Did Option Traders Anticipate the Crash? Evidence from Volatility Smiles in the U.K. with U.S. Comparisons

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INTRODUCTION

When using the Black/Scholes model, it is customary to apply a different volatility to each exercise price. If the underlying distribution of returns has fat tails relative to the normal distribution, then the result is a "volatility smile." If the underlying distribution is skewed, then the volatility smile should also be skewed. Early empirical studies found an exercise-price bias in observed prices and Rubinstein (1985) noted that the bias did not seem to be constant: sometimes high-exercise-price options were overvalued and at other times the converse. Recent empirical studies confirm the existence of volatility smiles in currencies [Taylor and Xu (1994a)] and stock indices (e.g., Taylor and Xu (1994b) for the U.S.A.; Heynen, (1994) for Holland; Beinert and Trautmann (1993) for Germany; and Kamiyama (1995a) for Japan). Revised lattice models for option pricing which take account of the smile have been proposed by Du-

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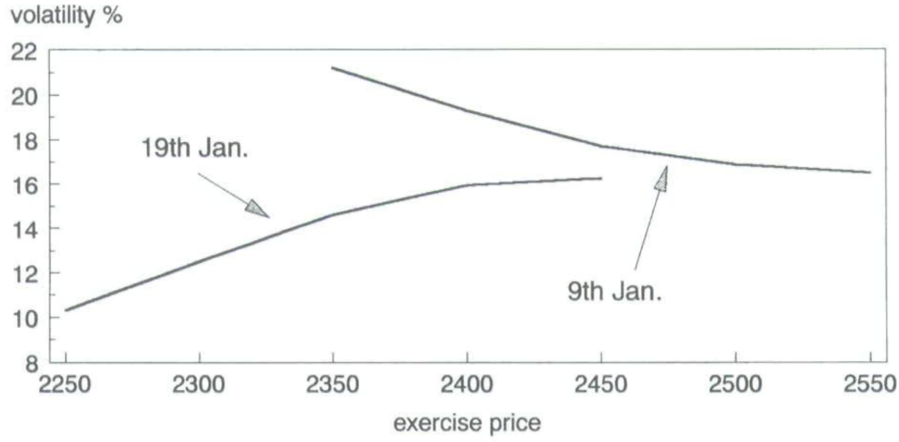

FIGURE 1
Volatility smiles on two days in January 1990.

pire (1994), Rubinstein (1994), Derman and Kani (1994), and Barle and Cakici (1995), among others.

This article is concerned with smiles in London's FTSE 100 index options. Previous studies concentrated upon the average size of the smile, but the objective here is different: it is to examine how the skewness of the smile changes over time and whether that is either a prediction of market movements or reflects past movements. A smile certainly exists, but are changes in its shape informative? The skewness measure of this article compares the volatilities of puts which have striking prices 2% below the forward price with calls which have striking prices 2% above the forward price. Thus, if the forward price is 100, the volatility of a put at 98 is compared with the volatility of a call at 102.

A priori one would expect stockmarket returns to show a left-skewed distribution: as the market falls, so it becomes more volatile. The reason is that companies become more leveraged when prices are low, which increases both the required return and its variance [Christie (1982)]. The literature on asymmetric GARCH models [see, for example, Crouhy and Rockinger (1993)] confirms this behavior. However, while a fall in the stockmarket increases the volatility [as confirmed for London's index options by Franks and Schwartz (1991)] it is not clear that skewness should be affected by market level. Changes in the skewness of the volatility smile can therefore be attributed to the behavior of traders (such as shifts in bullishness or other reactions) rather than to leverage.

Bates (1991) developed a similar measure to that used in this article and applied it to S&P 500 index options, finding that skewness was unrelated to the market Crash of 1987. The current results show that skewness in London was also unrelated to the Crash. However, U.S. traders became more pessimistic after the Crash, increasing the degree of left-skewness of the smile, but traders in London were more optimistic and in the short-term reacted to the Crash by slightly increasing the right-skewness of the smile. It is not clear why this difference in behavior occurred, but one possibility is that it reflects the predominant use of index options by fund managers in the United States as compared with small speculators in the United Kingdom.

The article is written as follows. In the second section the data collected for the study are discussed and the methods used in deriving the smiles and skewness are described. The third section gives the results and draws comparisons with the U.S. research and the fourth completes the article with a summary and conclusion.

DATA AND METHOD

The data for this study consist of closing prices for options on the FTSE 100 Index which are from the Financial Times and the London Stock Exchange Daily Official List and cover the period, July 1, 1985 to December 31, 1990. Contemporaneous spot prices are obtained from the same sources and verified with an equivalent series from LIFFE. Because the option prices in London are recorded as a "closing rotation" of quotes rather than being last-traded prices, there is no problem of synchroneity between the stock index and the option prices in this dataset.[1] Dividends (in index points) are obtained from the Stock Exchange and from Pradeep Yadav of the University of Strathclyde. Three-month interest rates are from Datastream.

The analysis is based upon options for the second-quoted month which has between 30 and 60 days to maturity.[2] The first step is to calculate implied volatilities for puts and calls at up to 5 exercise prices, using a 50-step binomial model which allows for early exercise and which accounts for the actual dividends paid over the life of each option.

Figure 1 gives an example of implied volatilities on two days in January 1990 which show different kinds of smile. On January 9th the smile showed a left-skewed pattern around the (calculated) February forward price of 2468. Ten days later, on January 19th, the forward price had fallen by 4.6% to 2354 and the smile had become right-skewed.

[1]The London Stock Exchange is a dealer market. The FTSE 100 Index is based upon the midpoint of the quotes for the constituent shares, so it is never "stale."

[2]In the preliminary study [Gemmill (1991)] it was found that results were unaffected by whether options with one, two or three months' maturity were used.

The measure of skewness is designed to capture this kind of change in the volatility smile. It compares the implied volatilities of calls, which have striking prices 2% above the forward price, with puts, which have striking prices 2% below the forward price. The reason for mixing calls and puts is that these are the most traded instruments at these exercise prices: if a trader is bullish, then an out-of-the-money call is purchased and if a trader is bearish, then an out-of-the-money put is purchased. The ±2% range is chosen (rather than ±3% or ±4%) as it is consistent with the available data and preliminary work [Gemmill (1991)] indicated that the results are not sensitive to range.

The basic skewness measure is,

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

where

skew	is the skewness measure in %
σ	is the implied volatility
and	
$(+x\%)$	denotes an exercise price which is $x\%$ above the forward price.[3]

One problem is that there are no options exactly 2% away from the forward price, so the relevant implied volatilities are linearly interpolated. A volatility is removed from the sample if it deviates by more than 30% from the average for all call or all put volatilities on that day. This results in rejection of 0.75% of all calls and 0.56% of all puts (there being 6016 calls and 6200 puts originally). In addition, any day is rejected if there are less than three call volatilities and three put volatilities available for interpolation, resulting in a loss of 39 days out of the total of 1387 (i.e. 2.8%).[4]

Continuing the example from January 9, 1990, with a forward price of 2468, the relevant ±2% exercise prices are 2418.6 and 2517.4. Interpolated values for the implied volatilities are 0.187 and 0.168, respectively. The skewness (based only on calls, rather than puts and calls, in

[3]Note that the choice of the +2% volatility in the denominator, rather than the 0% volatility or −2% volatility, is of no practical consequence.

[4]Rejection frequencies (days/total days available) are: 1985 (30/126); 1986 (5/250); 1987 (1/253); 1988 (1/253); 1989 (1/252); 1990 (1/253). The larger number of lost days in 1985 reflects the small number of exercise prices quoted at that time. For example, if there are only three exercise prices for calls on a particular day and one volatility is rejected, then there are not enough data for interpolation and the whole day is discarded.

this example) is equal to -11.3%. On January 19th, with a forward price of 2354, the relevant implied volatilities are 0.127 and 0.160, giving a skewness of $+26.2\%$.

A peculiarity of the FTSE 100 options over the sample period is that put implied volatilities are usually about 2% points higher than call implied volatilities for the same exercise price. To avoid a "put bias" in the smile, on each day the difference between implied volatilities for at-the-forward puts and calls is taken into account to produce a revised skewness statistic,

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

where

diff is the difference in implied volatility of at-the-forward puts from at-the-forward calls.

The at-the-forward estimates of volatility are made by interpolation, in the same way as for the $\pm 2\%$ values.

This measure of skewness is developed independently of that of Bates (1991), but is very similar. Bates's measure is calculated from *prices* which are $x\%$ away from the forward price rather than from *volatilities* at the $\pm x\%$ striking prices. His measure is,

$$\text{Bates}_t = \left\{\frac{C_t\,(+x\%) - P_t\,(-x\%)}{P_t\,(-x\%)}\right\} \times 100 \tag{3}$$

where

Bates is the Bates skewness measure in %
C is the call price
P is the put price
and
$(+x\%)$ denotes an exercise price which is $x\%$ above the forward price

As option prices are almost linear in volatility, there will be little difference in the behavior of the volatility-based skewness measure of eq. (2) and Bates's price-based measure, eq. (3): they are monotonically related. The volatility-based measure has two possible advantages. The first advantage is that prices are sensitive to maturity whereas volatility is not, which should make the volatility-based measure less prone to sampling

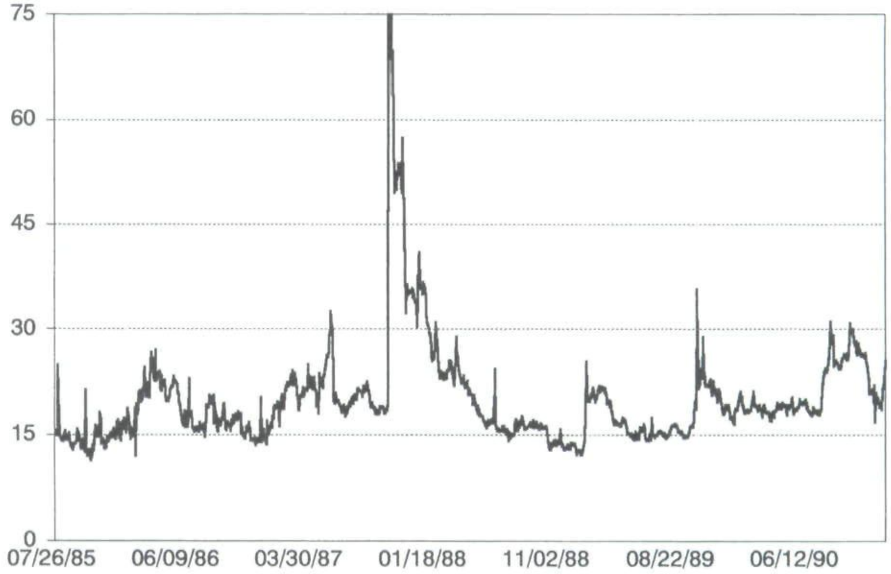

FIGURE 2
Implied volatility percent (av. of at-the-forward puts and calls).

error. The second advantage is that it is customary for traders to discuss volatility smiles and not price smiles. The volatility-based measure is therefore more consistent with market practice.

RESULTS

Results on Level and Skewness of Volatility

The level of implied volatility over the sample period (average of at-the-forward puts and calls) is plotted in Figure 2. There was a large spike at the time of the Crash, but otherwise volatility was seldom above 25%. There was no rise in volatility just prior to the Crash: it was 19.1% on 15th October 1987, peaked at 96.7% on 22nd October, and had fallen back to 36.4% by 1st December.[5]

The average volatility for the whole sample is 20.0% (see Table I, row 1). Dividing the data into pre- and post-Crash periods and omitting October 19 to November 30, 1987, there is a small increase in volatility from 18.3% pre-Crash to 19.8% post-Crash. One surprising result is that put volatilities are, on average, nearly 2 percentage points higher (21.0%)

[5]The Crash occurred on October 19, 1987. The London market was open on that Monday, but had been closed on Friday, October 16th, due to power cuts following a hurricane. There are therefore no data for October 16th.

TABLE I

Summary Statistics on Implied Volatility and Skewness

Period	*Number of Observations*	*For At-The Forward Options* — *Volatility (Average of Puts and Calls)*	*Put Volatility %*	*Call Volatility %*	*Difference in Volatility: Puts − Calls*	*Skewness Measure (Based on Puts 2% Below the Forward Price and Calls 2% Above the Forward Price)*
7/26/85 to 12/31/90 (whole period)	1348	20.05	20.99 (8.34)	19.10 (7.73)	1.89 ($t = 6.10$)[a]	−1.338 (8.872)
7/26/85 to 10/16/87 (pre-Crash)	542	18.34	18.83 (3.96)	17.85 (4.57)	0.98 ($t = 3.77$)[a]	−1.431 (10.934)
12/1/87 to 12/31/90 (post-Crash)	776	19.81	20.96 (5.62)	18.65 (5.97)	2.31 ($t = 7.85$)[a]	−1.127 (7.151)

Bracketed numbers are standard deviations, except where denoted as t values.
Skewness measure from eq. (2).
[a]Denotes t value (calculated assuming unequal variances) significant at the 1% level.

TABLE II

Comparison of Volatilities at- and in-the-money

Period	*No. of Obs.*	*Puts (−2%)*	*Puts (0%)*	*Difference*	*Calls (0%)*	*Calls (+2%)*	*Difference*
7/26/85 to 12/31/90		21.14	20.99	−0.14	19.10	18.93	−0.18
(whole period)	1348	(8.19)	(8.34)	(t = 0.47)	(7.73)	(7.63)	(t = 0.57)
7/26/85 to 10/16/87		18.84	18.83	−0.01	17.85	17.54	−0.30
(pre-Crash)	542	(3.62)	(3.96)	(t = 0.04)	(4.57)	(4.32)	(t = 1.15)
12/1/87 to 12/31/90		21.22	20.96	−0.26	18.65	18.55	0.10
(post-Crash)	776	(5.46)	(5.62)	(t = 0.92)	(5.97)	(5.71)	(t = 0.34)

($\pm x$%) denotes an option which is for exercise $\pm x$% from the forward price.
Bracketed numbers are standard deviations, except where denoted as t values.
No difference in the table is significant, according to a 5%-level t-test.

than call volatilities (19.1%) (significant at 1% level). The Crash increases this put/call difference from 0.98% in the first period to 2.31% in the second period (see rows 2 and 3 of Table I).

Row 1 of Table II indicates that the average volatility smile is small: puts which are 2%-below-the-forward price have a volatility of 21.1%, which is hardly greater than the 21.0% average for at-the-forward puts. Similarly, at-the-forward calls have an average volatility of 19.1%, while 2%-above-the-forward calls have a volatility of 18.9%. This rather flat profile is observed in both pre- and post-Crash periods (see rows 2 and 3 of Table II).

Another way of examining the average shape of the smile is to compute the skewness measure from eq. 2 (see Table I). It is significantly negative over the whole period (−1.338%) as well as over the two subperiods (pre-Crash −1.431% and post-Crash −1.127%). There is therefore only a very small amount of left-skewness in the smile and, surprisingly, this has not been changed by the Crash. The accepted wisdom is that traders have become more wary after the Crash and have started to buy low exercise-price puts as a defensive strategy. The results conclusively reject this behavior for London.

The absence of any strong skewness, on *average,* is rather misleading, however, as there are periods when the smile is highly skewed. The range in skewness is from −57% on August 5, 1987 to +61% on June 27, 1988. Skewness changes considerably from day to day, with larger changes before the Crash than after it (as reflected in pre- and post-Crash standard deviations of 10.934% and 7.151%, respectively, see Table I).

Figure 3 plots a 20-day moving average of the skewness statistic, which helps to show trends. The most left-skewed period for the whole

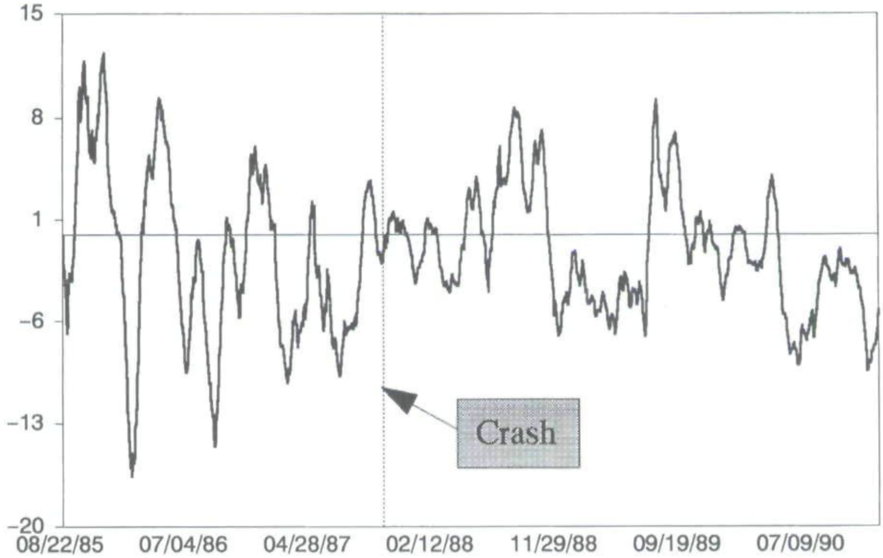

FIGURE 3
Skewness percent (20-day average).

6-year sample is around February 21, 1986, when the 20-day average reached -16.6%. The most right-skewed period is around November 12, 1985, when the 20-day average was $+12.4\%$. In 1987 before the Crash, there were two rather bearish periods, mid-February to mid-April and mid-June to early August. The volatility smile was not particularly left-skewed just before the Crash: the 20-day average for skewness was -1.876% on October 15, 1987, close to the sample average of -1.338%. Immediately after the Crash there was an increase in the right-skewness of the smile—it averaged $+1.021\%$ for the period, October 20 to November 30, 1987. It, therefore, appears that after the market crash, London's traders have not become more bearish and may have become slightly more bullish.

One potential danger is that the phenomenon being measured is just noise, rather than something systematic. However, if the skewness were noise, its size on one day would be unrelated to its size on previous days. Figure 4 plots the first 10 partial autocorrelations of skewness, of which the first 4 are significantly positive. This indicates that there is a strong relationship between skewness on one day and its size on previous days, a result which is confirmed for both pre- and post-Crash periods[6] and is

[6]The first three partial autocorrelations are significant (5% level) before the Crash (0.43, 0.21, 0.27) and the first two are significant (5% level) after the Crash (0.50, 0.23).

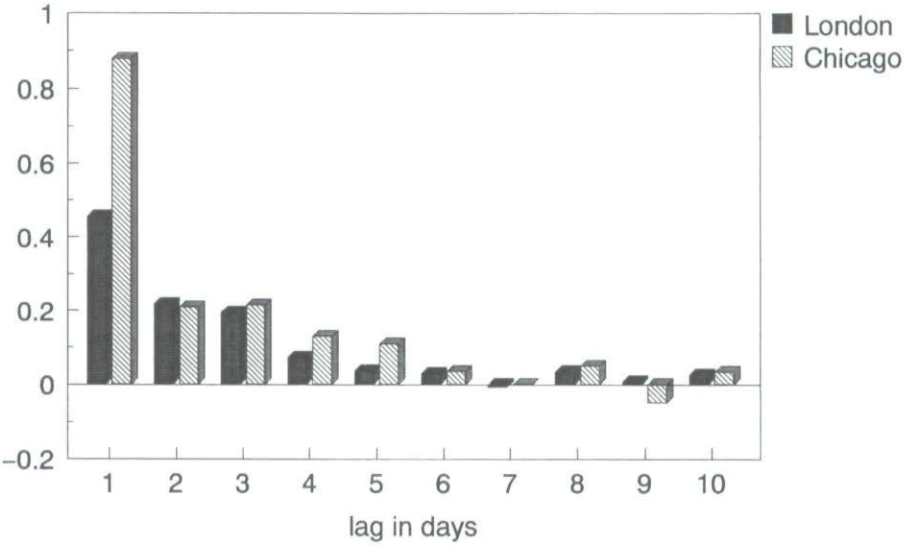

FIGURE 4
Partial autocorrelations of skewness.

TABLE III

Distributional Statistics for Daily Returns on FTSE 100 Index

Period	*No. of Obs.*	*Mean %*	*sd %*	*sd annualized %*	*skewness*	*excess Kurtosis*
7/1/85 to 12/31/90 (whole period)	1436	0.03840	1.05206	16.63	−2.41[a]	29.71[a]
7/1/85 to 10/16/87 (pre-Crash)	600	0.10379	0.82955	13.12	−0.30[a]	−0.19
12/1/87 to 12/31/90 (post-Crash)	805	0.03790	0.86066	13.61	−0.25[a]	1.13[a]

sd denotes standard deviation.
Expected values for a normal distribution are skewness = 0 end excess kurtosis = 0.
[a]Denotes significantly different from a normal distribution at the 1% level.

similar to results with U.S. data (also plotted in Fig. 4). The hypothesis, that the skewness of the smile is just noise, is therefore rejected.

Skewness in Options and in the Observed Distribution

An obvious question is whether the observed distribution of returns on the FTSE 100 gives skewness which is similar to that of the average volatility smile. The first row of Table III gives statistics on the first four moments of FTSE 100 returns for the whole of the sample period. Relative to a normal distribution, returns on the FTSE 100 show a high degree of skewness (sk = −2.41) and of kurtosis (ku = 29.71). However, most of the skewness and kurtosis come from the period around the Crash. The second row of the table considers the pre-Crash period and the third row, the post-Crash period (excluding October 19, to November 30, 1987). In both subperiods there is small, but significant, skewness (sk = −0.30 and sk = −0.25, respectively) and only in the second subperiod is there any modest (but significant) kurtosis (ku = 1.13). These results suggest that the very small left-skewness of the volatility smile, which is found in both subperiods, is matched rather closely by the modest left-skewness of observed FTSE 100 returns. In setting the skewness of the volatility smile, traders may therefore be following the shape of the observed distribution.

While skewness of the implied and actual distributions is similar, the estimated standard deviations (i.e., volatilities) of the two distributions are quite different. The pre-Crash volatility of the observed returns is 13.1% and the post-Crash volatility is 13.6% (see Table III, rows 2 and 3). The implied volatilities for these periods (averages of at-the-forward puts and calls) are 18.3% and 19.8%, respectively (see Table I, rows 2 and 3). There is, therefore, an upward bias of at least 5% in the implied volatility, which is too large to be explained by transactions costs or data errors and suggests that writing options was potentially profitable over this period.[7]

Skewness in Relation to Market Level and Other Factors

It has already been noted that skewness has become more positive in the immediate aftermath of the Crash. That raises the question of whether there is any general relationship between skewness and the level of the FTSE 100 Index. To examine this, a number of regressions are estimated with skewness as dependent variable and either the level of the index or change in the index as independent variable.

The first regression examines whether skewness (SKEW) is related to the linearly detrended level of the FTSE 100 (FTRES). Preliminary work indicated a high degree of autocorrelation of the residuals (estimated $\rho = 0.50$) so the equation is estimated in generalized differences.

[7]This is consistent with the analysis of Dawson and Gemmill (1991) in which market-making in options is found to be very profitable.

To avoid mistaken inferences due to heteroskedasticity, the White (1980) method is used to give consistent estimates of standard errors and t-statistics (in this and in all subsequent regressions). The result is:

$$\underset{}{\mathrm{SKEW}_t = -1.3202 - 0.00417\ \mathrm{FTRES}_t} \qquad \begin{aligned} &R^2 = 0.0031 \\ &n = 1298 \\ &\rho = 0.50 \\ &\mathrm{DW} = 2.22 \end{aligned} \tag{4}$$
$$\qquad (3.09) \qquad (2.00) \qquad (t\text{-values in brackets})$$

The negative coefficient on FTRES indicates that there is a small, but significant, negative relationship between skewness and the market level; i.e., when the market is high, the smile is left-skewed, and vice versa.

Equation (4) is a long-term relationship, but there may also exist a short-term relationship between the skewness of the smile on a particular day (SKEW_t) and returns on the Index for that day (RFT_t). The estimated relationship [with correction for autocorrelation again of $\rho = 0.50$] is:

$$\mathrm{SKEW}_t = -1.3249 - 1.1156\ \mathrm{RFT}_t \qquad \begin{aligned} &R^2 = 0.0273 \\ &n = 1298 \\ &\rho = 0.50 \\ &\mathrm{DW} = 2.21 \end{aligned} \tag{5}$$
$$\qquad (3.14) \qquad (4.51) \qquad (t\text{-values in brackets})$$

The negative coefficient on RFT in eq. (5) confirms that on days when the market rises there tends to be an increase in left-skewness of the volatility smile. This is also consistent with right-skewness increasing immediately after the Crash.

Although the smile is not particularly skewed before the Crash, it is still possible that it has some power to forecast subsequent movements in the market. To test this, a regression is estimated between returns on the market for day t and skewness on the day before. The result is

$$\mathrm{RFT}_t = 0.0384 - 0.0051\ \mathrm{SKEW}_{t-1} \qquad \begin{aligned} &R^2 = 0.0020 \\ &n = 1348 \\ &\mathrm{DW} = 2.04 \end{aligned} \tag{6}$$
$$\qquad (1.36) \qquad (1.70) \qquad (t\text{-values in brackets})$$

(For this relationship, the Durbin–Watson statistic indicates no need for an autocorrelation correction). Equation (6) shows a negative (and insignificant) relationship between returns on one day and the skewness of the volatility smile on the previous day. When the equation is estimated separately for pre- and post-Crash periods, it is negative in both and significant (5% level) in the pre-Crash period. The hypothesis that positive skewness is a forecast of a rising market is therefore rejected: it may even be a weak forecast of a falling market.

These results imply that if skewness is a measure of traders' bullishness, the optimism is generally misplaced. To test whether skewness is really a measure of bullishness, it is compared with some other potential measures of traders' optimism. These include (i) the (detrended) daily premium over net asset value of investment trusts (closed-end mutual funds); (ii) monthly net purchases of unit trusts (open-end mutual funds); and (iii) a call–put signal (CPS) based on the relative volumes of calls and puts traded daily on FTSE 100 options.[8] Skewness is negatively correlated with each of these variables: with the investment-trust premium it is -0.031 (not significant); with monthly unit trust purchases it is -0.039 (not significant); and with the call–put signal it is -0.086 (significant at the 1% level).[9] These results confirm that skewness of the volatility smile is not a simple measure of traders' bullishness. On days when the FTSE 100 rises, more calls than puts are traded, but the volatility smile becomes more left-skewed. This suggests that the volatility smile is not induced by liquidity effects, which would make it more right-skewed on such days, but reflects a more complicated pattern of behavior by traders and investors.

U.K. and U.S. Results Compared

Several studies indicate the close correlation of daily returns on U.K. and U.S. stockmarkets [e.g., Roll (1988); King and Wadhwani (1990)] and that volatility spillovers occur from one market to another [e.g., Hamao, Masulis and Ng (1990)]. Given such close relationships, an interesting question is whether smiles on the two markets also show similarities.

As already explained, David Bates's price-based measure of skewness is closely (and monotonically) related to the volatility-based measure of this study. He provided estimates of his measure for S&P 500 futures options for the 1985–1989 period. U.K. and U.S. skewness are compared in Figure 5. (There are 1156 days on which the markets may be compared, each data set having some missing days.) The behavior of the two markets is quite different, as indicated by the insignificant correlation of the skewness measures ($r = -0.015$). Figure 5 shows that left skewness of the

[8]The call–put signal is (no. of calls − no. of puts)/(no. of calls + no. of puts). This signal is used rather than the more familiar call/put ratio because the latter is not normally distributed, [see Martikainen and Puttonen (1994)].

[9]Significance is measured by the F-test in a linear regression.

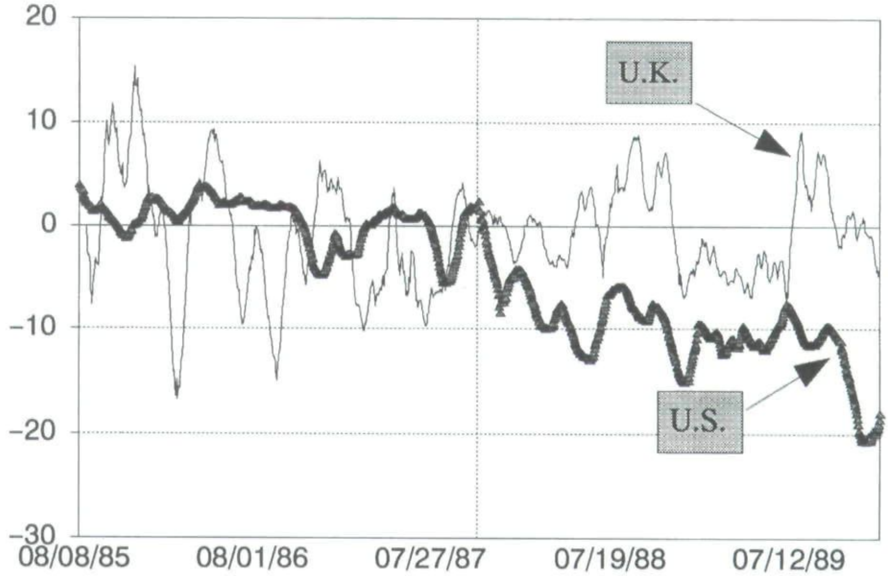

FIGURE 5
U.K. and U.S. skewness (20-day moving averages).

smile is not evident in the United States or the United Kingdom prior to the Crash. Both have a period of bearishness around June–July 1987, but have become normal again thereafter. Much more interesting is the period after the Crash, when the smile becomes very left-skewed in the United States but hardly changes in the United Kingdom. It appears that traders in the S&P 500 options are very concerned about further crashes, whereas traders in London's FTSE 100 options are no more worried after the Crash than they were before. This rather bullish behavior of London's traders does not appear to be unique, as some recent evidence from German stock options [Trautmann and Beinert (1995)] indicates a similar post-Crash rebound in expectations.

The difference between the U.S. and U.K. results is intriguing. One possibility is that it reflects the relative development of the two markets. Over the sample period, the volume in London was rather modest (averaging less than 6000 contracts per day) and not sufficient to provide fund managers with the means to buy downside insurance. The main users were small speculators. By contrast, the U.S. markets in index options together had a daily volume of nearly 400,000 contracts. The failure of portfolio-insurance strategies based upon futures to perform well in the Crash may have induced U.S. fund managers to buy more out-of-the-money puts after the Crash, thus increasing the left-skewness of the volatility smile. The difference in the U.S. and U.K. results may be reflective of different kinds of participants in the two markets.[10]

SUMMARY AND CONCLUSIONS

This article focuses on the changing shape of the volatility smile. Just as Bates (1991) found for the United States, there is no evidence that implied volatilities in London's index options were unusually large just before the Crash. Neither is the smile particularly skewed to the left, which would be an indication that traders were concerned about such an event. It seems that option traders were taken completely by surprise when the Crash occurred.

Left-skewness has greatly increased in the United States after the Crash, but it has not increased in the United Kingdom. The regressions suggest that, if anything, there is a tendency for a fall in the London market to be associated with an increase in the right-skewness of the smile. The accepted wisdom is that, after the Crash, traders in index options bought more out-of-the-money puts to insure themselves. That is consistent with the U.S. results but not with the U.K. results. One explanation for this difference in behavior may be that there is sufficient liquidity in the U.S. markets for fund managers to be active hedgers, whereas the U.K. market is predominantly used by small speculators.

The skewness of the smile in the United Kingdom persists for several days, just as it does in the United States, so it is not just a randomly determined phenomenon. In addition, the smile is, on average, slightly left-skewed for the 28 months before the Crash and the 37 months thereafter, which is consistent with the slight skewness of the observed distribution for returns on the FTSE 100 Index over the same periods.

What appears to happen in the U.K. is as follows. On a day when the FTSE 100 rises, there are relatively more purchases of calls than puts. This might be expected to induce a right-skewness to the volatility smile, as small speculators buy out-of-the-money calls, but the opposite occurs: left-skewness increases. It seems that rather than a liquidity effect driving option volatility, market-makers are contrarian in their behavior. The higher the market rises, the more they worry that a fall may occur and the more they charge for out-of-the-money puts. Nevertheless, the effect is weak and traders were not behaving in this cautious way just before the Crash of 1987.

[10]Unfortunately, neither LIFFE nor the U.S. exchanges (CBOE and CME) are able to provide data on who uses index options, so it is not possible to test the hypothesis that users differ in the U.S. and U.K.

One implication of these results is that there is a gap in understanding about what causes smiles to change, so their development over time cannot easily be modeled. When an implied binomial tree is fitted to an existing smile, it is generally assumed that the smile will maintain its current shape. This study's results show that the smile can change its shape dramatically over a few weeks, which calls into question such a static approach. One approach would be to develop implied binomial trees which have stochastic rather than deterministic smiles.

Many questions remain for further research. The first would be an examination of why put implied volatilities exceed those of calls. It would be interesting to know whether this could be arbitraged or whether it is a reflection of model errors (despite the use of a model which allows for dividends and early exercise). Kamara and Miller (1995) also find that put volatilities exceed call volatilities in the United States, but the difference is too small to arbitrage. The second is an examination of what may be causing the persistent difference of about 5% between implied volatility (circa 19%) and observed volatility (circa 14%) across both puts and calls. This difference is too large to be simply due to transactions costs. A similar anomaly has been noted for index options in the United States [Day and Lewis (1992); Fleming (1993); Bates (1995)] and in Japan [Kamiyama (1995b)]. The third area for more research is to extend the sample period to see whether more recent data confirm the independence of smiles across U.S., European and Japanese markets, or whether spillovers occur as they do in the underlying asset markets. Finally, the greatest challenge is to develop a satisfactory behavioral theory of the smile, which can explain the way smiles evolve over time.

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