figure1, implied volatility of call and put option moves in similar fashion. In addition, there's some outlier in implied volatility which is more than 100%. This is probably caused by supply or demand shock including program short or realization of arbitrage trading. Further, the progress of volatility spread, which refers to differences between volatilities of two options, is illustrated in Figure 3.

<Insert Figure 3 here>

The volatility spread of KOSPI200 index option moves around 0 as the theory shows but has bit of bias in minus direction.

2. Implied Volatility by KOSPI200 Futures

KOSPI200 futures have KOSPI200 index as underlying asset. The trading unit is 0.5million won per index which is delivered by cash every three months in 3, 6, 9, 12. Futures price tends to be converged to spot price as expiration is coming. Therefore, it can be used as underlying asset for option on spot if their maturity matches. Here we have attempted to analyze the changes in volatility spread if KOSPI200 futures price is set as underlying value. In doing so, we used the same method used in previous section for

KOSPI200 spot and the Table 2, Figure 4, Figure 5 shows summary statistics and historical trend of implied volatility and volatility spread when KOSPI200 future price is set as underlying asset.

<Insert Table 2 here>

<Insert Figure 4 here>

<Insert Figure 5 here>

<Insert Figure 6 here>

As the table and figures indicate, it seems that there is not huge differences in implied volatility compared with prior Black-Sholes based volatility. However, the figure for volatility spread shows there is huge differences in the factor. A noticeable feature is that there are four areas in which spread is almost 0. Taking into account the fact that data has been analyzed from 28th of June in 2011 to 10th of August in 2012, the expiration dates of option and future matched with each other in March, June, Sept., Dec. only and the volatility spread is almost 0 on the areas.

Another feature is that similar shapes are repeated. There are 14 times of maturity dates in total for both option and future. Volatility spread tends to head to outlier on each maturity date. However, the figure converges to 0 every three months and it heads to outlier when there is large gap between maturity dates of nearby option and nearby future. This implies that nearby KOSPI200 futures can be used as underlying asset when its maturity matches that of option which comes four times a year. In other periods, it would not be appropriate to use KOSPI200 futures as underlying asset for the option.

3. Implied Volatility Affected by KOSPI200 Future Synthetic

If nearby KOSPI200 futures cannot be used as underlying asset due to unmatched maturity with nearby option, synthetic futures can be alternative. The price of synthetic future, which comes from put-call parity, has been utilized here to sort out the unmatched maturity between futures and option. Table 3, Figure 7, Figure 8 and Figure 9 show summary statistics and graph of implied volatility and volatility spread which set synthetic future as underlying asset.

<Insert Table 3 here>

<Insert Figure 7 here>

<Insert Figure 8 here>

<Insert Figure 9 here>

First of all, it is no surprising to see the remarkable adequacy. According to theory, the implied volatilities of call and put options should be the same but there spread has come out as a result of applying the model of Black-Scholes(1973). However, In case of Black(1977) with combination of synthetic future underlying, there has been other number but not 0 on the 14th decimal point of spread's maximum value. That is to say, this perfectly matches to theory that differences between volatilities have been 0.

KOSPI200 index(spot) is hard to say tradable. Transaction occurs regarding KOSPI200 through derivative such as ETF. Despite this fact, the index cannot be seen as actually-traded product. That is to say, if there is arbitrage opportunity exists based on the model of Black-Scholes (1973), theoretical strategy cannot be implemented in the market therefore there can be gap between theory and reality. Even put-call parity violation could not be exploited with index spot.

However, the strategy based on model of Black (1976) and put-call parity are traded in practice by using future synthetics and actual future. Therefore, arbitrage opportunity will be exploited if there is the opportunity and this will disappear instantly. The fact that volatility spread appears to be almost 0 in every case mean that the market satisfy the conditions for no-arbitrage.

Actually, the 4 areas of zero at section 4.2 means no-arbitrage area between synthetic futures and actual futures. Other than those areas, because of maturity mismatch, we can’t tell whether there is arbitrage opportunity or not between synthetic and actual future.

Another noticeable fact is the repetitive shape of volatility spread. The minutely data collected from 28th of June in 2011 to 10th of August in 2012 has shown fourteen times of expiration dates in total with repetitive shape. Volatility spread increases as expiration come close likewise decrease after that repetitively. There need to be more detailed research but it can be seen that the opportunity for arbitrage trading increases because of abnormal factors resulted from expiration.

Ⅴ Analysis on the Causes of Volatility Spread

The cause of volatility is explained here by using future and spot basis. Merton(1973) has argued that the option price based on underlying asset with dividend can be calculated by using formula (2)

$$C = Se^{-d*T}N(d1) - Ke^{-r*T}N(d2) \quad \ldots\ldots (2)$$

$$d1 = \frac{\ln\left(\frac{S}{K}\right) + (r - d + \frac{1}{2} * \sigma^2)}{2a}, \quad d2 = d1 - \sqrt{\sigma}$$

C : Call Option Price, S : Underlying Asset Price, d : Dividend Rate,

r : Risk-Free Rate of Return, T : Time Left Until Expiration Date, σ: Underlying Asset Volatility

After Merton's proportion (1973), Black(1976) has shown that formula (4) comes out by substituting the interaction formula (3) of future and spot into formula (2) and the option price can be calculated by using formula (4).

$$F = Se^{(r-d)T} \quad \ldots\ldots (3)$$

$$C = e^{-rT}(FN(d1) - KN(d2)) \quad \ldots\ldots (4)$$

$$d1 = \frac{\ln\left(\frac{S}{K}\right) + (\frac{1}{2} * \sigma^2)}{2a}, \quad d2 = d1 - \sqrt{\sigma}$$

C : Call Option Price, S : Underlying Future Price, d : Dividend Rate,

r : Risk-Free Rate of Return, T : Time Left Until Expiration Date, σ: Underlying Asset Volatility

According to theory, the prices used by Merton (1973) and Black (1976) are the same if the price of future is the same with theoretical future price. Therefore, the implied volatilities, which is one of the main subjects of this research, should be the same irrespective of which type of model is applied to one option.

According to these, if the future price is the same with theoretical price, volatility spread would show the same result. Since volatility spreads according to Black(77) model is zero, if future price is the same with theoretical price, volatility spreads according to Black-Scholes(73) would be zero as well. This implies that the cause of implied volatility can be found by examining which variable leads to differences between future and its theoretical price. Formula (3) represents static replication of future by spot. The following formula comes out by applying linear approximation to exponential of the above formula and with little modification.

$$F \approx S(1 + (r - d)T) \qquad (5)$$

$$F - S = S(r - d)T \qquad (6)$$

Left hand side of this formula (6) is the basis is of spot and future and it is determined by spot price, interest rate and dividend rate. The spot price and interest rate are traded in the market and there are values with which the participants mostly agree in between such factors. Therefore, the dividend rate is major uncertain key factor to decide the level of basis. However, KOSPI200 does not have ex-dividend as discussed earlier therefore it is hard to see KOSPI200 basis as expected dividend of spot. The implied dividend rate, according to theory, should be 0 to satisfy conditions of no-arbitrage trading. However, due to difficulty of index trading as discussed earlier, implied dividend rate won’t be zero. The objective this research is to find the cause of volatility spread rather than of basis of spot and future. Therefore, we will not discuss about the cause of implied dividend rate which need further research.

As examined earlier, the implied volatility, if calculated by substituting implied dividend rate into the model of Black-Scholes(1973), is exactly the same with the implied volatility of Black(1977). Further, we have already seen from the section 4 that the volatility spreads are zero if future price is set as underlying asset. If so, the volatility spread, which sets spot at the underlying value, would show the same results(all zero) by substituting implied dividend rate of future into the formula. The formula(7) suggests formula for calculating implied dividend rate and the <table 4> indicates statistical summary of volatility spread by substituting the dividend rate, which has been calculated by using formula (7), into the model of Black-Scholes (1973).

$$d = r - \frac{1}{T}\ln(\frac{F}{S}) \quad , (7)$$

<Insert Table 4 here>

As the table indicates, the level of volatility is very small that the ninth decimal number of maximum value is not 0 but the other number if we calculate volatility spread by using implied dividend rate. That is to say, most of the volatility spreads are zero practically, which are calculated by taking into account implied dividend rate.

The section 4 and 5 can be summarized as follows. Firstly, if underlying asset is actively traded volatility spread does not exist. As examined in section 4, if the future price is set as underlying asset, volatility spreads was zeros during the period of matched maturity.

Secondly, volatility spread should be 0 under no arbitrage argument but could be have non-zeros value affected by lack of liquidity or certain limitations in trading. If spot is set as underlying value, considering index spot is not traded therefore volatility spread, volatility spreads can take place. As examined in section 5, the fact that volatility spread has non-zero value means that implied dividend rate has non-zeros value for KOSPI200 which supposed to be no dividend.

Ⅵ Volatility Spread and Information Content

Here, we examine the implied dividend rates of spot and future or basis of spot and future have same strength of information content with volatility spreads or more, which should have according to prior discussion. As examined earlier, the implied dividend rate, volatility spread, basis of spot and future can be seen as the same content although they have different value and shape.

First of all, we repeat the VAR analysis of Sol Kim and Geul Lee (2011) for more recent period to see volatility spread still has information on predicting KOSPI200 index return rate. The table 5 shows the results from analysis.

< Insert Table 5 here >

The results show that volatility spread has been found to precede return rate of KKOSPI200 index by 27 about minutes. Such findings are similar to the prior research of Sol Kim and Geul Lee (2011) and it supports the fact that after the periods in Kim(2011) there was not much change in market efficiency and liquidity. We are now more confident on information content in volatility spreads.

In addition, we examine basis of spot and future have the same information content with volatility spreads and this is the ultimate goal of this research. In doing so, vector auto-regression model (VAR) with basis of spot and future has been employed and the results are indicated in table 6.

In table 6, basis of spot and future have been set as explanatory variables and results have been coincide with hypothesis. The significant levels appeared to be almost the same until 27th lag and the levels have decreased from 28th one. All these indicate that, the variables have the information content of same strength with volatility spread. This can show that the information of volatility spread for KOSPI index return rate is very similar to that of basis of spot and future.

Further, the same analysis has been carried out by using implied dividend rate which has been examined in section 6. The table 7 below indicates the results from VAR which set dividend rate as explanatory variable.

<Insert Table 6 here>

<Insert Table 7 here>

In table 7, as discussed in section 5, implied dividend rate has been found to precede KOSPI index rate of return by 27 minutes as the volatility spread and basis of spot and future. The significance of implied dividend rate decreases from 26th but still significant until 27th lag that we can say that it has the same information content with volatility spread.

According to the results from above two tables(6,7), one can find out that as long as they contain information about basis of future and spot, information content of would have the same all the time irrespective of which type of variables. In this research, such findings have been verified by using two variables. One is basis of spot ant future which refers to the direct gap between spot and future. The other one is implied dividend rate which determines logarithmic gap between the spot ant future basis. However, if there is variable which refers to basis of spot and future with unexpected shape, such as volatility spread, it would have information content which precedes KOSPI index return rate by about 27 or 28 minutes.

As these findings indicate, the three variables shares the same information content and shows same strength of information content respectively. However, if any two variables only have common information source and nothing much on their own, their explanatory power is redundant. To see if it is true, two variables together, basis and spread, will be set as explanatory variables and VAR will be implemented to find which variable is more reliable or redundant. If one variable is more fundamental and reliable than the other, the weaker one will lose its explanatory power to the KOSPI200 index return rate. The table 8 indicates the results of vector auto-regression which uses volatility spread, basis of spot and future as explanatory variables.

<Insert Table 8 here>

The Table 8 indicates that which variable, among volatility spread and basis of spot and future, has better information content. As the three tables show, the two variables will apparently precede KOSPI200 index return. A significant shown in Table 8 is that the volatility spread loses it's significance at the third lag. After third lag, Volatility spread becomes significant again but not consistently. In contrast, the significance of basis of spot and future maintains until 17th lag. According to these results, the information content of basis of spot and future is stronger than that of volatility. This is because, as examined earlier, the origin of volatility spread and implied dividend rate is the basis of spot and future. Based on all these findings, the basis of spot and future has the same information content with volatility spread and therefore more fundamental and possibly stronger information content.

Ⅶ Conclusion

The KOSPI200 index option market has shown the great amount of liquidity in the world making itself most analyzable. Considering that most of gap between practice and theory in derivatives pricing is originated from illiquidity, it is very attractive to sort out the liquidity factor to researcher.

In this research, the source of volatility spread, which leads KOSPI200 index return rate, has been examined. In doing so, empirical research has been carried out on the source of volatility spread with theoretical evidence. Further, we examined if the source have the same information content with volatility spread itself. The findings can be summarized as follows.

Firstly, it is appropriate to choose “actively tradable” underlying asset to measure implied volatility of option. If the futures price, which is the outcome of active trading, is used as underlying asset, there is almost no violation of call-put parity empirically, therefore no volatility spreads. If index is set as underlying, which is not exactly tradable, empirically call-put parity doesn’t hold often and implied volatility of call option and put option diff can differ from each other, i.e. volatility spreads take place. This implies that market participants build their position based on tradable asset such as futures and synthetic futures and they treat these tradable asset as underlying asset for KOSPI200 index option. In other words, they choose to use Black(1977) model over Black-Scholes model(1977). This choice is only rational to avoid actual arbitrage loss or gain in real market.

Secondly, the source of volatility spread has been found to be the gap between spot and future prices. This research shows that if futures price is applied to underlying, volatility spreads is practically zero all the time during the period of selection. Further, the volatility spread, which occurs when spot is set as underlying asset, has been found to be caused by basis of spot and future. To show it, implied dividend rate is applied and there attempt remove volatility spreads even when spot is used as underlying asset.

Thirdly, implied dividend rate or basis of spot and future has been found to have the same information content with volatility spread. This has been verified through vector auto-regression model. In addition, there can be about 1 minute of time lag but the majority of information content of three variables has been found to be at the same level.

These three findings indicate that it is theoretically ideal if volatility spread should always be zero with no arbitrage argument. However, there can be significant level of gap between practice and theory if underlying asset is not actually tradable itself.

This research can have the following implications. Firstly, it has been found that the market participants can decide price based on pricing model. According to this research, the participants accept the price of replicated portfolio, which can be made by using option price(actively traded) rather than spot(theoretically calculated). Further, they do trading according to the criteria set by model of Black (1976).

Secondly, the information content of volatility spread has found to be still valid to recent data and this improves the reliability of research carried out by Sol Kim and Geul Lee (2011). In addition, it can be seen that volatility spread do have the information content in the market.

Thirdly, despite its relatively lengthy calculation procedure to obtain volatility spread, the information content in volatility spread can be seen as same with that of basis of spot and future. Sol Kim and Geul Lee (2011) shows that volatility spread have original information content especially compared with volatility skew. But this research shows that volatility spread has similar information content with basis of future and spot. These results are expected to contribute to further research on the information content of volatility spread to large extent. This is because, analyzing the reason why basis of spot and future precedes index rate of return seems to be able to provide more objective and simple insights compared to analyzing why volatility spread precedes index rate of return.

There seems to be need of further research on following areas. This paper has found that the information content of volatility spread is resulted from the basis of spot and future. However, such finding cannot provide the fundamental reason why the gap between spot and future precedes KOSPI200 return rate. Further, the value of volatility spread shows periodic pattern as maturity time approaches. To explain this pattern will be interesting issue.

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Table 1

Summary Statistics for KOSPI200 Index, implied volatility from nearby call option(Imp_Call_BS), implied volatility from nearby put option(Imp_Put_BS) and difference of call and put implied volatility(Volatility Spread)

KOSPI200 nearby contract data for option and index has been collected per minute from 28th of June in 2011 to 10th of August in 2012. **Implied volatility in this table is calculated from KOSPI200 index as underlying using Black-Sholes model.**

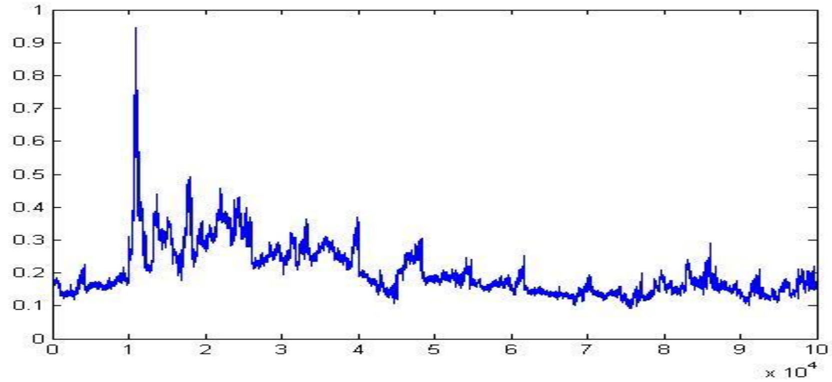
	KOSPI200	Imp_Call_BS	Imp_Put_BS	Volatility Spread
Mean	250.83882	0.20261	0.22070	-0.01809
Standard Deviation	15.30268	0.07860	0.09226	0.03451
Max Value	287.34000	0.94474	1.03179	0.16813
Min Value	213.12000	0.09307	0.09753	-0.43227
Sample Size	100372	100372	100372	100372

KOSPI200 Index and Basic Statistics of Implied Volatility

Figure 1

Historical Trend of Call option implied Volatility of KOSPI200 Index from Black-Scholes model from 28th of June in 2011 to 10th of August in 2012 every minute

Call option implied volatility fluctuates with distinct peaks. Peak may arise due to sudden market movement such as massive basis arbitrage transactions or news arrival.

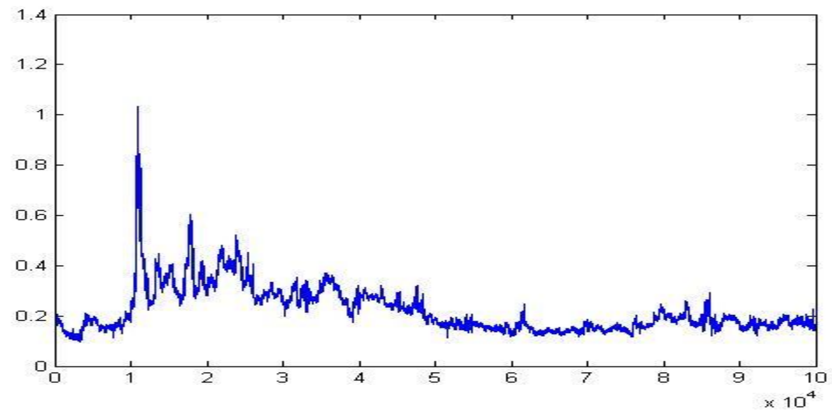


Call option implied volatility in historical order(June,28 2011~August,10,2012)

Figure 2

Historical Trend of Put option implied Volatility of KOSPI200 Index from Black-Scholes model from 28th of June in 2011 to 10th of August in 2012 every minute

Call and put implied volatility shows similar pattern since they share common underlying asset.



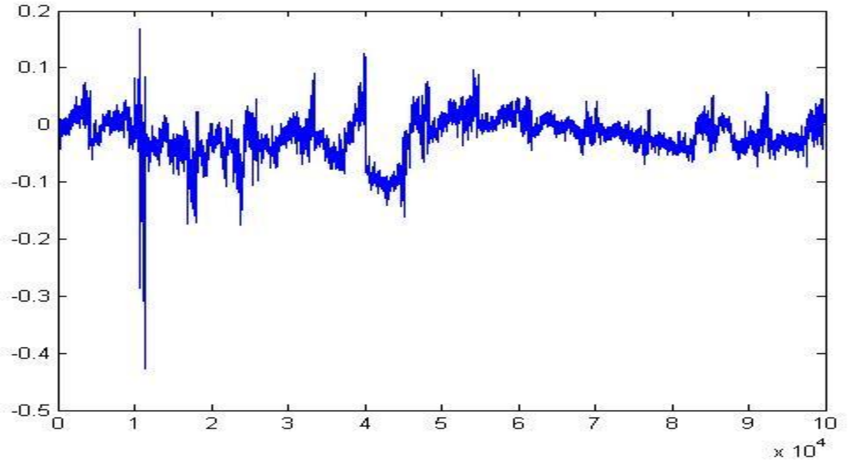
Put option implied volatility in historical order(June,28 2011~August,10,2012)

Figure 3

Historical Trend of implied Volatility Spread of KOSPI200 Index from Black-Scholes model

from 28th of June in 2011 to 10th of August in 2012 every minute

Volatility spread moves along center zero line. Typically spread range from minus to plus 10%



Volatility Spreads in historical order (June,28 2011~August,10,2012)

Table 2

Summary Statistics

for KOSPI200 futures, implied volatility from nearby call option(Imp_Call_BL), implied volatility from nearby put option(Imp_Put_BL) and difference of call and put implied volatility(Volatility Spread)

KOSPI200 nearby contract data for option and futures has been collected per minute from 28th of June in 2011 to 10th of August in 2012. **Implied volatility in this table is calculated from KOSPI200 futures as underlying using Black model.**

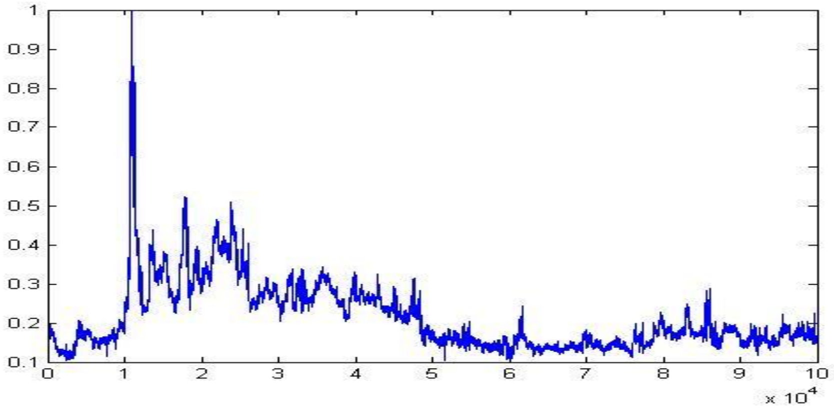
	KOSPI200 Future	Imp_Call_BL	Imp_Put_BL	Volatility Spread
Mean	251.511848	0.1971	0.2259	-0.028775783
Standard Deviation	15.9331405	0.0883	0.0834	0.029339539
Max Value	288.95	0.9374	0.9962	0.025160447
Min Value	214.1	0.0232	0.1234	-0.254483147
Sample Size	100372	100372	100372	100372

Figure 4

Historical Trend of Call option implied Volatility of KOSPI200 future from Black model

from 28th of June in 2011 to 10th of August in 2012 every minute

Call option implied volatility fluctuates with distinct peaks. Peak may arise due to sudden market movement such as massive basis arbitrage transactions or news arrival.



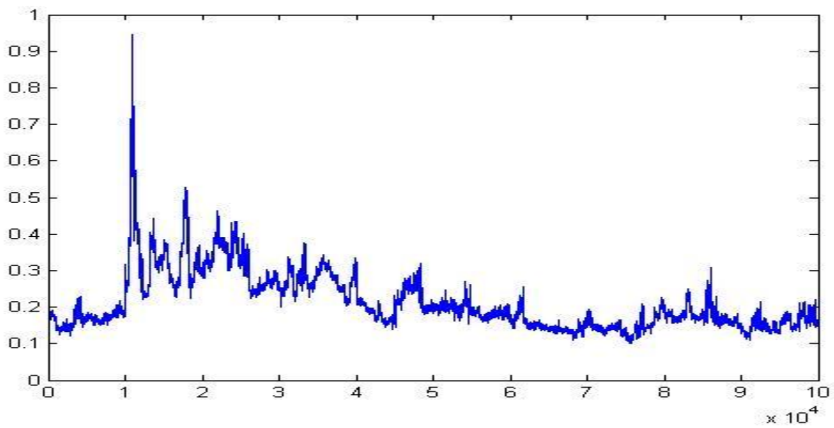
Call option implied volatility in historical order(June,28 2011~August,10,2012)

Figure 5

Historical Trend of Put option implied Volatility of KOSPI200 future from Black model

from 28th of June in 2011 to 10th of August in 2012 every minute

Call and put implied volatility shows similar pattern since they share common underlying asset.



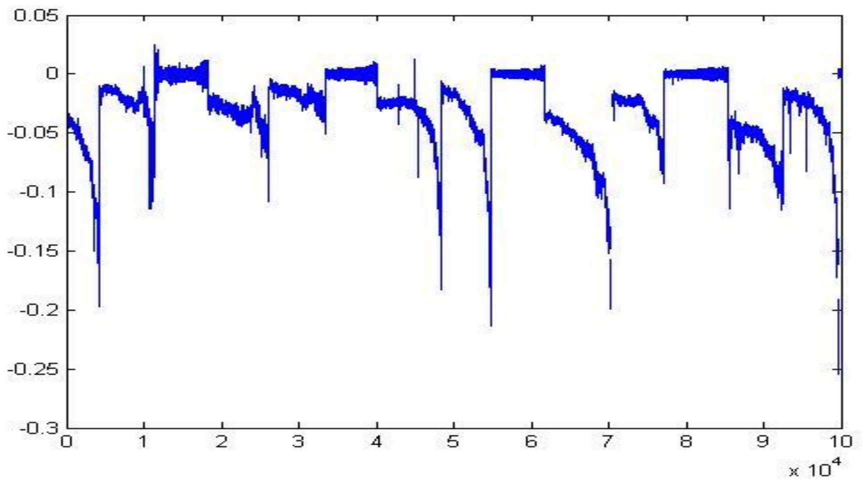
Put option implied volatility in historical order(June,28 2011~August,10,2012)

Figure 6

Historical Trend of implied Volatility Spread using KOSPI200 future from Black model

from 28th of June in 2011 to 10th of August in 2012 every minute

Volatility spreads shows periodic pattern. **A noticeable feature is that there are four areas in which spread is almost 0.** Magnitude of volatility spreads converge to zero when nearby future and option has same maturity. In area of unmatched maturity between nearby future and option, magnitude of spreads gradually grows until nearby time to maturity of two instruments match. KOSPI200 option has maturity date every month whereas future has every three months(Mar., Jun.,Sep.,Dec.). During data range, 4 areas(each has 1 month long) has matched maturity of future and option. In these areas, volatility spreads of Black model converges to zeros much closer than that of Black-Scholes model(Typically spreads range from minus to plus 1%).



Volatility Spreads in historical order (June,28 2011~August,10,2012)

Table 3

Summary Statistics for KOSPI200 synthetic futures, implied volatility from nearby call option (denoted as Imp_Call_BLS), implied volatility from nearby put option (denoted as Imp_Put_BLS) and difference of call and put implied volatility(Volatility Spread)

KOSPI200 index and nearby contract data for option index has been collected per minute from 28th of June in 2011 to 10th of August in 2012. **Implied volatility in this table is calculated from KOSPI200 synthetic futures as underlying using Black model.**

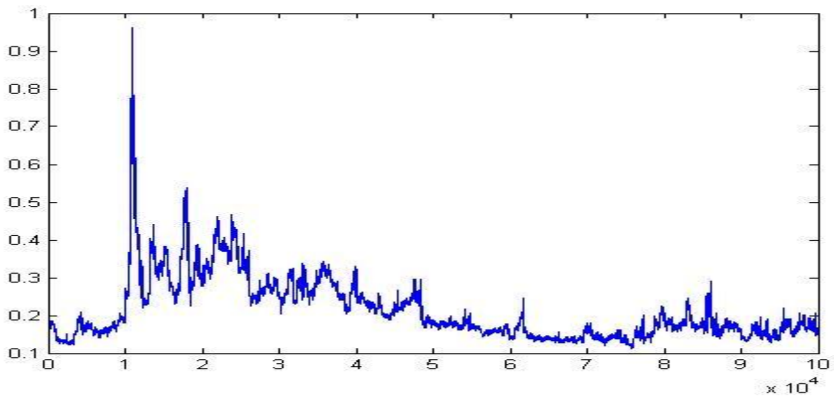
	Futures Synthetic	Imp_Call_BLS	Imp_Put_BLS	Volatility Spread
Mean	250.9218	0.2124	0.2124	2.0385E-17
Standard deviation	15.7572	0.0843	0.0843	1.4539E-15
Max Value	287.5801	0.9609	0.9609	1.57652E-14
Min Value	213.4023	0.1122	0.1122	-1.32394E-14
Sample Size	100372	100372	100372	100372

Figure 7

Historical Trend of Call option implied Volatility of KOSPI200 synthetic future from Black model

from 28th of June in 2011 to 10th of August in 2012 every minute

Call option implied volatility fluctuates with distinct peaks. Peak may arise due to sudden market movement such as massive basis arbitrage transactions or news arrival.



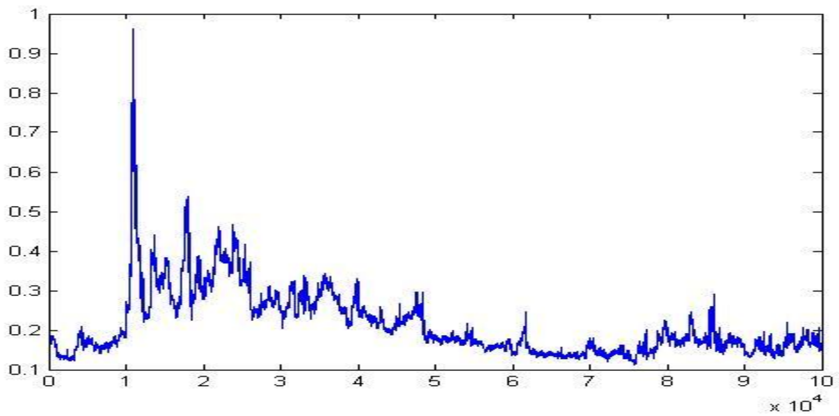
Call option implied volatility in historical order(June,28 2011~August,10,2012)

Figure 8

Historical Trend of Put option implied Volatility of KOSPI200 synthetic future from Black model

from 28th of June in 2011 to 10th of August in 2012 every minute

Call and put implied volatility shows identical pattern since they share common underlying asset.



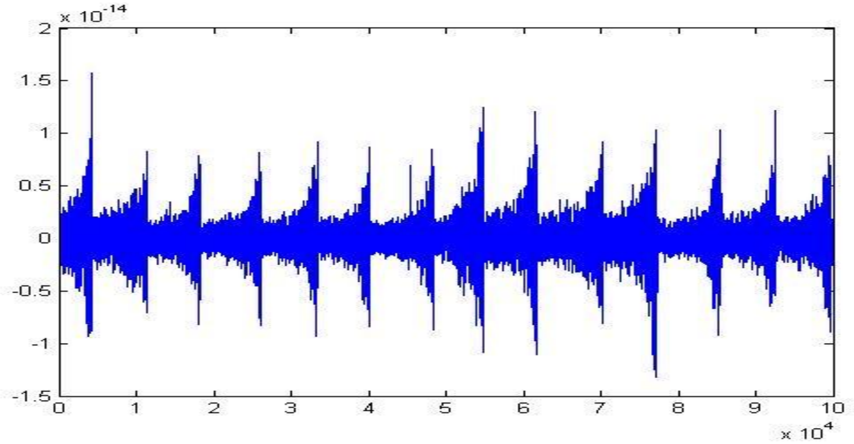
Call option implied volatility in historical order(June,28 2011~August,10,2012)

Figure 9

Historical Trend of implied Volatility Spread of KOSPI200 synthetic future from Black model

from 28th of June in 2011 to 10th of August in 2012 every minute

Volatility spread is practically zero all the time. Periodic pattern represents numerical noise amplified in vicinity of option maturity.



Volatility Spread in historical order(June,28 2011~August,10,2012)

Table 4

Summary Statistics for implied dividend rate, implied volatility from nearby call option(denoted as Imp_Call_DR), implied volatility from nearby put option(Imp_Put_DR) and difference of call and put implied volatility(Volatility Spread)

KOSPI200 index and nearby contract data for option index has been collected per minute from 28th of June in 2011 to 10th of August in 2012. **Implied volatility in this table is calculated with KOSPI200 index as underlying and implied dividend rate as dividend rate using Black-Scholes model. Volatility Spreads are practically zero.** Implied dividend rate are calculated with following relation, $d = r - \frac{1}{T}\ln(\frac{F}{S})$, r = risk free rate(CD91), T = time to maturity annualized, F= futures, S = spot , **here we use synthesized future as F not to be affected by maturity mismatch**.

	Implied Dividend Rate	Imp_Call_DR	Imp_Put_DR	Volatility Spread
Mean	0.026808	0.212409	0.212409	-3.38257E-13
Standard Deviation	0.086996	0.084286	0.084286	1.83341E-10
Max Value	2.456443	0.960874	0.960874	1.88231E-09
Min Value	-0.63606	0.112177	0.112177	-8.89538E-10
Sample Size	10372	10372	10372	10372

Table 5

Information Content in volatility spread leading KOSPI200 index return

(Jun. 28, 2011~Aug. 10,2012) This table represents VAR analysis result with 30 lags(minutes) as following relation

$R_t = \sum_{i=1}^{30} \alpha(i) \cdot R_{t-i} + \sum_{i=1}^{30} \beta(i) \cdot VS_{t-i}$, R_t denotes KOSPI200 index return at t, $\alpha(i)$ denotes corresponding coefficient at ith lag. VS_t denotes volatility spread at t, $\beta(i)$ denotes corresponding coefficient at ith lag. **6th** column represents P-value of coefficient β and **3rd** column does P-value of coefficient α. Volatility spreads shows firm forecasting power on return rate within confidence level of 1% with positive coefficients upto 27th lag. **Volatility spreads are calculated using Black-Scholes model(index underlying) with zero dividend rate. Since frequency of the sample is relatively high(minutely), return shows autocorrelation upto 4 lags as shown in 3rd column.**

Variable	Coefficient	P-Value	Variable	Coefficient	P-Value
α(t-1)	0.046	0.0001	β(t-1)	0.0263	0.0001
α(t-2)	0.034	0.0001	β(t-2)	0.0203	0.0001
α(t-3)	0.017	0.0001	β(t-3)	0.0129	0.0001
α(t-4)	-0.009	0.0057	β(t-4)	0.0088	0.0001
α(t-5)	0.001	0.665	β(t-5)	0.0114	0.0001
α(t-6)	-0.013	0.0001	β(t-6)	0.0081	0.0001
α(t-7)	-0.014	0.0001	β(t-7)	0.0095	0.0001
α(t-8)	-0.003	0.3335	β(t-8)	0.0081	0.0001
α(t-9)	-0.005	0.1366	β(t-9)	0.0080	0.0001
α(t-10)	-0.008	0.0159	β(t-10)	0.0059	0.0001
α(t-11)	0.001	0.6539	β(t-11)	0.0065	0.0001
α(t-12)	-0.003	0.3765	β(t-12)	0.0050	0.0001
α(t-13)	-0.002	0.4907	β(t-13)	0.0053	0.0001
α(t-14)	-0.003	0.3327	β(t-14)	0.0046	0.0001
α(t-15)	-0.003	0.3491	β(t-15)	0.0036	0.0001
α(t-16)	0.002	0.5464	β(t-16)	0.0047	0.0001
α(t-17)	0.009	0.0072	β(t-17)	0.0047	0.0001
α(t-18)	0.002	0.4787	β(t-18)	0.0034	0.0001
α(t-19)	0.005	0.1025	β(t-19)	0.0033	0.0001
α(t-20)	-0.007	0.0221	β(t-20)	0.0030	0.0001
α(t-21)	-0.004	0.2414	β(t-21)	0.0041	0.0001
α(t-22)	-0.002	0.4784	β(t-22)	0.0035	0.0001
α(t-23)	-0.008	0.0097	β(t-23)	0.0029	0.0001
α(t-24)	-0.002	0.623	β(t-24)	0.0039	0.0001
α(t-25)	0.000	0.8784	β(t-25)	0.0016	0.0007
α(t-26)	-0.008	0.013	β(t-26)	0.0014	0.004
α(t-27)	0.000	0.9828	β(t-27)	0.0019	0.0001
α(t-28)	-0.003	0.3295	β(t-28)	0.0008	0.0818
α(t-29)	0.001	0.7903	β(t-29)	-0.0002	0.7006
α(t-30)	-0.001	0.6648	β(t-30)	-0.0003	0.4029

Table 6

Information Content in future-spot basis leading KOSPI200 index return

(Jun. 28, 2011~Aug. 10,2012) This table represents VAR analysis result with 30 lags(minutes) as following relation

$R_t = \sum_{i=1}^{30} \alpha(i) \cdot R_{t-i} + \sum_{i=1}^{30} \beta(i) \cdot Basis_{t-i}$, R_t denotes KOSPI200 index return at t, $\alpha(i)$ denotes corresponding coefficient at ith lag. $Basis_t$ denotes future minus spot at t, $\beta(i)$ denotes corresponding coefficient at ith lag. 6th column represents P-value of coefficient β and **3rd** column does P-value of coefficient α. Future-spot basis shows solid forecasting power on return rate within confidence level of 1% with positive coefficients upto 27th lag. **This result represents basis has almost similar forecasting power with volatility spread implying their share common source of information. Nearby futures are used to calculate future-spot basis.**

Variable	Coefficient	P-Value	Variable	Coefficient	P-Value
α(t-1)	0.051	0.0001	β(t-1)	0.0018	0.0001
α(t-2)	0.034	0.0001	β(t-2)	0.0013	0.0001
α(t-3)	0.021	0.0001	β(t-3)	0.0009	0.0001
α(t-4)	-0.005	0.1497	β(t-4)	0.0007	0.0001
α(t-5)	0.000	0.9959	β(t-5)	0.0007	0.0001
α(t-6)	-0.014	0.0001	β(t-6)	0.0005	0.0001
α(t-7)	-0.013	0.0001	β(t-7)	0.0006	0.0001
α(t-8)	-0.004	0.2764	β(t-8)	0.0005	0.0001
α(t-9)	-0.006	0.0777	β(t-9)	0.0005	0.0001
α(t-10)	-0.006	0.0569	β(t-10)	0.0004	0.0001
α(t-11)	0.001	0.7365	β(t-11)	0.0004	0.0001
α(t-12)	-0.003	0.3788	β(t-12)	0.0003	0.0001
α(t-13)	-0.001	0.8355	β(t-13)	0.0003	0.0001
α(t-14)	-0.004	0.2093	β(t-14)	0.0003	0.0001
α(t-15)	-0.002	0.5705	β(t-15)	0.0002	0.0001
α(t-16)	0.002	0.5497	β(t-16)	0.0003	0.0001
α(t-17)	0.009	0.0074	β(t-17)	0.0003	0.0001
α(t-18)	0.003	0.3043	β(t-18)	0.0002	0.0001
α(t-19)	0.006	0.0709	β(t-19)	0.0002	0.0001
α(t-20)	-0.008	0.0095	β(t-20)	0.0002	0.0001
α(t-21)	-0.005	0.1425	β(t-21)	0.0002	0.0001
α(t-22)	-0.002	0.4748	β(t-22)	0.0002	0.0001
α(t-23)	-0.007	0.0359	β(t-23)	0.0002	0.0001
α(t-24)	-0.004	0.2027	β(t-24)	0.0002	0.0001
α(t-25)	0.000	0.8831	β(t-25)	0.0001	0.0003
α(t-26)	-0.009	0.0048	β(t-26)	0.0001	0.0074
α(t-27)	-0.001	0.7801	β(t-27)	0.0001	0.0001
α(t-28)	-0.003	0.306	β(t-28)	0.0001	0.0177
α(t-29)	0.003	0.3651	β(t-29)	0.0000	0.4127
α(t-30)	-0.001	0.6489	β(t-30)	0.0000	0.4593

Table 7

Information Content in implied dividend rate leading KOSPI200 index return

(Jun. 28, 2011~Aug. 10,2012) This table represents VAR analysis result with 30 lags(minutes) as following relation

$R_t = \sum_{i=1}^{30} \alpha(i) \cdot R_{t-i} + \sum_{i=1}^{30} \beta(i) \cdot ImpDiv_{t-i}$, R_t denotes KOSPI200 index return at t, $\alpha(i)$ denotes corresponding coefficient at ith lag. $ImpDiv_t$ denotes future minus spot at t, $\beta(i)$ denotes corresponding coefficient at ith lag. 6th column represents P-value of coefficient β and **3rd** column does P-value of coefficient α. Future-spot basis shows solid forecasting power on return rate within confidence level of 1% with positive coefficients upto 27th lag. **This result represents implied dividend rate has almost similar forecasting power with volatility spread implying they share common source of information. Nearby futures are used to calculate future-spot basis.**

Variable	Coefficient	P-Value	Variable	Coefficient	P-Value
α(t-1)	0.031	0.0001	β(t-1)	0.0034	0.0001
α(t-2)	0.022	0.0001	β(t-2)	-0.0038	0.0001
α(t-3)	0.009	0.0031	β(t-3)	-0.0034	0.0001
α(t-4)	-0.012	0.0001	β(t-4)	-0.0018	0.0001
α(t-5)	-0.003	0.2782	β(t-5)	-0.0010	0.0001
α(t-6)	-0.013	0.0001	β(t-6)	-0.0021	0.0001
α(t-7)	-0.014	0.0001	β(t-7)	-0.0014	0.0001
α(t-8)	-0.002	0.4963	β(t-8)	-0.0019	0.0001
α(t-9)	-0.004	0.1799	β(t-9)	-0.0014	0.0001
α(t-10)	-0.007	0.0199	β(t-10)	-0.0015	0.0001
α(t-11)	0.002	0.6093	β(t-11)	-0.0009	0.0001
α(t-12)	-0.001	0.6756	β(t-12)	-0.0013	0.0001
α(t-13)	-0.004	0.1844	β(t-13)	-0.0009	0.0001
α(t-14)	-0.003	0.3522	β(t-14)	-0.0009	0.0001
α(t-15)	-0.002	0.4383	β(t-15)	-0.0010	0.0001
α(t-16)	0.004	0.1896	β(t-16)	-0.0007	0.0001
α(t-17)	0.010	0.0014	β(t-17)	-0.0011	0.0001
α(t-18)	0.004	0.2236	β(t-18)	-0.0011	0.0001
α(t-19)	0.006	0.0793	β(t-19)	-0.0006	0.0001
α(t-20)	-0.007	0.0239	β(t-20)	-0.0007	0.0001
α(t-21)	-0.005	0.1406	β(t-21)	-0.0006	0.0001
α(t-22)	-0.001	0.7754	β(t-22)	-0.0009	0.0001
α(t-23)	-0.008	0.012	β(t-23)	-0.0009	0.0001
α(t-24)	-0.001	0.8489	β(t-24)	-0.0006	0.0001
α(t-25)	0.001	0.8732	β(t-25)	-0.0010	0.0001
α(t-26)	-0.007	0.0304	β(t-26)	-0.0004	0.0072
α(t-27)	0.000	0.8865	β(t-27)	-0.0003	0.0142
α(t-28)	-0.003	0.2906	β(t-28)	-0.0003	0.0226
α(t-29)	0.000	0.9215	β(t-29)	-0.0001	0.4995
α(t-30)	-0.001	0.8309	β(t-30)	0.0002	0.1153

Table 8

Information Content in future-spot basis crowding out volatility spreads

(Jun. 28, 2011~Aug. 10,2012) We performed VAR analysis including basis and spreads all together. The VAR analysis with 30 lags(minutes) is performed following fashion, $R_t = \sum_{i=1}^{30} \alpha(i) \cdot R_{t-i} + \sum_{i=1}^{30} \beta(i) \cdot VS_{t-i} + \sum_{i=1}^{30} \gamma(i) \cdot Basis_{t-i}$, R_t denotes KOSPI200 index return at t, $\alpha(i)$ denotes corresponding coefficient at ith lag, $Basis_t$ denotes future minus spot at t, $\beta(i)$ denotes corresponding coefficient at ith lag. **6th** column represents P-value of coefficient β and **9th** column does P-value of coefficient γ. This table indicates that which variable, among volatility spread and basis of spot and future, has better information content. Basis shows solid forecasting power on return rate within confidence level of 1% with positive coefficients upto **16th** lag while spread have lost its significance at lag 3. After lag 3, spreads show alternating fashion in its significance on predicting index return rate. **This table demonstrates volatility spread and basis of spot and future shares same informational source and basis has more fundamental information content. Volatility spreads are calculated using Black-Scholes model(index underlying) with zero dividend rate. Nearby futures are used to calculate future-spot basis.**

Variable	Coefficient	P-Value	Variable	Coefficient	P-Value	Variable	Coefficient	P-Value
α(-1)	0.052	0.0001	β(-1)	0.0038	0.0001	γ(-1)	0.00159	0.0001
α(-2)	0.035	0.0001	β(-2)	0.0044	0.0001	γ(-2)	0.00108	0.0001
α(-3)	0.020	0.0001	β(-3)	-0.0005	0.5692	γ(-3)	0.00091	0.0001
α(-4)	-0.006	0.077939	β(-4)	-0.0025	0.002367	γ(-4)	0.00077	0.0001
α(-5)	0.001	0.736727	β(-5)	0.0037	9.00E-06	γ(-5)	0.00052	0.0001
α(-6)	-0.014	1.30E-05	β(-6)	0.0007	0.419225	γ(-6)	0.0005	0.0001
α(-7)	-0.013	6.20E-05	β(-7)	0.0027	0.001311	γ(-7)	0.00046	0.0001
α(-8)	-0.003	0.278561	β(-8)	0.0018	0.029474	γ(-8)	0.00043	0.0001
α(-9)	-0.005	0.091395	β(-9)	0.0023	0.006944	γ(-9)	0.00039	0.0001
α(-10)	-0.006	0.056333	β(-10)	0.0004	0.675906	γ(-10)	0.0004	0.0001
α(-11)	0.001	0.738456	β(-11)	0.0023	0.007328	γ(-11)	0.00029	0.0001
α(-12)	-0.003	0.379387	β(-12)	0.0004	0.648676	γ(-12)	0.00032	0.0001
α(-13)	-0.001	0.856229	β(-13)	0.0017	0.046437	γ(-13)	0.00025	0.0001
α(-14)	-0.004	0.26256	β(-14)	0.0023	0.007837	γ(-14)	0.00016	0.001294
α(-15)	-0.002	0.447069	β(-15)	0.0009	0.280447	γ(-15)	0.00019	0.000141
α(-16)	0.002	0.484175	β(-16)	0.0025	0.004072	γ(-16)	0.00016	0.00106
α(-17)	0.008	0.008411	β(-17)	0.0030	0.000429	γ(-17)	0.00011	0.020578
α(-18)	0.003	0.286741	β(-18)	0.0011	0.200451	γ(-18)	0.00016	0.000981
α(-19)	0.005	0.102095	β(-19)	0.0025	0.003206	γ(-19)	0.00005	0.301271
α(-20)	-0.007	0.022238	β(-20)	0.0020	0.021578	γ(-20)	0.00006	0.193996
α(-21)	-0.004	0.172267	β(-21)	0.0022	0.008791	γ(-21)	0.00012	0.01825
α(-22)	-0.002	0.460368	β(-22)	0.0016	0.055249	γ(-22)	0.00011	0.026408
α(-23)	-0.007	0.020811	β(-23)	0.0012	0.173287	γ(-23)	0.00011	0.019428
α(-24)	-0.003	0.293108	β(-24)	0.0038	6.00E-06	γ(-24)	-0.00002	0.637973
α(-25)	-0.001	0.806081	β(-25)	0.0003	0.745423	γ(-25)	0.00008	0.081199
α(-26)	-0.009	0.003584	β(-26)	0.0001	0.944209	γ(-26)	0.00007	0.138048
α(-27)	0.000	0.889307	β(-27)	0.0000	0.970262	γ(-27)	0.00012	0.007915
α(-28)	-0.003	0.28744	β(-28)	-0.0017	0.033801	γ(-28)	0.00014	0.001502
α(-29)	0.002	0.482851	β(-29)	-0.0019	0.009821	γ(-29)	0.00011	0.008861
α(-30)	-0.002	0.561497	β(-30)	-0.0009	0.194218	γ(-30)	0.00003	0.476761