Is Systematic Risk Priced in Options?

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(January 17, 2006)

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JEL classification code: G10, G13

*Both authors acknowledge the financial support from the Social Sciences and Humanities Research Council of Canada. We are grateful to N. Kapadia, G. Bakshi and D. Madan for supplying the data set and thank Baha Circi and Jun Zhou for their research assistance. We also thank seminar/conference participants at McMaster University, Queen's University, CFTC, Institute of Economics of Academia Sinica, and the 2005 annual meeting of the Northern Finance Association for their comments. Both authors are with the Joseph L. Rotman School of Management, University of Toronto. Duan's email: jcduan@rotman.utoronto.ca; Wei's email: wei@rotman.utoronto.ca.

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Abstract

In this empirical study, we challenge the prevalent notion that systematic risk of the underlying asset has no effect on option prices as long as the total risk remains fixed, a long cherished prediction of the Black-Scholes option pricing theory. We do so by examining two testable hypotheses relating both the level and slope of implied volatility curves to the systematic risk of the underlying asset. Using daily option quotes on the S&P 100 index and its 30 largest component stocks, we show that after controlling for the underlying asset's total risk, a higher amount of systematic risk leads to a higher level of implied volatility and a steeper slope of the implied volatility curve. The findings are robust to various alternative specifications and estimations. Our empirical conclusions turn out to be consistent with the newly emerged GARCH option pricing theory.

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1 Introduction

Since the seminal work of Black and Scholes (1973), literally thousands of papers have been written to apply or generalize the Black-Scholes option pricing theory and to empirically test various option pricing models. The empirical evidence to date suggests that the Black-Scholes model exhibits serious structural biases, which are (1) the Black-Scholes implied volatility smile/smirk phenomenon, (2) the term structure of implied volatility and its flattening with maturity, (3) the Black-Scholes implied volatilities being systematically higher than the historical or realized volatility, (4) the risk-neutral return distribution's negative skewness being more pronounced than that of the physical return distribution, and (5) the index options having more pronounced volatility smile/smirk than individual options. The first three biases are well known, see for example, Dumas, Fleming and Whaley (1998). The fourth and fifth biases are documented for the post 1987 crash markets in, for example, Jackwerth (2000), Dennis and Mayhew (2002), and Bakshi, Kapadia and Madan (2003) (BKM hereafter).

It turns out that the first two biases can be tackled by simply relaxing the geometric Brownian motion assumption; for example, one can introduce jumps and/or stochastic volatility without altering the risk-neutral pricing premise of the Black-Scholes theory. The last three biases, however, appear to be fundamentally at odd with the idea of risk-neutral pricing. They indicate structural differences between the risk-neutral and physical return distributions.

Our study is motivated by this realization. Particularly, since the risk-neutral return distribution differs from the physical one by a risk premium term, we suspect that these empirical regularities may be attributed in part to the systematic risk of the underlying asset. The last empirical regularity is particularly suggestive because a broad-based equity index is expected to have a higher systematic risk vis-à-vis individual stocks. We therefore empirically examine whether the implied volatility pattern is related to the systematic risk of the underlying asset. Our results demonstrate convincingly that the options' implied volatilities are indeed influenced by the systematic risk of the underlying asset. Specifically, after controlling for the overall level of total risk, a higher amount of systematic risk leads to a higher level of implied volatility and a steeper implied volatility curve. In short, systematic risk is priced in options.

Despite the large body of empirical literature devoted to the analysis of the implied volatility, we are only aware of Dennis and Mayhew (2002) that empirically established the link between the risk-neutral skewness and the systematic risk of the underlying stock. The lack of attention on systematic risk is not at all surprising. The most cherished prediction of the Black-Scholes theory is that the option price is independent of the systematic risk of the underlying asset. If the total asset risk is fixed, the proportions of the systematic and idiosyncratic risks will have no effect on the option price.

Researchers have long been pondering the causes for the aforementioned five empirical regularities in option prices. Among them, there are several models that employ a general equilibrium approach to jointly determining the stock and option prices. For example, Grossman and Zhou (1996) constructed an insurer/non-insurer trading model to establish a predication of volatility skew. David and Veronesi (2002) developed an incomplete information model by assuming that investors do not know the drift rate of the dividend process. Buraschi and Jiltsov (2005) created an incomplete-market model with heterogenous agents disagreeing on the dividend growth rate. Although these model offer interesting insights, they appear to offer no specific prediction as to how the option prices are directly linked to the systematic risk of the underlying asset. Therefore, they are unlikely to satisfactorily resolve the last three of the aforementioned five empirical regularities.

An alternative line of option pricing literature based on the GARCH model offers an interesting perspective on the role of systematic risk.[1] The local risk-neutral valuation theory developed by Duan (1995) implies that the option price is a direct function of its underlying asset's risk premium for assets exhibiting a GARCH-type feature. Kallsen and Taqqu (1998) and Duan (2001) showed that the same theoretical dependence on the underlying asset's risk premium also prevails in two different complete-market formulations of the GARCH option pricing model, which in turn suggests that such a theoretical prediction need not be restricted to models with incomplete market and/or asymmetric information. We will show later that the GARCH option pricing approach can indeed explain all five empirical regularities reported in the empirical option literature. In addition, it can be used to reconcile the empirical findings reported in this paper.

BKM (2003) developed a theoretical relationship between the implied volatility and the risk-neutral skewness and kurtosis, and empirically demonstrated that differential pricing of individual stock options and options on the index is indeed related to their differences in the risk-neutral skewness and kurtosis. Our study goes further in demonstrating that the pricing of options depends on how much systematic risk is contained in the underlying asset's total

[1] Heynen, Kemna and Vorst (1994), Duan (1995), Ritchken and Trevor (1999), Duan and Wei (1999), Hardle and Hafner (2000), Heston and Nandi (2000), Hsieh and Ritchken (2000), Duan and Zhang (2001), Lehar, Scheicher and Schittenkopf (2002), Lehnert (2003), Christoffersen and Jacobs (2004), Christoffersen, Heston and Jacobs (2004), Duan and Pliska (2004), Duan, Ritchken and Sun (2005, 2006), and Stentoft (2005) are some examples.

risk. In fact, we argue that the implied volatility, risk-neutral skewness, and kurtosis are all tied to the systematic risk. Thus, finding that the risk-neutral skewness and kurtosis are capable of explaining variations in the implied volatility can be expected.

We use option quotes for the S&P 100 index and its 30 largest component stocks from January 1, 1991 to December 31, 1995, a data set identical to the study by BKM (2003). The key variable employed in our study is the systematic risk proportion, which is defined as the ratio of the systematic variance over the total variance. We test two specific null hypotheses: (1) the level of implied volatility is not related to the systematic risk proportion, and (2) the slope of the implied volatility curve is not related to the systematic risk proportion. Both hypotheses are strongly rejected, indicating that the systematic risk plays an important role in determining option prices. Our empirical findings are robust in sub-samples and to different specifications and estimations. Interestingly, these empirical results are consistent with the GARCH option pricing model, which predicts that a higher systematic risk proportion leads to (1) a higher level of implied volatility and (2) a steeper negative slope in the implied volatility smile/smirk curve.

The remainder of this paper is organized as follows. Section 2 lays out the hypotheses and testing procedures, and reports the main results. The data and test results are given in three subsections. Various robustness checks are reported in Section 3. The GARCH option pricing theory and its specific predictions concerning systematic risk are discussed in Section 4. Section 5 concludes the paper.

2 Empirical relation between systematic risk of the underlying asset and option prices

According to the Black-Scholes (1973) option pricing theory, option prices do not depend on how much systematic risk is contained in the underlying asset as long as its total risk is fixed. To illustrate, imagine two stocks that are identical in every aspect except for the level of systematic risk or risk premium. The prices of options on these two stocks must be equal if the terms of the options are identical. When these option prices are converted into implied volatilities, they should not be related to systematic risk at all.[2] It is difficult to find two stocks that are identical in every respect except for the systematic risk. In the

[2] Here we distinguish the general Black-Scholes option pricing theory from the specific Black-Scholes formula which is valid only under the geometric Brownian motion assumption. In other words, one can actually have the volatility smile/smirk phenomenon under the general Black-Scholes option pricing theory by discarding the geometric Brownian motion assumption.

empirical analysis, we must therefore control for the difference in total risk in studying the option pricing behavior across different underlying stocks.

The key variable used in differentiating stocks in terms of systematic risk is the systematic risk proportion. For the j-th stock, we define its systematic risk proportion b_j as the ratio of the systematic variance over the total variance. The two testable hypotheses based on the general Black-Scholes option pricing theory are formalized as follows:

- **Hypothesis 1:** The implied volatility level of the options on the j-th stock is unrelated to the systematic risk proportion b_j.
- **Hypothesis 2:** The slope of the implied volatility smile/smirk curve of the options on the j-th stock is unrelated to the systematic risk proportion b_j.

Several empirical issues need to be sorted out before we proceed to the tests. To begin with, how do we estimate the average volatility, or the overall level of total risk? Since we use the Black-Scholes implied volatility to characterize the option pricing structure, it is natural to use some versions of historical volatility to proxy the future average volatility. The key issue is how far back we should go in estimating the historical volatility. Balancing between estimation efficiency from a larger sample and the relatively shorter options maturities in the data sample, we opt for a one-year (250 days) rolling window in calculating the volatility on a daily basis. Later in the robustness checks, we repeat the tests using a five-year rolling window and a weekly frequency.

Another issue is the empirical characterization of the implied volatility curve. BKM (2003) assumed a constant slope on the logarithmic scale for the curve. While this strategy greatly simplifies the testing procedures and enhances the testing power (by lumping more observations together), it tends to mix the intricate features of the curve in different regions of the moneyness spectrum. To reveal potentially different features for different moneyness regions, we piecewise linearize the implied volatility curve into four distinct moneyness buckets, i.e., $K/S = [0.9, 0.95), [0.95, 1.0), [1.0, 1.05)$ and $[1.05, 1.10]$, and conduct tests within each bucket.

As discussed earlier, we use time series of daily returns to estimate the systematic risk proportion. Specifically, we run daily, one-year rolling window, OLS regressions for stock j:

$$R_{jt} = \alpha_j + \beta_j R_{mt} + \xi_{jt}, \tag{1}$$

from which the systematic risk and total risk can be calculated as $\beta_j^2 \sigma_m^2$ and σ_j^2. The systematic risk proportion is simply $b_j \equiv \beta_j^2 \sigma_m^2 / \sigma_j^2$ for a particular day, which can in this case be viewed as the regression R^2. If we need a measure of systematic risk proportion for a period of, say, 4 weeks, we need to somehow average the daily estimates. In our study, we first average the daily variances over the period, and then calculate a b_j. For robustness checks, we later repeat the tests by first computing the daily proportions and then averaging them over the period in question.

To test our hypotheses, we follow BKM (2003) and perform the Fama-MacBeth (1973) type two-pass regressions. We need to obtain time series of estimates for the level and slope of the implied volatility curve, which are used to run the cross-sectional regressions to determine whether they are related to the systematic risk proportion. The cross-sectional regression is repeated over time and the time-averaged regression coefficients are used to determine whether a hypothesis is rejected or not.

In order to estimate the level and slope of the implied volatility curve in the first-pass regressions, we need to decide on the length of non-overlapping regression windows. While a weekly window provides sufficient number of options in the study by BKM (2003), we must increase the window length because the option data have been further divided into four moneyness buckets. This is particularly necessary in ensuring reasonable estimates for the risk-neutral skewness and kurtosis. We adopt a window of one month (4 weeks). Thus, the second-pass regression (for testing the effect of the systematic risk proportion on the level and slope of the implied volatility curve) is performed on a monthly basis. The risk-neutral skewness and kurtosis are estimated in the same way as in BKM (2003).

With the above in mind, we proceed with hypothesis testing as follows. In the first-pass regression, for each stock and moneyness bucket, we lump all the observations in a four-week period and repeat the following regression for the j-th stock:

$$\sigma_{jk}^{imp} - \sigma_j^{his} = a_{0j} + a_{1j}(y_{jk} - \bar{y}_j) + \varepsilon_{jk}, \qquad k = 1, 2, ..., I_j, \tag{2}$$

for 65 times (260 weeks divided by 4). In the above, I_j is the number of options in a particular moneyness bucket for the j-th stock, $y_{jk} = K_{jk}/S_{jk}$, and $\bar{y}_j$ is the sample average of y_{jk}.The intercept α_{0j} and regression coefficient a_{1j} are measures of the level and the slope of the implied volatility for a particular moneyness bucket, after adjusting for the j-th stock's total risk, σ_j^{his}.[3]

In the second pass, we perform three versions of cross-section regressions for each of the 65 non-overlapping periods using the intercept from the first-pass regressions as the dependent

[3]Historical volatility for the j-th stock is actually day-specific. The time subscript is omitted to simplify notation. The moneyness variable y_{jk} is adjusted by its mean to ensure that the intercept α_{0j} is the average difference between the implied volatility and the historical volatility for each month/bucket.

variable: for $j = 1, 2, \cdots, 31$,

$$a_{0j} = \gamma_0 + \gamma_1 b_j + e_j \tag{3}$$

$$a_{0j} = \gamma_0 + \gamma_2 Skew_j^{(rn)} + \gamma_3 Kurt_j^{(rn)} + e_j \tag{4}$$

$$a_{0j} = \gamma_0 + \gamma_1 b_j + \gamma_2 Skew_j^{(rn)} + \gamma_3 Kurt_j^{(rn)} + e_j \tag{5}$$

The time-series of the regression coefficients, 65 in total, are then averaged and its corresponding t-statistic is calculated with a first-order serial correlation correction. Regression (3) is an unconditional test of Hypothesis 1, and we should not reject it if $\gamma_1 = 0$. Regression (5) is a conditional test of Hypothesis 1, controlling for the effects of the risk-neutral skewness and kurtosis, and we should obtain $\gamma_1 = 0$ if the systematic risk proportion exerts no effect once the influence of risk-neutral skewness and kurtosis is considered. Regression (4) is performed purely for comparison purposes. BKM (2003) predicted that the slope of the implied volatility curve should be positively related to the risk-neutral skewness and kurtosis, although their theory does not have a prediction on the level per se.

To test Hypothesis 2, we simply repeat the regressions in (3), (4), and (5) by using the intercept a_{1j} from the first-pass regression as the dependent variable. The testing procedure is the same as that for a_{0j}. Since we have subtracted the historical volatility from the implied volatility, the empirical finding obtained by BKM (2003) with regard to the slope may potentially be affected.[4]

2.1 Data and preliminary investigations

The option data used in this study are identical to those in BKM (2003), covering the period of January 1, 1991 to December 31, 1995 for a total of 260 weeks. We refer readers to BKM (2003) for detailed descriptions. The data consist of triple-panel (stock, maturity and exercise price) bid-ask quotes for options written on the 30 largest component stocks of the S&P 100 index and on the S&P 100 index itself. The options are American style and traded on the Chicago Board of Options Exchange. The data frequency is daily, and the bid-ask quotes are the last quotes prior to 3:00pm (CST). Only out-of-the-money call and put options are retained in this data set. Since out-of-the-money puts (calls) correspond to in-the-money calls (puts), the data set effectively covers the whole moneyness spectrum.

[4]For all the monthly cross-section regressions, we require that there are at least 10 observations. This screening criterion, although not binding most of the time, is necessary since the skewness and kurtosis estimates (which require numerical integration over enough option prices) are not always available for every stock within each month.

As in BKM (2003), the data are screened on three fronts: 1) we only retain options which have both bid and ask quotes, 2) we eliminate option prices that violate the arbitrage conditions (i.e., the option price must be smaller than the stock price, but larger than the stock price minus the present value of the exercise price and the dividends, and 3) we eliminate the deep out-of-the-money puts (i.e., $K/S < 0.9$) and calls (i.e., $K/S > 1.1$) and retain the moneyness range from 0.9 to 1.1. BKM (2003) cleansed the very short and very long maturity options, and retained only those with more than 9 days and less than 120 days to expiration. In our study, we extend the cut-off for the longer maturity to 180 days.[5] In addition, since we use a 4-week window for time-series regressions, we set a lower cut-off of maturity to 20 days. Therefore, for our empirical study, we examine three maturity ranges: short-term: $20 - 70$ days, medium-term: $71 - 120$ days, and long-term: $121 - 180$ days.

For each particular option, the implied volatility based on the Black-Scholes formula is available. BKM (2003) showed that these implied volatilities are very close to their counterparts backed out from the binomial tree. In other words, the difference between the precise American style implied volatilities and the European style Black-Scholes volatilities is negligible. In our study, the implied volatility based on the Black-Scholes formula is used.

The daily stock prices, downloaded from Yahoo! Finance, are used to calculate historical volatilities and the proportion of systematic risk in the total risk. We use the S&P 500 index as a proxy for the market portfolio.

Tables 1A, 1B, and 1C report summary statistics. Table 1A reports the number of observations grouped according to maturity and moneyness. It is seen that options on different stocks tend to have different levels of liquidity, judging by the total number of observations. For example, IBM and Xerox enjoy a much higher liquidity than MCI Communications and Northern Telecom. Of course, options on the S&P 100 index have the highest liquidity. In addition, within each maturity range, near-the-money options and options with lower exercise prices (i.e., out-of-the-money puts) are traded more often than options with higher exercise prices (i.e., out-of-the-money calls). Moreover, short maturity options are generally traded more often than medium or long maturity options.

Table 1B reports the average implied volatility for each maturity-moneyness group. It also reports the average historical volatility and the average proportion of systematic risk for each stock. Several observations are in order. First, the volatility smile/smirk is clearly

[5] As apparent in Table 1A, most of the index option observations concentrate in the short-term and medium-term maturity ranges. This is the main reason why BKM (2003) omitted maturities beyond 120 days. We decide to include the long-term range since all individual stocks have enough observations in this range.

present for all stocks. The curve is downward sloping for most stocks when the option maturity is medium-term ($71 - 120$ days) or long-term ($121 - 180$). However, for short-term options ($20 - 70$ days), the implied volatility tends to curve up in the last moneyness bucket, $K/S = 1.05 - 1.10$. Second, it is apparent that, within the same moneyness bucket, the implied volatility is generally lower for longer term options. Third, the average implied volatility and the average historical volatility are generally close, and the former is higher than the latter for more than half of the stocks (19 out of 30), reinforcing the third bias mentioned at the beginning of the paper, i.e., implied volatilities are usually higher than the historical volatilities. The S&P 100 index has the highest volatility differential which is 0.0327. Finally, excluding the S&P 100 index, the systematic risk proportions range from 0.089 for MCI Communications to 0.380 for General Electric (GE). The average proportion across all stocks excluding the S&P 100 index is 0.235.

To see the general association between the stocks' key characteristics and the systematic risk proportion, we sort the stocks into quintiles by their systematic risk proportions, and calculate the average value of the characteristic variables for each quintile. The variables we examine are the ones used for later tests, namely, a) the average implied volatility minus the average historical volatility, b) the average slope of the implied volatility curve, c) the average risk-neutral skewness, and d) the average risk-neutral kurtosis. Since the last two variables do not change across moneyness, we only divide the sample into maturity buckets. Given the magnitude of the S&P 100 index's systematic risk proportion, we put it in a separate group, quintile 5. The first quintile contains 6 stocks and the other three contain 8 stocks each. Since the estimations are done monthly as described before, the sorting is also done monthly, and the average variables are calculated for each quintile. We then average the monthly quantities for each quintile over 65 months. Table 1C contains the results. The most striking is the association between the systematic risk proportion and the implied volatility differential. A higher systematic risk proportion is associated with a higher implied volatility differential. For the other three variables, although not entirely monotonic, we see a clear positive association between the systematic risk proportion and the magnitude of the slope of the implied volatility curve, the risk-neutral skewness and kurtosis.[6] Therefore, the sorting results already indicate a strong rejection of the two null hypotheses.

Finally, before proceeding to the formal tests, we carry out two preliminary investigations. First, we perform a crude parametric test of Hypothesis 1. Second, we demonstrate why the systematic risk proportion is a better measure than beta for our tests. To this end,

[6] One should not be alarmed by the seemingly smaller skewness and kurtosis of the index for the long-term maturity. This is mainly due to the lack of enough observations, as apparent in Table 1A.

we first regress the difference between the average implied volatility and the average historical volatility on the average systematic risk proportion; we then do the same regression using average beta as the explanatory variable. The average volatilities and systematic risk proportions are from Table 1B. Average betas are calculated separately. OLS regressions are done for the entire sample and for various moneyness and maturity buckets. For each bucket, we run two versions of the regression: one with the S&P 100 index and the other without. The results are reported in Table 2. The R^2 and t-values overwhelmingly show that the adjusted implied volatilities are positively related to the systematic risk proportions, while having no statistical relation to betas. This observation applies to all moneyness/maturity buckets, with or without the index. Thus, Hypothesis 1 is rejected with a high level of confidence. The fact that beta is not a good measure of systematic risk for our purpose is not surprising. A higher beta doesn't always mean that the systematic risk accounts for most of the total risk. By the same token, equal betas doesn't mean equal systematic risk proportions. This point can be illustrated by a simple example. Suppose the market volatility is $\sigma_m = 0.2$ and there are two stocks, A and B, with $\sigma_A = 0.4$ and $\sigma_B = 0.5$. If the stocks' correlations with the market are $\rho_A = 0.75$ and $\rho_B = 0.60$, then the two stocks will have the same beta, 1.50, yet very different systematic risk proportions, 0.563 versus 0.360.

2.2 Level effect tests

We now proceed to the formal tests. Table 3 reports the test results for the level effect, i.e., tests pertaining to Hypothesis 1. To conserve space, we omit the intercepts from the second-pass regressions. Panel A reveals a strong rejection of Hypothesis 1. The coefficient γ_1 is positive across all moneyness and maturity buckets, and all the corresponding t-values save one are significant. In fact, almost all of them are significant at the 1% level. Not only positive on average, the vast majority of the 65 γ_1 estimates are positive, as indicated by the percentages under $\gamma_1 > 0$. Moving to Panel B where we control for the effects of the risk-neutral skewness and kurtosis, the γ_1 estimates are still significant for most of the moneyness and maturity buckets. Comparing with the unconditional tests in Panel A, the significance level for the lower moneyness range ($K/S = 0.9 - 1.0$) goes down slightly. Nonetheless, just as the unconditional tests in Panel A, only one t-value is insignificant, and almost all of them are significant at the 1% level. Overall, the unconditional and conditional tests both show a strong level effect. The implied volatility levels, controlling for the stock specific total volatilities, are significantly and positively related to the systematic risk proportion of the underlying stock.

In terms of economic significance, the R^2 shows that the systematic risk proportion does a better job for the lower moneyness range in explaining the cross-sectional differences in the level of implied volatilities. For the univariate regressions covering all maturities, the systematic risk proportion alone explains 14.5%, 7.8%, 7.3% and 5.4% of the cross-sectional variations in the implied volatility for the four moneyness buckets respectively. When the risk-neutral skewness and kurtosis are added to the regressions, the corresponding numbers are 24.8%, 18.8%, 17.9% and 15.2%. Obviously, the implied volatilities are also affected by many other firm-specific variables not examined in this study, such as the ones examined by Dennis and Mayhew (2002). The focus of this paper is to establish the linkage between the option prices and the systematic risk. We therefore do not go further to exhaustively investigate all the potential factors affecting the implied volatility.

The regression results also offer some other interesting insights. First of all, judging by the magnitude and t-value of the regression coefficient γ_1 as well as the percentage of positive entries, we see that the effect of systematic risk proportion itself also takes a smirk pattern across moneyness. The effect is much stronger for the lower moneyness buckets. As the exercise price becomes higher, the level effect becomes weaker. This is consistent with the pattern of the implied volatilities.

Second, in terms of maturities, it is clear that the effect is stronger for short-term ($20-70$ days) options, and it becomes weaker as the maturity gets longer. This is true for both the unconditional and conditional tests. The fact that the long-term options see the weakest effect is remarkably consistent with the predictions of the GARCH option pricing theory (viz, the implied volatility curve flattens out for very long-term options), a point to be addressed later in Section 4.

Finally, in both the unconditional and conditional tests, the coefficients for the risk-neutral skewness and kurtosis are mostly insignificant and the signs are mixed. Nevertheless, as shown in Panel B, the effect of the systematic risk proportion on the implied volatility level remains significant, even after controlling for the risk-neutral skewness and kurtosis.

2.3 Slope effect tests

Table 4 reports the results for the slope effect tests, i.e., tests pertaining to Hypothesis 2. The results are very similar to those in Table 2 in terms of rejecting the hypothesis. For most parts, the slope of the implied volatility curve is related to the systematic risk proportion in a statistically significant fashion. The bigger the systematic risk proportion, the steeper the slope. The significance remains after controlling for the risk-neutral skewness and kurtosis.

Therefore, Hypothesis 2 is also strongly rejected.

Other observations regarding moneyness and maturity are also similar to those in Table 3. The weakening of the systematic risk effect on the slope is especially pronounced with the upper tail of the moneyness range, i.e., 1.05 - 1.10. This is due to the slight curving back of the implied volatility curve in this region. As for maturity, we also observe a weaker effect with long-term options. Again, this is consistent with the predictions of the GARCH option pricing theory, which we will elaborate in Section 4.

BKM (2003) predicted positive coefficients for the risk-neutral skewness and kurtosis in describing the slope of implied volatilities. We do observe positive (and sometimes significant) γ_2 and γ_3 for the lower region of K/S. For the upper region, they are mostly negative, although not always significant. When we combine the moneyness buckets and run a single regression as in BKM (2003), we obtain the sign and significance as shown in BKM (2003). This implies that it is very crucial to examine the properties of the implied volatility by separating moneyness buckets.

In terms of economic significance, the R^2 is lower than its level effect counterpart. For the univariate regressions covering all maturities, the systematic risk proportions explain 4.7%, 4.8%, 5.5% and 1.6% of the cross-sectional variations in the slope for the four moneyness buckets respectively. The numbers do improve to 13.9%, 13.4%, 12.0% and 11.3% when the risk-neutral skewness and kurtosis are added to the regressions. Similar to the level of implied volatilities, the slope is also affected by many factors other than the ones we examine. For example, Peña, Rubio and Serna (1999, 2001) found that the curvature of the volatility smile is positively and significantly related to the bid-ask spread; Ederington and Guan (2002) investigated the link between the curvature of the volatility smile and the hedging pressure; and Bollen and Whaley (2004) attributed the smile curvature to the net buying pressure or asymmetrical demand and supply. We contribute to the literature by showing that the slope is also explained by the systematic risk of the underlying.

3 Robustness checks

3.1 Alternative ways of calculating the systematic risk proportion

As described earlier, in the second pass regression, the monthly systematic risk proportion, b_j is calculated by using the average systematic and total risks within the 4-week period. To see if our testing results are sensitive to how b_j is calculated, we repeat the tests by using the average $b_j's$ within the 4-week period. In other words, we first calculate the daily proportions, and then average them to obtain a single estimate for the 4-week period. The results remain virtually the same, we therefore omit them for brevity. For completeness, we have also repeated the tests by using $\sqrt{b_j} = |\frac{\beta_j \sigma_m}{\sigma_j}|$ in the second-pass regressions. The results are slightly weaker, but the statistical significance is retained in most cases. There is an intuitive justification for using the variance ratio rather than the standard deviation ratio. After all, variance is the natural measure of risk since it is additive for independent risks.

3.2 Sub-sample results

The main purpose here is to see if the results hold up in different time periods and if the general level of volatility matters. To this end, we first plot in Figure 1 the daily implied and historical volatilities for the S&P 100 index. The daily implied volatility is simply the average of the implied volatilities for all contracts on each day; the daily historical volatility is the annualized standard deviation from the one-year rolling window (annualization is done by multiplying $\sqrt{250}$ to the daily volatilities). It is clear that the two volatility series are generally correlated. To be precise, the correlation coefficient is 0.644 over the entire sample period. More importantly, the volatility has a rough dichotomy between the two halves of the sample period, with the first half seeing a generally higher volatility than the second half. We therefore perform the sub-sample tests by cutting the sample into equal halves. To offset the reduction in the number of options in a sub-sample, we use two moneyness buckets: [0.9, 1.0) and [1.0, 1.1]. Moreover, in order to make more meaningful comparisons, we also re-run all regressions for the whole sample using the two moneyness buckets. Tables 5 and 6 report the sub-sample test results for the level and slope effects.

Table 5 indicates a very strong level effect for both sub-sample periods. The regression coefficient γ_1 is positive and significant (mostly at the 1% level) for all cases, regardless of whether it is controlled for the risk-neutral skewness and kurtosis. The t-values for γ_1 are bigger for the first half of the sample. This implies that the impact of the systematic risk on option values is stronger when the overall total risk is high. Turning to the slope effect, Table 6 reveals a similar significance level regarding the impact of the systematic risk. The regression coefficient γ_1 is negative for all cases and its t-value is highly significant for almost all cases. Although the t-values are larger in the second sample with the univariate regressions in the lower region of the moneyness range, an overall dichotomy between the two sub-samples doesn't appear to exist as far as the slope effect is concerned.

Other features observed in Tables 3 and 4 are also present in Tables 5 and 6. For instance, both the level and slope effects are weaker with long-term options and for the upper region of the moneyness range ($K/S = 1.0 - 1.1$). Taken together, the sub-sample tests clearly demonstrate that the impact of systematic risk on option prices are quite robust across sub-sample periods.

3.3 Data frequency and sample size for the systematic risk estimation

In estimating the historical volatility and its composition, we run the OLS regression in (2) using a one-year rolling window with daily frequency. As mentioned before, our choice of daily frequency and one-year rolling window is a balanced consideration of estimation efficiency and the relatively short maturity of options. However, the shorter window and higher data frequency raise the concern that the resulting risk estimates may be highly time-varying and do not necessarily reflect changes in the systematic risk proportion. This concern may be alleviated by realizing that the risk measure we use in the second pass regression is the ratio of the systematic risk over the total risk and that this ratio may be stable despite the variation in the two absolute risk measures. Nonetheless, in order to assess the potential impact, we repeat the tests using a five-year rolling window at a weekly frequency, a frequency used by such institutions as Datastream and Standard and Poor's when estimating betas. The weekly frequency is implemented by using data points on Wednesdays. Once we obtain the weekly risk estimates, we match them back to the original data and run the two-pass regressions as before. In other words, we still utilize all available option data. To conserve space, we report the level and slope test results in one table, Table 7. For brevity, we only report the regression coefficient and its t-value together with the R^2 for the univariate regression (with the systematic risk proportion being the only explanatory variable) and the multivariate regression (with the risk-neutral skewness and kurtosis as well as the systematic risk proportion as the explanatory variables). It is clear from the table that the previous conclusions hold up for both the level effect and the slope effect. Overall, the statistical significance weakens slightly, but this is by no means uniform. In some cases, the t-values actually go up slightly. Since the longer window period and the lower data frequency do not alter the qualitative conclusions, for consistency and ease of comparison, we will continue to use the one-year rolling window at the daily frequency for subsequent robustness checks.[7]

[7] We have also re-run the regressions using a five-year rolling window at daily frequency. The results are virtually the same as those using a one-year rolling window. We omit the results for brevity.

3.4 Exclusion of the S&P 100 index

Table 1B clearly shows that the S&P 100 index is an underlying asset with a substantially higher systematic risk than ordinary stocks. Although Table 2 crudely demonstrates that the general association between implied volatilities and the systematic risk proportion holds no matter whether the index is included or not, it is useful to ascertain the precise influence of the index on the overall conclusions. To this end, we repeat the tests by excluding all options written on the index. Again, to conserve space, we report the results in Table 8 in the same fashion as in Table 7. Comparing Panel A with Table 3, it is seen that the t-values for γ_1 decrease slightly for most cases, but the significance remains in all cases. Therefore, the level effect also holds strongly with stock options. Comparing Panel B of Table 8 with Table 4, we see that the regression coefficient γ_1 retains the right sign, but its significance has reduced substantially. Some t-values are still significant and many have their magnitudes larger than one. Thus, the slope effect is weaker among stock options. This is consistent with the well-established empirical regularity: the slope of the implied volatility curve for stock options is much flatter than that for index options. The flatter slope impedes the testing power in our case. Nevertheless, the results in Table 8 demonstrate that our general conclusions hold with or without index options. In fact, one may even argue that the stronger influence of the index options actually reinforces our conclusions, since the index has the highest systematic risk proportion and the largest difference between the implied and the historical volatilities, as apparent in Table 1B. At any rate, for consistency and ease of comparison, we keep index options in the analysis for subsequent robustness checks.

3.5 Panel regressions

In our two-pass regressions, we use an estimated parameter from the first pass as a dependent variable for the second pass. This may give rise to several econometric issues such as the asymptotic properties of the second-pass estimators, which in turn could cast doubt about the statistical inferences we have drawn. To address this concern, we run a single-pass, panel regression and test the two hypotheses therein. Specifically, we run the following panel regression for each moneyness/maturity bucket:

$$\begin{aligned}\sigma_{ij}^{imp} - \sigma_{ij}^{his} &= [\alpha_0 + \alpha_1(b_{ij} - \bar{b}_i)] + [\beta_0 + \beta_1(b_{ij} - \bar{b}_i)](y_{ij} - \bar{y}_j) + \varepsilon_{ij} \\ &= \alpha_0 + \alpha_1(b_{ij} - \bar{b}_i) + \beta_0(y_{ij} - \bar{y}_j) + \beta_1(b_{ij} - \bar{b}_i)(y_{ij} - \bar{y}_j) + \varepsilon_{ij}, \qquad (6)\end{aligned}$$

where $\bar{b}_i$ is the observation–weighted, cross-sectional average of the systematic risk proportion for each day, $\bar{y}_i$ is the sample average of moneyness for stock j or the index within the bucket.

Broadly speaking, α_0 can be understood as the average differential between the implied volatility and the historical volatility over all stocks and the index within the entire sample period. Similarly, β_0 can be understood as the average slope of the implied volatility curve. They are not exactly the said quantities due to the interaction term $b_{ij} * y_{ij}$. The coefficient α_1 picks up the level effect. If the systematic risk proportion doesn't affect the price level or the adjusted implied volatility, then α_1 should not be different from zero, statistically speaking. A positive α_1 would confirm the level effect. By the same token, the coefficient β_1 picks up the slope effect. If the systematic risk proportion does not affect the slope of the implied volatility curve, then β_1 should be zero. A negative β_1 would imply that a stock with a higher than average systematic risk proportion will have a slope steeper than the average slope of all implied volatility curves, confirming the slope effect.

Table 9 contains the results. Judging by the t-values of the coefficient α_1, Hypothesis 1 is rejected at an extraordinary level of significance, reaffirming the level effect. As for the coefficient β_1, except for three cases, the t-values are also significant and large for many cases. Therefore, Hypothesis 2 is also rejected, confirming the slope effect. If anything, the panel regression results indicate that our two-pass regression tests err on the conservative side. We have also repeated the tests by calculating $\bar{b}_i$ as the simple average of the stocks' systematic risk proportions (i.e., not weighted by the number of observations). The results are almost identical to those in Table 9.[8]

3.6 Systematic risk estimation using Fama-French factors

So far, all the tests use systematic risk estimates from a single factor model, the market model. Insofar as different stocks may have different exposures to certain systematic risk factors, it is imperative to ascertain if our results are robust to the multi-factor model. To this end, we re-estimate the systematic risk by adding the two Fama-French factors, i.e., SMB and HML, to the market factor.[9] By definition, the systematic risk proportion estimated with the two additional factors will be higher than the previous one. The question is, will it increase proportionally across stocks so that our level and slope effects would hold up? To this end, we repeat the two-pass regressions using the newly estimated systematic risk

[8] Incidentally, it is seen that the coefficient α_0 is negative for the moneyness measure K/S beyond 1.0. This should be intuitive given the downward sloping feature of a typical implied volatility curve: implied volatilities in the moneyness range beyond 1.0 are lower than the average volatility at the mid-point or the at-the-money point.

[9] The daily factors are downloaded from the web-page of Kenneth French.

proportions, and report the results in Table 10.[10] Once again, the table takes the same format of Tables 7 and 8 to conserve space. Comparing Table 10 with Table 3 (level effect) and Table 4 (slope effect), we see that the results remain virtually the same. This is another indirect support for the choice of the systematic risk proportion over the beta for our study. Since we have controlled for the overall level of risk, what matters is the composition of the total risk, not the absolute magnitude of the components. As long as the same estimation procedure is applied to all stocks, the cross-sectional feature would manifest itself. Therefore, one may also infer that our results are likely robust to more sophisticated estimation methods, e.g., a shrinkage Bayesian estimator or some sort of optimal estimator, for the systematic risk.

Incidentally, the more encompassing estimation of the systematic risk did not improve the cross-sectional explanatory power either. Comparing with Tables 3 and 4, it is seen that the R^2 actually goes down slightly for the level tests, while remains more or less the same for the slope tests.

4 Empirical results vs. predictions of the GARCH option pricing model

In this section, we offer a potential explanation for our empirical findings using the GARCH option pricing theory of Duan (1995). We argue that the empirical findings concerning the effect of systematic risk are in effect predicted by the GARCH option pricing theory.

We use a nonlinear asymmetric GARCH(1,1) process of Engle and Ng (1993) to illustrate the main point. Using a different GARCH specification will not alter the basic conclusion. The stock return with respect to the physical probability measure P is assumed to follow:

$$\begin{aligned}
\ln\frac{S_{t+1}}{S_t} &= r_{t+1} + \lambda_{t+1}\sigma_{t+1} - \frac{1}{2}\sigma_{t+1}^2 + \sigma_{t+1}\varepsilon_{t+1} \\
\sigma_{t+1}^2 &= \alpha_0 + \alpha_1\sigma_t^2 + \alpha_2\sigma_t^2(\varepsilon_t - \theta)^2 \\
\varepsilon_{t+1}|\phi_t &\overset{P}{\backsim} N(0,1)
\end{aligned} \tag{7}$$

where ϕ_t is the information set containing all information up to and including time t; α_0, α_1, α_2, and θ are the GARCH parameters governing the variance process; and $N(0,1)$ denotes a standard normal distribution. r_{t+1} is the risk-free interest rate and λ_{t+1} is the risk premium per unit of standard deviation, both of which can be stochastic but must be predictable

[10] Although not reported, we also calculated the average of the newly estimated systematic risk proportion for each stock (i.e., the counter part of the last column of Table 1B). The correlation between the two proportions is 0.985, and the average difference between the two proportions is 0.036.

in the sense that they are measurable with respect to ϕ_t. We use a time subscript for the interest rate and the risk premium to allow them to be potentially stochastic. The term $\lambda_{t+1}\sigma_{t+1}$ captures the total risk premium.

Duan (1995) showed that the system in (7) can be converted, for the purpose of pricing derivatives, to one that is locally risk-neutral with respect to the pricing measure Q:

$$\begin{aligned} \ln\frac{S_{t+1}}{S_t} &= r_{t+1} - \frac{1}{2}\sigma_{t+1}^2 + \sigma_{t+1}\xi_{t+1} \\ \sigma_{t+1}^2 &= \alpha_0 + \alpha_1\sigma_t^2 + \alpha_2\sigma_t^2(\xi_t - \lambda_t - \theta)^2 \\ \xi_{t+1}|\phi_t &\overset{Q}{\backsim} N(0,1) \end{aligned} \tag{8}$$

where $\xi_t = \varepsilon_t + \lambda_t$. It is seen that the risk premium, λ_t plays a critical role in the GARCH option pricing model. In contrast to the Black-Scholes theory and other generalizations, an option's value is a direct function of the stock's expected return (via the risk premium λ_t).

Although it is intuitively clear that λ_t can be related to the systematic risk of the underlying asset, a formal relationship in the GARCH framework was first derived in Duan and Wei (2005). In addition to the assumptions needed for the GARCH option pricing model, they assumed the resulting stochastic discount factor follows a one-factor (the market portfolio return) linear structure. They were able to express the risk premium per unit of return standard deviation for the j-th asset as

$$\lambda_{jt} = \frac{c_t\beta_{jt}\sigma_{mt}}{\sigma_{jt}} \tag{9}$$

where $\beta_{jt} = Cov^P\left(\ln\frac{S_{jt}}{S_{j(t-1)}}, \ln\frac{m_t}{m_{t-1}}|\phi_{t-1}\right)/\sigma_{m,t}^2$, $\ln\frac{m_t}{m_{t-1}}$ and $\sigma_{m,t}^2$ are the log return and variance of the market portfolio, and c_t can be time-varying but is the same across different assets. Thus, the risk premium can be explicitly tied to the systematic risk β_{jt}.

The above result implies that a higher systematic risk leads to a higher asset risk premium. In particular, λ_j^2 is directly proportional to the systematic risk proportion b_j, a measure employed in our empirical analysis. Therefore, rejection of both hypotheses 1 and 2 should not be surprising in light of the GARCH option pricing model. More strikingly, the signs of the coefficients for the level and slope tests turn out to be consistent with the prediction of the GARCH option pricing model. Specifically, a higher systematic risk proportion leads to (1) a higher level of implied volatility vis-à-vis the historical volatility and (2) more negatively sloped volatility smile/smirk. We now elaborate on why the GARCH option pricing model generates these two predictions.

Figure 2 can be used to develop an intuitive appreciation of the behavior of the Black-Scholes implied volatility under the GARCH option pricing model. This figure provides three implied volatility curves by varying the level of the asset risk premium. The GARCH parameters used to generate these graphs are $\alpha_0 = 8 \times 10^{-6}$, $\alpha_1 = 0.85$, $\alpha_2 = 0.08$ and $\theta = 0.5$. These parameter values imply a physical stationary return volatility of 20% per annum. We assume that the initial conditional volatility is at this stationary level and then let it evolve according to the GARCH system. We compute the option prices using 50,000 sample paths in a Monte Carlo simulation coupled with the empirical martingale adjustment of Duan and Simonato (1998). We fix the maturity at 60 business days while varying the strike price. Once the option prices are computed, they are converted to the Black-Scholes implied volatilities. It is evident from these graphs that the GARCH option pricing model yields the smile/smirk pattern typically observed for the exchange-traded option contracts. These graphs show that a higher λ (due to a higher systematic risk without changing the total physical risk) leads to a higher implied volatility curve across all strike prices, which implies a positive level effect. A higher λ also makes the curve sloped more steeply, which is clearly a negative slope effect.

The above predictions in effect reflect the fact that a higher risk premium simply leads to higher volatility and kurtosis and more negative skewness for the risk-neutral cumulative return distribution. Assuming a constant $\lambda > 0$ and leverage effect ($\theta > 0$), Theorem 3.1 of Duan (1995) can be used to conclude that the risk-neutral stationary return variance is $\alpha_0/[1 - \alpha_1 - \alpha_2(1 + (\theta + \lambda)^2)]$, an increase from $\alpha_0/[1 - \alpha_1 - \alpha_2(1 + \theta^2)]$ under measure P. A higher risk-neutral volatility is actually due to the fact that the risk-neutral volatility is governed by a larger persistence parameter $\alpha_1 + \alpha_2(1 + (\theta + \lambda)^2)$ in comparison to the one under measure P (i.e., $\alpha_1 + \alpha_2(1 + \theta^2)$). The risk-neutral volatility dynamic thus has a slower mean-reversion, implying a slower flattening of the volatility smile/smirk. Furthermore, the risk-neutral cumulative return becomes more skewed because the correlation between the one-period return and volatility becomes $-2\alpha_2(\theta + \lambda)$ as opposed to $-2\alpha_2\theta$ under measure P. The risk-neutral cumulative return also has fatter tails than the cumulative return under the physical measure.

We illustrate these features in Figures 3-5 using the same parameter values as in Figure 2. In these plots, we compute the risk-neutral cumulative return's volatility, skewness and kurtosis for different maturities using the same simulation procedure as for Figure 2. The volatilities in Figure 3 are annualized in the usual manner, i.e., dividing by the square root of the maturity (in years). When $\lambda = 0$, the risk-neutral cumulative return volatility equals the physical volatility. Since the initial conditional volatility is set to the physical stationary volatility of 20%, it is not surprising to see it staying at 20% for different maturities. When

$\lambda > 0$, the stationary risk-neutral volatility will be higher than the physical stationary volatility. Naturally, the risk-neutral cumulative return volatility will be increasing with maturity. If we had used an initial conditional volatility much higher than the stationary level, these curves would be downward sloping but the curve corresponding to a higher λ would continue to stay above the one under a lower λ. In short, the risk-neutral volatility is monotonically increasing in λ for a given maturity.

Figure 4 indicates that the risk-neutral cumulative return's skewness is a decreasing function of λ, meaning the risk-neutral distribution becomes more negatively skewed when λ is larger.[11] Corresponding to a given λ, we see an interesting pattern in relation to maturity. Since the one-period conditional return distribution is normal, the skewness has to start from zero. The negative correlation between return and volatility leads to a negative skewness for the cumulative return distribution. The skewness will, however, diminish with maturity, a result due to the central limit theorem. Similarly, we observe the risk-neutral cumulative return's kurtosis increases with λ for a given maturity. If we fix λ and examine how the kurtosis behaves in relation to maturity, it is clear that the risk-neutral kurtosis begins at 3, i.e., conditional normality, and then increases with maturity to a point (i.e., a maturity of roughly 50 days). After that, it begins to decline toward 3, again due to the central limit theorem.

Figures 4-5 suggest that under the GARCH option pricing theory, the risk-neutral skewness and kurtosis are functions of λ, which is in turn a function of the systematic risk proportion b. We now empirically verify this claim. We regress cross-sectionally the risk-neutral skewness and kurtosis of 30 companies and the S&P100 index on their systematic risk proportion. That is, for $j = 1, \cdots, 31$,

$$Skew_j^{(rn)} = \gamma_0 + \gamma_1 b_j + e_j \qquad (10)$$

$$Kurt_j^{(rn)} = \gamma_0 + \gamma_2 b_j + e_j \qquad (11)$$

Again we run the cross-sectional regressions on a monthly basis as in Section 2 and report the average regression coefficients over all months in our sample. The t-statistics are computed from these monthly regression coefficients after taking into account their potential autocorrelation. For the risk-neutral skewness, we find $\hat{\gamma}_0 = -1.549$ with a t-value of -26.834 and $\hat{\gamma}_1 = -1.336$ with a t-value of -5.113. This result indicates that the risk-neutral return distributions are on average negatively skewed and the degree of the negative skewness is proportional to the systematic risk proportion. Our regression results for the risk-neutral

[11] Monte Carlo errors are more evident in Figures 4-5 in comparison with Figures 2-3. The difference in the magnitude is of course due to the fact that skewness and kurtosis are of power 3 and 4.

kurtosis are $\hat{\gamma}_0 = 3.307$ with a t-value of 10.323 and $\hat{\gamma}_1 = 6.884$ with a t-value of 3.892. This finding suggests that the stocks in our sample have on average leptokurtic risk-neutral return distributions and the kurtosis is increasing with the systematic risk proportion.[12]

In BKM (2003), the level and slope of the implied volatility curve have been found to be related to the risk-neutral skewness and kurtosis. Our results suggest that the level and slope of the implied volatility curve and the risk-neutral skewness and kurtosis are all largely influenced by the systematic risk proportion.

5 Summary and Conclusions

In this study, we empirically examine the relationship between option prices and the systematic risk of the underlying asset. The study is motivated by the realization that the risk premium or systematic risk of the underlying asset may play a role in determining the empirically observed difference between the risk-neutral and physical return distributions. The original Black-Scholes option pricing theory assumes a constant volatility which captures the riskiness of the underlying. Although there have been many subsequent studies generalizing the constant volatility assumption and the return distribution in general, almost all of the studies stipulate that volatility is the only measure of the underlying asset's risk profile. The decomposition of the total risk into systematic and non-systematic risks plays no role in the valuation of options. We empirically invalidates this point in the current study.

We show conclusively that option prices are related to the amount of systematic risk. After controlling for the overall level of total risk, a higher amount of systematic risk leads to a higher level of implied volatility and a steeper implied volatility curve. The effect remains strong after controlling for the risk-neutral skewness and kurtosis. The results are also robust to various alternative estimations of the variables and specifications of the tests. In summary, we have shown that the implied volatility smile/smirk phenomenon is predictably related to how the total risk is decomposed into systematic and non-systematic risks, a result that is fundamentally contradictory to the essence of the general Black-Scholes option pricing theory.

We offer a potential explanation to the findings using the recently emerged GARCH option pricing theory. When volatility is stochastic and depends on the return innovation, the underlying asset's risk premium becomes an integral part of option valuation by entering

[12] The regressions are also repeated by excluding the index. For the skewness regression, $\hat{\gamma}_0 = -1.592$, $t = -13.068$, $\hat{\gamma}_1 = -0.943$, $t = -2.842$; for the kurtosis regression, $\hat{\gamma}_0 = 3.614$, $t = 6.855$, $\hat{\gamma}_1 = 4.460$, $t = 3.332$. The t-values do go down, but are still significant.

into the return volatility dynamic under the locally risk-neutral pricing measure. In fact, the GARCH option pricing theory specifically predicts that a higher systematic risk will increase the risk-neutral volatility vis-à-vis the physical volatility and make the skewness and kurtosis of the risk-neutral cumulative return distribution more pronounced. As a result, the level and slope of the implied volatility curve are predictably linked to the systematic risk proportion of the underlying asset.

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Table 1A: Summary statistics – number of observation

	Ticker	Stock	Short-term Options: 20 - 70 days in Maturity					Medium-term Options: 71 - 120 days in Maturity					Long-term Options: 121 - 180 days in Maturity					All
			Moneyness, K/S					Moneyness, K/S					Moneyness, K/S					
			[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]	[0.90-1.10]	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]	[0.90-1.10]	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]	[0.90-1.10]	Options
1.	AIG	American Int'l	1351	1635	1700	1096	5782	635	640	662	478	2415	706	753	781	547	2787	10984
2.	AIT	Ameritech	775	1039	1150	558	3522	409	413	455	371	1648	490	478	553	418	1939	7109
3.	AN	Amoco	761	902	1037	663	3363	442	397	448	399	1686	513	451	558	423	1945	6994
4.	AXP	American Express	677	745	686	610	2718	236	347	250	224	1057	382	321	336	317	1356	5131
5.	BA	Boeing Company	871	687	976	703	3237	401	298	454	321	1474	449	364	515	378	1706	6417
6.	BAC	BankAmerica Corp.	917	688	874	719	3198	328	264	319	302	1213	436	307	405	352	1500	5911
7.	BEL	Bell Atlantic	855	842	977	728	3402	343	363	346	362	1414	508	347	491	372	1718	6534
8.	BMY	Bristol-Myers	1103	1127	1252	932	4414	483	512	540	443	1978	610	557	663	559	2389	8781
9.	CCI	Citicorp	709	677	650	704	2740	258	278	230	274	1040	335	321	290	326	1272	5052
10.	DD	Du Pont	967	881	942	892	3682	381	387	349	380	1497	512	409	474	445	1840	7019
11.	DIS	Walt Disney	1205	1276	1271	1199	4951	511	520	524	513	2068	585	621	616	551	2373	9392
12.	F	Ford Moter	823	788	829	725	3165	393	394	360	380	1527	450	448	444	433	1775	6467
13.	GE	General Electric	1268	1331	1401	1125	5125	608	576	640	533	2357	706	688	758	614	2766	10248
14.	GM	General Motors	894	780	794	911	3379	419	334	362	424	1539	467	433	426	465	1791	6709
15.	HWP	Hewlett-Packard	1256	1254	1294	1121	4925	601	550	588	490	2229	667	642	663	564	2536	9690
16.	IBM	Int. Bus. Machines	1294	1300	1467	1287	5348	517	508	579	504	2108	663	625	684	606	2578	10034
17.	JNJ	Johnson & Johnson	1105	1017	1142	879	4143	459	406	435	360	1660	611	505	546	432	2094	7897
18.	KO	Coca Cola Co.	1052	952	952	892	3848	458	476	400	433	1767	600	464	502	536	2102	7717
19.	MCD	McDonald's Corp.	896	563	914	685	3058	379	284	392	334	1389	506	292	511	352	1661	6108
20.	MCQ	MCI Comm.	741	555	628	697	2621	290	258	218	299	1065	382	251	319	312	1264	4950
21.	MMM	Minn Mining	1268	1519	1548	1281	5616	568	598	603	549	2318	663	719	703	660	2745	10679
22.	MOB	Mobil Corp.	1037	1277	1376	901	4591	630	645	626	551	2452	741	690	758	676	2865	9908
23.	MRK	Merck & Co.	1189	1177	1178	889	4433	515	497	473	369	1854	610	542	529	425	2106	8393
24.	NT	Northern Telecom	659	576	675	565	2475	272	214	254	235	975	341	249	328	267	1185	4635
25.	PEP	PepsiCo Inc.	692	740	611	718	2761	252	285	240	288	1065	336	359	269	349	1313	5139
26.	SLB	Schlumberger Ltd.	893	1069	1119	907	3988	382	430	451	377	1640	444	507	492	463	1906	7534
27.	T	AT&T	969	739	992	807	3507	392	261	415	280	1348	459	362	416	435	1672	6527
28.	WMT	Wal-Mart	973	714	786	699	3172	508	285	398	300	1491	527	429	438	370	1764	6427
29.	XON	Exxon Corp.	1044	1000	1151	875	4070	462	427	414	435	1738	587	442	526	539	2094	7902
30.	XRX	Xerox Corp.	1333	1520	1569	1202	5624	563	584	599	521	2267	687	687	730	596	2700	10591
31.	OEX	S&P 100 Index	8206	8707	8766	3814	29493	5149	5997	6035	2597	19778	117	146	152	77	492	49763
		Total	37783	38077	40707	29784	146351	18244	18428	19059	14326	70057	16090	14409	15876	13859	60234	276642

Notes: This table reports the number of observations within each moneyness bucket under a particular maturity range for options on the 30 largest component stocks in the S&P100 index and on the S&P100 index itself. Each observation is the last quote prior to 3:00pm (CST). The far right column under each maturity range is simply the sum of the preceding four columns. The last column of the table contains the total number of observations for each firm. The last row contains the total of each column. The sample period is from January 1, 1991 to December 31, 1995. All options are American style.

Table 1B: Summary statistics – implied volatility, historical volatility and systematic risk proportion

			Short-term Options: 20 - 70 days in Maturity					Medium-term Options: 71 - 120 days in Maturity					Long-term Options: 121 - 180 days in Maturity					Average	Average	Systematic
			Moneyness, K/S					Moneyness, K/S					Moneyness, K/S					Implied	Historical	Risk
			[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]	[0.90-1.10]	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]	[0.90-1.10]	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]	[0.90-1.10]	Volatility	Volatility	Proportion
1.	AIG	American Int'l	0.2371	0.2281	0.2125	0.2146	0.2231	0.2282	0.2277	0.2126	0.2125	0.2207	0.2253	0.2268	0.2109	0.2099	0.2187	0.2214	0.2093	0.275
2.	AIT	Ameritech	0.2226	0.2056	0.1710	0.1806	0.1941	0.2189	0.2176	0.1684	0.1664	0.1928	0.2233	0.2273	0.1602	0.1583	0.1923	0.1933	0.1824	0.229
3.	AN	Amoco	0.2197	0.1927	0.1717	0.1910	0.1920	0.2003	0.1978	0.1676	0.1715	0.1842	0.2020	0.2028	0.1660	0.1662	0.1841	0.1879	0.1922	0.127
4.	AXP	American Express	0.3140	0.2935	0.2868	0.3009	0.2986	0.3060	0.2962	0.2979	0.3064	0.3010	0.3047	0.2948	0.2898	0.2959	0.2966	0.2986	0.2995	0.207
5.	BA	Boeing Company	0.2734	0.2539	0.2372	0.2481	0.2528	0.2563	0.2537	0.2316	0.2343	0.2434	0.2528	0.2498	0.2302	0.2292	0.2401	0.2473	0.2408	0.165
6.	BAC	BankAmerica Corp.	0.3078	0.2924	0.2664	0.2662	0.2838	0.2977	0.2989	0.2632	0.2588	0.2792	0.2929	0.2877	0.2564	0.2515	0.2723	0.2800	0.2700	0.257
7.	BEL	Bell Atlantic	0.2324	0.2084	0.1794	0.1978	0.2038	0.2219	0.2160	0.1816	0.1788	0.1995	0.2227	0.2227	0.1796	0.1723	0.1995	0.2017	0.2076	0.214
8.	BMY	Bristol-Myers	0.2304	0.2143	0.1884	0.2039	0.2088	0.2157	0.2110	0.1801	0.1849	0.1979	0.2147	0.2170	0.1783	0.1800	0.1970	0.2031	0.2003	0.290
9.	CCI	Citicorp	0.3403	0.3156	0.3058	0.3045	0.3168	0.3326	0.3241	0.3105	0.3033	0.3177	0.3279	0.3123	0.3006	0.2982	0.3101	0.3153	0.3357	0.208
10.	DD	Du Pont	0.2512	0.2430	0.2188	0.2254	0.2347	0.2438	0.2451	0.2134	0.2151	0.2298	0.2433	0.2429	0.2117	0.2112	0.2273	0.2317	0.2211	0.261
11.	DIS	Walt Disney	0.2975	0.2820	0.2608	0.2603	0.2751	0.2921	0.2835	0.2629	0.2588	0.2743	0.2827	0.2807	0.2568	0.2547	0.2689	0.2733	0.2540	0.268
12.	F	Ford Moter	0.3200	0.3014	0.2807	0.2867	0.2974	0.3118	0.2974	0.2763	0.2752	0.2906	0.3089	0.3040	0.2723	0.2718	0.2895	0.2936	0.2928	0.237
13.	GE	General Electric	0.2402	0.2141	0.1849	0.1899	0.2073	0.2257	0.2187	0.1809	0.1788	0.2012	0.2253	0.2216	0.1789	0.1736	0.2002	0.2040	0.1862	0.380
14.	GM	General Motors	0.3125	0.2918	0.2880	0.2904	0.2960	0.3031	0.2846	0.2875	0.2852	0.2905	0.3008	0.2940	0.2869	0.2864	0.2921	0.2937	0.3010	0.234
15.	HWP	Hewlett-Packard	0.3323	0.3251	0.3095	0.3121	0.3199	0.3260	0.3232	0.3094	0.3094	0.3173	0.3127	0.3154	0.2935	0.2980	0.3051	0.3154	0.3230	0.212
16.	IBM	Int. Bus. Machines	0.2874	0.2675	0.2589	0.2616	0.2685	0.2787	0.2703	0.2527	0.2513	0.2630	0.2696	0.2647	0.2453	0.2452	0.2562	0.2642	0.2544	0.218
17.	JNJ	Johnson & Johnson	0.2531	0.2406	0.2243	0.2259	0.2363	0.2437	0.2425	0.2205	0.2153	0.2312	0.2416	0.2390	0.2135	0.2112	0.2274	0.2329	0.2336	0.303
18.	KO	Coca Cola Co.	0.2605	0.2382	0.2157	0.2142	0.2331	0.2403	0.2344	0.2096	0.1987	0.2216	0.2381	0.2334	0.2096	0.1951	0.2193	0.2267	0.2148	0.326
19.	MCD	McDonald's Corp.	0.2687	0.2416	0.2229	0.2287	0.2411	0.2504	0.2413	0.2236	0.2163	0.2328	0.2513	0.2448	0.2259	0.2219	0.2361	0.2378	0.2255	0.230
20.	MCQ	MCI Comm.	0.3574	0.3285	0.2983	0.3137	0.3255	0.3368	0.3253	0.2995	0.3051	0.3175	0.3311	0.3208	0.2980	0.3015	0.3134	0.3207	0.4037	0.089
21.	MMM	Minn Mining	0.2252	0.2044	0.1819	0.1883	0.1992	0.2147	0.2057	0.1761	0.1744	0.1928	0.2106	0.2057	0.1743	0.1721	0.1908	0.1956	0.1783	0.270
22.	MOB	Mobil Corp.	0.2079	0.1920	0.1675	0.1788	0.1856	0.1928	0.1933	0.1633	0.1625	0.1786	0.1969	0.1966	0.1572	0.1587	0.1773	0.1815	0.1777	0.122
23.	MRK	Merck & Co.	0.2710	0.2545	0.2392	0.2547	0.2549	0.2579	0.2552	0.2345	0.2413	0.2479	0.2530	0.2491	0.2309	0.2403	0.2439	0.2506	0.2332	0.356
24.	NT	Northern Telecom	0.3172	0.3013	0.2825	0.2902	0.2979	0.2955	0.2900	0.2766	0.2744	0.2843	0.3057	0.2937	0.2784	0.2809	0.2900	0.2930	0.2764	0.216
25.	PEP	PepsiCo Inc.	0.2732	0.2302	0.2258	0.2316	0.2404	0.2684	0.2375	0.2320	0.2194	0.2387	0.2533	0.2359	0.2118	0.2143	0.2297	0.2373	0.2438	0.272
26.	SLB	Schlumberger Ltd.	0.2567	0.2507	0.2344	0.2403	0.2451	0.2474	0.2484	0.2270	0.2241	0.2367	0.2459	0.2495	0.2227	0.2240	0.2356	0.2409	0.2506	0.118
27.	T	AT&T	0.2319	0.2035	0.1865	0.2019	0.2062	0.2185	0.2034	0.1839	0.1897	0.1990	0.2173	0.2020	0.1855	0.1836	0.1973	0.2024	0.1961	0.260
28.	WMT	Wal-Mart	0.3022	0.2819	0.2556	0.2698	0.2790	0.2818	0.2843	0.2524	0.2676	0.2716	0.2825	0.2778	0.2614	0.2556	0.2705	0.2749	0.2581	0.349
29.	XON	Exxon Corp.	0.1991	0.1710	0.1525	0.1649	0.1717	0.1831	0.1726	0.1425	0.1449	0.1613	0.1807	0.1770	0.1424	0.1377	0.1592	0.1661	0.1688	0.166
30.	XRX	Xerox Corp.	0.2715	0.2623	0.2361	0.2345	0.2512	0.2626	0.2630	0.2303	0.2263	0.2458	0.2612	0.2618	0.2203	0.2198	0.2412	0.2475	0.2333	0.180
31.	OEX	S&P 100 Index	0.1846	0.1470	0.1162	0.1171	0.1444	0.1716	0.1503	0.1209	0.1136	0.1421	0.1667	0.1523	0.1256	0.1188	0.1422	0.1435	0.1108	0.952

Notes: This table reports the average implied volatilities within each moneyness bucket under a particular maturity range for options on the 30 largest component stocks in the S&P100 index and on the S&P100 index itself. The third last column of the table contains the average implied volatility for the entire sample, while the second last column contains the average historical volatility over the sample period. The last column contains the average proportion of systematic variance over the total variance.

Table 1C: Sorting of stocks' characteristics by systematic risk proportion

Quintile	Systematic Risk Proportion	Implied volatility minus historical volatility: Short-term	Medium-term	Long-term	Overall
1	0.112	-0.009	-0.015	-0.019	-0.012
2	0.188	-0.001	-0.007	-0.008	-0.004
3	0.253	0.009	0.004	0.003	0.006
4	0.346	0.011	0.006	0.004	0.008
5	0.952	0.032	0.030	0.028	0.031

Quintile	Systematic Risk Proportion	Slope of implied volatility curve: Short-term	Medium-term	Long-term	Overall
1	0.112	-0.215	-0.220	-0.251	-0.224
2	0.188	-0.207	-0.221	-0.239	-0.216
3	0.253	-0.230	-0.213	-0.225	-0.225
4	0.346	-0.266	-0.250	-0.255	-0.258
5	0.952	-0.586	-0.497	-0.458	-0.550

Quintile	Systematic Risk Proportion	Risk-Neutral Skewness: Short-term	Medium-term	Long-term	Overall
1	0.112	-1.573	-1.980	-1.693	-1.709
2	0.188	-1.750	-2.055	-1.698	-1.824
3	0.253	-1.744	-2.001	-1.637	-1.780
4	0.346	-1.919	-2.195	-1.823	-1.966
5	0.952	-3.479	-2.087	-1.551	-2.778

Quintile	Systematic Risk Proportion	Risk-Neutral Kurtosis: Short-term	Medium-term	Long-term	Overall
1	0.112	3.449	5.495	4.017	4.115
2	0.188	4.313	6.047	4.258	4.766
3	0.253	4.275	5.798	4.060	4.588
4	0.346	5.052	6.595	4.714	5.383
5	0.952	14.716	4.738	2.551	9.691

Notes: This table summarizes the properties of five groups of individual stocks / index sorted by their systematic risk proportions. The four properties are a) the average implied volatility minus the average historical volatility, b) the average slope of the implied volatility curves, c) the average risk-neutral skewness, and d) the average risk-neutral kurtosis. The maturity ranges for short-term, medium-term and long-term options are, respectively, 20-70 days, 71-120 days, and 121-180 days. The heading "Overall" is for all maturities combined. Given the magnitude of the S&P 100 index's systematic risk proportion, we put it in a separate group, quintile 5. The first quintile contains 6 stocks and the other three contain 8 stocks each. To be consistent with the estimation procedures described at the beginning of Section 2, we estimate the variables monthly. Thus, the sorting is also done monthly, and the average variables are calculated for each quintile. We then average the monthly quantities for each quintile over 65 months.

Table 2: Preliminary tests for the relationship between implied volatility and the systematic risk

	With S&P100 Index		Without S&P100 Index	
	systematic risk proportion	beta	systematic risk proportion	beta
Overall	0.259	0.019	0.328	0.020
	3.183	-0.757	**3.694**	-0.746
Moneyness, K / S 0.90 - 0.95	0.350	0.039	0.333	0.042
	3.954	-1.079	**3.746**	-1.109
Moneyness, K / S 0.95 - 1.00	0.207	0.060	0.264	0.062
	2.748	-1.361	**3.169**	-1.356
Moneyness, K / S 1.00 - 1.05	0.199	0.000	0.305	0.001
	2.680	-0.149	**3.504**	-0.128
Moneyness, K / S 1.05 - 1.10	0.153	0.005	0.277	0.005
	2.290	-0.376	**3.271**	-0.358
Short maturity	0.239	0.024	0.323	0.024
	3.018	-0.850	**3.657**	-0.838
Medium maturity	0.271	0.008	0.339	0.008
	3.284	-0.496	**3.791**	-0.479
Long maturity	0.271	0.022	0.312	0.022
	3.283	-0.808	**3.566**	-0.801

Notes: This table contains results for two univariate cross-sectional regressions under various sample constructions. In the first regression, the dependent variable is the average difference between the implied volatility and the historical volatility and the explanatory variable is the average systematic risk proportion, i.e., $\sigma_j^{imp} - \sigma_j^{his} = \gamma_0 + \gamma_1 b_j + e_j$. In the second regression, the explanatory variable is the average beta, i.e., $\sigma_j^{imp} - \sigma_j^{his} = \gamma_0 + \gamma_1 \beta_j + e_j$. The averages are taken or calculated from Table 1B. The regressions are run for the entire sample first, which corresponds to the "Overall" case. We then run the regressions for each of the four moneyness buckets. Finally, we run the regressions for each of the three maturity ranges. For each particular sample construction, we run regressions either with or without the S&P 100 index. For each pair of numbers, the first number is the R^2, and the second number is the *t*-value (a negative *t*-value indicates that the regression coefficient is negative). The *t*-values in bold type are significant at least at the 10% level for two-tail tests. The maturity ranges for short-term, medium-term and long-term are, respectively, 20-70 days, 71-120 days, and 121-180 days.

Table 3: Regression tests for the level effect

Panel A: Separate Regressions on Systematic Risk Proportion, and Skewness and Kurtosis

		γ_1 avg.	γ_1 t	$\gamma_1 > 0$	R^2	γ_2 avg.	γ_2 t	γ_3 avg.	γ_3 t	R^2
	All maturities	0.077	**16.061**	100.0%	0.145	-0.013	-1.644	-0.002	-1.067	0.111
Moneyness	Short-term	0.074	**16.233**	100.0%	0.159	-0.014	**-2.182**	-0.001	-0.446	0.155
K/S	Medium-term	0.064	**14.245**	100.0%	0.231	-0.030	**-3.285**	-0.006	**-2.978**	0.200
0.90 - 0.95	Long-term	0.104	**3.978**	79.6%	0.131	-0.009	-0.972	-0.003	-1.377	0.179
Moneyness	All maturities	0.051	**11.979**	100.0%	0.078	-0.011	-1.353	-0.002	-1.207	0.095
K/S	Short-term	0.044	**11.920**	98.5%	0.073	-0.004	-0.680	0.000	0.239	0.113
0.95 - 1.00	Medium-term	0.036	**6.364**	93.6%	0.083	-0.010	-0.953	-0.003	-1.162	0.213
	Long-term	0.032	1.552	63.9%	0.077	-0.004	-0.343	-0.002	-0.767	0.268
Moneyness	All maturities	0.047	**5.424**	98.5%	0.073	0.014	**2.158**	0.003	**2.770**	0.094
K/S	Short-term	0.037	**5.386**	96.9%	0.056	0.018	**3.235**	0.004	**3.737**	0.120
1.00 - 1.05	Medium-term	0.027	**4.786**	90.9%	0.090	0.011	**1.689**	0.001	1.149	0.238
	Long-term	0.093	**4.164**	78.6%	0.149	0.010	1.087	0.001	0.363	0.219
Moneyness	All maturities	0.037	**4.636**	96.9%	0.054	0.014	**2.070**	0.003	**2.507**	0.082
K/S	Short-term	0.024	**4.061**	78.5%	0.042	0.008	1.412	0.002	**2.024**	0.102
1.05 - 1.10	Medium-term	0.023	**3.725**	84.0%	0.055	0.003	0.265	0.000	0.136	0.197
	Long-term	0.051	**2.744**	71.4%	0.110	0.017	**2.742**	0.003	1.585	0.236

Panel B: Combined Regressions on Systematic Risk Proportion, Skewness and Kurtosis

		γ_1 avg.	γ_1 t	$\gamma_1 > 0$	γ_2 avg.	γ_2 t	γ_3 avg.	γ_3 t	R^2
	All maturities	0.088	**10.044**	100.0%	-0.017	-1.521	-0.004	**-1.652**	0.248
Moneyness	Short-term	0.085	**4.905**	89.2%	-0.014	**-1.780**	-0.003	-1.312	0.287
K/S	Medium-term	0.066	**11.120**	100.0%	-0.010	-0.855	-0.001	-0.503	0.408
0.90 - 0.95	Long-term	0.102	**3.802**	81.8%	-0.014	-1.464	-0.005	**-1.986**	0.301
Moneyness	All maturities	0.067	**5.536**	96.9%	-0.014	-1.244	-0.004	-1.640	0.188
K/S	Short-term	0.057	**3.902**	87.7%	-0.003	-0.478	-0.001	-0.684	0.191
0.95 - 1.00	Medium-term	0.037	**6.363**	93.6%	-0.004	-0.365	-0.002	-0.639	0.301
	Long-term	0.034	1.531	61.1%	-0.003	-0.268	-0.002	-0.809	0.345
Moneyness	All maturities	0.056	**5.769**	93.9%	0.010	1.167	0.002	0.904	0.179
K/S	Short-term	0.045	**3.455**	81.5%	0.016	**2.512**	0.003	**1.905**	0.200
1.00 - 1.05	Medium-term	0.033	**4.718**	87.9%	0.021	**3.181**	0.004	**2.666**	0.343
	Long-term	0.091	**3.183**	78.6%	0.012	1.515	0.002	0.825	0.364
Moneyness	All maturities	0.049	**5.257**	87.7%	0.012	1.255	0.002	0.999	0.152
K/S	Short-term	0.033	**2.429**	72.3%	0.010	1.373	0.002	1.267	0.177
1.05 - 1.10	Medium-term	0.034	**6.165**	88.0%	0.011	0.969	0.001	0.594	0.287
	Long-term	0.058	**2.237**	60.0%	0.011	**2.114**	0.001	0.716	0.347

Notes: This table contains two-pass regression results for the level effect tests. In the first pass, for each firm, we regress the difference between the implied volatility and the historical volatility on moneyness for non-overlapping periods of one month (i.e., 4 weeks): $\sigma_i^{imp} - \sigma_i^{his} = a_0 + a_1(y_i - \bar{y}) + \varepsilon_i$. We thus obtain a monthly time-series of the intercept a_0 and the slope coefficient a_1 for all firms including the S&P100 index. The moneyness variable is adjusted by the sample mean within the month so that the intercept a_0 is the average of the difference between the implied volatility and the historical volatility. In the second pass, we cross-sectionally regress the intercept a_0 on the systematic risk proportion b, the risk-neutral skewness and kurtosis. This regression is done every month in three different forms: (1) $a_{0j} = \gamma_0 + \gamma_1 b_j + e_j$, (2) $a_{0j} = \gamma_0 + \gamma_2 Skew_j^{(rn)} + \gamma_3 Kurt_j^{(rn)} + e_j$ and (3) $a_{0j} = \gamma_0 + \gamma_1 b_j + \gamma_2 Skew_j^{(rn)} + \gamma_3 Kurt_j^{(rn)} + e_j$. The monthly regression coefficients are then averaged, and the corresponding *t*-values calculated with a first-order serial correlation correction. The results for regressions (1) and (2) are reported in Panel A, while those for regression (3) are in Panel B. To conserve space, we omit the regression intercept and its *t*-value. The *t*-values in bold type are significant at least at the 10% level, for two-tailed tests. The entries under $\gamma_1 > 0$ are percentages of the monthly coefficient γ_1 that are positive. The reported R^2 is the average R^2 from monthly cross-sectional regressions. The risk-neutral skewness and kurtosis are estimated using the same procedure as in Bakshi, Kapadia and Madan (2003). The maturity ranges for short-term, medium-term and long-term are, respectively, 20-70 days, 71-120 days, and 121-180 days. The regressions are performed separately for four moneyness buckets.

Table 4: Regression tests for the slope effect

Panel A: Separate Regressions on Systematic Risk Proportion, and Skewness and Kurtosis

		γ_1				γ_2		γ_3		
		avg.	*t*	$\gamma_1 < 0$	R^2	avg.	*t*	avg.	*t*	R^2
	All maturities	-0.431	**-5.394**	86.2%	0.047	0.455	**7.995**	0.074	**4.622**	0.101
Moneyness	Short-term	-0.363	**-5.123**	78.5%	0.032	0.322	**3.836**	0.040	**2.487**	0.107
K/S	Medium-term	-0.411	**-7.813**	93.6%	0.100	0.257	**3.838**	0.045	**2.679**	0.153
0.90 - 0.95	Long-term	-0.183	-1.099	54.6%	0.092	0.057	1.124	0.006	0.435	0.195
Moneyness	All maturities	-0.441	**-6.163**	92.3%	0.048	-0.016	-0.180	-0.013	-0.625	0.092
K/S	Short-term	-0.583	**-10.989**	95.4%	0.061	-0.081	-1.509	-0.037	**-2.856**	0.093
0.95 - 1.00	Medium-term	-0.534	**-14.137**	100.0%	0.158	0.134	1.140	0.026	0.967	0.135
	Long-term	-0.212	**-2.002**	63.9%	0.056	0.060	1.139	0.012	1.109	0.139
Moneyness	All maturities	-0.557	**-6.343**	98.5%	0.055	0.015	0.240	-0.009	-0.583	0.073
K/S	Short-term	-0.612	**-6.825**	93.9%	0.060	-0.096	-1.082	-0.032	**-1.655**	0.098
1.00 - 1.05	Medium-term	-0.500	**-9.634**	97.0%	0.167	0.108	1.277	0.034	**1.910**	0.223
	Long-term	-0.563	**-2.629**	73.8%	0.087	0.034	0.524	0.007	0.369	0.189
Moneyness	All maturities	0.003	0.054	49.2%	0.016	-0.124	-1.583	-0.026	-1.388	0.090
K/S	Short-term	-0.053	-0.971	56.9%	0.021	-0.271	**-2.747**	-0.066	**-2.816**	0.114
1.05 - 1.10	Medium-term	-0.158	**-2.038**	68.0%	0.060	-0.107	-1.258	-0.032	**-2.337**	0.149
	Long-term	-0.311	-1.633	54.3%	0.090	-0.154	**-2.115**	-0.045	**-1.875**	0.181

Panel B: Combined Regressions on Systematic Risk Proportion, Skewness and Kurtosis

		γ_1			γ_2		γ_3		
		avg.	*t*	$\gamma_1 < 0$	avg.	*t*	avg.	*t*	R^2
	All maturities	-0.349	**-4.086**	76.9%	0.453	**7.511**	0.079	**5.022**	0.139
Moneyness	Short-term	-0.250	**-1.656**	56.9%	0.347	**3.861**	0.049	**2.838**	0.144
K/S	Medium-term	-0.528	**-6.436**	93.5%	0.033	0.228	-0.008	-0.217	0.264
0.90 - 0.95	Long-term	-0.276	-1.322	59.1%	0.027	0.438	-0.004	-0.249	0.302
Moneyness	All maturities	-0.433	**-4.742**	81.5%	-0.040	-0.424	-0.007	-0.364	0.134
K/S	Short-term	-0.511	**-5.847**	78.5%	-0.131	**-2.340**	-0.035	**-2.626**	0.140
0.95 - 1.00	Medium-term	-0.556	**-8.017**	93.5%	0.017	0.175	0.003	0.119	0.281
	Long-term	-0.259	**-2.244**	63.9%	0.067	1.471	0.019	**1.792**	0.186
Moneyness	All maturities	-0.479	**-5.326**	86.2%	-0.017	-0.320	-0.007	-0.530	0.120
K/S	Short-term	-0.518	**-3.926**	76.9%	-0.127	-1.624	-0.029	**-1.656**	0.150
1.00 - 1.05	Medium-term	-0.434	**-6.625**	90.9%	-0.011	-0.144	0.011	0.695	0.361
	Long-term	-0.619	**-2.248**	69.0%	0.045	0.568	0.014	0.674	0.276
Moneyness	All maturities	-0.007	-0.099	52.3%	-0.139	**-1.734**	-0.030	-1.537	0.113
K/S	Short-term	0.052	0.515	50.8%	-0.293	**-2.823**	-0.071	**-2.907**	0.148
1.05 - 1.10	Medium-term	-0.160	**-1.788**	64.0%	-0.154	-1.269	-0.045	**-1.816**	0.224
	Long-term	-0.376	-1.556	57.1%	-0.128	-1.574	-0.040	-1.430	0.280

Notes: This table contains two-pass regression results for the slope effect tests. In the first pass, for each firm, we regress the difference between the implied volatility and the historical volatility on moneyness for non-overlapping periods of one month (i.e., 4 weeks): $\sigma_i^{imp} - \sigma_i^{his} = a_0 + a_1(y_i - \bar{y}) + \varepsilon_i$. We thus obtain a monthly time-series of the intercept a_0 and the slope coefficient a_1 for all firms including the S&P100 index. The moneyness variable is adjusted by the sample mean within the month so that the intercept a_0 is the average of the difference between the implied volatility and the historical volatility. In the second pass, we cross-sectionally regress the slope a_1 on the systematic risk proportion b, the risk-neutral skewness and kurtosis. This regression is done every month in three different forms: (1) $a_{1j} = \gamma_0 + \gamma_1 b_j + e_j$, (2) $a_{1j} = \gamma_0 + \gamma_2 Skew_j^{(rn)} + \gamma_3 Kurt_j^{(rn)} + e_j$ and (3) $a_{1j} = \gamma_0 + \gamma_1 b_j + \gamma_2 Skew_j^{(rn)} + \gamma_3 Kurt_j^{(rn)} + e_j$. The monthly regression coefficients are then averaged, and the corresponding *t*-values calculated with a first-order serial correlation correction. The results for regressions (1) and (2) are reported in Panel A, while those for regression (3) are in Panel B. To conserve space, we omit the regression intercept and its *t*-value. The *t*-values in bold type are significant at least at the 10% level, for two-tailed tests. The entries under $\gamma_1 <$ are percentages of the monthly coefficient γ_1 that are negative. The reported R^2 is the average R^2 from monthly cross-sectional regressions. The risk-neutral skewness and kurtosis are estimated using the same procedure as in Bakshi, Kapadia and Madan (2003). The maturity ranges for short-term, medium-term and long-term are, respectively, 20-70 days, 71-120 days, and 121-180 days. The regressions are performed separately for four moneyness buckets.

Table 5: Sub-sample regression tests for the level effect

Panel A: Regressions on Systematic Risk Proportion

		Whole Sample, 01/01/91 - 31/12/95				Sub-sample, 01/01/91 - 30/06/93				Sub-sample, 01/07/93 - 31/12/95			
		γ_1				γ_1				γ_1			
		avg.	*t*	$\gamma_1 > 0$	R^2	*avg.*	*t*	$\gamma_1 > 0$	R^2	*avg.*	*t*	$\gamma_1 > 0$	R^2
	All maturities	0.067	**12.683**	100.0%	0.103	0.070	**13.825**	100.0%	0.107	0.065	**6.468**	100.0%	0.099
Moneyness	Short-term	0.066	**11.814**	100.0%	0.098	0.067	**12.080**	100.0%	0.100	0.064	**6.490**	100.0%	0.095
K/S	Medium-term	0.060	**12.727**	100.0%	0.169	0.063	**9.175**	100.0%	0.165	0.058	**8.939**	100.0%	0.172
0.90 - 1.00	Long-term	0.077	**6.001**	83.1%	0.119	0.079	**6.784**	87.5%	0.113	0.075	**3.245**	78.8%	0.125
Moneyness	All maturities	0.045	**5.114**	96.9%	0.064	0.059	**6.337**	96.9%	0.099	0.031	**3.249**	97.0%	0.029
K/S	Short-term	0.038	**4.910**	96.9%	0.048	0.053	**6.584**	96.9%	0.078	0.024	**2.421**	97.0%	0.019
1.00 - 1.10	Medium-term	0.039	**8.910**	95.1%	0.102	0.051	**8.138**	93.1%	0.125	0.029	**5.910**	96.9%	0.081
	Long-term	0.082	**5.826**	84.6%	0.127	0.098	**9.478**	90.6%	0.176	0.067	**2.528**	78.8%	0.080

Panel B: Regressions on Skewness and Kurtosis

		Whole Sample, 01/01/91 - 31/12/95					Sub-sample, 01/01/91 - 30/06/93					Sub-sample, 01/07/93 - 31/12/95				
		γ_2		γ_3			γ_2		γ_3			γ_2		γ_3		
		avg.	*t*	*avg.*	*t*	R^2	*avg.*	*t*	*avg.*	*t*	R^2	*avg.*	*t*	*avg.*	*t*	R^2
	All maturities	-0.012	-1.541	-0.002	-1.143	0.091	-0.005	-0.535	-0.002	-0.971	0.067	-0.018	-1.516	-0.002	-0.600	0.115
Moneyness	Short-term	-0.011	**-2.213**	-0.001	-0.733	0.110	-0.005	-0.755	0.000	-0.211	0.061	-0.018	**-2.298**	-0.001	-0.644	0.156
K/S	Medium-term	-0.021	**-3.208**	-0.005	**-3.417**	0.171	-0.016	-1.544	-0.004	**-2.101**	0.192	-0.025	**-3.208**	-0.005	**-2.680**	0.152
0.90 - 1.00	Long-term	-0.018	**-2.369**	-0.007	**-3.135**	0.136	-0.019	-1.469	-0.008	**-2.201**	0.165	-0.018	**-2.105**	-0.005	**-2.505**	0.108
Moneyness	All maturities	0.014	**2.058**	0.003	**2.480**	0.082	0.023	**3.873**	0.004	**2.622**	0.075	0.005	0.418	0.003	1.126	0.089
K/S	Short-term	0.014	**2.729**	0.003	**3.358**	0.081	0.024	**5.049**	0.005	**5.142**	0.070	0.004	0.566	0.002	1.190	0.091
1.00 - 1.10	Medium-term	0.002	0.322	0.000	-0.173	0.169	0.003	0.302	-0.001	-0.356	0.204	0.001	0.129	0.000	0.159	0.137
	Long-term	0.007	1.370	0.001	0.449	0.154	0.009	1.028	0.001	0.248	0.173	0.005	0.890	0.001	0.476	0.136

Panel C: Combined Regressions on Systematic Risk Proportion, Skewness and Kurtosis

		Whole Sample, 01/01/91 - 31/12/95					Sub-sample, 01/01/91 - 30/06/93					Sub-sample, 01/07/93 - 31/12/95				
		γ_1		γ_2	γ_3		γ_1		γ_2	γ_3		γ_1		γ_2	γ_3	
		t	$\gamma_1 > 0$	*t*	*t*	R^2	*t*	$\gamma_1 > 0$	*t*	*t*	R^2	*t*	$\gamma_1 > 0$	*t*	*t*	R^2
	All maturities	**7.945**	100.0%	-1.500	**-1.742**	0.200	**15.112**	100.0%	-0.685	-1.490	0.194	**3.934**	100.0%	-1.199	-1.050	0.206
Moneyness	Short-term	**5.436**	90.8%	**-1.967**	**-1.714**	0.201	**10.507**	100.0%	-0.401	-1.266	0.165	**2.514**	81.8%	**-2.069**	-1.298	0.235
K/S	Medium-term	**17.608**	100.0%	**-1.999**	**-2.242**	0.300	**10.732**	100.0%	-1.282	**-1.717**	0.322	**15.554**	100.0%	-1.505	-1.364	0.280
0.90 - 1.00	Long-term	**6.000**	86.2%	**-2.053**	**-2.681**	0.253	**7.276**	93.8%	-1.355	**-2.163**	0.275	**3.156**	78.8%	**-1.662**	**-1.857**	0.231
Moneyness	All maturities	**5.759**	93.9%	1.055	0.791	0.158	**8.435**	100.0%	**2.470**	1.109	0.191	**2.929**	87.9%	0.059	0.218	0.126
K/S	Short-term	**3.553**	81.5%	**1.962**	1.526	0.146	**9.420**	100.0%	**4.952**	**3.056**	0.165	**1.116**	63.6%	0.154	0.258	0.128
1.00 - 1.10	Medium-term	**11.217**	96.7%	1.199	0.773	0.275	**8.502**	96.6%	0.507	0.030	0.317	**8.412**	96.9%	1.284	1.148	0.238
	Long-term	**5.701**	81.5%	1.138	0.570	0.278	**11.537**	90.6%	0.665	-0.022	0.335	**2.394**	72.7%	0.961	1.247	0.223

Notes: This table contains two-pass regression results for the level effect tests. The regressions are run for the whole sample (01/01/91-31/12/95) as well as two sub-samples: (01/01/91-30/06/93) and (01/07/93-31/12/95). In the first pass, for each firm, we regress the difference between the implied volatility and the historical volatility on moneyness for non-overlapping periods of one month (i.e., 4 weeks): $\sigma_i^{imp} - \sigma_i^{his} = a_0 + a_1(y_i - \overline{y}) + \varepsilon_i$. We thus obtain a monthly time-series of the intercept a_0 and the slope coefficient a_1 for all firms including the S&P100 index. The moneyness variable is adjusted by the sample mean within the month so that the intercept a_0 is the average of the difference between the implied volatility and the historical volatility. In the second pass, we cross-sectionally regress the intercept a_0 on the systematic risk proportion b, the risk-neutral skewness and kurtosis. This regression is done every month in three different forms: (1) $a_{0j} = \gamma_0 + \gamma_1 b_j + e_j$, (2) $a_{0j} = \gamma_0 + \gamma_2 Skew_j^{(rn)} + \gamma_3 Kurt_j^{(rn)} + e_j$ and (3) $a_{0j} = \gamma_0 + \gamma_1 b_j + \gamma_2 Skew_j^{(rn)} + \gamma_3 Kurt_j^{(rn)} + e_j$. The monthly regression coefficients are then averaged, and the corresponding *t*-values calculated with a first-order serial correlation correction. The results for regressions (1), (2) and (3) are reported in Panels A, B and C, respectively. To conserve space, we omit the regression intercept and its *t*-value. The *t*-values in bold type are significant at least at the 10% level, for two-tailed tests. In Panel C, the coefficients are omitted for brevity. The entries under $\gamma_1 > 0$ (in Panels A and C) are percentages of the monthly coefficient γ_1 that are positive. The reported R^2 is the average R^2 from monthly cross-sectional regressions. The risk-neutral skewness and kurtosis are estimated using the same procedure as in Bakshi, Kapadia and Madan (2003). The maturity ranges for short-term, medium-term and long-term are, respectively, 20-70 days, 71-120 days, and 121-180 days. The regressions are performed separately for two moneyness buckets.

Table 6: Sub-sample regression tests for the slope effect

Panel A: Regressions on Systematic Risk Proportion

		Whole Sample, 01/01/91 - 31/12/95				Sub-sample, 01/01/91 - 30/06/93				Sub-sample, 01/07/93 - 31/12/95			
		γ_1				γ_1				γ_1			
		avg.	*t*	$\gamma_1 < 0$	R^2	*avg.*	*t*	$\gamma_1 < 0$	R^2	*avg.*	*t*	$\gamma_1 < 0$	R^2
	All maturities	-0.450	**-8.994**	93.9%	0.100	-0.304	**-4.823**	87.5%	0.078	-0.592	**-22.074**	100.0%	0.121
Moneyness	Short-term	-0.439	**-7.697**	89.2%	0.064	-0.284	**-4.858**	78.1%	0.046	-0.589	**-10.568**	100.0%	0.083
K/S	Medium-term	-0.453	**-13.044**	95.2%	0.207	-0.346	**-8.111**	90.0%	0.193	-0.553	**-19.904**	100.0%	0.221
0.90 - 1.00	Long-term	-0.232	**-3.264**	66.2%	0.103	-0.118	-1.491	65.6%	0.082	-0.343	**-3.871**	66.7%	0.123
Moneyness	All maturities	-0.392	**-10.920**	96.9%	0.064	-0.404	**-6.357**	93.8%	0.081	-0.380	**-10.449**	100.0%	0.049
K/S	Short-term	-0.461	**-14.048**	100.0%	0.056	-0.506	**-10.184**	100.0%	0.072	-0.418	**-9.036**	100.0%	0.041
1.00 - 1.10	Medium-term	-0.394	**-12.904**	98.4%	0.130	-0.374	**-7.760**	96.6%	0.119	-0.412	**-9.708**	100.0%	0.140
	Long-term	-0.382	**-5.637**	78.5%	0.090	-0.305	**-4.943**	81.3%	0.073	-0.456	**-3.831**	75.8%	0.106

Panel B: Regressions on Skewness and Kurtosis

		Whole Sample, 01/01/91 - 31/12/95					Sub-sample, 01/01/91 - 30/06/93					Sub-sample, 01/07/93 - 31/12/95				
		γ_2		γ_3			γ_2		γ_3			γ_2		γ_3		
		avg.	*t*	*avg.*	*t*	R^2	*avg.*	*t*	*avg.*	*t*	R^2	*avg.*	*t*	*avg.*	*t*	R^2
	All maturities	0.206	**7.295**	0.025	**3.562**	0.124	0.213	**5.230**	0.036	**3.338**	0.089	0.200	**4.878**	0.015	**1.690**	0.159
Moneyness	Short-term	0.201	**5.938**	0.025	**3.746**	0.105	0.180	**3.367**	0.031	**2.978**	0.078	0.221	**5.031**	0.020	**2.300**	0.132
K/S	Medium-term	0.235	**4.655**	0.043	**3.773**	0.158	0.135	**2.939**	0.026	**2.690**	0.115	0.329	**4.409**	0.058	**3.141**	0.199
0.90 - 1.00	Long-term	0.114	**5.108**	0.030	**2.919**	0.102	0.095	**3.628**	0.021	**2.518**	0.093	0.133	**3.868**	0.039	**2.138**	0.110
Moneyness	All maturities	0.019	0.550	-0.004	-0.554	0.066	0.037	0.627	0.007	0.584	0.062	0.002	0.050	-0.015	**-1.938**	0.070
K/S	Short-term	-0.077	**-1.883**	-0.030	**-4.203**	0.089	-0.068	-1.008	-0.027	**-2.104**	0.083	-0.085	**-1.747**	-0.034	**-4.567**	0.095
1.00 - 1.10	Medium-term	0.044	1.260	0.009	1.058	0.118	0.029	0.803	0.012	1.623	0.118	0.057	0.972	0.007	0.426	0.118
	Long-term	0.022	0.856	0.003	0.410	0.096	0.004	0.127	-0.003	-0.280	0.092	0.038	1.045	0.009	0.858	0.099

Panel C: Combined Regressions on Systematic Risk Proportion, Skewness and Kurtosis

		Whole Sample, 01/01/91 - 31/12/95					Sub-sample, 01/01/91 - 30/06/93					Sub-sample, 01/07/93 - 31/12/95				
		γ_1		γ_2	γ_3		γ_1		γ_2	γ_3		γ_1		γ_2	γ_3	
		t	$\gamma_1 < 0$	*t*	*t*	R^2	*t*	$\gamma_1 < 0$	*t*	*t*	R^2	*t*	$\gamma_1 < 0$	*t*	*t*	R^2
	All maturities	**-9.204**	0.877	**6.317**	**3.913**	0.189	**-6.090**	0.844	**4.353**	**3.509**	0.155	**-7.061**	0.909	**4.361**	**2.044**	0.222
Moneyness	Short-term	**-6.563**	0.800	**6.096**	**5.208**	0.141	**-4.774**	0.688	**3.159**	**3.350**	0.111	**-5.354**	0.909	**5.681**	**3.770**	0.170
K/S	Medium-term	**-15.379**	0.936	**3.275**	**2.324**	0.314	**-7.942**	0.867	**2.228**	**1.650**	0.304	**-18.827**	1.000	**2.654**	**1.804**	0.324
0.90 - 1.00	Long-term	**-2.164**	0.631	**4.007**	**2.095**	0.193	-0.519	0.594	**3.229**	**1.974**	0.165	**-2.829**	0.667	**2.456**	1.415	0.220
Moneyness	All maturities	**-6.948**	0.892	0.163	-0.210	0.118	**-6.062**	0.938	0.208	0.553	0.132	**-4.297**	0.849	0.028	-0.781	0.103
K/S	Short-term	**-6.156**	0.800	**-2.278**	**-3.415**	0.130	**-9.398**	0.938	-1.427	**-1.656**	0.141	**-2.480**	0.667	**-1.829**	**-4.103**	0.119
1.00 - 1.10	Medium-term	**-10.119**	0.934	-0.376	-0.255	0.236	**-7.257**	0.897	0.670	1.274	0.223	**-6.853**	0.969	-0.759	-0.808	0.248
	Long-term	**-4.632**	0.769	0.554	-0.021	0.173	**-3.288**	0.750	0.466	-0.145	0.162	**-3.464**	0.788	0.308	0.127	0.184

Notes: This table contains two-pass regression results for the slope effect tests. The regressions are run for the whole sample (01/01/91-31/12/95) as well as two sub-samples: (01/01/91-30/06/93) and (01/07/93-31/12/95). In the first pass, for each firm, we regress the difference between the implied volatility and the historical volatility on moneyness for non-overlapping periods of one month (i.e., 4 weeks): $\sigma_i^{imp} - \sigma_i^{his} = a_0 + a_1(y_i - \bar{y}) + \varepsilon_i$. We thus obtain a monthly time-series of the intercept a_0 and the slope coefficient a_1 for all firms including the S&P100 index. The moneyness variable is adjusted by the sample mean within the month so that the intercept a_0 is the average of the difference between the implied volatility and the historical volatility. In the second pass, we cross-sectionally regress the slope a_1 on the systematic risk proportion b, the risk-neutral skewness and kurtosis. This regression is done every month in three different forms: (1) $a_{1j} = \gamma_0 + \gamma_1 b_j + e_j$, (2) $a_{1j} = \gamma_0 + \gamma_2 Skew_j^{(rn)} + \gamma_3 Kurt_j^{(rn)} + e_j$ and (3) $a_{1j} = \gamma_0 + \gamma_1 b_j + \gamma_2 Skew_j^{(rn)} + \gamma_3 Kurt_j^{(rn)} + e_j$. The monthly regression coefficients are then averaged, and the corresponding *t*-values calculated with a first-order serial correlation correction. The results for regressions (1), (2) and (3) are reported in Panels A, B and C, respectively. To conserve space, we omit the regression intercept and its *t*-value. The *t*-values in bold type are significant at least at the 10% level, for two-tailed tests. In Panel C, the coefficients are omitted for brevity. The entries under $\gamma_1 < 0$ (in Panels A and C) are percentages of the monthly coefficient γ_1 that are negative. The reported R^2 is the average R^2 from monthly cross-sectional regressions. The risk-neutral skewness and kurtosis are estimated using the same procedure as in Bakshi, Kapadia and Madan (2003). The maturity ranges for short-term, medium-term and long-term are, respectively, 20-70 days, 71-120 days, and 121-180 days. The regressions are performed separately for two moneyness buckets.

Table 7: Level and slope effect tests using an alternative estimation of the systematic risk proportion

Panel A: Level Effects

		Univariate Regressions			Multivariate Regressions						
		γ_1			γ_1		γ_2		γ_3		
		avg.	t	R^2	avg.	t	avg.	t	avg.	t	R^2
	All maturities	0.392	**4.480**	0.050	0.327	**4.106**	-0.384	**-7.952**	-0.069	**-5.263**	0.135
Moneyness	Short-term	0.273	**3.033**	0.034	0.113	0.921	-0.260	**-3.669**	-0.033	**-2.533**	0.139
K/S	Medium-term	0.405	**8.166**	0.123	0.476	**10.991**	-0.125	-1.568	-0.017	-0.801	0.268
0.90 - 0.95	Long-term	0.109	1.644	0.065	0.129	1.344	-0.023	-0.508	0.002	0.133	0.256
Moneyness	All maturities	0.432	**7.307**	0.064	0.389	**4.785**	0.045	0.513	0.009	0.460	0.146
K/S	Short-term	0.512	**8.165**	0.061	0.381	**3.831**	0.094	1.572	0.030	**2.090**	0.158
0.95 - 1.00	Medium-term	0.517	**8.574**	0.162	0.543	**6.182**	-0.065	-0.713	-0.021	-0.808	0.279
	Long-term	0.142	**1.732**	0.078	0.213	**2.617**	-0.014	-0.249	-0.005	-0.462	0.204
Moneyness	All maturities	0.545	**4.753**	0.068	0.484	**4.351**	0.056	1.110	0.013	1.043	0.133
K/S	Short-term	0.610	**4.446**	0.071	0.489	**3.010**	0.192	**2.461**	0.042	**2.296**	0.156
1.00 - 1.05	Medium-term	0.584	**9.157**	0.186	0.543	**6.341**	0.003	0.035	-0.013	-0.866	0.364
	Long-term	0.607	**4.549**	0.150	0.573	**4.256**	0.015	0.191	0.002	0.078	0.332
Moneyness	All maturities	0.042	0.500	0.032	0.047	0.457	0.193	**2.207**	0.042	**2.045**	0.121
K/S	Short-term	0.191	**2.430**	0.036	0.110	1.115	0.337	**2.982**	0.080	**3.233**	0.153
1.05 - 1.10	Medium-term	0.197	**2.592**	0.075	0.233	**2.890**	0.168	1.470	0.043	**2.034**	0.219
	Long-term	0.339	**3.433**	0.098	0.235	**2.013**	0.209	**2.470**	0.054	**2.212**	0.277

Panel B: Slope Effects

		Univariate Regressions			Multivariate Regressions						
		γ_1			γ_1		γ_2		γ_3		
		avg.	t	R^2	avg.	t	avg.	t	avg.	t	R^2
	All maturities	-0.347	**-3.701**	0.044	-0.268	**-3.144**	0.412	**7.629**	0.073	**4.907**	0.129
Moneyness	Short-term	-0.226	**-2.299**	0.031	-0.051	-0.387	0.279	**3.682**	0.037	**2.571**	0.136
K/S	Medium-term	-0.388	**-7.331**	0.114	-0.467	**-9.181**	0.117	1.411	0.013	0.624	0.258
0.90 - 0.95	Long-term	-0.092	-1.348	0.060	-0.118	-1.151	0.011	0.215	-0.008	-0.564	0.256
Moneyness	All maturities	-0.402	**-6.389**	0.061	-0.349	**-4.006**	-0.041	-0.469	-0.009	-0.474	0.145
K/S	Short-term	-0.514	**-8.385**	0.059	-0.376	**-3.657**	-0.092	-1.538	-0.030	**-2.098**	0.156
0.95 - 1.00	Medium-term	-0.527	**-9.938**	0.161	-0.556	**-6.895**	0.079	0.862	0.022	0.863	0.275
	Long-term	-0.184	**-2.191**	0.081	-0.249	**-2.813**	0.031	0.604	0.009	0.785	0.208
Moneyness	All maturities	-0.483	**-4.362**	0.061	-0.419	**-3.899**	-0.031	-0.614	-0.009	-0.688	0.125
K/S	Short-term	-0.572	**-4.194**	0.068	-0.456	**-2.840**	-0.166	**-2.178**	-0.037	**-2.068**	0.152
1.00 - 1.05	Medium-term	-0.578	**-9.055**	0.189	-0.535	**-6.438**	0.025	0.280	0.018	1.073	0.372
	Long-term	-0.572	**-4.495**	0.147	-0.537	**-4.211**	-0.002	-0.031	0.000	0.003	0.326
Moneyness	All maturities	0.003	0.043	0.031	0.006	0.068	-0.153	**-1.917**	-0.034	**-1.798**	0.120
K/S	Short-term	-0.158	**-2.179**	0.035	-0.076	-0.845	-0.296	**-2.912**	-0.071	**-3.170**	0.151
1.05 - 1.10	Medium-term	-0.165	**-2.197**	0.080	-0.196	**-2.364**	-0.142	-1.225	-0.037	**-1.713**	0.223
	Long-term	-0.280	**-3.076**	0.092	-0.188	**-1.807**	-0.181	**-2.347**	-0.049	**-2.082**	0.280

Notes: This table contains two-pass regression results for the level and slope effect tests using an alternative estimation of the systematic risk proportion. Instead of running the daily, one-year rolling window OLS regressions in estimating the systematic and total risks, we now run weekly, five-year rolling window regressions. In other words, the data frequency is weekly (Wednesday to Wednesday) and the sample period is five years. The weekly estimates are annualized and merged with the option data. The two-pass regressions are then run in the same fashion as in Table 3 and Table 4. Panel A corresponds to Table 3 and Panel B corresponds to Table 4. Please refer to those tables for further explanations. Here, to conserve space, we only report the regression coefficients together with their *t*-values and the average R^2 . For brevity, we also omit the results for regressions whose explanatory variables are only the skewness and kurtosis. The *t*-values in bold type are significant at least at the 10% level, for two-tailed tests.

Table 8: Level and slope effect tests without the index

Panel A: Level Effects

		Univariate Regressions			Multivariate Regressions						
		γ_1			γ_1		γ_2		γ_3		
		avg.	*t*	R^2	avg.	*t*	avg.	*t*	avg.	*t*	R^2
	All maturities	0.102	**3.513**	0.099	0.119	**4.078**	-0.022	**-1.979**	-0.005	**-2.261**	0.215
Moneyness	Short-term	0.102	**4.033**	0.120	0.109	**4.054**	-0.018	**-2.165**	-0.003	**-1.780**	0.257
K/S	Medium-term	0.087	**2.912**	0.138	0.113	**3.700**	-0.007	-0.448	-0.001	-0.356	0.348
0.90 - 0.95	Long-term	0.104	**3.978**	0.131	0.102	**3.802**	-0.014	-1.464	-0.005	**-1.986**	0.301
Moneyness	All maturities	0.090	**4.196**	0.084	0.102	**4.656**	-0.017	-1.602	-0.005	**-2.142**	0.196
K/S	Short-term	0.078	**5.375**	0.076	0.079	**4.787**	-0.005	-0.607	-0.001	-0.897	0.193
0.95 - 1.00	Medium-term	0.087	**2.376**	0.084	0.097	**2.213**	0.002	-0.142	-0.001	-0.289	0.335
	Long-term	0.031	1.512	0.078	0.033	1.511	-0.003	-0.252	-0.002	-0.782	0.346
Moneyness	All maturities	0.087	**3.200**	0.098	0.096	**3.799**	0.006	-0.595	0.000	0.249	0.204
K/S	Short-term	0.072	**3.620**	0.091	0.079	**3.978**	0.013	**-2.033**	0.002	-1.374	0.233
1.00 - 1.05	Medium-term	0.045	**1.913**	0.104	0.068	**2.457**	0.014	-1.191	0.002	-0.721	0.382
	Long-term	0.093	**4.164**	0.149	0.091	**3.183**	0.012	-1.515	0.002	-0.825	0.364
Moneyness	All maturities	0.076	**2.909**	0.097	0.087	**3.099**	0.008	-0.792	0.001	-0.502	0.193
K/S	Short-term	0.057	**2.756**	0.101	0.057	**2.533**	0.006	-0.711	0.001	-0.375	0.244
1.05 - 1.10	Medium-term	0.117	**2.659**	0.139	0.147	**2.647**	0.006	-0.357	0.001	-0.230	0.363
	Long-term	0.051	**2.744**	0.110	0.058	**2.237**	0.011	**-2.114**	0.001	-0.716	0.347

Panel B: Slope Effects

		Univariate Regressions			Multivariate Regressions						
		γ_1			γ_1		γ_2		γ_3		
		avg.	*t*	R^2	avg.	*t*	avg.	*t*	avg.	*t*	R^2
	All maturities	-0.145	-0.643	0.049	-0.148	-0.625	0.407	**6.458**	0.067	**3.948**	0.147
Moneyness	Short-term	-0.261	-1.050	0.054	-0.129	-0.410	0.319	**2.964**	0.036	1.525	0.175
K/S	Medium-term	-0.274	-0.817	0.105	-0.271	-0.730	0.046	0.436	-0.010	-0.359	0.276
0.90 - 0.95	Long-term	-0.183	-1.099	0.092	-0.276	-1.322	0.027	0.438	-0.004	-0.249	0.302
Moneyness	All maturities	0.071	0.478	0.031	0.056	0.358	-0.032	-0.321	-0.005	-0.208	0.123
K/S	Short-term	-0.082	-0.648	0.032	-0.066	-0.464	-0.105	-1.471	-0.026	-1.389	0.120
0.95 - 1.00	Medium-term	-0.164	-0.625	0.087	-0.023	-0.084	0.098	0.428	0.033	0.644	0.257
	Long-term	-0.205	**-1.932**	0.057	-0.248	**-2.120**	0.065	1.428	0.018	**1.675**	0.187
Moneyness	All maturities	-0.551	**-3.395**	0.045	-0.506	**-2.609**	-0.051	-0.868	-0.014	-0.941	0.114
K/S	Short-term	-0.758	**-3.448**	0.068	-0.784	**-3.156**	-0.163	**-1.798**	-0.036	**-1.772**	0.167
1.00 - 1.05	Medium-term	0.263	1.036	0.114	0.309	0.991	0.003	0.031	0.007	0.415	0.331
	Long-term	-0.563	**-2.629**	0.087	-0.619	**-2.248**	0.045	0.568	0.014	0.674	0.276
Moneyness	All maturities	-0.229	-1.261	0.036	-0.302	-1.579	-0.153	**-1.816**	-0.035	**-1.695**	0.138
K/S	Short-term	-0.323	-1.229	0.051	-0.259	-1.060	-0.369	-3.973	-0.093	**-4.668**	0.177
1.05 - 1.10	Medium-term	-0.432	-1.542	0.105	-0.723	**-1.703**	-0.141	-0.943	-0.048	-1.498	0.264
	Long-term	-0.311	-1.633	0.090	-0.376	-1.556	-0.128	-1.574	-0.040	-1.430	0.280

Notes: This table contains two-pass regression results for the level and slope effect tests by excluding the S&P 100 index from the sample. The testing procedures are the same as those in Tables 3 and 4. Panel A corresponds to Table 3 and Panel B corresponds to Table 4. Please refer to those tables for further explanations. In Tables 3 and 4, the second-pass cross-sectional regressions are run over the 30 stocks and the S&P 100 index; in this table, the cross-sectional regressions are run over the 30 stocks only. To conserve space, we only report the regression coefficients together with their *t*-values and the average R^2. For brevity, we also omit the results for regressions whose explanatory variables are only the skewness and kurtosis. The *t*-values in bold type are significant at least at the 10% level, for two-tailed tests.

Table 9: Level and slope effect tests based on panel regressions

		α_0	*t*	α_1	*t*	β_0	*t*	β_1	*t*	R^2
	All maturities	0.032	**225.24**	0.068	**143.46**	-0.361	**-36.74**	-0.730	**-21.88**	0.237
Moneyness	Short-term	0.038	**188.15**	0.066	**100.35**	-0.566	**-39.50**	-0.615	**-13.25**	0.238
K/S	Medium-term	0.032	**129.59**	0.064	**85.19**	-0.275	**-16.16**	-0.636	**-12.06**	0.295
0.90 - 0.95	Long-term	0.016	**55.14**	0.088	**33.45**	-0.021	-1.07	-0.660	**-3.60**	0.066
Moneyness	All maturities	0.018	**141.22**	0.037	**85.62**	-0.229	**-24.92**	-0.616	**-20.58**	0.106
K/S	Short-term	0.018	**95.65**	0.036	**60.20**	-0.318	**-24.25**	-0.654	**-15.68**	0.105
0.95 - 1.00	Medium-term	0.022	**97.10**	0.038	**55.64**	-0.202	**-12.33**	-0.524	**-10.87**	0.155
	Long-term	0.015	**51.96**	0.053	**21.06**	-0.026	-1.29	-0.511	**-2.79**	0.030
Moneyness	All maturities	-0.007	**-53.81**	0.028	**63.67**	-0.057	**-6.22**	-0.409	**-13.47**	0.053
K/S	Short-term	-0.006	**-30.28**	0.022	**36.59**	-0.050	**-3.84**	-0.428	**-10.26**	0.035
1.00 - 1.05	Medium-term	-0.004	**-18.34**	0.029	**43.31**	-0.090	**-5.56**	-0.427	**-8.92**	0.095
	Long-term	-0.014	**-48.34**	0.075	**28.78**	-0.026	-1.26	-0.098	-0.53	0.050
Moneyness	All maturities	-0.008	**-53.31**	0.021	**31.73**	0.070	**6.40**	0.050	0.95	0.018
K/S	Short-term	-0.003	**-13.91**	0.014	**15.16**	0.201	**12.50**	-0.117	-1.59	0.013
1.05 - 1.10	Medium-term	-0.011	**-37.30**	0.021	**20.60**	-0.010	-0.50	0.240	**2.87**	0.029
	Long-term	-0.017	**-56.35**	0.066	**22.52**	-0.055	**-2.66**	-0.415	**-1.96**	0.036

Notes: This table contains panel regression results for the level and slope effect tests. For each moneyness / maturity bucket, instead of running the Fama-MacBeth two pass-regressions, we lump the entire sample and run the following panel regression: $\sigma_{ij}^{imp} - \sigma_{ij}^{his} = [(\alpha_0 + \alpha_1(b_{ij} - \overline{b_i})] + [(\beta_0 + \beta_1(b_{ij} - \overline{b_i}))(y_{ij} - \overline{y_j})] + \varepsilon_{ij}$, where $\overline{b_i}$ is the cross-sectional average of the systematic risk proportion for each day, and $\overline{y_j}$ is the sample average of moneyness for stock *j* or the index within the bucket. This panel regression tests the level and slope effects simultaneously. Specifically, if the systematic risk proportion doesn't affect the price level or the level of the implied volatility (after adjusting for the historical volatility), then the coefficient α_1 should not be significantly different from zero; likewise, if the systematic risk proportion doesn't affect the slope of the implied volatility curve, then the coefficient β_1 should not be significantly different from zero. The *t*-values in bold type are significant at least at the 10% level, for two-tailed test.

Table 10: Level and slope effect tests using systematic risk estimates derived from Fama-French factors

Panel A: Level Effects

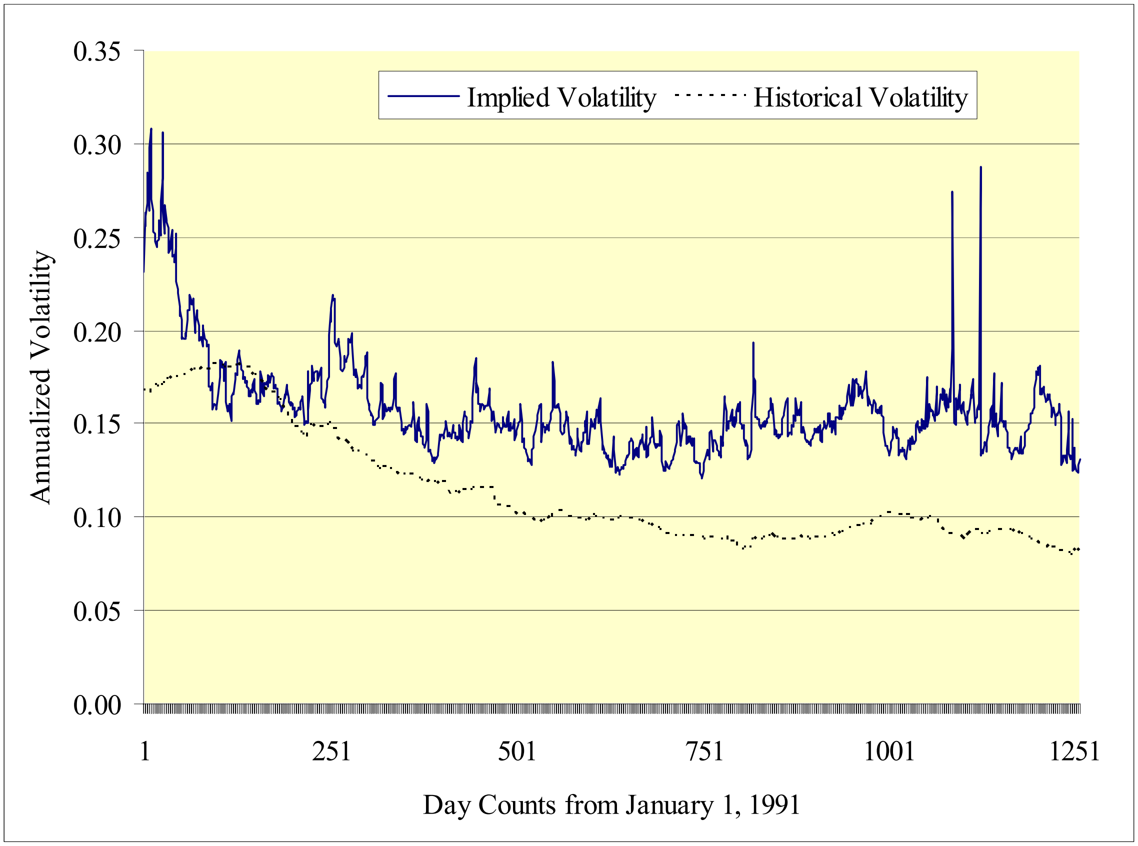
		Univariate Regressions			Multivariate Regressions						
		γ_1			γ_1		γ_2		γ_3		
		avg.	t	R^2	avg.	t	avg.	t	avg.	t	R^2
	All maturities	0.069	**13.009**	0.120	0.074	**8.601**	-0.017	-1.552	-0.004	-1.618	0.221
Moneyness	Short-term	0.069	**15.816**	0.142	0.072	**5.887**	-0.013	**-1.787**	-0.002	-1.230	0.262
K/S	Medium-term	0.064	**14.167**	0.219	0.065	**10.874**	-0.013	-1.158	-0.002	-0.836	0.397
0.90 - 0.95	Long-term	0.074	**5.916**	0.089	0.070	**5.758**	-0.011	-1.092	-0.004	-1.622	0.262
Moneyness	All maturities	0.045	**10.776**	0.063	0.057	**5.218**	-0.014	-1.251	-0.004	-1.604	0.169
K/S	Short-term	0.041	**10.568**	0.066	0.047	**3.877**	-0.003	-0.401	-0.001	-0.432	0.176
0.95 - 1.00	Medium-term	0.032	**5.375**	0.076	0.032	**5.484**	-0.008	-0.682	-0.002	-0.937	0.296
	Long-term	0.010	0.661	0.065	0.021	**1.873**	-0.003	-0.248	-0.002	-0.716	0.328
Moneyness	All maturities	0.040	**4.076**	0.061	0.046	**4.103**	0.011	1.307	0.002	1.199	0.165
K/S	Short-term	0.032	**3.980**	0.052	0.034	**2.849**	0.016	**2.771**	0.003	**2.432**	0.192
1.00 - 1.05	Medium-term	0.025	**3.295**	0.089	0.032	**4.067**	0.020	**3.176**	0.003	**2.600**	0.342
	Long-term	0.071	**3.621**	0.134	0.074	**3.120**	0.014	**1.796**	0.002	0.986	0.362
Moneyness	All maturities	0.030	**3.735**	0.045	0.037	**3.998**	0.013	1.501	0.002	1.420	0.138
K/S	Short-term	0.020	**3.361**	0.039	0.025	**1.878**	0.011	1.490	0.002	1.585	0.171
1.05 - 1.10	Medium-term	0.020	**2.720**	0.056	0.030	**4.683**	0.009	0.808	0.001	0.443	0.279
	Long-term	0.024	1.544	0.106	0.036	**1.832**	0.012	**2.288**	0.001	0.766	0.334

Panel B: Slope Effects

		Univariate Regressions			Multivariate Regressions						
		γ_1			γ_1		γ_2		γ_3		
		avg.	t	R^2	avg.	t	avg.	t	avg.	t	R^2
	All maturities	-0.464	**-6.628**	0.051	-0.400	**-5.260**	0.454	**7.500**	0.080	**5.041**	0.142
Moneyness	Short-term	-0.372	**-5.766**	0.033	-0.230	**-1.819**	0.346	**3.791**	0.048	**2.762**	0.142
K/S	Medium-term	-0.430	**-8.799**	0.101	-0.528	**-8.403**	0.067	0.536	0.001	0.046	0.262
0.90 - 0.95	Long-term	-0.231	-1.459	0.104	-0.287	-1.417	0.049	0.801	0.002	0.105	0.310
Moneyness	All maturities	-0.426	**-7.016**	0.048	-0.396	**-5.342**	-0.045	-0.497	-0.011	-0.528	0.134
K/S	Short-term	-0.558	**-11.463**	0.055	-0.446	**-5.854**	-0.130	**-2.272**	-0.038	**-2.745**	0.135
0.95 - 1.00	Medium-term	-0.522	**-16.269**	0.149	-0.526	**-7.930**	0.046	0.437	0.008	0.328	0.271
	Long-term	-0.133	-1.303	0.052	-0.144	-0.906	0.075	1.431	0.030	1.478	0.187
Moneyness	All maturities	-0.507	**-5.781**	0.048	-0.421	**-5.020**	-0.003	-0.059	-0.005	-0.367	0.113
K/S	Short-term	-0.564	**-6.132**	0.055	-0.446	**-3.190**	-0.113	-1.370	-0.027	-1.450	0.146
1.00 - 1.05	Medium-term	-0.492	**-9.356**	0.156	-0.424	**-6.733**	0.000	0.004	0.013	0.873	0.351
	Long-term	-0.481	**-2.459**	0.089	-0.488	**-2.032**	0.039	0.555	0.013	0.660	0.287
Moneyness	All maturities	-0.007	-0.159	0.017	-0.011	-0.173	-0.144	**-1.809**	-0.030	-1.570	0.112
K/S	Short-term	-0.047	-0.800	0.023	0.029	0.265	-0.298	**-2.838**	-0.070	**-2.777**	0.151
1.05 - 1.10	Medium-term	-0.158	**-2.124**	0.059	-0.162	**-1.835**	-0.161	-1.326	-0.047	**-1.904**	0.222
	Long-term	-0.255	-1.553	0.089	-0.386	**-2.050**	-0.116	-1.566	-0.038	-1.458	0.278

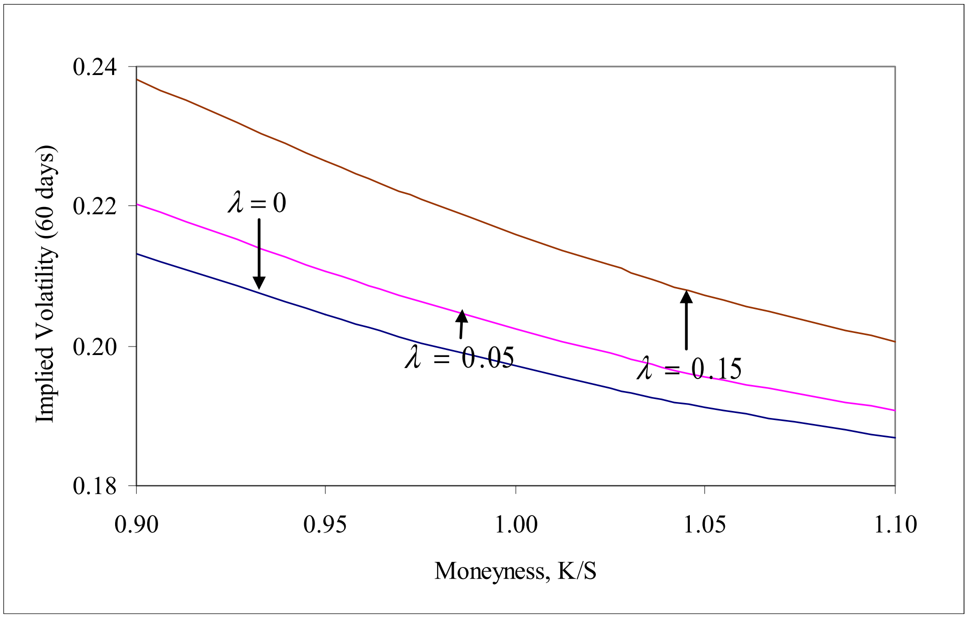
Notes: This table contains two-pass regression results for the level and slope effect tests using systematic risk estimates derived from the Fama-French factors. The testing procedures are otherwise the same as those in Tables 3 and 4. Panel A corresponds to Table 3 and Panel B corresponds to Table 4. Please refer to those tables for further explanations. In Tables 3 and 4, the systematic risk is estimated by regressing the stock's returns on the market returns (S&P 500). Here, the systematic risk is estimated by regressing the stock's returns on the two Fama-French factors as well as on the market returns. The daily Fama-French factors are downloaded from Kenneth French's website. To conserve space, we only report the regression coefficients together with their *t*-values and the average R^2. For brevity, we also omit the results for regressions whose explanatory variables are only the skewness and kurtosis. The *t*-values in bold type are significant at least at the 10% level, for two-tailed tests

Figure 1: Daily implied and historical volatilities for the S&P100 index



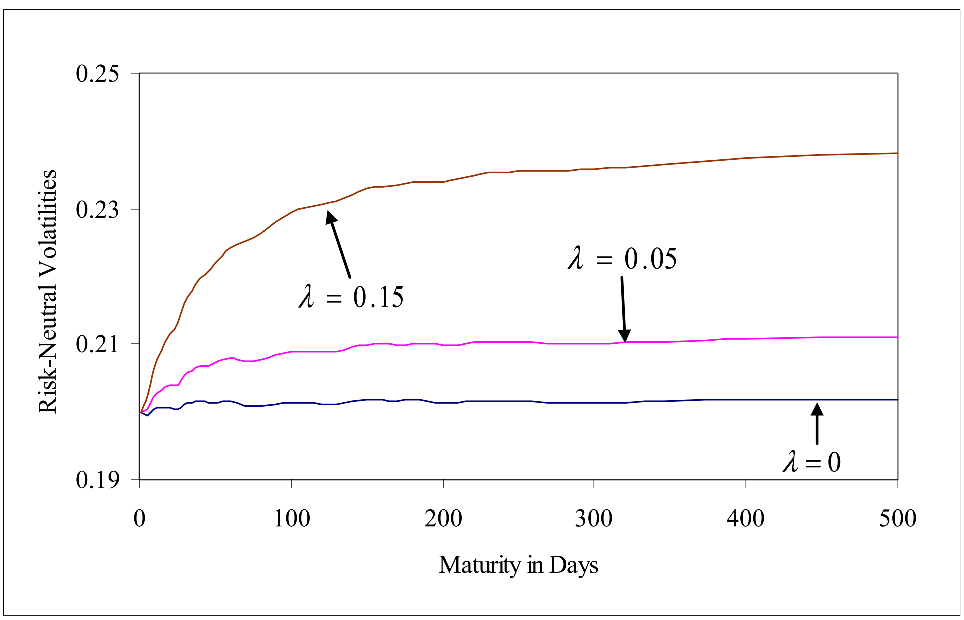
Note: This figure plots S&P100 index's daily implied and historical volatilities (annualized) for the sample period from January 1, 1991 to December 31, 1995. The historical volatility is computed using the one-year rolling window of daily returns and is annualized by multiplying $\sqrt{250}$. The daily implied volatility is the average of the implied volatilities of all the contracts in our sample on each day. The correlation coefficient between the two daily volatility series is 0.644.

Figure 2: The implied volatility as a function of moneyness corresponding to different levels of asset risk premium



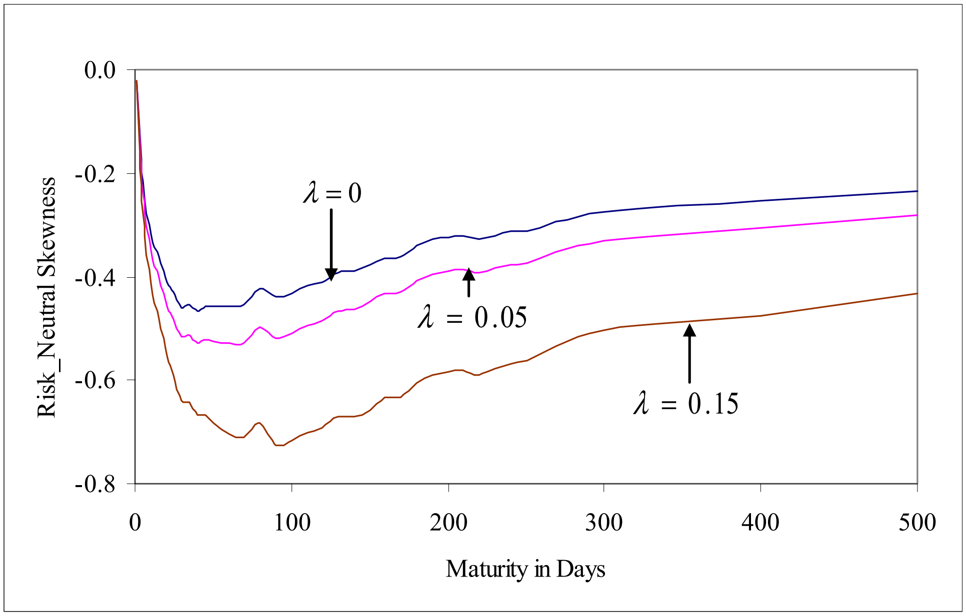
Note: Each curve depicts the Black-Scholes implied volatilities of European options in relation to K/S. The option maturity is fixed at 60 business days. The option values are computed using the GARCH option pricing model for three different levels of asset risk premium.

Figure 3: The standardized volatility of the risk-neutral cumulative return distribution as a function of maturity corresponding to different levels of asset risk premium



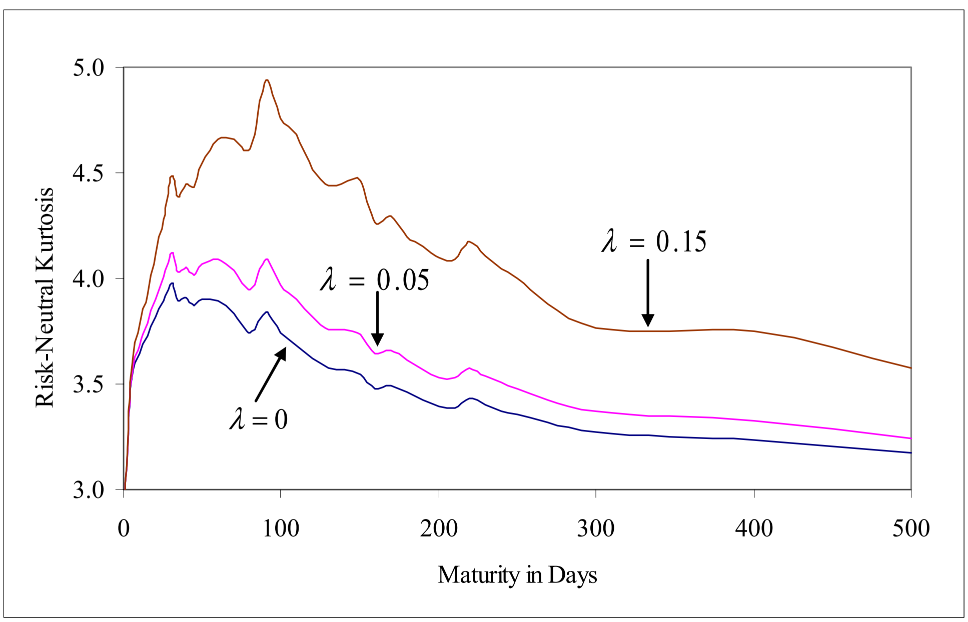
Note: Each curve depicts the standard deviation of the risk-neutral cumulative return distribution in relation to the maturity stated in number of business days. The standard deviation has been annualized using the square root of the maturity. The risk-neutral cumulative return distribution is obtained by a 50,000-path empirical martingale simulation using the GARCH option pricing model under different levels of asset risk premium.

Figure 4: The skewness of the risk-neutral cumulative return distribution as a function of maturity corresponding to different levels of asset risk premium



Note: Each curve depicts the skewness of the risk-neutral cumulative return distribution in relation to the maturity stated in number of business days. The risk-neutral cumulative return distribution is obtained by a 50000-path empirical martingale simulation using the GARCH option pricing model under different levels of asset risk premium.

Figure 5: The kurtosis of the risk-neutral cumulative return distribution as a function of maturity corresponding to different levels of asset risk premium



Note: Each curve depicts the kurtosis of the risk-neutral cumulative return distribution in relation to the maturity stated in number of business days. The risk-neutral cumulative return distribution is obtained by a 50,000-path empirical martingale simulation using the GARCH option pricing model under different levels of asset risk premium.