Option-Implied Equity Risk and the Cross-Section of Stock Returns

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ABSTRACT

Motivated by the great interest of measuring the equity risk in practice and the forward-looking nature of options prices, this paper develops an option-implied approach to better identify the equity risk. While option-implied information could potentially be arbitrary, our refined approach facilitates the estimation of systematic risk with controlling for the non-trivial pricing effect from idiosyncratic skewness. We show that our option-implied equity risk significantly predicts the future stock returns and the associated premium is also a strong predictor of future market returns. Overall, the option-implied equity risk well characterizes asset prices both in the cross-section and in the aggregate.

Keywords: Idiosyncratic skewness; option-implied beta; expected stock returns; equity risk; equity options

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1. Introduction

While the classical CAPM (Sharpe, 1964; Lintner, 1965; Black, Jensen and Scholes, 1972) is the most widely used method in practice for measuring equity risk,[1] several studies have documented its failure to well characterize cross-sectional asset prices (e.g., Fama and French (1992; 1993, 2004) and Lewellen and Nagel (2006). Due to the role of informational trading in the options market,[2] an abundance of recent papers (e.g. Conrad, Dittmar, and Ghysels (2013) and An, Ang, Bali and Cakici (2014)) link option market-based measures to future stock returns.[3] Recently, Chang, Christoffersen, Jacobs, and Vainberg (2012; hereafter, CCJV) construct a simple estimate for market beta from option prices, but however well this option-implied beta predicts the future market beta, Buss and Vilkov (2012) show that it's relation with the future stock returns is quite flat. Thus, given the importance of measuring equity risk in practice and the informational advantage in options market, developing a refined option-implied measure of equity risk and investigating its predictive power for future stock returns seems quite worthwhile.

Using forward-looking information in options market, we develop a refined method for better identifying systematic market risk as a predictor for the cross-section of stock returns. While the option-implied information could either come from systematic risk or idiosyncratic risk, our approach extends from CCJV in facilitating the identification of the systematic risk with control for the nontrivial pricing effect from the idiosyncratic skewness.[4] When the

[1] See, for example, Graham and Harvey (2001), Welch (2008), and Block (1999).
[2] See, for example, Stephan and Whaley (1990), Easley, O'Hara, and Srinivas (1998), Lee and Yi (2001), Chakravarty, Gluen, and Mayhew (2004), Cao, Chen, and Griffin (2005), and Pan and Poteshman (2006).
[3] See, for example, Christensen and Prabhala (1998), Fleming (1998), and Busch, Christensen, and Nielsen (2011), Bali and Hovakimian (2009), Cremers, Halling and Weinbaum (2015), Xing, Zhang and Zhao (2010).
[4] We use the canonical individual-market relation in the third moments derived from the seminal work of Bakshi, Kapadia, and Madan (2003). We propose a non-linear generalized method of moments estimation to infer the option-implied beta since, in general, the role of market beta is non-linearly incorporated into the third moments.

idiosyncratic skewness is zero, CCJV's estimate is identical to ours. In contrast, when the idiosyncratic skewness has asset pricing effects (e.g. Boyer, Mitton and Vornik (2010) and Conrad, Dittmar, and Ghysels (2013)), CCJV's estimate could be biased and thus our option-implied beta potentially provides higher asset pricing power.

We find that our option-implied beta is strong predictor of future stock returns and the associated premium is also a strong predictor of future market returns. Specifically, we find that a long-short portfolio formed on the option-implied beta generates an average monthly return of 0.960% with a significantly positive *t*-statistic of 3.47 on a risk-adjusted basis. While the results in the sample are restricted to the firms with equity options outstanding that are typically liquid and of high market capitalization, it is worth noting that transaction costs and potential short selling constraints are not taken into consideration. In addition, consistent with the property of market beta, we show that our option-implied beta is a significant predictor for future stock returns as well as future realized betas. We further show that the long-short portfolio returns formed on the option-implied beta (e.g. the implied market risk premium) could significantly forecast the future market returns with a *t*-statistic of 3.01. Thus, while the evidence for the implied market risk premium is inferred from the restricted sample, it is also consistent with the aggregate market returns. More importantly, the results suggest that the implied market risk premium is significantly associated with future macroeconomic variables, providing support for the economic significance of option-implied betas. Overall, our empirical findings suggest that the option-implied beta provides useful information for better identifying the market risk premium in the cross section of stock returns as well as in the aggregate market returns.

Our investigation sheds light on identifying the relevant systematic market risk for asset pricing from various potential option-implied information. First of all, in supportive of the classical CAPM, we find that the option-implied beta is priced even after controlling for several firm characteristics. Second, our implied beta can be viewed as an empirical as well as methodological extension of the seminal work of Chang et al. (2012) and Buss and Vilkov (2012).[5] In particular, we find the idiosyncratic skewness does correlate with CCJV's implied beta but does not with ours, which might partly explain the weak performance for the portfolios formed on CCJV's risk measure. Our study is also different from Buss and Vilkov (2012) as they are essentially testing a two-factor model that consists of a market factor and a correlation factor.[6]

As a final point, our findings also complement the abundance of papers in the literature linking option market-based measures to future stock returns. For example, An, Ang, Bali and Cakici (2014) support the notion of informed trading in the options market using innovations in implied volatility, and Chesney, Crameri and Mancini (2015) provide security-level evidence that this is indeed the case. While we agree that the option-implied beta inherits the advantage of informational option trading that improves the estimation precision of market risk, our paper diverges from these studies as we focus on systematic market risk rather than information risk.[7]

The remainder of this paper is organized as follows. Section 2 describes the estimation of equity betas using individual stock option prices. Section 3 discusses the data and Section 4 presents the empirical results. Finally, the conclusions drawn from this study are in Section 5.

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[5] Chang, Christoffersen, Jacobs, and Vainberg (2012) are not the first to estimate equity betas using individual stock option prices. French, Groth and Kolari (1983), Chen, Kim, and Panda (2009), and Buss and Vilkov (2012) also develop methods for estimating betas with option price information. Furthermore, António, Chung, and Wang (2009) aim to calculate forward-looking estimates of the cost of equity using the market prices of stocks and stock options by deriving equilibrium option pricing formulae.

[6] Buss and Vilkov (2012) estimate option-implied correlations to construct an option-implied predictor of factor betas. Their empirical approach must know the index weights for each stock, and so it is not easy to allow sample firms over the number of stocks that comprise the S&P 500 index.

[7] Since informed traders might prefer the options markets to the stock market, our findings may partly support the hypothesis that informed trading in the equity options and informed trading in the index options exhibit commonality, which facilitates the identification of the systematic market risk.

2. Option-implied equity risk

In this study we assume that the log-return R_i on stock i follows a one-factor model of the following form:

$$R_i = \alpha_i + \beta_i R_m + \varepsilon_i, \tag{1}$$

where the mean of the market return R_m is μ_m. The idiosyncratic shock ε_i has zero mean and is assumed to be independent of the market return R_m.[8] Under the single-factor return structure with an independent idiosyncratic assumption, Chang, Christoffersen, Jacobs, and Vainberg (2012) derive the skewness of R_i ($SKEW_i$) as:

$$SKEW_i = \frac{\beta_i^3 SKEW_m VAR_m^{3/2} + SKEW_{\varepsilon,i} VAR_{\varepsilon,i}^{3/2}}{VAR_i^{3/2}} \tag{2}$$

Here, VAR_i and $SKEW_i$ represent the second and third moments of the return distribution of stock *i*, respectively; and $VAR_{\varepsilon,i}$ and $SKEW_{\varepsilon,i}$ represent the variance and skewness of the unsystematic risk component for a firm *i*, respectively. After some algebraic operations, Equation (2) can be expressed as follows:

$$SKEW_i VAR_i^{3/2} = \underbrace{\beta_i^3 SKEW_m VAR_m^{3/2}}_{systematic} + \underbrace{SKEW_{\varepsilon,i} VAR_{\varepsilon,i}^{3/2}}_{idiosyncratic} \tag{3}$$

In other words, the option-implied information, in general, contains information for both systematic risk and idiosyncratic risk. We thus define the function $\Theta(\bullet)$ as the orthogonal condition with respect to β_i, i.e.:

$$\Theta(\beta_i) = SKEW_i VAR_i^{3/2} - \beta_i^3 SKEW_m VAR_m^{3/2} - SKEW_{\varepsilon,i} VAR_{\varepsilon,i}^{3/2} = 0\,. \tag{4}$$

[8] As shown in Bakshi, Kapadia, and Madan (2003) and Duan and Wei (2009), the same one-factor model structure is assumed to hold under the risk-neutral measure, except that the intercept term α_i may undergo a mean shift. Preserving the same structure ensures that systematic risk remains unchanged under the risk-neutral measure, i.e. $\beta_i^{rn} = \beta_i$, where the superscript *rn* stands for risk-neutral.

Chang et al. (2012) impose the assumption of zero idiosyncratic skewness to obtain the option-implied equity risk for firm *i* as follows:

$$\beta_i^{CCJV} = \left(\frac{SKEW_i}{SKEW_m} \right)^{1/3} \left(\frac{VAR_i}{VAR_m} \right)^{1/2}. \tag{5}$$

However, their estimate of option-implied beta might be biased if the last term that consists of the idiosyncratic skewness and the idiosyncratic volatility in the right-hand side of Equation (3) is non-zero.[9]

To tackle this problem, we identify the idiosyncratic terms using the following canonical relation between individual skewness and market skewness of Bakshi, Kapadia, and Madan (2003) and the relation between individual variance and market variance:

$$\begin{aligned} \Upsilon_i SKEW_{\varepsilon,i} &= SKEW_i - \Psi_i SKEW_m, \\ VAR_{\varepsilon,i} &= VAR_i - \beta_i^2 VAR_m \end{aligned} \tag{6}$$

where $\Psi_i = (1 + \frac{V_{\varepsilon,i}}{\beta_i^2 (V_m - e^{-r\tau} \mu_m^2)})^{-3/2}$; $\Upsilon_i = (1 + \frac{\beta_i^2 (V_m - e^{-r\tau} \mu_m^2)}{V_{\varepsilon,i}})^{-3/2}$ with $0 \le \Psi_i \le 1$ and $0 \le \Upsilon_i \le 1$; r is the risk-free rate; τ is the time to maturity; $V_{\varepsilon,i}$ and V_m are the price of the idiosyncratic volatility contract and the price of the market volatility contract, respectively; and μ_m is the risk-neutral expected value of the log market return implicitly defined by a risk-neutral valuation relationship.[10]

We now can rewrite Equation (4) as the orthogonal condition for the systematic market risk

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[9] The measure of option-implied beta with the assumption of zero idiosyncratic skewness is only defined for individual stocks with a negative risk-neutral skewness, because the market risk-neutral skewness is negative.

[10] Bakshi, Kapadia, and Madan (2003) define the volatility contract, the cubic contract, and the quartic contract for the stock return of the period from t to $t+\tau$ as $V(t,\tau) = E^Q\{e^{-r\tau} \mathrm{R}(t+\tau)^2\}$, $\mathrm{W}(t,\tau) = E^Q\{e^{-r\tau} \mathrm{R}(t+\tau)^3\}$, and $\mathrm{X}(t,\tau) = E^Q\{e^{-r\tau} \mathrm{R}(t+\tau)^4\}$, respectively, where symbol $E^Q\{\bullet\}$ represents the expectation operator under risk-neutral density. Here, $\mu(t,\tau)$ is implicitly defined by $\mu(t,\tau) = e^{r\tau} - 1 - \frac{e^{r\tau}}{2} V(t,\tau) - \frac{e^{r\tau}}{6} W(t,\tau) - \frac{e^{r\tau}}{24} X(t,\tau)$.

(β_i) that incorporates the information from the linear relationship between the individual stock and the index market in the second and the third moments, yielding the orthogonal function:

$$\begin{aligned}\Theta(\beta_i) &= SKEW_i VAR_i^{3/2} - \beta_i^3 SKEW_m VAR_m^{3/2} \\ &- \left(SKEW_i - \Psi_i^{'} SKEW_m\right)\left(VAR_i - \beta_i^2 VAR_m\right)^{3/2} \Big/ \Upsilon_i^{'} = 0,\end{aligned} \tag{7}$$

where $\Psi_i^{'} = (1 + \dfrac{V_i - \beta_i^2 V_m}{\beta_i^2 (V_m - e^{-r\tau}\mu_m^2)})^{-3/2}$; and $\Upsilon_i^{'} = (1 + \dfrac{\beta_i^2 (V_m - e^{-r\tau}\mu_m^2)}{V_i - \beta_i^2 V_m})^{-3/2}$ with $0 \le \Psi_i^{'} \le 1$ and $0 \le \Upsilon_i^{'} \le 1$. The detailed implementation procedure is presented in Appendix A.

3. Data and descriptive statistics

We obtain the index and equity option data from the OptionMetrics database. The time period is from January 1996 to December 2012. For options on individual stocks, we extract the security ID, date, expiration date, call or put identifier, strike price, best bid, best offer, and implied volatility from the option price file. For options on a market portfolio, we choose the Chicago Board Options Exchange's option's option on the S&P 500 index (ticker symbol SPX), which is typically regarded as the major U.S. market proxy. The risk-free interest rates are from OptionMetrics' zero curves file, which is formed by a collection of continuously-compounded zero-coupon interest rates with various maturities. The linear interpolation method is applied to generate interest rates that exactly match the time-to-maturities of options.

We follow Jiang and Tian (2005) and Goyal and Saretto (2009) to apply several data filters. First, we eliminate option prices that violate arbitrage bounds. Second, we filter out all observations for which the bid price is equal to zero, the ask price is lower than the bid price, the bid-ask spread is lower than the minimum tick size, or the option open interest is equal to zero. Finally, to compute risk-neutral moments, we also eliminate those contracts that are in-the-money options (the ratio of strike price to stock price for puts is greater than 1.03 and for calls is less than 1.03).

For each month t, we use daily option price data to calculate the option-implied moments of the one-month return distribution at each day for each firm, using the model-free approach of Jiang and Tian (2005) and Carr and Wu (2009). To ensure that the options have good liquidity and information, we use nearby and second nearby options with maturities that are nearest to one month. The option-implied moments are first calculated from nearby and second nearby options, respectively. Next, option-implied moments of the above two maturities are linearly interpolated to yield the option-implied moments of one-month maturity. Finally, we take these daily option-implied moments in month t to estimate the monthly option-implied beta for each firm through a non-linear GMM based on Equation (7).

Stock prices, bid prices, ask prices, monthly returns, number of outstanding shares, and trading volume data are obtained from the Center for Research in Security Prices (CRSP). We exclude stocks with zero share prices or those missing the number of shares outstanding. Following the standard approach of Fama and French (1992), we utilize CRSP and COMPUSTAT data to construct accounting variables.[11]

Table 1 contains descriptive statistics of option-implied betas and firm characteristics for the full sample period of January 1996 to December 2012. The variables *pre-ranking beta*, *size*, and *book-to-market ratio* (B/M) are computed using the method of Fama and French (1992).[12]

[11] The Compustat sample for calendar year *t* includes those firms with fiscal year-ends in *t* that have (a) stockholders' equity, (b) liabilities, or (c) common equity and preferred stock at par value.

[12] In each month, we use the previous 24 to 60 (as available) months of returns to estimate pre-ranking betas using the market model. Stocks are assigned to 10*10 portfolios on the basis of size and pre-ranking betas. This procedure rolls every month. We then compute the equal-weighted portfolio returns. For each size-beta (i.e. pre-ranking beta) portfolio, we run the full-period time-series regression of the portfolio returns on the current month's and the prior month's value-weighted market returns. The portfolio beta is estimated as the sum of the slopes of these two market returns. The sum is meant to adjust for the effects of non-synchronous trading (Dimson, 1979). Finally, we allocate the portfolio beta of a size-beta (i.e. pre-ranking beta) portfolio to each stock in the portfolio. These are the post-ranking betas to be used in the cross-sectional regressions of individual stock returns.

We refer to Equation (12) of Chang et al. (2012) to compute CCJV's implied beta (Variable CCJV beta) using the 30-day risk neutral skewness implied by option prices combined with 30-day option-implied volatilities. As suggested by Buss and Vilkov (2012), we delete those CCJV's implied betas for stocks that have a positive risk-neutral skewness when the market risk-neutral skewness is negative. Other firm characteristic variables include: (1) Variable $Skew^{Idiosyncratic}$, calculated by using Equation (2) of Boyer et al. (2010), denotes historical estimates of idiosyncratic skewness for a firm using daily stock return data; (2) *Amihud* (multiplied by 10^8) represents the illiquidity ratio of Amihud (2002), defined as the daily ratio of the absolute return on a day to the dollar trading volume on that day averaged over the prior 12 months;[13] and (3) *Lagged return* (%) is the compound return over the six months ending at the beginning of the previous month.[14] We also follow Cremers and Weinbaum (2010) and Xing, Zhang, and Zhao (2010) to measure implied volatility spread (IV^{Spread}) and implied volatility skew (IV^{Skew}) for each stock, respectively.[15] For each firm, we average the daily risk-neutral skewness of one-month maturity as $Skew^{RNM}$. As shown in An, Ang, Bali, and Cakici (2014), we use the average of the-end-of-month annualized call and put implied volatilities of at-the-money 30-day maturities to compute implied volatility innovations, which we denote as ΔCVOL and ΔPVOL, respectively.

Size is measured in June of year *t*. Book-to-market ratio (B/M) is measured using market equity in December of year *t*-1.

[13] Lou and Sadka (2011) also use the Amihud (2002) illiquidity measure as a measure of the liquidity level of a given stock, whereas Chordia, Goyal, Sadka, Sadka and Shivakumar (2009) measure monthly illiquidity as the average of the daily price impacts of the order flow.

[14] The lagged stock return variables are constructed to exclude the return during the immediate prior month in order to avoid any spurious association between the prior month return and the current month return caused by thin trading or bid-ask spread effects.

[15] A monthly measure of the implied volatility spread or implied volatility skew for a firm is the average of its daily estimates in each month. We refer to Cremers and Weinbaum (2010) to define the implied volatility spread as the open-interest-weighted average of the difference in implied volatilities between call options and put options with the same maturity and strike price, whereas the implied volatility skew of Xing, Zhang, and Zhao (2010) is defined as the difference between the implied volatilities of out-of-the-money put options and at-the-money call options.

After merging option-implied beta data with the CRSP stock data, our final sample includes 130,841 observations from 3,484 unique optioned firms. There are on average 641 stocks per month during the sample period. Table 1 reports summary statistics for the variables used in this study. In each month, we first compute the cross-sectional statistics for each security and then report the time-series average. The mean of pre-ranking beta is 1.318, which is close to the mean of the option-implied beta, 1.316. Because the sign of risk-neutral individual skewness must be the same as the sign of risk-neutral market skewness, the average of CCJV's beta is 1.572, which is slightly higher than the mean of our option-implied beta. The time-series average for the cross-sectional average of firm size is about $10.64 billion,[16] which is natural as optioned firms are relatively large and have a growth-type characteristic, and thus their B/M ratios (25th: 0.19; 50th: 0.32; 75th: 0.54) are relatively low in comparison to the full sample of firms listed in the three major stock exchanges (NYSE, AMEX, and NASDAQ). Moreover, optioned firms have a median illiquidity ratio of $0.069*10^{-8}$, which is far less than the median illiquidity ratio reported in Amihud (2002), $0.308*10^{-6}$, for all firms traded on NYSE/NASDAQ/AMEX. Firms with an implied beta have a mean of 12.60% in past stock returns, a mean of -0.827 in implied volatility spread measured in percentage terms, a mean of 0.054 in implied volatility skew, and a mean of -0.478 in risk-neutral skewness. The averages of implied volatility innovation (shown in percentage terms) for call and put options are around -0.094 and -0.087, respectively.

<Table 1 is inserted about here>

4. Empirical results

4.1 Basic portfolio-sorting analyses

[16] This value is close to the average firm size ($10.22 billion) reported in Xing, Zhang, and Zhao (2010).

In this subsection we examine future portfolio returns and the firm characteristics of quintile portfolios based on the sorting of option-implied betas in Table 2. At the beginning of each month we sort all optioned firms according to their implied betas of the last month and then allocate them into five portfolios. We calculate monthly portfolio returns over a one-month holding period and report their time-series averages in Panel A of Table 2. The quintile portfolios are equal-weighted. The result shows that the portfolio's return is monotonically increasing as the portfolio's implied beta rises. Moreover, the return of the long-short portfolio with long positions in stocks with high implied betas and short positions in stocks with low implied betas (G5-G1) is significantly different from zero, i.e. 1.21% per month with a *t*-statistic of 2.59. Thus, the result indicates that the risk-return relation predicted by CAPM is strongly supported when the equity risk is measured by our option-implied beta.

We next show characteristics of these five portfolios in Panel B of Table 2. On average, each quintile portfolio has about 128 stocks per month. Regarding the characteristics of the implied beta sorting portfolios, there are several points worth discussing. First, Panel B shows that the implied beta is positively associated with the pre-ranking beta and CCJV beta, suggesting that these measures likely capture the systematic risk in the same direction. Second, a higher implied beta is associated with a relatively smaller firm size although there is no clear pattern between implied beta and book-to-market ratio. Moreover, the group of firms with the highest implied beta exhibits the highest past stock returns. Third, we observe that implied beta is positively related to stock illiquidity, which is consistent with the findings of Haugen and Baker (1996), Datar et al. (1998), and Chordia et al. (2001) in that there is a negative correlation between liquidity and expected stock return. Finally, turning the focus on option market-based variables, higher implied beta firms seem to have greater negative volatility spread, more positive volatility skew, and less negative risk-neutral skewness.[17] Moreover, there is no clear pattern between implied beta and the measures of implied volatility innovation, implying the magnitude of option-implied betas cannot completely be attributed to the changes in implied volatility.

<Table 2 is inserted about here>

As shown in Panel A of Table 2, the future portfolio return is a monotonic increasing function of our option-implied beta, which incorporates the role of idiosyncratic skewness into the estimation. In order to demonstrate the important role of idiosyncratic skewness on systematic risk, which is implied from traded option prices, we further report future portfolio returns sorted by the CCJV beta, which includes an assumption of zero idiosyncratic skewness, in Panel A of Table 3. When we sort the available stocks into portfolios based on the CCJV betas at the end of each month and compute the one-month holding period returns for each portfolio, it is clear from Panel A that the return difference between the extreme quintile portfolios is only about 0.17% with a *t*-statistic of 0.74. Moreover, the risk-return relation demonstrates noise and a relatively flat line, which are consistent with the finding of Figure 1 in Buss and Vilkov (2012). More importantly, we also observe that idiosyncratic skewness decreases as the CCJV beta increases in Panel A. This is why the empirical evidence of the risk-return relation can be improved when we refine the estimates for the option-implied beta by relaxing the assumption of zero idiosyncratic skewness used in Chang, Christoffersen, Jacobs, and Vainberg (2012), providing support for the theoretical implications of CAPM.

[17] In the literature, these options-based variables are found to predict future returns. For instance, Xing, Zhang, and Zhao (2010) provide evidence in support of informed trading in the options markets for the significantly negative relationship between implied volatility skew and future equity returns. In our later Fama-MacBeth regressions (Table 6), we also note that implied volatility skew is generally significantly related to future returns. However, while we agree that the option-implied beta inherits the advantage of informational option trading that improves the estimation precision of the market risk, option-implied beta conceptually differs from these variables in which we focus on systematic market risk.

To compare the risk measure performances of option-implied betas with that of historical betas, we also examine the long-short portfolio returns when stocks are sorted and allocated based on pre-ranking betas for optioned firms and all CRSP firms, respectively. As shown in Panel B of Table 3, the relationship between pre-ranking beta and portfolio return is generally positive, but quite flat, which is consistent with the findings of Friend and Blume (1970), Black, Jensen and Scholes (1972), and Stambaugh (1982). As a result, the long-short portfolio (G5-G1) return is not statistically different from zero for optioned stocks sorted by pre-ranking betas. We further sort all CRSP firms based on pre-ranking betas in Panel C of Table 3 and find that the positive risk-return relation still holds, but is weak due to the insignificant long-short portfolio return. Therefore, the overall results of Table 3 suggest that option-implied beta is a better measure for equity risk than CCJV-implied beta and pre-ranking beta.

<Table 3 is inserted about here>

4.2 Risk-adjusted returns of option-implied beta portfolios

Aside from analyzing raw returns, we also run time-series regressions to examine the risk-adjusted returns of quintile portfolios sorted by option-implied betas. The common risk factors include the Fama and French (1993) three factors, the momentum factor of Carhart (1997), and the liquidity factor of Pastor and Stambaugh (2003). Table 4 shows the one-month holding-period risk-adjusted returns of quintile portfolios formed on implied betas. We report the equal-weighted abnormal returns for each portfolio and for the long-short portfolio with long positions in stocks with high implied betas and short positions in stocks with low implied betas (G5-G1). While the portfolio returns are extensively adjusted for common risk premium including the liquidity factor, the real effect of transaction cost is not considered in the risk-adjusted returns.

It is apparent from Table 4 that, no matter which model is used in the time-series regressions, the risk-adjusted returns (alphas) are generally increasing when the option-implied betas rise. For example, when the portfolio returns are regressed on the three risk factors of Fama and French (1993), alphas increase from -0.596% to 0.363% for the lowest to the highest quintile portfolios. The abnormal returns of the portfolio consisting of the lowest (highest) implied beta stocks are negative (positive) no matter which factor model is applied. Thus, the risk-adjusted returns of the long-short portfolio are significantly different from zero. The abnormal returns of the long-short portfolio are indeed economically important. For example, when all five risk factors are included in the regression, the risk-adjusted equal-weighted return of the long-short portfolio is 1.124% per month (with a *t*-statistic of 3.88), which is equivalent to 13.49% per year. While the results in the sample are restricted to the firms with equity options outstanding that are typically liquid and of high market capitalization, it is worth noting that transaction costs and potential short selling constraints are not taken into consideration

<Table 4 is inserted about here>

We next analyze the factor loadings in the time-series regressions of the long-short portfolio returns examined in Table 5.[18] Table 5 reports the coefficient estimates and the corresponding *t*-statistics. The results suggest that the option-implied betas indeed capture the systematic risk of the market, because the long-short portfolio returns have significantly positive loadings on the market factor (ranging from 0.532 to 0.836) in all the regression models.[19] In

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[18] We also study whether the long-short portfolio strategy lasts over longer time horizons. Our results suggest that the abnormal returns generally become smaller in magnitude when the holding period increases. Moreover, the long-short portfolio return remains economically and statistically positive for a two-month holding period, i.e. an average monthly return of 0.745% with a t-statistic of 2.79. In addition, we conduct dependent double-sorting analyses for robustness. A more detailed report of the results is available upon request.

[19] The intercepts in all the regression models are also statistically significant. To clarify whether the intercepts are related to the future market premium, we regress the future market premium on implied beta portfolio return, as evidenced later in Subsection 4.5. We especially thank an anonymous reviewer for pointing this out to us.

contrast, the factor loadings on the HML factor, the momentum factor, and the liquidity factor are statistically insignificant. Thus, the long-short portfolio consistently reflects the market risk premium in the stock market portfolio.

<Table 5 is inserted about here>

4.3 Fama-MacBeth regressions of stock returns on option-implied betas and other control variables

In addition to the implied beta sorting portfolio analyses, we also study the cross-sectional determinants of stock returns using month-by-month Fama-MacBeth (1973) regressions, i.e.:

$$R_{i,t+1} - R_{f,t+1} = a_{0,t+1} + \gamma_{t+1}\beta_{i,t} + \Gamma_{t+1}\left(\text{Control variables in month } t\right) + \varepsilon_{i,t+1}. \tag{8}$$

Here, $R_{i,t+1} - R_{f,t+1}$ and $\beta_{i,t}$ are the ex post excess return and the implied beta of stock i, respectively. Note that the regression coefficient of implied beta in Equation (8), γ_{t+1}, is the estimated market risk premium.

Table 6 presents the average coefficients of Fama-MacBeth regressions and their *t*-statistics with Newey-West adjustments in parentheses.[20] It should be emphasized that the average coefficient of implied beta in Model 1 is significantly positive, while the average coefficient of post-ranking beta in Model 2 is indifferent from zero, indicating that option-implied betas outperform post-ranking betas in determining cross-sectional stock returns. Moreover, the average coefficients of implied beta in Models 3 to 11 are still statistically significant when several control variables, such as firm size, book-to market ratio, Amihud's illiquidity measure, past stock return, and five option-market based measures, are included in the regressions. Overall, the average coefficients of implied beta (i.e. the average of monthly market risk

[20] We use Newey-West adjusted *t*-statistics to overcome the potential problem in which the residuals of the cross-sectional regressions may be serially correlated.

premia), ranging from 0.746% to 0.801%, are stable and comparable to the annual market risk premia documented in the literature (see, e.g., Brealey and Myers (2000), Fama and French (2002), and Ibbotson and Chen (2003), among others).

<Table 6 is inserted about here>

4.5 Risk premium for option-implied beta and future market risk premium

In this subsection we investigate the relation between the long-short portfolio returns formed on implied beta and future market risk premium. More specifically, we regress the future market risk premium on the long-short portfolio returns over an *n*-month holding period for *n* = 1, 2, 3, 6.[21] We find the coefficient of the long-short portfolio returns over a one-month holding period is 0.139 with a *t*-statistic of 3.01. The results strongly show that the return differential associated with the implied beta reflects the forward-looking risk premium for the next month. This finding might explain why the contemporaneous market returns cannot fully capture the long-short portfolio returns, because the intercepts reported in Table 5 are statistically significant.

To further investigate the economic significance of option-implied betas, we examine whether the market risk premium reflected in the options market contains relevant information about the macroeconomic conditions. We thus perform the following time-series regression model to investigate the relation between the option-implied market risk premium (γ) at month *t* and future macroeconomic variables:

$$\gamma_t = a + bDEF_{t+1} + cDIV_{t+1} + dTERM_{t+1} + eTB_{t+1} + fPCE_{t+1} + \varepsilon_t. \quad (9)$$

Following Petkova and Zhang (2005) and Chen, Kim, and Panda (2009), the macroeconomic variables used in this paper are: TB is the 3-month Treasury bill yield; $TERM$ is the term

[21] The results of this table are not reported herein, but are available from the authors upon request.

spread and defined as the difference between the yield on the 10-year government bond and the yield on the three-month Treasury bill; DEF is the default spread and defined as the difference between the yield on Moody's BAA rated bonds and the yield on Moody's AAA rated bonds; DIV is the dividend yield on the value-weighted market; and PCE is the growth rate of personal consumption expenditures.

Table 7 presents the coefficient estimates on the macroeconomic variables and the corresponding *t*-statistics in parentheses. The results suggest that the market risk premium estimates are significantly associated with future macroeconomic conditions. The coefficient estimates of the dividend yield, the term spread, and the short-term interest rates (TB) are statistically significant. In particular, the market risk premium estimate generally has a positive relation with the future dividend yield, indicating that when the dividend yield is expected to rise in the future, the market risk premium can capture the upward trend of the stock markets.

<Table 7 is inserted about here>

4.6 The performance of option-implied beta in forecasting realized beta

From Table 8 we study the cross-sectional predictive ability of option-implied equity risk on *ex-post* realized beta, which is estimated using *n*-day daily stock returns for n = 30, 60, 180, 365. In all regressions, the average coefficients of Fama-MacBeth regressions and their *t*-statistics with Newey-West adjustments in parentheses are reported. All four coefficients of option-implied beta are statistically positive at the 5% significance level. Moreover, the option-implied beta has substantial predictive power for ex-post realized betas, and the predictive power of the option-implied beta is uniformly higher than that of pre-ranking historical beta for ex-post realized betas. In sum, we find that the option-implied beta is a strong predictor of future realized beta.

<Table 8 is inserted about here>

5. Conclusions

Using the forward-looking information in option prices, our paper extends Chang, Christoffersen, Jacobs, and Vainberg (2012) to develop a refined option-implied equity risk and contributes to literature in two aspects. First, our approach facilitates the identification of systematic risk in the presence of idiosyncratic risk. Second, we test our option-implied equity risk extensively in the cross-sectional stock returns as well as the aggregate market returns. We find that our option-implied equity risk generates significant return differentials in the cross-section and the associated risk premium could also predict the future market returns.

Interestingly, while forward-looking information utilized by our option-implied equity risk is only available for firms with equity options outstanding, the corresponding implied market risk premium also provides forward-looking information about the aggregate market returns as well as several macroeconomic variables. Thus, our findings suggest that researchers could use our approach in practice to better quantify the equity risk in the firm-level, measure the risk premium in the cross-section, and predict the market returns as well as the real economy in the aggregate.

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Appendix A. Calculation procedure for our option-implied beta

To obtain our option-implied equity risk for each firm, we have to input daily estimates of option-implied moments in month t into Equation (8) of this paper. Here, we calculate the daily option-implied moments of the one-month return distribution at each day for each firm by using the model-free approach of Jiang and Tian (2005) and Carr and Wu (2009). More specifically, we compute option-implied moments by integrating Equations (A1)-(A7), which are shown as:

$$VAR(t,\tau) = e^{r\tau}V(t,\tau) - \mu(t,\tau)^2 \tag{A1}$$

$$Skew(t,\tau) = \frac{e^{r\tau}W(t,\tau) - 3\mu(t,\tau)e^{r\tau}V(t,\tau) + 2\mu(t,\tau)^3}{\left[e^{r\tau}V(t,\tau) - \mu(t,\tau)^2\right]^{3/2}} \tag{A2}$$

$$Kurt(t,\tau) = \frac{e^{r\tau}X(t,\tau) - 4\mu(t,\tau)W(t,\tau) + 6e^{r\tau}\mu(t,\tau)^2V(t,\tau) - \mu(t,\tau)^4}{\left[e^{r\tau}V(t,\tau) - \mu(t,\tau)^2\right]^2}, \tag{A3}$$

where

$$\mu(t,\tau) = e^{r\tau} - 1 - \frac{e^{r\tau}}{2}V(t,\tau) - \frac{e^{r\tau}}{6}W(t,\tau) - \frac{e^{r\tau}}{24}X(t,\tau), \tag{A4}$$

and $V(t, \tau)$, $W(t, \tau)$, and $X(t, \tau)$ are the weighted sums of OTM call option prices $C(t, \tau, K)$ and put option prices $P(t, \tau, K)$, with time to maturity τ and strike price K, given the underlying asset price S_t:

$$V(t,\tau) = \int_{S_t}^{\infty} \frac{2(1-\ln(K/S_t))}{K^2} C(t,\tau,K)dK + \int_{0}^{S_t} \frac{2(1+\ln(S_t/K))}{K^2} P(t,\tau,K)dK \tag{A5}$$

$$W(t,\tau) = \int_{S_t}^{\infty} \frac{6\ln(K/S_t) - 3\left[\ln(K/S_t)\right]^2}{K^2} C(t,\tau,K)dK - \int_{0}^{S_t} \frac{6\ln(S_t/K) + 3\left[\ln(S_t/K)\right]^2}{K^2} P(t,\tau,K)dK \tag{A6}$$

$$X(t,\tau)=\int_{S_t}^{\infty}\frac{12\left[\ln(K/S_t)\right]^2-4\left[\ln(K/S_t)\right]^3}{K^2}C(t,\tau,K)dK$$
$$+\int_{0}^{S_t}\frac{12\left[\ln(S_t/K)\right]+4\left[\ln(S_t/K)\right]^3}{K^2}P(t,\tau,K)dK \qquad \text{(A7)}$$

Following Jiang and Tian (2005) and Carr and Wu (2009), we exclude those firms that do not have at least two out-of-the-money call prices and two out-of-the-money put prices. In reality, we also only have discrete option prices available. To overcome this problem, Carr and Wu (2009) and Jiang and Tian (2005) interpolate implied volatilities using a cubic spline method across moneyness levels to obtain a continuum of implied volatilities for each maturity. Note that the cubic spline method is only effective for interpolating between the maximum and minimum available strike prices. For moneyness levels below (above) the available moneyness level in the market, they simply extrapolate the implied volatility of the lowest (highest) available strike price. After implementing this interpolation-extrapolation technique, they are able to extract a fine grid of 1,000 implied volatilities for moneyness levels between 1% and 300%. They then convert these implied volatilities into call and put prices using the following rule: moneyness levels smaller than 100% ($K/S < 1$) are used to generate put prices and moneyness levels larger than 100% ($K/S > 1$) are used to generate call prices. This fine grid of option prices is then used to compute the option-implied moments by approximating the volatility, cubic, and quartic contracts using trapezoidal numerical integration.

After obtaining these daily risk-neutral moments for each firm, we then linearly interpolate using the two contracts nearest to the 30-day maturity to get the 30-day VAR, Skew, and Kurt contracts, always using one contract with maturity longer than 30 days and one contract with maturity shorter than 30 days. Using daily estimates of option-implied moments of the one-month return distribution, we perform a non-linear generalized method of moments estimation of Equation (8) to compute the monthly option-implied beta for each firm.

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Table 1. Descriptive Statistics: Optioned Firms from January 1996 to December 2012

This table reports descriptive statistics of firm characteristics for the optioned firms. Data are obtained from CRSP, Compustat (for stocks), and OptionMetrics (for options). For each trading day in a given month, we calculate the option-implied moments of one-month return distribution from option prices for each firm, using the model-free approach of Jiang and Tian (2005) and Carr and Wu (2009). For each firm, these daily option-implied moments are inputted into Equation (4) to estimate a firm's monthly implied beta (Variable Implied Beta). We refer to Equation (12) of Chang et al. (2012) to compute CCJV's implied beta (Variable CCJV beta) using the risk neutral model-free moments. As suggested by Buss and Vilkov (2012), we delete those CCJV's implied betas in which stocks have a positive risk-neutral skewness when the market risk-neutral skewness is negative. We use the standard approach of Fama and French (1992) to estimate pre-ranking beta, firm size (measured in billions of dollars), and book-to-market ratio. Idiosyncratic Skewness (Variable $Skew^{Idiosyncratic}$) is calculated by using Equation (2) of Boyer et al. (2010). Variable Amihud (multiplied by 10^8) is the illiquidity measure of Amihud (2002), defined as the daily ratio of the absolute return on a day to the dollar trading volume on that day averaged over the prior 12 months. Variable LagRet is the compound stock return over the six months ending at the beginning of the previous month. Following Cremers and Weinbaum (2010), we compute the daily volatility spread and then average these daily observations to obtain the monthly volatility spread in percentage terms (Variable IV^{Spread}) for each firm. We refer to Xing et al. (2010) to calculate the daily implied volatility smirk for each firm and then use the monthly average volatility smirk as Variable IV^{Skew}. For each firm, we average the daily option-implied skewness of one-month maturity as $Skew^{RNM}$. As shown in An et al. (2014), we use the average of the-end-of-month annualized call and put implied volatilities of at-the-money 30-day maturities to compute implied volatility innovations, which we denote as ΔCVOL (%) and ΔPVOL (%), respectively. At the end of each month from January 1996 to December 2012 (204 months), cross-sectional summary statistics for each variable are calculated. Table 1 reports the time-series averages of the cross-sectional summary statistics (across firms).

Time-Series Average for Monthly Cross-Sectional Summary Statistics

	Implied Beta	CCJV Beta	Pre-ranking Beta	Size	B/M	$Skew^{Idiosyncratic}$	Amihud	LagRet	IV^{Spread}	IV^{Skew}	$Skew^{RNM}$	ΔCVOL	ΔPVOL
Mean	1.316	1.572	1.318	10.635	0.405	0.099	0.204	0.126	-0.827	0.054	-0.478	-0.094	-0.087
5%	0.269	0.765	0.327	0.356	0.066	-1.911	0.006	-0.305	-8.626	-0.007	-1.166	-12.571	-12.175
25%	0.996	1.283	0.764	1.064	0.187	-0.682	0.024	-0.080	-2.614	0.024	-0.662	-3.958	-3.862
50%	1.306	1.560	1.175	2.876	0.324	0.099	0.069	0.075	-0.576	0.044	-0.427	-0.124	-0.150
75%	1.655	1.844	1.727	8.900	0.536	0.884	0.208	0.259	1.282	0.072	-0.239	3.743	3.629
95%	2.255	2.485	2.782	46.430	1.012	2.117	0.824	0.704	6.210	0.149	0.044	12.525	12.338

Table 2. Implied Beta-Sorted Portfolios

This table reports portfolio returns (Panel A) and portfolio characteristics (Panel B) sorted by the implied beta over the period between January 1996 and December 2012. At the end of each month starting from January 1996, stocks are sorted and grouped into five portfolios in ascending order based on their monthly implied betas. The G1 portfolio contains the lowest fifth of implied beta stocks at the beginning of each holding period, and the G5 portfolio contains the highest fifth of implied beta stocks at the beginning of each holding period. "G5-G1" represents a zero-investment strategy that longs G5 and shorts G1. We report the equally-weighted raw portfolio returns for each portfolio in Panel A. HP1m (%) represents the equally-weighted portfolio return over a one-month holding period. The *t*-statistics are reported in parentheses below the coefficients. Variable "Avg. Firms" is the average number of stocks in each portfolio per month. In Panel B, we refer to Equation (12) of Chang et al. (2012) to compute CCJV's implied beta (Variable CCJV beta). As suggested by Buss and Vilkov (2012), we delete those CCJV's implied betas in which stocks have a positive risk-neutral skewness when the market risk-neutral skewness is negative. Pre-ranking beta, firm size (measured in billions of dollars), and book-to-market ratio (B/M) are estimated using the standard approach of Fama and French (1992). Idiosyncratic Skewness (Variable $Skew^{Idiosyncratic}$) is calculated by using Equation (2) of Boyer et al. (2010). Variable Amihud (multiplied by 10^8) is the illiquidity measure of Amihud (2002), defined as the daily ratio of the absolute return on a day to the dollar trading volume on that day averaged over the prior 12 months. Variable LagRet is the compound stock return over the six months ending at the beginning of the previous month. Following Cremers and Weinbaum (2010), we compute daily volatility spread and then average these daily observations to obtain monthly volatility spread in percentage terms (Variable IV^{Spread}) for each firm. We refer to Xing et al. (2010) to calculate the daily implied volatility smirk for each firm and then use the monthly average volatility smirk as Variable IV^{Skew}. For each firm, we average the daily option-implied skewness of one-month maturity as $Skew^{RNM}$. As shown in An et al. (2014), we use the average of the-end-of-month annualized call and put implied volatilities of at-the-money 30-day maturities to compute implied volatility innovations, which we denote as ΔCVOL (%) and ΔPVOL (%), respectively.

Panel A. Implied Beta Portfolio Returns						
	G1	G2	G3	G4	G5	G5-G1
Implied Beta	0.521	1.062	1.308	1.579	2.113	1.591
HP1m (%)	0.204	0.695	0.977	1.023	1.415	1.211
t-stat	(0.56)	(1.89)	(2.18)	(1.92)	(1.97)	(2.59)
Avg. Firms	129	128	128	128	128	n/a
Panel B. Implied Beta Portfolio Characteristics						
CCJV Beta	1.416	1.480	1.568	1.631	1.741	0.325
Pre-ranking Beta	0.778	0.866	1.158	1.501	2.293	1.515
Size	13.122	14.229	12.287	9.531	5.617	-7.505
B/M	0.414	0.427	0.418	0.412	0.430	0.016
$Skew^{Idiosyncratic}$	0.096	0.091	0.096	0.104	0.102	0.006
Amihud	0.166	0.156	0.191	0.234	0.274	0.108
LagRet	0.106	0.104	0.114	0.128	0.181	0.075
IV^{Spread}	-0.770	-0.744	-0.789	-0.883	-0.958	-0.188
IV^{Skew}	0.053	0.052	0.053	0.054	0.060	0.007
$Skew^{RNM}$	-0.503	-0.507	-0.485	-0.465	-0.433	0.070
ΔCVOL	0.016	-0.112	0.359	-0.158	-0.237	-0.253
ΔPVOL	0.044	-0.095	0.055	-0.223	-0.217	-0.261

Table 3. Average Monthly Quintile Portfolio Returns sorted by CCJV Beta and Pre-ranking Beta

In Panel A, we report average quintile portfolio returns sorted by CCJV beta over the period between January 1996 and December 2012. G1 portfolio contains the lowest fifth of CCJV beta stocks at the beginning of each holding period, and G5 portfolio contains the highest fifth of CCJV beta stocks at the beginning of each holding period. "G5-G1" represents a zero-investment strategy that longs G5 and shorts G1. We also report idiosyncratic Skewness (Variable $Skew^{Idiosyncratic}$), which is calculated by using Equation (2) of Boyer et al. (2010) for each CCJV portfolio. Panels B and C report average quintile portfolio returns sorted by pre-ranking beta of Fama and French (1992). In Panel B we only include optioned firms in the sample, whereas the sample used in Panel C includes CRSP non-financial firms with available data for the pre-ranking beta. For both samples, we repeat the procedure of Panel A to sort and group the stocks into five portfolios based on the pre-ranking beta. HP1m (%) represents the equally-weighted portfolio return over a one-month holding period. The *t*-statistics are reported in parentheses below the coefficients. "Avg. Firms" represents the average number of stocks in a portfolio per month during the period from January 1996 to December 2012.

Panel A. Optioned firms sorted by CCJV beta

	G1	G2	G3	G4	G5	G5-G1
CCJV Beta	0.905	1.344	1.561	1.783	2.270	1.365
$Skew^{Idiosyncratic}$	0.185	0.143	0.097	0.096	0.081	-0.105
HP1m (%)	0.647	0.816	1.063	0.885	0.821	0.174
t-stat	1.38	1.63	2.06	1.75	1.87	0.74
Avg. Firms	118	118	118	118	118	n/a

Panel B. Optioned firms sorted by pre-ranking beta

	G1	G2	G3	G4	G5	G5-G1
Pre-ranking Beta	0.778	0.866	1.158	1.501	2.293	1.516
HP1m (%)	0.726	0.882	0.868	0.914	0.921	0.195
t-stat	(0.94)	(1.53)	(2.07)	(2.43)	(2.63)	(1.15)
Avg. Firms	129	128	128	128	128	n/a

Panel C. All CRSP firms sorted by pre-ranking beta

	G1	G2	G3	G4	G5	G5-G1
Pre-ranking Beta	-0.219	0.581	0.965	1.473	2.899	3.118
HP1m (%)	0.772	1.138	1.154	1.207	1.250	0.478
t-stat	(1.11)	(1.25)	(1.47)	(2.28)	(3.12)	(1.59)
Avg. Firms	1084	1083	1083	1083	1083	n/a

Table 4. Risk-Adjusted Returns of Implied Beta Portfolios

Table 4 reports risk-adjusted returns of implied beta portfolios over the period January 1996 to December 2012. For each trading day in a given month, we calculate the option-implied moments of a one-month return distribution from option prices for each firm, using the model-free approach of Jiang and Tian (2005) and Carr and Wu (2009). For each firm, these daily option-implied moments inputted into Equation (5) to estimate a firm's monthly implied beta (Variable Implied Beta). At the end of each month starting from January 1996, stocks are sorted in ascending order based on their monthly implied betas of the previous month. Optioned stocks are then grouped into five equally-weighted groups based on market capitalization portfolios. These portfolios are held for the subsequent one month. G1 portfolio contains the lowest fifth of implied beta stocks at the beginning of each holding period, whereas G5 portfolio contains the highest fifth of implied beta stocks at the beginning of each holding period. "G5-G1" represents a zero investment strategy of a long G5 portfolio and a short G1 portfolio. In addition to reporting the raw portfolio returns (Avg. Return) for each portfolio, risk-adjusted portfolio returns are the intercepts from time-series regressions of raw portfolio returns on the market factor ($\text{Alpha}_{\text{CAPM}}$), the Fama-French (1993) 3-factor model ($\text{Alpha}_{\text{FF3}}$), the Carhart (1997) 4-factor model ($\text{Alpha}_{\text{Carhart4}}$), and a five-factor model ($\text{Alpha}_{\text{LIQ5}}$) that adds the Pastor and Stambaugh (2003) traded liquidity risk factor to the Carhart model. The one-month T-bill rate and the Carhart (1997) four factors are downloaded from Kenneth French's website, and the liquidity factor of Pastor and Stambaugh (2003) is obtained from Wharton Research Data Services. The *t*-statistics are reported in parentheses below the coefficients.

	G1	G2	G3	G4	G5	G5 – G1
Avg. Return	0.204	0.695	0.977	1.023	1.415	1.211
t-stat	(0.56)	(1.89)	(2.18)	(1.92)	(1.97)	(2.59)
$\text{Alpha}_{\text{CAPM}}$	-0.491	-0.009	0.102	0.181	0.317	0.808
t-stat	(-3.46)	(-0.07)	(0.53)	(1.01)	(0.88)	(2.11)
$\text{Alpha}_{\text{FF3}}$	-0.596	-0.125	0.028	0.081	0.363	0.960
t-stat	(-4.26)	(-1.26)	(0.21)	(0.56)	(1.45)	(3.47)
$\text{Alpha}_{\text{Carhart4}}$	-0.620	-0.130	0.080	0.089	0.468	1.088
t-stat	(-4.36)	(-1.27)	(0.54)	(0.67)	(1.84)	(3.82)
$\text{Alpha}_{\text{LIQ5}}$	-0.655	-0.155	0.003	0.034	0.489	1.124
t-stat	(-4.50)	(-1.52)	(0.02)	(0.25)	(1.79)	(3.88)

Table 5. Regressions of Long-Short Portfolio Returns (G5-G1) on the Market (MKT), Size (SMB), Book-to-market (HML), Momentum (MOM), and Liquidity (LIQ) Factors

At the end of each month during our sample period, optioned stocks are sorted in ascending order based on their implied beta, which is estimated by using Equation (5). For each sorting, implied beta stocks are grouped into five equally-weighted portfolios. The quintile portfolios are held until the end of the subsequent month. G1 portfolio includes firms with the lowest fifth of implied beta stocks, whereas G5 includes firms with the highest fifth of implied beta stocks. "G5-G1" represents a zero-investment strategy of a long G5 portfolio and a short G1 portfolio. This table reports factor loadings of raw long-short portfolio returns on the market factor, the Fama-French (1993) 3-factor model, the Carhart (1997) 4-factor model, and a five-factor model, which adds the liquidity risk factor of Pastor and Stambaugh (2003) to the Carhart model. The one-month T-bill rate and the Carhart (1997) four factors are downloaded from Kenneth French's website, and the liquidity factor of Pastor and Stambaugh (2003) is obtained from Wharton Research Data Services. The sample includes stocks having implied beta over the period January 1996 to December 2012. The *t*-statistics are reported in parentheses.

	Long-Short Portfolio Returns			
HP1m	Model 1	Model 2	Model 3	Model 4
Intercept	0.808	0.960	1.088	1.124
t-stat	(2.11)	(3.47)	(3.82)	(3.88)
MKT	0.836	0.615	0.532	0.537
t-stat	(2.28)	(2.12)	(2.27)	(2.29)
SMB		0.519	0.550	0.549
t-stat		(1.61)	(1.52)	(1.50)
HML		-0.678	-0.739	-0.744
t-stat		(-1.37)	(-1.48)	(-1.55)
MOM			-0.192	-0.190
t-stat			(-0.96)	(-0.87)
LIQ				-0.054
t-stat				(-1.05)
Adj. R^2	0.039	0.067	0.070	0.070

Table 6. Time-Series Average for Month-by-Month Cross-Sectional Regressions of Stock Returns

This table reports the time-series averages of the cross-sectional regression coefficients for implied beta and several control variables. The dependent variable is stock return (in percent) in month $t+1$. At the end of month *t*, firm characteristics are estimated as follows. For each trading day in a given month, we calculate the option-implied moments of a one-month return distribution from option prices for each firm, using the model-free approach of Jiang and Tian (2005) and Carr and Wu (2009). For each firm, these daily option-implied moments inputted into Equation (5) to estimate a firm's monthly implied beta (Variable Implied Beta). Post-ranking beta is estimated using the standard approach of Fama and French (1992). "ln(Size)" is the natural logarithm of market capitalization measured in billions of dollars, and "ln(B/M)" is the natural logarithm of the book-to-market ratio of Fama and French (1992). "LagRet" is the compound return over the six months ending at the beginning of the previous month, since past stock returns are shown to affect their expected returns. "Amihud" (multiplied by 10^8) is the illiquidity measure of Amihud (2002), defined as the daily ratio of the absolute return on a day to the dollar trading volume on that day averaged over the prior 12 months. Following Cremers and Weinbaum (2010), we compute daily volatility spread and then average these daily observations to obtain the monthly volatility spread (Variable IV^{Spread}) for each firm. We refer to Xing, Zhang, and Zhao (2010) to calculate the daily implied volatility smirk for each firm and then use the monthly average volatility smirk as Variable IV^{Skew}. For each firm, we average the daily option-implied skewness of one-month maturity as $Skew^{RNM}$. As shown in An, Ang, Bali, and Cakici (2014), we use the average of the-end-of-month annualized call and put implied volatilities of at-the-money 30-day maturities to compute implied volatility innovations, which we denote as ΔCVOL and ΔPVOL, respectively. The sample period is from January 1996 to December 2012.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11
Intercept	-0.206	1.010	0.030	0.082	0.011	0.007	-0.007	0.286	0.424	0.344	0.319
t-stat	(-0.61)	(2.41)	(1.06)	(0.16)	(0.02)	(0.01)	(-0.01)	(0.57)	(0.84)	(0.68)	(0.63)
Implied Beta	0.797		0.801	0.764	0.751	0.746	0.756	0.759	0.761	0.755	0.750
t-stat	(2.54)		(3.37)	(2.99)	(2.84)	(2.86)	(2.93)	(3.12)	(3.03)	(3.01)	(3.02)
Post-ranking Beta		0.081	0.109	0.065	0.048	0.059	0.061	0.113	0.102	0.167	0.175
t-stat		(1.19)	(0.24)	(0.16)	(0.12)	(0.15)	(0.15)	(0.28)	(0.26)	(0.43)	(0.45)
ln(Size)				-0.010	-0.006	-0.006	-0.008	-0.124	-0.098	-0.090	-0.086
t-stat				(-0.12)	(-0.08)	(-0.08)	(-0.10)	(-1.54)	(-1.18)	(-1.10)	(-1.05)
ln(B/M)				0.158	0.160	0.162	0.138	0.134	0.137	0.134	0.127
t-stat				(1.20)	(1.24)	(1.24)	(1.06)	(1.03)	(1.05)	(1.05)	(1.00)
LagRet					0.004	0.004	0.004	0.003	0.003	0.003	0.003
t-stat					(0.80)	(0.77)	(0.80)	(0.67)	(0.77)	(0.70)	(0.73)
Amihud						-0.249	-0.131	0.359	0.351	0.369	0.398
t-stat						(-1.17)	(-0.58)	(1.04)	(1.01)	(1.00)	(1.10)
IV^{Spread}							2.596	2.319	2.277	1.963	0.986
t-stat							(2.43)	(2.18)	(2.12)	(1.81)	(0.84)
IV^{Skew}								-2.579	-2.165	-2.211	-1.871
t-stat								(-2.18)	(-1.81)	(-1.81)	(-1.74)
$Skew^{RNM}$									0.316	0.273	0.289
t-stat									(2.15)	(1.87)	(1.98)
ΔCVOL										1.070	4.181
t-stat										(1.16)	(2.65)
ΔPVOL											-3.510
t-stat											(-2.11)
Adj. R^2	0.028	0.031	0.036	0.053	0.066	0.069	0.073	0.078	0.079	0.085	0.087

Table 7. Relations between the Market Risk Premium and Future Macroeconomic Variables

This table presents the estimation results for the time-series regressions of the market risk premium on future macroeconomic variables: $\gamma_t = a + bDEF_{t+1} + cDIV_{t+1} + dTERM_{t+1} + eTB_{t+1} + fPCE_{t+1} + \varepsilon_t$, where γ_t is the implied market risk premium in month t. The macroeconomic variables used as explanatory variables are as follows: TB is the 3-month Treasury bill (geometric average) yield; TERM is the term spread defined as the difference between the yield on the 10-year government bond and the yield on the three-month Treasury bill; DEF is the default spread defined as the difference between the yield on Moody's BAA rated bonds and the yield on Moody's AAA rated bonds; DIV is the dividend yield on the value-weighted market; and PCE is the growth rate of personal consumption expenditures. The sample period is from January 1996 to December 2012. The *t*-statistics are reported in parentheses below the coefficients.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	0.232	0.458	0.258	0.564	0.115	0.276
t-stat	(2.44)	(2.74)	(3.93)	(5.11)	(1.31)	(0.80)
DEF	0.100					0.218
t-stat	(1.18)					(1.60)
DIV		18.254				15.285
t-stat		(2.02)				(1.11)
TERM			0.077			0.065
t-stat			(2.42)			(1.07)
TB				0.102		0.106
t-stat				(3.17)		(2.66)
PCE					0.009	0.034
t-stat					(0.20)	(0.72)
Adj. R^2	0.007	0.020	0.028	0.056	0.001	0.072

Table 8. Time-Series Average for Month-by-Month Cross-Sectional Regressions of Realized Betas on Implied Betas

Table 9 reports the time-series averages of the cross-sectional regression coefficients for implied beta and several control variables. For each trading day in a given month, we calculate the option-implied moments of a one-month return distribution from option prices for each firm, using the model-free approach of Jiang and Tian (2005) and Carr and Wu (2009). For each firm, these daily option-implied moments are used to input into Equation (5) to estimate a firm's monthly option-implied beta. Pre-ranking beta is estimated using the standard approach of Fama and French (1992). The dependent variable is *ex-post* realized beta (30-, 65-, 180-, and 365-day horizons). Regressions are run for every month *t* from January 1996 to December 2012, and the time-series means of monthly cross-sectional coefficient estimates are reported along with the time-series *t*-statistics (in parentheses).

	Realized Beta 30-day horizons	Realized Beta 60-day horizons	Realized Beta 180-day horizons	Realized Beta 365-day horizons
Intercept	0.413	0.428	0.478	0.528
t-stat	(12.53)	(12.91)	(14.79)	(17.47)
Implied Beta	0.020	0.022	0.054	0.057
t-stat	(1.97)	(2.16)	(3.29)	(3.24)
Pre-ranking Beta	0.649	0.635	0.594	0.555
t-stat	(1.85)	(1.73)	(1.69)	(1.91)
ln(Size)	-0.028	-0.030	-0.033	-0.033
t-stat	(-4.33)	(-4.51)	(-4.97)	(-4.61)
ln(B/M)	0.023	0.025	0.022	0.013
t-stat	(2.14)	(2.19)	(2.07)	(1.29)
LagRet	0.001	0.001	0.001	0.001
t-stat	(2.56)	(2.91)	(4.66)	(4.83)
Amihud	-0.030	-0.031	-0.040	-0.048
t-stat	(-1.06)	(-1.26)	(-2.21)	(-2.95)
IV^{Spread}	0.016	-0.019	-0.086	-0.102
t-stat	(0.23)	(-0.31)	(-2.05)	(-2.27)
IV^{Skew}	-0.295	-0.279	-0.224	-0.216
t-stat	(-4.45)	(-4.43)	(-3.93)	(-3.78)
$Skew^{RNM}$	0.012	0.008	0.005	-0.005
t-stat	(1.54)	(1.14)	(0.67)	(-0.76)
ΔCVOL	0.050	0.092	0.120	0.104
t-stat	(0.71)	(1.68)	(3.47)	(3.20)
ΔPVOL	0.183	0.136	0.090	0.056
t-stat	(2.72)	(2.61)	(2.44)	(1.82)
Adj. R^2	0.368	0.421	0.492	0.503