ELSEVIER

Pacific-Basin Finance Journal 214 (2001) xxx

PACIFIC-BASIN FINANCE JOURNAL

www.elsevier.com/locate/econbase

Volatility prediction during prolonged crises: evidence from Korean index options

Gurmeet S. Bhabra [a,*], Maria Liliana Gonzalez [a], Myeong Sup Kim [a,b], John G. Powell [a]

[a] *Department of Finance and Quantitative Analysis, University of Otago, P.O. Box 56 Dunedin, New Zealand*
[b] *INTERLINK, South Korea*

Abstract

This paper examines KOSPI200 index option prices in order to investigate whether index option implied volatilities foreshadowed the 1997 economic crisis in Korea. Results indicate the absence of strong fears of an impending market downturn prior to the crisis. Put option implied volatilities rose sharply as the crisis intensified, however, and the difference between put and call implied volatilities reached extreme levels compared to results found in previous studies of financial crises in developed markets. The study indicates that option traders reacted to the crisis rather than predicting its onset, perhaps reflecting the youthfulness of the market. Traders also appear to have learned from the crisis as it intensified. © 2001 Published by Elsevier Science B.V.

JEL classification: G13; G15
Keywords: Financial crises; Volatility; Index options; Implied volatility; Developing markets

1. Introduction

The onset of the Asian financial crisis and the extreme volatility it engendered caught many financial market observers by surprise, thus affecting the extent to which policy makers and market participants could react to the crisis in a timely manner. Forewarning of the crisis and its accompanying financial market volatility could therefore have been helpful. If early warning signs were available then options markets might have been likely to provide them because volatility predictions can be extremely important to the profitability of option market trades. This paper therefore examines stock index option

* Corresponding author. Tel.: +64-3-479-5124; fax: +64-3-479-8193.
E-mail address: gbhabra@commerce.otago.ac.nz (G.S. Bhabra).

0927-538X/01/$ - see front matter © 2001 Published by Elsevier Science B.V.
PII: S0927-538X(01)00005-1

prices during the Asian financial crisis in order to determine whether options traders were able to predict volatility shifts as the crisis evolved. The Korean index option market is chosen for the analysis because it is an important new market, which had just commenced trading when Korea became a focus of the Asian crisis. An analysis of this relatively immature market during the Asian crisis should therefore provide an interesting contrast to previous studies of options markets during crises that have examined more mature, developed markets. Previous studies have also tended to examine short, severe financial crises such as the stock market crash of 1987 whereas the Korean economic crisis was a series of major downturns and recoveries extending over many months, thus providing an additional contrast. The prolonged nature of the Korean financial crisis also allowed external forces such as the International Monetary Fund (IMF) to have an important influence on financial market developments which does not tend to happen with shorter financial crises.

When trading of standardized index options on the KOSPI200 index of 200 leading Korean stocks commenced in July 1997 the Korean economy was already beginning to feel the effects of the Asian financial crisis. A real sense of panic did not engulf market participants, however, until the downgrade of Korea's foreign debt by Standard and Poor on October 23, 1997. The Korean stock market reacted to the news by falling more than 5% the following day, the biggest single-day loss up to that date. The KOSPI200 subsequently lost an additional third of its value by the end of the year before recovering in early 1998, all the time displaying extreme volatility. Implied volatility from Korean put and call index options for the time period leading up to and including the Korean downgrade can be examined to determine whether option traders anticipated this extreme volatility since option prices are based upon option market participants' collective assessment of future volatility.

Implied volatilities of out-of-the-money index put and call options are analyzed in this paper to determine whether options traders increased their assessment of the probability of large stock market falls as the Korean economic crisis intensified. The analysis utilizes the Bates (1991) and Gemmill (1996) observation that option traders who correctly anticipate that the likelihood of a market crash has increased would tend to obtain the highest rate of profit by purchasing out-of-the-money puts. This extra buying pressure would drive up their prices and implied volatilities relative to other options, so out-of-the money put implied volatilities can be compared to call options' implied volatilities in order to discern expectations of an impending market downturn. This comparison indicates whether or not the implied distribution function of index returns has become negatively skewed, thus revealing option traders' assessment of the probability of large potential stock market losses (Jackwerth and Rubinstein, 1996; Corrado, 1999). Volatility expectations implicit in index option prices should provide an unbiased, efficient forecast of future volatility because forecast efficiency deviations would imply the existence of expected profit opportunities which option traders would want to exploit (Canina and Figlewski, 1993; Christensen and Prabhala, 1998). Index option implied volatility should therefore incorporate all available information that can be used to forecast volatility, thus implying that option markets are the most obvious place to look for evidence of an increased assessment of the likelihood of large stock market falls (see also Christensen and Prabhala, 1998; Chen et al., 1999).

An examination of put and call option implied volatilities reveals that index options market participants did not initially forecast the Korean financial crisis, as might be expected given that the Korean index options market had existed for only a few months when the worst of the crisis occurred. Options traders appear to have learned from the crisis as it intensified, however, since there is evidence that they had limited success predicting subsequent shifts in the stock market during the crisis. The evidence also supports an interpretation that options traders reacted to the crisis as it unfolded since changes in index option implied volatilities were correlated with contemporaneous and lagged changes in the level of the market. These results contrast with previous studies of established index option markets during shorter financial crises (see, e.g., Bates, 1991; Gemmill, 1996).

Section 2 provides an overview of the Korean economy and financial markets during the Korean financial crisis. Section 3 presents techniques that utilize index put and call option data in order to determine whether option traders anticipated, or were simply reacting to, the unfolding of the financial crisis. Section 4 presents and interprets the paper's results. A brief discussion concludes the paper.

2. The Korean economic crisis

It is widely believed that the Asian financial crisis had its origin in Thailand. Speculative attacks on the Thai baht occurred when the Thai baht peg began to appear excessive given a weakening economy, a balance of trade deficit, and banking sector problems related to excessive corporate leverage as well as property speculation. As a result the Thai central bank announced a managed float of the baht and called on the IMF for technical assistance on July 2, 1997. The Asian crisis quickly spread to other emerging South East Asian countries, including South Korea. At first Korea was considered immune from the financial turmoil buffeting the Thai and Indonesian economies, but a series of bankruptcies by a few leading Korean companies combined with the effects of the South East Asian economic turmoil helped to precipitate a financial crisis in Korea as well. Korea's economic problems became acute during the latter half of 1997, culminating in a bailout of Korea by the IMF on December 3, 1997 just 15 days prior to a presidential election.

It can be argued that the roots of Korea's economic problems began to emerge as early as 1993 when Korean companies used foreign borrowing to finance aggressive expansion of industries such as automobiles, ships, petrochemicals, and steel. Companies in neighbouring countries such as China, Japan, and Malaysia were also expanding in similar areas, however, leading to a drop in prices of key exports. As a result, Korea's current account deficit grew to US$23.7 billion or 4.7% of GDP in 1996 (Samsung Economic Research Institute, 1997).

The first obvious sign of trouble in the Korean economy hit the market in January 1997 when Hanbo Group, the 14th largest conglomerate in Korea, collapsed with US$6.7 billion in bad loans (International Herald Tribune, 1997). The Hanbo case illustrated the difficulties facing Korea's largest firms, so financial companies began to panic and call in corporate loans. Liquidity thus disappeared, leading to a series of bankruptcies of over-leveraged companies that left financial companies with ever-increasing non-performing loans. By early 1997, the level of non-performing loans was over 70% of banks' equity (International Herald Tribune, 1997).

The Korean stock market initially ignored the Hanbo bankruptcy at the end of January, 1997, but by March it had begun to decline (see Fig. 1). The fall accelerated on March 19, 1997 when Sammi Steel, the 26th largest company in Korea, defaulted on a loan. The KOSPI200 declined by 4.5% for three consecutive days in response to this news. The Korean won also fell sharply and the Korea Central Bank used US$3 billion in official foreign exchange reserves by the end of March in an effort to support the currency (International Herald Tribune, 1997).

The value of the Korean currency and interest rates stabilized during the second quarter of 1997, and the stock market actually increased by nearly 20% during the quarter. The stock market recovery ended when additional bankruptcies in the summer, especially that of Kia Motor on July 15, 1997, created renewed capital market suspicions regarding the soundness of the Korean economy. Korea was on the eve of a presidential election, so the government was not inclined to take potentially unpopular measures to control the impending financial collapse. Korea First Bank, the main creditor to Kia and Hanbo, required a bailout in August 1997 when Kia failed to make some payments on its US$10 billion debt. Foreign investors also began to distrust the soundness of Asian economies in general following the IMF bailout of Thailand in August, 1997, so they cut credit lines or demanded a higher premium on loans to most Korean banks. The Korean won fell sharply in response to these events and exceeded 900 to the US dollar on August 19, 1997. Despite these negative signs, the stock market did not react strongly until the exchange rate hit a new record low in late August.

The government's failure to resolve Kia's bankruptcy quickly or satisfactorily created a feeling of financial crisis that deepened when, on October 22, 1997, the government

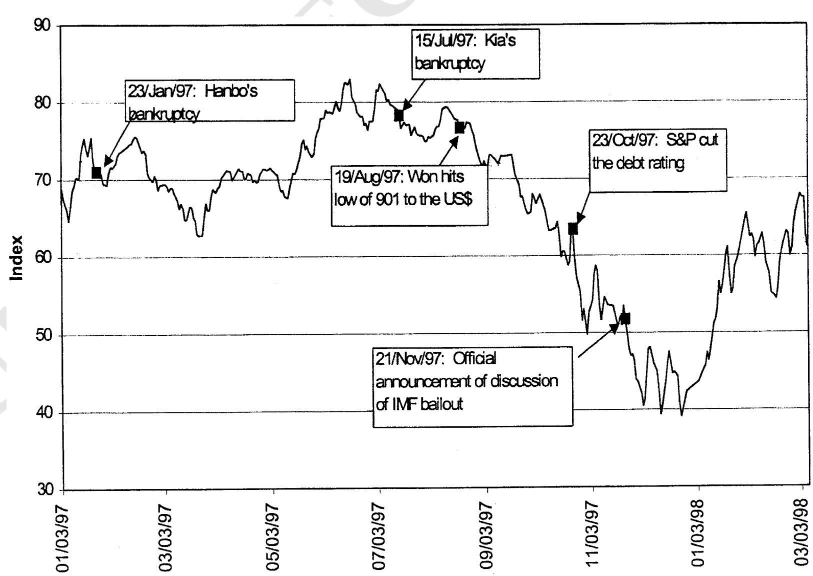

Fig. 1. Daily level of the KOSPI200.

instructed state-run Korean Development Bank to convert US$3.2 billion of its loan to Kia Motors into an equity stake. The crisis further intensified the following day when Standard and Poor's cut the rating of Korean foreign debt in response to the government's decision that day to nationalize Kia. A sense of crisis engulfed market participants and the Korean currency plunged the following day, with share prices falling more than 5%. Share prices fell a further 6.5% on October 28, 1997, and Korea's currency ended at 953 to the US dollar despite central bank intervention. On November 17 the Korea Central Bank announced it would no longer defend the value of the Korean currency and the won immediately fell its daily limit from 986 won to the US dollar to 1008.6.

The compounding of events made foreign investors accelerate their exodus from the Korean capital market. The amount of money exiting the Korean stock market in October of 1997 was nearly three times the quantity in September (Samsung Economic Research Institute, 1997). Foreign banks slashed credit lines by more than US$30 billion in the fourth quarter of 1997. Net usable official foreign exchange reserves plunged to less than US$5 billion in mid-December from more than US$30 billion at the beginning of the year. This rapid deterioration meant Korea was on the verge of defaulting on its heavy foreign currency debt obligations that had been built up during half a decade of rapid corporate expansion. The government therefore announced on November 21, 1997, that it was discussing details of a bailout package with the IMF. The IMF finally agreed to a US$57 billion package on December 3, 1997, the largest in the IMF's history, after more than a week of intense negotiations (International Herald Tribune, 1997). The financial market situation actually worsened, however, when two of the presidential candidates announced that they would renegotiate the IMF agreement if elected. This further undermined foreign investor confidence and the exchange rate collapsed to nearly 2000 won to the US dollar at the end of December and 3-year corporate bond rates rose above 30% per annum. Share prices fell a further 25% in December, 1997.

A turning point in the crisis came on December 24, 1997 when the newly elected president steadfastly pledged to follow the terms of the IMF agreement and accelerate the implementation of the assistance programme. As a result, Korea escaped the risk of a debt moratorium. Korea's markets finally began to recover and by early March, 1998 the share index had returned to the same level as a year earlier. A gradual return to stability following the jump to an extreme level of volatility during the final quarter of 1997 is illustrated in Fig. 2 which plots the realized annualized standard deviation of daily returns of the KOSPI200 index during the remaining life of the active near-term index option contract (along with call option implied volatility for the active near-term option) during 1997 and early 1998.[1] It is interesting to note that during October, 1997, a sharp rise in realized return volatility occurred much sooner than the sharp rise in call option implied volatility, thus suggesting that option traders in this infant market did not

[1] Call option implied volatility is computed for the active near-term contract using the dividend-adjusted Black–Scholes option pricing formula. Realized index return volatility is calculated using Eq. (2) of Christensen and Prabhala (1998) for the remaining life of the active near-term option contract. Both volatility measures are expressed in annual terms. Section 3.2 provides details of the data set used for these calculations.

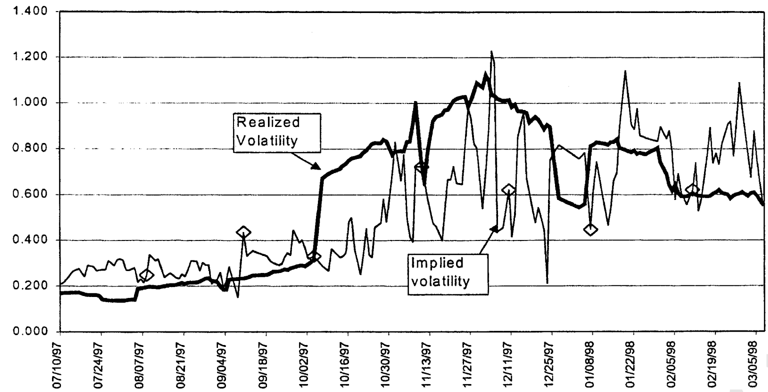

Fig. 2. Realized and implied volatility level. Realized volatility is the standard deviation of daily KOSPI200 returns realized during the remaining life of the active near-term option contract (see Section 3.2 for a description). Implied volatility is for the at-the-money call option with the same time to maturity. A diamond (◇) indicates a contract maturity shift.

initially anticipate the full effect the crisis would have on return volatility. This issue is explored in detail in Section 4 using call and put option implied volatility.

3. Method and data

Financial market crises are generally characterized by extreme volatility, so studies that examine whether option traders are able to predict crises tend to focus on the extent to which shifts in implied volatility foreshadow subsequent changes in actual volatility during the crises. Bates (1991) and Gemmill (1996) extended this method of analysis by observing that option traders who predict an increased likelihood of an impending market crash would expect to profit by buying index put options, especially out-of-the-money put options, in anticipation of a large decline in stock prices. This extra buying pressure would make index put options expensive relative to otherwise identical call options, so option traders' predictions of an impending crash should be discernable from increases in put option implied volatility relative to the implied volatility of call options. Variations in implied volatility of Korean index options can therefore be examined to determine whether option traders predicted, or simply reacted to, shifts in the market as the Korean economic crisis intensified.

3.1. Method

The probability of extreme events occurring should be reflected in the price and implied volatility of out-of-the-money options, so Gemmill (1996) compared out-of-the-money put option implied volatility with implied volatility from otherwise identical call options to examine whether option traders predicted the 1987 stock market crash in the

US and the UK. Gemmill (1996) used the following skewness measure skew_t to capture variations in implied volatility:

$$\text{skew}_t = \left\{ \frac{\sigma_t(+2\%) - \sigma_t(-2\%)}{\sigma_t(+2\%)} \right\} 100. \tag{1}$$

where $\sigma_t(+2\%)$ is implied volatility from a call option with an exercise price 2% above the forward price, and $\sigma_t(-2\%)$ is implied volatility from a put option with exercise price 2% below the forwardprice.[2]

Skew_t was estimated in Gemmill (1996) in order to determine whether large negative values of the skewness measure preceded the 1987 stock market crash, thus indicating whether option traders had increased their assessment of the probability of a potential market crash. Skew_t is estimated in this paper over the time period preceding and including the Korean financial crises to examine if differences in implied volatilities of KOSPI200 index put and call options could have been used to predict the Korean economic crisis. The alternative possibility that option traders simply reacted to the crisis as it unfolded is tested by regressing the Gemmill skewness measure skew_t on contemporaneous and lagged values of KOSPI200 returns.

3.2. Data

This study analyzes data for options on the KOSPI200. KOSPI200 index options began trading on the Korean Stock Exchange in July 1997 just prior to the full onset of the Korean economic crisis. Trading was quiet at first but soon intensified as the economic crisis worsened. A daily average of only 1246 contracts were traded in July 1997 whereas trading had peaked at a level of nearly 83,000 contracts per day by December 1997, with the contract size being 100,000 times the level of the index. Table 1 displays daily trading volume of KOSPI200 options contracts for the study's sample period of July 1997 through March 1998. Table 1 shows that the trading volume of call options and put options increased significantly from October through December 1997 when serious financial turmoil enveloped Korea's capital markets. During these 3 months, the average daily trading volume of call options was 46,365, nearly five times as much as that of put options. Thereafter, trading volume of call options dropped significantly whereas put option volume continued to rise.

KOSPI200 options are European. The maturities of the options contracts are the three consecutive near-term months plus three additional months from a quarterly cycle (March, June, September, and December). The last trading day of the options contracts

[2] Bates (1991) shows that results are not sensitive to the use of alternative ranges such as 2%, 4% or 6%. 2% out-of-the-money options are chosen for analyzing volatility because these options are heavily traded over the sample period. Finding an option with an exercise price exactly 2% above the forward price is not possible so the relevant implied volatilities are linearly interpolated.

Table 1
Volume of KOSPI200 option contracts from July 1997–March 1998

Month/Year	Trading days	Call volume	Put volume	Total volume	Daily average
July/1997	21	14,876	11,281	26,157	1246
Aug/1997	25	53,471	398,131	93,284	3731
Sept/1997	23	162,727	64,127	226,854	9863
Oct/1997	26	804,576	148,861	953,437	36,671
Nov/1997	25	1,170,215	242,010	1,412,225	56,489
Dec/1997	22	1,409,916	324,551	1,816,467	82,567
Jan/1998	22	450,326	447,751	898,077	40,822
Feb/1998	24	520,414	497,454	1,017,868	42,411

is the second Thursday of the contract month. Option trading hours are from 9:00–11:30 for the morning session and 13:00–15:15 for the afternoon session, with the option market closing 15 min after the stock market closes.

The closing spot price of the KOSPI200 as well as 3 p.m. transaction data for prices of call and put options on the KOSPI200 were collected from the Korean Stock Exchange for the study. Implied volatilities for put and call options with up to four exercise prices were calculated for each day for the nearest maturity month contract. The nearest maturity month was chosen for the analysis because it was generally the only contract with non-negligible trading volume during most of the sample period. The analysis was shifted to the next contract if the remaining time to maturity was 7 days or less because trading volume shifted to the next maturity contract at this time, and an option with a maturity less than 8 days is also unlikely to provide much information about future volatility as well as being subject to possible expiration effects.

Estimation of the Gemmill skewness measure ($skew_t$) generally required data for at least two out-of-the-money call options and two out-of-the-money put options because it is usually not possible to find options exactly 2% out of the money, so the relevant implied volatilities had to be linearly interpolated. There are eight missing observations for the Gemmill skewness measure for days when the required out-of-the-money put and call option contracts did not trade. The missing observations tended to occur when the appropriate near-term contracts had a longer maturity. The KOSPI200 contains mostly dividend-paying stocks, so call and put implied volatilities implicit in options prices were estimated using the dividend-adjusted Black–Scholes option pricing formula (Black and Scholes, 1973). Realized volatilities for the time period corresponding to the remaining life of each option contract were calculated using Eq. (2) of Christensen and Prabhala (1998). All volatility measures are expressed in annual terms.

4. Results and discussion

The levels of out-the-money put and call implied volatilities during the Korean economic crisis are shown in Fig. 3. The striking result from Fig. 3 is that the level of

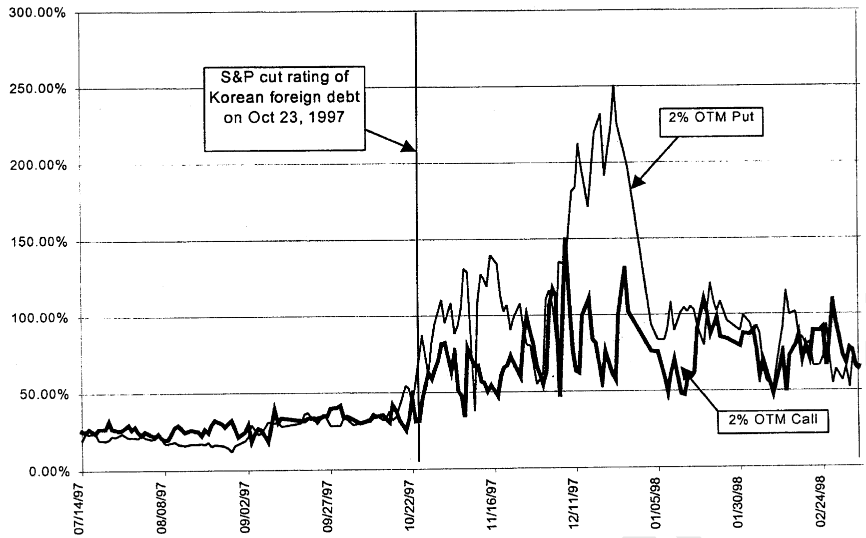

Fig. 3. Out-of-the-money call and put implied volatility.

call implied volatility differs sharply at times from the level of put implied volatility (periodic put-call parity violations, while not directly examined in this paper, can be inferred from Fig. 3). In the sample period, before the Korean downgrade on October 23, 1997 put implied volatilities were generally lower than call implied volatilities even though important events leading up to the downgrade had already occurred. Four days before the news of the downgrade put implied volatility began to exceed call implied volatility, suggesting an increased assessment of downside potential. Fears appear to have subsided when the stock market rose 6.3% the day before the news of the downgrade, however, and call implied volatility returned to the level of put implied volatility. Higher put implied volatilities a few days prior to October 23 might therefore have been a reflection of a preceding decline in stock prices rather than a prediction of impending financial turmoil since the stock market had fallen 21.2% from September 19 to October 18, 1997.

Fig. 3 shows that when the crisis intensified following the Korean downgrade put implied volatilities rose sharply relative to call implied volatilities. This suggests that external recognition of the financial crisis via Standard and Poor's downgrade of Korea's foreign debt led investors to price put options significantly higher than otherwise identical call options. Index put option implied volatilities eventually reached extreme levels as the crisis worsened, thus indicating that traders might have been successful in predicting the intensification of the crisis during sub-periods within the crisis. This is reflected in Table 2 which compares call and put implied volatilities over the entire sample period (July, 1997 to March, 1998) as well as two sub-periods. Over the sub-period prior to the Korean downgrade average annualized implied volatility (25.64%) for out-of-the-money puts was more than three percentage points lower than

Table 2
Mean levels of implied volatility

Period	Number of observations	At-the-money-options			Out-of-the-money-options		
		Put (%)	Call (%)	Difference Put–Call	Put (%)	Call (%)	Difference Put–Call
Full	182	71.67	54.95	16.72 (0.00025)	72.01	54.66	17.35 (0.00011)
Pre-crisis	78	24.99	29.86	−4.87 (0.00009)	25.64	29.06	−3.42 (0.00379)
Crisis	104	106.69	73.78	32.91 (0.00000)	106.79	73.86	32.93 (0.00000)

Summary of mean levels for implied volatility. The columns headed Difference Put–Call show the mean difference between Put and Call options, and the *p*-value associated with the test for mean differences is given in parentheses. The pre-crisis period is 11 July 1997 to 22 October 1997 for a total of 83 trading days and the crisis period extends from 23 October 1997 to 7 March of 1998 for a total of 107 trading days. There were eight missing observations.

average implied volatility (29.06%) for out-of-the-money calls, but this is sharply reversed following the downgrade when the average put implied volatility (106.79%) was nearly 33 percentage points higher than the average call implied volatility (73.86%).[3] An increase in negative sentiment is also indicated by the significant increase in the trading volume of put options immediately after the Korean downgrade. The ratio of trading volume of put options to total volume increased from 0.203 prior to the downgrade to 0.3254 during the period following the downgrade (see Table 1).

The impression created of option traders predicting the intensification of the crisis but not its onset is reinforced by the skewness summary statistics presented in Table 3. If option investors had detected the impending financial crisis during the pre-crisis period then it would be expected that the average skewness measure would have a negative value, but the average skewness measure prior to the Korean downgrade was actually +10.96, suggesting an assessment of good upside potential rather than excessive downside risk. This gets reversed with the downgrade of Korean debt. The average skewness measure for the time period following the downgrade is −54.91, a huge negative skewness level compared to previous financial crises studies (see, e.g., Gemmill, 1996).

The very high prices paid for puts relative to otherwise identical call options at the height of the crisis period seems to reflect a concern about the potential for further declines in stock prices (see also Fig. 4 which graphs the 6-day moving average of the skewness measure and the daily KOSPI200 level). It is interesting to note that negative skewness measures persisted through February, 1998 even though the stock market was already recovering strongly by late December, 1997 following the newly elected president's pledge to adhere to the terms of the IMF agreement.

[3] The study's results are insensitive to whether out-of-the-money or at-the-money options are used in the analysis because the correlation between the implied volatility of at- and out-of-the-money call options is .991 while the correlation between the implied volatility of at- and out-of-the-money put options is .996 during the sample period.

Table 3
Summary statistics for Gemmill's skewness measure, KOSPI200 returns and realized volatility

Variable	Period	Number of observations	Mean	Median	Std. dev.	Min	Max
Skewness measure	Full	182	− 26.68	− 2.69	69.21	− 335.37	62.42
	Pre-crisis	78	10.96	12.28	27.00	− 111.69	62.42
	Crisis	104	− 54.91	− 31.37	77.43	− 335.37	49.82
KOSPI200 returns	Full	190	− 0.0014	− 0.0011	0.0319	− 0.0800	0.0750
	Pre-crisis	83	− 0.0028	− 0.0023	0.0152	− 0.0472	0.0651
	Crisis	107	− 0.0002	0.0013	0.0404	− 0.0800	0.0750
Realized volatility	Full	190	0.5076	0.5842	0.2536	0.1188	1.0576
	Pre-crisis	83	0.2953	0.1987	0.2005	0.1188	0.7725
	Crisis	107	0.6724	0.6713	0.1446	0.2397	1.0576

Descriptive statistics for Gemmill's skewness measure, KOSPI200 returns and realized volatility. Realized volatility is the standard deviation of daily KOSPI200 returns realized during the remaining life of the active near term option contract (see Section 3.2 for a description). The statistics corresponding to the full period are calculated using the observations from 11 July 1997 to 7 March 1998 for a total of 190 trading days. The pre-crisis period is 11 July 1997 to 22 October 1997 for a total of 83 trading days and the crisis period extends from 23 October 1997 to 7 March of 1998 for a total of 107 trading days. There were eight missing observations for Gemmill's skewness measure.

The ability of the skewness measure to forecast volatility leading up to and during the crisis can also be examined by regressing realized volatility during the remaining life of the active near-term option contract ($RVol_t$) on the corresponding skewness measure ($Skew_t$). An autoregressive AR(2) model is used to correct for serial correlation.

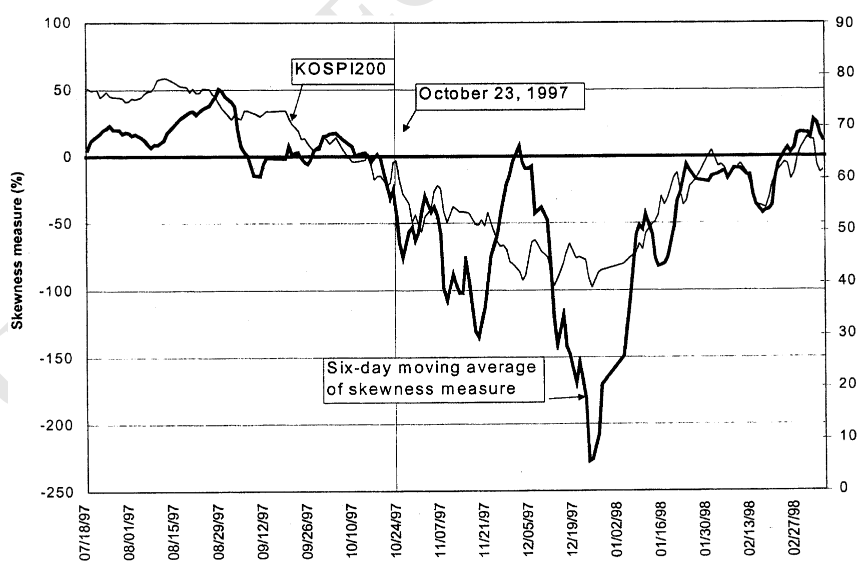

Fig. 4. KOSPI200 level and 6-day moving average of the skewness measure.

GARCH parameters are not required, despite the presence of a few outliers, because their inclusion would have increased the mean square error of the AR(2) model by at least 24%. Akike's Information Criterion (AIC) and Schwarz's Bayesian Criterion (SBC) also suggested that an AR(2) model was the most appropriate.[4] The model used is

$$\mathrm{RVol}_t = \alpha + \beta\,\mathrm{Skew}_t + \epsilon_t, \tag{2}$$

$$\text{where} \quad \epsilon_t = \sum_{i=1}^{2} \phi_i \epsilon_{t-1} + \nu_t. \tag{3}$$

The parameters of the model were estimated using maximum likelihood. The regression was estimated for the entire sample and was also estimated separately for the pre-crisis and crisis periods in order to take account of a volatility regime shift that occurred during October of 1997 (see also Christensen and Prabhala, 1998). The results, presented in Table 4, reinforce the message that option traders were unable to forecast shifts in volatility prior to the onset of the crisis. An interesting possibility is that option traders who forecasted an increased likelihood of an impending market crash would have purchased longer-term put option contracts in order to attempt to profit from their prediction. This possibility is examined by substituting observations for longer maturity contracts into the data set whenever possible (a total of 16 substitutions were made) and re-running the regression of actual volatility on the skewness measure (see the right side of Table 4).[5] The results tend to reject the hypothesis that longer maturity contracts were more informative for predicting an impending market crash.

Another possibility is that option traders in this nascent market did not initially forecast the onset of the crisis but soon learned from their experience and were in a better position to predict subsequent shifts in volatility when the crisis intensified. The results for the entire crisis time period do not support this hypothesis, but the sharp rise in put implied volatilities during sub-periods within the crisis (see Figs. 3 and 4) suggests that option traders might have been able to predict volatility shifts during the worst part of the crisis. To examine this possibility, the analysis in Table 4 was repeated for the period October 23 to November 15, 1997. The regression R^2 for this shorter period was 10 times higher than for the entire crisis period and the point estimate for the Gemmill skewness coefficient became marginally significant (p-value = 0.11), thus providing weak support for this hypothesis (results not reported).

In order to further test the hypothesis that option traders reacted to rather than predicted the crisis, the skewness measure was regressed on contemporaneous and

---

[4] Christensen and Prabhala (1998) argue that the use of overlapping realized volatility overstates the explanatory power of historical volatility in a regression analysis, and therefore caution against the use of overlapping volatility observations, but using only one observation from each contract month was not an option in this study due to the short time period during which Korean index options have been in existence.

[5] Observations with a contract maturity less than a month were replaced with a longer maturity contract data point if longer maturity contracts traded on that day. On many days only the shorter maturity contracts traded. Analysis of covariance was used to test for differences in the slope coefficient of the skewness measure for maturities less than versus greater than a month, and no differences were found (results not reported).

Table 4
Regression of realized volatility on Gemmill's skewness measure

Variable	Estimated coefficient	Shorter days to maturity			Longer days to maturity		
		Full sample	Pre-crisis period	Crisis period	Full sample	Pre-crisis period	Crisis period
Intercept	α	0.4566	0.4177	0.6621	0.4593	0.4279	0.6653
		(0.0007)	(0.3531)	(< 0.0001)	(0.0009)	(0.3709)	(< 0.0001)
Gemmill	β_1	−0.000096	−0.000116	−0.000098	−0.00008	−0.000154	−0.000088
		(0.1933)	(0.5221)	(0.2859)	(0.2056)	(0.3464)	(0.2801)
AR(1)	ϕ_1	1.0544	0.9823	1.0411	1.0426	0.9752	1.0292
		(< 0.0001)	(< 0.0001)	(< 0.0001)	(< 0.0001)	(< 0.0001)	(< 0.0001)
AR(2)	ϕ_2	−0.0797	0.0089	−0.1590	−0.0664	0.0180	−0.1584
		(0.3497)	(0.9598)	(0.1482)	(0.4115)	(0.8884)	(0.1462)
Degrees of freedom		178	74	100	178	74	100
Durbin–Watson		1.8351	1.5042	1.9623	1.8237	1.4804	1.9610
		(0.1376)	(0.0132)	(0.4376)	(0.1231)	(0.0100)	(0.4402)
Regression R^2		0.0095	0.0059	0.0115	0.0090	0.0123	0.0117
Total R^2		0.9559	0.9620	0.8204	0.9572	0.9723	0.8017

The entries provided correspond to maximum likelihood estimations of linear regression coefficients with autoregressive errors. The regression model is for realized volatility on the contemporaneous measure of skewness. Gemmill's skewness measure is computed as in Eq. (1) and the fitted model is given in Eq. (2). The *p*-values associated with the significance of the parameters are given in parentheses underneath. The periods considered are full (11 July 1997–7 March 1998), pre-crisis (11 July–22 October 1997) and crisis (23 October 1997–7 March 1998). The model was fitted to two different data sets. Results for the original data set are presented in the first panel, and the second panel contains results for a data set created by substituting 16 observations from longer maturity contracts into the original data set. The entries in the row headed regression R^2 corresponds to the R^2 for the regression model, and the Total R^2 is for the model that includes the autoregressive AR(2) error process.

lagged market returns. An AR(3)–GARCH(1,1) process was used to correct for serial correlation and GARCH effects. The initial estimates indicated an explosive process for the sample as a whole, with the GARCH parameters summing to slightly more than one for the full sample but not for the sub-periods, so restrictions were imposed on the regression for the full sample using an Integrated GARCH (IGARCH) process. The regression model used was

$$\text{Skew}_t = \alpha + \beta_1 R_t + \beta_2 \text{A}6R_{t-1} + \epsilon_t, \tag{4}$$

$$\text{where} \quad \epsilon_t = \sum_{i=1}^{3} \phi_i \epsilon_{t-i} + \nu_t, \tag{5}$$

$$\nu_t = \sqrt{h_t}\, e_t, \tag{6}$$

$$h_t = \omega + \delta_1 \nu_{t-1} + \gamma_1 h_{t-1}, \tag{7}$$

$$e_t \sim N(0,1), \tag{8}$$

R_t is return on day t, and $\text{A}6R_{t-1}$ is the average of returns for the six days prior to day t. The regression was estimated using maximum likelihood estimation, and the

Table 5
Regression of the skewness measure on returns

Variable	Estimated coefficient	Full sample	Pre-crisis period	Crisis period
Intercept	α	15.5984 (0.4018)	34.6188 (0.2113)	−39.5481 (0.0737)
KOSPI200	β_1	322.81 (< 0.0001)	607.82 (< 0.0001)	465.4773 (< 0.0001)
A6R_{t-1}	β_2	−1178 (< 0.0001)	1003.15 (0.3997)	−1274.65 (0.0004)
AR(1)	ϕ_1	0.6555 (< 0.0001)	1.0414 (< 0.0001)	0.6290 (< 0.0001)
AR(2)	ϕ_2	0.0409 (0.7511)	−0.3534 (0.2362)	0.1639 (0.2293)
AR(3)	ϕ_3	0.1499 (0.0334)	0.2359 (0.1476)	−0.0064 (0.9476)
ARCH 0	ω	94.2336 (0.0061)	72.1495 (0.1855)	1251.04 (0.0001)
ARCH 1	δ_1	0.4224 (< 0.0001)	0.3840 (0.0907)	0.5072 (0.0618)
GARCH 1	γ_1	0.5776 (< 0.0001)	0.5215 (0.0102)	0.0000 (1.0000)
Degrees of freedom		156	61	95
Total R^2		0.6727	0.4422	0.6130

The entries provided correspond to maximum likelihood estimations of linear regression coefficients with an AR(3)–IGARCH(1,1) error model for the full sample and an AR(3)–GARCH(1,1) error model for each period. The regression model is for Gemmill's skewness measure on contemporaneous KOSPI200 returns and a 6-day average of KOSPI200 returns preceding the date on which the skewness is computed (A6R$_{t-1}$). The skewness measure is computed as in Eq. (1) and the fitted model is given in Eq. (4) . The p-values associated with the significance of the parameters are given in parentheses underneath. The periods considered are full (11 July 1997–7 March 1998), pre-crisis (11 July–22 October 1997) and crisis (23 October 1997–7 March 1998). The entries in the row headed Total R^2 corresponds to the models that include the autoregressive and GARCH effects.

results are presented in Table 5. Contemporaneous returns were highly correlated with the skewness measure, whereas a 6-day average of lagged returns was negatively correlated with the subsequent value of the skewness measure during the crisis period. These results are much stronger than in Gemmill (1996), with half of the variation in the skewness measure being explained in this study whereas in the Gemmill (1996) study of index options during the 1987 Crash only a few percent of the variation was explained.[6] The results indicate that options traders tended to react to sharp changes in the level of the market by paying relatively more (less) for put options as the market fell (recovered), but falling share prices over a number of days perhaps created expectations of a subsequent reversal which encouraged (discouraged) call (put) option purchases in anticipation of the reversal. This latter factor could have been especially important after the announcement of the bailout assistance from the IMF if market participants thought the market might re-bound.

The possibility that option traders expected a recovery when the market fell sharply was tested by regressing returns on lagged values of the skewness measure. An

[6] About half of the additional explanatory power resulted from the need to correct for serial correlation and heteroskedasticity; correction for serial correlation was not required in Gemmill (1996). Separate regressions for the pre-crisis and crisis period were also carried out because the variability of the skewness measure and returns was more stable in each sub-period. Analysis of covariance was used to test whether the results depended upon time to maturity, but no differences were found.

Table 6
Regression of annualized index returns on the lagged skewness measure

Period	Intercept α	SKEW_{t-1} β_1	DW (p-value)	R^2	Total R^2	Number of observations
Pre-crisis	0.0933 (0.1624)	0.0949 (0.2958)	1.6997 (0.0818)	0.0172	0.3252	77
Crisis	0.1024 (0.3232)	0.1951 (0.0551)	1.9404 (0.3667)	0.0390	0.1143	103

The entries provided correspond to maximum likelihood estimations of linear regression coefficients with autoregressive errors. The regression model is for annualized KOSPI200 index returns on the lagged skewness measure (SKEW_{t-1}). The skewness measure is computed as in Eq. (1) and the fitted model is given in Eq. (9). The p-values associated with the significance of the parameters are given in parentheses underneath. The pre-crisis period starts on 11 July 1997 and ends on 22 October 1997, the day preceding the downgrade of Korean debt by Standard and Poor's. The crisis period is 23 October 1997 to 7 March 1998. The entries in the column headed DW corresponds to the Durbin–Watson statistic, Regression R^2 to the R^2 for the regression model and the Total R^2 is for the model that includes the autoregressive AR(1) error process.

autoregressive AR(1) model is used to correct for serial correlation, but GARCH parameters are not included because they were insignificant when the two periods (pre-crisis and crisis) are considered separately. The autoregressive regression equation was fitted using maximum likelihood:

$$R_t = \alpha + \beta \mathrm{skew}_{t-1} + \epsilon_t, \tag{9}$$

$$\text{where} \quad \epsilon_t = \phi\epsilon_{t-1} + \nu_t. \tag{10}$$

Regression results presented in Table 6 indicate that the skewness measure had marginally significant explanatory power in the expected direction, but only in the time period following the Korean downgrade. This result suggests that options traders in this new market might have learned from the crisis as it intensified. The results are therefore weakly consistent with the interpretation that option traders correctly anticipated a reversal when the stock market fell sharply. It can be noted that Gemmill (1996) found that the skewness measure was not able to predict returns during shorter crises in developed markets.

5. Conclusion

This study suggests that youthful options markets in developing countries behave quite differently from mature options markets during financial crises, especially if the crisis is a prolonged series of sharp falls and recoveries like the Korean economic crisis. Options traders in Korea appear to have reacted to the crisis as it intensified rather than predicting its onset, with half of the variation in implied volatility skewness being explainable using contemporaneous and lagged returns, a result not previously found in developed country options markets during financial crises like the 1987 stock market crash. Differences between index put and call implied volatilities were extreme during the Korean crisis compared to skewness measures encountered in previous studies, thus not only suggesting extreme reactions to market moves by options traders but also perhaps reflecting the youthfulness of the market. Korean index option traders appear to have learned as the crisis intensified, however, with the implied volatility skewness measure foreshadowing subsequent changes in the market level in the latter part of the sample period, a result not found in previous studies of shorter financial crises.

Acknowledgements

We are grateful to Tim Brailsford, Charles Corrado, Richard Heaney, Amnon Levy, Jing Shi and an anonymous referee for helpful comments, suggestions, and advice. We are also thankful to Ki Sung Kim for providing the data used in this paper.

References

Bates, D.S., 1991. The Crash of ’87: was it expected? The evidence from option markets. Journal of Finance 46, 1009–1044.

Black, F., Scholes, M., 1973. The pricing of options and corporate liabilities. Journal of Political Economy 81, 637–654.

Canina, L., Figlewski, S., 1993. The informational content of implied volatility. The Review of Financial Studies 6, 659–681.

Chen, J., Hong, H., Stein, J.C., 1999. Forecasting crashes: trading volume, past returns and conditional skewness in stock prices. Stanford University Working Paper.

Christensen, B.J., Prabhala, N.R., 1998. The relation between implied and realized Volatility. Journal of Financial Economics 50, 125–150.

Corrado, C.J., 1999. General purpose, semi-parametric option pricing formulas. University of Missouri—Columbia Working Paper.

Gemmill, G., 1996. Did option traders anticipate the crash? Evidence from volatility smiles in the UK with US comparisons. The Journal of Futures Markets 16, 881–897.

International Herald Tribune, 1997. Various Issues.

Jackwerth, J.C., Rubinstein, M., 1996. Recovering probability distributions from option prices. Journal of Finance 51, 1611–1652.

Samsung Economic Research Institute, 1997. Research Report. Samsung Economic Research Institute Report.