Information Content of Implied Volatility of Asian Equity Indices

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Abstract

In this paper we look at the ability of implied volatility to predict the volatility realized over the life of the option in Asian equity indices. We find that in Hong Kong and Taiwan the implied volatility is an unbiased predictor of future realized volatility, whereas in South Korea and India the implied volatility is a poor predictor. Regardless of information content of implied volatility for future realized volatility, it is nevertheless true that there is a great deal of predictability of implied volatility across all Asian markets.

Introduction

The genesis of this study lies in our attempt to understand the ability of the Indian equity index implied volatility in predicting the realized volatility. To our surprise not only the implied volatility of Indian index options was poor and biased predictors of the realized volatility, the realized volatility itself had insignificant autocorrelation. These observations were in direct contradiction with the observed and widely reported phenomena in the US market (Christensen and Prabhala, 1998; Christensen and Hansen, 2002). This led us to ask if the phenomenon in the Indian market was an anomaly or there was a spectrum of predictability with the US and the Indian market being on two extremes. We examine the information content of implied volatility in four Asian markets namely Hong Kong, India, South Korea and Taiwan. We realized that part of our results for the Indian market could be driven by relative lack of liquidity of the market. Selection of markets from Asia liberated us from such biases, since among these markets South Korea is the third largest in the world on the basis of number of contracts traded.

We examine the autocorrelation of realized volatility and consider its presence as a proxy for overall forecastability. We find that the forecastability of realized volatility (indicated by significant autocorrelation) of equity index is not the same across markets. While the Hong Kong and Taiwan markets rank similar to the US market in forecastability, the South Korean market is similar to the Indian market in its lack of forecastability. Since South Korea has a very liquid index option market, we rule out the possibility that the phenomenon could be related to lack of liquidity of the index options.

Implied volatility is widely believed to very informative over the life of the option (Latane and Rendleman, 1976). The evidence seems to be mixed in the Asian countries under examination. The predictive ability of implied volatility is high in markets where the realized volatility is persistent and low where the realized volatility is not persistent. We suspect that the predictive ability of the implied volatility is driven by the persistence of realized volatility in equity markets. The implied volatility on the other hand is persistent and predictable in all the markets.

These findings demonstrate that option-pricing models that assume a persistent volatility structure are not adequate for option pricing in all the markets. We would also like to caution researchers that biasing all developments on the US market evidence might be leading us into an incomplete understanding.

Data

Currently equity index options are traded in four Asian markets (has the same connotations as country), namely Hong Kong, India, South Korea and Taiwan. All the index options are European options. We have used the data on the most active index options in each of these countries. Since the date on which each market introduced index options differs from market to market, we have data starting from different periods in each of them.

We have data on Hang Seng, the Hong Kong equity index, from 31st January, 1996 to 31st December 2004. The data on South Korea is on the index KOSPI, starting from 12th January, 2001 to 10th December, 2004. The data on Taiwan is on the index TWSEW, starting from 17th January, 2002 to 16th December, 2004. For India, we have data on the option closing prices from 4th July 2001 to 28th October 2004.

We have obtained the Indian option closing prices from National Stock Exchange, India. The exchange provides the money market rates as well as index closing values for S&P CNX NIFTY (henceforth referred to as NIFTY). NIFTY closing value is reported on daily basis net of the dividends. The index options are also written on this value only.

Nifty options contracts have a maximum of 3-month trading cycle - the near month (one), the next month (two) and the far month (three). On expiry of the near month contract, new contracts are introduced at new strike prices for both call and put options, on the trading day following the expiry of the near month contract. Nifty options contracts expire on the last Thursday of the expiry month[1].

We use continuous non-overlapping near month at the money options data. For example we start on 4th June 2001 with near month option data for index option (Index Closing = 1127, Strike Price = 1140) closing on 28th June 2001. On 29th June 2001 we pick the second data element, index option (Index Closing = 1108, Strike Price = 1110) closing on 26th July 2001. An entire sequence of option prices is constructed in this manner. For each data element we have the index closing price, strike value, MIBOR (Mumbai Inter Bank Overnight Rate) and option closing price. We solve for the Black Scholes implied volatility numerically by minimizing difference with the theoretical and observed call price. The theoretical Call price is given by

$C_t = S_t N(d_1) - K_t \exp(-r_{f,t}\tau_t) N(d_2)$

τ_t stands for time to expire (expressed in calendar days/365).

The implied volatility ($\sigma_{i,t}$) is expressed as % per annum.

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[1] If the last Thursday is a trading holiday, the contracts expire on the previous trading day.

The implied volatility represents the expected volatility priced in the option value, we also compute the realized volatility over each option's life. This is computed as the standard deviation of the daily index returns over the remaining life of the option.

$\sigma_{h.t} = (1/\tau_t \sum(r_{t,k}-\mu_t)^2)^{1/2}$

where τ_t is the trading day to expiration, $r_{t,k}$ is the log index return on day k of period t, and μ_t is the average return of the period t. The $\sigma_{h.t}$ is annualized assuming 252 trading days in a year. We constructed these two series (realized volatility and implied volatility) for both Call as well as Put options.

We have obtained the implied volatility data for Hong Kong, South Korea and Taiwan from Bloomberg™. We isolated implied volatilities for the beginning of each trading cycle for these markets. This provides us with non-overlapping implied volatility estimates of the index options.

Bloomberg™ provides implied volatility for an equity index using the weighted average of implied volatilities of three near month at-the-money options on the index. The weighing is based on the absolute difference of the index strike from the underlying. We illustrate the scheme using an example.

At a given day the index I has closed at 113.75. On that day the three options A, B and C have had strike prices of 110, 115 and 120 respectively. A measure called difference, which is the absolute difference from the index closing, is defined for the weighing. For option A, the difference is 3.75, for option B, the difference is 1.25 and for option C it is 6.25. The total difference is the sum of these differences, which in our example is equal to 11.25.

The implied volatilities v_A, v_B and v_C of options A, B and C respectively are calculated as we have explained in the case of NIFTY options. To arrive at the implied volatility of the index v_{Index}; v_A, v_B and v_C are weighted based on a measure called the percent difference from the index closing.

Percent difference = | Total Difference - Difference | / Total Difference * 100

One can observe that if there are exactly at-the-money options trading on a particular day, the two methods of reporting implied volatility (one used for Indian market and the other for Hong Kong, South Korea and Taiwan) are equivalent.

We obtain the daily index closing values from http://finance.yahoo.com. The index closing values are used to create estimates of the realized volatility as detailed in the case of NIFTY.

Discussion of empirical results[2]

The descriptive statistics for the implied and the realized volatility are provided in Table 1. Table 2 presents the autocorrelation and partial autocorrelation of realized volatility. The extent of autocorrelation is not uniform across the markets. In Hong Kong and Taiwan there is significant persistence with autocorrelation around 0.6 (p values of 0.000 in both cases). There is no autocorrelation in India, while South Korea has first order autocorrelation of 0.31 (p value = 0.028). We consider the presence of autocorrelation as an indication of persistence. By this measure two out of four markets that we consider have non-persistent realized volatility. The degree of persistence among

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[2] The discussion presented is based on the level of volatility. Very similar conclusions are reached based on log volatilities.

the markets with high persistence is not uniform either, with Hong Kong being the most persistent market.

We have used the OLS encompassing regression (Canina and Figlewski, 1993) to examine the information content of implied volatility.

$\text{Realized Volatility}_t = c + \alpha^*\text{Implied Volatility}_t + \beta^*\text{Realized Volatility}_{t-1} + \text{Error}$

If the implied volatility has any information content, α would be different from zero. If the implied volatility is an unbiased estimator of the realized volatility then α should be equal to one and c should be equal to zero. If all the information is present in the previous instances of realized volatility only then α should be equal to zero and β should be significant.

The majority of earlier studies (Canina and Figlewski, 1993; Christensen and Prabhala, 1998) have looked at the information content of call implied volatility only. Christensen and Hansen (2002) have looked at the information content of puts and calls, by including both put and calls implied volatilities simultaneously. However given that these two series are highly correlated we use put and call implied volatilities separately.

We report the coefficients for call implied volatilities in Table 3A. We provide bootstarp regression coefficients as suggested by Efron and Tibshirani (1993) for the call implied volatilities in Table 3B. Since the mean and standard error of the estimates are similar in both the tables we restrict the discussion to Table 4A. We run the regressions in three settings, the first two have the values of α and β respectively restricted to be equal to zero. In all three regressions none of the estimated coefficients is significant for NIFTY. For KOSPI the α (0.59, s.e. = 0.16) is significant but not one (p value for Wald coefficient test = 0.00), when β is set equal to zero. Once we allow the β to be free the estimate for α (0.55, s.e. 0.28) does not change however its significance drops drastically. For Hang Seng when β is restricted to zero, α (0.62, s.e. 0.28) is once again significant but different from one (p value for Wald coefficient test = 0.05). When β is allowed to be free, the estimated value of α (0.35, s.e. 0.21) drops considerably and so does the significance. For TWESW when β is restricted to zero α (0.70, s.e. 0.20) is significant but different from one (p value for Wald coefficient test = 0.00). When β is allowed to be free, α (0.25, s.e 0.24) becomes insignificant. The regressions for put implied volatilities are reported in Table 3B. The results are qualitatively similar to Table 3A.

As shown first by Christensen and Prabhala (1998), there is a potential misspecification problem in interpreting the results of encompassing regression presented in Tables 3A and 3B. The misspecification is driven by the potential measurement error implicit in the implied volatility. To circumvent this difficulty we implement a two stage least square regression method. In the first stage we regress implied volatility on two instruments namely lagged realized volatility and lagged implied volatility. We used the fitted values of implied volatility as the regressor in the second stage.

First stage regression,

$\text{Implied Volatility}_t = c + \alpha{*}\text{Implied Volatility}_{t-1} + \beta{*}\text{Realized Volatility}_{t-1} + \text{Error}$

In second stage,

$\text{Realized Volatility}_t = c + \alpha{*}\text{Implied Volatility}_{\text{estimated from first stage}} + \text{Error}$

In contrast to previous studies (Christensen and Prabhala, 1998; Christensen and Hansen, 2002), we do not include the lagged realized volatility separately in the second stage. The generated regressor used in the second stage regression is a linear combination of lagged realized volatility and lagged implied volatility. Including lagged realized volatility in a regression along with the generated regressor would result in a multi collinearity problem by construction. Similarly the approach followed by Christensen and Hansen, 2002 in which both put and call regressors are specified together in the second stage regression would subject the model to the multi collinearity problem.

The results of the first stage regression are presented in Table 5A (the bootstrapped estimates are presented in Table 5B), while the second stage results are in Table 6. The two instruments that we use seem to do a good job in explaining the movement of implied volatility, whether call or put. Other than indicating that the instrumental variable approach is sound, the results of the instrumental variable regression given in Table 5A also give rise to some substantive issues. For example, they point out the high degree of predictability of implied volatility across markets[3]. This is true regardless of the bias or information content of implied volatility with respect to subsequent realized volatility.

In the case of NIFTY, neither the call implied volatility nor the put implied volatility has any information content. The point estimates are 0.66 (s.e 0.43) for call and 0.43 (s.e. 0.43) for puts. For KOSPI, there is some information content but also bias in implied volatility, the point estimates are 0.50 (s.e. 0.24) and 0.42(s.e. 0.21) for calls and puts respectively. For Hang Seng, implied volatility is an unbiased forecast of future realized volatility, the point estimates are 0.97(s.e. 0.12) and 0.90 (s.e. 0.11) for calls and puts respectively. For TWESW the call and put point estimates, 1.31 (s.e. 0.28) for call

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[3] A look at the coefficients shows that predictability of implied volatility is because of lagged realized volatility in all the markets.

and 0.72 (s.e. 0.16) for puts. Among all the estimates we find only Hang Seng Call implied volatility to be an unbiased predictor of the realized volatility (Refer Table 6, Wald Coefficient test).

Conclusions

The study shows that the forecastability of realized volatility of equity index is not the same across markets. It demonstrates that the forecastability is high in Hong Kong and Taiwan like it is in the US however it is not predictable in India and South Korea. Since South Korea is the world's third largest index option market in terms of the number of contracts traded, we rule out the possibility that the phenomenon could be related to lack of liquidity of the index options.

The evidence on information content of implied volatility seems to be mixed. The predictive ability of implied volatility is high in markets where the realized volatility is persistent and low where the realized volatility is not persistent. Just like the US, Hong Kong and Taiwan markets' implied volatility have high predictive ability, but not so for the South Korean and the Indian market. We suspect that the predictive ability of the implied volatility is driven by the persistence of realized volatility in equity markets. Regardless of the predictability of realized volatility and regardless of the predictive content or the bias of implied volatility, it is true across all markets that there is greater amount of predictability in implied volatility than in realized volatility. We think that this is a puzzle that needs to be explained. We can think of two plausible explanations for these observations, the first possibility is that option prices contain a market risk premium not only on the asset itself, but also on its volatility (Chernov, 2002) and hence implied volatility can be a poor or a biased predictor of the realized volatility. The other possibility is that options markets are backward looking and hence don’t contain additional information on the future realized volatility.

At this point, we would like to caution that the current theoretical development in option pricing might be the favored by the chance predictability of realized volatility in the US market. Due to the unpredictability of the realized volatility, option pricing is more challenging in these two Asian markets viz. India and South Korea.

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Table 1: Descriptive statistics for realized and implied volatility of the Asian Equity Indices

Country	Index	Volatility Measure	Mean	Standard Deviation	Skewness	Kurtosis
Hong Kong	Hangseng	R	24.5%	13.3%	2.46	12.13
		CI	26.5%	9.6%	1.13	5.02
		PI	28.7%	11.4%	1.77	7.53
Korea	KOSPI	R	26.9%	9.0%	0.42	2.47
		CI	30.1%	7.4%	0.44	3.12
		PI	33.1%	8.0%	0.10	2.34
India	NIFTY	R	19.9%	9.6%	3.02	14.94
		CI	17.2%	6.1%	0.61	3.15
		PI	22.4%	7.2%	1.08	4.80
Taiwan	TWESW	R	22.6%	7.5%	0.36	2.33
		CI	25.9%	5.5%	0.06	2.20
		PI	26.2%	8.4%	0.97	4.86

R is realized volatility for the index in the option maturity cycle. The realized volatility is computed as the standard deviation of the daily index returns over the life of an option.

$\sigma_{h.t} = (1/\tau_t \Sigma(r_{t,k}-\mu_t)^2)^{½}$

where τ_t is the trading day to expiration, $r_{t,k}$ is the log index return on day k of period t, and μ_t is the average return of the period t. The $\sigma_{h.t}$ is annualized assuming 252 trading days in a year.

CI is the implied volatility as inverted from three at the money Call options closing prices using the Black Scholes Merton (BSM) equation. PI is the implied volatility as inverted from three at the money Put options closing prices using the BSM equation. The weighing scheme for Puts is the same as the weighing scheme for the Calls.

Hang Seng data: 31st January, 1996 to 31st December 2004

KOSPI data :12th January, 2001 to 10th December, 2004.

TWSEW data: 17th January, 2002 to 16th December, 2004.

NIFTY data: 4th July 2001 to 28th October 2004.

Table 2: Autocorrelations and Partial autocorrelations of realized volatility for the Asian Equity Indices

Country	Index	Lag	AC	PAC	Q-Stat	Probability
Hong Kong	Hangseng	1	0.61	0.61	41.26	0.000
		2	0.41	0.05	59.75	0.000
		3	0.45	0.28	81.98	0.000
		4	0.39	0.02	99.50	0.000
		5	0.24	-0.10	106.12	0.000
Korea	KOSPI	1	0.31	0.31	4.82	0.028
		2	0.03	-0.07	4.87	0.088
		3	0.12	0.14	5.58	0.134
		4	0.11	0.03	6.22	0.183
		5	0.15	0.13	7.55	0.183
India	NIFTY	1	0.23	0.23	2.29	0.130
		2	0.10	0.06	2.78	0.249
		3	0.05	0.02	2.90	0.407
		4	0.14	0.12	3.77	0.438
		5	0.01	-0.05	3.78	0.582
Taiwan	TWESW	1	0.60	0.60	14.16	0.000
		2	0.29	-0.11	17.61	0.000
		3	0.10	-0.04	18.05	0.000
		4	-0.04	-0.10	18.12	0.001
		5	-0.04	0.08	18.18	0.003

Hang Seng data: 31st January, 1996 to 31st December 2004

KOSPI data :12th January, 2001 to 10th December, 2004.

TWSEW data: 17th January, 2002 to 16th December, 2004.

NIFTY data: 4th July 2001 to 28th October 2004.

Table 3A: Predictability of realized volatility of the Asian equity indices by call implied volatility and lagged realized volatility based on OLS regression

Index	C	IndexREAL(-1)	IndexCALLVOL	Adjusted R Square
Hangseng	0.09 (0.02)	0.62 (0.08)		0.37
	0.02 (0.03)		0.83 (0.11)	0.35
	0.05 (0.03)	0.40 (0.15)	0.35 (0.21)	0.39
KOSPI	0.18 (0.04)	0.32 (0.14)		0.09
	0.09 (0.05)		0.59 (0.16)	0.22
	0.10 (0.05)	0.00 (0.21)	0.55 (0.28)	0.14
NIFTY	0.15 (0.04)	0.23 (0.16)		0.03
	0.13 (0.04)		0.42 (0.24)	0.05
	0.12 (0.05)	0.11 (0.20)	0.32 (0.31)	0.03
TWESW	0.07 (0.03)	0.67 (0.14)		0.40
	0.05 (0.05)		0.70 (0.20)	0.24
	0.03 (0.05)	0.55 (0.19)	0.25 (0.24)	0.40

In all cases the dependent variable is the realized volatility of the index. IndexReal(-1) is lagged realized volatility for the index. IndexCALLVOL is the implied volatility for at the money the call options. The figures in the parenthesis indicate the standard error.

Hang Seng data: 31st January, 1996 to 31st December 2004

KOSPI data :12th January, 2001 to 10th December, 2004.

TWSEW data: 17th January, 2002 to 16th December, 2004.

NIFTY data: 4th July 2001 to 28th October 2004.

Table 3B: Predictability of realized volatility of the Asian equity indices by put implied volatility and lagged realized volatility based on OLS regression

Index	C	IndexREAL(-1)	IndexPUTVOL	Adjusted R Square
Hangseng	0.09 (0.02)	0.62 (0.08)		0.37
	0.02 (0.03)		0.79 (0.08)	0.44
	0.03 (0.03)	0.19 (0.13)	0.59 (0.15)	0.45
KOSPI	0.18 (0.04)	0.32 (0.14)		0.09
	0.18 (0.04)		0.32 (0.14)	0.09
	0.08 (0.05)	-0.16 (0.23)	0.69 (0.27)	0.19
NIFTY	0.15 (0.04)	0.23 (0.16)		0.03
	0.10 (0.05)		0.44 (0.20)	0.08
	0.10 (0.05)	-0.03 (0.23)	0.46 (0.31)	0.06
TWESW	0.07 (0.03)	0.67 (0.14)		0.40
	0.10 (0.04)		0.48 (0.13)	0.27
	0.07 (0.04)	0.62 (0.23)	0.06 (0.20)	0.38

In all cases the dependent variable is the realized volatility of the index. IndexReal(-1) is lagged realized volatility for the index. IndexPUTVOL is the implied volatility for at the money the call options. The figures in the parenthesis indicate the standard error.

Hang Seng data: 31st January, 1996 to 31st December 2004

KOSPI data :12th January, 2001 to 10th December, 2004.

TWSEW data: 17th January, 2002 to 16th December, 2004.

NIFTY data: 4th July 2001 to 28th October 2004.

Table 4A: Predictability of realized volatility of the Asian equity indices by call implied volatility and lagged realized volatility based on bootstrapped regression

Index	C	IndexREAL(-1)	IndexCALLVOL
Hangseng	0.09 (0.03)	0.65 (0.14)	
	0.02 (0.02)		0.84 (0.10)
	0.05 (0.03)	0.43 (0.31)	0.35 (0.32)
KOSPI	0.18 (0.04)	0.32 (0.12)	
	0.05 (0.06)		0.54 (0.18)
	0.10 (0.06)	0.00 (0.23)	0.54 (0.34)
NIFTY	0.15 (0.03)	0.26 (0.16)	
	0.13 (0.04)		0.43 (0.22)
	0.12 (0.04)	0.09 (0.17)	0.35 (0.26)
TWESW	0.07 (0.03)	0.68 (0.13)	
	0.04 (0.05)		0.73 (0.21)
	0.03 (0.05)	0.57 (0.23)	0.22 (0.33)

In all cases the dependent variable is the realized volatility of the index. IndexReal(-1) is lagged realized volatility for the index. IndexCALLVOL is the implied volatility for at the money the put options. The figures in the parenthesis indicate the standard error.

Hang Seng data: 31st January, 1996 to 31st December 2004

KOSPI data :12th January, 2001 to 10th December, 2004.

TWSEW data: 17th January, 2002 to 16th December, 2004.

NIFTY data: 4th July 2001 to 28th October 2004.

Table 4B: Predictability of realized volatility of the Asian equity indices by call implied volatility and lagged realized volatility based on bootstrapped regression

Index	C	IndexREAL(-1)	IndexPUTVOL
Hangseng	0.05 (0.03)	0.43 (0.31)	
	0.02 (0.02)		0.80 (0.09)
	0.02 (0.03)	0.21 (0.28)	0.60 (0.26)
KOSPI	0.18 (0.04)	0.32 (0.12)	
	0.09 (0.04)		0.53 (0.12)
	0.08 (0.04)	-0.17 (0.20)	0.70 (0.21)
NIFTY	0.15 (0.03)	0.26 (0.16)	
	0.10 (0.06)		0.45 (0.29)
	0.10 (0.07)	-0.01 (0.24)	0.47 (0.47)
TWESW	0.07 (0.03)	0.68 (0.13)	
	0.09 (0.03)		0.52 (0.13)
	0.064 (0.032)	0.60 (0.26)	0.09 (0.21)

In all cases the dependent variable is the realized volatility of the index. IndexReal(-1) is lagged realized volatility for the index. IndexPUTVOL is the implied volatility for at the money the call options. The figures in the parenthesis indicate the standard error.

Hang Seng data: 31st January, 1996 to 31st December 2004

KOSPI data :12th January, 2001 to 10th December, 2004.

TWSEW data: 17th January, 2002 to 16th December, 2004.

NIFTY data: 4th July 2001 to 28th October 2004.

Table 5A: Instrument specification for implied volatilities for the Asian indices

Index	C	IndexREAL(-1)	IndexOptionVOL(-1)	Adjusted R Square
Hangseng_Call	0.05 (0.01)	0.47 (0.04)	0.37 (0.05)	0.83
Hangseng_Put	0.07 (0.02)	0.55 (0.06)	0.30 (0.07)	0.74
KOSPI_Call	0.10 (0.03)	0.53 (0.08)	0.18 (0.10)	0.62
KOSPI_Put	0.07 (0.02)	0.56 (0.07)	0.31 (0.08)	0.74
NIFTY_Call	0.05 (0.02)	0.33 (0.08)	0.31 (0.13)	0.42
NIFTY_Put	0.04 (0.02)	0.46 (0.07)	0.39 (0.10)	0.67
TWESW_Call	0.13 (0.04)	0.48 (0.12)	0.08 (0.15)	0.40
TWESW_Put	0.03 (0.03)	0.77 (0.14)	0.20 (0.12)	0.62

The dependent variable is the observed option implied volatility. In case of call options the independent variables are the lagged observed call implied volatility and lagged realized volatility. In case of put options the independent variables are the lagged observed put implied volatility and lagged realized volatility. The figures in the parenthesis indicate the standard error.

Hang Seng data: 31st January, 1996 to 31st December 2004

KOSPI data :12th January, 2001 to 10th December, 2004.

TWSEW data: 17th January, 2002 to 16th December, 2004.

NIFTY data: 4th July 2001 to 28th October 2004.

Table 5B: Instrument specification obtained by the bootstrap method for implied volatilities for the Asian indices

Index	C	IndexREAL(-1)	IndexOptionVOL(-1)
Hangseng_Call	0.05 (0.01)	0.45 (0.06)	0.39 (0.07)
Hangseng_Put	0.07 (0.19)	0.55 (0.08)	0.30 (0.08)
KOSPI_Call	0.10 (0.02)	0.53 (0.10)	0.19 (0.11)
KOSPI_Put	0.07 (0.02)	0.56 (0.09)	0.31 (0.10)
NIFTY_Call	0.04 (0.03)	0.40 (0.18)	0.29 (0.10)
NIFTY_Put	0.04 (0.02)	0.46 (0.10)	0.40 (0.11)
TWESW_Call	0.13 (0.04)	0.49 (0.10)	0.10 (0.13)
TWESW_Put	0.03 (0.03)	0.76 (0.24)	0.21 (0.13)

The dependent variable is the observed option implied volatility. In case of call options the independent variables are the lagged observed call implied volatility and lagged realized volatility. In case of put options the independent variables are the lagged observed put implied volatility and lagged realized volatility. The figures in the parenthesis indicate the standard error. Note that none of the instruments are statistically different from the one obtained by OLS estimation in Table 5A.

Hang Seng data: 31st January, 1996 to 31st December 2004

KOSPI data :12th January, 2001 to 10th December, 2004.

TWSEW data: 17th January, 2002 to 16th December, 2004.

NIFTY data: 4th July 2001 to 28th October 2004.

Table 6: Baisedness and Predictive ability of implied volatility when observed through an instrumental variable

Dependent Variable	C	Call implied volatility	Put implied volatility	Adjusted R Square	F statistic (P values)Wald TestC =0, α =1
Hangseng realized volatility	-0.01 (0.03)	0.97 (0.12)		0.38	1.77 (0.17)
	-0.01 (0.03)		0.90 (0.11)	0.38	8.29 (0.00)
KOSPI realized volatility	0.12 (0.07)	0.50 (0.24)		0.07	5.27 (0.01)
	0.13 (0.07)		0.42 (0.21)	0.06	16.47 (0.00)
NIFTY realized volatility	0.09 (0.08)	0.66 (0.43)		0.03	1.87 (0.17)
	0.10 (0.07)		0.43 (0.29)	0.03	3.26 (0.05)
TWESW realized volatility	-0.12 (0.07)	1.31 (0.28)		0.39	6.86 (0.00)
	0.04 (0.04)		0.72 (0.16)	0.36	7.07 (0.00)

The figures in the parenthesis indicate the standard error unless mentioned otherwise.

Hang Seng data: 31st January, 1996 to 31st December 2004

KOSPI data :12th January, 2001 to 10th December, 2004.

TWSEW data: 17th January, 2002 to 16th December, 2004.

NIFTY data: 4th July 2001 to 28th October 2004.