The Puzzle of Index Option Returns

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Abstract

We document that leverage-adjusted returns on S&P 500 index call and put portfolios are decreasing in their strike-to-price ratio over 1986-2010, contrary to the prediction of the Black-Scholes-Merton model. We test a large number of plausible unconditional factor models and find that only factors which capture jumps in the market index and market volatility and factors which capture volatility and liquidity reasonably explain the cross-section of index options. The principal finding is that these factors require economically and statistically different factor premia on subsamples split across type (calls and puts), maturity, and moneyness, pointing towards market segmentation and illiquidity.

Current draft: February 9, 2012

(JEL G11, G13, G14)
Keywords: index option mispricing; price jumps; volatility jumps; volatility; liquidity; demand-based option pricing; market segmentation; limits to arbitrage

We thank Muzaffer Akat, Michal Czerwonko, Günter Franke, Bruce Grundy, Christopher Jones, Ralph Koijen, Stefan Ruenzi, and seminar participants at the Capital Markets Board of Turkey, Özyeğin University, Sabanci University, and the Universities of Konstanz and Manchester for valuable comments. We remain responsible for errors and omissions. Constantinides acknowledges financial support from the Center for Research in Security Prices of the University of Chicago, Booth School of Business.

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Contrary to the predictions of the Black and Scholes (1973) and Merton (1973a) model (hereafter "BSM") model, we find that, over the period 1986-2010, the leverage-adjusted average returns on index calls are too low and put returns are too high relative to the average returns on the index; and the leverage-adjusted average returns on index call and put options are decreasing in their strike-to-price ratio. Specifically, we find that a factor model with the S&P 500 index as the sole factor fails to explain the cross-section of index option returns consisting of calls and puts of various maturities and moneyness. The monthly root mean squared error is 48 bps and is economically large.

A plausible explanation for these results is that one or more priced factors are missing. The innovation of any state variable that drives the stochastic discount factor is a potential factor. Plausible candidates include factors related to economic crises, volatility, liquidity, market sentiment, and macroeconomic conditions and the Fama-French and momentum factors. We test a large number of plausible unconditional factor models, where the factor premia are estimated either from the universe of equities or the universe of options. We concentrate on factors which consistently perform well when their premia are estimated from either universe, as we find them more credible.

We find that either one of two crisis-related factors reasonably explains the cross-section of call and put portfolio returns, reducing the monthly root mean square error to about 23 bps when the factor premia are estimated from the universe of equities (14 for premia estimated from the universe of options). These are *Jump*, a factor that captures jumps in the price of the market index, and *Volatility Jump*, a factor that captures jumps in market volatility. Figures I and II display the time series of *Jump* and *Volatility Jump*, respectively, and Table I displays their correlation. The series are highly correlated (-72%) and both capture major financial crises, including the October 1987 crash, the Asian financial crisis, the Russian default, 9/11, the WorldCom bankruptcy, and the Lehman bankruptcy. Furthermore, *Jump* and *Volatility Jump* reduce the pricing errors of the 25 Fama-French portfolios by more than size or momentum and almost as much as value. These two factors capture much of the spirit of stochastic volatility and stochastic jump models (e.g. Bates (1996)). What we find empirically though is that *Volatility*

Jump performs better than *Volatility* itself since *Volatility* has a root mean squared error of 29 bps (13bps using option based premia).[1]

[Table I and Figures I and II about here]

This third factor, *Volatility,* also helps explain the cross-section of index options. *Volatility* is defined as the change in the implied volatility of our at-the-money index call portfolio. *Volatility* is plotted in Figure III. *Volatility* is moderately correlated with *Jump* (-42%) and *Volatility Jump* (29%). It reaches peak values during the '87 crash, the Russian default crisis, and the Lehman bankruptcy, among others.

[Figure III about here]

A fourth factor that works almost as well in explaining the cross-section of index option returns is the Pastor and Stambaugh (2003) *Liquidity* factor. The root mean squared error is 28 bps (11 bps using option based premia). Figure IV displays the time series of *Liquidity*. *Liquidity* is moderately correlated with *Jump* (31%) and *Volatility Jump* (-29%) because, in addition to the above major financial crises, it captures other periods of changes in liquidity. Furthermore, *Liquidity* is a continuous measure whereas *Jump* and *Volatility Jump* are zero most of the time.

[Figure IV about here]

The most important and unsettling finding in our paper is that any of these factors requires economically and statistically different factor premia on samples split across option type (calls and puts), maturity, and moneyness. Having constructed a full cross section of 54 option portfolios along these dimensions, we are able to assess the performance of the most promising pricing models across groups. In particular, puts with short maturity and low moneyness require dramatically higher premia than other options. As reported above, our best two-factor models with premia based on the universe of options still have pricing errors of between 11 and 14 bps

[1] See also Eraker, Johannes, and Polson (2003) who enrich stochastic volatility, stochastic jump models by including jumps in volatility.

which remain sizeable compared to a typical return of 67 bps. Only if we further split our sample along the lines of type (calls and puts), maturity, and moneyness do we further improve pricing errors for the subsamples to between 1 bps and 8 bps. We feel that this last push is economically and statistically important to allow for option pricing where finally the pricing errors are small compared to typical returns.

The first explanation that comes to mind is model misspecification. Specifically, it is possible that the factor loadings and premia are state dependent, contrary to the maintained hypothesis of the unconditional factor pricing models which we test. If this is the case, one needs to provide economic motivation for the model that explains the observed differences across option attributes. Bates (2003) shares our skepticism of this explanation, arguing that "[t]o blithely attribute divergences between objective and risk-neutral probability measures to the free 'risk premium' parameters within an affine model is to abdicate one's responsibilities as a financial economist…a renewed focus on the explicit financial intermediation of the underlying risks by option market makers is needed."

The explanation of model misspecification is inconsistent with our finding that short maturity OTM puts, which comprise our most challenging portfolios, can be priced well with a very high premium for *Liquidity*. No other factor achieves this result. This suggests that short maturity OTM puts are expensive because they offer protection against severe disruptions of market liquidity.

Further evidence against model misspecification with the three factors *Jump, Volatility Jump,* and *Volatility* is provided by the fact that when we add *Liquidity* as a third factor to the model with *Jump, Volatility Jump,* or *Volatility,* the rms error of OTM puts decreases from 11-19 bps to 5-6 bps. Furthermore, the *Jump, Volatility Jump,* or *Volatility* premia are no longer statistically different across type, moneyness and maturity.

The importance of liquidity in pricing options is also reflected in the demand patterns of different groups of investors, as studied by Bollen and Whaley (2004) and Garleanu, Pedersen, and Poteshman (2009). Our analysis of supply and demand for the options in our portfolios by different groups of investors is broadly consistent with segmentation across option type,[2]

[2] Even though call and put prices are linked through the put-call parity, this scenario is plausible if the option and index markets are segmented.

maturity, and moneyness. We find that small, medium, and large customers, firms, and market makers take different and often opposite average net positions across our option portfolios.

Relating these demand patterns to returns is more challenging. Garleanu et al. (2009) propose net market-maker demand as a key driver of returns. Indeed, we find that market maker positions line up well with the returns of calls versus puts, and the returns of short versus long maturity options. When it comes to our puzzling short maturity OTM put portfolios however, we observe very low net market-maker positions and large trading volumes. Given the high returns to selling these options, the low net position of market makers suggests a strong reluctance to sell them. A plausible interpretation of our findings is that market makers are exceedingly averse to severe market liquidity shortages, resulting in very high prices for the highly exposed short maturity OTM puts.

The paper is organized as follows. In Section I, we review the literature. In Section II, we describe the data sets, filters, and the formation of portfolios of options. We present our empirical results of tests of the BSM model in Section III. In Section IV, we present our findings on crisis-related factors. In Section V, we present and discuss our principal finding that the above factors require economically and statistically different premia on samples split across type (calls and puts), moneyness, and maturity. We conclude in Section VI. In the appendices, we examine a broad spectrum of alternative factors that do not work, test for robustness, and present technical material.

I. Review of the Literature

The first line of index options research addresses the predictions of the BSM model. Rubinstein (1985) rejected the prediction that the implied volatility of individual stock options is constant across strikes and Rubinstein (1994) rejected the corresponding prediction for index options. An equivalent prediction is that the risk-neutral stock price distribution is lognormal. Jackwerth and Rubinstein (1996) confirmed that, prior to the October 1987 crash, the risk-neutral stock price distribution implied by option prices is close to lognormal, consistent with a moderate implied volatility smile. Thereafter, the distribution is systematically left-skewed and leptokurtic, consistent with a more pronounced skew in implied volatilities.[3] Rubinstein (1994) extended the complete-market no-arbitrage model by modeling volatility as a deterministic function of the price, $\sigma = \sigma(S,t)$. Dumas, Fleming, and Whaley (1998) rejected this model, pointing out that deterministic volatility models do not predict option prices well and that the parameters change widely across time.

The second line of index options research eliminates the assumption of the BSM model that the underlying security price (in our case, the index price) is a geometric Brownian motion. The market is no longer complete and an index option cannot be priced relative to the index price by the no-arbitrage argument. In this line of index options research, the stochastic discount factor is assumed to be a (possibly non-linear) function of just one state variable, the market. Ait-Sahalia and Lo (2000), Jackwerth (2000), and Rosenberg and Engle (2002) estimated the stochastic discount factor implied by the observed cross section of prices of S&P 500 index options as a function of wealth, where wealth is proxied by the S&P 500 index level. Jackwerth (2000) reported that the stochastic discount factor is everywhere decreasing during the pre-crash period 1986-1987, but widespread violations occur over the post-crash period 1987-1995. Ait-Sahalia and Lo (2000) and Rosenberg and Engle (2002) reported violations as well. Thus, we are faced with an empirical stochastic discount factor puzzle that has been corroborated for other countries in Shive and Shumway (2004). Coval and Shumway (2001) rejected the one-factor model by showing that zero beta, at-the-money straddles produce negative returns. Constantinides, Jackwerth, and Perrakis (2009) found that S&P 500 index options are often overpriced and these options may be incorporated in portfolios that stochastically dominate portfolios that do not include them. Constantinides, Czerwonko, Jackwerth, and Perrakis (2011) corroborated this evidence on S&P 500 index futures options and provided out-of-sample empirical evidence that portfolios which incorporate such overpriced options stochastically dominate portfolios that do not include them. They rejected the hypothesis that the observed cross-sections of one-month S&P 500 index futures option prices are consistent with various economic models that explicitly allow for a dynamically incomplete market and also an

[3] A number of methods for estimating the risk-neutral stock price distribution from the cross section of option prices exist, e.g. Ait-Sahalia and Lo (1998). Jackwerth (2004) reviewed the parametric and non-parametric methods for estimating the risk-neutral distribution.

imperfect market that recognizes trading costs and bid-ask spreads in the context of a one-factor model which is not necessarily linear.

Our tests confirm the above findings. Specifically, we reject the hypothesis that leverage-adjusted option returns are independent of moneyness on S&P 500 index put portfolio returns. We also reject the hypothesis on S&P 500 index call portfolio returns for the subperiod 1986-1995 (Berkeley database) and marginally so for the period 1996-2010 (OptionMetrics database). We further consider a stochastic discount factor linear in the market return and realized volatility, effectively a quadratic function of the market return. We find that this stochastic discount factor does not explain the cross-section of option returns either.

The third line of research recognizes that there may be priced factors over and above the market. Many of these models are critically discussed in Hull (2011), Jackwerth (2004), McDonald (2006), and Singleton (2006). Historically, the literature evolved via the stochastic jump model of Merton (1976) and the stochastic volatility model of Heston (1993) into the modern stochastic volatility models of Britten-Jones and Neuberger (2000), Christoffersen, Heston, and Jacobs (2010), and Jones (2006); and the combined stochastic–volatility, stochastic-jump models of Bates (1996) and Santa-Clara and Yan (2010) and models with jumps in both the price and volatility such as Duffie, Pan, and Singleton (2000), Eraker, Johannes, and Polson (2003), and Lian (2011). Our main tests fall under this line of research.

Crisis-related factors are motivated by several strands of recent research. Barro (2006) and Rietz (1988) modeled rare economic disasters in consumption growth. Broadie, Chernov, and Johannes (2009) adapted the model to address the pricing of index options. Benzoni, Collin-Dufresne, and Goldstein (2007) demonstrated that jumps in expected dividend growth rates can generate the stark regime shift that occurred at the time of the 1987 crash. Drechsler and Yaron (2011) and Shaliastovitch (2008) generated the smile observed in the implied volatilities by modeling jumps in consumption growth. Ghosh and Constantinides (2011) presented a two-regime equilibrium model and argued that volatility shocks in the consumption and dividend growth processes induce jumps in the volatility of the market return. The regime associated with higher market volatility is correlated with economic recessions and periods of stock market downturns. The model partly explains the cross-section of equity returns and sheds light on the predictability of the market return and consumption and dividend growth.

Beyond stochastic volatility and jumps, a number of authors added other factors. Chabi-Yo, Garcia, and Renault (2008) introduced a latent variable upon which fundamental variables or preferences might depend. Bates (2008) included the number of stock markets crashes as a state variable. Brennan, Liu, and Xia (2008) introduced the interest rate and the maximal Sharpe ratio as additional state variables. Christoffersen, Heston, and Jacobs (2006) added conditional skewness in a GARCH setting while Kozhan, Neuberger, and Schneider (2010) directly introduced a skew risk premium. Other lines of research include buying pressure, suggested by Bollen and Whaley (2004), and Garleanu, Pedersen, and Poteshman (2009); behavioral explanations based on sentiment, suggested by Han (2008) and Shefrin (2005); disagreement risk suggested by Buraschi, Trojani, and Vedolin (2011) who modeled investors with heterogeneous beliefs, giving rise to time-varying premia on volatility and correlation risk; and embedded leverage, suggested by Frazzini and Petersen (2011). Our main tests fall under this line of research also.

Finally, calibrated equilibrium models can generate the volatility smile pattern observed in option prices. David and Veronesi (2002) modeled the investors' learning about fundamentals, calibrated their model to earnings data, and provided a close fit to the panel of S&P 500 option prices. Liu, Pan, and Wang (2005) investigated rare-event premia driven by uncertainty aversion in the context of a calibrated equilibrium model and demonstrated that the model generates volatility smiles similar to those observed in option prices. The models discussed above concerning jumps in expected dividend growth (Benzoni, Collin-Dufresne, and Goldstein (2007)) and consumption growth (Drechsler and Yaron (2011) and Shaliastovitch (2008)) also belong into this category.

Almost all of the previously-cited research was done on index options or index futures options. For related research on individual stock options see Buraschi, Trojani, and Vedolin (2011), Chaudhuri and Schroder (2009), Christoffersen, Goyenko, Jacobs, and Karoui (2011), Duarte and Jones (2007), Şerban, Lehoczky, and Seppi (2008), and Ni (2007).

II. Data Sets, Filters, and Portfolio Formation

A cross-section of index option returns of different moneyness and maturities presents a novel set of technical challenges. The first one is to obtain statistically significant variation in the cross-section of returns because estimation errors, which could be driven in part by data errors, may lead to the conclusion that even naïve models are consistent with the data. We address this issue by constructing a cross-section of portfolios of options with different moneyness and maturity as opposed to individual options.[4] We construct the return series of 54 portfolios of S&P 500 European style options (SPX). Each portfolio is made up of either calls or puts with one of nine target moneyness ratios, K/S = 0.90, 0.925, 0.95, 0.975, 1.00, 1.025, 1.05, 1.075, and 1.10, and one of three target maturities, 30, 60, or 90 days. Our data starts in April 1986 and ends in October 2010. We carry out our main tests over this time period. We verify the robustness of our results by also analyzing the subsample that excludes the destabilizing effects of the 1987 crash and the 2008 financial crisis. Appendix A provides technical details on the data sets, filters, portfolio formation, and pricing tests.

The second challenge is to generate portfolio returns that are stationary and only moderately skewed. We address this issue by deleveraging the portfolios to have a target market beta of one. In constructing a leverage-adjusted portfolio, we approximate the elasticity with respect to the index with the elasticity implied by the BSM model, without, however, asserting that this elasticity equals the true elasticity with respect to the index. In our tests, we explicitly adjust for the market beta instead of presuming that it equals one. We also revise the portfolios daily in a way that the moneyness, maturity, and leverage of each portfolio remain fairly constant. The procedure significantly reduces the variability of returns and produces returns about as close to normal as the index itself. We validate our primary findings on monthly holding period returns with deleveraging but without rebalancing.

The third challenge stems from the occasional lack of price quotes when we wish to trade out of an options position, which may lead to survivorship bias, look-ahead bias, or the revision of the portfolios at artificial prices. We address these problems and also demonstrate that our results are insensitive to the method of portfolio revision.

II.1 Data sets

The master Berkeley Options Database contains intraday quotes on individual SPX options from April 2, 1986 through December 31, 1995. To be consistent with the OptionMetrics database

[4] See Buraschi and Jackwerth (2001) for an early construction of portfolios to reduce the noise in option returns, a point also made in Coval and Shumway (2001) who use straddles and Broadie, Chernov, and Johannes (2009) who use straddles and spreads.

which reports only closing prices, we extract from the master Berkeley Options Database a sample of closing prices and refer to it as the "Berkeley database". We describe the construction of the Berkeley database in Appendix A.1.

The OptionMetrics database contains end-of-day quotes from January 4, 1996 to October 31, 2010. The end-of-day quotes are collected using a proprietary method similar to the one we outlined for the Berkeley database. OptionMetrics provides the dividend yield and open interest of each option contract, and we collect that as well.

The bid-ask spreads of calls and puts, as a percentage of the average bid and ask prices, are generally similar for the Berkeley and OptionMetrics data sets. The spreads for ATM and ITM options are about 5%. The percentage spreads for OTM options are typically two to three times higher.

II.2 Filters

We sift the option prices through several filters to ensure that only options with reliable quotes enter our portfolios. The filtered data consist of 173,125 observations from the Berkeley database (52 % calls) and 824,397 observations from OptionMetrics (49 % calls). The filters are described in Appendix A.1. We also demonstrate robustness by lifting our filters.

II.3 Portfolio formation

We use the filtered data to form portfolios and calculate their returns. We trade in and out of portfolios daily to obtain monthly returns. We buy and sell options at their bid-ask midpoints. One may argue that transaction costs derail our rebalancing which is carried out at the bid-ask midpoints. Note that we motivate portfolio rebalancing as a statistical procedure for obtaining monthly portfolio returns with distribution close to normal rather than as an implementable trading strategy. As a robustness check, we validate our primary findings on monthly holding period returns without rebalancing.

We select which options go into each portfolio every day through a bivariate Gaussian kernel procedure with weights centered on the target maturity and moneyness, as explained in Appendix A.3.

We revise each portfolio daily. If a held option has a quote in the filtered data, we use this quote as the trade-out price; if it does not have a quote in the filtered data but has a quote in the unfiltered data, we use this quote as the trade-out price. If the option does not have a quote in the unfiltered data, we hold it until it reappears or, if necessary, until the end of the month at which point we interpolate its price, as explained in Appendix A.3. When holding on to a missing option, we keep it on the books at the purchase price and rescale its weight, dividing it by the daily portfolio return to fix the original dollar investment in the option. When the option reappears, its new price reflects the cumulative return on the option throughout its time in the portfolio.[5]

Statistics on missing options are displayed in the appendix in Table A.2. The problem of missing options is concentrated in the Berkeley database, where 19% of calls and 24% of puts go missing on the following trading day. While many of these options reappear before the end of the month, the process of carrying missing options on the books leads to more missing options at the end of the month than at the beginning. These two effects offset each other so that at the end of the month in the Berkeley database, 19% of calls and 24% of puts are interpolated based on a fitted implied volatility curve. By contrast, in OptionMetrics, only 0.1% of all observations ever go missing.

We test the BSM model on monthly rates of return of daily-rebalanced, leverage-adjusted portfolios constructed as follows. First, we calculate the daily return of each leverage-adjusted option as the daily return on a portfolio consisting of ω_{BSM}^{-1} dollars invested in the option and $1-\omega_{BSM}^{-1}$ dollars in the risk free rate, where ω_{BSM} is the BSM elasticity based on the implied volatility of the option. Second, we combine the leverage-adjusted daily option returns into daily portfolio returns using the weights obtained with the bivariate Gaussian kernel procedure described earlier. Third, we multiply the daily portfolio returns within each month to obtain the compounded monthly portfolio returns. Finally, we convert the monthly portfolio returns into percentage monthly rates of return. Later on, we test factor models on monthly excess returns that we construct by subtracting the monthly return on one-month T-Bills (obtained from CRSP) from the monthly returns.

The aggregation of options into portfolios, the daily rebalancing of the portfolios, and the adjustment for leverage have the effect of moderating the highly skewed distribution of naked

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[5] For example, if we invest 2 cents in a call and the value of our portfolio doubles from $1 to $2 while the call is not traded, the weight of the call becomes 0.01. If the call then comes back and its price too has doubled, its weight is appropriately restored to 0.02, giving the correct cumulative portfolio return of 100%. In this way, we avoid any look-ahead bias and minimize the effect of missing options on the monthly portfolio return. Options that ultimately reappear do not introduce an error.

options held to maturity. In Table II, the reported Jarque–Bera statistics, skewness, and excess kurtosis of the leverage-adjusted portfolios indicate that the deviation of the return distributions from normality is moderate. Specifically, the ATM put portfolios have skewness of about -1 and excess kurtosis around 3.9 across all maturities. By contrast, the S&P 500 index over the same period has skewness of -0.82 and excess kurtosis of 2.3. The deep OTM put and call 30-day portfolios have the highest skewness (-1.49 and 1.38) and highest excess kurtosis (5.40 and 6.66). We also report distributional statistics for long-short strategies across moneyness and maturity. The returns of these strategies tend to be significantly less volatile but somewhat farther from normal than the underlying portfolios.

[Tables II about here]

In Table A.3 of the appendix, we report results for monthly option returns with leverage adjustment but without rebalancing, where we have replaced our maturity 30-day target with a 45-day target to ensure that options bought at the beginning of the month are available at the end. The skewness and excess kurtosis of our near-the-money portfolios remain roughly the same, while the OTM call and put portfolios see their skewness and excess kurtosis increase. Finally, if we do not adjust for leverage but continue to rebalance daily, both skewness and excess kurtosis increase dramatically across all portfolios (Table A.4 of the appendix). This suggests that the leverage adjustment and, to a lesser extent, the daily rebalancing lead to returns that are closer to normal and, therefore, easier to work with from a statistical point of view.

The leverage adjustment of the options in our portfolios aims to make the monthly index betas of these portfolios close to one. These betas need not exactly equal one for two reasons. First, we leverage-adjust options using the elasticity implied by the BSM model which may not be the exact elasticity, if the BSM model is not applicable to these options. Second, we leverage-adjust daily returns which we subsequently compound into monthly returns; this is not the same as leverage adjusting monthly returns. Indeed, the call portfolio monthly betas reported in Table II are lower than one and as low as 0.58 while the put portfolio betas range from 0.93 to 1.06. These discrepancies are not a cause for concern because in the formal tests of the hypothesis H_{ICAPM} we explicitly adjust for the market beta instead of presuming that it equals one.

III. Empirical Results for the Black-Scholes-Merton Model

Recall that the BSM model implies that the instantaneous expected rate of return of a leverage-adjusted option equals the instantaneous expected rate of return of the underlying security and is independent of the option moneyness, maturity, type (put or call), or any other characteristic of the option. This hypothesis is rejected for the portfolios of put options. In Table II, the portfolio returns are strongly decreasing in the *K/S* ratio. The differences in returns across moneyness are economically large. The monthly return difference between the put portfolios with moneyness 1.10 and 0.90 is -138 bps for 30-day options and -38 bps for 90-day options. All of these differences are highly statistically significant. Put returns also vary considerably across maturity. At a moneyness ratio of 0.90, the 30-day put portfolio has a return 100 bps higher than the 90-day portfolio (highly significant), the gap narrows to 17 bps at the money (still highly significant), and disappears at the deep ITM end.

As for our call portfolios, their returns are also strongly decreasing in the moneyness ratio, and increasing in maturity at the OTM end. Specifically, the difference in returns between 1.10 and 0.90 moneyness ratio call portfolios is 47 bps at 30-day maturity and 28 bps at 90 days. All of these differences are highly statistically significant. Across maturities, returns are very similar for low and moderate moneyness ratios, but at the OTM end 90-day portfolios tend to earn about 20-25 bps more than the corresponding 30-day portfolios.

In addition to the patterns across moneyness and maturity, we also note that the level of option portfolio returns is quite different across calls, puts, and the index. While all our portfolios have betas close to one with respect to the S&P 500 whose sample average return is 86 bps, call returns are between zero and 50 bps, whereas put returns are between 70 and 200 bps.

To check the robustness of our results, in Table A.3 of the appendix we report returns without rebalancing and in Table A.4 of the appendix we report results without adjusting for leverage. While the higher skewness and excess kurtosis tend to increase standard errors, the patterns that emerge are unchanged.

We present a number of robustness checks with tables relegated to the appendix. We split the sample into the early Berkeley part and the latter OptionMetrics part (Tables A.5 and A.6 of the appendix). The put portfolio returns are equally strong across the two subsamples. For the calls, the ITM returns tend to be lower (only 10 bps) in the OptionMetrics subsample and while they still decrease as moneyness rises, the drop is not statistically significant. To check our particular method of filtering the data, we remove all data filters. The monthly portfolio returns are displayed in the appendix in Table A.7 and are virtually identical to the results presented in Table II.

As another robustness check, we exclude the destabilizing effects of the October 1987 crash and the 2008 financial crisis. The monthly portfolio returns from July 1988 to June 2007 in Table A.8 of the appendix are very similar to those in Table II, though the average returns are higher - as expected.

Recall that, if a held option does not have a quote at the end of the month either in the filtered or the unfiltered data, we set the trade-out price equal to the BSM price with volatility obtained from the fitted implied volatility curve. As a final robustness check with results available in Tables A.9 and A.10, we calculate the monthly portfolio returns when we subtract or add two percentage points to the fitted implied volatility in setting the trade-out price. The monthly portfolio returns are quite close to the results presented in Table II.

In the next section, we seek to explain the cross section of option portfolio returns with a series of crisis-related factor pricing models. As a preliminary step in that investigation, we allow for the market index to be the sole factor, thereby testing the CAPM. We find that the CAPM does not explain the cross section of option portfolio returns. In particular, the returns of OTM puts remain out of line. The formal test results of the CAPM provide a robustness check of the BSM results reported in this section for two reasons. First, the CAPM does not rely on the maintained hypothesis of the BSM model that the market is complete. Second, we estimate the market betas of the portfolios without asserting that these betas equal one.

IV. Empirical Results for Crisis-Related Factors

Our rejection of the BSM model motivates our tests of Merton's (1973b) unconditional ICAPM. The ICAPM specifies neither the number nor the identity of the factors. We seek to explain the returns of the cross-section of option portfolios with unconditional factor pricing models, that is, under the maintained hypothesis that the factor premia and the factor betas are constant over the sample period from April 1986 until October 2010. The risk factors are suggested by either the equities or options literatures, or both. Throughout, the term "factors" refers to "monthly factor innovations". Appendix B provides a listing of the factors and their descriptions. In most of our main tests of the ICAPM, we limit the number of factors to at most two because the cross-section of test assets has only a small number of principal components. However, we also show some results for three factor models in order to refute the notion that the more limited two-factor models suffer from missing factors and could be mispecified.

In our broad quest for factors that explain the cross-section of index option returns, we seek factors and their associated premia, estimated from the universe of index options, (along with the market factor and the equity market premium) which explain, at least in part, the variation across moneyness (the level and slope) and maturity of index option returns. As a stricter criterion, we also seek factors and their associated premia, estimated from the universe of *equities*, (along with the market factor and the equity market premium) which explain the cross-section of index option returns, thereby investigating the degree of integration or differential liquidity of the equity and option markets.[6] Of all the factors that we consider, the crisis-related factors, *Jump*, *Volatility Jump*, *Volatility,* and *Liquidity*, are the only ones that meet this challenge. We thus concentrate on these factors which can be consistently estimated from either the universe of equities or options. However, we find that their premia vary significantly due to variations in option type, maturity, and moneyness which we will argue is potentially related to market segmentation.

IV.1 Methodology

The cross-section of option portfolios consists of 27 call and 27 put portfolios. There are only two sizeable principal components in the covariance structure of the option portfolios, accounting for 89% and 10% of the variance, respectively. This feature of the covariance structure guides our test design. We normally limit the pricing model to at most two factors at a time, with the market proxied by the S&P 500 index being always the first factor and at times being the sole factor. Thus with each model we test one new factor at a time. For our best-performing models, however, we also investigate three-factor models.

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[6] This approach is in the spirit of the recommendation in Lewellen, Nagel, and Shanken (2010) to expand the set of test assets to include other portfolios.

We first estimate the factor premia from the cross-section of equity returns, where we use the standard Fama-French 25 portfolios, and test whether these premia explain the cross-section of option returns. We then apply a lower hurdle for the model by estimating the factor premia from the cross-section of option returns and testing whether these premia explain the cross-section of option returns. We also test whether the premia estimated from the universe of equities equal the premia estimated from the universe of options.

Our leverage-adjusted option portfolios with daily rebalancing have portfolio returns closer to normal than is common in the option pricing literature. For this reason, we are comfortable with a linear pricing test. However, we also consider non-linear pricing tests with return jumps and volatility as factors. Our approach consists of several stages and may potentially introduce unaccounted errors-in-the-variables. We deal with this issue by reporting bootstrapped standard errors. Our approach is described in detail in Appendix A.4.

IV.2 Empirical Results

We show that four crisis-related factors, *Jump, Volatility Jump*, *Volatility*, and *Liquidity*, work reasonably well in explaining the cross-section of option returns, even when we impose the stricter standard of estimating the premium from the universe of equities. *Jump* is defined as the sum of all daily returns of the S&P 500 that are lower than -4% within each month, zero if there are none. Approximately 7% of the months have nonzero jump. *Volatility Jump* is defined as the sum of all daily increases in the ATM call portfolio implied volatility that are greater than 4%, zero otherwise. Approximately 10% of the months have nonzero *Volatility Jump*. *Volatility* is defined as the end-of-month ATM call portfolio implied volatility minus the beginning-of-month volatility. *Liquidity* is defined as the innovation of the market-wide liquidity factor proposed by Pastor and Stambaugh (2003).

The first panel of Table III displays the risk premia, betas, alphas, and pricing errors for each of these factors plus for the model with the S&P 500 as a sole factor. We expect *Jump* to earn a positive premium as assets whose prices fall with the market are risky. We expect *Volatility Jump* and *Volatility* to earn negative premia because assets that have high returns during periods of increased volatility provide a useful hedge. We also expect the *Liquidity* premium to be positive because assets that covary positively with *Liquidity* are risky. The premia estimated from the universe of equities have the right signs and are statistically significant but for *Volatility*. The premia estimated from the universe of options have the right signs, are not significantly different from zero (but for *Volatility*), and are not significantly different from their counterparts estimated from the universe of equities.

[Table III about here]

The second and third panels of Table III display the betas and alphas of call portfolios for selected moneyness and maturities. The *Jump* betas of the call portfolios are negative and statistically significant, consistent with the intuition that calls provide downside protection. The *Jump* betas of the put portfolios are not statistically significant but are positive, as to be expected, since our leverage-adjusted portfolios hold puts short, which exposes them to downside risk. The call portfolios have positive *Volatility Jump* and *Volatility* betas that are increasing both in magnitude and statistical significance towards the OTM call portfolios. This is intuitive since buying calls, in general, and OTM calls in particular, is a positive bet on volatility. Conversely, selling puts is a negative bet on volatility and the put portfolios have negative betas that become larger and more statistically significant in the direction of the OTM put portfolios. The differential sign and variation across moneyness of the loadings of our portfolios with respect to *Jump, Volatility Jump, and Volatility* allow these factors to capture the variation in option portfolio returns. By comparison, the *Liquidity* betas of the option portfolios are generally small and insignificant.

Each of the four factors does a good job in pricing the level of option returns. Almost none of the call and put alphas is statistically different from zero, irrespective of whether the premium is estimated from the universe of equities or the universe of options. Exceptions occur with some put alphas being significantly different from zero when the factors are *Volatility Jump* or *Volatility* and the premia are estimated from the universe of options. This occurs because the standard errors are small.

All four factors explain the slope of call returns: the difference between the OTM and ITM call alphas is small compared to the difference in raw returns. None of the four factors accounts well for the pronounced slope in put returns with an equity-based premium. Using *Volatility Jump*, this slope is reduced by about a third. *Volatility Jump* reduces the pricing error of the 30-day OTM put portfolio by two thirds, from 59 bps to 19 bps and renders it statistically insignificant.

Frazzini and Pedersen (2011) argue that securities with embedded leverage have higher prices because they allow investors to take levered positions without borrowing. The results in Table II support this hypothesis. Both 30-day and 90-day OTM call portfolios have higher average returns than the corresponding ITM calls. Also 30-day and 90-day OTM put portfolios have higher average returns than the corresponding ITM puts. (Recall that put portfolios have a short position in puts.) The same results obtain in Table III when the alphas are adjusted for market beta. However, this pattern is weakened and, in some instances, reversed when we introduce *Jump*, *Volatility Jump*, *Volatility*, or *Liquidity* as a second factor. For example, the pattern is reversed in Table III for both call and put portfolios when the alphas are also adjusted for exposure to *Liquidity* with an option-based *Liquidity* premium. It appears that the returns of the OTM calls and puts are systematically related to market conditions.

For *Jump, Volatility Jump*, *Volatility*, and *Liquidity*, the root-mean-squared (rms) pricing error of the option returns is 23 bps (p-value 7%), 29 bps (p-value 1%), 21 bps (p-value 40%), and 28 bps (p-value 17%), respectively, when the premium is estimated from the universe of equities and drops further to 13 bps (p-value 21%), 13 bps (p-value 6%), 14 bps (p-value 52%), and 11 bps (p-value 63%), respectively, when the premium is estimated from the universe of options. These numbers contrast to the rms error of 48 bps obtained from the single-factor model with the S&P 500 index as the only factor and premium estimated from the universe of equities. Thus, each one of the factors *Jump* and *Volatility Jump*, and, to a lesser extent, *Volatility* and *Liquidity* is able to account for a large part of the level of option portfolio returns, even when their premium is estimated among equities.

In Table A.11 of the appendix, we report results for the portfolios without daily rebalancing. The point estimates become generally noisier as the portfolios are farther from normal. The pricing errors are higher, but the four crisis-related factors continue to improve pricing even with equity-based premia. In Table A.12 of the appendix, we focus on the OptionMetrics subsample, 1996-2010. *Jump* and *Volatility* continue to do well and *Volatility Jump* does well with an option-based premium but less so with a equity-based premium. The ability of *Liquidity* to price the cross-section of options and equities is reduced, and the estimated premium is statistically different between the two markets.

We perform two additional robustness tests. In the first, reported in Table A.13 of the appendix, we omit the 1987 crash and the 2008 financial crisis from the sample. As the crises comprise the most pronounced episodes for our *Jump* and *Volatility Jump* factors, their explanatory power is reduced, while *Volatility* remains strong. We view the crises as revealing important risks associated with options and therefore choose to focus on the full sample. In a second robustness test, reported in Table A.14 of the appendix, we replace the 25 Fama-French portfolios with 10 factor-specific decile portfolios formed by sorting stocks according to their loadings on each factor. Given the large variation in factor loadings across these portfolios, the estimated factor premia are smaller in magnitude and result in higher pricing errors.

We also explore a large number of alternative factors, namely, *Market, Size, Value, Momentum, Realized Volatility* (RV), *Realized Volatility minus Implied Volatility* (RV-IV), *Implied Volatility Slope, Volume, Open Interest, OTM Put Volume, Bid-Ask Spread, Sentiment, SPF Dispersion, Retail Call Demand, Retail Put Demand, Default Spread, Term Spread, Sharpe Ratio, Riskfree Rate, Inflation*, and *GDP*. We present and discuss these results in Appendix C. We find that these factors improve option pricing only when we base the premia on the universe of options. The pricing performance deteriorates once we require equity-based premia. This result demonstrates that the task of finding a factor that can account for the cross section of option portfolio returns is a non-trivial one.

V. Variation in Factor Premia

We have established that the three factors arising from the underlying stochastic process of the index, *Jump, Volatility Jump,* and, to a lesser extent, *Volatility* work reasonably well in explaining the cross-section of option returns. We have also established that the factor *Liquidity* works reasonably well in explaining the cross-section. Factors related to the equity markets, the macro-economy, and the option market micro-structure matter much less.

Even with *Jump, Volatility Jump,* or *Volatility* as factors and option-based premia, the monthly pricing errors in Table V are about 13 bps and are large compared to a typical option return of 67 bps. The alphas for options of different type (put or call), maturity, and moneyness vary widely, suggesting that these factors cannot simultaneously deal with different options.

Related concerns arise when we consider that option pricing models are often recalibrated to different times to maturity since one parameter set often cannot adequately price options of different maturities.

We further address these issues by splitting the sample two ways. In Table IV, Panel A, we split the sample according to maturity (30 and 90 days) and type (puts and calls); in Panel B, we split the sample two ways according to moneyness (K/S $\leq$ 0.95 and K/S $\geq$ 1.05) and type (puts and calls). Table A.15 of the appendix presents results for the OptionMetrics subperiod, 1996 to 2010.

[Table IV about here]

For the market model with the S&P 500 as the sole factor, all cross-differences in the premia are economically and statistically significant. In Table IV Panel A, 30-day puts require higher market premium than 30-day calls; 90-day puts require higher premium than 90-day calls; 30-day puts require higher premium than 90-day puts; and 30-day calls require lower premium than 90-day calls. Likewise, in Panel B, all cross-differences in the premia are economically and statistically significant. In Table A.15 of the appendix, similar results obtain in the 1996-2010 OptionMetrics subsample and some differences are statistically significant.

When we introduce *Jump, Volatility Jump,* or *Volatility* as a second factor the most striking finding is that OTM puts require a very different premium than ITM calls. These differences are both economically and statistically significant. When we introduce *Liquidity* as a second factor, the OTM puts require a higher *Liquidity* premium that ITM calls but the difference is only marginally significant. Other differences that are both economically and statistically significant are: OTM puts require a higher *Jump* premium than ITM puts; 30-day puts require a lower *Volatility Jump* premium than 30-day calls; OTM puts require a lower *Volatility Jump* premium than ITM puts; 30-day puts require a lower *Volatility* premium than 30-day calls; 30-day puts require a lower *Volatility* premium than 90-day puts; and OTM puts require a lower *Volatility* premium than ITM puts. Similar results obtain in the 1996-2010 OptionMetrics subsample.

While two-factor models might be mispecified, it emerges that three-factor models reduce the remaining pricing errors to such an extent, that we are confident about our specification. It emerges that, normally, two factor models suffice but for the OTM puts, the appropriate model has a third liquidity factor. This suggests that short maturity OTM puts are expensive because they offer protection against severe disruptions of market liquidity.

In Table V, we add *Liquidity* as a third factor to the models with *Jump, Volatility Jump,* or *Volatility* as the second factor. The rms error decreases from 11-19 bps to 5-6 bps. Furthermore, the *Jump, Volatility Jump,* or *Volatility* premia are no longer statistically different across moneyness, maturity, and type. Whereas the premia differences turn insignificant even when a third factor other than *Liquidity* is introduced, this may be partly due to the high correlation between the three factors *Jump, Volatility Jump,* or *Volatility* is high (see Table I). Note, by contrast, that the correlations between the three factors and *Liquidity* are small.

[Tables V about here]

We conclude that factor premia depend on option type, maturity and moneyness. In particular, our short-maturity leverage-adjusted OTM put portfolios demand much higher premia than other portfolios. Do limits to arbitrage in the form of illiquidity, supply/demand imbalances, and market segmentation provide an explanation?

We find evidence in Figure V that such supply/demand imbalances and market segmentation are indeed likely. Panel A shows that, for short-dated calls, the main market players are large customers who are short the calls while market makers and firms are long these calls. However, for OTM calls, this pattern reverses and large customers are long the calls while market makers are short. Thus, the short dated OTM calls exhibit distinct demand patterns from other calls. The typical call pattern continues to hold for medium term (Panel B) and long term (Panel C) calls where the role of firms is reduced and the main pattern is that large customers supply calls while market makers (and less so firms) demand them.

[Figure V about here]

For short dated puts (Panel D), this pattern completely changes and now large customers, aided by small customers and, to a lesser degree, medium customers demand put options while market makers and few firms supply them. However, this pattern is reversed for OTM short dated puts. Market makers demand them and large customers supply them, albeit in small net amounts. Again, the typical put pattern continues to hold for medium term (Panel E) and long term (Panel F) puts where the role of firms is reduced and the main pattern is that large customers demand puts while market makers (and less so firms) supply them. We see that these different demand patterns suggest market segmentation across many dimensions: puts differ from calls, OTM short dated options differ from ATM and ITM short-dated options, and short dated options altogether differ from medium and long dated options.

The next step is to relate these demand patterns to returns. Garleanu, Pedersen, and Poteshman (2009) argue that market makers who face customer demand imbalances may require a premium for holding large net positions. Market segments where market makers tend to hold short positions should see high returns to selling. We see from Figure V that indeed market makers are large net sellers of puts, and very small net buyers of calls, which is consistent with the high returns to selling puts and low returns to buying calls that we find. Furthermore, the net positions of market makers decrease with option maturity for puts but not calls. We find the same pattern in returns across maturity. Holding option type and maturity constant, market maker positions line up well with the returns of short maturity calls across moneyness: returns decrease in moneyness as does the net position of market makers. However, we see that for short maturity OTM puts, net market maker demand is slightly positive, whereas the return to selling these portfolios is extremely high.

Figure VI shows the CAPM-adjusted alphas and the alphas from the *Index* and *Jump* two-factor model for the short-dated OTM puts (Table III, columns 1 and 2), along with the demand for these options. We see that, whereas market-maker demand is U-shaped, the abnormal returns and alphas of these portfolios are steeply decreasing. In fact, the alphas of ATM and ITM puts are close to zero. Our OTM put portfolios have high leverage-adjusted returns with little evidence of market-maker demand imbalance. We point out, however, that net demand is indeed much lower for these portfolios than for others, even though they are heavily traded. In other words, the market for short-maturity OTM puts appears to be distinct from its neighbors and demand imbalances may not be the sole explanation of option portfolio returns.

[Figure VI about here]

VI. Concluding Remarks

We established that the leverage-adjusted returns on S&P 500 index options strongly reject the predictions of the Black-Scholes-Merton model. We then considered a wide range of unconditional factor pricing models, where the factor premia are estimated either from the universe of equities or the universe of options. Of all the factors that we consider, the four crisis-related factors, *Jump, Volatility Jump*, *Volatility*, and *Liquidity* are the only ones that work reasonably well in explaining the cross-section of index option returns. This finding holds independent of estimating the premia from the universe of options or equities.

The primary contribution of this paper is to identify the tensions within these factor models when confronted with a full cross-section of 54 index options, a cross section much larger than typically employed in option return research. The factors require economically and statistically different premia on samples split across the attributes of type (calls and puts), maturity, and moneyness. In particular, puts with short maturity and low moneyness require dramatically higher premia than other options. Our findings indicate that the prices of short maturity out-of-the-money puts are consistent with a high premium for exposure to severe disruptions in market liquidity.

A great deal of current research addresses the limits to arbitrage in derivatives markets in which the pattern of supply and demand is markedly different across different types of options and across market makers, firms, and customers of various sizes. It is plausible that this pattern of supply and demand differentially distorts different types of option prices and provides in part an explanation for the tensions within factor models which we identify in this paper.

Appendix A: Data and Methodology

A.1 Data sets

The master Berkeley Option Database consists of intraday quotes on individual options and we seek to extract a single end-of-day cross section of quotes, comparable to the quotes provided by OptionMetrics in the latter part of our sample. In addition, we seek to avoid the issue of non-synchronous trading. To that end, on each trading day, we find the minute between 3:00 PM and 4:00 PM Central Standard Time with the largest number of simultaneous quotes. We stop at 4:00 PM because the market closes at 4:15 PM and we wish to avoid contamination relating to last minute trading activity. We record all option quotes in that minute.

Next we add not so far recorded quotes in the adjacent minutes within the same hour one after the other. Here, we assume that the implied volatilities stay constant within that final hour of the day. Based on this assumption, we create hypothetical option prices for the option in adjacent minutes. About half of our observations from the Berkeley database are obtained from a single minute. The pattern of returns across our portfolios remains unchanged if we use only the observations obtained from the single minute.

We also record the intraday volume of each of our end-of-day options, as well as total daily call volume and total daily put volume. We further collect the present value of all realized dividend payments during the remaining life of each option, discounting with the relevant constant maturity T-bill rate from the H.15 statistical release of the Federal Reserve. We work out the associated continuously compounded dividend yield.

The OptionMetrics database is already in the form of end-of-day quotes collected using a proprietary method similar to the one we outline for the Berkeley database. OptionMetrics provides the dividend yield and open interest of each option.

A.2 Filters

We apply three levels of filters designed to minimize possible quoting errors. In constructing our portfolios, we apply these filters on the trade-in (buy) side to make sure that we are buying into reliable quotes. Applying our filters on the buy side minimizes the problem of having to make up trade-out prices for options that were bought but cannot be sold due to missing observations.

When we seek to exit our position, if no quote is available in the filtered data, we look for a price in the raw data. The filters are described below.

Level 1 filters:

<u>"Identical" filter</u> The OptionMetrics data set contain duplicate observations, defined as two or more quotes with identical option type, strike, expiration date, and price. In each such case, we eliminate all but one of the quotes.

<u>"Identical except price" filter</u> There are a few sets of quotes with identical terms (type, strike, and maturity) but different prices. When this occurs, we keep the quote whose T-Bill-based implied volatility is closest to that of its moneyness neighbors, and delete the others.

<u>"Bid = 0" filter</u> We remove quotes of zero for bids thereby avoiding low valued options. Also, a zero bid may indicate censoring as negative bids cannot be recorded.

Level 2 filters:

<u>"Days to maturity <7 or >180" filter</u> We remove all options with fewer than 7 or more than 180 calendar days to expiration. The short maturity options tend to move erratically close to expiration and the long maturity options lack volume and open interest.

<u>"IV<5% or >100%" filter</u> We remove all option quotes with implied volatilities lower than 5% or higher than 100%, computed using T-Bill interest rates. Such extreme values likely indicate quotation problems or simply low value.

<u>"Moneyness <0.8 or >1.2" filter</u> We remove all option quotes with moneyness, the ratio of strike price to index price, below 0.8 or above 1.2. These options have little value beyond their intrinsic value and are also very thinly traded.

<u>"Implied interest rate <0" filter</u> When filtering outliers we use T-Bill interest rates to compute implied volatilities. T-Bill interest rates are obtained from the Federal Reserve's H.15 release. We assign a T-Bill rate to each observation by assuming that we can use the next shortest rate if the time to expiration of the option is shorter than the shortest constant maturity rate.

Our goal is to obtain an interest rate that is as close as possible to the one faced by investors in the options market. It appears that the T-Bill rates are not the relevant ones when pricing these options. Specifically, when the T-Bill rates are used, put and call implied volatilities do not line up very well; for example the T-Bill rate tends to be too high for short maturity options, perhaps because no T-Bill has maturity of less than a month. To address these issues, we compute a put-call-parity-implied interest rate. Since we believe that put-call parity holds reasonably well in this deep and liquid European options market, we use the put-call-parity implied interest rate as our interest rate in the remainder of the paper and for further filters.

To construct this rate, we take all put-call pairs of a given maturity and impose put-call parity using the bid-ask midpoint as the price, and allowing the interest rate to adjust. We remove 14,200 pairs with a negative implied interest rate. We then take the median implied interest rate across all remaining pairs of the same maturity with moneyness between 0.95 and 1.05 and assign it to all quotes with that maturity. We are able to directly assign an implied interest rate to 93% of our sample in this way. We fill in the gaps by interpolating across maturities and if necessary, across days. Our implied interest rate is on average 45 basis points below the T-Bill rate.

"Unable to compute IV" filter We remove quotes that imply negative time value.

Level 3 filters:

"IV" filter We remove implied volatility outliers to reduce the prevalence of apparent butterfly arbitrage. For each date and maturity, we fit a quadratic curve (separately to puts and calls) through the observed log implied volatilities. We calibrate a confidence band around all curves using the entire sample. Combining the information from all days and maturities in the sample, we compute a typical (one standard deviation) relative distance in percent from the level of the fitted curve for different levels of moneyness (0.8, 0.85, …, 1.2). Thus, for each fitted IV curve, we compute the relative distance of all option IVs from the fitted IV curve and we calculate the standard deviation of these relative distances for each moneyness bin. In a second pass, we check for each option's IV, how many standard deviations it is apart from the fitted IV curve. These distances are tight in and around the money (about 2%) and wide in the out of the money range (around 3.5%).

“Put-call parity” filter For every put-call pair with the same date, maturity, and moneyness, we insure that put-call parity holds and that violations are eliminated. Thus, for each put-call pair, we find the bid-ask midpoint put-call-parity implied interest rate. Next, we trim outliers in a similar way as with the IV filter. Specifically, we use the whole sample of distances of the put-call parity implied interest rates from the corresponding daily median implied interest rate to find the standard deviation of the corresponding distances. This distance is computed to be about 90 basis points.

We record the number of observations at each filtering level in Table A.1. Before the application of the filters, the Berkeley database consists of 269,461 observations and the OptionMetrics database consists of 3,908,176 3,711,535 observations. Level 1 filters eliminate 34% of the prices from the OptionMetrics database but none from the Berkeley database. Level 2 filters eliminate about 28% of the observations from Berkeley and as many as 64% from OptionMetrics (mostly the maturity filter) and level 3 filters eliminate 10% of observations from each dataset. We also note that our filters produce 124 trading days with no surviving observations. These dropped days represent 2% of the trading days in our sample and since they are determined without the use of forward-looking information, we safely do not rebalance our portfolios during those days.

[Table A.1 about here]

Next, we compute implied volatilities based on the put-call parity implied interest rate, and 95% of these are within 1.4% of the T-Bill implied volatilities. In the remainder of the paper, we work exclusively with these implied volatilities.

A.3 Portfolio formation

We form 54 portfolios, 27 made up of calls and 27 made up of puts, each with targeted time to maturity 30, 60, or 90 days and targeted moneyness 0.90 0.925 0.95, 0.975, 1.00 1.025, 1.05, 1.075, 1.10, where moneyness is the ratio of strike price to index price. Specifically, at each date t, we use a bivariate Gaussian weighting kernel in moneyness and days to maturity to calculate weights for each portfolio. The weighting kernel has bandwidths of 10 days to maturity and 0.0125 in moneyness, although alternative settings make little difference. We remove options whose portfolio weights are less than 1% from the portfolio to reduce the effect of outliers on our targeted portfolios. The weights are normalized to sum to one.

For each option in a portfolio, we look for a quote on day *t+1*, including quotes from the unfiltered data in our search. If a quote is found, the quoted price is used to compute a return for the option. If not, we check if the option is about to expire in which case we use its expiration payoff to calculate a return. If expiry is not imminent, we hold the option in the portfolio until it reappears, or until the end of the month, whichever comes first. If the option fails to reappear by the end of the month, we compute an interpolated price by fitting an implied volatility surface that is quadratic in maturity and moneyness to the log implied volatilities of the available filtered options and use the fitted implied volatility to deduce a price for the missing option. When holding on to an option in a portfolio because of a missing quote, we record a daily return of one and adjust its weight to account for the returns on the remaining options. Whenever the option reappears, is exercised, or its price is interpolated, we compute a cumulative return and use the rebalanced weight to calculate the resulting portfolio return. In this way, options that go missing and reappear before the end of the month do not introduce an error.

When forming the portfolios, 95% of options bought are found and sold by the end of the month, 5% are sold using an interpolated price, and a negligible number expire while in the portfolio. The interpolated options are found almost exclusively within the Berkeley database, where they make up as much as 19% of calls and 24% of puts.

In testing our hypothesis H_0, we construct leverage-adjusted portfolios. Rather than investing one dollar in the option, we invest ω_{BSM}^{-1} dollars in the option and $1-\omega_{BSM}^{-1}$ dollars in the risk free rate, where ω_{BSM} is the BSM elasticity based on the implied volatility of the option. The BSM elasticity is $\left(\partial C_{BSM}/\partial S\right)\times\left(S/C_{BSM}\right)$ for a call and $\left(\partial P_{BSM}/\partial S\right)\times\left(S/P_{BSM}\right)$ for a put. Note that the elasticity of a call is greater than one. Therefore, a leverage-adjusted call option consists of a portfolio with investment in a fraction of a call and investment in the risk free rate. The elasticity of a put is negative and less than minus one. Therefore, a leverage-adjusted put option consists of portfolio with a short position in fraction of a put and more than 100% investment in the risk free rate.

In the next step, we combine the leverage-adjusted option returns into portfolio returns using their weights. Finally, we compound the daily returns into monthly returns.

A.4 Pricing tests

Our factor pricing tests use two-stage OLS with bootstrapped standard errors and p-values. Specifically, in our main run we calculate the factor betas of our option portfolios. Then we regress the average excess returns of the portfolios on their betas and record the estimated premia. In the second cross-sectional stage, we impose the restriction that the intercept, corresponding to the excess return on a zero-beta asset, is equal to zero. This restriction increases the power of our tests and ensures that we do not obtain spurious results whereby small differences in factor loadings across our highly correlated portfolios, together with a large premium, appear to fit the cross section of option returns. We calculate a J-statistic to test the hypothesis that all portfolio pricing errors are zero.

To calculate our bootstrapped standard errors, we draw 10,000 simulations under the null of zero pricing error for each of our portfolios. Specifically, we subtract the estimated pricing errors from the returns of our portfolios and draw a sample of equal length to our underlying sample with replacement. We then perform our two-stage pricing test and calculate a new set of betas, premia, and alphas for each run. We calculate bootstrapped standard errors as the standard deviation of the quantities in question. We calculate bootstrapped p-values by comparing our actual J-statistic to the J-statistics drawn under the null of zero alpha in the bootstrapped runs.

Appendix B: Description of the Factors

Market proxies

S&P: monthly return of the S&P 500 index in excess of the return of the one-month T-Bill.

Market: monthly return of the CRSP value-weighted market index in excess of the return of the one-month T-Bill.

Equity-based factors

Size: monthly return on the Fama and French size factor (SMB). Source: http://mba.tuck.dartmouth.edu/pages/faculty/ken.french

Value: monthly return on the Fama and French value factor (HML). Source: http://mba.tuck.dartmouth.edu/pages/faculty/ken.french

Momentum: momentum factor, the excess return on a portfolio long stocks with high returns over the period from 12 to two months before portfolio formation and short stocks with low returns over the same period. Source: http://mba.tuck.dartmouth.edu/pages/faculty/ken.french

Volatility-related factors

Jump: the sum of all daily returns of the S&P 500 that are lower than -4% within each month, zero if there are none; approximately 7% of the months have nonzero jump.

Volatility Jump: the sum of all daily increases in the ATM call portfolio implied volatility that are greater than 4%, zero otherwise; approximately 10% of the months have nonzero *Volatility Jump*.

Volatility: end-of-the-month ATM call portfolio implied volatility minus the beginning-of-the-month ATM call portfolio implied volatility. Using the CBOE-provided shorter time-series VIX does significantly change the results.

RV: annualized realized daily volatility over the month minus the realized volatility over the previous month.

RV-IV: change over last month in the difference between the annualized realized volatility during the month and the annualized monthly ATM implied volatility at the beginning of the month.

Slope: change over last month in the difference between the average of the OTM call and ITM put portfolio implied volatility and the average of the ITM call and OTM put portfolio implied volatility. Using the CBOE-provided shorter time-series SKEW does significantly change the results.

Liquidity-related factors

Liquidity: innovation of market-wide liquidity factor proposed by Pastor and Stambaugh (2003). Source: Wharton Research Data Services.

Volume: percentage change in the monthly option volume.

Open Interest: percentage change in the beginning of the month total option open interest, available only since 1996.

OTM Put Volume: percentage change in the monthly 0.95 OTM put option volume.

Bid-Ask: percentage change in the weighted average percentage bid-ask spread of the ATM call portfolio.

Factors based on sentiment and noise-trader beliefs

Sentiment: sentiment factor proposed by Baker and Wurgler (2006).

SPF Dispersion: measure based on the Survey of Professional Forecasters from the Federal Reserve Bank of Philadelphia. Largely following Shaliastovich (2008), we take the cross-sectional dispersion of one-quarter-ahead nominal GDP growth forecasts and scale by the square-root of the number of forecasts to get a measure of the precision of the forecasts. We then difference the series to obtain an innovation in forecast dispersion. We apply the corresponding quarterly observation to each month in the quarter.

Retail Call Demand: monthly difference in net call demand (in number of contracts) by small and medium size investors, as classified and provided by Market Data Express.

Retail Put Demand: monthly difference in net put demand (in number of contracts) by small and medium size investors, as classified and provided by Market Data Express.

Macro-based and other factors

Default: monthly premium of the BAA bond return over the AAA bond return, differenced over time.

Term: monthly premium of the 10-year bond return over the three-month T-Bill return, differenced over time.

Sharpe: innovation in the market Sharpe ratio as in Brennan, Wang, and Xia (2004).

Riskfree: change in the one-month LIBOR.

Inflation: innovation in inflation as in Brennan, Wang, and Xia (2004).

GDP: return on a portfolio mimicking GDP growth, as in Vassalou (2003).

Appendix C: Other Factor Pricing Models

We survey a large number of factors that prove unsuccessful in explaining the cross-section of index option returns: the Fama-French factors Market, Size, and Value and also Momentum (Section C.1); the volatility-related factors Volatility (implied volatility), RV (realized volatility), IV-RV (implied-minus-realized volatility), and Slope (Section C.2); the liquidity-related factors Volume (trading volume), Open Interest, OTM Put Volume, and Bid-Ask (bid-ask spread) (Section C.3); factors that reflect sentiment, the Baker and Wurgler (2006) sentiment factor, and SPF Dispersion (forecast dispersion from the Survey of Professional Forecasts) and factors that reflect noise-trader beliefs, as captured by Retail Call Demand and Retail Put Demand (Section C.4); and the macro factors Default (default premium), Term (term premium), Sharpe (market Sharpe ratio), Riskfree (risk free rate), Inflation, and GDP (Section C.5). Our main point is to contrast the results with those of Section V and demonstrate that although there are only two sizeable principal components in the cross-section of option portfolio returns, it is by no means an easy task to identify a factor that can account for both the level and slope of their returns, especially with a premium consistent with the pricing of equities.

C.1 Pricing with equity-based factors

The hypothesis that the unconditional CAPM prices the cross-section of index option returns at the monthly frequency relaxes the maintained hypothesis of the BSM model that the market is complete. In the first column of Table C.1, we display the market betas of the index options, where the market return is proxied by the return on the S&P 500 index. The betas are close to one, ranging between 0.77 and 1.02, suggesting that our leverage adjustment works reasonably well. First, we estimate the premium on the universe of equities. The price of market risk (58 bps) is close to the average market premium, which is 54 bps per month in our sample. In the same column, we display the pricing error (alpha) for each option portfolio. The hypothesis that the alphas are jointly zero is rejected.

[Table C.1 about here]

The alphas of the call portfolios are negative and statistically significant. These negative alphas are also economically significant: at about -60 bps per month, they are much bigger than the actual return on any of our call portfolios (17 to 32 bps). Therefore, index calls are expensive based on the S&P 500 single-factor model. This conclusion is consistent with our earlier finding that the average excess return on all five call portfolios in the same period is negative, as shown by their negative Sharpe ratios reported in Table II.

The alpha of the OTM puts is large, positive, and statistically significant. The alphas of the other put portfolios are small positive or small negative. Recall that puts are held short in these portfolios because their BSM elasticity is negative. Therefore, the OTM index puts are expensive based on the S&P 500 single-factor model. This conclusion is consistent with our finding in Table II that our put portfolios have returns of the order of 100 bps per month even though they have betas close to one and the S&P premium is only half that. In addition, the large negative alpha of -69 bps for the ITM-OTM long-short put portfolio strategy is consistent with our earlier finding of a -72 bps spread between these portfolios in the raw leverage-adjusted returns in Table II.

Next we provide a lower hurdle for the model by choosing the equity premium that best fits the universe of index options. This additional freedom has little impact on performance. There is a fundamental tension between our call portfolios which have low returns and therefore require a lower market premium, and our high put portfolio returns, which demand a high market premium. Allowing a free market premium cannot resolve this tension.

The results are robust to the replacement of the S&P 500 index return with the CRSP value-weighted market return as proxy for the market (second column of Table C.1). The overall conclusion is that the unconditional CAPM does not explain the cross-section of option returns even though it relaxes the maintained hypothesis of the BSM model that the market is complete.

We proceed to examine the factors Size, Value, and Momentum. Of these, Size is perhaps the most interesting as it leads to small pricing errors when its premium is estimated among options. However, the required premium of 327 bps is forty times higher than the sample return of the Size factor, which is implausible. With an equity-based premium, Size is unable to make a dent in the alphas of our option portfolios. We attribute these results, in part, to the negative correlation of Size with market volatility: the correlation of Size with ATM implied volatility (Volatility) is -0.17 and with realized volatility (RV) is -0.28. The negative volatility premium and positive volatility betas of the option portfolios that we report in the next section correspond to the positive Size premium and negative Size betas. Furthermore, the Size premium may be implausibly high because the size factor is a noisy proxy for volatility.

Value and Momentum are associated with small and insignificant betas which leads to alphas that remain as high as in the CAPM. Furthermore, the option-based premia of Value and Momentum are inconsistent with their equity-based premium or sample means both in economic and statistical terms. The overall conclusion is that the equity-based factors, Market (or S&P), Size, Value, and Momentum, do not explain the cross-section of option returns even though they play a major role in explaining the cross-section of equity returns. At best, the size factor partly proxies for the implied and realized market volatility, discussed in Section C.2.

C.2 Pricing with volatility-related factors

We consider six volatility-related factors defined in Appendix B. For comparison, the set includes *Jump*, *Volatility Jump, and Volatility*, which we extensively discussed in Section V. In addition to being ubiquitous amongst practitioners and researchers on options, some of these factors may proxy for a factor which is a nonlinear function of the market return. The use of ATM volatility as a factor does not introduce circular reasoning because we use volatility to explain the cross section of option returns and not just the ATM option return. We obtain similar results when we replace the ATM volatility with realized volatility. Results with the shorter CBOE-calculated time-series of the VIX and SKEW factors are similar to our results for *Volatility* and Slope, respectively, and are not reported here. We pair each factor with the S&P 500 index as the first factor. The results are reported in Table C.2.

[Table C.2 about here]

Volatility and RV obtain strong positive betas for calls as expected and *Volatility* also obtains strong negative put betas. The betas with respect to RV-IV and Slope are small and insignificant. The equity-based premium for *Volatility* is -10 bps and insignificant. The option-based premium is -126 bps and strongly significant. While *Volatility* obtains strong betas that line up well across calls and puts and across moneyness, its premium as reflected in the pricing of equities is too small to reduce the pricing errors of the option portfolios. With the exception of

Jump and *Volatility Jump*, the other factors in Table C.2 prove unsuccessful when we impose the restriction that their premium be estimated among stocks.

Of these, Slope presents the most extreme case. Whereas the point estimate of the Slope premium is 84 bps (s.e. 56 bps) when estimated from the universe of equities, the estimate is -512 bps (s.e. 303 bps) when estimated from the universe of options. The rms error drops from 53 bps to 17 bps and the p-value climbs from zero to 75%. The results for Slope illustrate the key challenge in fitting our option portfolios: both the level and the spread across moneyness in the returns of the option portfolios are out of line with the BSM model. By design, Slope does a good job in accounting for the spread in returns (notice the small alphas of the long-short option portfolio strategies,) but it turns out to do poorly on the level of returns, leaving the rms alpha relatively high. Any successful pricing model has to account for both the spread across moneyness and the level of option returns.

The conclusion is that amongst the six volatility-related factors, *Jump, Volatility, and Volatility Jump* are the only three factors that work reasonably well in explaining the cross-section of option returns, even when we impose the stricter standard of estimating the premium from the universe of equities.

C.3 Pricing with liquidity factors

We consider five factors that reflect liquidity, defined in Appendix B. For comparison, the set includes *Liquidity* that we extensively discussed in Section V. We pair each factor with the S&P 500 index as the first factor. The results are reported in Table C.3.

[Table C.3 about here]

With the exception of *Liquidity*, a common feature of these factors is that each of them explains the cross-section of option returns with very low rms error (7-13 bps) when the premium is estimated from the universe of options. However, they do not improve upon the single factor model when the premium is estimated from the universe of equities.

Bid-Ask shares some of the positive attributes of *Liquidity*. The Bid-Ask betas of the calls are statistically different from zero but the betas of the puts are not. The premium estimated from the universe of equities is positive but insignificantly different from zero. The rms error is

39 bps, compared to the rms error of 47 bps obtained from the single-factor model with the S&P 500 index as the only factor. However, the Bid-Ask premium estimated from the universe of options is almost ten times as high and not significantly different from zero.

The remaining three factors (Volume, Open Interest, and OTM Put Volume) have very different premia estimated from the universe of equities versus the universe of options. Furthermore, they do not improve upon the single factor model when the premium is estimated from the universe of equities. We conclude that these factors do not work well across the equity and option markets.

C.4 Pricing with factors based on sentiment and retail option demand

We consider four factors that reflect sentiment and noise-trader demand, defined in Appendix B. We pair each factor with the S&P 500 index as the first factor. The results are reported in Table C.4.

[Table C.4 about here]

Retail Put Demand shows limited promise in explaining the cross-section of option returns with an option-based premium. The Retail Put Demand betas of the call and put portfolios and the difference in the betas of the ITM and OTM call and put portfolios are statistically different from zero. This leads to a low rms error of 10 bps when the premium is estimated from the universe of options. However, the equity-based point estimate of the Retail Put Demand premium is small and positive, which leads to poor performance.

Of the remaining three factors, Retail Call Demand, Sentiment, and SPF Dispersion have mostly insignificant betas and insignificant premia. They fail to capture the spread in put portfolio returns, even when their premia are estimated from the universe of options. None of these factors improves upon the single factor model when the premium is estimated from the universe of equities. We conclude that these factors do not capture the variation in option portfolio returns well, particularly in a way that is consistent across the equity and option markets.

C.5 Pricing with macro-based factors

We consider six factors that either reflect macroeconomic conditions or have been suggested in the literature, defined in Appendix B. We pair each factor with the S&P 500 index as the first factor. The results are reported in Table C.5.

[Table C.5 about here]

With few exceptions, the betas and premia are not significantly different from zero. In all specifications, the pricing errors resulting from equity-based premia are large, ranging from 42 bps for GDP to 56 bps for Riskfree. These factors fail to reconcile the spread in put returns with the level of call returns. When the premia are estimated from the universe of options, the rms error is low and the p-value is high. We consider these results as spurious and dismiss these factors in view of their insignificant betas and premia.

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Table I. Pairwise correlations of our principal factors. S&P is the excess return on the S&P 500 index. *Jump* is the sum of all daily S&P 500 returns lower than -4% in a given month, zero if there are none. *Volatility Jump* is the sum of all daily increases in the ATM call portfolio implied volatility that are greater than 4%, zero otherwise. *Volatility* is the ATM call portfolio implied volatility at the end of the month minus its value at the beginning of the month. *Liquidity* is the innovation in market-wide liquidity proposed by Pastor and Stambaugh (2003). The data is from April 1986 to October 2010.

	Jump	*Volatility Jump*	*Volatility*	*Liquidity*
S&P	0.43	-0.45	-0.59	0.29
Jump		-0.72	-0.42	0.31
Volatility Jump			0.29	-0.29
Volatility				-0.31

Table II. Average percentage monthly returns of the leverage-adjusted portfolios with daily rebalancing. We omit portfolios with moneyness 0.925, 0.975, 1.025, 1.075 and maturity 60 days to conserve space. For comparison, the S&P 500 has an average return of 0.86%; its volatility is 4.57%; it has skewness of -0.82, excess kurtosis of 2.30; and Jarque-Bera p-value of 0.00. April 1986 to October 2010.

	Calls						Puts					
K/S	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo
						Average returns						
30 days	0.46	0.40	0.20	0.05	-0.01	-0.47	2.11	1.58	1.03	0.78	0.73	-1.38
(s.e.)	(0.25)	(0.25)	(0.24)	(0.24)	(0.23)	(0.17)	(0.36)	(0.33)	(0.29)	(0.27)	(0.27)	(0.19)
90 days	0.49	0.42	0.37	0.31	0.21	-0.28	1.10	1.07	0.86	0.77	0.73	-0.38
(s.e.)	(0.25)	(0.24)	(0.24)	(0.25)	(0.25)	(0.11)	(0.34)	(0.31)	(0.29)	(0.28)	(0.27)	(0.14)
90-30	0.03	0.02	0.16	0.26	0.22		-1.00	-0.51	-0.17	-0.00	0.00	
(s.e.)	(0.02)	(0.02)	(0.03)	(0.06)	(0.11)		(0.11)	(0.08)	(0.03)	(0.02)	(0.02)	
						Volatility						
30 days	4.30	4.22	4.20	4.13	4.03	2.87	6.17	5.62	5.06	4.71	4.56	3.35
90 days	4.22	4.18	4.19	4.22	4.24	1.96	5.79	5.32	5.03	4.78	4.66	2.38
90-30	0.34	0.35	0.48	1.10	1.82		1.94	1.32	0.53	0.42	0.40	
						Skewness						
30 days	-0.32	-0.23	-0.03	0.47	1.31	1.38	-1.49	-1.38	-0.98	-0.72	-0.59	1.52
90 days	-0.28	-0.16	-0.03	0.19	0.46	1.37	-1.18	-1.15	-0.99	-0.82	-0.68	1.36
90-30	2.19	0.39	-0.28	-0.66	0.26		-0.01	1.98	0.24	-0.56	-0.64	
						Excess kurtosis						
30 days	0.56	0.56	0.74	1.98	5.40	4.83	6.66	5.39	3.96	2.70	1.73	6.90
90 days	0.50	0.54	0.67	0.94	1.41	5.22	5.29	4.68	3.80	3.08	2.30	4.45
90-30	11.34	3.91	3.18	1.68	5.49		5.04	14.09	2.46	2.70	4.45	
						Jarque-Bera normality test p-value						
30 days	0.02	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90 days	0.03	0.07	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90-30	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	
						S&P 500 betas						
30 days	0.88	0.86	0.82	0.72	0.58		1.06	1.02	0.99	0.96	0.93	
90 days	0.86	0.85	0.83	0.80	0.74		1.06	1.03	1.00	0.97	0.95	

Table III. Asset pricing tests with selected factors described in Appendix C. The stock-based (option-based) results estimate factor premia from the 25 Fama-French portfolios (54 option portfolios). We report betas (factor loadings) and pricing errors (alphas) for four representative portfolios (the rest fall in between). We run two-stage OLS with 10,000 bootstrap simulations. We report bootstrapped standard errors, root-mean-squared pricing errors, and a bootstrapped p-value for the joint hypothesis that all pricing errors are zero. April 1986 to October 2010.

	Factor premia									
1st factor	S&P		S&P		S&P		S&P		S&P	
Stock-based	0.64	(0.31)	0.49	(0.30)	0.57	(0.32)	0.53	(0.28)	0.46	(0.31)
Option-based	0.42	(0.28)	0.53	(0.47)	0.42	(0.33)	0.35	(0.29)	0.58	(0.58)
Difference	0.21	(0.17)	-0.05	(0.39)	0.16	(0.25)	0.18	(0.17)	-0.11	(0.59)
2nd factor			Jump		Volatility Jump		Volatility		Liquidity	
Stock-based			1.39	(0.79)	-4.02	(1.70)	-1.05	(0.91)	5.90	(2.25)
Option-based			2.36	(1.68)	-4.78	(3.34)	-1.79	(0.48)	14.33	(11.54)
Difference			-0.98	(1.81)	0.76	(3.68)	0.73	(0.95)	-8.44	(11.67)
	Call portfolios									
	Betas (for 2nd factor)									
30 days, 95%	0.86	(0.04)	-0.19	(0.06)	0.06	(0.02)	0.14	(0.05)	-0.03	(0.03)
30 days, 105%	0.72	(0.06)	-0.29	(0.09)	0.13	(0.04)	0.32	(0.06)	-0.05	(0.04)
90 days, 95%	0.85	(0.04)	-0.20	(0.06)	0.07	(0.02)	0.15	(0.05)	-0.03	(0.03)
90 days, 105%	0.80	(0.05)	-0.27	(0.08)	0.12	(0.03)	0.28	(0.06)	-0.04	(0.03)
	Alphas (using stock-based premia)									
30 days, 95%	-0.48	(0.17)	-0.11	(0.23)	-0.20	(0.24)	-0.28	(0.18)	-0.19	(0.23)
30 days, 105%	-0.75	(0.21)	-0.29	(0.31)	-0.24	(0.34)	-0.44	(0.31)	-0.35	(0.29)
90 days, 95%	-0.45	(0.17)	-0.08	(0.23)	-0.16	(0.24)	-0.26	(0.18)	-0.13	(0.23)
90 days, 105%	-0.54	(0.20)	-0.09	(0.29)	-0.06	(0.32)	-0.25	(0.28)	-0.16	(0.27)
	Alphas (using option-based premia)									
30 days, 95%	-0.30	(0.07)	0.03	(0.07)	-0.02	(0.10)	0.00	(0.03)	-0.07	(0.13)
30 days, 105%	-0.60	(0.14)	-0.05	(0.10)	-0.01	(0.10)	-0.04	(0.06)	-0.03	(0.22)
90 days, 95%	-0.27	(0.07)	0.07	(0.06)	0.03	(0.07)	0.02	(0.03)	0.03	(0.11)
90 days, 105%	-0.37	(0.12)	0.13	(0.07)	0.17	(0.09)	0.13	(0.04)	0.10	(0.17)

Put portfolios										
	Betas (for 2nd factor)									
30 days, 95%	1.02	(0.06)	0.22	(0.17)	-0.13	(0.06)	-0.41	(0.12)	0.04	(0.06)
30 days, 105%	0.96	(0.04)	0.00	(0.11)	-0.02	(0.04)	-0.10	(0.09)	-0.02	(0.04)
90 days, 95%	1.03	(0.05)	0.15	(0.14)	-0.09	(0.05)	-0.32	(0.10)	0.02	(0.05)
90 days, 105%	0.97	(0.04)	0.02	(0.12)	-0.04	(0.03)	-0.13	(0.09)	-0.01	(0.04)
	Alphas (using stock-based premia)									
30 days, 95%	0.59	(0.22)	0.48	(0.35)	0.19	(0.35)	0.40	(0.44)	0.53	(0.32)
30 days, 105%	-0.17	(0.16)	-0.03	(0.21)	-0.20	(0.20)	-0.14	(0.18)	0.09	(0.24)
90 days, 95%	0.08	(0.19)	0.05	(0.27)	-0.18	(0.27)	-0.05	(0.34)	0.11	(0.26)
90 days, 105%	-0.18	(0.17)	-0.06	(0.21)	-0.27	(0.21)	-0.17	(0.20)	0.06	(0.24)
	Alphas (using option-based premia)									
30 days, 95%	0.81	(0.15)	0.23	(0.13)	0.24	(0.11)	0.24	(0.06)	0.05	(0.29)
30 days, 105%	0.04	(0.04)	-0.07	(0.12)	-0.07	(0.11)	-0.05	(0.04)	0.12	(0.18)
90 days, 95%	0.30	(0.10)	-0.14	(0.08)	-0.09	(0.10)	-0.14	(0.04)	-0.21	(0.19)
90 days, 105%	0.03	(0.05)	-0.12	(0.10)	-0.15	(0.07)	-0.10	(0.04)	0.05	(0.15)
	Stock portfolio test statistics (using stock-based premia)									
R.m.s. (p)	0.26	(0.00)	0.24	(0.00)	0.23	(0.00)	0.26	(0.00)	0.21	(0.01)
	Option portfolio test statistics (using stock-based premia)									
R.m.s. (p)	0.48	(0.03)	0.23	(0.07)	0.21	(0.40)	0.29	(0.01)	0.28	(0.17)
	Option portfolio test statistics (using option-based premia)									
R.m.s. (p)	0.44	(0.02)	0.13	(0.21)	0.14	(0.52)	0.13	(0.06)	0.11	(0.63)

Table IV: Factor premia and pricing errors for selected factors by option type, maturity (Panel A) and moneyness (Panel B). The factors are described in Appendix C. All premia are estimated among the 54 option portfolios using two-stage OLS, allowing for different premia across types, maturities, or moneyness. We report bootstrapped standard errors and a bootstrapped p-value for the joint hypothesis that all alphas are zero, both of which are based on 10,000 simulations. April 1986 through October 2010.

Panel A: Maturity

Factor premia (standard errors)

	S&P			S&P			S&P			S&P			S&P		
	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff
30-day	0.91	-0.12	1.04	0.46	0.49	-0.03	0.27	0.28	-0.01	0.17	0.29	-0.12	0.69	0.27	0.42
	(0.31)	(0.30)	(0.21)	(0.70)	(0.35)	(0.55)	(0.49)	(0.28)	(0.43)	(0.34)	(0.28)	(0.19)	(1.02)	(0.44)	(0.90)
90-day	0.57	0.03	0.54	0.42	0.48	-0.07	0.28	0.31	-0.02	0.31	0.29	0.02	0.53	0.35	0.18
	(0.30)	(0.29)	(0.18)	(0.41)	(0.41)	(0.25)	(0.34)	(0.28)	(0.18)	(0.28)	(0.28)	(0.08)	(0.47)	(0.42)	(0.39)
Diff	0.34	-0.16	0.88	0.04	0.01	-0.03	-0.02	-0.02	-0.04	-0.14	0.00	-0.12	0.16	-0.08	0.34
	(0.05)	(0.04)	(0.20)	(0.38)	(0.22)	(0.49)	(0.26)	(0.09)	(0.39)	(0.15)	(0.07)	(0.18)	(0.74)	(0.27)	(0.92)
				Jump			Volatility Jump			Volatility			Liquidity		
				Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff
30-day				4.05	2.24	1.80	-7.91	-3.73	-4.18	-2.84	-1.61	-1.23	15.70	8.68	7.03
				(2.09)	(1.52)	(1.50)	(4.12)	(2.61)	(2.74)	(0.74)	(0.67)	(0.59)	(13.88)	(9.87)	(14.21)
90-day				1.89	1.78	0.11	-4.44	-2.68	-1.75	-1.32	-1.16	-0.16	8.08	7.78	0.30
				(1.19)	(1.41)	(1.26)	(2.05)	(1.81)	(2.04)	(0.42)	(0.59)	(0.45)	(5.88)	(7.65)	(7.70)
Diff				2.16	0.46	2.26	-3.47	-1.05	-5.23	-1.52	-0.45	-1.68	7.62	0.89	7.92
				(1.46)	(1.14)	(1.58)	(3.80)	(1.56)	(3.19)	(0.53)	(0.39)	(0.56)	(12.23)	(8.73)	(13.69)

Root-mean-squared pricing errors (p-values)

	Puts	Calls	Puts	Calls	Puts	Calls	Puts	Calls	Puts	Calls
30-day	0.45	0.19	0.08	0.05	0.08	0.04	0.08	0.04	0.09	0.06
	(0.00)	(0.00)	(0.26)	(0.47)	(0.56)	(0.50)	(0.07)	(0.28)	(0.64)	(0.57)
90-day	0.13	0.09	0.03	0.01	0.05	0.01	0.03	0.01	0.02	0.02
	(0.03)	(0.02)	(0.50)	(0.58)	(0.59)	(0.54)	(0.39)	(0.65)	(0.86)	(0.49)

Panel B: Moneyness

Factor premia (standard errors)

	S&P			S&P			S&P			S&P			S&P		
	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff
K/S≤0.95	1.07	0.12	0.95	-0.36	0.38	-0.75	-0.35	0.24	-0.58	-0.77	0.33	-1.10	-0.03	0.23	-0.25
	(0.34)	(0.28)	(0.22)	(0.87)	(0.30)	(0.75)	(0.76)	(0.28)	(0.73)	(0.54)	(0.28)	(0.43)	(1.04)	(0.30)	(0.96)
K/S>1.05	0.43	-0.27	0.70	0.43	0.69	-0.26	0.42	0.51	-0.09	0.36	0.56	-0.20	0.46	0.24	0.22
	(0.28)	(0.33)	(0.21)	(0.34)	(0.43)	(0.43)	(0.28)	(0.37)	(0.31)	(0.28)	(0.37)	(0.26)	(0.30)	(0.39)	(0.31)
Diff	0.64	0.39	1.34	-0.80	-0.31	-1.05	-0.77	-0.28	-0.86	-1.13	-0.23	-1.33	-0.48	-0.01	-0.27
	(0.14)	(0.13)	(0.32)	(0.70)	(0.37)	(0.96)	(0.67)	(0.28)	(0.84)	(0.46)	(0.25)	(0.52)	(0.97)	(0.25)	(1.06)

	Jump			Volatility Jump			Volatility			Liquidity		
	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff
K/S≤0.95	6.67	1.38	5.29	-11.38	-2.05	-9.33	-4.01	-1.57	-2.44	30.88	4.12	26.76
	(2.74)	(0.63)	(2.52)	(4.34)	(0.94)	(4.25)	(1.19)	(0.53)	(1.04)	(14.96)	(2.44)	(14.88)
K/S>1.05	0.77	2.64	-1.87	-0.69	-4.64	3.95	-0.94	-2.14	1.20	1.89	7.77	-5.88
	(1.28)	(1.69)	(1.87)	(1.04)	(2.82)	(2.93)	(0.50)	(0.94)	(0.90)	(3.08)	(5.09)	(5.62)
Diff	5.91	-1.26	4.04	-10.69	2.58	-6.74	-3.07	0.57	-1.86	28.98	-3.65	23.10
	(2.55)	(1.55)	(2.43)	(4.34)	(2.67)	(4.10)	(1.09)	(0.84)	(1.20)	(14.77)	(5.26)	(14.83)

Root-mean-squared pricing errors (p-values)

	Puts	Calls	Puts	Calls	Puts	Calls	Puts	Calls	Puts	Calls
K/S≤0.95	0.33	0.03	0.16	0.02	0.11	0.02	0.19	0.01	0.07	0.02
	(0.00)	(0.01)	(0.24)	(0.19)	(0.29)	(0.09)	(0.03)	(0.59)	(0.84)	(0.18)
K/S>1.05	0.03	0.12	0.03	0.06	0.03	0.07	0.02	0.05	0.03	0.08
	(0.23)	(0.00)	(0.29)	(0.21)	(0.23)	(0.27)	(0.29)	(0.28)	(0.23)	(0.20)

Table V: Factor premia and pricing errors with three factors for selected factors by option type, maturity (Panel A) and moneyness (Panel B). The factors are described in Appendix C. All premia are estimated among the 54 option portfolios using two-stage OLS, allowing for different premia across types, maturities, or moneyness. Bootstrapped standard errors and p-values. April 1986 through October 2010.

Panel A: Maturity

Factor premia (standard errors)

	S&P			S&P			S&P			S&P			S&P		
	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff
30-day	0.91	-0.12	1.04	0.55	1.14	-0.59	0.42	0.28	0.13	0.16	-0.01	0.17	0.25	0.30	-0.05
	(0.31)	(0.30)	(0.22)	(0.65)	(0.43)	(0.62)	(0.50)	(0.33)	(0.50)	(0.53)	(0.34)	(0.52)	(0.39)	(0.33)	(0.33)
90-day	0.57	0.03	0.54	0.49	0.57	-0.08	0.50	0.30	0.20	0.46	0.42	0.03	0.45	0.27	0.18
	(0.30)	(0.29)	(0.18)	(0.44)	(0.43)	(0.41)	(0.40)	(0.29)	(0.30)	(0.40)	(0.33)	(0.32)	(0.33)	(0.29)	(0.22)
Diff	0.34	-0.16	0.88	0.06	0.57	-0.02	-0.09	-0.01	0.12	-0.29	-0.43	-0.26	-0.20	0.03	-0.02
	(0.05)	(0.04)	(0.21)	(0.38)	(0.40)	(0.56)	(0.32)	(0.21)	(0.41)	(0.37)	(0.30)	(0.45)	(0.27)	(0.19)	(0.28)
				Jump			Volatility Jump			Volatility Jump			Volatility		
				Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff
30-day				3.20	5.77	-2.57	-6.43	-6.11	-0.32	-9.08	-4.31	-4.77	-2.72	-2.34	-0.38
				(2.40)	(1.91)	(2.28)	(4.03)	(2.78)	(3.80)	(3.68)	(2.51)	(3.43)	(0.84)	(0.90)	(0.96)
90-day				1.37	2.34	-0.97	-2.32	-2.79	0.47	-2.26	-2.64	0.38	-1.22	-1.19	-0.03
				(1.51)	(1.51)	(1.70)	(2.10)	(1.83)	(2.25)	(1.67)	(1.75)	(1.79)	(0.49)	(0.62)	(0.55)
Diff				1.83	3.44	0.87	-4.11	-3.31	-3.63	-6.82	-1.67	-6.44	-1.49	-1.15	-1.53
				(1.77)	(1.85)	(2.21)	(3.67)	(2.15)	(3.53)	(3.43)	(1.93)	(3.34)	(0.66)	(0.71)	(0.73)
				Liquidity			Liquidity			Jump			Liquidity		
				Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff
30-day				7.56	-22.25	29.82	6.57	-10.76	17.32	1.60	-0.29	1.89	3.16	-10.94	14.10
				(7.80)	(7.88)	(10.15)	(5.26)	(5.60)	(7.56)	(2.01)	(1.37)	(2.07)	(4.35)	(4.66)	(6.34)
90-day				5.61	-4.28	9.89	7.37	-0.55	7.92	1.98	1.45	0.52	5.48	-1.18	6.67
				(4.28)	(4.75)	(5.93)	(4.24)	(2.66)	(4.52)	(1.25)	(0.95)	(1.38)	(2.19)	(2.46)	(3.15)
Diff				1.96	-17.97	11.85	-0.81	-10.21	7.12	-0.38	-1.74	0.15	-2.33	-9.76	4.34
				(7.28)	(8.15)	(8.32)	(5.84)	(5.86)	(5.43)	(1.87)	(1.43)	(1.89)	(4.55)	(5.08)	(4.92)

Root-mean-squared pricing errors (p-values)

	Puts	Calls	Puts	Calls	Puts	Calls	Puts	Calls	Puts	Calls
30-day	0.45	0.19	0.08	0.03	0.08	0.03	0.08	0.03	0.08	0.03
	(0.00)	(0.00)	(0.24)	(0.73)	(0.17)	(0.79)	(0.09)	(0.63)	(0.03)	(0.44)
90-day	0.13	0.09	0.02	0.01	0.02	0.01	0.03	0.01	0.01	0.01
	(0.03)	(0.02)	(0.72)	(0.69)	(0.81)	(0.52)	(0.32)	(0.47)	(0.70)	(0.67)

Panel B: Moneyness

Factor premia (standard errors)

	S&P			S&P			S&P			S&P			S&P		
	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff
K/S≤0.95	1.07	0.12	0.95	-0.15	0.68	-0.82	-0.18	0.21	-0.39	-0.19	0.63	-0.81	-0.26	0.36	-0.62
	(0.34)	(0.28)	(0.22)	(1.11)	(0.37)	(1.09)	(0.86)	(0.31)	(0.79)	(0.84)	(0.35)	(0.82)	(0.96)	(0.31)	(0.96)
K/S>1.05	0.43	-0.27	0.70	0.33	1.15	-0.82	0.44	0.53	-0.08	0.48	0.68	-0.20	0.24	0.58	-0.34
	(0.28)	(0.33)	(0.21)	(0.37)	(0.58)	(0.62)	(0.31)	(0.37)	(0.33)	(0.37)	(0.46)	(0.48)	(0.31)	(0.40)	(0.33)
Diff	0.64	0.39	1.34	-0.48	-0.47	-1.30	-0.62	-0.32	-0.71	-0.67	-0.05	-0.87	-0.51	-0.22	-0.84
	(0.14)	(0.14)	(0.32)	(1.07)	(0.57)	(1.24)	(0.79)	(0.32)	(0.90)	(0.80)	(0.43)	(0.92)	(0.95)	(0.32)	(0.99)
				Jump			Volatility Jump			Volatility Jump			Volatility		
				Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff
K/S≤0.95				4.26	3.01	1.25	-8.28	0.07	-8.35	-12.83	-0.79	-12.04	-3.59	-2.04	-1.55
				(4.09)	(1.13)	(3.96)	(5.59)	(1.48)	(5.57)	(5.02)	(1.33)	(5.34)	(1.85)	(0.78)	(1.84)
K/S>1.05				1.07	4.56	-3.50	-0.72	-4.82	4.09	-1.21	-3.95	2.74	-0.82	-2.28	1.46
				(1.59)	(2.45)	(2.69)	(1.14)	(2.80)	(2.93)	(1.94)	(2.49)	(2.86)	(0.58)	(1.04)	(1.03)
Diff				3.19	-1.55	-0.30	-7.56	4.89	-3.46	-11.62	3.16	-8.88	-2.77	0.24	-1.31
				(4.13)	(2.41)	(4.18)	(5.54)	(3.04)	(5.56)	(5.20)	(2.69)	(4.97)	(1.83)	(1.08)	(1.93)

	Liquidity			Liquidity			Jump			Liquidity		
	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff
K/S≤0.95	26.67	-7.99	34.66	22.36	7.18	15.18	-0.38	2.57	-2.95	26.52	-2.97	29.50
	(18.61)	(4.29)	(18.85)	(11.43)	(3.68)	(11.67)	(2.27)	(0.94)	(2.46)	(14.68)	(3.73)	(15.10)
K/S>1.05	-6.15	-8.89	2.74	1.24	0.30	0.94	1.43	2.54	-1.11	-4.40	-1.14	-3.26
	(4.05)	(6.31)	(7.16)	(3.08)	(4.44)	(5.29)	(1.68)	(2.01)	(2.44)	(3.10)	(3.38)	(4.47)
Diff	32.81	0.89	35.55	21.11	6.87	22.05	-1.82	0.03	-2.92	30.92	-1.84	27.66
	(18.81)	(6.98)	(19.21)	(11.72)	(5.47)	(11.77)	(2.76)	(2.03)	(2.67)	(14.89)	(4.93)	(15.13)

Root-mean-squared pricing errors (p-values)

	Puts	Calls	Puts	Calls	Puts	Calls	Puts	Calls	Puts	Calls
K/S≤0.95	0.33	0.03	0.06	0.02	0.05	0.02	0.09	0.02	0.06	0.01
	(0.00)	(0.01)	(0.53)	(0.47)	(0.49)	(0.22)	(0.63)	(0.63)	(0.64)	(0.78)
K/S>1.05	0.03	0.12	0.02	0.05	0.03	0.07	0.02	0.06	0.02	0.05
	(0.22)	(0.00)	(0.40)	(0.51)	(0.19)	(0.25)	(0.20)	(0.19)	(0.45)	(0.26)

Table A.1: Number of observations that are removed by each of our filters for the Berkeley (April 1986 to December 1995) and OptionMetrics (January 1996 to October 2010) subperiods.

		Berkeley		OptionMetrics		Total	
		Deleted	Remaining	Deleted	Remaining	Deleted	Remaining
Starting	Calls		143,261		1,952,806		2,096,067
	Puts		126,199		1,955,370		2,081,569
	All		269,461		3,908,176		4,177,637
Level 1 filters	Identical	0		1,132,475		1,132,475	
	Identical except price	0		111		111	
	Bid = 0	0		212,493		212,493	
	All		269,461		2,563,097		2,832,558
Level 2 filters	Days to expiration < 7 or > 180	63,939		1,074,744		1,138,683	
	IV < 5% or > 100%	184		9,308		9,492	
	K/S < 0.8 or > 1.2	7,905		418,715		426,620	
	Implied interest rate < 0	1,880		121,550		123,430	
	Unable to compute IV	890		17,639		18,529	
	All		194,663		921,140		1,115,803
Implied interest rate	Directly assigned		189,072		916,646		1,105,718
	Interpolated		5,591		4,492		10,083
	All		194,663		921,140		1,115,803
Level 3 filters	IV filter	11,282		55,421		66,703	
	Put-call parity filter	10,256		41,320		51,576	
	All		173,125		824,397		997,522
Final	Calls		90,968		405,958		496,926
	Puts		82,157		418,439		500,596
	All		173,125		824,397		997,522

Table A.2. Summary statistics on filters for the Berkeley (April 1986 to December 1995) and OptionMetrics (January 1996 to October 2010) databases. Filters are applied on the buy side but relaxed on the sell side. Found observations are those options with records on the day following the purchase day. If the same option is bought and sold two days in a row, it will appear as being found twice. Missing observations are those options that disappear on the day following the day on which they were purchased. If an option remains missing for two days, it is counted as missing twice. Expired observations are options that expire while being held as missing in the portfolio. Expired options are assigned their exercise value. Missing options are held until found, or their implied volatility is interpolated at the end of the month using a fit quadratic in moneyness and linear in maturity and the interaction between moneyness and maturity.

	Calls				Puts			
Observations	Berkeley		OptionMetrics		Berkeley		OptionMetrics	
				All trading days				
Found	67,468	81%	274,223	100%	62,800	76%	279,484	100%
Missing	15,656	19%	331	0%	20,231	24%	330	0%
Expired	216	0%	8	0%	325	0%	18	0%
				Last trading day of the month				
Found	3,649	81%	13,285	100%	3,437	76%	13,403	100%
Interpolated	873	19%	46	0%	1,091	24%	39	0%

Table A.3. Average percentage monthly returns of the leverage-adjusted portfolios *without* rebalancing. We omit portfolios with moneyness 0.925, 0.975, 1.025, 1.075 and maturity 60 days to conserve space. For comparison, the S&P 500 has an average return of 0.86%; its volatility is 4.57%; it has skewness of -0.82, excess kurtosis of 2.30; and Jarque-Bera p-value of 0.00. April 1986 to October 2010.

	Calls						Puts					
K/S	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo
Average returns												
45 days	0.34	0.18	-0.01	-0.07	0.01	-0.32	2.25	1.88	1.30	0.90	0.77	-1.48
(s.e.)	(0.26)	(0.26)	(0.26)	(0.27)	(0.31)	(0.25)	(0.34)	(0.30)	(0.30)	(0.28)	(0.27)	(0.23)
90 days	0.36	0.25	0.13	0.07	0.13	-0.23	1.78	1.49	1.16	0.89	0.77	-1.01
(s.e.)	(0.25)	(0.25)	(0.25)	(0.26)	(0.30)	(0.19)	(0.32)	(0.30)	(0.29)	(0.28)	(0.27)	(0.16)
90-45	0.02	0.07	0.14	0.14	0.12		-0.47	-0.39	-0.14	-0.01	0.00	
(s.e.)	(0.02)	(0.02)	(0.03)	(0.06)	(0.09)		(0.10)	(0.05)	(0.03)	(0.02)	(0.02)	
Volatility												
45 days	4.48	4.46	4.39	4.57	5.31	4.24	5.90	5.21	5.09	4.87	4.68	4.02
90 days	4.37	4.34	4.32	4.54	5.13	3.34	5.58	5.16	5.00	4.81	4.67	2.76
90-30	0.27	0.30	0.47	0.97	1.62		1.65	0.94	0.47	0.32	0.26	
Skewness												
45 days	-0.13	0.14	0.81	2.45	4.79	3.14	-5.94	-3.07	-1.71	-0.94	-0.58	6.52
90 days	-0.10	0.14	0.59	1.82	3.61	3.72	-3.36	-2.23	-1.52	-0.99	-0.69	4.76
90-45	1.33	1.28	-0.36	-2.43	-5.04		5.67	0.66	-0.32	-0.71	-0.93	
Excess kurtosis												
45 days	0.25	0.12	1.19	9.11	29.95	18.53	53.09	14.75	5.45	2.64	1.78	74.36
90 days	0.26	0.23	0.83	6.40	20.23	25.43	19.52	9.15	4.97	2.82	1.92	42.58
90-45	8.47	3.88	2.68	20.16	62.79		71.54	5.60	1.67	3.84	5.40	
Jarque-Bera normality test p-value												
45 days	0.39	0.50	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	
90 days	0.47	0.40	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	
S&P betas												
45 days	0.91	0.89	0.82	0.72	0.66		0.94	0.94	1.00	0.99	0.95	
90 days	0.89	0.87	0.83	0.79	0.75		1.00	0.98	0.99	0.97	0.95	

Table A.4. Average percentage monthly returns of the leverage-*unadjusted* portfolios with daily rebalancing. We omit portfolios with moneyness 0.925, 0.975, 1.025, 1.075 and maturity 60 days to conserve space. For comparison, the S&P 500 has an average return of 0.86%; its volatility is 4.57%; it has skewness of -0.82, excess kurtosis of 2.30; and Jarque-Bera p-value of 0.00. April 1986 to October 2010.

	Calls						Puts					
K/S	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo
						Average returns						
30 days	0.22	-1.11	-1.36	13.67	16.11	15.90	-49.83	-39.55	-28.59	-12.43	-6.69	43.14
(s.e.)	(2.17)	(3.50)	(9.07)	(28.06)	(28.20)	(27.21)	(7.70)	(10.05)	(5.99)	(3.66)	(2.61)	(6.45)
90 days	0.63	0.30	0.98	7.71	6.75	6.12	-13.26	-16.21	-11.22	-8.17	-5.39	7.87
(s.e.)	(1.83)	(2.58)	(4.32)	(8.26)	(10.01)	(8.81)	(7.06)	(4.64)	(3.82)	(2.86)	(2.28)	(5.60)
90-30	0.41	1.42	2.34	-5.96	-9.37		36.57	23.33	17.37	4.26	1.30	
(s.e.)	(0.47)	(1.09)	(5.44)	(23.25)	(22.73)		(4.12)	(6.43)	(2.69)	(1.06)	(0.52)	
						Volatility						
30 days	37.31	60.08	155.78	481.98	484.30	467.30	132.30	172.57	102.83	62.94	44.87	110.80
90 days	31.37	44.30	74.18	141.91	172.00	151.40	121.23	79.72	65.66	49.13	39.17	96.14
90-30	8.12	18.68	93.40	399.38	390.45		70.68	110.38	46.27	18.28	8.90	
						Skewness						
30 days	0.64	1.85	5.42	10.29	9.15	9.44	7.11	9.62	6.13	2.30	1.49	-7.87
90 days	0.50	1.55	3.55	5.15	4.51	4.98	8.80	5.32	3.59	2.03	1.52	-11.28
90-30	-1.58	-2.56	-6.60	-12.39	-11.71		-8.72	-9.95	-8.16	-2.72	-0.63	
						Excess kurtosis						
30 days	1.21	6.97	37.68	119.17	98.81	104.71	61.08	113.39	60.44	9.37	4.15	73.46
90 days	0.85	6.42	23.50	38.24	25.81	29.99	108.11	47.40	23.30	7.01	4.07	157.05
90-30	6.09	10.46	51.00	168.13	159.66		122.47	113.00	94.60	13.07	2.62	
						Jarque-Bera normality test p-value						
30 days	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	
90 days	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	
						S&P betas						
30 days	7.24	10.55	18.81	33.91	36.33		-17.21	-21.20	-16.97	-12.12	-8.80	
90 days	6.20	8.19	11.79	17.90	20.20		-17.76	-13.70	-12.12	-9.57	-7.74	

Table A.5: Average percentage monthly returns of selected leverage-adjusted portfolios with daily rebalancing, Berkeley subsample. For comparison, the S&P 500 has average return 0.86%; volatility 4.57%; skewness -0.82, excess kurtosis 2.30; and Jarque-Bera p-value 0.00. April 1986 to December 1995.

	Calls						Puts					
K/S	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo
						Average returns						
30 days	0.99	0.90	0.59	0.32	0.11	-0.88	2.95	2.46	1.76	1.42	1.38	-1.57
(s.e.)	(0.37)	(0.36)	(0.37)	(0.34)	(0.34)	(0.23)	(0.45)	(0.40)	(0.37)	(0.37)	(0.37)	(0.29)
90 days	1.05	0.92	0.80	0.69	0.46	-0.59	1.58	1.78	1.55	1.42	1.36	-0.22
(s.e.)	(0.35)	(0.35)	(0.36)	(0.37)	(0.37)	(0.17)	(0.46)	(0.41)	(0.38)	(0.37)	(0.37)	(0.24)
90-30	0.06	0.02	0.21	0.36	0.35		-1.37	-0.68	-0.21	0.00	-0.01	
(s.e.)	(0.04)	(0.04)	(0.04)	(0.11)	(0.18)		(0.21)	(0.13)	(0.05)	(0.04)	(0.04)	
						Volatility						
30 days	3.98	3.89	3.96	3.71	3.66	2.50	4.83	4.31	3.99	3.98	4.00	3.09
90 days	3.82	3.81	3.90	3.97	4.01	1.84	5.03	4.42	4.13	3.98	4.00	2.57
90-30	0.45	0.41	0.47	1.14	1.96		2.28	1.37	0.56	0.49	0.49	
						Skewness						
30 days	-0.24	-0.15	0.14	0.97	1.84	0.70	-2.37	-2.05	-1.07	-0.58	-0.49	0.81
90 days	-0.22	-0.04	0.16	0.50	0.75	1.06	-1.59	-1.39	-1.01	-0.71	-0.58	1.49
90-30	2.11	0.98	0.94	-0.50	1.33		-0.67	0.41	0.08	-0.40	-0.11	
						Excess kurtosis						
30 days	0.87	0.85	1.00	2.69	5.16	1.56	8.12	6.64	2.90	1.46	1.03	1.51
90 days	0.81	0.82	0.97	1.29	1.42	4.74	4.74	3.90	2.73	1.69	1.30	3.38
90-30	7.69	2.75	1.45	0.64	8.55		2.31	4.45	2.04	2.58	1.82	
						Jarque-Bera normality test p-value						
30 days	0.06	0.09	0.05	0.00	0.00		0.00	0.00	0.00	0.00	0.02	
90 days	0.09	0.13	0.06	0.01	0.00		0.00	0.00	0.00	0.00	0.01	
						S&P betas						
30 days	0.86	0.84	0.84	0.71	0.59		0.86	0.81	0.85	0.86	0.86	-0.00
90 days	0.83	0.83	0.83	0.81	0.76		0.93	0.90	0.88	0.86	0.86	-0.07

Table A.6: Average percentage monthly returns of selected leverage-adjusted portfolios with daily rebalancing, OptionMetrics sample. For comparison, the S&P 500 has average return 0.86%; volatility 4.57%; skewness -0.82, excess kurtosis 2.30; and Jarque-Bera p-value 0.00. January 1996 to October 2010.

	Calls						Puts					
K/S	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo
						Average returns						
30 days	0.11	0.08	-0.06	-0.14	-0.08	-0.19	1.56	1.00	0.55	0.36	0.30	-1.26
(s.e.)	(0.34)	(0.33)	(0.32)	(0.33)	(0.32)	(0.23)	(0.51)	(0.47)	(0.42)	(0.38)	(0.36)	(0.26)
90 days	0.12	0.10	0.08	0.06	0.05	-0.08	0.79	0.60	0.41	0.35	0.31	-0.48
(s.e.)	(0.33)	(0.33)	(0.33)	(0.33)	(0.33)	(0.15)	(0.47)	(0.44)	(0.41)	(0.39)	(0.38)	(0.17)
90-30	0.02	0.02	0.13	0.20	0.13		-0.77	-0.40	-0.14	-0.01	0.01	
(s.e.)	(0.02)	(0.02)	(0.04)	(0.08)	(0.13)		(0.12)	(0.10)	(0.04)	(0.03)	(0.02)	
						Volatility						
30 days	4.47	4.40	4.33	4.38	4.26	3.07	6.86	6.28	5.61	5.10	4.86	3.51
90 days	4.43	4.38	4.36	4.37	4.39	2.00	6.23	5.81	5.50	5.21	5.01	2.24
90-30	0.24	0.30	0.49	1.07	1.72		1.65	1.27	0.52	0.36	0.33	
						Skewness						
30 days	-0.32	-0.21	-0.09	0.30	1.10	1.54	-1.14	-1.07	-0.81	-0.66	-0.54	1.80
90 days	-0.24	-0.16	-0.07	0.07	0.34	1.53	-0.97	-0.96	-0.86	-0.74	-0.63	1.18
90-30	0.67	-0.62	-0.99	-0.81	-0.81		1.54	3.37	0.39	-0.80	-1.55	
						Excess kurtosis						
30 days	0.34	0.36	0.54	1.55	5.25	5.17	5.54	4.32	3.44	2.62	1.71	8.68
90 days	0.28	0.33	0.45	0.68	1.33	5.34	5.07	4.32	3.48	2.92	2.25	5.21
90-30	2.21	4.53	3.74	2.51	1.36		7.70	22.10	2.76	1.57	8.74	
						Jarque-Bera normality test p-value						
30 days	0.11	0.26	0.24	0.00	0.00		0.00	0.00	0.00	0.00	0.00	
90 days	0.25	0.40	0.38	0.12	0.00		0.00	0.00	0.00	0.00	0.00	
						S&P betas						
30 days	0.89	0.86	0.81	0.73	0.58		1.16	1.13	1.07	1.00	0.97	
90 days	0.88	0.86	0.83	0.79	0.73		1.13	1.09	1.06	1.02	1.00	

Table A.7: Average percentage monthly returns of selected leverage-adjusted portfolios with daily rebalancing, no filters. For comparison, the S&P 500 has average return 0.86%; volatility 4.57%; skewness -0.82, excess kurtosis 2.30; and Jarque-Bera p-value 0.00. April 1986 to Oct. 2010.

	Calls						Puts					
K/S	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo
						Average returns						
30 days	0.42	0.34	0.25	0.12	0.67	0.25	2.25	-0.43	0.92	0.73	0.73	-1.53
(s.e.)	(0.25)	(0.25)	(0.25)	(0.25)	(0.23)	(0.20)	(0.45)	(2.11)	(0.32)	(0.29)	(0.28)	(0.28)
90 days	0.45	0.38	0.31	0.26	0.13	-0.32	0.90	0.96	0.78	0.71	0.68	-0.22
(s.e.)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.11)	(0.43)	(0.35)	(0.32)	(0.30)	(0.28)	(0.23)
90-30	0.03	0.05	0.06	0.14	-0.54		-1.35	1.39	-0.14	-0.02	-0.04	
(s.e.)	(0.02)	(0.02)	(0.03)	(0.10)	(0.14)		(0.13)	(2.08)	(0.04)	(0.03)	(0.03)	
						Volatility						
30 days	4.35	4.27	4.23	4.34	3.87	3.40	7.69	36.30	5.42	4.96	4.80	4.78
90 days	4.26	4.22	4.25	4.28	4.22	1.89	7.45	6.09	5.46	5.09	4.89	3.95
90-30	0.33	0.35	0.56	1.73	2.37		2.22	35.72	0.67	0.49	0.49	
						Skewness						
30 days	-0.39	-0.30	0.02	1.60	1.06	1.09	-4.96	-16.26	-1.75	-1.29	-1.03	5.64
90 days	-0.36	-0.22	-0.06	0.18	0.43	1.03	-5.04	-3.13	-2.18	-1.63	-1.32	7.95
90-30	0.57	1.03	-0.73	-4.46	-0.82		-1.42	17.02	-1.43	-2.52	-0.92	
						Excess kurtosis						
30 days	0.80	0.67	0.98	9.86	3.29	2.56	46.64	270.97	9.29	6.25	4.44	57.14
90 days	0.77	0.66	0.77	0.96	1.54	2.96	49.62	24.24	13.89	8.99	6.71	90.75
90-30	3.40	4.66	2.51	45.55	1.97		17.32	288.41	16.51	21.41	16.00	
						Jarque-Bera normality test p-value						
30 days	0.00	0.01	0.01	0.00	0.00		0.00	0.00	0.00	0.00	0.00	
90 days	0.01	0.03	0.03	0.01	0.00		0.00	0.00	0.00	0.00	0.00	
						S&P betas						
30 days	0.90	0.88	0.83	0.71	0.50		1.24	1.49	1.08	1.02	0.99	
90 days	0.88	0.86	0.85	0.81	0.75		1.27	1.16	1.08	1.03	1.00	

Table A.8: Average percentage monthly returns of selected leverage-adjusted portfolios with daily rebalancing, excluding crises. For comparison, the S&P 500 has average return 0.86%; volatility 4.57%; skewness -0.82, excess kurtosis 2.30; and Jarque-Bera p-value 0.00. July 1988 to June 2007.

	Calls						Puts					
K/S	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo
							Average returns					
30 days	0.59	0.53	0.35	0.21	0.15	-0.43	2.40	1.78	1.12	0.87	0.83	-1.57
(s.e.)	(0.25)	(0.25)	(0.26)	(0.26)	(0.26)	(0.17)	(0.32)	(0.30)	(0.27)	(0.26)	(0.26)	(0.19)
90 days	0.59	0.53	0.49	0.45	0.40	-0.19	1.28	1.22	0.95	0.86	0.82	-0.46
(s.e.)	(0.25)	(0.25)	(0.25)	(0.26)	(0.26)	(0.12)	(0.31)	(0.29)	(0.27)	(0.26)	(0.26)	(0.14)
90-30	0.01	0.00	0.14	0.23	0.25		-1.12	-0.57	-0.17	-0.01	-0.01	
(s.e.)	(0.02)	(0.02)	(0.03)	(0.07)	(0.12)		(0.12)	(0.08)	(0.03)	(0.03)	(0.02)	
							Volatility					
30 days	3.85	3.83	3.88	3.88	3.86	2.54	4.82	4.51	4.14	3.98	3.96	2.89
90 days	3.79	3.78	3.82	3.91	3.98	1.85	4.71	4.32	4.14	4.00	3.95	2.18
90-30	0.24	0.30	0.41	1.06	1.77		1.85	1.22	0.51	0.39	0.34	
							Skewness					
30 days	-0.23	-0.14	0.03	0.67	1.62	1.47	-1.34	-1.12	-0.66	-0.42	-0.33	1.31
90 days	-0.19	-0.10	0.03	0.27	0.60	1.53	-0.86	-0.82	-0.74	-0.56	-0.40	1.50
90-30	0.43	0.08	-0.14	-0.56	0.73		-0.57	2.21	0.29	-0.43	-0.56	
							Excess kurtosis					
30 days	0.48	0.37	0.51	2.01	6.11	5.54	3.84	3.28	1.90	1.09	0.70	3.80
90 days	0.34	0.32	0.36	0.47	1.10	6.16	2.36	2.29	1.98	1.46	0.85	4.34
90-30	2.28	5.13	1.43	1.45	7.56		5.34	20.79	2.52	2.37	3.13	
							Jarque-Bera normality test p-value					
30 days	0.09	0.31	0.24	0.00	0.00		0.00	0.00	0.00	0.00	0.02	
90 days	0.25	0.46	0.49	0.07	0.00		0.00	0.00	0.00	0.00	0.01	
							S&P betas					
30 days	0.93	0.92	0.90	0.82	0.70		0.93	0.94	0.96	0.96	0.96	
90 days	0.92	0.91	0.90	0.87	0.83		1.00	0.98	0.97	0.96	0.96	

Table A.9: Average percentage monthly returns of the leverage-adjusted portfolios with rebalancing, adding two percentage points to the fitted implied volatility of missing options. We show selected portfolios, the others fall in between. For comparison, the S&P 500 has average return 0.86%; volatility 4.57%; skewness -0.82, excess kurtosis 2.30; and Jarque-Bera p-value 0.00. April 1986 to October 2010.

	Calls						Puts					
K/S	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo
							Average returns					
30 days	0.46	0.41	0.21	0.14	0.15	-0.32	1.95	1.52	1.01	0.77	0.72	-1.23
(s.e.)	(0.25)	(0.25)	(0.24)	(0.24)	(0.24)	(0.17)	(0.36)	(0.33)	(0.29)	(0.27)	(0.27)	(0.20)
90 days	0.50	0.44	0.39	0.42	0.47	-0.03	0.86	0.95	0.82	0.75	0.71	-0.15
(s.e.)	(0.25)	(0.24)	(0.24)	(0.25)	(0.25)	(0.12)	(0.34)	(0.31)	(0.29)	(0.28)	(0.27)	(0.15)
90-30	0.04	0.03	0.18	0.28	0.32		-1.09	-0.57	-0.19	-0.02	-0.01	
(s.e.)	(0.02)	(0.02)	(0.03)	(0.07)	(0.12)		(0.12)	(0.08)	(0.03)	(0.03)	(0.02)	
							Volatility					
30 days	4.30	4.22	4.20	4.15	4.06	2.84	6.15	5.61	5.05	4.70	4.56	3.36
90 days	4.22	4.18	4.20	4.25	4.31	2.04	5.84	5.32	5.02	4.78	4.65	2.52
90-30	0.35	0.36	0.50	1.17	1.98		2.11	1.34	0.54	0.43	0.41	
							Skewness					
30 days	-0.32	-0.23	-0.04	0.44	1.28	1.39	-1.46	-1.38	-0.98	-0.72	-0.59	1.46
90 days	-0.28	-0.16	-0.04	0.16	0.38	1.53	-1.11	-1.11	-0.98	-0.81	-0.68	1.55
90-30	2.36	0.59	-0.19	-0.61	0.44		-0.58	1.82	0.20	-0.52	-0.57	
							Excess kurtosis					
30 days	0.56	0.56	0.73	1.90	5.30	4.87	6.65	5.41	3.97	2.71	1.74	6.58
90 days	0.50	0.54	0.66	0.88	1.31	5.93	4.94	4.62	3.80	3.08	2.31	5.31
90-30	12.76	4.44	3.05	2.50	5.61		5.74	14.23	2.24	2.32	3.98	
							Jarque-Bera normality test p-value					
30 days	0.02	0.04	0.04	0.00	0.00		0.00	0.00	0.00	0.00	0.00	
90 days	0.03	0.07	0.06	0.01	0.00		0.00	0.00	0.00	0.00	0.00	
							S&P betas					
30 days	0.88	0.86	0.82	0.73	0.59		1.06	1.02	0.99	0.96	0.93	
90 days	0.87	0.85	0.84	0.80	0.75		1.06	1.02	1.00	0.97	0.95	

Table A.10: Average percentage monthly returns of the leverage-adjusted portfolios with rebalancing, subtracting two percentage points from the fitted implied volatility of missing options. We show selected portfolios, the others fall in between. For comparison, the S&P 500 has average return 0.86%; volatility 4.57%; skewness -0.82, excess kurtosis 2.30; and Jarque-Bera p-value 0.00. April 1986 to October 2010.

	Calls						Puts					
K/S	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo	90.0%	95.0%	100.0%	105.0%	110.0%	Hi-Lo
							Average returns					
30 days	0.45	0.40	0.19	-0.02	-0.10	-0.55	2.23	1.63	1.05	0.79	0.73	-1.49
(s.e.)	(0.25)	(0.25)	(0.24)	(0.24)	(0.23)	(0.17)	(0.36)	(0.33)	(0.29)	(0.27)	(0.27)	(0.20)
90 days	0.48	0.41	0.34	0.21	0.05	-0.43	1.32	1.18	0.90	0.79	0.74	-0.57
(s.e.)	(0.25)	(0.24)	(0.24)	(0.24)	(0.25)	(0.12)	(0.34)	(0.31)	(0.29)	(0.28)	(0.27)	(0.14)
90-30	0.03	0.01	0.15	0.23	0.15		-0.91	-0.45	-0.15	0.01	0.01	
(s.e.)	(0.02)	(0.02)	(0.03)	(0.06)	(0.10)		(0.11)	(0.08)	(0.03)	(0.02)	(0.02)	
							Volatility					
30 days	4.30	4.22	4.19	4.11	4.01	2.91	6.19	5.64	5.06	4.71	4.57	3.36
90 days	4.22	4.18	4.19	4.20	4.23	1.99	5.78	5.34	5.04	4.79	4.66	2.33
90-30	0.33	0.34	0.49	1.09	1.78		1.86	1.34	0.56	0.41	0.39	
							Skewness					
30 days	-0.32	-0.22	-0.03	0.49	1.32	1.32	-1.51	-1.39	-0.98	-0.72	-0.59	1.53
90 days	-0.28	-0.16	-0.02	0.22	0.50	1.13	-1.23	-1.17	-0.99	-0.82	-0.69	1.19
90-30	2.02	0.27	-0.26	-0.53	0.06		0.46	1.93	0.34	-0.60	-0.70	
							Excess kurtosis					
30 days	0.56	0.56	0.75	2.05	5.42	4.69	6.63	5.37	3.95	2.69	1.72	6.93
90 days	0.50	0.54	0.67	0.98	1.43	4.28	5.47	4.66	3.79	3.06	2.29	3.97
90-30	10.21	3.76	2.94	1.49	3.83		4.50	12.32	2.37	2.90	4.60	
							Jarque-Bera normality test p-value					
30 days	0.02	0.04	0.03	0.00	0.00		0.00	0.00	0.00	0.00	0.00	
90 days	0.03	0.08	0.05	0.01	0.00		0.00	0.00	0.00	0.00	0.00	
							S&P betas					
30 days	0.88	0.86	0.82	0.72	0.57		1.06	1.02	0.99	0.96	0.93	
90 days	0.86	0.85	0.83	0.79	0.73		1.06	1.03	1.00	0.97	0.95	

Table A.11. Asset pricing tests with selected factors, portfolios *without rebalancing*. The stock-based (option-based) results estimate factor premia from the 25 Fama-French portfolios (54 option portfolios). We report betas (factor loadings) and pricing errors (alphas) for four representative portfolios (the rest fall in between). We run two-stage OLS with 10,000 bootstrap simulations. We report root-mean-squared pricing errors, and bootstrapped standard errors and p-values for the joint hypothesis that all pricing errors are zero. April 1986 to October 2010.

	Factor premia									
1st factor	S&P		S&P		S&P		S&P		S&P	
Stock-based	0.64	(0.31)	0.49	(0.29)	0.57	(0.31)	0.53	(0.28)	0.46	(0.31)
Option-based	0.49	(0.28)	0.56	(0.44)	0.57	(0.43)	0.37	(0.29)	0.60	(0.52)
Difference	0.15	(0.16)	-0.07	(0.36)	0.00	(0.39)	0.16	(0.16)	-0.13	(0.50)
2nd factor			Jump		Volatility Jump		Volatility		Liquidity	
Stock-based			1.39	(0.79)	-4.02	(1.70)	-1.05	(0.91)	5.90	(2.20)
Option-based			3.21	(3.78)	-11.98	(10.89)	-2.01	(0.51)	14.48	(13.89)
Difference			-1.82	(3.79)	7.96	(10.90)	0.96	(0.89)	-8.59	(13.96)
	Call portfolios									
	Betas (for 2nd factor)									
30 days, 95%	0.89	(0.05)	-0.18	(0.11)	0.04	(0.03)	0.18	(0.07)	-0.03	(0.04)
30 days, 105%	0.72	(0.08)	-0.21	(0.11)	0.07	(0.04)	0.39	(0.09)	-0.04	(0.04)
90 days, 95%	0.87	(0.05)	-0.18	(0.10)	0.04	(0.03)	0.18	(0.07)	-0.03	(0.03)
90 days, 105%	0.79	(0.08)	-0.22	(0.11)	0.07	(0.04)	0.38	(0.09)	-0.04	(0.04)
	Alphas (using stock-based premia)									
30 days, 95%	-0.72	(0.19)	-0.37	(0.27)	-0.53	(0.25)	-0.49	(0.21)	-0.40	(0.27)
30 days, 105%	-0.87	(0.22)	-0.50	(0.30)	-0.58	(0.30)	-0.49	(0.37)	-0.52	(0.31)
90 days, 95%	-0.64	(0.18)	-0.29	(0.25)	-0.44	(0.24)	-0.41	(0.20)	-0.34	(0.25)
90 days, 105%	-0.77	(0.21)	-0.38	(0.29)	-0.45	(0.29)	-0.40	(0.36)	-0.41	(0.29)
	Alphas (using option-based premia)									
30 days, 95%	-0.59	(0.10)	-0.11	(0.19)	-0.24	(0.25)	-0.15	(0.08)	-0.27	(0.20)
30 days, 105%	-0.76	(0.16)	-0.18	(0.21)	-0.04	(0.26)	0.04	(0.10)	-0.28	(0.29)
90 days, 95%	-0.51	(0.09)	-0.03	(0.13)	-0.12	(0.21)	-0.08	(0.08)	-0.24	(0.20)
90 days, 105%	-0.65	(0.15)	-0.04	(0.17)	0.13	(0.25)	0.13	(0.08)	-0.19	(0.23)

	Put portfolios									
	Betas (for 2^{nd} factor)									
30 days, 95%	0.94	(0.09)	0.27	(0.16)	-0.06	(0.07)	-0.52	(0.05)	0.05	(0.05)
30 days, 105%	0.99	(0.04)	-0.03	(0.09)	0.01	(0.03)	-0.18	(0.08)	-0.02	(0.03)
90 days, 95%	0.98	(0.07)	0.18	(0.12)	-0.04	(0.06)	-0.45	(0.06)	0.02	(0.04)
90 days, 105%	0.97	(0.04)	-0.03	(0.09)	0.00	(0.03)	-0.19	(0.08)	-0.02	(0.03)
	Alphas (using stock-based premia)									
30 days, 95%	0.95	(0.22)	0.75	(0.33)	0.78	(0.29)	0.66	(0.45)	0.85	(0.27)
30 days, 105%	-0.06	(0.17)	0.12	(0.19)	0.02	(0.20)	-0.10	(0.22)	0.21	(0.23)
90 days, 95%	0.53	(0.19)	0.46	(0.25)	0.44	(0.25)	0.30	(0.40)	0.57	(0.24)
90 days, 105%	-0.06	(0.17)	0.11	(0.19)	0.00	(0.20)	-0.11	(0.23)	0.20	(0.23)
	Alphas (using option-based premia)									
30 days, 95%	1.09	(0.18)	0.20	(0.22)	0.27	(0.30)	0.26	(0.08)	0.34	(0.31)
30 days, 105%	0.08	(0.06)	0.12	(0.21)	0.08	(0.21)	-0.13	(0.09)	0.23	(0.24)
90 days, 95%	0.68	(0.13)	0.08	(0.18)	0.11	(0.30)	-0.02	(0.07)	0.24	(0.22)
90 days, 105%	0.08	(0.06)	0.10	(0.18)	0.02	(0.18)	-0.15	(0.10)	0.21	(0.20)
	Stock portfolio test statistics (using stock-based premia)									
R.m.s. (p)	0.26	(0.00)	0.24	(0.00)	0.23	(0.00)	0.26	(0.00)	0.21	(0.01)
	Option portfolio test statistics (using stock-based premia)									
R.m.s. (p)	0.68	(0.01)	0.41	(0.34)	0.47	(0.30)	0.42	(0.15)	0.46	(0.38)
	Option portfolio test statistics (using option-based premia)									
R.m.s. (p)	0.66	(0.00)	0.15	(0.41)	0.16	(0.71)	0.17	(0.40)	0.27	(0.52)

Table A.12: Asset pricing tests with selected factors, *OptionMetrics subperiod*. The stock-based (option-based) results estimate factor premia from the 25 Fama-French portfolios (54 option portfolios). We report betas (factor loadings) and pricing errors (alphas) for four representative portfolios (the rest fall in between). We run two-stage OLS with 10,000 bootstrap simulations. We report bootstrapped standard errors, root-mean-squared pricing errors, and a bootstrapped p-value for the joint hypothesis that all pricing errors are zero. January 1996 to October 2010.

	Factor premia									
1st factor	S&P		S&P		S&P		S&P		S&P	
Stock-based	0.64	(0.41)	0.43	(0.41)	0.58	(0.43)	0.51	(0.40)	0.52	(0.41)
Option-based	0.10	(0.37)	0.11	(0.59)	0.06	(0.40)	-0.03	(0.37)	0.13	(0.45)
Difference	0.54	(0.23)	0.32	(0.49)	0.53	(0.27)	0.54	(0.22)	0.39	(0.36)
2nd factor			Jump		Volatility Jump		Volatility		Liquidity	
Stock-based			2.11	(1.01)	-3.63	(1.86)	-1.43	(1.07)	4.94	(2.71)
Option-based			1.72	(2.77)	-2.71	(2.03)	-0.98	(0.48)	23.64	(8.31)
Difference			0.39	(2.88)	-0.91	(2.91)	-0.44	(1.07)	-18.70	(8.73)
	Call portfolios									
	Betas (for 2nd factor)									
30 days, 95%	0.86	(0.04)	-0.17	(0.07)	0.08	(0.02)	0.13	(0.07)	0.00	(0.02)
30 days, 105%	0.73	(0.07)	-0.26	(0.12)	0.16	(0.04)	0.37	(0.09)	0.00	(0.04)
90 days, 95%	0.86	(0.04)	-0.17	(0.07)	0.08	(0.02)	0.13	(0.07)	0.00	(0.02)
90 days, 105%	0.79	(0.06)	-0.24	(0.10)	0.13	(0.03)	0.32	(0.07)	0.00	(0.03)
	Alphas (using stock-based premia)									
30 days, 95%	-0.74	(0.24)	-0.21	(0.31)	-0.44	(0.33)	-0.47	(0.29)	-0.63	(0.25)
30 days, 105%	-0.87	(0.29)	-0.19	(0.44)	-0.30	(0.49)	-0.36	(0.49)	-0.77	(0.31)
90 days, 95%	-0.72	(0.23)	-0.19	(0.31)	-0.42	(0.32)	-0.46	(0.28)	-0.60	(0.25)
90 days, 105%	-0.71	(0.27)	-0.07	(0.40)	-0.24	(0.43)	-0.25	(0.44)	-0.61	(0.28)
	Alphas (using option-based premia)									
30 days, 95%	-0.27	(0.10)	0.01	(0.07)	-0.03	(0.06)	-0.03	(0.04)	-0.25	(0.09)
30 days, 105%	-0.48	(0.19)	-0.04	(0.12)	0.00	(0.08)	-0.01	(0.08)	-0.41	(0.16)
90 days, 95%	-0.25	(0.10)	0.03	(0.08)	-0.01	(0.06)	-0.01	(0.03)	-0.18	(0.08)
90 days, 105%	-0.29	(0.16)	0.11	(0.08)	0.11	(0.05)	0.14	(0.04)	-0.29	(0.13)

	Put portfolios									
	Betas (for 2nd factor)									
30 days, 95%	1.13	(0.08)	0.25	(0.22)	-0.17	(0.05)	-0.61	(0.13)	0.02	(0.07)
30 days, 105%	1.00	(0.04)	0.07	(0.14)	-0.06	(0.03)	-0.20	(0.12)	-0.01	(0.04)
90 days, 95%	1.09	(0.06)	0.18	(0.18)	-0.13	(0.04)	-0.47	(0.12)	0.00	(0.06)
90 days, 105%	1.02	(0.04)	0.08	(0.15)	-0.07	(0.03)	-0.25	(0.11)	-0.01	(0.04)
	Alphas (using stock-based premia)									
30 days, 95%	0.01	(0.31)	-0.24	(0.48)	-0.47	(0.47)	-0.51	(0.65)	0.03	(0.39)
30 days, 105%	-0.55	(0.23)	-0.46	(0.27)	-0.68	(0.26)	-0.63	(0.27)	-0.39	(0.28)
90 days, 95%	-0.37	(0.27)	-0.49	(0.38)	-0.72	(0.37)	-0.73	(0.50)	-0.25	(0.33)
90 days, 105%	-0.57	(0.23)	-0.52	(0.28)	-0.74	(0.27)	-0.70	(0.30)	-0.41	(0.28)
	Alphas (using option-based premia)									
30 days, 95%	0.62	(0.18)	0.19	(0.14)	0.21	(0.08)	0.16	(0.07)	0.03	(0.22)
30 days, 105%	-0.01	(0.05)	-0.13	(0.10)	-0.12	(0.06)	-0.07	(0.04)	0.16	(0.09)
90 days, 95%	0.22	(0.13)	-0.09	(0.09)	-0.08	(0.05)	-0.10	(0.04)	0.11	(0.10)
90 days, 105%	-0.02	(0.06)	-0.17	(0.07)	-0.16	(0.06)	-0.13	(0.04)	0.14	(0.08)
	Stock portfolio test statistics (using stock-based premia)									
R.m.s. (p)	0.30	(0.00)	0.26	(0.05)	0.26	(0.04)	0.30	(0.04)	0.27	(0.12)
	Option portfolio test statistics (using stock-based premia)									
R.m.s. (p)	0.62	(0.14)	0.34	(0.61)	0.53	(0.61)	0.53	(0.62)	0.51	(0.52)
	Option portfolio test statistics (using option-based premia)									
R.m.s. (p)	0.36	(0.10)	0.14	(0.56)	0.15	(0.50)	0.12	(0.47)	0.29	(0.91)

Table A.13: Asset pricing tests with selected factors described in Appendix C, excluding crises. The stock-based (option-based) results estimate factor premia from the 25 Fama-French portfolios (54 option portfolios). We report betas (factor loadings) and pricing errors (alphas) for four representative portfolios (the rest fall in between). We run two-stage OLS with 10,000 bootstrap simulations and report bootstrapped standard errors, root-mean-squared pricing errors, and a bootstrapped p-value for the joint test that all pricing errors are zero. July 1988 to June 2007.

	Factor premia									
1st factor	S&P		S&P		S&P		S&P		S&P	
Stock-based	0.84	(0.33)	0.77	(0.29)	0.96	(0.32)	0.62	(0.29)	0.64	(0.33)
Option-based	0.50	(0.27)	0.40	(0.30)	0.47	(0.30)	0.49	(0.28)	-0.23	(0.58)
Difference	0.34	(0.19)	0.37	(0.20)	0.49	(0.26)	0.13	(0.15)	0.87	(0.58)
2nd factor			Jump		Volatility Jump		Volatility		Liquidity	
Stock-based			0.22	(0.26)	-2.32	(1.06)	-1.44	(0.82)	6.99	(2.61)
Option-based			0.93	(0.39)	-3.56	(1.99)	-1.58	(0.37)	20.64	(14.56)
Difference			-0.71	(0.46)	1.24	(2.29)	0.14	(0.79)	-13.64	(14.58)
	Call portfolios									
	Betas (for 2nd factor)									
30 days, 95%	0.92	(0.03)	-0.27	(0.11)	0.05	(0.04)	0.18	(0.04)	0.02	(0.02)
30 days, 105%	0.82	(0.05)	-0.38	(0.10)	0.17	(0.07)	0.40	(0.06)	0.00	(0.03)
90 days, 95%	0.91	(0.03)	-0.23	(0.09)	0.05	(0.04)	0.18	(0.04)	0.02	(0.02)
90 days, 105%	0.87	(0.05)	-0.49	(0.15)	0.14	(0.07)	0.41	(0.05)	0.01	(0.02)
	Alphas (using stock-based premia)									
30 days, 95%	-0.60	(0.20)	-0.49	(0.17)	-0.60	(0.20)	-0.20	(0.20)	-0.54	(0.22)
30 days, 105%	-0.84	(0.23)	-0.72	(0.19)	-0.58	(0.28)	-0.20	(0.34)	-0.71	(0.24)
90 days, 95%	-0.60	(0.19)	-0.49	(0.16)	-0.60	(0.20)	-0.19	(0.20)	-0.53	(0.21)
90 days, 105%	-0.65	(0.23)	-0.51	(0.22)	-0.47	(0.26)	0.00	(0.35)	-0.53	(0.24)
	Alphas (using option-based premia)									
30 days, 95%	-0.30	(0.06)	0.05	(0.07)	-0.08	(0.07)	-0.05	(0.04)	0.03	(0.13)
30 days, 105%	-0.56	(0.13)	-0.13	(0.12)	0.06	(0.09)	-0.02	(0.08)	-0.05	(0.26)
90 days, 95%	-0.29	(0.05)	0.01	(0.04)	-0.07	(0.04)	-0.03	(0.03)	0.04	(0.13)
90 days, 105%	-0.35	(0.11)	0.18	(0.08)	0.16	(0.06)	0.20	(0.04)	0.14	(0.19)

	Put portfolios									
	Betas (for 2nd factor)									
30 days, 95%	0.94	(0.06)	1.01	(0.30)	-0.19	(0.09)	-0.52	(0.09)	0.08	(0.04)
30 days, 105%	0.96	(0.03)	0.12	(0.14)	-0.05	(0.04)	-0.05	(0.05)	0.04	(0.02)
90 days, 95%	0.98	(0.05)	0.75	(0.22)	-0.14	(0.07)	-0.38	(0.07)	0.06	(0.03)
90 days, 105%	0.96	(0.03)	0.24	(0.14)	-0.07	(0.04)	-0.13	(0.05)	0.04	(0.02)
	Alphas (using stock-based premia)									
30 days, 95%	0.63	(0.22)	0.54	(0.34)	0.12	(0.35)	0.24	(0.45)	0.26	(0.33)
30 days, 105%	-0.30	(0.18)	-0.25	(0.15)	-0.53	(0.21)	-0.15	(0.15)	-0.38	(0.22)
90 days, 95%	0.03	(0.19)	-0.01	(0.27)	-0.38	(0.28)	-0.18	(0.33)	-0.19	(0.27)
90 days, 105%	-0.31	(0.18)	-0.28	(0.16)	-0.58	(0.21)	-0.24	(0.17)	-0.39	(0.22)
	Alphas (using option-based premia)									
30 days, 95%	0.94	(0.15)	0.14	(0.10)	0.33	(0.09)	0.26	(0.07)	-0.06	(0.34)
30 days, 105%	0.02	(0.03)	0.02	(0.08)	-0.12	(0.07)	-0.03	(0.04)	-0.08	(0.10)
90 days, 95%	0.36	(0.10)	-0.20	(0.08)	-0.09	(0.06)	-0.14	(0.05)	-0.18	(0.20)
90 days, 105%	0.01	(0.05)	-0.10	(0.07)	-0.20	(0.07)	-0.15	(0.04)	-0.09	(0.11)
	Stock portfolio test statistics (using stock-based premia)									
R.m.s. (p)	0.35	(0.00)	0.35	(0.00)	0.33	(0.00)	0.33	(0.00)	0.27	(0.02)
	Option portfolio test statistics (using stock-based premia)									
R.m.s. (p)	0.57	(0.01)	0.48	(0.06)	0.51	(0.24)	0.21	(0.15)	0.49	(0.12)
	Option portfolio test statistics (using option-based premia)									
R.m.s. (p)	0.47	(0.01)	0.14	(0.50)	0.20	(0.45)	0.16	(0.16)	0.15	(0.81)

Table A.14: Asset pricing tests with selected factors described in Appendix C, decile portfolios. The stock-based (option-based) results estimate factor premia from 10 factor-specific decile portfolios (54 option portfolios). We report betas (factor loadings) and pricing errors (alphas) for four representative portfolios. We run two-stage OLS with 10,000 bootstrap simulations. We report bootstrapped standard errors, root-mean-squared pricing errors, and a bootstrapped p-value for the joint hypothesis that all pricing errors are zero. April 1986 to October 2010.

	Factor premia									
1^{st} factor	S&P		S&P		S&P		S&P		S&P	
Stock-based	0.67	(0.34)	0.67	(0.33)	0.71	(0.34)	0.65	(0.33)	0.57	(0.34)
Option-based	0.42	(0.28)	0.53	(0.46)	0.42	(0.33)	0.35	(0.28)	0.58	(0.58)
Difference	0.24	(0.21)	0.14	(0.41)	0.29	(0.28)	0.30	(0.24)	0.00	(0.58)
2^{nd} factor			Jump		Volatility Jump		Volatility		Liquidity	
Stock-based			0.48	(0.30)	-0.48	(0.62)	-0.66	(0.33)	3.01	(2.07)
Option-based			2.36	(1.64)	-4.78	(3.32)	-1.79	(0.48)	14.33	(11.48)
Difference			-1.88	(1.63)	4.29	(3.29)	1.12	(0.45)	-11.32	(11.50)

	Call portfolios									
	Betas (for 2^{nd} factor)									
30 days, 95%	0.86	(0.04)	-0.19	(0.06)	0.06	(0.03)	0.14	(0.05)	-0.03	(0.03)
30 days, 105%	0.72	(0.06)	-0.29	(0.09)	0.13	(0.04)	0.32	(0.06)	-0.05	(0.04)
90 days, 95%	0.85	(0.04)	-0.20	(0.06)	0.07	(0.02)	0.15	(0.05)	-0.03	(0.03)
90 days, 105%	0.80	(0.05)	-0.27	(0.07)	0.12	(0.03)	0.28	(0.06)	-0.04	(0.03)
	Alphas (using stock-based premia)									
30 days, 95%	-0.51	(0.21)	-0.46	(0.17)	-0.54	(0.20)	-0.45	(0.19)	-0.36	(0.22)
30 days, 105%	-0.77	(0.23)	-0.70	(0.20)	-0.81	(0.21)	-0.67	(0.20)	-0.57	(0.25)
90 days, 95%	-0.48	(0.21)	-0.43	(0.17)	-0.52	(0.20)	-0.43	(0.19)	-0.32	(0.22)
90 days, 105%	-0.56	(0.23)	-0.49	(0.19)	-0.60	(0.21)	-0.47	(0.19)	-0.37	(0.24)
	Alphas (using option-based premia)									
30 days, 95%	-0.30	(0.07)	0.03	(0.07)	-0.02	(0.10)	0.00	(0.03)	-0.07	(0.13)
30 days, 105%	-0.60	(0.14)	-0.05	(0.10)	-0.01	(0.09)	-0.04	(0.06)	-0.03	(0.22)
90 days, 95%	-0.27	(0.07)	0.07	(0.06)	0.03	(0.07)	0.02	(0.03)	0.03	(0.11)
90 days, 105%	-0.37	(0.12)	0.13	(0.08)	0.17	(0.09)	0.13	(0.04)	0.10	(0.17)

	Put portfolios									
	Betas (for 2nd factor)									
30 days, 95%	1.02	(0.06)	0.22	(0.17)	-0.13	(0.06)	-0.41	(0.13)	0.04	(0.06)
30 days, 105%	0.96	(0.04)	0.00	(0.11)	-0.02	(0.04)	-0.10	(0.09)	-0.02	(0.04)
90 days, 95%	1.03	(0.05)	0.15	(0.14)	-0.09	(0.05)	-0.32	(0.10)	0.02	(0.05)
90 days, 105%	0.97	(0.04)	0.02	(0.12)	-0.04	(0.03)	-0.13	(0.09)	-0.01	(0.04)
	Alphas (using stock-based premia)									
30 days, 95%	0.56	(0.25)	0.50	(0.29)	0.53	(0.27)	0.47	(0.28)	0.54	(0.32)
30 days, 105%	-0.20	(0.20)	-0.20	(0.20)	-0.23	(0.21)	-0.21	(0.21)	-0.06	(0.23)
90 days, 95%	0.05	(0.23)	0.01	(0.25)	0.01	(0.24)	-0.03	(0.25)	0.07	(0.27)
90 days, 105%	-0.21	(0.21)	-0.21	(0.21)	-0.24	(0.21)	-0.23	(0.22)	-0.09	(0.24)
	Alphas (using option-based premia)									
30 days, 95%	0.81	(0.15)	0.23	(0.13)	0.24	(0.10)	0.24	(0.06)	0.05	(0.29)
30 days, 105%	0.04	(0.04)	-0.07	(0.11)	-0.07	(0.11)	-0.05	(0.04)	0.12	(0.18)
90 days, 95%	0.30	(0.10)	-0.14	(0.08)	-0.09	(0.10)	-0.14	(0.04)	-0.21	(0.19)
90 days, 105%	0.03	(0.05)	-0.12	(0.10)	-0.15	(0.07)	-0.10	(0.04)	0.05	(0.15)
	Stock portfolio test statistics (using stock-based premia)									
R.m.s. (p)	0.10	(0.20)	0.18	(0.00)	0.17	(0.02)	0.15	(0.06)	0.15	(0.16)
	Option portfolio test statistics (using stock-based premia)									
R.m.s. (p)	0.49	(0.02)	0.44	(0.03)	0.51	(0.02)	0.43	(0.01)	0.37	(0.06)
	Option portfolio test statistics (using option-based premia)									
R.m.s. (p)	0.44	(0.02)	0.13	(0.20)	0.14	(0.52)	0.13	(0.06)	0.11	(0.64)

Table A.15: Factor premia and pricing errors for selected factors by option type, maturity (Panel A) and moneyness (Panel B), *OptionMetrics subperiod*. The factors are described in Appendix C. All premia are estimated among the 54 option portfolios using two-stage OLS, allowing for different premia across types, maturities, or moneyness. We report bootstrapped standard errors and a bootstrapped p-value for the joint hypothesis that all alphas are zero, both of which are based on 10,000 simulations. April 1986 through October 2010.

Panel A: Maturity

Factor premia (standard errors)

	S&P			S&P			S&P			S&P			S&P		
	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff
30-day	0.46	-0.35	0.81	-0.17	0.02	-0.19	-0.28	-0.09	-0.19	-0.28	-0.12	-0.17	0.32	-0.29	0.61
	(0.41)	(0.41)	(0.28)	(0.91)	(0.49)	(0.74)	(0.47)	(0.38)	(0.28)	(0.41)	(0.38)	(0.18)	(1.12)	(0.45)	(1.06)
90-day	0.21	-0.22	0.43	-0.13	-0.06	-0.07	-0.20	-0.11	-0.10	-0.19	-0.14	-0.06	0.31	-0.21	0.53
	(0.39)	(0.40)	(0.24)	(0.63)	(0.43)	(0.42)	(0.43)	(0.38)	(0.17)	(0.38)	(0.37)	(0.12)	(0.64)	(0.42)	(0.51)
Diff	0.25	-0.13	0.68	-0.04	0.09	-0.11	-0.08	0.02	-0.17	-0.09	0.02	-0.15	0.00	-0.08	0.53
	(0.05)	(0.04)	(0.26)	(0.47)	(0.21)	(0.72)	(0.10)	(0.08)	(0.24)	(0.11)	(0.07)	(0.21)	(0.89)	(0.20)	(1.07)

				Jump			Volatility Jump			Volatility			Liquidity		
				Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff
30-day				4.06	1.42	2.64	-6.15	-1.73	-4.42	-1.70	-0.72	-0.98	24.35	10.58	13.76
				(5.09)	(2.21)	(4.34)	(3.53)	(1.88)	(2.61)	(0.61)	(0.77)	(0.56)	(24.03)	(8.22)	(22.75)
90-day				2.73	0.62	2.11	-4.10	-0.80	-3.30	-1.06	-0.24	-0.82	23.67	5.99	17.69
				(2.77)	(1.44)	(2.34)	(2.57)	(1.69)	(1.79)	(0.46)	(0.53)	(0.33)	(13.41)	(6.28)	(12.54)
Diff				1.33	0.80	3.44	-2.05	-0.93	-5.35	-0.65	-0.49	-1.47	0.68	4.60	18.36
				(3.72)	(1.43)	(4.59)	(1.82)	(0.96)	(2.70)	(0.29)	(0.43)	(0.46)	(21.72)	(7.48)	(23.30)

Root-mean-squared pricing errors (p-values)

	Puts	Calls	Puts	Calls	Puts	Calls	Puts	Calls	Puts	Calls
30-day	0.40	0.12	0.11	0.04	0.11	0.04	0.09	0.03	0.15	0.09
	(0.01)	(0.19)	(0.15)	(0.78)	(0.05)	(0.73)	(0.03)	(0.84)	(0.72)	(0.55)
90-day	0.15	0.04	0.04	0.01	0.05	0.01	0.04	0.01	0.10	0.03
	(0.06)	(0.53)	(0.24)	(0.97)	(0.15)	(0.98)	(0.09)	(0.95)	(0.74)	(0.62)

Panel B: Moneyness

	Factor premia (standard errors)														
	S&P			S&P			S&P			S&P			S&P		
	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff
K/S≤0.95	0.61	-0.19	0.80	-0.87	-0.08	-0.79	-1.00	-0.10	-0.90	-1.09	-0.13	-0.95	0.45	-0.19	0.63
	(0.43)	(0.38)	(0.26)	(1.04)	(0.38)	(0.90)	(0.78)	(0.37)	(0.67)	(0.54)	(0.37)	(0.45)	(0.85)	(0.39)	(0.74)
K/S>1.05	0.06	-0.40	0.46	0.02	0.14	-0.12	-0.00	0.03	-0.04	-0.02	0.12	-0.14	0.15	-0.34	0.49
	(0.38)	(0.45)	(0.29)	(0.44)	(0.50)	(0.43)	(0.39)	(0.44)	(0.30)	(0.37)	(0.49)	(0.34)	(0.43)	(0.47)	(0.36)
Diff	0.55	0.21	1.01	-0.88	-0.22	-1.01	-1.00	-0.13	-1.03	-1.07	-0.26	-1.21	0.30	0.15	0.78
	(0.15)	(0.18)	(0.42)	(0.79)	(0.35)	(1.05)	(0.63)	(0.25)	(0.80)	(0.46)	(0.33)	(0.58)	(0.75)	(0.24)	(0.84)
				Jump			Volatility Jump			Volatility			Liquidity		
				Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff	Puts	Calls	Diff
K/S≤0.95				6.76	0.58	6.18	-9.81	-1.02	-8.79	-2.48	-0.36	-2.12	19.83	2.66	17.17
				(4.81)	(0.68)	(4.66)	(5.42)	(1.22)	(5.03)	(1.05)	(0.52)	(0.93)	(10.10)	(3.32)	(9.81)
K/S>1.05				0.90	1.48	-0.57	-1.34	-1.91	0.57	-0.43	-1.08	0.65	8.32	7.16	1.16
				(1.51)	(1.85)	(1.77)	(1.51)	(2.08)	(1.83)	(0.46)	(1.16)	(1.03)	(6.45)	(5.36)	(7.43)
Diff				5.86	-0.89	5.28	-8.47	0.89	-7.90	-2.04	0.72	-1.40	11.51	-4.50	12.67
				(4.36)	(1.59)	(4.31)	(4.89)	(1.77)	(4.76)	(0.95)	(1.02)	(1.34)	(10.48)	(5.51)	(10.23)
	Root-mean-squared pricing errors (p-values)														
	Puts	Calls		Puts	Calls		Puts	Calls		Puts	Calls		Puts	Calls	
K/S≤0.95	0.28	0.02		0.05	0.01		0.04	0.01		0.08	0.01		0.18	0.01	
	(0.00)	(0.34)		(0.73)	(0.55)		(0.95)	(0.53)		(0.65)	(0.34)		(0.28)	(0.42)	
K/S>1.05	0.02	0.08		0.01	0.06		0.01	0.05		0.01	0.06		0.01	0.06	
	(0.37)	(0.24)		(0.68)	(0.41)		(0.65)	(0.47)		(0.43)	(0.57)		(0.95)	(0.40)	

Table C.1: Asset pricing tests with stock-based factors, described in Appendix C. The stock-based (option-based) results estimate factor premia from the 25 Fama-French portfolios (54 option portfolios). We report betas (factor loadings) and pricing errors (alphas) for four representative portfolios (the rest fall in between). We run two-stage OLS with 10,000 bootstrap simulations. We report bootstrapped standard errors, root-mean-squared pricing errors, and a bootstrapped p-value for the joint hypothesis that all pricing errors are zero. April 1986 to October 2010.

	Factor premia									
1st factor	S&P		Market		S&P		S&P		S&P	
Stock-based	0.64	(0.31)	0.61	(0.29)	0.70	(0.29)	0.63	(0.31)	0.61	(0.30)
Option-based	0.42	(0.28)	0.45	(0.29)	0.37	(0.30)	0.45	(0.32)	1.37	(0.55)
Difference	0.21	(0.17)	0.16	(0.17)	0.32	(0.19)	0.19	(0.23)	-0.76	(0.51)
2nd factor					Size		Value		Momentum	
Stock-based					-0.05	(0.21)	0.25	(0.23)	-1.42	(1.12)
Option-based					3.20	(1.39)	-15.23	(3.70)	20.16	(7.75)
Difference					-3.26	(1.33)	15.47	(3.69)	-21.58	(7.82)

	Call portfolios									
	Betas (for 2nd factor)									
30 days, 95%	0.86	(0.04)	0.81	(0.04)	-0.07	(0.03)	0.01	(0.04)	-0.04	(0.03)
30 days, 105%	0.72	(0.06)	0.67	(0.06)	-0.18	(0.06)	-0.01	(0.07)	-0.06	(0.03)
90 days, 95%	0.85	(0.04)	0.81	(0.04)	-0.07	(0.03)	0.01	(0.04)	-0.04	(0.03)
90 days, 105%	0.80	(0.05)	0.75	(0.05)	-0.13	(0.04)	-0.01	(0.06)	-0.04	(0.03)
	Alphas (using stock-based premia)									
30 days, 95%	-0.48	(0.17)	-0.43	(0.16)	-0.54	(0.15)	-0.48	(0.18)	-0.51	(0.17)
30 days, 105%	-0.75	(0.21)	-0.70	(0.20)	-0.81	(0.18)	-0.75	(0.21)	-0.82	(0.21)
90 days, 95%	-0.45	(0.17)	-0.41	(0.16)	-0.51	(0.14)	-0.45	(0.18)	-0.49	(0.17)
90 days, 105%	-0.54	(0.20)	-0.49	(0.19)	-0.60	(0.17)	-0.53	(0.21)	-0.57	(0.20)
	Alphas (using option-based premia)									
30 days, 95%	-0.30	(0.07)	-0.30	(0.08)	-0.03	(0.04)	-0.10	(0.08)	-0.25	(0.11)
30 days, 105%	-0.60	(0.14)	-0.59	(0.14)	0.00	(0.08)	-0.71	(0.15)	0.02	(0.24)
90 days, 95%	-0.27	(0.07)	-0.28	(0.07)	-0.01	(0.04)	-0.21	(0.06)	-0.27	(0.11)
90 days, 105%	-0.37	(0.12)	-0.37	(0.12)	0.09	(0.05)	-0.50	(0.11)	-0.31	(0.17)

	Put portfolios									
	Betas (for 2nd factor)									
30 days, 95%	1.02	(0.06)	1.01	(0.06)	0.18	(0.06)	-0.02	(0.06)	-0.01	(0.04)
30 days, 105%	0.96	(0.04)	0.93	(0.04)	0.05	(0.04)	0.01	(0.03)	-0.05	(0.03)
90 days, 95%	1.03	(0.05)	1.01	(0.05)	0.15	(0.05)	0.01	(0.05)	-0.04	(0.03)
90 days, 105%	0.97	(0.04)	0.94	(0.04)	0.07	(0.04)	0.01	(0.04)	-0.05	(0.03)
	Alphas (using stock-based premia)									
30 days, 95%	0.59	(0.22)	0.62	(0.22)	0.55	(0.21)	0.61	(0.23)	0.60	(0.22)
30 days, 105%	-0.17	(0.17)	-0.13	(0.16)	-0.22	(0.14)	-0.17	(0.17)	-0.21	(0.16)
90 days, 95%	0.08	(0.19)	0.11	(0.19)	0.03	(0.17)	0.08	(0.20)	0.05	(0.19)
90 days, 105%	-0.18	(0.17)	-0.14	(0.16)	-0.23	(0.14)	-0.18	(0.17)	-0.23	(0.17)
	Alphas (using option-based premia)									
30 days, 95%	0.81	(0.15)	0.79	(0.14)	0.28	(0.07)	0.42	(0.16)	0.15	(0.28)
30 days, 105%	0.04	(0.04)	0.02	(0.04)	-0.07	(0.05)	0.15	(0.06)	0.18	(0.11)
90 days, 95%	0.30	(0.10)	0.28	(0.10)	-0.12	(0.05)	0.40	(0.10)	0.19	(0.16)
90 days, 105%	0.03	(0.05)	0.01	(0.05)	-0.13	(0.05)	0.16	(0.06)	0.21	(0.12)
	Stock portfolio test statistics (using stock-based premia)									
R.m.s. (p)	0.26	(0.00)	0.27	(0.00)	0.26	(0.00)	0.20	(0.00)	0.25	(0.00)
	Option portfolio test statistics (using stock-based premia)									
R.m.s. (p)	0.48	(0.02)	0.45	(0.02)	0.51	(0.02)	0.48	(0.02)	0.51	(0.01)
	Option portfolio test statistics (using option-based premia)									
R.m.s. (p)	0.44	(0.02)	0.43	(0.02)	0.14	(0.21)	0.39	(0.74)	0.30	(0.59)

Table C.2: Asset pricing tests with volatility-related, described in Appendix C. The stock-based (option-based) results estimate factor premia from the 25 Fama-French portfolios (54 option portfolios). We report betas (factor loadings) and pricing errors (alphas) for four representative portfolios (the rest fall in between). We run two-stage OLS with 10,000 bootstrap simulations. We report bootstrapped standard errors, root-mean-squared pricing errors, and a bootstrapped p-value for the joint hypothesis that all pricing errors are zero. April 1986 to October 2010.

	Factor premia											
1st factor	S&P		S&P		S&P		S&P		S&P		S&P	
Stock-based	0.49	(0.29)	0.53	(0.28)	0.57	(0.32)	0.61	(0.28)	0.62	(0.29)	0.61	(0.32)
Option-based	0.53	(0.47)	0.35	(0.29)	0.42	(0.33)	0.41	(0.29)	0.37	(0.30)	0.27	(0.33)
Difference	-0.05	(0.40)	0.18	(0.17)	0.16	(0.25)	0.21	(0.18)	0.25	(0.20)	0.34	(0.26)
2nd factor	Jump		Volatility		Volatility Jump		RV		RV-IV		Slope	
Stock-based	1.39	(0.79)	-1.05	(0.92)	-4.02	(1.69)	-0.37	(1.60)	-0.35	(2.10)	0.85	(0.57)
Option-based	2.36	(1.73)	-1.79	(0.48)	-4.78	(3.35)	-3.52	(1.14)	4.57	(1.52)	-2.94	(1.24)
Difference	-0.98	(1.85)	0.73	(0.96)	0.76	(3.65)	3.15	(1.81)	-4.92	(2.44)	3.78	(1.37)
	Call portfolios											
	Betas (for 2nd factor)											
30 days, 95%	-0.19	(0.06)	0.14	(0.05)	0.06	(0.03)	0.08	(0.02)	-0.06	(0.02)	0.03	(0.08)
30 days, 105%	-0.29	(0.09)	0.32	(0.06)	0.13	(0.04)	0.17	(0.04)	-0.12	(0.03)	0.02	(0.12)
90 days, 95%	-0.20	(0.06)	0.15	(0.05)	0.07	(0.02)	0.08	(0.03)	-0.06	(0.02)	0.05	(0.08)
90 days, 105%	-0.27	(0.07)	0.28	(0.06)	0.12	(0.03)	0.13	(0.04)	-0.09	(0.03)	0.09	(0.10)
	Alphas (using stock-based premia)											
30 days, 95%	-0.11	(0.23)	-0.28	(0.18)	-0.20	(0.24)	-0.44	(0.20)	-0.50	(0.19)	-0.48	(0.19)
30 days, 105%	-0.29	(0.31)	-0.44	(0.32)	-0.24	(0.34)	-0.71	(0.32)	-0.80	(0.31)	-0.72	(0.24)
90 days, 95%	-0.08	(0.23)	-0.26	(0.18)	-0.16	(0.24)	-0.42	(0.19)	-0.48	(0.19)	-0.48	(0.19)
90 days, 105%	-0.09	(0.28)	-0.25	(0.28)	-0.06	(0.31)	-0.49	(0.27)	-0.57	(0.26)	-0.57	(0.22)
	Alphas (using option-based premia)											
30 days, 95%	0.03	(0.07)	0.00	(0.03)	-0.02	(0.10)	0.00	(0.03)	0.00	(0.03)	-0.07	(0.13)
30 days, 105%	-0.05	(0.10)	-0.04	(0.06)	-0.01	(0.10)	0.00	(0.06)	0.01	(0.06)	-0.38	(0.22)
90 days, 95%	0.07	(0.06)	0.02	(0.03)	0.03	(0.07)	0.02	(0.03)	0.01	(0.03)	0.01	(0.12)
90 days, 105%	0.13	(0.08)	0.13	(0.04)	0.17	(0.09)	0.11	(0.04)	0.09	(0.05)	0.03	(0.16)

	Put portfolios											
	Betas (for 2nd factor)											
30 days, 95%	0.22	(0.17)	-0.41	(0.13)	-0.13	(0.06)	-0.18	(0.06)	0.14	(0.05)	-0.30	(0.23)
30 days, 105%	0.00	(0.11)	-0.10	(0.09)	-0.02	(0.04)	-0.05	(0.04)	0.03	(0.03)	0.04	(0.12)
90 days, 95%	0.15	(0.14)	-0.32	(0.10)	-0.09	(0.05)	-0.14	(0.05)	0.11	(0.04)	-0.15	(0.20)
90 days, 105%	0.02	(0.12)	-0.13	(0.09)	-0.04	(0.03)	-0.05	(0.04)	0.04	(0.03)	0.00	(0.10)
	Alphas (using stock-based premia)											
30 days, 95%	0.48	(0.35)	0.40	(0.45)	0.19	(0.35)	0.63	(0.33)	0.70	(0.35)	0.87	(0.33)
30 days, 105%	-0.03	(0.21)	-0.14	(0.19)	-0.20	(0.21)	-0.13	(0.15)	-0.14	(0.16)	-0.19	(0.18)
90 days, 95%	0.05	(0.27)	-0.05	(0.34)	-0.18	(0.27)	0.11	(0.25)	0.14	(0.27)	0.21	(0.25)
90 days, 105%	-0.06	(0.22)	-0.17	(0.20)	-0.27	(0.21)	-0.15	(0.16)	-0.16	(0.17)	-0.18	(0.18)
	Alphas (using option-based premia)											
30 days, 95%	0.23	(0.13)	0.24	(0.06)	0.24	(0.10)	0.24	(0.07)	0.22	(0.07)	0.08	(0.25)
30 days, 105%	-0.07	(0.11)	-0.05	(0.04)	-0.07	(0.11)	-0.09	(0.04)	-0.08	(0.05)	0.29	(0.17)
90 days, 95%	-0.14	(0.08)	-0.14	(0.04)	-0.09	(0.10)	-0.13	(0.04)	-0.14	(0.05)	0.00	(0.19)
90 days, 105%	-0.12	(0.10)	-0.10	(0.04)	-0.15	(0.07)	-0.13	(0.04)	-0.11	(0.04)	0.16	(0.11)

	Stock portfolio test statistics (using stock-based premia)											
R.m.s. (p)	0.24	(0.00)	0.26	(0.00)	0.23	(0.00)	0.27	(0.00)	0.27	(0.00)	0.24	(0.00)
	Option portfolio test statistics (using stock-based premia)											
R.m.s. (p)	0.23	(0.07)	0.29	(0.01)	0.21	(0.39)	0.46	(0.03)	0.52	(0.10)	0.54	(0.22)
	Option portfolio test statistics (using option-based premia)											
R.m.s. (p)	0.13	(0.21)	0.13	(0.06)	0.14	(0.51)	0.14	(0.12)	0.13	(0.30)	0.21	(0.63)

Table C.3: Asset pricing tests with liquidity-related, described in Appendix C. The stock-based (option-based) results estimate factor premia from the 25 Fama-French portfolios (54 option portfolios). We report betas (factor loadings) and pricing errors (alphas) for four representative portfolios (the rest fall in between). We run two-stage OLS with 10,000 bootstrap simulations. We report bootstrapped standard errors, root-mean-squared pricing errors, and a bootstrapped p-value for the joint hypothesis that all pricing errors are zero. April 1986 to October 2010.

	Factor premia									
1st factor	S&P		Market		S&P		S&P		S&P	
Stock-based	0.46	(0.31)	0.66	(0.30)	0.44	(0.42)	0.59	(0.31)	0.60	(0.31)
Option-based	0.58	(0.57)	0.33	(0.31)	-0.22	(0.48)	0.52	(0.36)	-0.04	(0.49)
Difference	-0.11	(0.58)	0.32	(0.20)	0.66	(0.38)	0.07	(0.25)	0.64	(0.45)
2nd factor	Liquidity		Volume		Open Interest		OTM Put Volume		Bid-Ask	
Stock-based	5.90	(2.22)	0.12	(0.10)	-0.09	(0.09)	0.48	(0.22)	-1.30	(1.08)
Option-based	14.33	(11.65)	-0.39	(0.19)	-1.01	(0.44)	-0.79	(0.48)	9.59	(8.52)
Difference	-8.44	(11.72)	0.51	(0.20)	0.92	(0.44)	1.27	(0.53)	-10.89	(8.63)

	Call portfolios									
	Betas (for 2nd factor)									
30 days, 95%	-0.03	(0.03)	0.45	(0.29)	-0.06	(0.62)	0.41	(0.18)	0.02	(0.03)
30 days, 105%	-0.05	(0.04)	1.41	(0.46)	0.28	(1.01)	0.88	(0.30)	-0.03	(0.04)
90 days, 95%	-0.03	(0.03)	0.45	(0.28)	-0.21	(0.59)	0.35	(0.17)	0.01	(0.03)
90 days, 105%	-0.04	(0.03)	1.04	(0.42)	-0.05	(0.85)	0.72	(0.28)	-0.01	(0.03)
	Alphas (using stock-based premia)									
30 days, 95%	-0.19	(0.23)	-0.54	(0.16)	-0.61	(0.24)	-0.63	(0.20)	-0.42	(0.18)
30 days, 105%	-0.35	(0.28)	-0.90	(0.23)	-0.67	(0.29)	-1.10	(0.27)	-0.76	(0.20)
90 days, 95%	-0.13	(0.23)	-0.52	(0.16)	-0.59	(0.23)	-0.58	(0.19)	-0.41	(0.17)
90 days, 105%	-0.16	(0.26)	-0.66	(0.20)	-0.56	(0.28)	-0.82	(0.24)	-0.51	(0.19)
	Alphas (using option-based premia)									
30 days, 95%	-0.07	(0.13)	-0.04	(0.05)	-0.09	(0.11)	-0.05	(0.08)	-0.10	(0.15)
30 days, 105%	-0.03	(0.22)	0.06	(0.09)	0.08	(0.21)	0.07	(0.12)	0.01	(0.23)
90 days, 95%	0.03	(0.11)	-0.02	(0.05)	-0.22	(0.11)	-0.08	(0.08)	0.02	(0.11)
90 days, 105%	0.10	(0.17)	0.13	(0.06)	-0.08	(0.17)	0.15	(0.10)	0.05	(0.18)

	Put portfolios									
	Betas (for 2nd factor)									
30 days, 95%	0.04	(0.06)	-1.68	(0.67)	-0.95	(1.28)	-0.53	(0.35)	0.11	(0.09)
30 days, 105%	-0.02	(0.04)	-0.43	(0.37)	-0.15	(0.70)	-0.03	(0.21)	0.06	(0.06)
90 days, 95%	0.02	(0.05)	-1.22	(0.55)	-0.34	(1.06)	-0.20	(0.30)	0.09	(0.07)
90 days, 105%	-0.01	(0.04)	-0.51	(0.37)	-0.21	(0.75)	-0.05	(0.22)	0.07	(0.06)
	Alphas (using stock-based premia)									
30 days, 95%	0.53	(0.31)	0.77	(0.28)	0.08	(0.32)	0.89	(0.28)	0.78	(0.29)
30 days, 105%	0.09	(0.24)	-0.15	(0.17)	-0.43	(0.23)	-0.12	(0.19)	-0.05	(0.20)
90 days, 95%	0.11	(0.26)	0.18	(0.23)	-0.26	(0.27)	0.20	(0.22)	0.23	(0.25)
90 days, 105%	0.06	(0.24)	-0.16	(0.17)	-0.47	(0.23)	-0.13	(0.19)	-0.06	(0.21)
	Alphas (using option-based premia)									
30 days, 95%	0.05	(0.29)	0.24	(0.09)	-0.05	(0.22)	0.29	(0.12)	0.23	(0.22)
30 days, 105%	0.12	(0.18)	-0.06	(0.06)	0.11	(0.12)	-0.09	(0.07)	-0.10	(0.10)
90 days, 95%	-0.21	(0.19)	-0.11	(0.07)	0.15	(0.15)	0.02	(0.13)	-0.13	(0.16)
90 days, 105%	0.05	(0.15)	-0.10	(0.06)	0.02	(0.11)	-0.12	(0.09)	-0.15	(0.10)
	Stock portfolio test statistics (using stock-based premia)									
R.m.s. (p)	0.21	(0.01)	0.27	(0.00)	0.30	(0.01)	0.23	(0.01)	0.26	(0.00)
	Option portfolio test statistics (using stock-based premia)									
R.m.s. (p)	0.28	(0.15)	0.58	(0.16)	0.50	(0.40)	0.69	(0.21)	0.50	(0.01)
	Option portfolio test statistics (using option-based premia)									
R.m.s. (p)	0.11	(0.63)	0.13	(0.59)	0.11	(0.94)	0.15	(0.53)	0.14	(0.78)

Table C.4: Asset pricing tests with factors related to demand and sentiment, described in Appendix C. The stock-based (option-based) results estimate factor premia from the 25 Fama-French portfolios (54 option portfolios). We report betas (factor loadings) and pricing errors (alphas) for four representative portfolios (the rest fall in between). We run two-stage OLS with 10,000 bootstrap runs and report bootstrapped standard errors, root-mean-squared pricing errors, and a bootstrapped p-value for the joint hypothesis that all pricing errors are zero. April 1986 to October 2010.

	Factor premia							
1st factor	S&P		Market		S&P		S&P	
Stock-based	0.83	(0.31)	0.62	(0.32)	0.58	(0.31)	0.74	(0.31)
Option-based	0.52	(0.30)	0.53	(0.29)	0.24	(0.34)	0.30	(0.30)
Difference	0.32	(0.25)	0.09	(0.21)	0.35	(0.25)	0.44	(0.19)
2nd factor	Sentiment		SPF Dispersion		Retail Call Dem.		Retail Put Dem.	
Stock-based	-0.05	(0.10)	-2.58	(1.29)	-0.11	(0.22)	0.25	(0.35)
Option-based	-2.95	(1.07)	4.44	(2.21)	-0.59	(0.42)	-0.69	(0.47)
Difference	2.90	(1.08)	-7.02	(2.54)	0.48	(0.45)	0.94	(0.55)

	Call portfolios							
	Betas (for 2nd factor)							
30 days, 95%	0.00	(0.11)	-0.01	(0.04)	0.20	(0.27)	0.36	(0.16)
30 days, 105%	0.07	(0.16)	-0.03	(0.05)	0.75	(0.41)	0.78	(0.29)
90 days, 95%	0.01	(0.11)	-0.01	(0.04)	0.13	(0.25)	0.30	(0.14)
90 days, 105%	0.11	(0.15)	-0.04	(0.04)	0.62	(0.38)	0.64	(0.22)
	Alphas (using stock-based premia)							
30 days, 95%	-0.55	(0.18)	-0.50	(0.18)	-0.49	(0.18)	-0.76	(0.21)
30 days, 105%	-0.80	(0.22)	-0.81	(0.23)	-0.61	(0.26)	-1.05	(0.33)
90 days, 95%	-0.52	(0.18)	-0.47	(0.18)	-0.49	(0.17)	-0.73	(0.20)
90 days, 105%	-0.58	(0.21)	-0.63	(0.22)	-0.46	(0.24)	-0.85	(0.29)
	Alphas (using option-based premia)							
30 days, 95%	-0.29	(0.06)	-0.33	(0.06)	-0.09	(0.07)	-0.02	(0.04)
30 days, 105%	-0.37	(0.13)	-0.55	(0.10)	0.01	(0.11)	0.04	(0.09)
90 days, 95%	-0.23	(0.06)	-0.31	(0.05)	-0.12	(0.07)	-0.05	(0.04)
90 days, 105%	-0.01	(0.13)	-0.26	(0.09)	0.12	(0.08)	0.12	(0.07)

	Put portfolios							
	Betas (for 2nd factor)							
30 days, 95%	0.02	(0.24)	-0.03	(0.06)	-0.64	(0.40)	-0.88	(0.33)
30 days, 105%	-0.03	(0.13)	-0.01	(0.04)	-0.42	(0.21)	-0.12	(0.18)
90 days, 95%	-0.08	(0.18)	-0.03	(0.06)	-0.61	(0.26)	-0.49	(0.25)
90 days, 105%	-0.04	(0.13)	0.00	(0.04)	-0.49	(0.21)	-0.20	(0.18)
	Alphas (using stock-based premia)							
30 days, 95%	0.62	(0.21)	0.53	(0.27)	0.41	(0.26)	0.56	(0.35)
30 days, 105%	-0.21	(0.16)	-0.19	(0.18)	-0.34	(0.18)	-0.42	(0.17)
90 days, 95%	0.03	(0.17)	0.02	(0.23)	-0.07	(0.22)	-0.03	(0.24)
90 days, 105%	-0.24	(0.16)	-0.17	(0.19)	-0.38	(0.18)	-0.43	(0.17)
	Alphas (using option-based premia)							
30 days, 95%	0.98	(0.15)	0.83	(0.11)	0.47	(0.17)	0.19	(0.09)
30 days, 105%	-0.02	(0.05)	0.00	(0.05)	-0.19	(0.06)	-0.09	(0.07)
90 days, 95%	0.11	(0.10)	0.31	(0.07)	0.01	(0.08)	-0.03	(0.05)
90 days, 105%	-0.05	(0.06)	-0.07	(0.06)	-0.26	(0.06)	-0.17	(0.07)
	Stock portfolio test statistics (using stock-based premia)							
R.m.s. (p)	0.26	(0.00)	0.22	(0.01)	0.28	(0.00)	0.28	(0.01)
	Option portfolio test statistics (using stock-based premia)							
R.m.s. (p)	0.52	(0.03)	0.50	(0.06)	0.44	(0.05)	0.68	(0.01)
	Option portfolio test statistics (using option-based premia)							
R.m.s. (p)	0.43	(0.48)	0.43	(0.49)	0.24	(0.35)	0.14	(0.45)

Table C.5: Asset pricing tests with macroeconomic factors, described in Appendix C. The stock-based (option-based) results estimate factor premia from the 25 Fama-French portfolios (54 option portfolios). We report betas (factor loadings) and pricing errors (alphas) for four representative portfolios (the rest fall in between). We run two-stage OLS with 10,000 bootstrap runs and report bootstrapped standard errors, root-mean-squared pricing errors, and a bootstrapped p-value for the joint hypothesis that all pricing errors are zero. April 1986 to October 2010.

Factor premia												
1st factor	S&P		Market		S&P		S&P		S&P		S&P	
Stock-based	0.62	(0.29)	0.67	(0.31)	0.84	(0.41)	0.68	(0.30)	0.81	(0.40)	0.55	(0.36)
Option-based	0.56	(0.63)	0.10	(0.44)	1.62	(0.48)	0.65	(0.35)	1.26	(0.46)	0.64	(0.39)
Difference	0.07	(0.58)	0.56	(0.40)	-0.78	(0.45)	0.04	(0.29)	-0.45	(0.39)	-0.10	(0.33)
2nd factor	Default		Term		Sharpe		Riskfree		Inflation		GDP	
Stock-based	-0.01	(0.03)	-0.16	(0.08)	-0.08	(0.04)	0.19	(0.09)	0.15	(0.15)	0.09	(0.03)
Option-based	-0.13	(0.16)	-0.53	(0.43)	-0.47	(0.16)	-1.55	(0.67)	-1.06	(0.42)	0.57	(0.30)
Difference	0.12	(0.16)	0.37	(0.44)	0.39	(0.16)	1.74	(0.68)	1.21	(0.44)	-0.48	(0.30)

Call portfolios												
	Betas (for 2nd factor)											
30 days, 95%	3.58	(1.17)	-0.07	(0.48)	1.24	(1.14)	0.35	(0.41)	0.39	(0.39)	-0.38	(0.34)
30 days, 105%	5.41	(1.59)	0.67	(0.65)	2.62	(2.08)	0.32	(0.73)	0.54	(0.60)	-1.58	(0.54)
90 days, 95%	3.43	(1.15)	-0.04	(0.47)	1.37	(1.08)	0.27	(0.37)	0.41	(0.37)	-0.43	(0.33)
90 days, 105%	4.37	(1.63)	0.28	(0.58)	2.10	(1.76)	0.32	(0.57)	0.44	(0.55)	-1.11	(0.49)
	Alphas (using stock-based premia)											
30 days, 95%	-0.45	(0.16)	-0.52	(0.20)	-0.21	(0.27)	-0.58	(0.17)	-0.35	(0.23)	-0.26	(0.23)
30 days, 105%	-0.71	(0.21)	-0.67	(0.25)	-0.37	(0.34)	-0.85	(0.21)	-0.64	(0.28)	-0.50	(0.27)
90 days, 95%	-0.42	(0.16)	-0.49	(0.20)	-0.17	(0.28)	-0.54	(0.17)	-0.32	(0.22)	-0.24	(0.23)
90 days, 105%	-0.50	(0.19)	-0.52	(0.23)	-0.18	(0.32)	-0.63	(0.20)	-0.39	(0.26)	-0.28	(0.26)
	Alphas (using option-based premia)											
30 days, 95%	0.05	(0.11)	-0.06	(0.12)	-0.41	(0.12)	0.05	(0.12)	-0.27	(0.12)	-0.16	(0.12)
30 days, 105%	0.00	(0.24)	-0.01	(0.20)	0.04	(0.24)	-0.27	(0.18)	-0.35	(0.23)	0.18	(0.16)
90 days, 95%	0.05	(0.12)	-0.02	(0.11)	-0.31	(0.12)	-0.05	(0.11)	-0.21	(0.11)	-0.12	(0.10)
90 days, 105%	0.09	(0.16)	0.03	(0.16)	-0.02	(0.17)	-0.05	(0.14)	-0.24	(0.19)	0.17	(0.12)

Put portfolios

	Betas (for 2nd factor)											
30 days, 95%	-2.60	(3.76)	-1.30	(1.33)	1.00	(2.82)	0.15	(0.97)	0.35	(1.03)	0.85	(0.62)
30 days, 105%	-0.74	(2.39)	-0.84	(0.86)	1.86	(1.35)	-0.09	(0.49)	0.32	(0.56)	0.19	(0.35)
90 days, 95%	-1.98	(3.38)	-1.34	(1.14)	1.35	(2.43)	-0.21	(0.75)	0.12	(0.90)	0.81	(0.53)
90 days, 105%	-0.91	(2.56)	-0.90	(0.89)	1.77	(1.48)	-0.08	(0.50)	0.34	(0.55)	0.24	(0.37)
	Alphas (using stock-based premia)											
30 days, 95%	0.59	(0.23)	0.36	(0.28)	0.98	(0.31)	0.52	(0.23)	0.86	(0.30)	0.92	(0.22)
30 days, 105%	-0.16	(0.16)	-0.33	(0.19)	0.20	(0.27)	-0.20	(0.17)	0.03	(0.22)	0.06	(0.20)
90 days, 95%	0.08	(0.20)	-0.17	(0.24)	0.39	(0.28)	0.07	(0.19)	0.28	(0.26)	0.31	(0.21)
90 days, 105%	-0.17	(0.16)	-0.35	(0.20)	0.17	(0.26)	-0.21	(0.17)	0.00	(0.21)	0.04	(0.20)
	Alphas (using option-based premia)											
30 days, 95%	0.35	(0.19)	0.45	(0.24)	0.67	(0.24)	0.82	(0.24)	0.89	(0.29)	0.43	(0.18)
30 days, 105%	-0.18	(0.09)	-0.10	(0.10)	0.22	(0.10)	-0.32	(0.14)	0.00	(0.10)	-0.11	(0.08)
90 days, 95%	-0.09	(0.14)	-0.09	(0.14)	0.18	(0.19)	-0.26	(0.19)	0.01	(0.18)	-0.16	(0.12)
90 days, 105%	-0.21	(0.10)	-0.14	(0.09)	0.16	(0.11)	-0.31	(0.13)	0.01	(0.09)	-0.16	(0.08)
	Stock portfolio test statistics (using stock-based premia)											
R.m.s. (p)	0.26	(0.00)	0.22	(0.00)	0.23	(0.01)	0.25	(0.00)	0.28	(0.01)	0.21	(0.00)
	Option portfolio test statistics (using stock-based premia)											
R.m.s. (p)	0.46	(0.03)	0.45	(0.02)	0.42	(0.24)	0.53	(0.17)	0.49	(0.37)	0.44	(0.02)
	Option portfolio test statistics (using option-based premia)											
R.m.s. (p)	0.17	(0.39)	0.19	(0.57)	0.30	(0.94)	0.31	(0.79)	0.30	(0.92)	0.23	(0.45)

Figure I: The Time Series of *Jump*. This figure shows the time series of the *Jump* factor, defined in Appendix C from April 1986 to October 2010.

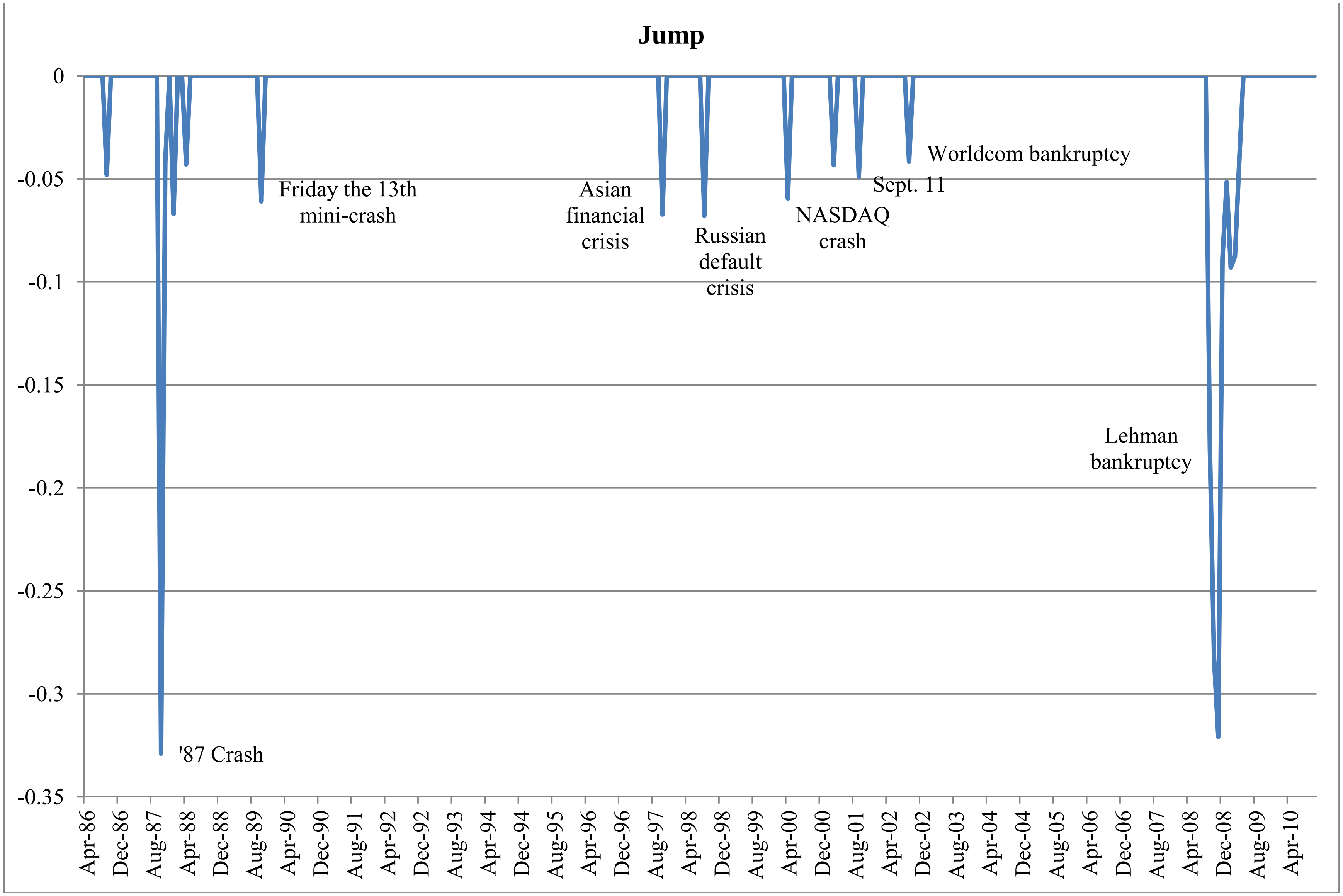


Figure II: The Time Series of *Volatility Jump*. This figure shows the time series of the *Volatility Jump* factor, defined in Appendix C from April 1986 to October 2010.

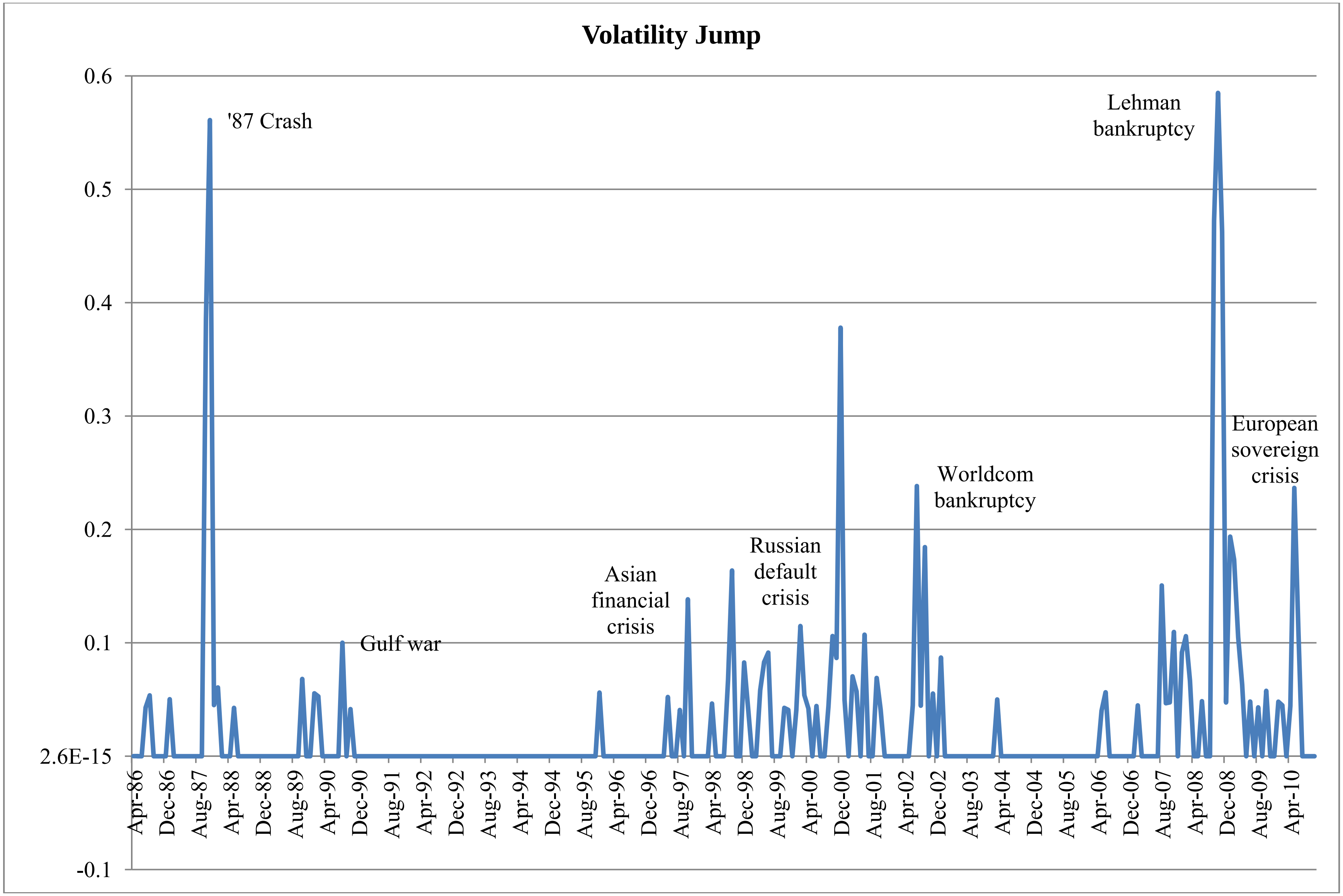


Figure III: The Time Series of *Volatility*. This figure shows the time series of the *Volatility* factor, defined in Appendix C from April 1986 to October 2010.

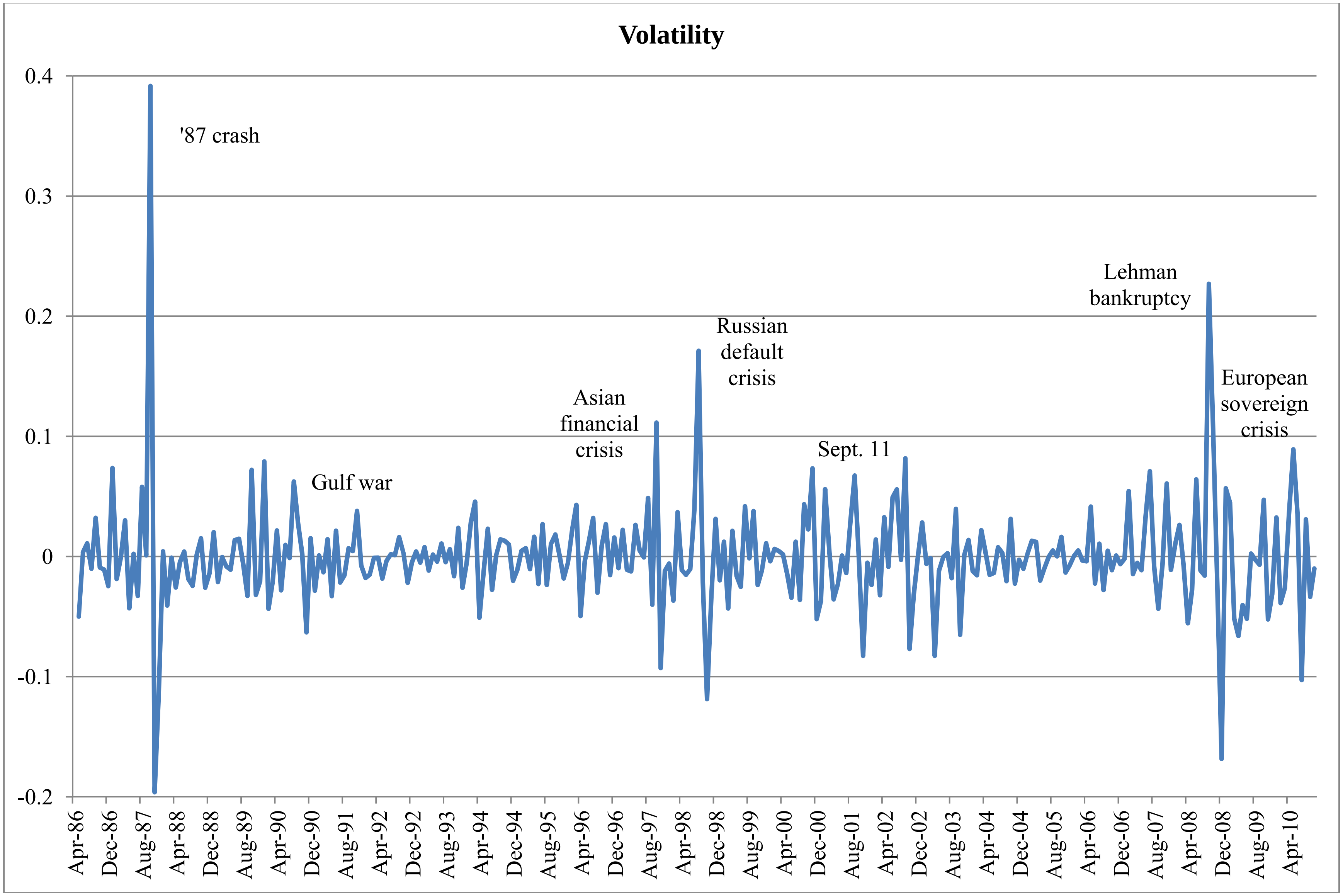


Figure IV: The Time Series of *Liquidity*. This figure shows the time series of the *Liquidity* factor, defined in Appendix C from April 1986 to October 2010.

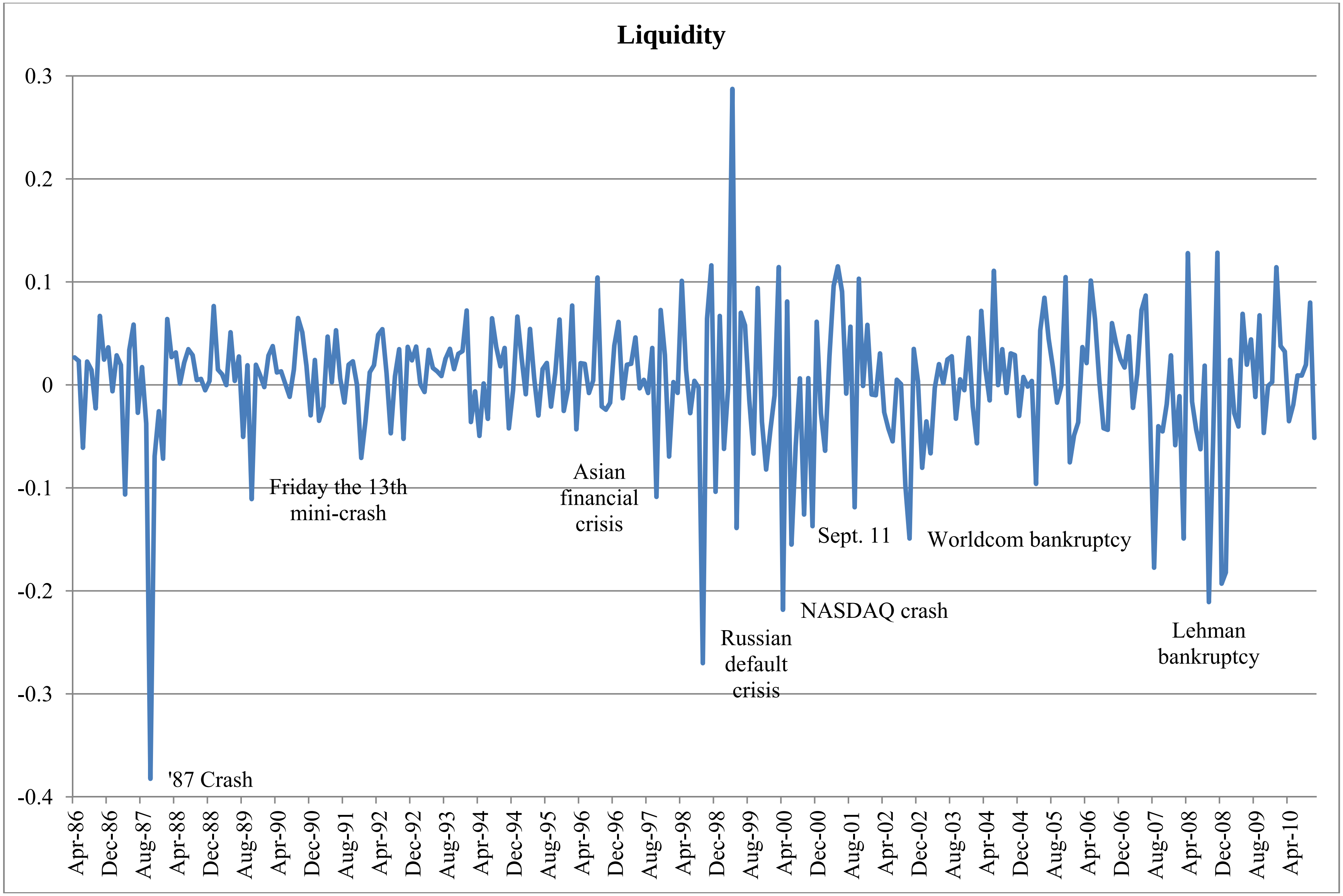
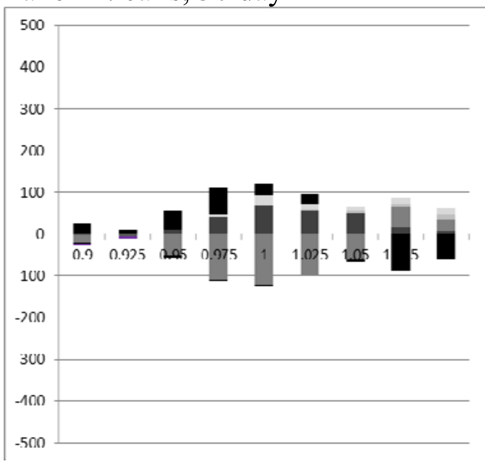
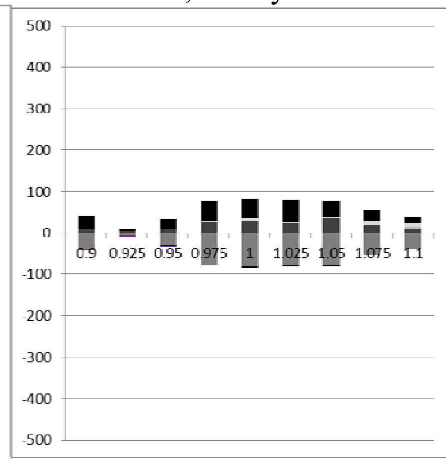


Figure V: Option demand . We depict the monthly average of option demands in contracts for 5 trader groups: market makers (black), firms (dark grey), large customers (medium grey), medium customers (light grey), small customers (very light grey). Demand is calculated as open buy – close buy – open sell + close sell. We organize calls (puts) in Panels A , B, and C (D, E, and F) according to maturity of 30, 60 and 90 days. The net demand at each moneyness level is computed using our option portfolio weights.

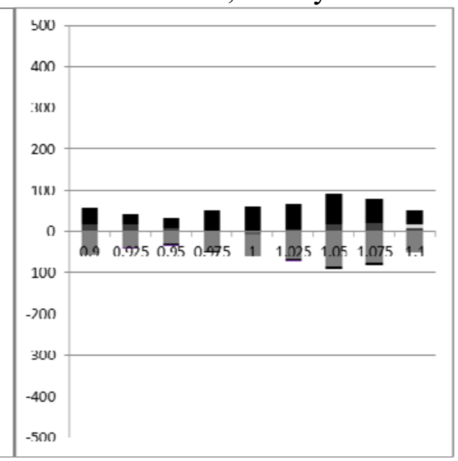
Panel A: calls, 30 day



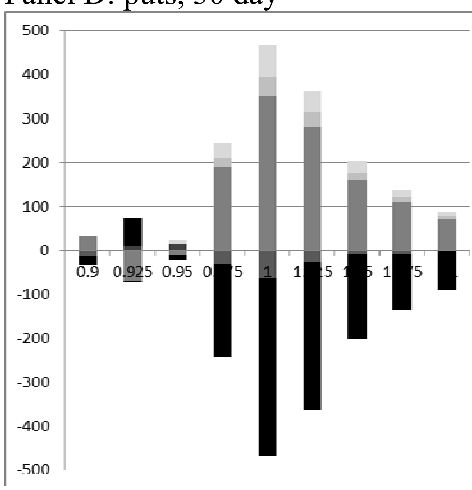
Panel B: calls, 60 day



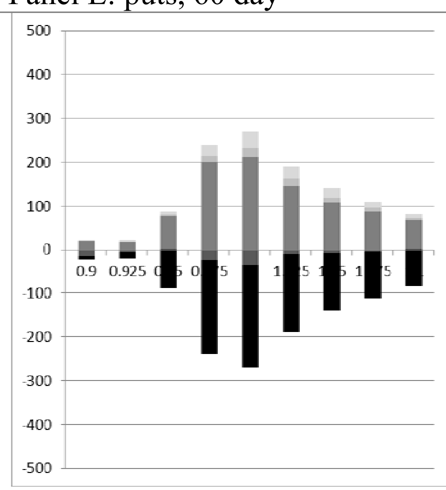
Panel C: calls, 90 day



Panel D: puts, 30 day



Panel E: puts, 60 day



Panel F: puts, 90 day

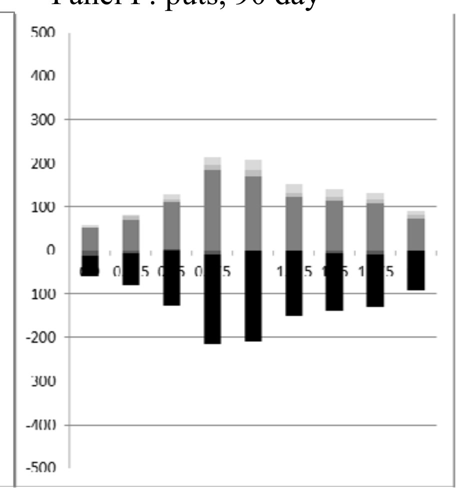


Figure VI: 30-day put portfolio demand and alphas. We depict the monthly average net demands (left axis) for our 30-day put portfolios for 5 trader groups: market makers (black), firms (dark grey), large customers (medium grey), medium customers (light grey), small customers (very light grey). Demand is calculated as open buy – close buy – open sell + close sell. We also depict the alphas (right axis) for these portfolios based on a one-factor model that includes the S&P 500 as the sole factor, as well as a two-factor model that also includes our *Jump* factor (see Table V, columns 1 and 2).