A Multi-perspective Assessment of Implied Volatility

Using S&P 100 and NASDAQ Index Options

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I. INTRODUCTION

In this paper, we try to examine the implied volatility of index options. For the purpose of analysis, we use the NASDAQ and S&P 100 index options from January 2, 1996 to November 30, 2001. We first describe the behavior of the implied volatility of NASDAQ and S&P 100 index options between January 2, 1996 and November 31, 2001. Second, we take a close look into the relationship between changes in implied volatility of the index options and the returns on the respective index. Next, we take the next step and try to find out whether there is any significant difference in the level of impact of positive versus negative returns on the respective index on the implied volatility of the option on that index. Then, we try to analyze and describe how implied volatility of both index options changed around 3 major events that took place during the time-frame of analysis: 1997 Southeast Asian currency crisis, 1998 Russian crisis and September 11 World Trade Center event. Finally, we try to find out whether the implied volatility of NASDAQ index option and that of S&P 100 index option changed at distinct rates over the period of analysis. We conclude our paper with a brief summary of findings.

II. PREVIOUS WORK

Previous research finds implied volatility embedded in S&P 100 index option not to be a good predictor of actual volatility. However, Christensen and Prabhala (1998) find that implied volatility outperforms past volatility in forecasting future volatility and even subsumes the information content of past volatility in some of their specifications. They attribute their significantly different results to their use of longer time series and non-overlapping data. Our research involves a similar analysis to that of Christensen and Prabhala. The period that they analyzed was rather a quiet period. October 1987 market crash was the major event. The period that we analyze is more

turbulent. We reexamine the relationship between implied volatility and actual volatility. In addition to S&P 100 index options, we also use the NASDAQ index options. Furthermore, our research looks into the relationship between return and volatility as well.

III. DATA

All the data used in this paper span a time frame from January 1, 1996 to November 31, 2001[1]. All the data have been obtained from Chicago Board of Option Exchange web-site (www.cboe.com).

Below is a descriptive summary of all the variables used to analyze implied volatility:

Table 1: SUMMARY STATISTICS FOR THE OPTIONS AND THE INDICES

	Variable	N	Mean	Standard Deviation	Minimum	Maximum
PANEL A						
	DVXN	*1491*	*43.16%*	*14.90%*	*24.00%*	*93.00%*
	DVIX	*1491*	*24.47%*	*5.67%*	*12.74%*	*49.04%*
PANEL B						
	DROEX	*1490*	*0.054%*	*1.27%*	*-7.24%*	*5.77%*
	DRNDX	*1490*	*0.099%*	*2.54%*	*-9.86%*	*18.77%*

**Descriptive statistics of all the variables used in the analyses: Average implied volatility of NASDAQ index options over the period is 43.16% with a standard deviation of 14.90%. Similarly, the mean implied volatility of S&P 100 index options is 24.47% with a standard deviation of 5.67%. The average daily return on the S&P 100 index turns out to be 0.054% with a standard deviation of 1.27% and that on the NASDAQ index is 0.099% with a standard deviation of 2.54%.*

where DVXN: implied volatility figure for NASDAQ index options in annualized terms

DVIX: implied volatility figure for S&P 100 index options in annualized terms

DROEX: daily return on the S&P 100 index

DRNDX: daily return on the NASDAQ index

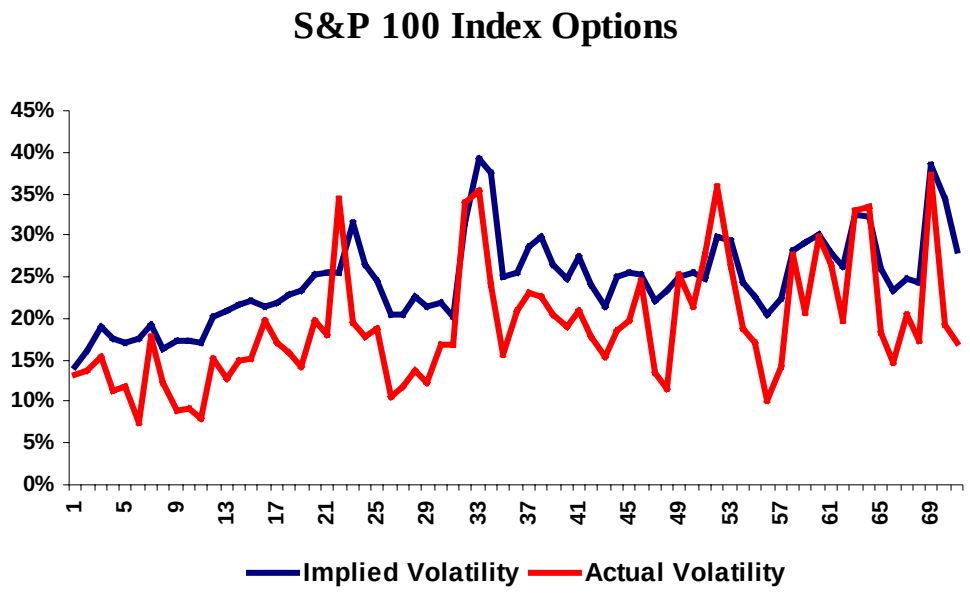
From January 1, 1996 to November 30, 2001, implied volatility of NASDAQ index options *("DVXN")* was in a range of 24% to 93% with a mean of 43.16% and a standard deviation of 14.90%. Implied volatility of S&P 100 index options *("DVIX")* was in a range of 12.74% to 49.04% with a mean of 24.47% and standard deviation of 5.67%. In the same period, daily return on NASDAQ index *("DRNDX")* ranged from –9.86% to 18.77% with a mean of 0.099% and standard deviation of 2.54%. Similarly, daily return on S&P 100 index *("DROEX")* had a minimum value of -7.24% and a maximum of 5.88% with a mean of 0.054% and a standard deviation of 1.27%.

IV. COMPARISON of IMPLIED VOLATILITY & ACTUAL VOLATILITY

As described above, implied volatility is obtained from the Black & Scholes formula by plugging in the stock price, strike price, option price and interest rate and solving for the only remaining variable, σ. The volatility figure obtained in this way is a forward looking volatility estimate. The realized (actual volatility) can be calculated by computing the standard deviation of the daily stock returns over a given period of time, which is taken to be 1 month for the purpose of this analysis. It should be noted that implied volatility is consistently higher than actual volatility. Therefore, implied volatility cannot be deemed as an accurate measure of actual volatility. However, if it is possible to show that there is somewhat a consistent relationship between implied volatility and actual volatility, this could be of help. The graph below shows the implied and actual volatility of S&P 100 index options from January 1, 1996 to November 31, 2001 on a monthly basis.

[1] VXN data for June 11, 1998, January 31, 1997, December 16, 1996 and December 4, 1996 are averages of the data of the previous trading day and the following trading day.

Figure 1: IMPLIED VERSUS ACTUAL VOLATILITY OF S&P 100 INDEX OPTIONS



* *A graph of the monthly implied volatility and actual volatility of S&P 100 index options from Jan 96 to Nov 01. . Actual volatility in month t is computed as the standard deviation of the daily returns on the S&P 100 index in month t. The reported figure for actual volatility is in annual terms. Implied volatility in month t is the mean of the daily implied volatility of the S&P 100 index option.*

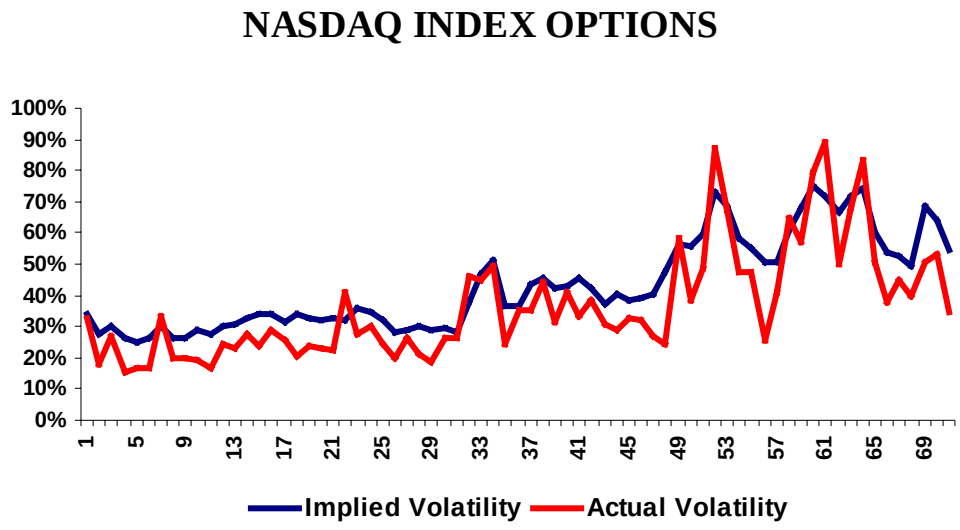
Table 2:SUMMARY STATISTICS FOR MONTHLY VOLATILITY OF S&P 100

Variable	N	Mean	Standard Deviation	Minimum	Maximum
Implied Volatility (S&P 100)	*71*	*24.54%*	*5.22%*	*14.15%*	*39.25%*
Actual Volatility (S&P 100)	*71*	*19.06%*	*7.12%*	*7.45%*	*37.39%*

**Descriptive statistics of the monthly implied volatility and actual volatility of S&P 100 index option: The mean monthly implied volatility of S&P 100 index options is 24.54% with a standard deviation of 5.22%. Similarly, the average monthly actual volatility of S&P 100 index options is 19.06% and the standard deviation is 7.12%.*

Below is the graph of the implied and realized volatility of NASDAQ index option:

Figure 2: IMPLIED VERSUS ACTUAL VOLATILITY OF NASDAQ INDEX OPTIONS



**A graph of the monthly implied volatility and actual volatility of NASDAQ index options from Jan 96 to Nov 01. Actual volatility in month t is computed as the standard deviation of the daily returns on the NASDAQ index in month t. The reported figure for actual volatility is in annual terms. Implied volatility in month t is the mean of the daily implied volatility of the NASDAQ index option.*

Table 3: SUMMARY STATISTICS FOR MONTHLY VOLATILITY OF NASDAQ

Variable	N	Mean	Standard Deviation	Minimum	Maximum
Implied Volatility (NASDAQ)	*71*	*43.28%*	*14.72%*	*24.80%*	*75.17%*
Actual Volatility (NASDAQ)	*71*	*36.69%*	*17.46%*	*15.41%*	*88.81%*

**Descriptive statistics of the monthly implied volatility and actual volatility of NASDAQ index option: The mean monthly implied volatility of NASDAQ index options is 43.28% with a standard deviation of 14.72%. Similarly, the average monthly actual volatility of NASDAQ index options is 36.69% and the standard deviation is 17.46%..*

As can be seen, there is a consistent trend between implied volatility and actual volatility for both S&P 100 and NASDAQ index options. Though implied volatility is usually higher than actual (realized) volatility, they seem to move together. Furthermore, we conducted a pair t-test to show that the implied volatility is consistently higher than actual volatility. AMVXN is the annualized monthly implied volatility for the NASDAQ index option and AMNDX is the annualized monthly actual volatility for the NASDAQ index option. Likewise, AMVIX represents the annualized monthly implied volatility for S&P 100 index options and AMOEX represents the annualized monthly actual volatility for S&P 100 index options. Below is the output for both hypotheses testing:

Table 4:

Paired T-Test and CI: AMVXN, AMNDX

```
Paired T for AMVXN - AMNDX

                 N      Mean     StDev   SE Mean
AMVXN           71    0.4328    0.1472    0.0175
AMNDX           71    0.3669    0.1746    0.0207
Difference      71   0.06597   0.07581   0.00900

99% lower bound for mean difference: 0.04455
T-Test of mean difference = 0 (vs > 0): T-Value = 7.33  P-Value = 0.000
```

** Output for the hypothesis testing of whether implied volatility of NASDAQ index options is higher than actual volatility of NASDAQ index options. We conclude with 99% confidence that implied volatility of NASDAQ index options is on average 4.46% higher than actual volatility of NASDAQ index options.*

Table 5:

Paired T-Test and CI: AMVIX, AMOEX

```
Paired T for AMVIX - AMOEX

                 N      Mean     StDev   SE Mean
AMVIX           71   0.24545   0.05216   0.00619
AMOEX           71   0.19057   0.07118   0.00845
Difference      71   0.05488   0.04278   0.00508

99% lower bound for mean difference: 0.04280
T-Test of mean difference = 0 (vs > 0): T-Value = 10.81  P-Value = 0.000
```

** Output for the hypothesis testing of whether implied volatility of S&P 100 index options is higher than actual volatility of S&P 100 index options. We conclude with 99% confidence that implied volatility of S&P 100 index options is on average 4.28% higher than actual volatility of S&P 100 index options.*

As can be seen, at 99% confidence level, we can conclude that annualized monthly implied volatility for both index options is significantly higher than actual annualized monthly volatility for both index options. In both cases, we get p-values very close to zero. Below is the table that shows the correlation among the implied monthly volatility of S&P100 index option (VIX), the actual monthly volatility of S&P 100 index option (OEX), the implied monthly volatility of NASDAQ index option (VXN) and the actual monthly volatility of NASDAQ index option (NDX):

Table 6:CORRELATION MATRIX FOR IMPLIED AND ACTUAL VOLATILITIES

	VXN	*VIX*	*OEX*	*NDX*
VXN	*1.00*			
VIX	*0.67*	*1.00*		
OEX	*0.64*	*0.80*	*1.00*	
NDX	*0.90*	*0.65*	*0.77*	*1.00*

***** *Correlation matrix of implied volatility and actual volatility of S&P 100 and NASDAQ index options: The correlation between implied and actual monthly volatility of S&P 100 index option is 0.8 and that between implied and actual monthly volatility of NASDAQ index option is 0.90. The correlation between the implied volatilities of both indices turns out to be 0.67 and that between the actual volatilities of both index options is 0.77*

The correlation between implied and actual monthly volatility of S&P 100 index option is 0.8 and that between implied and actual monthly volatility of NASDAQ index option is 0.90. The correlation between the implied volatilities of both indices turns out to be 0.67 and that between the actual volatilities of both index options is 0.77. Overall, we see a strong correlation among the monthly implied and actual volatilities of both index options. They tend to move in parallel.

V. RETURNS & VOLATILITY

It is a commonly held belief that when the return on an index is positive, the implied volatility of the option on that index decreases and likewise, when the return on an index is negative,

the implied volatility of the option on that index increases. As a first step, we regressed the daily change in the implied volatility of the NASDAQ and S&P 100 index options on the respective daily returns on both indices. Below is the output of the regression analyses for both index options:

Table 7:

A regression of Change in Implied Volatility of NASDAQ Index Option on Daily Return on NASDAQ

	Coefficient	t-statistic	p-value	DW	R-SQR
Constant	*0.0008*	*1.95*	*0.051*		
	(0.0004)				
Daily Return on NASDAQ	*-0.6101*	*-37.5*	*0.000*		
	(0.0163)				
F-statistic	*1405.26*		*0.000*		
				2.17	*48.6%*

** Output for regressing the daily return on NASDAQ index option on the daily change in the implied volatility of NASDAQ index option. Daily return on NASDAQ and daily change in the implied volatility of NASDAQ index option seem to move in opposite directions given the negative slope of the regression line. Regression analysis seems to be statistically significant given a close to zero p-value associated with the F-statistic.*

Table 8:

A regression of Change in Implied Volatility of S&P 100 Index Option on Daily Return on S&P 100

	Coefficient	t-statistic	p-value	DW	R-SQR
Constant	*0.0007*	*2.62*	*0.009*		
	(0.0003)				
Daily Return on S&P 100	*-1.1248*	*-54.11*	*0.000*		
	(0.0208)				
F-statistic	*2927.6*		*0.000*		
				2.21	*66.3%*

**Output for regressing the daily return on S&P100 index option on the daily change in the implied volatility of S&P 100 index option. Daily return on S&P 100 and daily change in the implied volatility of S&P 100 index option seem to move in opposite directions given the negative slope of the regression line. Regression analysis seems to be statistically significant given a close to zero p-value associated with the F-statistic.*

In both regressions, the negative sign of the slope confirms the belief that changes in implied volatility of an index option and daily returns on that index tend to move in opposite directions. The slope variables in both regressions seem to be statistically significant with t-statistics yielding close to zero p-values. Furthermore, the F-statistics in both regressions yield close to zero p-values, validating the significance of the regression analyses. Finally, the Durbin Watson statistic is close to 2, signifying that the error terms are independently distributed. As a result, we can conclude that

when we have a positive return on the index, the implied volatility of the option on that index is likely to go down. Similarly, when we have a negative return on the index, the implied volatility of the option on that index is likely to go up. One interesting observation is that the magnitude of the change in the implied volatility of S&P 100 index option is higher than that of the NASDAQ index option. One would expect the converse to be the case as NASDAQ contains new technology firms, which have more volatile businesses than old economy firms of the S&P 100. This might be partially explained by the fact that the volatility is already high in NASDAQ. The change from the already-high volatility associated with NASDAQ can be reasonably lower than that from a usual level of volatility associated with S&P 100.

In order to be able to assess the difference in the levels of impact between positive returns and negative returns on indices, we used the following regression equation:

$$\text{Change in IV} = a + b * \text{Return on index} + c * \text{Dummy} + d * (\text{Return on index} * \text{Dummy})$$

$$\text{Where Dummy} = \begin{cases} 1 \text{ if Return} > 0 \\ 0 \text{ otherwise} \end{cases}$$

Therefore, when the Return on the index is positive, the intercept would be (a+c) and the slope would be (b+d); whereas, when the return on the index is negative, the intercept would be a and the slope would be b only. Below are the regression results for both indices:

Table 9:

A regression of Change in Implied Volatility of S&P 100 Index Option on DUMOEX, DUMOEX *ROEX and DROEX

	Coefficient	t-statistic	p-value	DW	R-SQR
Constant	*-0.0023*	*-4.09*	*0.000*		
	(0.0006)				
DUMOEX	*0.0029*	*3.70*	*0.000*		
	(0.0008)				
*DUMOEX*ROEX*	*0.3169*	*5.17*	*0.000*		
	(0.0613)				
DROEX	*-1.3678*	*-31.5*	*0.000*		
	(0.0434)				
F-statistic	*1014.47*		*0.000*		
				2.16	*67.2%*

**Output for regressing the daily return on S&P100 index option and a dummy variable to capture the difference between positive and negative returns on the daily change in the implied volatility of S&P 100 index option. When we have a positive return on the index, by plugging 1 for the dummy variable, we get a slope coefficient of -1.053. As expected, a positive return on the index leads to a decline in implied volatility of the option on the index. Likewise, a negative return on the index leads to an increase in the implied volatility of the index option by 1.37 units. The regression analysis seems to be statistically significant given the close to zero p-value associated with the F-statistic.*

From the above analysis on the S&P 100 index, we can infer the following results:

- Both the intercept and slope of the regression lines for negative and positive returns are statistically significant and different. The p-value associated with the t-statistic is zero.
- Since Durbin-Watson statistic is close to 2, the error terms can be deemed to be independently distributed.
- A unit increase in the return on the S&P 100 index leads to a decrease of (-1.37 + 0.317) = -1.053 units in implied volatility of the S&P 100 index option.
- Similarly, a unit decrease in the return on the S&P 100 index leads to an increase of 1.37 units in implied volatility of the S&P 100 index option.

We conducted a hypothesis testing of whether the impact of a positive return is statistically different from that of a negative return. The t-statistic turns out to be –24.10 with an associated p-value of close to zero at 95% confidence level. Therefore, we conclude that the impact of a negative return is higher than that of a positive return.

Table 10:

A regression of Change in Implied Volatility of NASDAQ Index Option on DUMNDX, DUMNDX *RNDX and DRNDX

	Coefficient	t-statistic	p-value	DW	R-SQR
Constant	*-0.0001*	*-0.10*	*0.918*		
	(0.0009)				
DRNDX	*-0.6632*	*-18.30*	*0.000*		
	(0.0362)				
DUMNDX	*-0.0002*	*-0.13*	*0.900*		
	(0.0012)				
*DUMNDX*RNDX*	*0.1060*	*2.20*	*0.028*		
	(0.0482)				
F-statistic	*471.02*		*0.000*		
				2.17	*48.7%*

**Output for regressing the daily return on NASDAQ index option and a dummy variable to capture the difference between positive and negative returns on the daily change in the implied volatility of NASDAQ index option. When we have a positive return on the index, by plugging 1 for the dummy variable, we get a slope coefficient of –0.557. As expected, a positive return on the index leads to a decline in implied volatility of the option on the index. Likewise, a negative return on the index leads to an increase in the implied volatility of the index option by 0.663 units. The regression analysis seems to be statistically significant given the close to zero p-value associated with the F-statistic.*

From the above analysis on the NASDAQ index, we can infer the following results:

- The slope of the regression lines for negative and positive returns are statistically significant and different. The p-value associated with the t-statistic is zero. However, the intercept turns out to be statistically insignificant for both cases.
- Since the Durbin-Watson statistic is close to 2, the error terms can be considered to be independently distributed.
- A unit increase in the return on the NASDAQ index leads to a decrease of (-0.663 + 0.106) = -0.557 units in implied volatility of the NASDAQ index option.
- Similarly, a unit decrease in the return on the NASDAQ index leads to an increase of 0.663 units in implied volatility of the NASDAQ index option.

We conducted a hypothesis testing of whether the impact of a positive return is statistically different from that of a negative return. The t-statistic turns out to be –17.19 with an associated p-value of close to zero at 95% confidence level. Therefore, we again conclude that the impact of a negative return is higher than that of a positive return.

In both cases, we observe that decrease in the return on the index leads to a more drastic impact on the implied volatility of the respective option. This can be explained by the financial leverage[2]. As the equity value of the company declines, the financial leverage of the company becomes higher. The riskiness of the company increases, leading to a substantial increase in volatility. Similarly, as the company's equity value becomes higher, the financial leverage drops. Therefore, the equity becomes less risky and volatility decreases. As a result, when there is a positive return on the index, the financial leverage drops due to a higher equity value. This drop also leads to a concurrent drop in volatility in light of the aforementioned argument. Likewise, when there is a negative return on the index, the financial leverage increases due to a lower equity value. This increase in financial leverage also causes a simultaneous increase in volatility.

A different perspective to see the difference in the impact of positive versus non-positive returns on the implied volatility of the index option would involve the division of the data set into 2 groups. Specifically, the time period that spans from January 1, 1996 to March 1, 2000 can be considered as a bullish period and the time period from March 1, 2000 to November 31, 2001 can be deemed as a bearish period. In this case, we would like to test the unit change in implied volatility of an index option at bullish times versus bearish times. In order to make such an assessment, we regressed the daily change in implied volatility of both index options against the daily returns on the respective index once for the bullish period and once for the bearish period. Below is the output of the regression on S&P 100 index options for bearish and bullish times:

[2] Bekaert and Wu (2000), Black (1976), Christie (1982) and Nelson (1991)

Table 11:

A Regression of Change in Implied Volatility of S&P 100 Index Option on the Return on S&P 100 in a Bullish Period

	Coefficient	t-statistic	p-value	DW	R-SQR
Constant	*0.0013*	*4.03*	*0.000*		
	(0.0003)				
Daily Return on S&P 100	*-1.2244*	*-45.09*	*0.000*		
	(0.0272)				
F-statistic	*2032.84*		*0.000*		
				2.23	*66.0%*

**Output for regressing the daily return on S&P100 index option on the daily change in the implied volatility of S&P 100 index option during the bullish period of January 1996 to March 2000. Daily return on S&P 100 and daily change in the implied volatility of S&P 100 index option seem to move in opposite directions given the negative slope of the regression line. Regression analysis seems to be statistically significant given a close to zero p-value associated with the F-statistic.*

Table 12:

A Regression of Change in Implied Volatility of S&P 100 Index Option on the Return on S&P 100 in a Bearish Period

	Coefficient	t-statistic	p-value	DW	R-SQR
Constant	*-0.0004*	*-0.86*	*0.388*		
	(0.0005)				
Daily Return on S&P 100	*-0.9904*	*-31.91*	*0.000*		
	(0.0310)				
F-statistic	*1018.01*		*0.000*		
				2.14	*69.9%*

**Output for regressing the daily return on S&P100 index option on the daily change in the implied volatility of S&P 100 index option during the bearish period of March 2000 to November 2001. Daily return on S&P 100 and daily change in the implied volatility of S&P 100 index option seem to move in opposite directions given the negative slope of the regression line. Regression analysis seems to be statistically significant given a close to zero p-value associated with the F-statistic.*

From the above analysis, we can deduce the following:

- The slopes of the regression lines are statistically significant as the p-value associated with the t-statistic is close to zero. In other words, positive returns on an index option are associated with decreases in implied volatility of the options on that index.
- The Durbin-Watson statistics are close to 2, so there is no apparent problem with the assumption that the error terms are independently distributed.
- In a bullish market, a unit change in the return on the S&P 100 index leads to a change of 1.22 units in the opposite direction in the implied volatility of the S&P 100 index option.

❖ In a bearish market, a unit change in the return on the S&P 100 index leads to a change of only 0.99 units in the opposite direction in the implied volatility of the S&P 100 index option.

Below is the output of the regression on NASDAQ index options for bearish and bullish times:

Table 13:

A Regression of Change in Implied Volatility of NASDAQ Index Option on the Return on NASDAQ in a Bullish Period

	Coefficient	t-statistic	p-value	DW	R-SQR
Constant	*0.0016*	*4.26*	*0.000*		
	(0.0004)				
Daily Return on NASDAQ	*-0.6744*	*-33.99*	*0.000*		
	(0.198)				
F-statistic	*1155.63*		*0.000*		
				2.03	*52.4*

**Output for regressing the daily return on NASDAQ index option on the daily change in the implied volatility of NASDAQ index option during the bullish period of January 1996 to March 2000. Daily return on NASDAQ and daily change in the implied volatility of NASDAQ index option seem to move in opposite directions given the negative slope of the regression line. Regression analysis seems to be statistically significant given a close to zero p-value associated with the F-statistic.*

Table 14:

A Regression of Change in Implied Volatility of NASDAQ Index Option on the Return on NASDAQ in a Bearish Period

	Coefficient	t-statistic	p-value	DW	R-SQR
Constant	*-0.0010*	*-0.99*	*0.323*		
	(0.0010)				
Daily Return on NASDAQ	*-0.5681*	*-19.88*	*0.000*		
	(0.0286)				
F-statistic	*395.21*		*0.000*		
				2.29	*47.3%*

**Output for regressing the daily return on NASDAQ index option on the daily change in the implied volatility of NASDAQ index option during the bullish period of March 2000 to November 2001. Daily return on NASDAQ and daily change in the implied volatility of NASDAQ index option seem to move in opposite directions given the negative slope of the regression line. Regression analysis seems to be statistically significant given a close to zero p-value associated with the F-statistic.*

From the above analyses, we can draw the following conclusions:

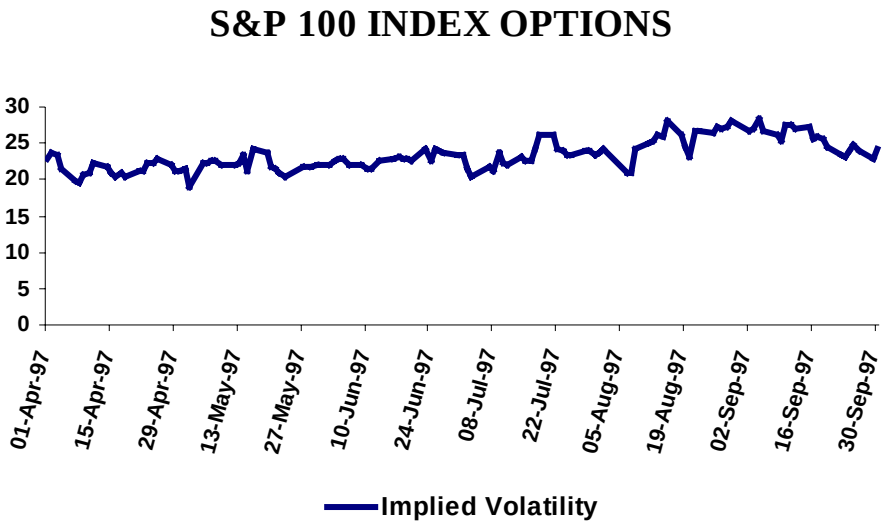
❖ The slopes of the regression lines are statistically significant as the p-value associated with the t-statistic is close to zero.

- The Durbin-Watson statistics are close to 2, so there is no apparent problem with the assumption that the error terms are independently distributed.
- In a bullish market, a unit change in the return on the S&P 100 index leads to a change of 0.674 units in the opposite direction in the implied volatility of the S&P 100 index option.
- In a bearish market, a unit change in the return on the S&P 100 index leads to a change of only 0.568 units in the opposite direction in the implied volatility of the S&P 100 index option.

VI. A DESCRIPTION OF TIMES OF CRISES

The time span in the data set includes 3 major events. Each event is analyzed within a six-month time frame such that the onset of the event falls into the midst of the six-month time frame. The first one is the Southeast Asian currency crisis in the summer of 1997. The second one is the Russian crisis that took place in the fall of 1998. Finally, the World Trade Center event took place on September 11, 2001. Below is the graphical display of the implied volatility of the S&P 100 index options between April 1, 1997 and September 30, 1997:

Figure 3: **IMPLIED VOLATILITY OF S&P 100 INDEX OPTIONS**

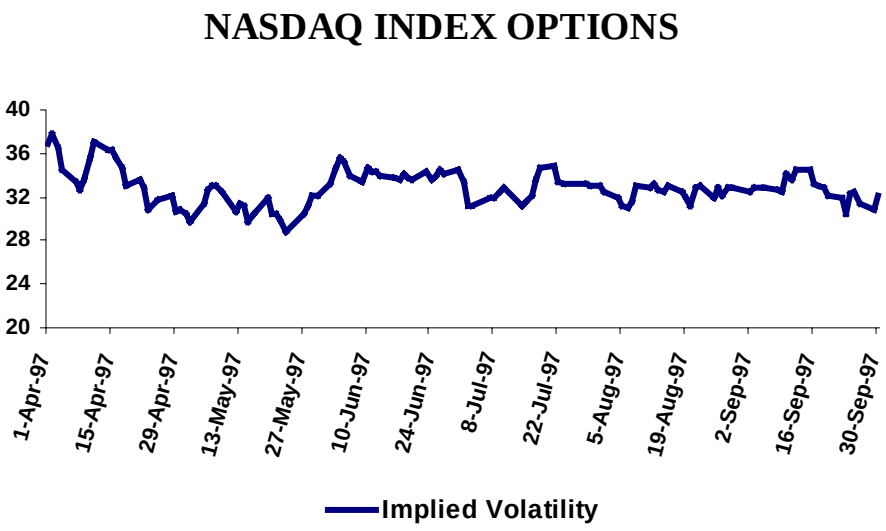


** A graphical display of the implied volatility of S&P 100 index options from April 1997 to Sep 1997. There appears to be no drastic change in the trend of the implied volatility due to the Southeast Asian currency crisis. Implied volatility seems to hover around a mean of 23.35%. It reached a minimum of 19.01% and a maximum of 28.28%.*

We would expect to see a drastic increase in implied volatility when the currency crisis broke out in Southeast Asia around June-July 1997. However, the implied volatility seems to maintain its trend and hover around an average of 23.35% in the six-month period analyzed. The minimum value

of implied volatility was 19.01% and the maximum was 28.28%. The graph below shows the implied volatility of NASDAQ index options between April 1, 1997 and September 30, 1997:

Figure 4:IMPLIED VOLATILITY OF NASDAQ INDEX OPTIONS



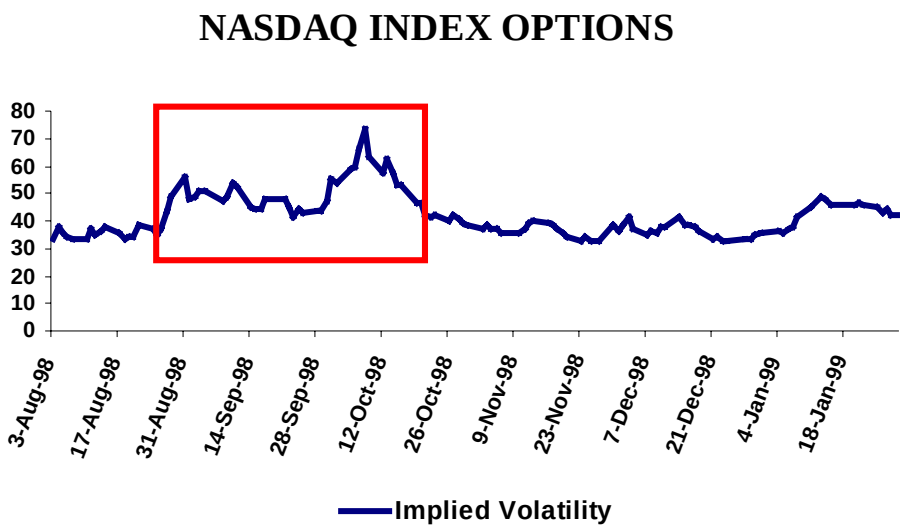
** A graphical display of the implied volatility of NASDAQ index options from April 1997 to Sep 1997. There appears to be no drastic change in the trend of the implied volatility due to the Southeast Asian currency crisis. Implied volatility seems to hover around a mean of 32.85%. It reached a minimum of 27.88% and a maximum of 37.73%.*

As it was the case with the implied volatility of S&P 100 index options, the implied volatility embedded in the NASDAQ index options do not seem to react to the Asian crisis. It fluctuates around the six-month mean of 32.85%. The implied volatility oscillated between 27.88% and 37.73%.

This discrepancy can be explained by the proposition that investors did not think that the volatility would be affected longer than a month or so. Since implied volatility is a forward-looking volatility projection, we don't see a peak in the months of June and July in 1997.

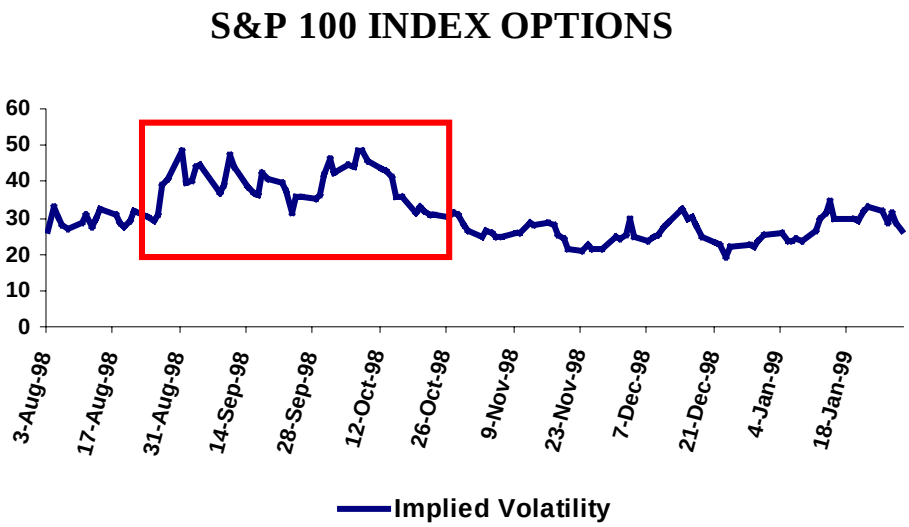
However, implied volatility seems to react strongly to the Russian crisis. Below are the graphs of the implied volatility of both NASDAQ and S&P 100 index options between August 3, 1998 and January 29, 1999:

Figure 5: IMPLIED VOLATILITY OF NASDAQ INDEX OPTIONS



** A graphical display of the implied volatility of NASDAQ index options from August 1998 to January 1999. There appears to be a drastic increase in the trend of the implied volatility due to the Russian crisis as shown by the rectangle. The NASDAQ index option took about 2 months to settle back to its former average level of 42.09%. Implied volatility was as low as 32.32% and skyrocketed to 73.73% on October 8, 1998.*

Figure 6: IMPLIED VOLATILITY OF S&P 100 INDEX OPTIONS

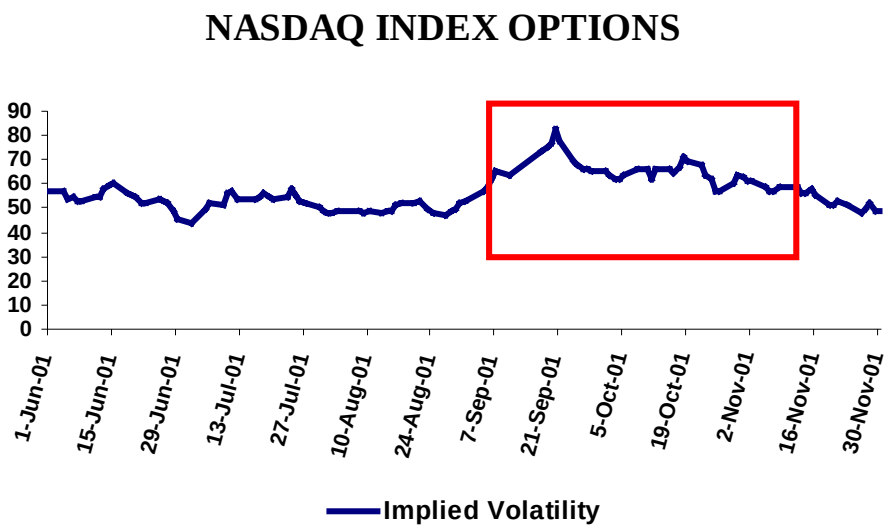


** A graphical display of the implied volatility of S&P 100 index options from August 1998 to January 1999. There appears to be a drastic increase in the trend of the implied volatility due to the Russian crisis as shown by the rectangle. the S&P 100 index option took a month and a half to get back to its previous mean level of 31.32%. The minimum value was 19.34%. However, implied volatility reached a peak of 48.56% on October 8, 1998.*

The NASDAQ index option took about 2 months to settle back to its former average level of 42.09%. Implied volatility was as low as 32.32% and skyrocketed to 73.73% on October 8, 1998. On the other hand, the S&P 100 index option took a month and a half to get back to its previous mean level of 31.32%. The minimum value was 19.34%. However, implied volatility reached a peak of 48.56% on October 8, 1998.

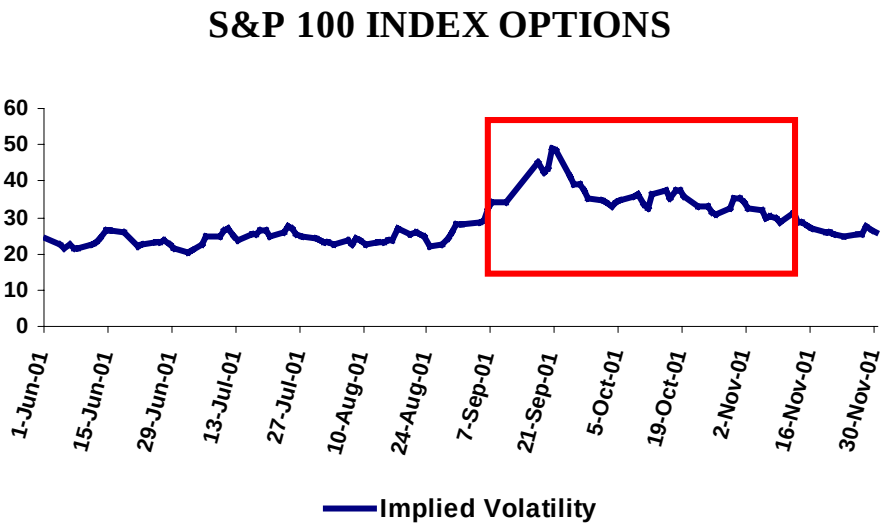
Similarly, we observe a drastic surge in implied volatility of both index options subsequent to the World Trade Center event on September 11, 2001. Below are the graphs of the implied volatility of NASDAQ and S&P 100 index options between June 1, 2001 and November 31, 2001:

Figure 7: IMPLIED VOLATILITY OF NASDAQ INDEX OPTIONS



** A graphical display of the implied volatility of NASDAQ index options from June 2001 to November 2001. There appears to be a drastic increase in the trend of the implied volatility due to the WTC event as shown by the rectangle. The NASDAQ index option took about one and a half months to get back to its previous average of about 56.69%. During this 6-month period, implied volatility went as low as 43.97% and soared to 82.49% on September 20, 2001.*

Figure 8: IMPLIED VOLATILITY OF S&P 100 INDEX OPTIONS



** A graphical display of the implied volatility of S&P 100 index options from June 2001 to November 2001. There appears to be a drastic increase in the trend of the implied volatility due to the WTC event as shown by the rectangle .The implied volatility of S&P 100 index options leveled down to former mean of 28.49%. The minimum value was 20.29%. Implied volatility reached a maximum of 49.04% on September 20, 2001.*

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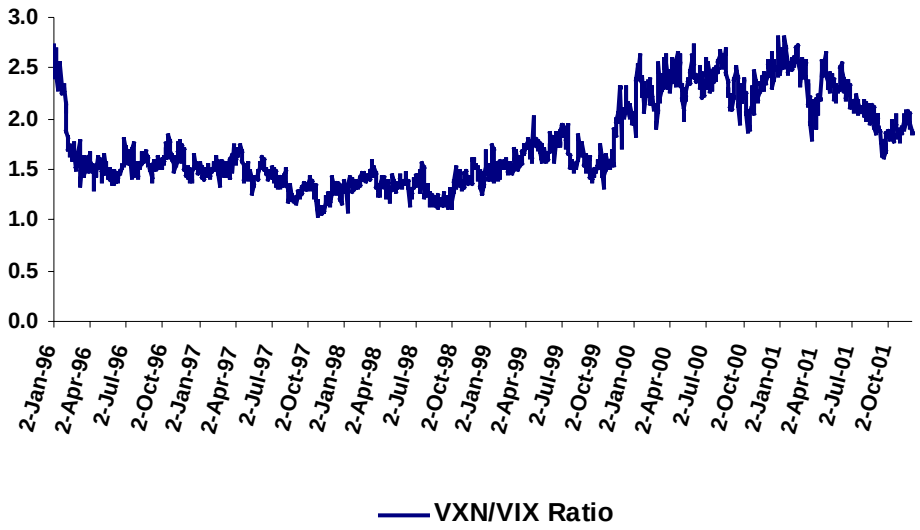
The NASDAQ index option took about one and a half months to get back to its previous average of about 56.69%. During this 6-month period, implied volatility went as low as 43.97% and soared to 82.49% on September 20, 2001. Meanwhile, within almost the same time frame, implied volatility of S&P 100 index options leveled down to former mean of 28.49%. The minimum value was 20.29%. Implied volatility reached a maximum of 49.04% on September 20, 2001.

As can easily be seen above, the NASDAQ index option generally has a higher volatility than the S&P 100 index option. We wanted to see whether the volatility of NASDAQ index options was significantly higher than that of the S&P 100 index option at bullish times versus bearish times. The graph below shows the ratio of the implied volatility of NASDAQ index options ("VXN") to the implied volatility of S&P 100 index options ("VIX") between January 1, 1996 and November 31, 2001:

Figure 9: VXN/VIX RATIO



** A plot of the ratio of implied volatility of NASDAQ index options to that of S&P 100 index options from Jan 1996 to November 2001. The ratio displays a strong trend towards increasing over time. During the bullish period which spans from January 2, 1996 to Feb 29, 2000, the ratio had a mean of 1.543. The lowest value was 1.039. It had a maximum of 2.717 on January 3, 1996. On the other hand, during the bearish period from March 1, 2000 to November 30, 2001, the ratio maintained an average of 2.278. The minimum value was 1.61. It reached a peak of 2.812 on January 12, 2001*

We clearly see from the graph above that the ratio increased significantly towards the end of the time frame. During the bullish period which spans from January 2, 1996 to Feb 29, 2000, the ratio had a mean of 1.543. The lowest value was 1.039. It had a maximum of 2.717 on January 3, 1996. On the other hand, during the bearish period from March 1, 2000 to November 30, 2001, the ratio maintained an average of 2.278. The minimum value was 1.61. It reached a peak of 2.812 on January 12, 2001. This is evidently the result of the technological bust. NASDAQ index is composed of primarily technology stocks. With the bust, the stock prices plummeted and the volatility soared. S&P 100 index, mostly composed of old economy firms, did not experience a paralleled drop in stock prices. Therefore, the volatility of the index options was not as high as that of NASDAQ index options. Both effects caused the ratio to get larger in time. We tested the hypotheses that the ratio in the bullish period is equal to the ratio in the bearish period against the alternative hypotheses that the ratio in the bearish period was significantly different from that in the bullish period. Below is the output of the hypothesis test:

Table 15:

Two-sample T for BEAR vs BULL

```
         N      Mean     StDev   SE Mean
BEAR   440     2.278     0.244     0.012
BULL  1051     1.543     0.271    0.0083

Difference = mu BEAR - mu BULL
Estimate for difference:  0.7353
95% CI for difference: (0.7060, 0.7646)
T-Test of difference = 0 (vs not =): T-Value = 49.23  P-Value = 0.000  DF = 1489
Both use Pooled StDev = 0.263
```

** Output for the hypothesis test as to whether the ratio of the implied volatility of NASDAQ index options to that of S&P 100 index options changed over time, especially from a bullish era (January 1996 to March 2000) to a bearish era (March 2000 to November 2001). We see that the ratio was significantly higher at bearish times than that at bullish times.*

The p-value associated with the t-statistic turns out to be close to zero, as a result of which we can reject the null hypothesis and conclude that the ratio changed significantly from the bullish to

the bearish period. The mean value for the ratio in the bearish era was 2.278 and that in the bullish era was 1.543. With the technological bust, the volatility of NASDAQ index options increased much more than that of S&P 100 index options, leading to a larger ratio.

VII. CONCLUSION

We find that implied volatility is indeed a good predictor of actual volatility as proposed by Christensen and Prabhala (1997) even in a more turbulent period that spans from January 1996 to November 2001. The monthly implied volatility and actual volatility of both index options exhibit a strong correlation coefficient. Moreover, the actual volatilities of both indices show a fairly strong correlation. We also show that the annualized monthly implied volatility is significantly higher than the actual volatility for both index options in line with empirical observations. Further, our analysis confirms the empirical observation that there is an inverse relationship between returns and implied volatility. Specifically, a positive return on both indices is associated with a decline in the implied volatility of the respective index option and vice versa. For both the S&P 100 index option and the NASDAQ index option, a negative return has a greater impact on the change of implied volatility than a positive return. We attribute this difference to the leverage effect and crashophobia. Surprisingly, the 1997 Southeast Asian currency crisis does not seem to have a significant impact on the implied volatility of index options contrary to what one might expect. We suggested that investors did not think the volatility would be affected longer than a month or so. Since implied volatility is forward-looking, we did not observe any peak in implied volatility of both index options around that period. However, we see a drastic surge in implied volatility of both index options around the periods when the 1998 Russian crisis and The September 11 World Trade Center event took place. Finally, we concluded that the ratio of implied volatility of the NASDAQ index options

to that of S&P 100 index options has increased significantly over time. Technological bust led to a far greater increase in the volatility of NASDAQ index options than in that of S&P 100 index options.

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