Option returns versus asset-pricing theory: Evidence from the European option market

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Practical applications

This article analyses risk–return profiles in the European equity index option market. Judging from empirical results for a comprehensive database of option prices, inconsistencies with broadly accepted asset-pricing concepts become evident. The study could therefore serve as a starting point for actual profitable trading strategies and encourage further practical research in the area of risk–return profiles of equity (index) options.

Abstract

Against the background of standard asset-pricing theory, this paper empirically investigates returns of index call and put options traded at the Eurex (European Exchange). We find that option returns are not fully consistent even with a very general asset-pricing framework. Under comparatively stronger Black–Scholes/CAPM assumptions, returns deviate significantly from expected values, though results are sensitive to option type, moneyness, and time-to-maturity. We also provide evidence that short positions in suitably chosen zero-beta straddle portfolios yield remarkable positive (excess) returns on average. Journal of Derivatives & Hedge Funds (2007) 13, 170–176. doi:10.1057/palgrave.jdhf.1850065

Keywords: options; asset-pricing theory; CAPM; implied volatility

INTRODUCTION

According to standard asset-pricing theory, options should exhibit expected returns that are in line with the systematic risk their holder is exposed to. Much of the recent research in options has focussed on valuation and hedging aspects, whereas option return characteristics, though of course closely related to studies of valuation models, have been addressed very rarely. Moreover, while there is an overwhelming literature on empirical CAPM studies, only few papers address option returns empirically (see, eg, Coval and Shumway,¹ Bakshi and Kapadia,² Jones³).

To the best of our knowledge, no comprehensive investigation of option returns has been carried out so far for the European

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equity option market that is widely concentrated at the Eurex (European Exchange), the world's largest derivatives exchange. Therefore, based on a study framework developed in Coval and Shumway,¹ we aim at filling a conspicuous gap in the empirical literature by conducting an analysis of Eurex index equity options with respect to compatibility with asset-pricing theory and potential trading strategies based thereon. For the period between January 2004 and December 2005, we find that option returns exhibit inconsistencies even with very general propositions of asset-pricing theory. Quantitatively, option returns deviate significantly from expected values in a Black–Scholes/CAPM framework, with results being sensitive to option type, moneyness, and time-to-maturity. With regard to exploitable trading opportunities against the CAPM background, short positions in certain zero-beta straddle portfolios are shown to yield remarkable positive (excess) returns on average that can readily cover usual transaction costs.

The remainder of the paper is organised as follows. In the next section, basic asset-pricing results applied to options are outlined briefly. The further section describes the composition of the data base. The final section presents and discusses the empirical results.

ASSET-PRICING RESULTS APPLIED TO OPTIONS

General asset-pricing framework

As proven in Coval and Shumway,¹ any (plain-vanilla) call option on a security will have a positive expected return that is increasing in the strike price. For any put

option, the expected return will lie below the risk-free rate and will be decreasing with the strike price. A straightforward interpretation is that the leverage effect should be 'priced'. A sufficient precondition for these relations to hold is that the stochastic discount factor is negatively correlated with the price of the underlying over its entire domain — a violation of this condition would not be in line with any of the existing asset-pricing theories. From an empirical perspective, these results thus allow a qualitative insight into the nature of option returns under very weak assumptions.

Black–Scholes/CAPM framework

Imposing the more strict assumptions required for the Black and Scholes⁴ model and the continuous-time CAPM model, in particular, asset prices following a Geometric Brownian Motion, allows a quantitative assessment of option returns. According to the CAPM Equation $E[r_i] = r + E[r_m - r]\beta_i$ with r as the risk-free (short-term) interest rate and r_m as the return on the market portfolio, a security's expected return $E[r_i]$ is linked to its systematic risk (given by the beta factor β_i) in an affine-linear way. For a call option in a Black–Scholes world, the beta is found to equal⁵

$$\beta_c = \frac{S}{C} \Phi(d_1) \beta_s \quad \text{with} \quad d_1 = \frac{\ln(S/K) + (r - \delta + \sigma^2/2)\tau}{\sigma\sqrt{\tau}} \quad (1)$$

where S denotes the current price of the underlying, K the option's strike price, σ the (constant) expected volatility, τ the option's time-to-maturity, and δ the continuous dividend yield of the underlying. $\Phi(x)$ stands for the c.d.f.

of the standard normal distribution, while β_s equals the beta of the underlying.⁶

In the special case of a zero beta, an option position is expected to yield the risk-free rate. Such zero-beta option portfolios can be constructed by combining two otherwise identical call and put options with market betas β_c and β_p , respectively. In order to satisfy the relation

$$\theta\beta_c + (1 - \theta)\beta_p = 0 \quad (2)$$

in such a straddle strategy, a weight function

$$\theta = \frac{-\beta_p}{\beta_c - \beta_p} \quad (3)$$

is applied. The return of a straddle portfolio is thus equal to the weighted sum of call and put returns. These relations will serve as a basis for the quantitative analysis of option returns.

DATA

We refer to exchange-traded plain-vanilla options on the German blue-chip stock index DAX, one of the leading equity indices in Europe. The index options are European-style with maturities of up to five years. They are traded liquidly at the Eurex, usually most actively for shorter times-to-maturity and near-the-money strikes. We employ daily settlement prices that refer to the close of the trading day at 5:30pm.⁷ In investigating the data from January 2004 to December 2005, we restrict our attention to records with option prices of at least ten times the minimum tick size of €0.10, that is, at least €1.00, and those with at least seven calendar days to maturity in order to avoid bias associated with very small option (time) values. Moreover, obviously erroneous records that violate distribution-free arbitrage boundaries are removed from the database.

The DAX quotes are obtained from the electronic XETRA trading system at the Frankfurt Stock Exchange at 5:30pm.⁸ The market environment in the reference period is characterised by a rather low DAX volatility of approximately 15 per cent p.a. with an index ranging between approximately 3,650 and 4,250 points in 2004, followed by a likewise steady increase to about 5,450 points during 2005. Risk-free interest rates are interpolated based on Euribor for intervals up to 12 months and German (AAA) government bonds for periods between two and five years. Any market frictions such as taxes are ignored. We end up with a total of 334,878 option records. For purposes of beta estimation (assuming $\beta_s^{\text{DAX}} = 1$), we employ the VDAX that serves as a reference measure of implied volatility in the Eurex DAX option market.⁹ We use discrete option returns in order to bound negative returns at -100% .

RESULTS

We calculate 331,911 daily option returns as described statistically in detail in Table 1, further divided by five moneyness and four time-to-maturity classes.¹⁰ Qualitatively, we first note that for some classes of (deep) out-of-the-money call options, the basic property of positive expected option returns is violated. For instance, very short-term out-of-the-money calls (class [A, -1]) exhibit a statistically significant mean daily return of -5.75 per cent during the examination period. Besides this phenomenon, we would expect an increase in the mean return from deep in-the-money through deep out-of-the-money call options due to the higher leverage. This holds across deep in-the-money, in-the-money, and at-the-money calls for all terms, while inconsistencies are obvious across

Table 1: Statistics of daily option returns (in %) and betas for different moneyness and time-to-maturity classes

Maturity class	Option returns	Calls					Puts				
		Moneyness class					Moneyness class				
		-2	-1	0	1	2	-2	-1	0	+1	+2
A	N	–	914	3,446	1,985	3,455	650	2,362	3,352	1,507	726
	Mean	–	–5.75	3.29	2.28	0.83	–4.30	–6.62	–2.52	0.65 [#]	–0.29 [#]
	Median	–	–8.33	0.00	2.43	1.03	–8.33	–14.29	–8.50	–0.51	0.06
	Std.dev.	–	35.40	38.04	11.79	4.83	28.64	37.42	36.07	13.89	5.60
	Minimum	–	–83.81	–82.11	–50.56	–27.99	–60.00	–77.04	–80.41	–31.10	–14.94
	Maximum	–	195.45	423.81	86.76	27.03	110.00	286.36	262.37	91.04	16.93
	Mean Beta	–	75.32	48.99	11.56	4.11	–0.54	–10.88	–36.50	–10.50	–3.88
B	N	260	5,875	8,421	5,775	7,871	6,648	6,344	8,397	4,867	1,736
	Mean	–4.64	–1.11	1.71	1.06	0.65	–3.90	–3.32	–1.17	0.49	0.55
	Median	–7.14	–3.45	0.85	1.24	0.78	–7.14	–7.17	–3.98	–0.55	0.45
	Std. dev.	27.01	27.13	17.92	8.47	4.33	22.02	23.15	18.44	10.83	5.41
	Minimum	–60.71	–77.05	–62.31	–39.58	–26.72	–61.36	–53.17	–49.23	–30.71	–13.94
	Maximum	110.00	218.18	153.15	51.88	22.72	145.95	300.00	225.56	62.47	25.08
	Mean Beta	72.90	51.95	22.86	10.03	4.20	–1.29	–12.52	–19.55	–9.89	–3.74
C	N	5,840	9,125	11,454	8,482	20,446	21,044	8,492	11,451	8,804	5,913
	Mean	–0.38 [#]	0.68	1.00	0.70	0.37	–1.46	–1.18	–0.78	–0.21	0.03 [#]
	Median	–1.65	0.39	0.95	0.87	0.53	–2.70	–2.23	–1.74	–0.86	–0.06
	Std. dev.	18.56	13.33	8.50	5.38	3.09	12.52	10.46	8.99	6.66	4.20
	Minimum	–73.21	–50.00	–32.16	–21.94	–21.75	–72.97	–34.40	–31.32	–21.63	–15.31
	Maximum	175.00	100.00	63.10	25.45	16.85	203.08	72.27	55.40	36.68	23.42
	Mean Beta	36.77	19.83	10.69	7.12	3.53	–1.48	–8.01	–9.95	–7.23	–3.61
D	N	13,531	10,346	12,041	8,926	28,366	29,487	8,926	12,039	10,348	12,259
	Mean	0.52	0.40	0.44	0.38	0.21	–0.41	–0.40	–0.34	–0.17	–0.13
	Median	0.33	0.61	0.58	0.55	0.34	–0.83	–0.71	–0.70	–0.53	–0.39
	Std. dev.	9.80	5.21	4.04	3.21	2.08	7.64	4.70	4.37	3.83	2.87
	Minimum	–68.79	–33.03	–19.31	–14.20	–11.19	–89.47	–32.89	–24.19	–17.67	–14.10
	Maximum	355.26	71.27	37.98	23.92	15.29	600.00	32.70	24.61	20.86	16.06
	Mean Beta	10.47	5.86	4.99	4.13	2.55	–1.19	–3.93	–4.58	–4.16	–3.01

[#]Not significant at the 5% level (two-sided *t*-tests). Moneyness classification: [–2] deep out-of-the-money ($M < -0.15$); [–1] out-of-the-money ($-0.15 \leq M < -0.05$); [0] at-the-money ($-0.05 \leq M < 0.05$); [+1] in-the-money ($0.05 \leq M < 0.15$); [+2] deep in-the-money ($0.15 \leq M$). Classes according to time-to-maturity (measured in calendar days): [A] very short-term ($\tau \leq 30$); [B] short-term ($30 < \tau \leq 90$); [C] medium-term ($90 < \tau \leq 365$); [D] long-term ($365 < \tau$).

the remaining moneyness classes. For put options, we would expect mean returns below the risk-free rate, decreasing with the moneyness. (Deep) in-the-money short-term puts (classes $[B, +1]$ and $[B, +2]$) with mean returns of approximately 0.5 per cent per day are found to violate this proposition to a great extent. Besides this and with the exception of very short-term options, put returns are found to be decreasing for decreasing strikes, as expected.¹¹

Applying the CAPM framework that allows a quantitative assessment of returns, among the classes of call options with positive mean returns, nearly all options clearly exhibit returns that are, on average, too high given the CAPM forecast. For very short-term at-the-money calls, for example, the mean daily return in 3,446 observations amounted to approximately 3.3 per cent and thus to an impressive annualised value of more than 700 per cent. With a risk-free rate around 3 per cent p.a. and an equity risk premium usually between 4 and 6 per cent p.a., a quick check reveals that average realised returns more than compensate for the option inherent risk, given by the mean beta of approximately 49. This carries over to all other call option classes as well. While we observe an intuitive return-risk pattern across many call option classes — the higher the mean beta, the higher the mean return —, however, this relation does not hold in all cases. For put options, mean realised returns in those option classes with average returns below the risk-free rate (ie, option classes that are, on average, in line with the very general proposition outlined at the beginning of the paper) are lower than expected. Short-term at-the-money puts with a mean daily return of -2.52 per cent and a mean beta of -36.5 are an example: The average losses from these puts are much higher than the CAPM

would suggest. In contrast to the call options, the picture of return-risk patterns for the puts is far more heterogenous. The lower the mean (signed) beta, the lower the mean return does hardly hold across moneyness classes for the different terms.

Turning to zero-beta portfolios, we analyse daily returns of 141,903 straddle strategies, for which descriptive statistics are provided in Table 2. The moneyness classification refers to the calls employed in the straddle portfolios.

We note that for very short-term and short-term options, straddle returns decrease from deep out-of-the-money through deep in-the-money classes, thereby changing sign from plus to minus. Strategies with at-the-money calls and puts in these term classes yield significantly negative returns of approximately -1.0 and -0.5 per cent per day, respectively. Selling straddles created from short-term at-the-money options thus promise remarkable (excess) returns that could easily cover usual transaction costs encountered in the option market. For medium-term options, the picture is less clear, while for long-term option strategies, we report straddle returns that do not significantly deviate from zero and that are thus conform with the CAPM framework.

Reflecting these results, we would like to point out that our findings are more or less robust against small changes in beta estimates. Compared to the study of Coval and Shumway,¹ who present an in-depth analysis of short-term S&P 100 and S&P 500 index options and find that expected option returns for both calls and puts are too low compared to their systematic risk, our results are similar for puts though different for calls. From a practical perspective, one might argue that settlement prices used in this study do not always reflect real trading

Table 2: Statistics of daily zero-beta straddle returns (in %) for different moneyness and time-to-maturity classes

Maturity class	Straddle returns	Moneyness class				
		−2	−1	0	1	2
A	<i>N</i>	–	291	2,893	1,232	251
	Mean	–	2.19	−1.04	−3.88	−6.40
	Median	–	−0.07	−2.29	−4.62	−9.08
	Std. dev.	–	10.07	7.63	14.28	23.63
	Minimum	–	−17.04	−45.14	−41.51	−55.89
	Maximum	–	47.09	78.85	98.56	99.03
B	<i>N</i>	73	3,371	8,192	5,246	3,309
	Mean	2.75	0.06 [#]	−0.51	−1.20	−4.56
	Median	2.24	−0.79	−0.98	−1.81	−5.98
	Std. dev.	6.16	4.73	3.55	6.34	15.17
	Minimum	−10.78	−12.03	−11.41	−35.80	−51.08
	Maximum	17.02	37.47	45.95	114.45	100.00
C	<i>N</i>	3,121	8,399	11,362	8,413	15,604
	Mean	0.05 [#]	−0.18	−0.08	−0.16	−1.57
	Median	−0.19	−0.32	−0.23	−0.51	−1.70
	Std. dev.	2.38	1.89	1.59	2.73	8.23
	Minimum	−11.11	−9.26	−7.68	−14.06	−72.97
	Maximum	15.03	12.28	16.32	44.19	120.00
D	<i>N</i>	11,605	10,268	11,969	8,896	27,408
	Mean	−0.01 [#]	0.02 [#]	0.01 [#]	−0.02 [#]	−0.36
	Median	−0.05	−0.02	−0.03	−0.07	−0.34
	Std. dev.	1.29	1.09	1.12	1.40	4.76
	Minimum	−18.70	−19.69	−19.12	−21.76	−89.47
	Maximum	21.30	23.21	22.85	24.99	235.74

[#] Not significant at the 5% level (two-sided *t*-tests).

Moneyness classes according to calls employed in the strategies: [−2] deep out-of-the-money; [−1] out-of-the-money; [0] at-the-money; [+1] in-the-money; [+2] deep in-the-money. Time-to-maturity classes: [A] very short-term; [B] short-term; [C] medium-term; [D] long-term.

opportunities. While this can indeed be the case for deep in-the-money or deep out-of-the-money and/or very long-term options, Eurex DAX options considered here trade, for instance, very actively for near-the-money strikes and shorter times-to-maturity. That means that straddle strategies in classes [A, 0] and [B, 0], for example, should be rather easily implementable. Beyond doubt, usual limitations regarding the CAPM and its assumptions apply. Moreover, using realised (ie, *ex post*) returns to verify expected (ie, *ex ante*) returns is frequently subject to criticism in empirical asset-pricing studies. There is also certain evidence in the empirical literature that claimed extraordinary returns can at least be partly attributed to other risk factors such as volatility and jump risk and the associated risk premia (see, for instance, Bakshi and Kapadia,² Jones³). Nevertheless, results in this study might yield a promising starting point for actual trading strategies and encourage further research in the area of option returns, especially in the European derivatives market.

References and Notes

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- 5 This expression is also referred to as the 'local' beta. Note that its use can impose certain bias in the context of discrete return periods. See Branger, N. and Schlag, C. (2007) 'Option betas: risk measures for options', *International Journal of Theoretical and Applied Finance*, forthcoming.
- 6 With $\Phi(d_1)$ as the 'delta' of a call option in a Black–Scholes world, practitioners identify the expression $\frac{S}{C}\Phi(d_1)$ as the option's 'omega', also referred to as the effective leverage. The put beta is easily derived as $\beta_p = -\frac{S}{P}\Phi(-d_1)\beta_s$.
- 7 Option settlement data was provided by Deutsche Börse, Frankfurt/Main, Germany. For details on Eurex products and contract specifications see Eurex (2006) Products, Frankfurt/Main, March 2006.
- 8 DAX data was obtained from Deutsche Börse, Frankfurt/Main, Germany. Since the underlying DAX is a performance index, we do not have to consider any dividend payments.
- 9 The VDAX reflects the current volatility level for fictitious at-the-money options with 45 calendar days to maturity.
- 10 Moneyness is defined as $M=(S-K)/K$ for call options and $M=(K-S)/K$ for put options, respectively.
- 11 We additionally note the pronounced skewness of option return distributions for both call and put options, especially for shorter times-to-maturity. Distributions mostly exhibit positive skewness except for some classes of (deep) in-the-money calls.