A Note on Nikkei Option Implied Volatilities and Post-Crash Fears*

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1. Introduction

A cornerstone in financial economic theory is that, in properly functioning efficient capital markets, prices contain valuable information for making decisions. This holds true for derivative instruments such as index options as well. Of particular interest is whether index option prices provide valuable information on the investor`s perception of stock price movements in the near future. In an efficient market, option prices could provide information on market downturns, to the extent that option contracts are forward looking instruments. One objective of the paper is to empirically document the "smile" pattern in implied volatilities in the early 1990s. A second objective, is to provide a preliminary investigation into the time series patterns of the "smile." This should shed some light on the issue of whether the options market contains information indicating a *subsequent* and substantial decline in Japanese stock market prices following the dramatic decline in prices in January of 1990.

Several papers empirically examine the informational efficiency of options markets around a stock market crash. Bates (1991, 2000) proposes using a skewness index to measure the degree to which the put premiums on an index are "overpriced." Gemmill (1996) develops a similar index measure using implied volatilities. Empirical evidence from the U.S. and U.K. markets confirm skewness patterns prior to the October 1987 crash. Bates (1991) finds that S&P 500 futures put options were expensive relative to calls in the summer preceding the October 1987 crash. However, in the two months just prior to the crash, the put prices returned to normal levels. Gemmill (1996) confirms the

Bates findings by looking at implied volatilites of FTSE 100 index options. Takezawa and Takezawa (2003) provide some evidence of statistically significant skewness in the Nikkei 225 stock index distribution; this could suggest that the option market provided information of a price decline as early as October 1989.

Bates (2000) and Rubinstein (1994), among others, document that these skewness patterns (relatively overpriced put options) continued after the 1987 crash as well. This could suggest post-crash fears of another sharp decline in market prices. Gemmill (1996), however, obtains figures indicating that such post-crash fears were less relevant in the post-1987 U.K. market.

2. Data and Methodology

Options on the Nikkei index began trading on the OSE in June 1989.[1] Daily Nikkei 225 option data (premium, strike, maturity) was obtained from the Osaka Securities Exchange (OSE) for the period from 1990 to 1993. Five strikes in increments of 500 yen are traded for each maturity. The underlying asset, the Nikkei index, data is collected from Data Stream. The following continuous dividend yields were used in calculating the implied volatilities: 0.69% for 1990, 0.76% 1991, 1% for 1992, and 0.85% for 1993. Dividend yield data can be found in the *OSE Factbook*.

A series of Euroyen (LIBOR) rates are used to interpolate the riskfree rate. Instead of applying a single LIBOR rate or the closest rate in terms of maturity, we interpolated the riskfree rate based on regressions. Euroyen term structure data for 7 days, 30 days, 60 days, 90 days, 180 days, 270 days, and 360 days are obtained on a daily basis (Data Stream). A linear regression is then fit to the seven rates to estimate a (linear) term structure for interpolating the appropriate riskfree rate. The regression takes the form,

$$r_t = a + b\frac{t}{360} + e$$

where, r_t is the LIBOR rate for maturity t, a and b are coefficients, and e the error term. The regression is re-estimated on a daily basis. All option contracts with less than 20 days to maturity were deleted from the sample. Contracts with less than 10 contract trading volume were deleted as well.

We use the Black-Scholes formula to obtain the implied volatilities (IV). When the asset prices are not correlated to the volatility and the volatility risk is not priced, then the price of the option, P_t, conditioned on an information set, Ω_t, is given by $P_t = E[BS(\bar{V}) \mid \Omega_t]$ where BS is the Black-Scholes formula, $\bar{V}$ is the average instantaneous volatility, and E is the expectations operator. For near-the-money options, then $P_t \approx BS(E(\bar{V} \mid \Omega_t))$. Hence, the Black-Scholes formula can be inverted to give us the implied expected instantaneous volatility of the underlying asset. The put price, P, is given by

$$P = N(-d_2)X\exp(-r(T-t)) - N(-d_1)S\exp(-q(T-t))$$

where

$$d_1 = \frac{\ln(\frac{S}{X}) + (r - q + \frac{V^2}{2})(T-t)}{V\sqrt{T-t}}$$

and

$$d_2 = d_1 - V\sqrt{T-t}\,.$$

$N(.)$ is the cumulative normal density, X is the strike price, S is the underlying index level, $T\text{-}t$ is the time to maturity for the option, r is the riskfree rate, q is the continuous rate dividend yield, and V is the volatility. Each IV is iteratively calculated to an accuracy of 0.001 (or up to a maximum of 10,000 iterations).

In this paper we obtained implied volatilities across all available strikes. Empirically, we expect to find IV which differ across strikes giving rise to the well documented "smile" pattern. For each year the IV are averaged into five categories based on moneyness, $\frac{S}{X}$:

Deep-in-the-money	$0.75 \le S/X < 0.85$,
In-the-money	$0.85 \le S/X < 0.95$,
Near-the-money	$0.95 \le S/X < 1.05$,
Out-of-the-money	$1.05 \le S/X < 1.15$,
Deep-out-of-the-money	$S/X > 1.15$.

3. Empirical Results and Remarks

As expected, we document a "smile" pattern for put options for each of the four years examined (Table 1). In other words, the mean implied volatility for the in-the-money and out-of-the-money options are relatively higher than the mean IV for near-the-money options. The magnitude of the IV figures are consistent with previous empirical work (金, 1996).

Since we document the "smile" effect by year it allows us to discern a pattern over time. Out-of-the-money put options on the stock index provides portfolio insurance against significant downward movements of the stock market. Investors will seek insurance when the market is anticipated to encounter a crash. As a consequence, one should expect the stock index put option to be priced higher relative to corresponding call options. We find the mean IV for in-the-money options $(0.85 \le S/X < 0.95)$ to decline dramatically from 1991 to 1992. A similar pattern exists for the deep-in-the-money options, however, due to the small number of observations we should take caution in interpreting this data. What is most interesting is the fact that the mean IV out-the-money put options remain relatively constant across 1990 to 1993. The only exception is the IV for the deep-out-of-the-money put option in 1990 which is significantly higher than the IV in years 1991, 1992, and 1993. This could suggest that put options were "over priced" indicating investor perception or "fear" of another sharp decline in stock prices in 1990. The lower mean IV could indicate that in the following year and beyond such "fears" of a crash dissipated.

An empirically rigorous approach to documenting post-crash fears would be to match the puts with calls in the same maturity bracket and make comparisons of the implied volatilities based on moneyness across time. This, however, is beyond the scope of this paper. The current note has the modest objective of simply documenting the IV smile and providing some interpretation of the structure of IV across several years following the 1990 crash in the Japanese market.

Table 1 Implied Volatilities for Nikkei Index Put Options by Moneyness

Year	Moneyness	Mean	Min	Max	Number Observations
1990	0.75<S/X<=0.85	0.873	0.220	1.910	21
	0.85<S/X<=0.95	0.842	0.130	3.820	187
	0.95<S/X<=1.05	0.431	0.010	6.58	830
	1.05<S/X<=1.15	0.447	0.110	4.640	555
	S/X>1.15	1.414	0.340	6.920	368
1991	0.75<S/X<=0.85	1.239	1.220	1.260	2
	0.85<S/X<=0.95	0.801	0.060	5.110	256
	0.95<S/X<=1.05	0.296	0.010	2.860	1554
	1.05<S/X<=1.15	0.343	0.100	1.160	1104
	S/X>1.15	0.446	0.240	0.930	305
1992	0.75<S/X<=0.85	0.706	0.230	2.930	121
	0.85<S/X<=0.95	0.389	0.080	3.910	1076
	0.95<S/X<=1.05	0.310	0.080	1.680	2375
	1.05<S/X<=1.15	0.3445	0.160	0.940	1254
	S/X>1.15	0.435	0.220	0.980	383
1993	0.75<S/X<=0.85	0.832	0.130	4.180	87
	0.85<S/X<=0.95	0.314	0.060	2.920	686
	0.95<S/X<=1.05	0.213	0.070	0.830	2919
	1.05<S/X<=1.15	0.248	0.140	0.870	1463
	S/X>1.15	0.306	0.220	0.740	177

Notes

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(1) For an introduction to the Nikkei stock index option market refer to Bailey and Ziemba (1991).

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インプライド・ボラティリティと市場下落に対する脅威に関する一考察

〈要　約〉

竹澤　伸哉

日経225プットオプション価格から算出したインプライド・ボラティリティのスマイル構造は、1990年から1991年にかけて、ディープ・アウト・オブ・ザ・マネー・オプションのインプライド・ボラティリティの大きな下落が確認された。その後、アウト・オブ・ザ・マネー・オプションのインプライド・ボラティリティは、1992年及び1993年には殆ど変化がみられなかった。