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The Information Content of Corridor Implied Variances and Their Economic Difference in the DJX Options Market

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The information content of corridor implied variances and their economic difference in the DJX options market

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Abstract: This paper investigates the ability of corridor implied variances (CIV) with different corridors to forecast conditional volatility of DJIA index returns, and compares their performance with a CBOE volatility index, VXD, by employing several GARCH models in a model-based out-of-sample context. Besides, it explores the reasons behind the differences in the forecasting ability of CIVs and VXD through a decomposition of the model-free implied volatility. In addition, it addresses the economic difference among aforementioned implied volatility measures in a simulated options market. We find that narrow-corridor CIVs outperform wide-corridor CIVs and VXD in terms of the forecasting ability, as wide-corridor CIVs and VXD impound information from deep out-of-the-money options whose prices contain large volatility risk premiums and may not reflect a fair market expectation of volatility. In the economic sense, wide-corridor CIVs and VXD outperform narrow-corridor CIVs in turbulent periods, while narrow-corridor CIVs outperform wide-corridor CIVs and VXD in medium- and low-volatility periods. The profitability pattern is consistent both in-sample and out-of-sample, before and after transaction costs are considered, and is also robust to option strategy choices.

Keywords: Corridor implied variance, model-free implied volatility, information content, volatility forecasting, GARCH models, option trading strategy

1 Introduction

Option-implied volatility continues to occupy a prominent role as an information source in forecasting future asset return volatility; see Figlewski (1997), Poon & Granger (2003), Gonzalez-Perez (2015) for a review. The rationale behind the argument that implied volatility reflects a fair market expectation of future asset return volatility is the belief that financial markets are informationally efficient: as risk-hedging instruments, options impound all the information about market participants' view on the future return volatility, and markets make efficient forecasts based on the available information. Thus, implied volatility is an unbiased market forecast of assets' future return variations.

Corridor implied variance (CIV) introduced by Carr & Madan (1998), Andersen & Bondarenko (2007) is originally served as a coherent fix to the model-free implied volatility (MFIV) based on the finding that an economically varying range of strikes generates artificial jumps in the volatility index. Andersen, Bondarenko & Conzalez-Perez (2011*a*,*b*), Andersen, Bondarenko & Gonzalez-Perez (2015) who find that their VIX replication is severely biased during the height of the flash crash due to a drain of liquidity in the options market, which generates artificial jumps that have economic significance, suggest noises in the MFIV depends on the option market microstructure. Evidence is also reported in favor of significant jump components in the model-free VIX. Notably, Becker, Clements & McClelland (2009) find that VIX is informative about market jump activities that option prices can predict. Bailey, Zheng & Zhou (2014) find that a large portion of VIX variability links to trader behaviour and macroeconomic fundamentals.

The rationale behind the argument that CIV is a superior information source for volatility forecasting to other implied measures is the consensus that volatility risk premiums significantly distort the

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market volatility expectations. CIV serves as a mechanism to mitigate the impact of volatility risk premiums (VRP) on the forecasting ability since these market volatility expectations are extracted from a range of options that are less sensitive to such impact (Andersen & Bondarenko 2007, Tsiaras 2010). Prokopczuk & Simen (2014) who find that VRP-adjusted model-free implied volatility significantly outperforms other competing volatility measures suggests that VRP significantly distorts market volatility expectations. Moreover, prices from deep out-of-the-money options misrepresent investors' view on the market volatility due to the illiquidity of such options, as a result, tails of the RND is estimated with less precision, indicating that tail risks may handicap the forecasting ability of wide-corridor CIVs. Extensive Literature have documented that large volatility risk premiums exist in the downside risk; see, e.g. Carr & Wu (2009) and Andersen & Bondarenko (2010). Results of Dotsis & Vlastakis (2016) suggest that out-of-the-money put index option prices are driven mainly by the market demand and supply pressure as hedgers seek insurance against market downside movements (Bollen & Whaley 2004, Garleanu, Pederson & Poteshman 2009). However, it should be noted that there is a mismatch between the use of CIV to forecast future realized volatility and its economic interpretations.

The use of CIV as an information source to forecast future realized volatility originates from Andersen & Bondarenko (2007) who find that corridor-fixed model-free implied volatility is more correlated to future realized volatility than the MFIV and VIX, and certain narrow CIV outperforms the at-the-money Black-Scholes implied volatility (BSIV). Tsiaras (2010) examine the forecasting ability of CIVs with different corridors from a symmetric cut of the risk-neutral distribution (RND) for individual stocks from DJIX 30 and find that CIVs with a wider corridor provide better forecasts than both BSIV and MFIV do. Muzzioli (2013), however, compare the forecasting performance of CIVs with both symmetric and asymmetric cut of the RND for the Italian stock index, and find, in contrast to the findings of Tsiaras (2010), that narrow-corridor CIV outperforms wide-corridor CIV; and they also find that CIV computed from the downside of the RND provides more accurate forecasts than CIV computed from the upside of the RND, which sharply contradicts from the results of Dotsis & Vlastakis (2016) who provide evidence that only upside risk is priced in cross-section stock returns, and subsumes all the relevant information for forecasting future volatility.

The goal of this paper is threefold. By employing DJX options data over around ten and a half years, first, we investigate the ability of CIVs with different corridors to forecast conditional volatility by using several GARCH models which incorporate the implied volatility measure, and compare their forecasting ability to that of a CBOE volatility index, VXD. Second, we investigate the forecasting ability of different price intervals of the RND through a decomposition of the corridor-fixed MFIV. Third, we examine the economic difference among CIVs and VXD in a simulated options market.

We make several contributions. First, we are the first to examine the performance of CIV to forecast conditional volatility in a model-based out-of-sample framework. Most prior work on the information content of implied volatility measures is purely in-sample on a priori grounds, which includes the work on the CIV: Andersen & Bondarenko (2007) for the S&P 500, Muzzioli (2010, 2011, 2013) for the Italian stock index, and Tsiaras (2010) for 30 component stocks from DJIA index. Instead of using implied volatility as a direct forecast of volatility, a distinct method is to use GARCH models which incorporate implied volatility in the conditional variance equation (we term this kind of GARCH models "GARCH-IV" models hereafter in the paper). Regression based methods of testing the forecasting ability of implied volatility measures are heavily affected by several factors: (1) measurement errors (e.g. liquidity concerns, nonsynchronous prices, inconsistency of the strike range) attribute to noisy implied volatility measures, which causes an "error-in-variable" problem; (2) the overlapping of forecast horizons of implied volatility measures leads to correlated forecast errors in the linear regression. Those problems are conventionally dealt with the instrumental regression which allows one to obtain a consistent and unbiased coefficient estimate; see Christensen & Prabhala (1998), Giot (2002), Corrado & Miller Jr. (2005), Bakanova (2010). In contrast, GARCH-IV models provide a way which is orthogonal to aforementioned factors to explore the incremental information of implied volatility measures about the future conditional volatility in addition to historical volatility. Moreover, most prior research works, including Giot (2002, 2003), Day & Lewis (1992), Xu & Taylor (1995) among others, use GARCH-IV models to compare the forecasting ability of different volatility measures in an in-sample context. However, as stated by Taylor (2005), the task of in-sample forecasting is to choose appropriate model parameters; the information about the future should be used for out-of-sample forecasting purposes on a rolling basis, rather than direct the selection of model parameters. In addition, in-sample forecasting may produce misleading results on the pecking order of the forecast accuracy (Dimson & Marsh 1990). Therefore, model-based out-sample framework is essential and important to access the forecasting ability of implied volatility measures.

Our second contribution is that we provide a comprehensive examination of the economic difference between different model-free implied volatility measures, which is missing in most prior volatility forecasting literature; and more importantly, our way of evaluation distinguishes itself from a test of market efficiency or forecast accuracy. Instead of looking for implied volatility measures with statistically significant non-zero mean returns or Sharpe ratios, we compare the difference between the profitability of CIVs and VXD by using a bootstrap t-test of certain performance measurements. As argued by Engle, Hong, Kane & Noh (1993), the arbitrage evaluation is a joint test of volatility forecast accuracy and market efficiency. Accordingly, significant non-zero mean rates of returns and Sharpe ratios from option trades can convey two pieces of messages: (1) volatility forecast is accurate, which indicates a correct model specification that is used for volatility forecasting, or a rich information content about the future volatility of the underlying asset price from some implied volatility measures; (2) the underlying asset price adjustment mechanism is irrational (market is inefficient), arbitrage opportunities exist in the market. However, (1) is potentially problematic as the profitability of option trades in the volatility information does not necessarily produce unbiased rankings of volatility forecast accuracy for two reasons. First, profitability is subject to the model risk (Chen & Leung 2003, Engle et al. 1993). Model risk comes from two sources: (1) errors introduced during the procedure of volatility forecasting, and (2) errors embedded in a specific option pricing model. Second, market imperfections (i.e., transaction costs, margin requirements) hind the profitability of competing volatility forecasts (Jha & Kalimipalli 2010, Santa-Clara & Saretto 2009, Figlewski 1989). Therefore, statistically significant non-zero mean returns and Sharpe ratios of option trades only convey the information about the efficiency of the market rather than volatility forecast accuracy, yet they don't reveal the economic difference among implied volatility measures. Thus a pairwise comparison between the trading performance of implied volatility measures is necessary for unveiling the difference among implied volatility measures in the economic sense. The reason for employing a bootstrap is because the return distribution of option trades in the volatility information are not normally distributed (even non-i.i.d.) for most implied volatility measures, which invalidates the use of standard critical values that are used to access the statistical significance of a test.

Our primary findings are as follows. Firstly, narrow-corridor CIVs outperform wide-corridor CIVs and VXD significantly in terms of conditional volatility forecasting performance, and the result is robust to the model choice. Secondly, deep out-of-the-money put options do not contain any information about future volatility, while near-the-money put options and out-of-the-money call options are informative about volatility. Thirdly, in terms of profitability, wide-corridor CIVs and VXD outperform narrow-corridor CIVs during market turmoil, and narrow-corridor CIVs outperform wide-corridor CIVs and VXD in medium- and low-volatility periods. Those patterns are consistent both in-sample and out-of-sample, before and after transaction costs are considered. Our results indicate that tail risks, especially left tail risks, distort the market volatility expectations, which handicap the forecasting ability of wide-corridor CIVs that impound information from options with strikes spanning a wide interval of the risk-neutral distribution. However, tail risks are found to be informative in high-volatility periods.

The paper unfolds as follows. In Section 2, we briefly introduce and discuss three market expectations of volatility: the BSIV, MFIV, and CIV, and their economic interpretations, and review some of the prior literature on the forecasting ability of aforementioned implied volatility measures. Section 3 provides a description of data sources and data processing procedures. Section 4 presents model specifications and out-of-sample performance of CIVs and VXD in forecasting conditional volatility. We examine the forecasting ability of different price intervals of the RND in Section 5. In Section 6, we carry out a trading simulation to examine the difference between the profitability of CIVs and VXD. Section 7 concludes the paper.

2 Market Expectations of Volatility

2.1 Black-Scholes Implied Volatility, BSIV

BSIV, either at-the-money BSIV or functions of at-the-money BSIV, is conventionally used as the risk-neutral market volatility expectation by numerous literature; see Poon & Granger (2003), Figlewski (1997) for a review. The rationale of aforementioned use of BS implied volatility has its root in the Efficient Market Hypothesis (EMH). According to EMH, if options markets are informationally efficient, option prices should reflect all the information that affect security prices and impound all the information that are relevant to the future return variations of the underlying asset. If option prices do not contain the optimal forecasts of future volatility of the underlying asset price, arbitrage trading strategies will be available and ultimately push option prices to the level that reflects the optimal forecasts of future asset return volatility (Figlewski 1997).

However, due to the assumption of deterministic volatility in the Black-Scholes model, there's no economic interpretation of such use of BSIV as market volatility expectation. Although Carr & Lee (2009) justify the economic motivation of using at-the-money BSIV as market volatility expectation by showing that at-the-money BSIV approximates the volatility swap rate, however, the use of at-the-money BSIV has to be with caution. The argument that at-the-money BSIV accurately approximates the volatility swap rate is only valid under three assumptions about financial markets: 1) no arbitrage is available in the market; 2) there are no erratic movements (e.g. price jumps) in the underlying asset price dynamics; 3) instantaneous volatility changes are uncorrelated with changes in price (Carr & Lee 2009). In fact, those assumptions are generally violated by the market, thus BSIV is a noisy market forecast of future return volatility.

Latane & Rendleman (1976), Chiras & Manaster (1978), Beckers (1981), Day & Lewis (1993), Jorion (1995) report that the BSIV or functions of BSIV provide better estimates of the future volatility than either the standard deviation calculated from historical prices or the conditional volatility obtained from GARCH models. In contrast, Canina & Figlewski (1993), Lamoureux & Lastrapes (1993) show that the BSIV is a biased forecast proxy and contains little information about the future volatility. Fleming (1998), Christensen & Prabhala (1998), Hansen (2001) find that the at-the-money BSIV from S&P 100 index options is an upward biased forecast of the realized volatility of the S&P 100 index, but has a superior forecasting performance to the historical volatility. Pong, Shackleton, Taylor & Xu (2004) compare the forecasting ability of intraday currency volatility and implied volatilities, and find that for one-day and one-week forecast horizons implied volatilities are as accurate as historical volatility forecasts, historical high-frequency volatility forecasts contain significant incremental information that is beyond the information contained in the implied volatility for short forecast horizons.

2.2 Model-Free Implied Volatility, MFIV

An orthodox way to obtain the market expectation of asset return volatility is through variance contracts. MFIV developed by Carr & Madan (1998), Demeterfi, Derman, Kamal & Zou (1999) is a synthesized variance swap rate. A variance swap can be seen as a forward contract which pays its holder an amount equal to the difference between the (no-barrier) realized variance of the underlying asset price and the variance swap rate. The variance swap rate, also called the variance strike of the variance swap, is a predetermined quantity when a variance contract is initiated; and like all other swaps, this quantity is chosen that the expected payoff of the variance swap is zero so that the contract is free to enter. Therefore, the variance swap rate represents the market expectation of the realized variance of the underlying asset over a future period. Since variance swaps are traded over-the-counter, the variance swap rate is not obtainable; a static replication of the variance swap rate is achievable by using a continuum of out-of-the-money European call and put options with weights equal to the reciprocal of the squared option strikes. Therefore, the (annulized) MFIV can be expressed in the following form:

$$\begin{aligned} E_0^{\mathbb{Q}}[RV] &= \frac{2e^{rT}}{T}\Big[\int_0^{F_0}\frac{P_0(K,T)}{K^2}\mathrm{d}K+\int_{F_0}^{\infty}\frac{C_0(K,T)}{K^2}\mathrm{d}K\Big] \\ &= \frac{2e^{rT}}{T}\int_0^{\infty}\frac{M_0(K,T)}{K^2}\mathrm{d}K \end{aligned} \tag{1}$$

where RV is the (no-barrier) realized variance over the period $[0,T]$; F_0 is the forward price at time 0; C_0 and P_0 are spot prices of out-of-the-money European call and put options, respectively; M_0 is the minimum of C_0 and P_0; r is the risk-free rate, T is the option's time to maturity.

Becker, Clements & White (2006) find the VIX is an inefficient proxy for the future realized volatility, whereas Jiang & Tian (2005) replicates the VIX from end-of-day SPX options data and find that the VIX replication not only contains the information in the BSIV but also subsumes the information in the historical volatility. Blair, Poon & Taylor (2001) compare the incremental information of VIX and high-frequency intraday returns in both in-sample and out-of-sample contexts. They find that VIX provides the most accurate volatility forecasts for all forecast horizons and performance measures whereas high-frequency intraday returns contain no significant information about the future volatility. Taylor, Yadav & Zhang (2010) compare the information content of historical volatility obtained from the ARCH model, at-the-money BSIV and model-free implied volatility in an out-of-sample context, and find that model-free implied volatility is more informative for firms with more actively traded options than historical volatility, and is inferior to at-the-money BSIV in general.

2.3 Corridor Implied Variance, CIV

CIV is economically interpreted as the replicated corridor variance swap rate. A corridor variance swap, an exotic version of a variance swap, can be seen as a forward contract which pays a premium on the realized variance when the underlying asset price is within a certain range. A corridor variance swap has a fixed leg which is the corridor variance swap rate, and a floating leg which is the corridor realized variance (realized variance calculated when the underlying asset price lies within a certain range); the quantity of the corridor variance swap rate is chosen so that the corridor variance swap has a zero-expected payoff. Therefore, the corridor variance swap rate represents a fair expectation of the corridor realized variance over the life time of the contract. A rigorous treatment of the corridor variance swap can be referred to Carr & Lewis (2004), Andersen et al. (2015). A static synthesis of the corridor variance swap rate by using out-of-the-money European call and put options is defined as:

$$\begin{aligned} E^{\mathbb{Q}}[RV_{B_l\le S\le B_u}] &= \frac{2e^{rT}}{T}\Big[\int_{B_l}^{F_0}\frac{P_0(K,T)}{K^2}\mathrm{d}K+\int_{F_0}^{B_u}\frac{C_0(K,T)}{K^2}\mathrm{d}K\Big] \\ &= \frac{2e^{rT}}{T}\int_{B_l}^{B_u}\frac{M_0(K,T)}{K^2}\mathrm{d}K \end{aligned} \tag{2}$$

where $RV_{B_l\le S\le B_u}$ is the realzied variance when the underlying asset price S is within the range $[B_l,B_u]$. $M_0(K,T)$ is the minimum of the spot prices of out-of-the-money Europeran call and put options.

Jiang & Tian (2005, 2007) study the errors introduced by numerical methods in implementing the MFIV, and propose several methods to mitigate the impact of those errors; however, approximation errors do not account for all the bias of the MFIV as a fair market expectation of future realized volatility. Andersen & Bondarenko (2007), Andersen et al. (2011*a*, 2015) investigate the behaviour of intraday high-frequency MFIV series extracted from S&P 500 index options in awareness of problems in computing MFIV due to the sparse strike points of available options. They find that the calculated MFIV is actually a CIV, and the effective range of the upper and lower strike limits vary stochastically with the forward price; and the inconsistency of the strike range used over time in computing the model-free implied volatility introduces jumps into the calculated model-free implied volatility, especially during the market turmoil (they use the example of a flash crash). Specifically, the MFIV (represented by a VIX replication in their studies) is severely downward biased when the effective strike range dramatically narrows during the height of the crash due to a drain of market liquidity, and is upward biased when the effective range is widened well beyond the level before the crash. As a result, they propose to choose the strike range that is consistent with the option-implied RND. The rationale behind the choice of the option-implied RND is that under the risk-neutral probability the risk-neutral underlying asset price is only possible to lie within the upper and lower strike limits which correspond to a selected upper and lower risk-neutral probabilities[1], respectively. And yet the RND function satisfies the requirement that the strike price which corresponds to 0.5 risk-neutral probability equals the forward price.

3 Data

Data used in this paper are obtained from several sources. We compute corridor implied variance indices from daily end-of-day DJX options (underlying: Dow Jones Industrial Average) obtained from the Chicago Board Options Exchange (CBOE). Daily DJIA index level and daily dividend yields are downloaded from the DataStream; The market-offered model-free implied volatility index, VXD (extracted from DJX options by the CBOE), is downloaded from Federal Reserve Economic Data (FRED) of the Federal Reserve Bank of St. Louis. Our sample period is from October 1, 2004 to March 6, 2015, and there are 2625 trading days in total. DJX options are European style, and have up to three near-term expiration months and up to three months on the March quarterly cycle (March, June, September and December), and may also have up to five years to maturity Leaps. Detailed procedures for data set construction are presented in Appendix.

Daily treasury yield curve rates, commonly referred as ”constant maturity treasury” rates (CMTs), are used as our risk-free rates and are obtained from the Board of Governors of the Federal Reserve System. Various maturities are available, including one-month, three-month, six-month, one-year, two-year rates and so on, and there are up to thirty-year rates available. Interest rates with intermedia maturities are linearly interpolated, and interest rates with maturities that are beyond available ranges are estimated by a natural cubic spline extrapolation.

Mid bid-ask prices are used as options prices due to the fact that the bid-ask spread introduces random noises to the implied volatility [e.g. Bounce effect of Bakshi, Cao & Chen (1997, 2000)], especially for nearby deep ITM options, one can eliminate the spread effects by using the mid-point of bid and ask prices instead of transaction prices (Figlewski 1997), and this is followed by many studies in options markets, e.g., Jiang & Tian (2005, 2007, 2010). Option’s time to maturity is calculated by the number of calendar days remaining to maturity less one (Dumas, Fleming & Whaley 1998).

4 Out-of-Sample Forecasting Performance

4.1 Volatility Measures

We numerically implement **Eq.**2 in the following form:

$$CIV = \frac{e^{rT}}{T}\sum_{i=1}^{m}\Big[g(K_i)+g(K_{i-1})\Big]\Delta K \tag{3}$$

where $g(K_i) = M_0(K_i,T)/K_i^2$, $\Delta K = (B_u - B_l)/m$, $K_i = B_l + i\Delta K$, $B_l, B_u = R^{-1}(p_l), R^{-1}(p_u)$. $R^{-1}(\cdot)$ is the empirical cumulative risk-neutral probability distribution function. As described by Jiang & Tian (2005, 2007), a large m eliminates the discretization error , we choose $m = 6000$ in this paper. Since the available strike price points are sparse, a natural cubic spline interpolation and a flat extrapolation[2] of the implied volatility with respect to options moneyness[3] are used to obtain option prices with intermedia strikes and strikes that are beyond the available range. Two sets of options with maturities closest to 30 (calendar) days are used to construct the corridor implied variance: near-term options with maturities smaller than 30 days and next-term options with maturities larger than 30 days. Applying **Eq.**3, near-term and next-term corridor implied variance CIV_{near} and CIV_{next} are obtained. Following the CBOE’s convention, corridor implied variance used in this paper is the linearly interpolated 30-day corridor implied variance by using CIV_{near} and CIV_{next}.

The RND is extracted from a cross section of option prices and approximated by the ratio statistic,

$R(K)$, which is formally proposed by Andersen et al. (2015) and defined as

$$R(K) = \frac{P(K)}{C(K) + P(K)} \tag{4}$$

where C, P are call and put option prices, respectively. This method overcomes the drawbacks of percentile-based methods, details are described in Andersen et al. (2011*a*). The statistic is a monotonically increasing function of the strike price. Therefore, for each chosen risk-neutral probability there must be a single corresponding strike price. We only consider a symmetric cut of the RND to construct CIVs, which means the lower and upper risk-neutral probabilities satisfy $p_l + p_u = 1$. We choose $p_l = 0, 0.01, 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45$, and denote the respective CIVs as CIV_0, CIV_1, CIV_5, CIV_{10}, CIV_{15}, CIV_{20}, CIV_{25}, CIV_{30}, CIV_{35}, CIV_{40}, CIV_{45}. For example, CIV_{20} is a corridor implied variance that is computed with lower and upper strike limits which correspond to risk-neutral probabilities of 0.2 and 0.8, respectively.

Daily realized volatility is calculated by the Parkinson's estimator of Parkinson (1980):

$$\sigma^2_{RV,t} = \frac{\ln(\text{High}_t) - \ln(\text{Low}_t)}{4\ln(2)} \tag{5}$$

where High_t and Low_t are daily high and low index levels, respectively.

4.2 *Model Specification and Volatility Forecasts*

Despite the economic interpretation of CIV, we explore the ability of CIVs and VXD in forecasting conditional volatility. In contrast to numerous prior research works in examining the information content of market volatility expectations, the forecasting performance is investigated in an out-of-sample context, which is very rare in the literature. Blair et al. (2001) use a TGARCH(1,1) specification which incorporates the model-free implied volatility measure and high-frequency realized volatility to study the incremental information content of implied volatility measures and index returns for S&P 100 index. Taylor et al. (2010) use a slightly variant, TGARCH(1,1)-MA(1), which incorporates the MFIV and at-the-money BSIV to study the forecasting performances of different implied volatility measures for a large number of individual stock options.

Similar to Blair et al. (2001), Taylor et al. (2010), we employ the TGRACH(1,1)-IV specification which is in the following form:

$$\begin{aligned}
&\ln\frac{P_t}{P_{t-1}} = \mu + \varepsilon_t \\
&\varepsilon_t|\Phi_{t-1} \sim N(0, h_t) \\
&h_t = \frac{\alpha_0 + \alpha_1\varepsilon^2_{t-1} + \theta\varepsilon^2_{t-1}1(\varepsilon_{t-1} < 0)}{1-\beta L} + \frac{\delta\sigma^2_{imp,t-1}}{1-\beta_v L}
\end{aligned} \tag{6}$$

where L is the lag operator, N is the normal density, Φ_t is the avaiable information set at time t, h_t is the conditional variance of asset returns, $1(\varepsilon_{t-1} < 0)$ is the indicator function: it equals 1 when $\varepsilon_{t-1} < 0$ and 0 otherwise. $\sigma_{imp,t}$ is the market volatility expectation term which is represented by either CIVs or VXD at time t.

There are two restricted versions of the TGARCH(1,1)-IV model as shown in **Eq.**6: (1) a volatility model that uses daily index returns alone when $\delta = 0$; (2) a volatility model that uses information in the market volatility expectation without explicit use of daily index returns when $\alpha_1 = \theta = 0$. We compared the in-sample volatility forecasting performance of aforementioned two restricted models with the unrestricted models by a log-likelihood ratio test, and we found that the unrestricted model consistently outperform restricted models significantly at 1% significance level[4]. Therefore, we only focus on the unrestricted model in comparing the out-of-sample forecasting performance. Thus, strictly speaking, the results of the out-of-sample volatility forecasts answer the question about the incremental information content of market volatility expectations.

The model is estimated by maximizing the log-likelihood function with respect to the normal density[5]. The following parameter constraints are imposed to ensure the non-negativity of the estimated conditional variance: $\alpha_1 \geq 0$, $\alpha_1 + \theta \geq 0$, $\beta \geq 0$ and $\beta_v \geq 0$. σ_{imp} is either CIV or VXD divided by 252 because market volatility expectations are all expressed in annualized variance, they should be rescaled to daily variances for model estimation.

We use a rolling-window forecasting technique to out-of-sample forecast the conditional variance of DJIA index returns. At each forecast origin, we use past 1000 observations of DJIA index returns and market volatility expectations to estimate the aforementioned model, and use the estimated parameter to compute out-of-sample forecasts. Since only lag 1 market volatility expectation is available at each forecast origin, the calculable forecast is one-day ahead conditional variance forecast, whereas multi-horizon forecasts are not computable by dynamic forecasting. The multiplicative method in Blair et al. (2001) by multiplying one-day ahead volatility forecast by the number of days in the forecast horizon may handicap the forecasting performance of market volatility expectations due to the stochastic feature of volatility; discussions and empirical research work on the square-root-of-time rule for compounding short-term volatility for long-horizons can be referred to Diebold, Hickman, Inoue & Schuermann (1998), Danielsson & Zigrand (2006), Balaban & Lu (2016).

4.3 One-day ahead conditional volatility forecasts

Table 1 reports the specifications of seven loss functions which include MAE, MAE-SD, MAE-LOG, MSE, MSE-SD, MSE-LOG and QLIKE. MAE and MAE-SD are indicators of absolute errors, whereas MSE and MSE-SD are indicators of squared errors. MAE-LOG, MSE-LOG and QLIKE penalize more on negative forecast errors (under-predictions).

Table 2 reports the relative forecast accuracy statistics that consist of means of aforementioned seven loss functions in the TGARCH-IV model framework. Relative statistic is the ratio between the error statistics of each CIV and that of the worst performing CIV. Rank is based on the relative statistics. R^2 statistic is obtained from regressing the realized daily variance on conditional volatility forecasts. P is the proportion of explained variability which is linear in the mean squared error; a larger value of P corresponds to a superior forecast accuracy. We also report the percentage of over-predictions.

We first focus on the means of loss functions. MAE, RMSE and MSE-SD suggest that CIV_{30} provides the most incremental information about future conditional volatility, whereas the other four loss functions (MAE-SD, MAE-LOG, MSE-LOG and QLIKE) are in favor of CIV_{45} in terms of information content in the TGARCH-IV framework. The discrepancy in the rankings of forecasting performance is mostly attributed to the different levels of over-predictions as MAE-LOG, MSE-LOG and QLIKE put more weight on the forecast accuracy for volatility peaks than valleys, and that CIV_{45} has the lowest percentage of over-predictions, standing at 77.31%, validates our claim. The widest-corridor CIV CIV_0 and VXD have the worst out-of-sample performance of forecasting conditional volatility. Narrow-corridor CIVs, from CIV_{30} to CIV_{45}, consistently have a better forecasting performance than wide-corridor CIVs and VXD, though there seems no linear relationship between corridor-width and out-of-sample forecasting performance. All CIVs and VXD overestimate the conditional volatility of DJIA index returns in more than 77% of periods of time. However, all relative statistics are close to 1, which indicates the small difference between the incremental information about future conditional volatility for the implied volatility measures.

We next look at the results based on R^2 and P. CIV_{30} outperforms all other CIVs, and VXD performs worse than CIVs based on both statistics. Except CIV_{35}, narrow-corridor CIVs, from CIV_{25} to CIV_{45}, outperform wide-corridor CIVs and VXD. CIV_0 consistently outperforms VXD, which may indicate a coherent MFIV behaves well than MFIV in a way that it reduces biases introduced by inconsistent corridors, which in turn improves the forecasting ability.

There are several reasons that have been put forward to explain why error and correlation based evaluation metrics have diverse views on the forecasting ability. We use R^2 as an example. Firstly, the correlation between biased forecasts and realized values is likely to be higher than the correlation between unbiased forecasts and realized values, which makes R^2 a bad standard to judge the forecast accuracy, especially when it is used ex ante (Taylor 2005). Secondly, R^2 is forced to be bounded when it is used to measure the correlation of forecasts of squared returns (Andersen & Bollerslev 1998). Thirdly, the ex post optimization of parameters in the linear combination of forecasts and realized values guarantees a larger value of R^2 than error-based proportion metric (Taylor 2005), leading to well diverse views on the pecking order of forecasting methods/information sources based on aforementioned evaluation metrics, which means the ranking of the forecast accuracy is loss-function dependent.

However, the error and correlation based evaluation metrics don't give a view on the statistical significance of the superiority of the forecasting performance of each CIVs. To access the statistical significance of the forecasting ability, similar to Koopman, Jungbacker & Hol (2005), we run the Superior Predictive Ability (SPA) test of White (2000), Hansen (2005). We follow Politis & Romano (1994) for the implementation of stationary bootstrap which is required by the SPA. We also follow Politis & White (2004), Politis, White & Patton (2009) to implement an auto block-length selection for the stationary bootstrap. The null hypothesis of the SPA test is that base model is not inferior to any alternative models. The p-value of the SPA test indicates the intensity of the base producing superior forecasts, and a p-value of 1 indicates that the base outperforms all other alternatives.

Table 3 reports the results of the Superior Predictive Ability (SPA) test. Three kinds of p-values are reported: consistent p-value p_c, and its lower bound P_l and upper bound p_u. Our focus here is the consistent p-values p_c only. For loss functions MAE, MSE and MSE-SD, CIV_{30} has a p-value of 1 which indicates CIV_{30} outperforms all other CIVs and VXD. For MSE-SD, MAE-LOG, MSE-LOG and QLIKE, CIV_{45} outperforms all other CIVs and VXD, with a p-value of 1. Wide-corridor CIVs, e.g. CIV_0 to CIV_{10}, and VXD, have smaller p-values than narrow-corridor CIVs do. The results of the SPA test confirm the results from error-based forecast evaluation metrics in a population sense.

4.4 Alternative Models

As a robustness check, we employ three other GARCH class models which also incorporate the implied volatility in the conditional variance equation, namely GARCH(1,1)-IV, EGARCH(1,1)-IV and NAGARCH(1,1)-IV models. Detailed model specifications, their restricted versions and parameter constraints are listed in Table 4. The procedure of out-of-sample conditional volatility forecasts is the same as described in Section 4.2. Similarly, only one-day ahead conditional volatility forecast is considered.

Table 5 reports the relative forecast accuracy of CIVs in alternative models. The first panel reports the results based on the GARCH-IV model. CIV_{35} has the best performance based on RMSE, while all other loss functions point to CIV_{30} as the best forecaster. Wide-corridor CIVs from CIV_0 to CIV_{10} and VXD have larger forecast errors than narrow-corridor CIVs from CIV_{15} to CIV_{45}. Interestingly, CIV_{45} no longer performs better than its wider-corridor counterparts. There seems to be a relation between corridor width and the forecasting performance among wide-corridor CIVs: the better the forecasting performance, the narrower the corridor. CIV_{45} has the lowest over-predictions with a percentage value of 78.29%, whereas CIV_0 has the largest over-predictions with a percentage value of 79.77%. R^2 and P have a slightly different view on the forecasting ability. The best performance zone moves to wider-corridor CIVs: CIVs from CIV_{10} to CIV_{35} outperform other CIVs which include two CIVs with the narrowest corridors, CIV_{40} and CIV_{45}. The second panel reports the result from EGARCH-IV model. Except R^2, all other evaluation metrics show a clear pattern of the forecasting ability of CIVs: the forecasting ability improves when corridor narrows. CIV_{45} outperforms all other CIVs and VXD in all evaluation catalogues. CIV_0 and VXD again have the worst performance. The third panel of Table 5 reports the results based on NAGARCH-IV. Similar patterns to that of GARCH-IV are presented by NAGARCH-IV. CIV_0 and VXD are inferior to other CIVs, whereas CIV_{30} and CIV_{35} have the best performance based on different metrics. CIVs from CIV_{15} to CIV_{35} are superior to other CIVs, including narrowest-corridor CIVs CIV_{40} and CIV_{45}.

Table 6 presents on the SPA test results for alternative models. Loss functions which emphasize on underestimations indicate CIV_{45} outperforms all other CIVs with a p-value of 1. Other loss functions, MAE, MSE and MSE-SD, are in favor of CIV_{30}. CIV_0, VXD, CIV_1, CIV_5 and CIV_{10} with low p-values are inferior to other CIVs in terms of the ability to forecast conditional volatility.

In sum, although slightly different rankings of CIVs are given by different models, which might be attributed to the different characteristics of GARCH models, the general picture is consistent: CIV_{30} and CIV_{45} consistently outperform other CIVs and VXD based on various evaluation metrics in all GARCH settings, with loss functions which emphasize on under-predictions being in favor of CIV_{45}. Wide-corridor CIVs such as CIV_0 and CIV_1, and the CBOE VXD underperform other narrow-corridor CIVs.

There seems an optimal corridor for forecasting conditional volatility. The explanation we propose here is that there seems to be a trade-off between cutting illiquid deep out-of-the-money options and an information loss in the tails of the risk neutral distribution, especially on the upside (call option side) of the risk neutral distribution since volatility risk premiums are more prominent in the downside risk than in the upside risk (Andersen & Bondarenko 2010).

5 Forecasting Ability of Different Risk-Neutral Price Intervals

5.1 Decoposition of the Model-Free Implied Volatility

Next we investigate the forecasting ability of different risk-neutral price intervals through a decomposition of MFIV to explain why narrow-corridor CIVs have a better forecasting performance than wide-corridor CIVs and VXD do. A corridor-fixed MFIV can be written as the sum of upside and downside risks (Andersen & Bondarenko 2010). In this section, we further decompose both upside and downside risks into several CIVs with the same bandwidth of the strike corridor. The bandwidth of the strike range is chosen to be consistent with the RND. We choose a bandwidth which is equal to 5% risk-neutral probability. Specifically, the corridor-fixed MFIV is decomposed as follows:

$$\begin{aligned} E^{\mathbb{Q}}[RV] =& E^{\mathbb{Q}}[RV_{S<F_0}] + E^{\mathbb{Q}}[RV_{S\geq F_0}] \\ =& E^{\mathbb{Q}}[RV_{R^{-1}(0)\leq S\leq R^{-1}(0.05)}] + E^{\mathbb{Q}}[RV_{R^{-1}(0.05)\leq S\leq R^{-1}(0.1)}] + \cdots \\ &+ E^{\mathbb{Q}}[RV_{R^{-1}(0.45)\leq S\leq F_0}] + E^{\mathbb{Q}}[RV_{F_0\leq S\leq R^{-1}(0.55)}] + \cdots \\ &+ E^{\mathbb{Q}}[RV_{R^{-1}(0.95)\leq S\leq R^{-1}(1)}] \end{aligned} \tag{7}$$

where $R^{-1}(0.5) = F_0$, $R^{-1}(\cdot)$ is the RND. The decomposition allows us to examine the forecasting ability of different price intervals of the RND. We denote $E^{\mathbb{Q}}[RV_{R^{-1}(p_1)\leq S\leq R^{-1}(p_2)}]$ as $\text{CIV}_{p_1-p_2}$

5.2 Results

An encompassing test is carried out by regressing monthly realized volatility on monthly CIVs extracted from price intervals on the left side of the RND and CIVs extracted from price intervals on the right side of the RND. Table 7 reports the result of this encompassing test. The coefficients of CIVs extracted from the left side ($\text{CIV}_{0-0.05}$, $\text{CIV}_{0.05-0.1}$, $\text{CIV}_{0.1-0.15}$, $\text{CIV}_{0.15-0.2}$, $\text{CIV}_{0.2-0.25}$) are not significantly different from zero, while the coefficients of the corresponding CIVs extracted from the right side are consistently significantly different from 0. Except the price interval that corresponds to a risk-neutral probability from 0.45 to 0.5, the coefficients of CIVs extracted from price intervals with risk-neutral probabilities from 0.25 to 0.45 on the left (put option) side of the RND and their corresponding CIVs on the right (call option) side [6] are all significantly from 0. The results indicate that deep out-of-the-money put options (whose strike prices correspond to a risk-neutral probability that is smaller than 0.25) does not contain any information about the future volatility, while near-the-money put options do contain volatility information. Out-of-the-money call options contain significant information about the future volatility.

6 Economic Analysis

In this section, we examine the difference between the profitability of CIVs and VXD based on options trading. Option strategies are constructed to only allow speculations on the volatility information. The volatility information is the information about the extent to which the underlying asset price moves. There are two types of option strategies that allow investors to speculate on the volatility information, namely straddles and delta-hedged portfolios.

Strategies that involve at least one put contract are considered here as such strategies generate higher returns; see, e.g. Coval & Shumway (2001), Bakshi & Kapadia (2003), Jones (2006), Driessen & Maenhout (2007), Santa-Clara & Saretto (2009), Bondarenko (2014). To ensure that returns from straddles are orthogonal to any risks that are associated with higher moments of the underlying asset returns, we consider a straddle variant, the so-called "zero-beta straddle" (Coval & Shumway 2001).

Noh, Engle & Kane (1994) find that GARCH volatility forecasts generate greater profits by trading in at-the-money straddles than forecasts from an implied volatility regression do. Bakshi et al. (1997) find that for at-the-money options, stochastic volatility based option pricing models have a better hedging performance than models that take jumps and the interest rate term structure into consideration. Jha & Kalimipalli (2010) use at-the-money straddles, strips and straps to access the the forecast accuracy of different conditional skewness models and find that by combining with implied volatilities, the performance of trades in skewness significantly improves but weakens after transaction costs are considered. Lim, Chen & Yap (2015) find that risk-neutral skewness brings a significant profit even after transaction costs for E-mini S&P 500 weekly options.

The procedure of the trading simulation is as follows in an 'ex post ante' manner: each market agent holds a view about future market volatility based on selected CIVs and VXD. On day t they use their selected CIV on that day to obtain a price forecast for their option strategy. If the option portfolio is underpriced (overpriced), they buy (sell) this option portfolio. And on day $t+1$, they rebalance their option portfolios based on their volatility forecasts on day $t+1$; daily returns are then calculated. In addition, we allow market agents to borrow at the risk-free rate and to invest profits from option trades in the risk-free asset. Therefore, we deduct (add) a daily risk-free rate from (to) the daily rate of return. We focus on short-term options: only options with a maturity that is smaller 60 days are traded. To avoid wildcard options, we also exclude options with a maturity that is smaller than 7 days. If an option that is traded on day t cannot be found on day $t+1$, the rate of return for this option is then recorded as -1 in the book. The return sample is divided into three subsamples: high-, medium- and low-volatility periods subsamples according to realized volatility calculated from historical DJIA index levels.

In addition to the aforementioned in-sample trading simulation, we also address the impact of transaction costs, and the out-of-sample trading performance of CIVs and VXD in this section. An alternative option strategy is used as a robustness check.

Bootstrap t-tests are employed to access the statistical significance of mean rates of returns, Sharpe ratios, mean differences and Sharpe ratio differences. p-values for mean rates of returns and mean differences are calculated based on Efron & Tibshirani (1993) and Efron (1979); p-values for Sharpe ratios are based on Opdyke (2007); and p-values for Sharpe ratio differences are based on Ledoit & Wolf (2008) to account for non i.i.d. returns. All p-values are obtained from a two-sided bootstrap t-test. The bootstrap t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement.

6.1 Results of Zero-Beta Straddles

Table 8 reports the summary statistics for returns from option trades based on CIVs and VXD. Panel A summarizes the statistics of option trades in zero-beta straddles. Both straddle price forecasts and market straddle prices decrease with the decrease in CIV's corridor width, which is attributed to the fact that the level for CIV with a narrow corridor is lower than that for a wide-corridor CIV. The fraction of call options in the portfolio also decreases with the decrease in corridor width in the whole, medium-volatility and low-volatility periods, whereas the fraction of calls increases with the decrease in corridor width in high-volatility periods. In all periods, market agents who employ wide-corridor CIVs, e.g., from CIV_0 to CIV_5 and VXD, buy straddles from the market in most of the time during our sample period; and agents who hold a view on the market volatility based on narrow-corridor CIVs, e.g., from CIV_{20} to CIV_{45}, become option writers who purely sell option portfolios.

Panel B of Table 8 summarizes daily returns from option trades. Numbers in bold indicate significance at 5% significance level. In all periods, CIV_0, CIV_1 and VXD generate more number of negative returns than the number of positive returns, while other CIVs with narrower corridors make profits on more days than days with losses; the number of days with positive returns for narrow-corridor CIVs from CIV_{15} to CIV_{45} is almost the same. In the whole sample, only CIV_{10} is able to generate significant positive mean profits. In high-volatility periods, narrow-corridor CIVs from CIV_{30} to CIV_{40} generate both significant negative mean returns and Sharpe ratios, CIV_{45} generates significant losses whereas it delivers an insignificant Sharpe ratio. Only CIV_1 in the wide-corridor spectrum generates a significant positive Sharpe ratio. In medium-volatility periods, except for CIV_5, all other CIVs and VXD carry significant mean returns which are negative for wide-corridor CIVs, CIV_0 and CIV_1, and VXD, and are positive for narrow-corridor CIVs from CIV_{10} to CIV_{45}. However, none of the CIVs and VXD can deliver a significant Sharpe ratio. In low-volatility periods, only narrow-corridor CIVs from CIV_{15} to CIV_{45} could generate significant positive mean returns. Besides, for all samples, wide-corridor CIVs and VXD have a positive skewed return distribution, whereas narrow-corridor CIVs have a leptokurtic return distribution. The skewness (kurtosis) of returns decreases (increases) with a decrease in corridor width.

Panel C and D present the difference between mean returns and Sharpe ratios of each implied volatility measure in different periods, and their p-values based on a two-sided bootstrap t-test. The null hypothesis of the t-test is that there are no differences among mean rates of returns (or Sharpe ratios) in different periods for a specific implied volatility measure. For wide-corridor CIVs (CIV_0 and CIV_1) and VXD, the mean return and the Sharpe ratio in high-volatility periods are significantly larger than those in medium- and low-volatility periods at 5% significance level; in contrast, for narrow-corridor CIVs from CIV_{15} to CIV_{45}, the mean return and the Sharpe ratio in high-volatility periods are significantly smaller than those in medium- and low-volatility periods at 5% significance level. However, no significant differences in means and Sharpe ratios are found between medium- and low-volatility periods for all implied volatility measures.

To access the economic difference between CIVs and VXD, we run a two-sided bootstrap t-test of mean rates of returns and Sharpe ratios. The null hypothesis of the t-test is that there is no difference between mean rates of returns or Sharpe ratios that are delivered by different implied volatility measures.

Table 9 reports the results of bootstrap t-test of mean return differences, two-sided p-values are reported in parentheses. Despite that in the whole sample there are very few significant differences that can be found among mean rates of returns of CIVs, the pattern of the profitability of CIVs and VXD in all three subsamples is rather clear. In high-volatility periods, narrower-corridor CIVs, from CIV_{15} to CIV_{45}, perform significantly worse than wider-corridor CIVs from CIV_0 to CIV_5, since significant negative mean differences are found at 5% significance level. VXD is found to perform better than narrow-corridor CIVs from CIV_{15} to CIV_{45}. In medium-volatility periods, narrow-corridor CIVs from CIV_{15} to CIV_{45}, however, outperform wide-corridor CIVs CIV_0 and CIV_1. CIV_5 and CIV_{10} are also found to be better than wide-corridor CIVs CIV_0 and CIV_1. The profitability pattern changes slightly since narrow-corridor CIVs from CIV_{15} to CIV_{45} are indifferent from CIV_5 in the medium-volatility periods. Narrow-corridor CIVs from CIV_5 to CIV_{45} are found to outperform VXD. In low-volatility periods, the pattern is similar to that in medium-volatility periods: narrow-corridor CIVs from CIV_{10} to CIV_{45} outperform wide-corridor CIVs (CIV_0 and CIV_1), and VXD is again found to be inferior to narrow-corridor CIVs from CIV_{10} to CIV_{45}. No significant mean return differences are found among wide-corridor or narrow-corridor CIVs.

Table 10 reports the results of bootstrap t-test of the Sharpe ratio differences, p-values are reported in parentheses. For whole sample, very few significant differences can be found except for CIV pairs such as CIV_0 and CIV_5, CIV_1 and CIV_5, and CIV_5 and VXD. The pattern of the profitability in terms of the Sharpe ratio stays the same as that in terms of the mean rate of return. In high-volatility periods, wide-corridor CIVs from CIV_0 to CIV_5 outperform narrow-corridor CIVs from CIV_{15} to CIV_{45}. VXD outperforms narrow-corridor CIVs from CIV_{15} to CIV_{45}. In medium-volatility periods, narrow-corridor CIVs from CIV_5 to CIV_{45} outperform wide-corridor CIVs (CIV_0 and CIV_1). VXD is inferior to narrow-corridor CIVs from CIV_5 to CIV_{45} significantly. In low-volatility periods, some narrow-corridor CIVs are found to be indifferent from wide-corridor CIVs in terms of the Sharpe ratio, e.g. CIV_{20}. CIV_{35}, CIV_{40} and CIV_{45} stay superior to wide-corridor CIVs, which is the same as they do in medium-volatility periods, whereas the pattern for narrow-corridor CIVs from CIV_{15} to CIV_{30} changs slightly as some of them are found to be indifferent from wide-corridor CIVs. Only three CIVs with the narrowest corridors (from CIV_{35} to CIV_{45}) are found to outperform VXD. In addition, significant differences in the Sharpe ratio are found among narrow-corridor CIVs. For example, CIV_{45} are found to be superior to CIVs from CIV_{15} to CIV_{40}. In contrast, no significant differences in the Sharpe ratio are found among narrow-corridor CIVs in both high- and medium-volatility periods.

We briefly summarize our findings here: wide-corridor CIVs (from CIV_0 to CIV_5) and VXD outperform narrow-corridor CIVs in terms of the profitability in high-volatility periods, and produce significant lower mean rates of returns and Sharpe ratios than narrow-corridor CIVs do in medium-volatility and low-volatility periods (except CIV_5). However, there are no significant differences that are found in the mean rate of return and the Sharpe ratio among wide-corridor CIVs and VXD, or among narrow-corridor CIVs.

Market agents whose trading decisions are based on narrow-corridor CIVs become option writers, while market agents whose trading decisions are based on wide-corridor CIVs and VXD become option buyers. The pattern of the profitability among CIVs and VXD in medium- and low-volatility periods contributes another piece of evidence to the observed phenomenon that option writers earn higher returns than option buyers. Jackwerth (2000), Coval & Shumway (2001), Bakshi & Kapadia (2003), Bondarenko (2014), Jones (2006), Driessen & Maenhout (2007) find that strategies that involve writing put options offer a higher Sharpe ratio. However, interestingly, market agents based on wide-corridor CIVs outperform agents based on narrow-corridor CIVs in high-volatility periods, which indicates that tail risks embedded in deep out-of-the-money options are valuable and may contain information about future volatility in turbulent periods.

6.2 Transaction Costs

Extensive literature has documented that transaction costs are quite substantial in the options market. Transaction costs are often a reason why significant profits become trivial in many previous work. We ignore the transaction costs when comparing the profitability of CIVs in the previous section, which is likely to be criticized. Therefore, we address this issue in this section by introducing transaction costs into our trading simulation.

Transaction costs mainly include two parts: the bid-ask spread and commission fees. The bid-ask spread reflects the supply and demand conditions in the options market, and is often seen to be quite small in a liquid market (i.e. the currency market). We introduce a 25% effective bid-ask spread[7]: the effective ask (bid) price is then the midpoint price plus (minus) 12.5% of the bid-ask spread. In addition, we also include a commission fee which is set to 0.5% of the value of the traded option portfolio; see (Hull 2012, Table 9.1) for a typical commission fee scheme in the options market. Since we close out our positions in the options market by an offsetting order, commission fees are payable both upon entering and exiting the current position in the market.

Table 11 reports the summary statistics from option trades in short-term at-the-money zero-beta straddles after transaction costs are considered. Panel A reports the summary statistics for daily returns. All CIVs and VXD generate significant negative mean rates of returns and Sharpe ratios in both whole sample and subsamples, which is attributed to the transaction costs that are taken into account. Narrow-corridor CIVs are able to generate positive returns on more days than wide-corridor CIVs and VXD do. The pattern of skewness and kurtosis of returns stays the same: the skewness (kurtosis) of returns decreases (increases) with a decrease in corridor width; wide-corridor CIVs and VXD have a positive skewed return distribution, whereas narrow-corridor CIVs have a leptokurtic return distribution. Panel B and C report the mean difference and the Sharpe ratio difference in different periods. Except for CIV_5 and CIV_{10}, wide-corridor CIVs and VXD have a significantly higher mean rates of returns in high-volatility periods than they do in medium- and low-volatility periods, while narrow-corridor CIVs (from CIV_{15} to CIV_{45}) perform better in medium- and low-volatility periods than they do in high-volatility periods. In terms of the Sharpe ratio, only wide-corridor CIVs (CIV_0 and CIV_1) and VXD are found to perform better in high-volatility periods, whereas no significant differences in the performance measured by the Sharpe ratio for narrow-corridor CIVs are found in different periods. Again, no significant differences are found between medium- and low-volatility periods for all CIVs and VXD.

Table 12 and Table 13 report the mean return differences and Sharpe ratio differences among CIVs and VXD after transaction costs are considered. The pattern of the profitability in terms of the mean rate of return in all three subsamples stays exactly the same as that in Table 9 before transaction costs are considered. In the whole sample, only CIV_{10} is found to outperform CIV_1, no other significant differences are found after transaction costs are considered. For the profitability in terms of the Sharpe ratio, there are a few changes to the pattern: in high-volatility periods, narrow-corridor CIVs from CIV_{15} to

CIV_{25} which are found to be inferior to wide-corridor CIVs (CIV_0 and CIV_1) are found to be indifferent from CIV_0 and CIV_1, VXD no longer outperforms narrow-corridor CIVs from CIV_{15} and CIV_{25}; In low-volatility periods, narrow-corridor CIVs from CIV_{10} to CIV_{45} are found to outperform wide corridor-CIVs; besides, CIV_{10} and CIV_{45} outperform CIV_5 significantly; VXD which is indifferent from CIVs from CIV_{10} to CIV_{25} before transaction costs is found to deliver a significantly smaller Sharpe ratio than those narrow-corridor CIVs do. Significant differences among narrow-corridor CIVs which appear before transaction costs no longer exist after transaction costs, for example, CIV_{45} which is found to be significantly better than CIV_{35} is indifferent from CIV_{35} after transaction costs are considered.

In sum, mean profits obtained from option trades in volatility information become trivial after transaction costs are considered; market agents who employ CIVs and VXD as their predictions of future market volatility are not able to gain a positive mean return from the market. However, narrow-corridor CIVs are still able to bring positive returns on more days than wide-corridor CIVs and VXD do. The reason for the observed negative mean rate of return is due to excess trades on days when profits are not large enough to cover the transaction costs. We expect narrow-CIVs can deliver a positive mean return when a price filter is imposed when making trading decisions. Transaction costs do not change the pattern of the profitability of CIVs and VXD in all samples in terms of both the mean rate of return and the Sharpe ratio.

6.3 Out-of-Sample Performance

In this section, we address the issue of the out-of-sample trading performance of CIVs and VXD. We start with fitting implied volatility measures by using a simple ARMA(1,1) model: on each trading day, we use past 252 implied volatilities (CIV or VXD) which are expressed in variance terms to estimate the parameters of an ARMA(1,1) model, and then use the estimated model to forecast 1-day ahead implied volatility. The implied volatility forecast is then used to price option portfolios on that day. The procedure is repeated on each trading day. The calculation of daily rates of returns is the same as in previous sections.

6.3.1 Before Transaction Costs

Table 14 reports the summary statistics for out-of-sample option trades in zero-beta straddles before transaction costs. Panel A shows that out-of-sample trading practice does not change the characteristics of option trades compared to in-sample trades: market agents who employ narrow-corridor CIVs (from CIV_{30} to CIV_{45}) become option writers whereas agents who employ wide-corridor CIVs and VXD buy options in most of time in all samples. The average straddle price forecast is a monotonic function of the corridor width. The fraction of call options in the option portfolio is less than but very close to one half. Panel B presents summary statistics for daily returns. Only CIV_{10} and CIV_{15} deliver significant positive mean returns in the whole sample, none of the implied volatility measures are able to generate significant Sharpe ratios. In high-volatility periods, narrow-corridor CIVs from CIV_{25} to CIV_{45} deliver significant negative mean returns, wide-corridor CIVs (CIV_0, CIV_1 and VXD) which are not able to deliver a significant mean returns in the in-sample trading simulations carry a significant positive mean rate of return. Narrow-corridor CIVs except CIV_{45} generate significant negative Sharpe ratios, and CIV_5 delivers a significant positive Sharpe ratio. In the medium-volatility periods, except CIV_{10} which generates a significant positive mean return, all other narrow-corridor CIVs can still deliver significant positive mean rates of returns. In comparison to in-sample simulations, wide-corridor CIVs and VXD deliver a mean return which is indifferent from zero in out-of-sample simulations. In low-volatility periods, narrow-corridor CIVs from CIV_{10} to CIV_{45} deliver positive mean returns, except CIV_{20}. None of CIVs and VXD generate significant Sharpe ratios in both medium- and low-volatility periods. Panel C and D report the mean differences and Sharpe ratio differences in different periods for each implied volatility measure. The pattern is similar to the pattern of the in-sample simulations: wide-corridor CIVs and VXD perform better in high-volatility periods than they do in medium- and low-volatility periods whereas narrow-corridor CIVs have a worse performance in high-volatility periods than they do in medium- and low-volatility periods. No significant differences are found between performances in medium- and low-volatility periods.

Table 15 reports mean differences from out-of-sample option trades in zero-beta straddles before transaction costs. No significant differences are found in the whole sample. In high-volatility periods, narrow-corridor CIVs from CIV_{20} to CIV_{45} have a worse performance than wide-corridor CIVs from CIV_0 to CIV_5; besides, narrow-corridor CIVs from CIV_{25} to CIV_{45} are found to be inferior to CIV_{10} and CIV_{15}. VXD is found to be superior to narrow-corridor CIVs from CIV_{20} to CIV_{45}. In comparison to the in-sample results, significant differences between narrow-corridor CIVs are found, for example, CIV_{10} and CIV_{15} are significantly better than CIVs with narrower corridors. In medium-volatility periods, narrow-corridor CIVs from CIV_{15} to CIV_{45} outperform CIVs with wider corridors except CIV_{10}. VXD is inferior to narrow-corridor CIVs, which stays the same as VXD does in the in-sample simulations. The pattern of the profitability of CIVs in low-volatility periods is the same as it is in the in-sample results in Table 9.

Table 16 reports Sharpe ratio differences from out-of-sample option trades in zero-beta straddles before transaction costs. In the whole sample, some significant differences in the Sharpe ratio are found between narrow-corridor CIVs. In high-volatility periods, narrow-corridor CIVs from CIV_{20} to CIV_{45} are inferior to wide-corridor CIVs from CIV_0 and CIV_5, which is consistent with the pattern in the in-sample results; however, they are also found to be significantly different from narrow-corridor CIVs CIV_{10} and CIV_{15}.VXD stays superior to CIV_{20} and CIVs with narrower corridors. The pattern of the profitability stays the same except that there are a few changes when comparing to in-sample results in Table 10. CIV_5 and CIV_{10} no longer outperform CIV_0 and CIV_1. VXD is found to be inferior to CIV_{15} and CIVs from CIV_{30} to CIV_{45}, and is indifferent from CIV_5, CIV_{10}, CIV_{20} and CIV_{25}. In low-volatility periods, many significant differences in the in-sample results disappear in the out-of-sample results. For example, CIV_{25} is no longer different from wide-corridor CIVs CIV_0 and CIV_1. And some new significant differences are found in the out-of-sample results, for example, CIV_{10} are found to outperform CIVs with wider corridors, which does not exist in the in-sample results.

6.3.2 After Transaction Costs

Table 17 reports the summary statistics of returns from out-of-sample option trades after transaction costs are considered. Similar to in-sample results in Table 11, all CIVs and VXD generate significant negative mean rates of returns and Sharpe ratios, which is again due to excess trading practice whose profits are not large enough to cover the transaction costs. Panel B and C shows that in high-volatility periods wide-corridor CIVs and VXD perform better than and narrow-corridor CIVs perform worse than they do respectively in medium- and low-volatility periods in terms of mean returns. In terms of the Sharpe ratio, wide-corridor CIVs and VXD in high-volatility periods outperform themselves in medium- and low-volatility periods, while narrow-corridor CIVs in high-volatility periods are found to be superior to themselves only in low-volatility periods. No significant differences between the performance in medium- and low-volatility periods are found for all implied volatility measures.

Table 18 reports the mean differences from out-of-sample option trades in zero-beta straddles after transaction costs are taken into account. No significant differences are found in the whole sample. In high-volatility periods, narrow-corridor CIVs from CIV_{20} to CIV_{45} are inferior to wide-corridor CIVs such as CIV_0, CIV_1 and CIV_5. Except CIV_{20}, they are also found to be inferior to CIV_{10} and CIV_{15}, which cannot be found in the in-sample simulation results. Similar to the in-sample results, VXD are found to outperform narrow-corridor CIVs in high-volatility periods. In medium-periods, narrow-corridor CIVs from CIV_{15} to CIV_{45} outperform wide-corridor CIVs from CIV_0 to CIV_5 except that CIV_{45} is statistically indifferent from CIV_5. VXD are found to perform worse than narrow-corridor CIVs from CIV_{15} to CIV_{45}, which is slightly different from the pattern of the in-sample results where VXD are also found inferior to CIV_5 and CIV_{10}. In low-volatility periods, some significant differences between wide- and narrow-corridor CIVs disappear in the out-of-sample results, for example, CIV_{20} is indifferent from CIV_1 in the out-of-sample context. VXD is only found to be inferior to CIV_{10}, CIV_{30} and CIVs with narrower corridors.

Table 19 reports the Sharpe ratio differences from out-of-sample option trades in zero-beta straddles after transaction costs are considered. Compared to in-sample results, the pattern of the whole sample where significant differences between narrow-corridor CIVs are found, is different from the pattern of in-sample results where only differences between wide-corridor CIVs are found to be significant. VXD is indifferent from all CIVs in the whole sample in terms of the profitability measured by the Sharpe ratio. In high-volatility periods, except that narrow-corridor CIVs from CIV_{30} to CIV_{45} are consistently inferior to wide-corridor CIVs CIV_0 and CIV_1 in both in-sample and out-of-sample results, narrow-corridor CIVs CIV_{20} and CIV_{25} are also found to be inferior to CIV_0 and CIV_1 in the out-of-sample simulations. Narrow-corridor CIVs, on the other hand, are indifferent from CIV_5 except CIV_{25}. Besides, in high-volatility periods, narrow-corridor CIVs are also found to be statistically different from each other. VXD is found to outperform narrow-corridor CIVs from CIV_{20} to CIV_{45}. In medium periods, despite that some significant differences in the in-sample results are found to be insignificant in the out-of-sample results, the pattern is similar to that in the in-sample simulation results: narrow-corridor CIVs outperform wide-corridor CIVs and VXD. In low-volatility periods, many narrow-corridor CIVs are no longer superior to wide-corridor CIVs and VXD in the out-of-sample context.

In sum, the pattern of the economic difference among CIVs and VXD stays generally the same as in the in-sample trading simulation results. One should note that there are slightly changes to the sample as we lose the first 252 trading days in order to perform out-of-sample forecasts of implied volatility measures. Besides, forecast errors do exist in the out-of-sample forecasting practice of implied volatility measures. However, none of those imperfections are able to change the pattern of the profitability of CIVs and VXD.

6.4 Alternative Option Strategies

The delta-hedged option portfolio is an alternative option strategy that allows investors to speculate on the volatility information. We use this strategy as a robustness check. Delta-hedged put[8] is an option strategy that involves buying (selling) a put option, and simultaneously buying (selling) delta number of the underlying assets so that the overall portfolio is insensitive to the price movements of the underlying asset. Therefore, a delta-hedged portfolio allows speculation on the volatility information only, in addition to straddles. The delta of an index option is the partial derivative of the option price with respect to the change in the index level. Since delta-hedging index options by using the underlying index is prohibitive, we use futures on the DJIA index to delta-hedge DJX put options. As stated by Harvey & Whaley (1992), there are several sources of noises in the delta hedged portfolios. Firstly, there is basis risk between DJIA index and futures. Secondly, delta values are valid only for diminutive index movements and at an instant time. However, they should not bias our results in a significant way. We do not report the results of delta-hedged puts in this paper, we provide them in the supplementary material which is attached to this paper. The results show a very similar profitability pattern to the pattern generated by option trades in zero-beta straddles.

7 Conclusions

We are the first to employ the corridor implied variance (CIV) to forecast conditional volatility to examine the information content of CIV in a model-based out-of-sample framework. The rationale behind the argument that CIV is a superior information source to other implied volatility measures for volatility forecasting is the consensus that volatility risk premiums (VRP) significantly distort market volatility expectations; CIV serves as a mechanism to alleviate the impact of VRP on the forecasting ability of implied volatility measures since CIV is extracted from near-the-money options; deep out-of-the-money options misrepresents investor's views about market volatility due to extreme illiquidity of such options.

We use several GARCH models which incorporate implied volatility measures to examine the forecasting ability of CIVs with different corridors, and a CBOE volatility index, VXD. We find that in the TGARCH framework, CIVs with a symmetric cut of 40% and 10% of the risk-neutral distribution (RND) outperform all other CIVs and VXD. The results from GARCH, EGARCH and NAGARCH are similar to that from the TGARCH model. Specifically, CIVs with a symmetric cut of 30% to 40% of the RND have the best forecasting performance for GARCH, a symmetric cut of 10% for EGARCH, and a symmetric cut of 30% to 40% for NAGARCH. The small discrepancies in the results can be attributed to the different characteristics of model settings. Simialr results are presented in Andersen & Bondarenko (2007), Muzzioli (2013) who also find narrow-corridor CIVs outperforms wide-corridor CIVs in terms of the forecasting ability for index options, while our results contradict with that of Tsiaras (2010) who find wide-corridor CIVs have a better forecasting performance for stock options, which might be contributed to different characteristics of index and stock options.

We also investigate the forecasting ability of different risk-neutral price intervals of the risk-neutral distribution through a decomposition of the model-free implied volatility. We find that deep out-of-the money put options (with strikes that are beyond 0.25 risk-neutral probability) does not contain any information about future volatility whereas near-the-money put options (with strikes that are inside 0.25 risk-neutral probability) do contain volatility information. Out-of-the-money call options with strikes that span the whole right side of the RND is informative about future volatility. Our results are similar to that of Dotsis & Vlastakis (2016). The indication is that large volatility risk premiums in the downside risk distort the market volatility expectation from put options, especially from deep out-of-the-money put options. Therefore, impounding the information from those put options handicap the forecasting ability of wide-corridor CIVs. In the other word, tail risks, especially left tail risks, handicap the forecasting ability of the model-free implied volatility.

Finally, we access the economic difference between CIVs and VXD via a trading simulation in the DJX options market. We find that market agents based on narrow-corridor CIVs becomes option writers while market agents based on wide corridor CIVs and VXD becomes option buyers. In medium-volatility and low-volatility periods, narrow-corridor CIVs significantly outperform wide-corridor CIVs and VXD; however, interestingly, in high-volatility periods, wide-corridor CIVs and VXD are superior to narrow-corridor CIVs in terms of the profitability. The results are robust to alternative option trading strategies, and hold both in-sample and out-of-sample, before and after transaction costs are considered. Our results indicate that tail risks is informative in turbulent periods while they distort market volatility expectations significantly in medium-volatility and low-volatility periods.

Notes

[1]The upper and lower strike limits B_u and B_l can be expressed by the RND function. Denote $R^{-1}(\cdot)$ as the inverse function of the cumulative risk-neutral probability distribution function, p_u and p_l as risk-neutral probabilities. Therefore, we have $B_u = R^{-1}(p_u)$ and $B_l = R^{-1}(p_l)$.

[2]There are two drawbacks of this flat extrapolation, as stated by Jiang & Tian (2007): (1) it tends to underestimate the implied volatility for strikes that are far from the at-the-money strike price due to volatility smile or skew; (2) kinks introduced into the implied volatility function violate no-arbitrage conditions. However, there are many occasions in our filtered options sample where the implied volatility function is monotonically decreasing with the strike price. As a result, if a linear extrapolation is used, the implied volatility for faraway-from-the money strikes on the call option side will be negative. Therefore, in this paper we use a flat extrapolation.

[3]The convention of BSIV interpolation for different assets is shown on **pp.4** in Malz (2014).

[4]Results of in-sample volatility forecasting performance of restricted and unrestricted models are not reported here since it's not the main research question we are exploring.

[5]A student-t or a generalized error distribution might provide better performance than a normal distribution does due to the observed leptokurtic distributed asset returns. However, since the information content of market volatility expectations are studied in the same model setting, the choice of the assumed density function is orthogonal to the ranking of the forecasting performance of different market volatility expectations

[6]For example, $\text{CIV}_{0.1-0.15}$ is the CIV extracted from the left (put option) side of the RND, its corresponding CIV extracted from the right (call option) side of RND is then $\text{CIV}_{0.85-0.9}$.

[7]In our unreported results, a larger or smaller effective bid-ask spread does not change the pattern of the profitability of CIVs, nor does the commission fee.

[8]The result of delta-hedged calls is similar to that of delta-hedged puts.

Appendix: Data Set Construction

Before options data can be employed, a clean data set of options has to be constructed. Several steps have been taken:

(1) Call and put options with the same maturity and strike prices on each trading day are matched. Moreover, a data cleaning procedure is performed on the data. In our DJX options sample, there are a lot of irregularities such as chaotic strike prices and maturity dates. Therefore, on each trading day, strike prices for the same maturity date are sorted in ascending order, and maturity dates are sorted in ascending order as well.

(2) The underlying asset price is calculated by deducting the cash dividends from the daily closing index levels. For DJIA index, daily actual dividends are not available, the dividend-adjusted prices are calculated by using daily dividend yield

$$S_i^* = S_i e^{-\zeta_i \tau_i}$$

where S_i^* is the dividend-adjusted index level, S_i is the daily closing index level, ζ_i is the daily dividend yield on day i, τ_i is options' time to maturity (annualized).

(3) We apply several option filters to exclude stale option quotes. These quotes are generated by options that are illiquid and likely mispriced. The filters are:

- Options with zero-bid quotes are excluded from the sample. These options are generally problematic and mispriced, and have extreme strike prices and are very illiquid.
- Options with less than 7 days time to maturity are excluded. These options are illiquid and are affected by microstructure factors.
- Options with implied volatility that is negative or larger than 100% are excluded. These options are generally deep out-of-money and mispriced.
- In-the-money options are excluded. In-the money options in this study are defined as options with moneyness that is smaller than 1 (moneyness here defined as the ratio of strike price to forward price). In-the-money options are generally overpriced and are less liquid than ATM and OTM options. Both OTM put and call options are used in order to ensure the range of the available strikes is sufficiently wide, and this will minimize the approximation errors due to extrapolation in BS implied volatility at strikes beyond the available strikes.
- Options that violate basic non-arbitrage conditions are excluded. Such options are eliminated because they offer arbitrage opportunities. Non-arbitrage conditions for European options include boundary, monotonic and convexity conditions.
  - 1) The boundary conditions for an European option are

$$\max(0, Ke^{-r\tau} - S^*) \leq P(K) \leq Ke^{-r\tau}$$
$$\max(0, S^* - Ke^{-r\tau}) \leq C(K) \leq S^*$$

  - 2) The monotonic condition requires that the option prices are a monotonic function of strike prices, and this relationship can be expressed as

$$-e^{-r\tau} \leq \frac{\partial}{\partial K} C(K) \leq 0 \leq \frac{\partial}{\partial K} P(K) \leq e^{-r\tau}$$

    The above relation can be implemented as follows, for $K_{i-1} < K_i$

$$-e^{-r\tau} \leq \frac{C(K_i) - C(K_{i-1})}{K_i - K_{i-1}} \leq 0 \leq \frac{P(K_i) - P(K_{i-1})}{K_i - K_{i-1}} \leq e^{-r\tau}$$

  - 3) The convexity restrictions, for $K_{i-1} < K_i < K_{i+1}$, are implemented as

$$\frac{O(K_{i+1}) - O(K_i)}{K_{i+1} - K_i} - \frac{O(K_i) - O(K_{i-1})}{K_i - K_{i-1}} \geq 0$$

where $O(\cdot)$ is either call or put option price.

(4) Similar to Andersen et al. (2011*a*), robust implied forward prices are calculated for options with the same time to maturity. The procedure is as follows:

- First, for each maturity pair, the VIX method is used to calculate the implied forward prices F, which can be expressed as

$$F = K^* + e^{r\tau}\big(C(K^*) - P(K^*)\big)$$

  where K^* is the strike price at which the absolute difference between the call and put prices is the smallest.
- Second, for all maturity pairs we set a threshold for the difference between call and put prices: \$8 for DJX options. Any put-call pairs that satisfy the threshold are included. Then by using the above equation each put-call pair produces a forward price. Finally, the median of the forward price series is chosen as the robust forward price and is denoted as F^*. F is retained if F deviates no more than 0.5% from F^*, otherwise F^* is used.

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Table 1. Specifications of Loss Functions

Loss	Specification
MAE	$\left\|\sigma^2_{RV,t} - h_t\right\|$
MAE-SD	$\left\|\sigma_{RV,t} - \sqrt{h_t}\right\|$
MAE-LOG	$\left\|\log\sigma^2_{RV,t} - \log h_t\right\|$
MSE	$\left(\sigma^2_{RV,t} - h_t\right)^2$
MSE-SD	$\left(\sigma_{RV,t} - \sqrt{h_t}\right)^2$
MSE-LOG	$\left(\log\sigma^2_{RV,t} - \log h_t\right)^2$
QLIKE	$\frac{\sigma^2_{RV,t}}{h_t} - \log\frac{\sigma^2_{RV,t}}{h_t} - 1$

Notes: $\sigma^2_{RV,t}$ is the realized volatility, h_t is the conditional volatility forecast.

Table 2. TGARCH-IV Out-of-Sample Relative Forecast Accuracy

CIV	*MAE*			*MAE − SD*			*MAE − LOG*			*RMSE*			*MSE − SD*			*MSE − LOG*			*QLIKE*			Over-prediction	R^2	*P*
	Errors $\times 10^5$	Relative	Rank	Errors $\times 10^3$	Relative	Rank	Errors	Relative	Rank	Errors $\times 10^4$	Relative	Rank	Errors $\times 10^5$	Relative	Rank	Errors	Relative	Rank	Errors	Relative	Rank	%		
CIV_0	9.7377	0.9988	11	3.6269	1.0000	12	0.8603	1.0000	12	2.5072	0.9893	11	2.6137	0.9957	11	1.1118	1.0000	12	0.3933	1.0000	12	77.86	0.5083	0.4880
CIV_1	9.6477	0.9896	10	3.5967	0.9917	8	0.8544	0.9932	8	2.4924	0.9835	10	2.5761	0.9814	10	1.0984	0.9879	8	0.3898	0.9912	7	77.68	0.5121	0.4940
CIV_5	9.6420	0.9890	9	3.6048	0.9939	10	0.8561	0.9952	10	2.4844	0.9803	9	2.5720	0.9798	9	1.1003	0.9897	10	0.3912	0.9948	9	77.61	0.5137	0.4973
CIV_{10}	9.6214	0.9869	8	3.6024	0.9932	9	0.8557	0.9947	9	2.4737	0.9760	5	2.5641	0.9768	8	1.0984	0.9879	8	0.3913	0.9950	10	77.92	0.5170	0.5016
CIV_{15}	9.5489	0.9795	6	3.5781	0.9865	5	0.8514	0.9897	5	2.4736	0.9760	5	2.5446	0.9693	6	1.0917	0.9819	5	0.3891	0.9894	3	77.68	0.5159	0.5016
CIV_{20}	9.5582	0.9804	7	3.5804	0.9872	6	0.8516	0.9900	6	2.4759	0.9769	8	2.5505	0.9716	7	1.0923	0.9825	6	0.3891	0.9895	5	77.92	0.5151	0.5007
CIV_{25}	9.5435	0.9789	4	3.5821	0.9876	7	0.8528	0.9914	7	2.4691	0.9742	2	2.5424	0.9685	3	1.0940	0.9840	7	0.3902	0.9922	8	77.80	0.5174	0.5035
CIV_{30}	9.5094	0.9754	1	3,5718	0.9848	2	0.8506	0.9888	2	2.4590	0.9703	1	2.5282	0.9631	1	1.0885	0.9791	2	0.3884	0.9876	2	77.86	0.5207	0.5075
CIV_{35}	9.5367	0.9782	3	3.5770	0.9862	3	0.8512	0.9895	4	2.4739	0.9761	7	2.5442	0.9692	5	1.0898	0.9802	3	0.3891	0.9896	6	77.80	0.5153	0.5015
CIV_{40}	9.5435	0.9789	4	3.5770	0.9862	3	0.8510	0.9892	3	2.4722	0.9755	4	2.5437	0.9690	4	1.0904	0.9808	4	0.3891	0.9894	3	77.68	0.5162	0.5022
CIV_{45}	9.5109	0.9756	2	3.5619	0.9821	1	0.8482	0.9860	1	2.4706	0.9749	3	2.5309	0.9641	2	1.0837	0.9747	1	0.3870	0.9840	1	77.31	0.5165	0.5028
VXD	9.7490	1.0000	12	3.6223	0.9987	11	0.8586	0.9981	11	2.5344	1.0000	12	2.6251	1.0000	12	1.1083	0.9969	11	0.3920	0.9969	11	77.68	0.4967	0.4769

Notes: MAE, MAE-SD, MAE-LOG, MSE, MSE-SD, MSE-LOG and QLIKE report the means of loss functions listed in Table 1. Over-prediction reports the percentage of overestimates. R^2 is obtained from regressing the daily realized volatility on one-day ahead conditional volatility forecasts. Daily realized volatility is calculated by the Parkinson's estimator defined in **Eq.** 5. *P* is the proportions of explained variability, and is defined as $P = 1 - \frac{\sum_{t=1}^{n-1}(\sigma^2_{RV,t} - h_t)^2}{\sum_{t=1}^{n-1}(\sigma^2_{RV,t} - \bar{\sigma}^2_{RV})^2}$, where n is the total number of conditional volatility forecasts.

Table 3. Superior predictive ability (SPA) test for TGARCH-IV conditional volatility forecasts

Loss		Base											
		CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}	VXD
MAE	p_l	0.0121	0.0638	0.0452	0.0354	0.2151	0.2856	0.3416	1	0.3441	0.3855	0.5131	0.0460
	p_c	0.0128	0.0638	0.0505	0.0415	0.2896	0.3521	0.4636	1	0.5607	0.5107	0.8858	0.0460
	p_u	0.0128	0.0756	0.0505	0.0415	0.3227	0.4041	0.4879	1	0.5905	0.5434	0.9019	0.0460
MAE-SD	p_l	0.0012	0.0350	0.0255	0.0118	0.1863	0.3209	0.2276	0.2819	0.3485	0.3635	1	0.0033
	p_c	0.0012	0.0357	0.0280	0.0131	0.2579	0.4003	0.2559	0.6099	0.4641	0.4663	1	0.0035
	p_u	0.0012	0.0589	0.0280	0.0131	0.3260	0.4970	0.3126	0.6439	0.5289	0.5181	1	0.0035
MAE-LOG	p_l	0.0010	0.0420	0.0191	0.0142	0.1859	0.3154	0.1581	0.2756	0.3409	0.3087	1	0.0038
	p_c	0.0010	0.0429	0.0215	0.0169	0.2664	0.4167	0.1870	0.5874	0.4699	0.4594	1	0.0039
	p_u	0.0010	0.0746	0.0215	0.0169	0.3488	0.5090	0.2215	0.6414	0.5324	0.4999	1	0.0039
MSE	p_l	0.0951	0.1021	0.1146	0.2178	0.3418	0.2703	0.2104	1	0.3785	0.2511	0.2856	0.1077
	p_c	0.0951	0.1022	0.1369	0.2382	0.5354	0.3521	0.5749	1	0.5703	0.3705	0.6378	0.1077
	p_u	0.0951	0.1022	0.1369	0.2382	0.5354	0.3521	0.5749	1	0.5703	0.3705	0.6378	0.1077
MSE-SD	p_l	0.0133	0.0712	0.0375	0.0259	0.2913	0.2230	0.2520	1	0.3436	0.2899	0.4571	0.0622
	p_c	0.0133	0.0712	0.0411	0.0289	0.3995	0.2902	0.3804	1	0.4540	0.3694	0.8629	0.0622
	p_u	0.0133	0.0931	0.0411	0.0289	0.4439	0.2902	0.4031	1	0.4902	0.3935	0.8884	0.0622
MSE-LOG	p_l	0.0023	0.0722	0.0787	0.0672	0.1823	0.2089	0.1770	0.2581	0.3197	0.3037	1	0.0017
	p_c	0.0023	0.0763	0.0890	0.0796	0.2670	0.3206	0.2311	0.6300	0.5384	0.4507	1	0.0019
	p_u	0.0023	0.1344	0.0890	0.0796	0.3640	0.3241	0.2311	0.6453	0.5384	0.4507	1	0.0019
QLIKE	p_l	0.0053	0.1160	0.0805	0.0460	0.0445	0.2998	0.1081	0.2504	0.2580	0.2803	1	0.0250
	p_c	0.0053	0.1307	0.0913	0.0489	0.0478	0.3996	0.1318	0.6147	0.3369	0.3758	1	0.0286
	p_u	0.0053	0.2138	0.0913	0.0489	0.0478	0.4597	0.1318	0.6783	0.3613	0.3988	1	0.0286

Notes: The null hypothesis of the SPA test is that the base is not inferior to any of the alternatives. p_c is the consistent p-values of the SPA test; p_l and p_u are lower and upper values for the consistent p-value p_c. The consistent p-values indicates the intensity of the base CIV producing superiority. A unity value of consistent p-values indicates that base CIV outperformed others.

Table 4. Specifications of Alternative Models

Models	Unrestricted Model	Restricted Model		General Constraints
		Returns Only	Implieds Only	
GARCH-IV	$h_t = \frac{\alpha_0+\alpha_1\varepsilon_{t-1}^2}{1-\beta L} + \frac{\delta\sigma_{imp,t-1}^2}{1-\beta_v L}$	$\delta = 0$	$\alpha_1 = 0$	$\alpha_1 \geq 0$
EGARCH-IV	$\ln h_t = \frac{\alpha_0+\alpha_1 Z_{t-1}+\kappa\left(\lvert Z_{t-1}\rvert-\sqrt{\frac{2}{\pi}}\right)}{1-\beta L} + \frac{\delta\ln\sigma_{imp,t-1}^2}{1-\beta_v L}$	$\delta = 0$	$\alpha_1 = 0$ $\kappa = 0$	None
NAGARCH-IV	$h_t = \frac{\alpha_0+\alpha_1\left(\varepsilon_{t-1}-\theta\sqrt{h_{t-1}}\right)^2}{1-\beta L} + \frac{\delta\sigma_{imp,t-1}^2}{1-\beta_v L}$	$\delta = 0$	$\alpha_1 = 0$	$\alpha_1 \geq 0$

Notes: In all specifications, $\sigma_{imp,t}$ is the implied volatility measure which is either CIV or VXD. The purpose of general constraints is to ensure the non-negativity of estimated conditional variances. In addition to general constraints, the constraints β, $\beta_v \geq 0$ are imposed to all models.

Table 5. Out-of-Sample Relative Forecast Accuracy of Alternative Models

CIV	*MAE*			*MAE − SD*			*MAE − LOG*			*RMSE*			*MSE − SD*			*MSE − LOG*			*QLIKE*			Over-prediction	R^2	*P*
	Errors $\times 10^5$	Relative	Rank	Errors $\times 10^3$	Relative	Rank	Errors	Relative	Rank	Errors $\times 10^4$	Relative	Rank	Errors $\times 10^5$	Relative	Rank	Errors	Relative	Rank	Errors	Relative	Rank	%		
GARCH-IV																								
CIV_0	9.7167	0.9933	11	3.8414	0.9984	11	0.9254	1.0000	12	2.5651	0.9802	11	2.7224	0.9840	11	1.2902	1.0000	12	0.4382	1.0000	11	79.77	0.4747	0.4641
CIV_1	9.5736	0.9787	10	3.7558	0.9839	10	0.9144	0.9881	10	2.5607	0.9785	10	2.6647	0.9632	10	1.2609	0.9773	10	0.4309	0.9834	10	79.34	0.4768	0.4659
CIV_5	9.4399	0.9650	9	3.7098	0.9718	9	0.9061	0.9791	9	2.5397	0.9705	9	2.6100	0.9434	9	1.2390	0.9603	9	0.4257	0.9716	9	78.97	0.4872	0.4746
CIV_{10}	9.4016	0.9611	8	3.6941	0.9677	8	0.9028	0.9755	8	2.5303	0.9669	5	2.5881	0.9355	8	1.2290	0.9525	8	0.4237	0.9669	8	78.60	0.4916	0.4785
CIV_{15}	9.3785	0.9587	5	3.6854	0.9654	6	0.9016	0.9742	7	2.5302	0.9668	4	2.5788	0.9321	6	1.2267	0.9508	7	0.4231	0.9655	6	78.66	0.4919	0.4786
CIV_{20}	9.3808	0.9590	6	3.6842	0.9651	5	0.9011	0.9737	6	2.5328	0.9678	6	2.5782	0.9319	5	1.2237	0.9485	6	0.4229	0.9652	5	78.66	0.4904	0.4775
CIV_{25}	9.3549	0.9563	3	3.6775	0.9633	3	0.9001	0.9726	3	2.5288	0.9663	3	2.5692	0.9287	3	1.2213	0.9466	4	0.4224	0.9640	4	78.47	0.4927	0.4792
CIV_{30}	9.3471	0.9555	1	3.6733	0.9622	1	0.8991	0.9716	1	2.5277	0.9659	2	2.5628	0.9264	1	1.2166	0.9430	1	0.4219	0.9628	1	78.60	0.4934	0.4796
CIV_{35}	9.3530	0.9561	2	3.6761	0.9630	2	0.8996	0.9721	2	2.5272	0.9657	1	2.5654	0.9273	2	1.2192	0.9449	3	0.4222	0.9636	2	78.66	0.4937	0.4798
CIV_{40}	9.3734	0.9582	4	3.6808	0.9642	4	0.9002	0.9728	4	2.5376	0.9697	8	2.5764	0.9313	4	1.2190	0.9448	2	0.4224	0.9639	3	78.54	0.4887	0.4755
CIV_{45}	9.3810	0.9590	6	3.6855	0.9654	6	0.9010	0.9736	5	2.5367	0.9693	7	2.5834	0.9338	7	1.2226	0.9476	5	0.4231	0.9655	6	78.29	0.4894	0.4759
VXD	9.7823	1.0000	12	3.8174	1.0000	12	0.9244	0.9989	11	2.6170	1.0000	12	2.7666	1.0000	12	1.2894	0.9993	11	0.4382	1.0000	11	79.70	0.4511	0.4422
EGARCH-IV																								
CIV_0	12.4393	0.9818	10	4.0163	0.9936	11	0.8712	0.9994	11	3.2554	0.9820	10	3.7386	0.9841	11	1.1464	1.0000	12	0.4039	1.0000	12	79.34	0.5655	0.1368
CIV_1	12.4431	0.9821	11	4.0078	0.9915	10	0.8684	0.9961	10	3.2673	0.9856	11	3.7354	0.9833	10	1.1380	0.9926	10	0.4017	0.9945	10	79.46	0.5672	0.1305
CIV_5	12.0984	0.9549	9	3.9648	0.9809	9	0.8653	0.9925	9	3.1028	0.9360	9	3.5663	0.9388	9	1.1267	0.9828	9	0.3994	0.9888	8	79.58	0.5728	0.2158
CIV_{10}	11.9503	0.9432	8	3.9476	0.9766	8	0.8642	0.9913	8	3.0268	0.9130	8	3.5041	0.9224	8	1.1241	0.9805	8	0.3993	0.9887	7	79.40	0.5743	0.2538
CIV_{15}	11.8731	0.9371	7	3.9402	0.9748	7	0.8638	0.9908	7	2.9851	0.9005	7	3.4652	0.9121	7	1.1209	0.9777	7	0.3989	0.9875	6	79.15	0.5757	0.2742
CIV_{20}	11.8336	0.9340	6	3.9335	0.9731	6	0.8630	0.9899	6	2.9648	0.8943	6	3.4459	0.9071	6	1.1195	0.9765	6	0.3982	0.9858	5	79.03	0.5739	0.2841
CIV_{25}	11.7328	0.9260	5	3.9216	0.9702	5	0.8623	0.9891	5	2.9183	0.8803	5	3.4040	0.8960	5	1.1184	0.9756	5	0.3979	0.9853	4	78.91	0.5740	0.3064
CIV_{30}	11.6025	0.9157	4	3.9033	0.9657	4	0.8607	0.9873	4	2.8603	0.8628	4	3.3468	0.8810	4	1.1127	0.9706	4	0.3967	0.9822	3	78.91	0.5757	0.3336
CIV_{35}	11.4671	0.9050	3	3.8851	0.9612	3	0.8598	0.9862	2	2.8002	0.8447	3	3.2805	0.8635	3	1.1099	0.9681	2	0.3960	0.9804	2	78.84	0.5747	0.3613
CIV_{40}	11.3439	0.8953	2	3.8713	0.9577	2	0.8598	0.9863	3	2.7412	0.8269	2	3.2276	0.8496	2	1.1116	0.9697	3	0.4011	0.9932	9	79.09	0.5711	0.3880
CIV_{45}	11.0538	0.8724	1	3.8254	0.9464	1	0.8566	0.9826	1	2.6469	0.7985	1	3.1002	0.8161	1	1.1047	0.9636	1	0.3952	0.9784	1	79.03	0.5766	0.4293
VXD	12.6702	1.0000	12	4.0421	1.0000	12	0.8718	1.0000	12	3.3151	1.0000	12	3.7989	1.0000	12	1.1450	0.9987	11	0.4035	0.9989	11	79.21	0.5332	0.1049
NAGARCH-IV																								
CIV_0	10.0722	1.0000	12	3.6755	1.0000	11	0.8522	0.9998	11	2.4216	0.9967	11	2.7307	0.9993	11	1.0996	1.0000	12	0.3912	0.9997	11	79.40	0.5606	0.5224
CIV_1	9.9793	0.9908	10	3.6488	0.9927	10	0.8473	0.9940	10	2.4070	0.9907	10	2.6950	0.9862	10	1.0874	0.9889	10	0.3885	0.9927	9	79.27	0.5632	0.5281
CIV_5	9.8950	0.9824	9	3.6327	0.9883	9	0.8452	0.9915	9	2.3881	0.9830	9	2.6655	0.9754	9	1.0824	0.9844	9	0.3875	0.9902	8	79.34	0.5661	0.5355
CIV_{10}	9.8619	0.9791	8	3.6282	0.9871	8	0.8449	0.9911	8	2.3810	0.9800	8	2.6574	0.9724	8	1.0821	0.9840	8	0.3890	0.9942	10	79.15	0.5669	0.5383
CIV_{15}	9.8151	0.9745	6	3.6160	0.9838	5	0.8431	0.9890	5	2.3734	0.9769	6	2.6368	0.9649	6	1.0767	0.9792	6	0.3879	0.9914	7	78.97	0.5683	0.5412
CIV_{20}	9.8072	0.9737	4	3.6134	0.9831	4	0.8425	0.9884	4	2.3725	0.9765	4	2.6344	0.9640	4	1.0755	0.9780	5	0.3877	0.9909	6	79.09	0.5683	0.5415
CIV_{25}	9.8009	0.9731	3	3.6124	0.9828	3	0.8424	0.9882	3	2.3714	0.9760	3	2.6341	0.9639	3	1.0753	0.9779	5	0.3875	0.9903	6	79.03	0.5682	0.5420
CIV_{30}	9.7865	0.9716	1	3.6071	0.9814	1	0.8413	0.9870	1	2.3701	0.9755	2	2.6302	0.9625	2	1.0725	0.9753	1	0.3869	0.9886	4	78.97	0.5683	0.5425
CIV_{35}	9.7947	0.9724	2	3.6108	0.9824	2	0.8421	0.9878	2	2.3691	0.9751	1	2.6282	0.9618	1	1.0733	0.9761	2	0.3858	0.9860	1	79.03	0.5684	0.5429
CIV_{40}	9.8140	0.9744	5	3.6168	0.9840	6	0.8432	0.9891	6	2.3728	0.9766	5	2.6358	0.9646	5	1.0752	0.9778	3	0.3862	0.9870	2	79.15	0.5671	0.5414
CIV_{45}	9.8193	0.9749	7	3.6187	0.9845	7	0.8437	0.9898	7	2.3737	0.9770	7	2.6370	0.9650	7	1.0777	0.9801	7	0.3865	0.9877	3	78.91	0.5670	0.5411
VXD	10.0679	0.9996	11	3.6755	1.0000	11	0.8524	1.0000	12	2.4296	1.0000	12	2.7327	1.0000	12	1.0974	0.9980	11	0.3913	1.0000	12	79.83	0.5547	0.5192

Notes: MAE, MAE-SD, MAE-LOG, MSE, MSE-SD, MSE-LOG and QLIKE report the means of loss functions listed in Table 1. Over-prediction reports the percentage of overestimates. R^2 is obtained from regressing the daily realized volatility on one-day ahead conditional volatility forecasts. Daily realized volatility is calculated by the Parkinson's estimator defined in **Eq.** 5. P is the proportions of explained variability, and is defined as $P = 1 - \frac{\sum_{t=1}^{n-1}(\sigma^2_{RV,t} - h_t)^2}{\sum_{t=1}^{n-1}(\sigma^2_{RV,t} - \bar{\sigma}^2_{RV})^2}$, where n is the total number of conditional volatility forecasts.

Table 6. Consistent p-values from superior predictive ability (SPA) test for alternative models conditional volatility forecasts

Loss	Base											
	CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}	VXD
GARCH-IV												
MAE	0.0006	0.0071	0.0181	0.0425	0.1003	0.1302	0.4349	1	0.2999	0.0904	0.0249	0.0054
MAE-SD	0.0000	0.0023	0.0080	0.0429	0.0907	0.0576	0.2814	1	0.2899	0.0991	0.0290	0.0000
MAE-LOG	0.0000	0.0003	0.0052	0.0443	0.0605	0.0818	0.4117	1	0.6390	0.4440	0.2092	0.0000
MSE	0.0816	0.1374	0.2447	0.5241	0.5516	0.4235	0.5471	0.7477	1	0.3567	0.3055	0.0958
MSE-SD	0.0000	0.0048	0.0102	0.0680	0.1029	0.1351	0.1198	1	0.1894	0.1284	0.0181	0.0087
MSE-LOG	0.0000	0.0002	0.0011	0.0484	0.0337	0.0600	0.1464	1	0.2937	0.4070	0.0047	0.0000
QLIKE	0.0000	0.0002	0.0211	0.2002	0.2753	0.3122	0.5410	1	0.5251	0.5757	0.1882	0.0000
EGARCH-IV												
MAE	0.1838	0.1968	0.1980	0.2077	0.2122	0.2169	0.1732	0.1440	0.2085	0.1526	1	0.1129
MAE-SD	0.1721	0.2065	0.2019	0.2113	0.1648	0.2073	0.1827	0.1865	0.3113	0.2251	1	0.0897
MAE-LOG	0.1557	0.2562	0.2797	0.2546	0.1653	0.1983	0.1922	0.4322	0.6039	0.3701	1	0.1179
MSE	0.2271	0.2389	0.2033	0.1894	0.1949	0.2072	0.1710	0.1343	0.1883	0.1390	1	0.1215
MSE-SD	0.1645	0.1884	0.2013	0.1644	0.1955	0.1888	0.1412	0.1121	0.2493	0.1278	1	0.0769
MSE-LOG	0.0468	0.0921	0.1600	0.1529	0.1704	0.1825	0.1765	0.3174	0.7108	0.3738	1	0.0510
QLIKE	0.0386	0.1316	0.2253	0.1612	0.1371	0.2010	0.1660	0.3038	0.8680	0.1700	1	0.0703
NAGARCH-IV												
MAE	0.0420	0.0667	0.0709	0.0506	0.2124	0.3148	0.2243	1	0.3748	0.0446	0.0134	0.0269
MAE-SD	0.0031	0.0429	0.0665	0.0341	0.2027	0.2971	0.1567	1	0.2390	0.0173	0.0007	0.0058
MAE-LOG	0.0007	0.0825	0.1571	0.0483	0.2293	0.3141	0.1522	1	0.2579	0.0163	0.0202	0.0214
MSE	0.0917	0.1272	0.1560	0.1222	0.2445	0.4781	0.3909	0.5161	1	0.1550	0.2574	0.1235
MSE-SD	0.0245	0.0735	0.0928	0.0456	0.4584	0.5731	0.4211	0.7766	1	0.1045	0.0203	0.0173
MSE-LOG	0.0002	0.1020	0.1407	0.0395	0.3116	0.4107	0.2370	1	0.6675	0.0860	0.0243	0.0129
QLIKE	0.0001	0.1513	0.3757	0.0950	0.3166	0.3152	0.2010	0.5942	1	0.5463	0.2656	0.0163

Notes: The null hypothesis of the SPA test is that the base is not inferior to any of the alternatives. Consistent p-values of the SPA test is the intensity of the base CIV producing superiority. A unity value of consistent p-values indicates that base CIV outperformed others.

Table 7. Encompassing test of CIVs extracted from options with strikes that correspond to different risk-neutral intervals

Left	β_{left}	β_{right}	Right
$\text{CIV}_{0-0.05}$	-0.0232	2.6730***	$\text{CIV}_{0.95-1}$
	(0.0920)	(0.8677)	
$\text{CIV}_{0.05-0.1}$	0.1049	2.3492***	$\text{CIV}_{0.9-0.85}$
	(0.1436)	(0.6977)	
$\text{CIV}_{0.1-0.15}$	0.0167	2.4542***	$\text{CIV}_{0.85-0.9}$
	(0.1936)	(0.6580)	
$\text{CIV}_{0.15-0.2}$	-0.2945	2.9908***	$\text{CIV}_{0.8-0.85}$
	(0.2925)	(0.8169)	
$\text{CIV}_{0.2-0.25}$	-0.8664	3.6509***	$\text{CIV}_{0.75-0.8}$
	(0.5400)	(1.1756)	
$\text{CIV}_{0.25-0.3}$	-0.5524*	2.8721***	$\text{CIV}_{0.7-0.75}$
	(0.3255)	(0.6551)	
$\text{CIV}_{0.3-0.35}$	-1.1811**	3.3111***	$\text{CIV}_{0.65-0.7}$
	(0.5799)	(0.9465)	
$\text{CIV}_{0.35-0.4}$	-1.3185**	3.0924***	$\text{CIV}_{0.6-0.65}$
	(0.5688)	(0.8254)	
$\text{CIV}_{0.4-0.45}$	-0.9864*	2.4137***	$\text{CIV}_{0.55-0.6}$
	(0.5228)	(0.6808)	
$\text{CIV}_{0.45-0.5}$	0.3169	0.8496***	$\text{CIV}_{0.5-0.55}$
	(0.3400)	(0.3242)	

Notes: The table reports the coefficients obtained from a linear regression by regressing monthly realized variance on the monthly observations of CIVs that are extarcted from put and call options. $CIV_{p_1-p_2}$ represents CIV that are extracted from options with strikes that correspond to a lower and upper risk-neutral probabilities of p_1 and p_2. In parentheses are Newey-West standard errors with 12 lags. *, ** and *** denote significance at 10%, 5% and 1% significance levels, respectively.

Table 8. Returns of Short-Term At-the-Money Zero-Beta Straddles before Transaction Costs

	CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}	VXD
Panel A: Option trading summary statistics												
Whole Periods												
Average Straddle Price (Forecasts)	2.0597	1.9816	1.8306	1.7018	1.5864	1.4726	1.3534	1.2229	1.0728	0.8883	0.6351	2.0573
Average Straddle Price (Market)	1.8412	1.8408	1.8399	1.8390	1.8380	1.8370	1.8356	1.8338	1.8312	1.8268	1.8167	1.8412
Long (short) straddle trades	2555(67)	2463(159)	1282(1340)	256(2366)	40(2582)	6(2616)	3(2619)	0(2622)	0(2622)	0(2622)	0(2622)	2532(90)
Average fraction of call options	0.4971	0.4972	0.4971	0.4968	0.4965	0.4961	0.4955	0.4945	0.4930	0.4901	0.4829	0.4971
High-Volatility Periods												
Average Straddle Price (Forecasts)	2.6822	2.5938	2.4093	2.2440	2.0937	1.9448	1.7880	1.6155	1.4178	1.1747	0.8412	2.6751
Average Straddle Price (Market)	2.4576	2.4573	2.4567	2.4560	2.4553	2.4546	2.4536	2.4523	2.4504	2.4473	2.4399	2.4576
Long (short) straddle trades	831(43)	786(88)	318(556)	34(840)	3(871)	2(872)	1(873)	0(874)	0(874)	0(874)	0(874)	826(48)
Average fraction of call options	0.4904	0.4907	0.4912	0.4917	0.4920	0.4923	0.4925	0.4926	0.4926	0.4920	0.4898	0.4904
Medium-Volatility Periods												
Average Straddle Price (Forecasts)	1.8822	1.8040	1.6618	1.5427	1.4373	1.3334	1.2251	1.1070	0.9710	0.8035	0.5741	1.8792
Average Straddle Price (Market)	1.6574	1.6570	1.6560	1.6551	1.6542	1.6531	1.6517	1.6499	1.6473	1.6429	1.6328	1.6574
Long (short) straddle trades	864(10)	841(33)	451(423)	101(773)	14(860)	2(872)	1(873)	0(874)	0(874)	0(874)	0(874)	853(21)
Average fraction of call options	0.5003	0.5004	0.5000	0.4996	0.4992	0.4986	0.4977	0.4965	0.4947	0.4912	0.4829	0.5003
Low-Volatility Periods												
Average Straddle Price (Forecasts)	1.6146	1.5470	1.4207	1.3186	1.2283	1.1396	1.0471	0.9461	0.8297	0.6867	0.4901	1.6176
Average Straddle Price (Market)	1.4088	1.4083	1.4070	1.4058	1.4046	1.4032	1.4015	1.3992	1.3958	1.3902	1.3774	1.4088
Long (short) straddle trades	860(14)	836(38)	513(361)	121(753)	23(851)	2(872)	1(873)	0(874)	0(874)	0(874)	0(874)	853(21)
Average fraction of call options	0.5007	0.5005	0.4999	0.4992	0.4984	0.4974	0.4961	0.4944	0.4917	0.4870	0.4760	0.5006
Panel B: Daily returns from option trades												
Whole Periods												
Number of + (-) returns	906(1716)	926(1696)	1313(1309)	1630(992)	1700(922)	1723(899)	1721(901)	1723(899)	1727(895)	1723(899)	1720(902)	916(1706)
Mean (%)	-0.2426	-0.2664	0.3425	**0.4396**	0.2532	0.3066	0.3253	0.2526	0.2578	0.2672	0.2900	-0.1832
Mean p-value	0.2776	0.2242	0.1248	0.0473	0.2480	0.1693	0.1390	0.2426	0.2266	0.2131	0.1820	0.4074
St.Dev (%)	11.4092	11.3853	11.3307	11.2811	11.2424	11.1950	11.1452	11.0928	11.0328	10.9877	11.1563	11.4082
Skewness	3.6901	3.6103	2.3126	-0.5169	-3.2799	-3.4144	-3.4732	-4.1233	-4.2519	-4.4789	-5.0190	3.6825
Kurtosis	31.1787	31.4313	31.4303	32.4378	33.2389	34.0926	35.1149	36.4605	38.6446	42.8182	54.6730	31.0687
Sharpe ratio (%)	-2.1264	-2.3394	3.0225	3.8969	2.2518	2.7383	2.9191	2.2772	2.3367	2.4321	2.5996	-1.6055
Sharpe ratio p-value	0.2764	0.2472	0.0597	0.1396	0.2512	0.2133	0.1992	0.2567	0.2511	0.2480	0.2333	0.3420
High-Volatility Periods												
Number of + (-) returns	337(537)	356(518)	476(398)	533(341)	537(337)	536(338)	536(338)	537(337)	541(333)	544(330)	540(334)	342(532)
Mean(%)	0.7961	0.8486	0.7782	-0.1175	-0.8049	-0.7990	-0.7889	**-1.0247**	**-1.0281**	**-1.0358**	**-1.0610**	0.8269
Mean p-value	0.0879	0.0683	0.0874	0.7980	0.0807	0.0793	0.0872	0.0324	0.0275	0.0272	0.0293	0.0791
St.Dev (%)	13.6098	13.5902	13.5637	13.5615	13.5173	13.4986	13.4844	13.4618	13.4679	13.5290	13.8942	13.6078
Skewness	3.5769	3.4281	1.7490	0.0321	-2.8737	-2.9014	-2.9409	-3.9601	-4.0565	-4.2498	-4.8553	3.5730
Kurtosis	27.0476	27.1909	27.9327	28.5165	28.3781	28.8141	29.4071	29.9156	31.3577	34.4583	45.6238	27.0384
Share ratio (%)	5.8497	**6.2441**	5.7373	-0.8663	-5.9542	-5.9194	-5.8506	**-7.6119**	**-7.6334**	**-7.6561**	-7.6365	6.0764
Sharpe ratio p-value	0.0956	0.0301	0.2081	0.7038	0.0701	0.0767	0.0728	0.0106	0.0137	0.0214	0.0634	0.0647
Medium-Volatility Periods												
Number of + (-) returns	283(591)	279(595)	432(442)	556(318)	584(290)	595(279)	594(280)	594(280)	591(283)	586(288)	575(299)	284(590)
Mean(%)	**-0.8760**	**-0.9846**	0.1921	**0.8792**	**0.8404**	**0.9399**	**0.9357**	**0.9601**	**0.9299**	**0.8782**	**0.7537**	**-0.7743**
Mean p-value	0.0135	0.0050	0.5751	0.0089	0.0142	0.0052	0.0074	0.0053	0.0069	0.0091	0.0247	0.0253
St.Dev (%)	9.9978	9.9638	9.9585	9.8741	9.8321	9.7765	9.7272	9.6690	9.6145	9.5887	9.8402	9.9987
Skewness	3.4428	3.4640	2.8849	-1.0077	-3.6360	-3.7449	-3.8429	-3.9660	-4.1411	-4.4173	-4.8552	3.4273
Kurtosis	31.7311	32.3773	31.2831	33.3307	35.2417	36.8320	38.4649	40.7839	43.9848	49.2770	58.0811	31.3050
Share ratio (%)	-8.7619	-9.8822	1.9287	8.9040	8.5479	9.6140	9.6192	9.9296	9.6716	9.1587	7.6589	-7.7437
Sharpe ratio p-value	0.1066	0.0915	0.6069	0.0946	0.1263	0.1041	0.1033	0.0967	0.1032	0.1190	0.1619	0.1368
Low-Volatility Periods												
Number of + (-) returns	286(588)	291(583)	405(469)	541(333)	579(295)	592(282)	591(283)	592(282)	595(279)	593(281)	605(269)	290(584)
Mean(%)	-0.6480	-0.6630	0.0571	0.5571	**0.7239**	**0.7788**	**0.8293**	**0.8224**	**0.8716**	**0.9593**	**1.1774**	-0.6021
Mean p-value	0.0623	0.0583	0.8724	0.0983	0.0350	0.0235	0.0149	0.0156	0.0077	0.0041	0.0005	0.0869
St.Dev (%)	10.1969	10.1626	10.1000	10.0075	9.9193	9.8302	9.7268	9.6055	9.4413	9.2161	8.9981	10.2002
Skewness	3.5277	3.5152	2.7000	-1.1926	-3.2509	-3.6484	-3.6958	-3.7442	-3.8126	-3.9020	-3.9090	3.5224
Kurtosis	29.4190	29.5935	28.8744	29.8175	31.1062	31.9092	32.7211	33.5860	34.9047	36.7323	37.4507	29.3446
Share ratio (%)	-6.3545	-6.5240	0.5657	5.5672	7.2980	7.9225	8.5254	8.5621	9.2317	10.4087	13.0853	-5.0924
Sharpe ratio p-value	0.1753	0.1678	0.8713	0.1989	0.1401	0.1318	0.1248	0.1190	0.1105	0.0900	0.0611	0.1867
Panel C: Mean Difference (%)												
High - Medium	**1.6721**	**1.8332**	0.5861	-0.9967	**-1.6453**	**-1.7390**	**-1.7246**	**-1.9848**	**-1.9579**	**-1.9140**	**-1.8147**	**1.6011**
	(0.0035)	(0.0017)	(0.3066)	(0.0764)	(0.0033)	(0.0017)	(0.0025)	(0.0005)	(0.0004)	(0.0012)	(0.0017)	(0.0055)
High - Low	**1.4441**	**1.5116**	0.7211	-0.6746	**-1.5288**	**-1.5778**	**-1.6182**	**-1.8471**	**-1.8997**	**-1.9951**	**-2.2385**	**1.4289**
	(0.0127)	(0.0077)	(0.2083)	(0.2412)	(0.0063)	(0.0056)	(0.0043)	(0.0012)	(0.0006)	(0.0009)	(0.0002)	(0.0130)
Medium - Low	-0.2280	-0.3216	0.1349	0.3220	0.1165	0.1611	0.1064	0.1377	0.0583	-0.0811	-0.4238	-0.1722
	(0.6400)	(0.5115)	(0.7852)	(0.4947)	(0.8056)	(0.7283)	(0.8216)	(0.7669)	(0.8970)	(0.8636)	(0.3547)	(0.7164)
Panel D: Sharpe Ratio Difference (%)												
High - Medium	**14.6116**	**16.1263**	3.8085	-9.7702	**-14.5021**	**-15.5335**	**-15.4699**	**-17.5414**	**-17.3050**	**-16.8147**	**-15.2954**	**13.8200**
	(0.0015)	(0.0007)	(0.4013)	(0.0655)	(0.0025)	(0.0019)	(0.0028)	(0.0003)	(0.0006)	(0.0010)	(0.0020)	(0.0023)
High - Low	**12.2042**	**12.7681**	5.1716	-6.4334	**-13.2522**	**-13.8419**	**-14.3760**	**-16.1740**	**-16.8652**	**-18.0648**	**-20.7217**	**11.9788**
	(0.0105)	(0.0093)	(0.2633)	(0.1877)	(0.0066)	(0.0036)	(0.0034)	(0.0009)	(0.0008)	(0.0006)	(0.0001)	(0.0131)
Medium - Low	-2.4074	-3.3582	1.3630	3.3368	1.2499	1.6916	1.0939	1.3675	0.4398	-1.2500	-5.4263	-1.8412
	(0.6399)	(0.5165)	(0.7776)	(0.5121)	(0.8032)	(0.7436)	(0.8394)	(0.8061)	(0.9351)	(0.8300)	(0.3585)	(0.7211)

Notes: The table reports the summary statistics from trades in short-term zero-beta straddles in the DJX options market from October 1, 2004 to March 6, 2015. On each trading day, market agents use CIVs to obtain a price forecast for the zero-beta straddle by using the Black-Scholes Model. The proportions for the call and put options in the straddle also depend on the CIV. They enter their positions in the market by buying (selling) the aforementioned option portfolio if the portfolio is underpriced (overpriced). On the next day, they close their positions of the previous day by an offsetting order so that they can rebalance their portfolio everyday. Only options with maturities that are between 7 to 60 days are traded. If an option traded on the previous day cannot be found on the next day, the rate of return for that option during this period is recorded as -1. The profit of the zero-beta straddle is calculated as:

$$\text{profit} = \frac{-C\beta_c + S}{P\beta_c - C\beta_c + S} r_c + \frac{P\beta_c}{P\beta_c - C\beta_c + S} r_p \tag{8}$$

where C and P are put and call option prices. S is the underlying index level; r_c and r_p are return on the call and put options, respectively. β_c is the market beta for the call option, and is defined as $\beta_c = \frac{S}{C}\Delta_c$, where Δ_c is the call option delta. The rate of return π can then be calculated. We allow market agents to borrow at the risk-free rate and to invest all profits from option trades into risk-free assets. Therefore, we deduct (add) a risk-free rate from (to) the rate of return of the zero-beta-straddle. No transaction cost is considered. The return sample is divided into three subsamples: high-, medium- and low-volatility period subsamples, according to realized volatility calculated from historical index levels. p-values for the mean and mean difference are based on Efron & Tibshirani (1993) and Efron (1979) via a transformation of original returns, and p-values for the Sharpe ratio are based on Opdyke (2007). All p-values are calculated through a bootstrap t-test. The t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. In parentheses are p-values. Numbers in bold indicate significance at 5% significance level.

Table 9. Mean Rate of Return Differences from Option Trades before Transaction Costs (Zero-Beta Straddles)

		B										
		CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}
	Whole Periods											
	CIV_1	-0.0237										
		(0.9394)										
	CIV_5	0.5851	0.6088									
		(0.0659)	(0.0550)									
	CIV_{10}	**0.6822**	**0.7060**	0.0971								
		(0.0317)	(0.0263)	(0.7558)								
	CIV_{15}	0.4958	0.5195	-0.0893	-0.1865							
		(0.1135)	(0.0988)	(0.7818)	(0.5477)							
	CIV_{20}	0.5492	0.5729	-0.0359	-0.1331	0.0534						
		(0.0775)	(0.0626)	(0.9111)	(0.6673)	(0.8643)						
A	CIV_{25}	0.5679	0.5917	-0.0171	-0.1143	0.0722	0.0188					
		(0.0661)	(0.0611)	(0.9613)	(0.7127)	(0.8176)	(0.9488)					
	CIV_{30}	0.4952	0.5190	-0.0899	-0.1870	-0.0006	-0.0540	-0.0727				
		(0.1097)	(0.0960)	(0.7727)	(0.5510)	(0.9983)	(0.8588)	(0.8082)				
	CIV_{35}	0.5004	0.5242	-0.0847	-0.1818	0.0046	-0.0488	-0.0675	0.0052			
		(0.1034)	(0.0894)	(0.7804)	(0.5577)	(0.9883)	(0.8756)	(0.8301)	(0.9862)			
	CIV_{40}	0.5098	0.5336	-0.0752	-0.1724	0.0141	-0.0393	-0.0581	0.0146	0.0094		
		(0.0991)	(0.0804)	(0.8094)	(0.5832)	(0.9639)	(0.9015)	(0.8418)	(0.9667)	(0.9752)		
	CIV_{45}	0.5326	0.5564	-0.0524	-0.1496	0.0369	-0.0165	-0.0353	0.0374	0.0322	0.0228	
		(0.0869)	(0.0761)	(0.8687)	(0.6268)	(0.9063)	(0.9584)	(0.9049)	(0.8991)	(0.9170)	(0.9400)	
	VXD	0.0595	0.0832	-0.5256	**-0.6228**	-0.4363	-0.4897	-0.5085	-0.4358	-0.4410	-0.4504	-0.4732
		(0.8527)	(0.7920)	(0.0951)	(0.0477)	(0.1628)	(0.1184)	(0.1031)	(0.1578)	(0.1631)	(0.1444)	(0.1285)
	High-Volatility Periods											
	CIV_1	0.0525										
		(0.9379)										
	CIV_5	-0.0179	-0.0704									
		(0.9762)	(0.9124)									
	CIV_{10}	-0.9136	-0.9661	-0.8957								
		(0.1671)	(0.1394)	(0.1761)								
	CIV_{15}	**-1.6010**	**-1.6534**	**-1.5830**	-0.6874							
		(0.0142)	(0.0123)	(0.0160)	(0.2838)							
	CIV_{20}	**-1.5952**	**-1.6476**	**-1.5772**	-0.6816	0.0058						
		(0.0156)	(0.0122)	(0.0149)	(0.2929)	(0.9937)						
A	CIV_{25}	**-1.5850**	**-1.6375**	**-1.5671**	-0.6714	0.0159	0.0101					
		(0.0155)	(0.0121)	(0.0136)	(0.3054)	(0.9797)	(0.9875)					
	CIV_{30}	**-1.8208**	**-1.8733**	**-1.8029**	-0.9072	-0.2198	-0.2257	-0.2358				
		(0.0057)	(0.0059)	(0.0054)	(0.1671)	(0.7340)	(0.7259)	(0.7177)				
	CIV_{35}	**-1.8242**	**-1.8767**	**-1.8063**	-0.9106	-0.2232	-0.2290	-0.2391	-0.0034			
		(0.0065)	(0.0036)	(0.0059)	(0.1601)	(0.7264)	(0.7328)	(0.7186)	(0.9948)			
	CIV_{40}	**-1.8319**	**-1.8844**	**-1.8140**	-0.9183	-0.2309	-0.2368	-0.2469	-0.0111	-0.0077		
		(0.0074)	(0.0048)	(0.0058)	(0.1556)	(0.7134)	(0.7086)	(0.7138)	(0.9846)	(0.9901)		
	CIV_{45}	**-1.8572**	**-1.9096**	**-1.8392**	-0.9435	-0.2562	-0.2620	-0.2721	-0.0363	-0.0330	-0.0252	
		(0.0059)	(0.0045)	(0.0067)	(0.1528)	(0.7030)	(0.6866)	(0.6880)	(0.9588)	(0.9640)	(0.9680)	
	VXD	0.0307	-0.0217	0.0487	0.9443	**1.6317**	**1.6259**	**1.6158**	**0.8516**	**1.8549**	**1.8627**	**1.8879**
		(0.9679)	(0.9745)	(0.9383)	(0.1541)	(0.0139)	(0.0131)	(0.0156)	(0.0042)	(0.0059)	(0.0052)	(0.0058)
	Medium-Volatility Periods											
	CIV_1	-0.1086										
		(0.8238)										
	CIV_5	**1.0681**	**1.1767**									
		(0.0230)	(0.0139)									
	CIV_{10}	**1.7552**	**1.8638**	0.6871								
		(0.0005)	(0.0002)	(0.1486)								
	CIV_{15}	**1.7164**	**1.8251**	0.6484	-0.0388							
		(0.0007)	(0.0005)	(0.1690)	(0.9332)							
	CIV_{20}	**1.8159**	**1.9246**	0.7478	0.0607	0.0995						
		(0.0004)	(0.0002)	(0.1086)	(0.8972)	(0.8265)						
A	CIV_{25}	**1.8117**	**1.9203**	0.7436	0.0565	0.0953	-0.0042					
		(0.0004)	(0.0002)	(0.1108)	(0.9062)	(0.8383)	(0.9948)					
	CIV_{30}	**1.8361**	**1.9447**	0.7680	0.0809	0.1197	0.0202	0.0244				
		(0.0002)	(0.0001)	(0.1015)	(0.8613)	(0.7958)	(0.9637)	(0.9613)				
	CIV_{35}	**1.8059**	**1.9145**	0.7378	0.0507	0.0894	-0.0100	-0.0058	-0.0302			
		(0.0002)	(0.0001)	(0.1086)	(0.9147)	(0.8457)	(0.9817)	(0.9903)	(0.9445)			
	CIV_{40}	**1.7542**	**1.8628**	0.6861	-0.0010	0.0378	-0.0617	-0.0575	-0.0819	-0.0517		
		(0.0004)	(0.0002)	(0.1471)	(0.9979)	(0.9383)	(0.8946)	(0.9039)	(0.8591)	(0.9149)		
	CIV_{45}	**1.6297**	**1.7383**	0.5616	-0.1255	-0.0868	-0.1863	-0.1820	-0.2064	-0.1762	-0.1245	
		(0.0013)	(0.0005)	(0.2239)	(0.7954)	(0.8605)	(0.6887)	(0.6996)	(0.6602)	(0.7063)	(0.7959)	
	VXD	0.1017	0.2104	**-0.9663**	**-1.6534**	**-1.6147**	**-1.7142**	**-1.7099**	**-1.7343**	**-1.7041**	**-1.6525**	**-1.5279**
		(0.8337)	(0.6599)	(0.0418)	(0.0010)	(0.0015)	(0.0007)	(0.0007)	(0.0007)	(0.0004)	(0.0009)	(0.0022)
	Low-Volatility Periods											
	CIV_1	-0.0150										
		(0.9782)										
	CIV_5	0.7051	0.7201									
		(0.1478)	(0.1321)									
	CIV_{10}	**1.2051**	**1.2201**	0.5000								
		(0.0148)	(0.0114)	(0.2917)								
	CIV_{15}	**1.3719**	**1.3869**	0.6668	0.1668							
		(0.0056)	(0.0051)	(0.1701)	(0.7223)							
	CIV_{20}	**1.4268**	**1.4418**	0.7217	0.2217	0.0549						
		(0.0034)	(0.0041)	(0.1285)	(0.6496)	(0.9006)						
A	CIV_{25}	**1.4772**	**1.4923**	0.7721	0.2721	0.1053	0.0505					
		(0.0030)	(0.0031)	(0.1045)	(0.5709)	(0.8275)	(0.9129)					
	CIV_{30}	**1.4704**	**1.4854**	0.7653	0.2653	0.0985	0.0436	-0.0068				
		(0.0033)	(0.0021)	(0.1087)	(0.5740)	(0.8233)	(0.9307)	(0.9888)				
	CIV_{35}	**1.5196**	**1.5346**	0.8145	0.3145	0.1477	0.0928	0.0423	0.0492			
		(0.0028)	(0.0020)	(0.0850)	(0.5030)	(0.7478)	(0.8460)	(0.9243)	(0.9120)			
	CIV_{40}	**1.6072**	**1.6223**	0.9021	0.4021	0.2354	0.1805	0.1300	0.1368	0.0877		
		(0.0011)	(0.0011)	(0.0529)	(0.3905)	(0.6092)	(0.6903)	(0.7716)	(0.7595)	(0.8446)		
	CIV_{45}	**1.8254**	**1.8404**	**1.1203**	0.6203	0.4535	0.3986	0.3482	0.3550	0.3058	0.2181	
		(0.0002)	(0.0003)	(0.0151)	(0.1730)	(0.3212)	(0.3762)	(0.4364)	(0.4276)	(0.4874)	(0.6308)	
	VXD	0.0459	0.0609	-0.6592	**-1.1592**	**-1.3260**	**-1.3809**	**-1.4313**	**-1.4245**	**-1.4737**	**-1.5613**	**-1.7795**
		(0.9313)	(0.9020)	(0.1752)	(0.0178)	(0.0091)	(0.0044)	(0.0032)	(0.0036)	(0.0032)	(0.0015)	(0.0004)

Notes: The table reports the differences between mean rates of returns from option trades that are based on different pairs of CIVs, and respective two-sided p-values for the mean difference in parentheses. The mean difference is calculated as $\bar{\pi}_A - \bar{\pi}_B$, where $\bar{\pi}_A$ and $\bar{\pi}_B$ are mean rates of returns from option trades that are based on CIVs in A and B, respectively. p-values for the mean difference are based on Efron & Tibshirani (1993) and Efron (1979), and are calculated based on a bootstrap t-test. The null hypothesis of the test is that there is no difference between the mean rates of returns for the zero-beta straddles based on different CIVs. The bootstrap t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. Numbers in bold indicate significance at 5% significance level.

Table 10. Sharpe Ratio Differences from Option Trades before Transaction Costs (Zero-Beta Straddles)

		B										
		CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}
	Whole Periods											
	CIV_1	-0.2130										
		(0.7541)										
	CIV_5	**5.1489**	**5.3619**									
		(0.0273)	(0.0252)									
	CIV_{10}	6.0233	6.2364	0.8744								
		(0.0786)	(0.0642)	(0.7356)								
	CIV_{15}	4.3783	4.5913	-0.7706	-1.6451							
		(0.2400)	(0.2191)	(0.8049)	(0.3971)							
	CIV_{20}	4.8648	5.0778	-0.2841	-1.1586	0.4865						
		(0.1993)	(0.1833)	(0.9256)	(0.5640)	(0.3549)						
A	CIV_{25}	5.0455	5.2585	-0.1034	-0.9778	0.6673	0.1808					
		(0.1944)	(0.1695)	(0.9728)	(0.6333)	(0.2078)	(0.1263)					
	CIV_{30}	4.4036	4.6167	-0.7452	-1.6197	0.0254	-0.4611	-0.6419				
		(0.2510)	(0.2261)	(0.8072)	(0.4416)	(0.9774)	(0.5707)	(0.4822)				
	CIV_{35}	4.4631	4.6761	-0.6858	-1.5602	0.0848	-0.4017	-0.5824	0.0595			
		(0.2380)	(0.2184)	(0.8194)	(0.4615)	(0.9329)	(0.6256)	(0.5196)	(0.5525)			
	CIV_{40}	4.5585	4.7715	-0.5904	-1.4649	0.1802	-0.3063	-0.4871	0.1548	0.0954		
		(0.2274)	(0.2204)	(0.8421)	(0.4992)	(0.8620)	(0.7303)	(0.5845)	(0.5667)	(0.5830)		
	CIV_{45}	4.7260	4.9390	-0.4229	-1.2973	0.3477	-0.1387	-0.3195	0.3224	0.2629	0.1675	
		(0.2052)	(0.1943)	(0.8920)	(0.5601)	(0.7825)	(0.8988)	(0.7695)	(0.6276)	(0.6395)	(0.6802)	
	VXD	0.5210	0.7340	**-4.6279**	-5.5024	-3.8573	-4.3438	-4.5246	-3.8827	-3.9421	-4.0375	-4.2050
		(0.0737)	(0.2848)	(0.0437)	(0.0942)	(0.3077)	(0.2464)	(0.2383)	(0.3131)	(0.2956)	(0.2934)	(0.2613)
	High-Volatility Periods											
	CIV_1	0.3944										
		(0.7904)										
	CIV_5	-0.1124	-0.5068									
		(0.9778)	(0.8872)									
	CIV_{10}	-6.7160	-7.1104	-6.6036								
		(0.2630)	(0.1881)	(0.1133)								
	CIV_{15}	**-11.8039**	**-12.1984**	**-11.6915**	-5.0880							
		(0.0397)	(0.0323)	(0.0176)	(0.1663)							
	CIV_{20}	**-11.7691**	**-12.1636**	**-11.6567**	-5.0532	0.0348						
		(0.0364)	(0.0311)	(0.0186)	(0.1642)	(0.5711)						
A	CIV_{25}	**-11.7003**	**-12.0948**	**-11.5879**	-4.9844	0.1036	0.0688					
		(0.0383)	(0.0331)	(0.0159)	(0.1751)	(0.4214)	(0.5190)					
	CIV_{30}	**-13.4616**	**-13.8560**	**-13.3492**	-6.7456	-1.6577	-1.6924	-1.7613				
		(0.0127)	(0.0100)	(0.0066)	(0.1790)	(0.4381)	(0.4454)	(0.4335)				
	CIV_{35}	**-13.4813**	**-13.8776**	**-13.3707**	-6.7672	-1.6792	-1.7140	-1.7828	-0.0215			
		(0.0117)	(0.0120)	(0.0065)	(0.1782)	(0.4525)	(0.4472)	(0.4394)	(0.8110)			
	CIV_{40}	**-13.5058**	**-13.9002**	**-13.3934**	-6.7898	-1.7018	-1.7366	-1.8054	-0.0442	-0.0226		
		(0.0115)	(0.0103)	(0.0065)	(0.1829)	(0.4608)	(0.4567)	(0.4404)	(0.8612)	(0.8900)		
	CIV_{45}	**-13.4862**	**-13.8806**	**-13.3738**	-6.7702	-1.6822	-1.7170	-1.7858	-0.0246	-0.0030	0.0196	
		(0.0091)	(0.0101)	(0.0052)	(0.1841)	(0.4766)	(0.4675)	(0.4634)	(0.9662)	(0.9951)	(0.9549)	
	VXD	0.2267	-0.1678	0.3391	6.9426	**12.0306**	**11.9958**	**11.9270**	**13.6883**	**13.7098**	**13.7324**	**13.7128**
		(0.3893)	(0.9075)	(0.9261)	(0.1935)	(0.0386)	(0.0374)	(0.0376)	(0.0134)	(0.0130)	(0.0143)	(0.0117)
	Medium-Volatility Periods											
	CIV_1	-1.1203										
		(0.3427)										
	CIV_5	**10.6906**	**11.8109**									
		(0.0065)	(0.0031)									
	CIV_{10}	**17.6658**	**18.7861**	6.9752								
		(0.0245)	(0.0142)	(0.2054)								
	CIV_{15}	**17.3097**	**18.4301**	6.6191	-0.3561							
		(0.0351)	(0.0220)	(0.2936)	(0.9274)							
	CIV_{20}	**18.3759**	**19.4962**	7.6853	0.7101	1.0661						
		(0.0288)	(0.0224)	(0.2254)	(0.8443)	(0.2039)						
A	CIV_{25}	**18.3811**	**19.5014**	7.6905	0.7153	1.0714	0.0052					
		(0.0314)	(0.0220)	(0.2189)	(0.8494)	(0.2564)	(0.9765)					
	CIV_{30}	**18.6914**	**19.8117**	8.0008	1.0256	1.3817	0.3155	0.3103				
		(0.0285)	(0.0222)	(0.2197)	(0.7890)	(0.2083)	(0.6064)	(0.5819)				
	CIV_{35}	**18.4334**	**19.5537**	7.7428	0.7676	1.1237	0.0575	0.0523	-0.2580			
		(0.0338)	(0.0205)	(0.2308)	(0.8412)	(0.3398)	(0.9358)	(0.9375)	(0.2399)			
	CIV_{40}	**17.9205**	**19.0408**	7.2299	0.2547	0.6108	-0.4554	-0.4606	-0.7709	-0.5129		
		(0.0331)	(0.0215)	(0.2659)	(0.9538)	(0.6618)	(0.6487)	(0.6128)	(0.1997)	(0.1757)		
	CIV_{45}	**16.4208**	**17.5411**	5.7302	-1.2450	-0.8889	-1.9551	-1.9603	-2.2706	-2.0126	-1.4997	
		(0.0459)	(0.0344)	(0.3593)	(0.7433)	(0.6524)	(0.2657)	(0.2375)	(0.1136)	(0.0896)	(0.0824)	
	VXD	1.0182	2.1385	**-9.6724**	**-16.6476**	**-16.2915**	**-17.3577**	**-17.3629**	**-17.6732**	**-17.4152**	**-16.9023**	**-15.4026**
		(0.1693)	(0.0853)	(0.0098)	(0.0207)	(0.0378)	(0.0349)	(0.0310)	(0.0335)	(0.0327)	(0.0358)	(0.0477)
	Low-Volatility Periods											
	CIV_1	-0.1695										
		(0.8530)										
	CIV_5	6.9202	7.0897									
		(0.0664)	(0.0510)									
	CIV_{10}	11.9216	12.0911	5.0014								
		(0.0640)	(0.0629)	(0.3204)								
	CIV_{15}	13.6525	**13.8220**	6.7323	1.7308							
		(0.0578)	(0.0479)	(0.2451)	(0.6050)							
	CIV_{20}	14.2769	14.4464	7.3567	2.3553	0.6245						
		(0.0589)	(0.0532)	(0.2196)	(0.5125)	(0.7108)						
A	CIV_{25}	**14.8799**	**15.0494**	7.9597	2.9582	1.2274	0.6029					
		(0.0452)	(0.0447)	(0.1965)	(0.4181)	(0.4565)	(0.2444)					
	CIV_{30}	14.9165	**15.0861**	7.9964	2.9949	1.2641	0.6396	0.0367				
		(0.0524)	(0.0470)	(0.1981)	(0.4224)	(0.4575)	(0.3861)	(0.9173)				
	CIV_{35}	**15.5862**	**15.7557**	8.6660	3.6646	1.9337	1.3093	0.7064	**0.6697**			
		(0.0467)	(0.0426)	(0.1813)	(0.3340)	(0.2712)	(0.1265)	(0.3413)	(0.0047)			
	CIV_{40}	**16.7632**	**16.9327**	9.8430	4.8415	3.1107	**2.4862**	1.8833	**1.8466**	**1.1770**		
		(0.0347)	(0.0328)	(0.1351)	(0.2285)	(0.1024)	(0.0395)	(0.0676)	(0.0052)	(0.0060)		
	CIV_{45}	**19.4397**	**19.6092**	12.5195	7.5181	**5.7873**	**5.1628**	**4.5599**	**4.5232**	**3.8535**	**2.6766**	
		(0.0173)	(0.0174)	(0.0697)	(0.0926)	(0.0206)	(0.0128)	(0.0166)	(0.0047)	(0.0065)	(0.0068)	
	VXD	0.4521	0.6216	-6.4681	-11.4696	-13.2004	-13.8249	-14.4278	-14.4645	**-15.1342**	**-16.3111**	**-18.9877**
		(0.3992)	(0.4970)	(0.0841)	(0.0792)	(0.0708)	(0.0668)	(0.0542)	(0.0589)	(0.0486)	(0.0390)	(0.0181)

Notes: The table reports the differences between Sharpe ratios from option trades that are based on different pairs of CIVs, and respective two-sided p-values for the Sharpe ratio difference in parentheses. The Sharpe ratio difference is calculated as $\text{Sharpe}_A - \text{Sharpe}_B$, where Sharpe_A and Sharpe_B are Sharpe ratios from option trades that are based on CIVs in A and B, respectively. p-values for the Sharpe ratio difference are based on Ledoit & Wolf (2008) for non i.i.d. returns. The null hypothesis is that there is no difference between the Sharpe ratios for the zero-beta straddles based on different CIVs. The bootstrap t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. Numbers in bold indicate significance at 5% significance level.

Table 11. Returns of Short-Term At-the-Money Zero-Beta Straddles after Transaction Costs

	CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}	VXD
Panel A: Daily returns from option trades												
Whole Periods												
Number of + (-) returns	581(2041)	593(2029)	840(1782)	1044(1578)	1094(1528)	1104(1518)	1105(1517)	1092(1530)	1089(1533)	1087(1535)	1095(1527)	585(2037)
Mean (%)	**-3.5996**	**-3.6261**	**-3.0499**	**-2.9925**	**-3.1904**	**-3.1403**	**-3.1283**	**-3.2121**	**-3.2098**	**-3.2055**	**-3.1949**	**-3.5434**
Mean p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
St.Dev (%)	10.9415	10.9346	11.1146	11.7867	11.9278	11.8943	11.8496	11.9236	11.8688	11.8318	12.0141	10.9228
Skewness	3.2186	3.1092	1.5315	-1.6984	-3.9721	-4.0857	-4.1438	-4.6222	-4.7406	-4.9410	-5.3839	3.2307
Kurtosis	28.0627	28.2037	27.7815	37.0854	38.8257	39.6107	40.5505	42.4624	44.4065	47.9486	57.4335	28.1108
Sharpe ratio (%)	**-32.8983**	**-33.1618**	**-27.4402**	**-25.3885**	**-26.7481**	**-26.4019**	**-26.3998**	**-26.9386**	**-27.0441**	**-27.0922**	**-26.5932**	**-32.4406**
Sharpe ratio p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
High-Volatility Periods												
Number of + (-) returns	219(655)	232(642)	315(559)	356(518)	357(517)	356(518)	355(519)	349(525)	350(524)	351(523)	349(525)	220(654)
Mean (%)	**-2.4940**	**-2.4459**	**-2.5512**	**-3.4793**	**-4.1723**	**-4.1674**	**-4.1737**	**-4.4129**	**-4.4181**	**-4.4291**	**-4.4621**	**-2.4661**
Mean p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
St.Dev (%)	13.0586	13.0681	13.4310	14.1876	14.2844	14.2686	14.2652	14.4676	14.4831	14.5593	14.9556	13.0514
Skewness	3.2372	3.0444	1.0099	-0.9199	-3.3686	-3.4004	-3.4381	-4.1721	-4.2640	-4.4431	-4.9865	3.2374
Kurtosis	26.0186	26.0277	26.1464	26.5842	28.1638	28.6127	29.1500	31.0079	32.3400	35.1332	44.9369	26.0493
Sharpe ratio (%)	**-19.0988**	**-18.7166**	**-18.9949**	**-24.5234**	**-29.2089**	**-29.2069**	**-29.2578**	**-30.5018**	**-30.5054**	**-30.4212**	**-29.8359**	**-18.8953**
Sharpe ratio p-value	0.0146	0.0160	0.0067	0.0007	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0153
Medium-Volatility Periods												
Number of + (-) returns	182(692)	181(693)	263(611)	337(537)	359(515)	367(507)	371(503)	374 (500)	372(502)	370(504)	360(514)	184(690)
Mean (%)	**-4.2183**	**-4.3291**	**-3.1867**	**-2.5383**	**-2.5919**	**-2.4953**	**-2.5015**	**-2.4854**	**-2.5191**	**-2.5769**	**-2.7162**	**-4.1230**
Mean p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
St.Dev (%)	9.7970	9.7655	9.9002	9.9424	10.2154	10.1602	10.1097	10.0040	9.9509	9.9293	10.1988	9.7458
Skewness	3.1661	3.1811	2.4721	-1.4519	-3.7613	-3.8649	-3.9579	-4.1158	-4.2788	-4.5308	-4.9096	3.2161
Kurtosis	30.2607	30.8676	28.4705	31.1124	35.1243	36.6097	38.1410	40.9538	43.9294	48.7713	56.5114	30.3933
Sharpe ratio (%)	**-43.0568**	**-44.3310**	**-32.1884**	**-25.5305**	**-25.3721**	**-24.5593**	**-24.7436**	**-24.8442**	**-25.3156**	**-25.9523**	**-26.6326**	**-42.3059**
Sharpe ratio p-value	0.0011	0.0010	0.0018	0.0007	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0009
Low-Volatility Periods												
Number of + (-) returns	180(694)	180(694)	262(612)	351(523)	378(496)	381(493)	379(495)	369(505)	367(507)	366(508)	386(488)	181(693)
Mean (%)	**-4.0863**	**-4.1033**	**-3.4116**	**-2.9598**	**-2.8072**	**-2.7582**	**-2.7096**	**-2.7379**	**-2.6922**	**-2.6105**	**-2.4064**	**-4.0411**
Mean p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
St.Dev (%)	9.5430	9.5244	9.5957	10.7941	10.8292	10.7844	10.6863	10.7357	10.5803	10.3675	10.1587	9.5461
Skewness	2.5555	2.5198	1.5166	-3.3006	-4.8329	-5.1203	-5.1904	-5.1767	-5.2792	-5.4120	-5.4303	2.5522
Kurtosis	18.2344	18.2539	17.3960	56.5048	57.0869	57.9559	59.3520	58.0606	60.1426	62.9004	63.4947	18.1821
Sharpe ratio (%)	**-42.8205**	**-43.0819**	**-35.5535**	**-27.4202**	**-25.9223**	**-25.5761**	**-25.3562**	**-25.5024**	**-25.4455**	**-25.1799**	**-23.6884**	**-42.3323**
Sharpe ratio p-value	0.0001	0.0006	0.0003	0.0007	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Panel B: Mean Difference (%)												
High - Medium	**1.7243**	**1.8832**	0.6355	-0.9409	**-1.5805**	**-1.6721**	**-1.6722**	**-1.9275**	**-1.8990**	**-1.8522**	**-1.7459**	**1.6569**
	(0.0020)	(0.0007)	(0.2571)	(0.1065)	(0.0085)	(0.0052)	(0.0044)	(0.0014)	(0.0020)	(0.0021)	(0.0051)	(0.0033)
High - Low	**1.5923**	**1.6574**	0.8604	-0.5195	**-1.3651**	**-1.4092**	**-1.4640**	**-1.6750**	**-1.7259**	**-1.8186**	**-2.0557**	**1.5750**
	(0.0032)	(0.0024)	(0.1219)	(0.3862)	(0.0273)	(0.0202)	(0.0169)	(0.0060)	(0.0051)	(0.0030)	(0.0004)	(0.0048)
Medium - Low	-0.1320	-0.2258	0.2249	0.4214	0.2153	0.2629	0.2081	0.2524	0.1731	0.0336	-0.3098	-0.0820
	(0.7776)	(0.6315)	(0.6255)	(0.3957)	(0.6684)	(0.6030)	(0.6669)	(0.6124)	(0.7262)	(0.9451)	(0.5230)	(0.8541)
Panel C: Sharpe Ratio Difference (%)												
High - Medium	**23.9581**	**25.6144**	13.1935	1.0071	-3.8368	-4.6477	-4.5142	-5.6576	-5.1898	-4.4689	-3.2033	**23.4106**
	(0.0047)	(0.0040)	(0.0699)	(0.8641)	(0.3191)	(0.2210)	(0.2504)	(0.0969)	(0.1319)	(0.2040)	(0.3969)	(0.0078)
High - Low	**23.7217**	**24.3653**	**16.5586**	2.8968	-3.2866	-3.6308	-3.9016	-4.9995	-5.0599	-5.2413	-6.1475	**23.4370**
	(0.0022)	(0.0013)	(0.0131)	(0.6165)	(0.4123)	(0.3530)	(0.3150)	(0.1282)	(0.1230)	(0.1197)	(0.0681)	(0.0019)
Medium - Low	-0.2363	-1.2491	3.3651	1.8897	0.5502	1.0169	0.6126	0.6582	0.1299	-0.7724	-2.9443	0.0265
	(0.9762)	(0.8864)	(0.6615)	(0.7537)	(0.8817)	(0.7797)	(0.8691)	(0.8531)	(0.9698)	(0.8364)	(0.4353)	(0.9976)

Notes: The table reports the summary statistics from trades in short-term zero-beta straddles in the DJX options market from October 1, 2004 to March 6, 2015. On each trading day, market agents use CIVs to obtain a price forecast for the zero-beta straddle by using the Black-Scholes Model. The proportions for the call and put options in the straddle also depend on the CIV. They enter their positions in the market by buying (selling) the aforementioned option portfolio if the portfolio is underpriced (overpriced). On the next day, they close their positions of the previous day by an offsetting order so that they can rebalance their portfolio everyday. Only options with maturities that are between 7 to 60 days are traded. If an option traded on the previous day cannot be found on the next day, the rate of return for that option during this period is recorded as -1. The profit of the zero-beta straddle is calculated as:

$$\text{profit} = \frac{-C\beta_c + S}{P\beta_c - C\beta_c + S} r_c + \frac{P\beta_c}{P\beta_c - C\beta_c + S} r_p \tag{9}$$

where C and P are put and call option prices. S is the underlying index level; r_c and r_p are return on the call and put options, respectively. β_c is the market beta for the call option, and is defined as $\beta_c = \frac{S}{C}\Delta_c$, where Δ_c is the call option delta. The rate of return π can then be calculated. We allow market agents to borrow at the risk-free rate and to invest all profits from option trades into risk-free assets. Therefore, we deduct (add) a risk-free rate from (to) the rate of return of the zero-beta-straddle. Transaction costs include a 25% effective bid-ask spread and a 0.5% commission fee; see (Hull 2012, Table 9.1) for a typical commission fee scheme in the options markets. Commission fees are payable both upon entering and exiting a position since an offsetting order is used to close out positions in the market. The return sample is divided into three subsamples: high-, medium- and low-volatility period subsamples, according to realized volatility calculated from historical index levels. p-values for the mean and mean difference are based on Efron & Tibshirani (1993) and Efron (1979) via a transformation of original returns, and p-values for the Sharpe ratio are based on Opdyke (2007). All p-values are calculated through a bootstrap t-test. The t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. In parentheses are p-values. Numbers in bold indicate significance at 5% significance level.

Table 12. Mean Rate of Return Differences from Option Trades after Transaction Costs (Zero-Beta Straddles)

		B										
		CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}
	Whole Periods											
	CIV_1	-0.0266										
		(0.9310)										
	CIV_5	0.5497	0.5763									
		(0.0689)	(0.0563)									
	CIV_{10}	0.6071	**0.6337**	0.0574								
		(0.0560)	(0.0462)	(0.8557)								
	CIV_{15}	0.4091	0.4357	-0.1406	-0.1980							
		(0.1995)	(0.1734)	(0.6718)	(0.5381)							
	CIV_{20}	0.4592	0.4858	-0.0905	-0.1479	0.0501						
		(0.1433)	(0.1210)	(0.7665)	(0.6511)	(0.8819)						
A	CIV_{25}	0.4713	0.4978	-0.0784	-0.1358	0.0622	0.0120					
		(0.1367)	(0.1137)	(0.8068)	(0.6745)	(0.8482)	(0.9709)					
	CIV_{30}	0.3875	0.4141	-0.1622	-0.2196	-0.0216	-0.0717	-0.0838				
		(0.2167)	(0.1923)	(0.6089)	(0.5062)	(0.9454)	(0.8298)	(0.7987)				
	CIV_{35}	0.3897	0.4163	-0.1600	-0.2174	-0.0194	-0.0695	-0.0816	0.0022			
		(0.2237)	(0.1861)	(0.6121)	(0.5141)	(0.9518)	(0.8301)	(0.8057)	(0.9946)			
	CIV_{40}	0.3940	0.4206	-0.1557	-0.2131	-0.0151	-0.0652	-0.0772	0.0066	0.0043		
		(0.2066)	(0.1850)	(0.6302)	(0.5117)	(0.9650)	(0.8398)	(0.8202)	(0.9867)	(0.9899)		
	CIV_{45}	0.4046	0.4312	-0.1451	-0.2025	-0.0045	-0.0546	-0.0667	0.0171	0.0149	0.0106	
		(0.2021)	(0.1752)	(0.6524)	(0.5294)	(0.9878)	(0.8645)	(0.8395)	(0.9590)	(0.9643)	(0.9748)	
	VXD	0.0561	0.0827	-0.4936	-0.5510	-0.3530	-0.4031	-0.4151	-0.3314	-0.3336	-0.3379	-0.3485
		(0.8586)	(0.7914)	(0.1011)	(0.0817)	(0.2631)	(0.1959)	(0.1899)	(0.2921)	(0.2922)	(0.2780)	(0.2771)
	High-Volatility Periods											
	CIV_1	0.0481										
		(0.9396)										
	CIV_5	-0.0572	-0.1053									
		(0.9281)	(0.8679)									
	CIV_{10}	-0.9852	-1.0334	-0.9281								
		(0.1358)	(0.1142)	(0.1573)								
	CIV_{15}	**-1.6783**	**-1.7264**	**-1.6211**	-0.6930							
		(0.0122)	(0.0100)	(0.0153)	(0.3151)							
	CIV_{20}	**-1.6734**	**-1.7215**	**-1.6162**	-0.6881	0.0049						
		(0.0108)	(0.0095)	(0.0155)	(0.3037)	(0.9940)						
A	CIV_{25}	**-1.6796**	**-1.7278**	**-1.6225**	-0.6944	-0.0014	-0.0063					
		(0.0126)	(0.0094)	(0.0152)	(0.3062)	(0.9979)	(0.9932)					
	CIV_{30}	**-1.9189**	**-1.9670**	**-1.8617**	-0.9336	-0.2406	-0.2455	-0.2392				
		(0.0061)	(0.0037)	(0.0063)	(0.1732)	(0.7270)	(0.7308)	(0.7301)				
	CIV_{35}	**-1.9241**	**-1.9722**	**-1.8669**	-0.9389	-0.2458	-0.2507	-0.2445	-0.0052			
		(0.0047)	(0.0039)	(0.0059)	(0.1690)	(0.7203)	(0.7242)	(0.7173)	(0.9945)			
	CIV_{40}	**-1.9351**	**-1.9832**	**-1.8779**	-0.9498	-0.2568	-0.2617	-0.2554	-0.0162	-0.0110		
		(0.0043)	(0.0046)	(0.0051)	(0.1664)	(0.7090)	(0.7035)	(0.7151)	(0.9802)	(0.9856)		
	CIV_{45}	**-1.9681**	**-2.0162**	**-1.9109**	-0.9829	-0.2898	-0.2947	-0.2885	-0.0492	-0.0440	-0.0330	
		(0.0041)	(0.0035)	(0.0063)	(0.1639)	(0.6736)	(0.6464)	(0.6785)	(0.9429)	(0.9506)	(0.9602)	
	VXD	0.0279	-0.0202	0.0851	1.0132	**1.7062**	**1.7013**	**1.7076**	**1.9468**	**1.9520**	**1.9630**	**1.9960**
		(0.9637)	(0.9758)	(0.8973)	(0.1207)	(0.0114)	(0.0098)	(0.0092)	(0.0047)	(0.0044)	(0.0042)	(0.0039)
	Medium-Volatility Periods											
	CIV_1	-0.1108										
		(0.8108)										
	CIV_5	**1.0316**	**1.1424**									
		(0.0258)	(0.0150)									
	CIV_{10}	**1.6799**	**1.7908**	0.6484								
		(0.0010)	(0.0003)	(0.1725)								
	CIV_{15}	**1.6264**	**1.7373**	0.5949	-0.0535							
		(0.0011)	(0.0003)	(0.2131)	(0.9134)							
	CIV_{20}	**1.7230**	**1.8338**	0.6914	0.0431	0.0966						
		(0.0005)	(0.0004)	(0.1612)	(0.9296)	(0.8443)						
A	CIV_{25}	**1.7168**	**1.8276**	0.6852	0.0369	0.0904	-0.0062					
		(0.0005)	(0.0002)	(0.1508)	(0.9401)	(0.8561)	(0.9898)					
	CIV_{30}	**1.7329**	**1.8437**	0.7013	0.0529	0.1064	0.0099	0.0161				
		(0.0008)	(0.0002)	(0.1455)	(0.9142)	(0.8198)	(0.9836)	(0.9730)				
	CIV_{35}	**1.6992**	**1.8100**	0.6676	0.0192	0.0727	-0.0238	-0.0176	-0.0337			
		(0.0005)	(0.0007)	(0.1565)	(0.9658)	(0.8822)	(0.9619)	(0.9680)	(0.9440)			
	CIV_{40}	**1.6414**	**1.7522**	0.6098	-0.3085	0.0150	-0.0816	-0.0754	-0.0915	-0.0578		
		(0.0012)	(0.0006)	(0.2069)	(0.9303)	(0.9777)	(0.8656)	(0.8724)	(0.8433)	(0.9015)		
	CIV_{45}	**1.5021**	**1.6129**	0.4705	-0.1779	-0.1244	-0.2209	-0.2147	-0.2308	-0.1971	-0.1393	
		(0.0031)	(0.0010)	(0.3309)	(0.7172)	(0.7970)	(0.6435)	(0.6649)	(0.6298)	(0.6852)	(0.7783)	
	VXD	0.0953	0.2061	**-0.9363**	**-1.5847**	**-1.5312**	**-1.6278**	**-1.6215**	**-1.6376**	**-1.6039**	**-1.5462**	**-1.4068**
		(0.8374)	(0.6566)	(0.0476)	(0.0006)	(0.0020)	(0.0012)	(0.0014)	(0.0011)	(0.0007)	(0.0027)	(0.0038)
	Low-Volatility Periods											
	CIV_1	-0.0169										
		(0.9696)										
	CIV_5	0.6747	0.6917									
		(0.1412)	(0.1325)									
	CIV_{10}	**1.1266**	**1.1435**	0.4519								
		(0.0213)	(0.0206)	(0.3495)								
	CIV_{15}	**1.2792**	**1.2961**	0.6044	0.1526							
		(0.0099)	(0.0097)	(0.2169)	(0.7657)							
	CIV_{20}	**1.3281**	**1.3451**	0.6534	0.2015	0.0489						
		(0.0067)	(0.0082)	(0.1827)	(0.6993)	(0.9259)						
A	CIV_{25}	**1.3767**	**1.3937**	0.7020	0.2501	0.0975	0.0486					
		(0.0062)	(0.0050)	(0.1479)	(0.6202)	(0.8444)	(0.9239)					
	CIV_{30}	**1.3485**	**1.3654**	0.6738	0.2219	0.0693	0.0204	-0.0282				
		(0.0064)	(0.0077)	(0.1640)	(0.6681)	(0.8961)	(0.9676)	(0.9574)				
	CIV_{35}	**1.3941**	**1.4111**	0.7194	0.2675	0.1150	0.0660	0.0174	0.0457			
		(0.0059)	(0.0047)	(0.1422)	(0.6043)	(0.8220)	(0.8971)	(0.9741)	(0.9289)			
	CIV_{40}	**1.4758**	**1.4928**	0.8011	0.3492	0.1966	0.1477	0.0991	0.1273	0.0817		
		(0.0037)	(0.0024)	(0.0941)	(0.4896)	(0.7043)	(0.7759)	(0.8406)	(0.7983)	(0.8689)		
	CIV_{45}	**1.6799**	**1.6969**	**1.0052**	0.5533	0.4008	0.3518	0.3032	0.3314	0.2858	0.2041	
		(0.0010)	(0.0008)	(0.0365)	(0.2714)	(0.4306)	(0.4901)	(0.5505)	(0.5046)	(0.5638)	(0.6809)	
	VXD	0.0453	0.0622	-0.6295	**-1.0813**	**-1.2339**	**-1.2829**	**-1.3314**	**-1.3032**	**-1.3489**	**-1.4306**	**-1.6347**
		(0.9190)	(0.8955)	(0.1689)	(0.0268)	(0.0130)	(0.0098)	(0.0078)	(0.0091)	(0.0068)	(0.0047)	(0.0010)

Notes: The table reports the differences between mean rates of returns from option trades that are based on different pairs of CIVs, and respective two-sided p-values for the mean difference in parentheses. The mean difference is calculated as $\bar{\pi}_A - \bar{\pi}_B$, where $\bar{\pi}_A$ and $\bar{\pi}_B$ are mean rates of returns from option trades that are based on CIVs in A and B, respectively. p-values for the mean difference are based on Efron & Tibshirani (1993) and Efron (1979), and are calculated based on a bootstrap t-test. The null hypothesis of the test is that there is no difference between the mean rates of returns for the zero-beta straddles based on different CIVs. The bootstrap t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. Numbers in bold indicate significance at 5% significance level.

Table 13. Sharpe Ratio Differences from Option Trades after Transaction Costs (Zero-Beta Straddles)

		B										
		CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}
	Whole Periods											
	CIV_1	-0.2635										
		(0.7006)										
	CIV_5	**5.4581**	**5.7216**									
		(0.0088)	(0.0072)									
	CIV_{10}	**7.5098**	**7.7733**	2.0517								
		(0.0173)	(0.0137)	(0.3743)								
	CIV_{15}	6.1502	6.4137	0.6921	-1.3596							
		(0.0887)	(0.0734)	(0.8115)	(0.4286)							
	CIV_{20}	6.4964	6.7599	1.0383	-1.0134	0.3462						
		(0.0714)	(0.0687)	(0.7043)	(0.5593)	(0.4400)						
A	CIV_{25}	6.4985	6.7620	1.0403	-1.0113	0.3483	0.0021					
		(0.0752)	(0.0642)	(0.7113)	(0.5573)	(0.4566)	(0.9846)					
	CIV_{30}	5.9597	6.2232	0.5016	-1.5501	0.1905	-0.5367	-0.5388				
		(0.1010)	(0.0865)	(0.8575)	(0.3942)	(0.7785)	(0.4174)	(0.4215)				
	CIV_{35}	5.8542	6.1177	0.3960	-1.6556	-0.2960	-0.6422	-0.6443	-0.1055			
		(0.1036)	(0.0936)	(0.8879)	(0.3601)	(0.6677)	(0.3156)	(0.3530)	(0.2832)			
	CIV_{40}	5.8061	6.0696	0.3479	-1.7037	-0.3441	-0.6903	-0.6924	-0.1537	-0.0481		
		(0.0925)	(0.0855)	(0.8969)	(0.3519)	(0.6548)	(0.2733)	(0.2635)	(0.5726)	(0.7841)		
	CIV_{45}	6.3051	6.5686	0.8469	-1.2047	0.1549	-0.1913	-0.1934	0.3453	0.4509	0.4990	
		(0.0728)	(0.0612)	(0.7662)	(0.5468)	(0.8776)	(0.8419)	(0.8340)	(0.6116)	(0.4463)	(0.2564)	
	VXD	0.4577	0.7212	**-5.0004**	**-7.0521**	-5.6925	-6.0387	-6.0408	-5.5020	-5.3965	-5.3483	-5.8474
		(0.0771)	(0.2898)	(0.0181)	(0.0260)	(0.1176)	(0.0990)	(0.0961)	(0.1283)	(0.1301)	(0.1316)	(0.0926)
	High-Volatility Periods											
	CIV_1	0.3821										
		(0.7782)										
	CIV_5	0.1038	-0.2783									
		(0.9755)	(0.9352)									
	CIV_{10}	-5.4246	-5.0867	-5.5284								
		(0.2811)	(0.2567)	(0.1515)								
	CIV_{15}	-10.1101	-10.4923	**-10.2140**	-4.6855							
		(0.0632)	(0.0627)	(0.0332)	(0.1525)							
	CIV_{20}	-10.1082	-10.4903	**-10.2120**	-4.6836	0.0020						
		(0.0661)	(0.0568)	(0.0300)	(0.1576)	(0.9773)						
A	CIV_{25}	-10.1590	-10.5411	**-10.2629**	-4.7344	-0.0489	-0.0509					
		(0.0632)	(0.0573)	(0.0291)	(0.1506)	(0.7022)	(0.4716)					
	CIV_{30}	**-11.4031**	**-11.7852**	**-11.5069**	-5.9785	-1.2929	-1.2949	-1.2441				
		(0.0330)	(0.0314)	(0.0160)	(0.1483)	(0.4381)	(0.4418)	(0.4353)				
	CIV_{35}	**-11.4066**	**-11.7887**	**-11.5105**	-5.9820	-1.2965	-1.2985	-1.2476	-0.0035			
		(0.0300)	(0.0308)	(0.0147)	(0.1488)	(0.9957)	(0.9997)	(0.4460)	(0.9808)			
	CIV_{40}	**-11.3224**	**-11.7046**	**-11.4263**	-5.8978	-1.2123	-1.2143	-1.1634	0.0806	0.0842		
		(0.0337)	(0.0273)	(0.0158)	(0.1555)	(0.8942)	(0.9282)	(0.9649)	(0.8399)	(0.7565)		
	CIV_{45}	**-10.7371**	**-11.1193**	**-10.8410**	-5.3125	-0.6270	-0.6290	-0.5781	0.6659	0.6695	0.5853	
		(0.0444)	(0.0387)	(0.0298)	(0.1989)	(0.8773)	(0.8745)	(0.8887)	(0.5967)	(0.5458)	(0.5061)	
	VXD	0.2035	-0.1787	0.0996	5.6281	10.3136	10.3116	10.3625	**11.6065**	**11.6101**	**11.5259**	**10.9406**
		(0.4213)	(0.8959)	(0.9795)	(0.2705)	(0.0603)	(0.0629)	(0.0619)	(0.0313)	(0.0276)	(0.0293)	(0.0430)
	Medium-Volatility Periods											
	CIV_1	-1.2742										
		(0.2931)										
	CIV_5	**10.8684**	**12.1426**									
		(0.0070)	(0.0028)									
	CIV_{10}	**17.5263**	**18.8005**	6.6579								
		(0.0207)	(0.0113)	(0.2074)								
	CIV_{15}	**17.6848**	**18.9590**	6.8163	0.1584							
		(0.0226)	(0.0156)	(0.2369)	(0.9627)							
	CIV_{20}	**18.4976**	**19.7718**	7.6291	0.9712	0.8128						
		(0.0232)	(0.0127)	(0.1925)	(0.7712)	(0.2812)						
A	CIV_{25}	**18.3132**	**19.5874**	7.4448	0.7869	0.6285	-0.1843					
		(0.0183)	(0.0148)	(0.2005)	(0.8180)	(0.4543)	(0.2553)					
	CIV_{30}	**18.2126**	**19.4868**	7.3442	0.6863	0.5279	-0.2849	-0.1006				
		(0.0234)	(0.0144)	(0.2015)	(0.8369)	(0.5548)	(0.4873)	(0.7684)				
	CIV_{35}	**17.7413**	**19.0155**	6.8728	0.2149	0.0565	-0.7563	-0.5720	-0.4714			
		(0.0202)	(0.0120)	(0.2225)	(0.9454)	(0.9560)	(0.1879)	(0.2179)	(0.0547)			
	CIV_{40}	**17.1045**	**18.3787**	6.2361	-0.4218	-0.5802	-1.3930	-1.2087	-1.1081	-0.6367		
		(0.0213)	(0.0145)	(0.2625)	(0.9006)	(0.6330)	(0.1249)	(0.1286)	(0.0748)	(0.0968)		
	CIV_{45}	**16.4242**	**17.6984**	5.5558	-1.1021	-1.2606	-2.0734	-1.8890	-1.7884	-1.3171	-0.6803	
		(0.0214)	(0.0124)	(0.2901)	(0.7466)	(0.4753)	(0.1965)	(0.2018)	(0.1766)	(0.2236)	(0.3471)	
	VXD	0.7510	2.0252	**-10.1174**	**-16.7754**	**-16.9338**	**-17.7466**	**-17.5623**	**-17.4616**	**-16.9903**	**-16.3535**	**-15.6732**
		(0.2344)	(0.0976)	(0.0095)	(0.0250)	(0.0275)	(0.0227)	(0.0244)	(0.0257)	(0.0225)	(0.0239)	(0.0241)
	Low-Volatility Periods											
	CIV_1	-0.2614										
		(0.7910)										
	CIV_5	7.2670	7.5284									
		(0.0686)	(0.0532)									
	CIV_{10}	**15.4003**	**15.6617**	**8.1333**								
		(0.0045)	(0.0041)	(0.0478)								
	CIV_{15}	**16.8982**	**17.1596**	9.6312	1.4979							
		(0.0117)	(0.0115)	(0.0633)	(0.5950)							
	CIV_{20}	**17.2444**	**17.5058**	9.9774	1.8441	0.3462						
		(0.0159)	(0.0125)	(0.0752)	(0.5705)	(0.8621)						
A	CIV_{25}	**17.4643**	**17.7257**	10.1973	2.0640	0.5661	0.2199					
		(0.0136)	(0.0119)	(0.0718)	(0.5205)	(0.7615)	(0.4839)					
	CIV_{30}	**17.3181**	**17.5795**	10.0511	1.9178	0.4199	0.0738	-0.1461				
		(0.0151)	(0.0117)	(0.0729)	(0.5596)	(0.8312)	(0.8295)	(0.4270)				
	CIV_{35}	**17.3750**	**17.6364**	10.1080	1.9747	0.4768	0.1306	-0.0893	0.0568			
		(0.0140)	(0.0108)	(0.0709)	(0.5385)	(0.8015)	(0.7559)	(0.7562)	(0.7127)			
	CIV_{40}	**17.6406**	**17.9020**	10.3736	2.2403	0.7424	0.3962	0.1763	0.3225	0.2656		
		(0.0117)	(0.0113)	(0.0592)	(0.4928)	(0.6887)	(0.5267)	(0.7372)	(0.4339)	(0.3318)		
	CIV_{45}	**19.1321**	**19.3935**	**11.8651**	3.7318	2.2339	1.8877	1.6678	1.8140	1.7571	**1.4915**	
		(0.0052)	(0.0056)	(0.0314)	(0.2699)	(0.2610)	(0.1382)	(0.1644)	(0.0866)	(0.0648)	(0.0349)	
	VXD	0.4882	0.7496	-6.7788	**-14.9121**	**-16.4100**	**-16.7562**	**-16.9761**	**-16.8300**	**-16.8868**	**-17.1524**	**-18.6439**
		(0.4170)	(0.4382)	(0.0890)	(0.0051)	(0.0134)	(0.0184)	(0.0180)	(0.0146)	(0.0140)	(0.0152)	(0.0079)

Notes: The table reports the differences between Sharpe ratios from option trades that are based on different pairs of CIVs, and respective two-sided p-values for the Sharpe ratio difference in parentheses. The Sharpe ratio difference is calculated as $Sharpe_A - Sharpe_B$, where $Sharpe_A$ and $Sharpe_B$ are Sharpe ratios from option trades that are based on CIVs in A and B, respectively. p-values for the Sharpe ratio difference are based on Ledoit & Wolf (2008) for non i.i.d. returns. The null hypothesis is that there is no difference between the Sharpe ratios for the zero-beta straddles based on different CIVs. The bootstrap t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. Numbers in bold indicate significance at 5% significance level.

Table 14. Returns of Out-of-Sample Trades in Short-Term At-the-Money Zero-Beta Straddles before Transaction Costs

	CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}	VXD
Panel A: Option trading summary statistics												
Whole Periods												
Average Straddle Price (Forecasts)	2.1619	2.0793	1.9217	1.7864	1.6647	1.5451	1.4197	1.2823	1.1249	0.9316	0.6667	2.1574
Average Straddle Price (Market)	1.9146	1.9142	1.9133	1.9124	1.9115	1.9105	1.9092	1.9075	1.9050	1.9007	1.8910	1.9146
Long (short) straddle trades	2125(245)	1995(375)	1403(967)	648(1722)	186(2184)	30(2340)	7(2363)	0(2370)	0(2370)	0(2370)	0(2370)	2117(253)
Average fraction of call options	0.4958	0.4959	0.4959	0.4958	0.4956	0.4953	0.4949	0.4942	0.4930	0.4907	0.4847	0.4958
High-Volatility Periods												
Average Straddle Price (Forecasts)	2.7217	2.6339	2.4487	2.2824	2.1286	1.9775	1.8180	1.6415	1.4407	1.1937	0.8556	2.7128
Average Straddle Price (Market)	2.5087	2.5084	2.5078	2.5072	2.5066	2.5058	2.5049	2.5036	2.5018	2.4986	2.4913	2.5087
Long (short) straddle trades	636(154)	576(214)	378(412)	145(645)	37(753)	6(784)	2(788)	0(790)	0(790)	0(790)	0(790)	638(152)
Average fraction of call options	0.4893	0.4896	0.4902	0.4906	0.4910	0.4913	0.4916	0.4918	0.4918	0.4913	0.4893	0.4893
Medium-Volatility Periods												
Average Straddle Price (Forecasts)	2.0327	1.9467	1.7944	1.6653	1.5511	1.4388	1.3214	1.1938	1.0470	0.8666	0.6198	2.0270
Average Straddle Price (Market)	1.7636	1.7632	1.7624	1.7615	1.7606	1.7597	1.7584	1.7568	1.7544	1.7504	1.7412	1.7636
Long (short) straddle trades	730(60)	686(104)	480(310)	239(551)	68(722)	14(776)	3(787)	0(790)	0(790)	0(790)	0(790)	722(68)
Average fraction of call options	0.4982	0.4983	0.4982	0.4981	0.4978	0.4975	0.4970	0.4962	0.4949	0.4924	0.4863	0.4982
Low-Volatility Periods												
Average Straddle Price (Forecasts)	1.7312	1.6572	1.5219	1.4115	1.3143	1.2191	1.1198	1.0116	0.8871	0.7345	0.5247	1.7324
Average Straddle Price (Market)	1.4714	1.4709	1.4697	1.4685	1.4673	1.4659	1.4643	1.4620	1.4587	1.4532	1.4406	1.4714
Long (short) straddle trades	759(31)	733(57)	545(245)	264(526)	81(709)	10(780)	2(788)	0(790)	0(790)	0(790)	0(790)	757(33)
Average fraction of call options	0.4998	0.4997	0.4992	0.4987	0.4980	0.4972	0.4962	0.4947	0.4924	0.4883	0.4786	0.4998
Panel B: Daily returns from option trades												
Whole Periods												
Number of + (-) returns	890(1480)	932(1438)	1090(1280)	1315(1055)	1497(873)	1536(834)	1549(821)	1558(812)	1563(807)	1556(814)	1559(811)	901(1469)
Mean (%)	0.1166	0.1870	0.1618	**0.5111**	**0.6950**	0.2339	0.1968	0.2418	0.2501	0.2658	0.3015	0.2424
Mean p-value	0.6243	0.4375	0.4978	0.0304	0.0032	0.3170	0.4064	0.2883	0.2839	0.2512	0.1983	0.3153
St.Dev (%)	11.5483	11.5248	11.4797	11.4279	11.3805	11.3608	11.3203	11.2755	11.2323	11.2096	11.4162	11.5455
Skewness	3.6102	3.5198	2.3837	1.9760	-0.4949	-3.4833	-4.1429	-4.2334	-4.3574	-4.5795	-5.1428	3.6641
Kurtosis	31.9877	32.1393	32.7907	33.2463	34.4502	35.1346	36.0448	37.4425	39.5685	43.6823	56.0774	31.8471
Sharpe ratio (%)	1.0099	1.6224	1.4093	4.4722	6.1073	2.0589	1.7384	2.1446	2.2270	2.3715	2.6412	2.0993
Sharpe ratio p-value	0.6397	0.4956	0.5729	0.1780	0.0558	0.2811	0.3287	0.2772	0.2668	0.2616	0.2399	0.4024
High-Volatility Periods												
Number of + (-) returns	345(445)	359(431)	395(395)	455(335)	483(307)	479(311)	479(311)	484(306)	489(301)	491(299)	490(300)	349(441)
Mean(%)	**1.2559**	**1.3074**	0.4344	0.4313	0.3399	-0.9472	**-1.1711**	**-1.1432**	**-1.1419**	**-1.1411**	**-1.1468**	**1.4801**
Mean p-value	0.0131	0.0098	0.3860	0.3968	0.4988	0.0542	0.0220	0.0215	0.0261	0.0267	0.0317	0.0052
St.Dev (%)	13.9420	13.9205	13.9464	13.9202	13.9039	13.8592	13.8284	13.8252	13.8421	13.9187	14.3330	13.9174
Skewness	3.2513	3.2380	1.6168	1.2058	0.4413	-2.8397	-3.8656	-3.9324	-4.0376	-4.2466	-4.9121	3.3606
Kurtosis	26.4430	26.5677	27.5243	27.9080	28.3781	28.3050	28.4879	29.3771	30.8931	34.1406	46.0766	26.3656
Share ratio (%)	9.0078	9.3921	**3.1147**	3.0980	2.4444	-6.8346	**-8.4686**	**-8.2693**	**-8.2496**	**-8.1980**	-8.0013	10.6349
Sharpe ratio p-value	0.0987	0.1266	0.0056	0.2787	0.3884	0.1178	0.0168	0.0176	0.0200	0.0297	0.0678	0.1250
Medium-Volatility Periods												
Number of + (-) returns	275(515)	293(497)	355(435)	429(361)	502(288)	523(267)	534(256)	536(254)	534(256)	524(266)	525(265)	280(510)
Mean(%)	-0.5033	-0.4619	-0.0614	0.2813	**0.9236**	**0.9223**	**0.9534**	**0.9927**	**0.9793**	**0.9579**	**0.9038**	-0.4132
Mean p-value	0.1367	0.1676	0.8517	0.3987	0.0042	0.0057	0.0051	0.0036	0.0029	0.0030	0.0053	0.2186
St.Dev (%)	9.4025	9.3762	9.3284	9.2683	9.1729	9.1162	9.0493	8.9712	8.8860	8.7978	8.8883	9.4046
Skewness	2.7628	2.2945	1.8249	1.3273	0.0114	-2.8518	-2.8874	-2.9181	-2.9280	-2.9238	-2.8400	2.7288
Kurtosis	22.0180	22.0024	21.7898	21.8638	22.6269	24.0785	24.5121	25.0337	25.5050	25.9538	25.0740	21.8481
Share ratio (%)	-5.3526	-4.9260	-0.6581	3.0355	10.0683	10.1171	10.5357	11.0651	11.0201	10.8879	10.1686	-4.3939
Sharpe ratio p-value	0.2195	0.2289	0.8278	0.2736	0.0853	0.0879	0.0893	0.0762	0.0759	0.0820	0.0934	0.2558
Low-Volatility Periods												
Number of + (-) returns	270(520)	280(510)	340(450)	431(359)	512(278)	534(256)	536(254)	538(252)	540(250)	541(249)	544(246)	272(518)
Mean(%)	-0.4027	0.2846	0.1123	**0.8206**	**0.8217**	0.7267	**0.8080**	**0.8760**	**0.9131**	**0.9807**	**1.1476**	-0.3397
Mean p-value	0.2926	0.4565	0.7673	0.0350	0.0307	0.0559	0.0372	0.0250	0.0194	0.0109	0.0044	0.3701
St.Dev (%)	10.7557	10.7335	10.6788	10.5969	10.5460	10.4992	10.4326	10.3551	10.2634	10.1576	10.1835	10.7606
Skewness	4.2376	4.2374	4.0082	3.8240	-2.7964	-4.5576	-4.6590	-4.7911	-4.9626	-5.2436	-5.7170	4.2255
Kurtosis	38.3335	38.4210	38.6350	38.9406	41.9554	43.3591	45.0380	47.2114	50.2290	55.3916	65.0443	38.1517
Share ratio (%)	-3.7441	-2.6515	1.0519	7.7442	7.7916	6.9211	7.7453	8.4596	8.8965	9.6544	11.2692	-3.1571
Sharpe ratio p-value	0.2893	0.3706	0.7904	0.1764	0.1451	0.1779	0.1534	0.1406	0.1390	0.1249	0.1115	0.3333
Panel C: Mean Difference (%)												
High - Medium	**1.7591**	**1.7693**	0.4958	0.1499	-0.5837	**-1.8695**	**-2.1245**	**-2.1359**	**-2.1212**	**-2.0990**	**-2.0506**	**1.8933**
	(0.0042)	(0.0037)	(0.4101)	(0.8065)	(0.3276)	(0.0016)	(0.0008)	(0.0008)	(0.0004)	(0.0006)	(0.0007)	(0.0024)
High - Low	**1.6586**	**1.5920**	0.3221	-0.3894	-0.4818	**-1.6739**	**-1.9791**	**-2.0192**	**-2.0550**	**-2.1217**	**-2.2944**	**1.8198**
	(0.0084)	(0.0106)	(0.6176)	(0.5239)	(0.4456)	(0.0068)	(0.0016)	(0.0008)	(0.0010)	(0.0010)	(0.0004)	(0.0031)
Medium - Low	-0.1006	-0.1773	-0.1737	-0.5393	0.1019	0.1956	0.1454	0.1167	0.0662	-0.0228	-0.2438	-0.0735
	(0.8452)	(0.7296)	(0.7253)	(0.2843)	(0.8301)	(0.6995)	(0.7650)	(0.8160)	(0.8893)	(0.9659)	(0.6116)	(0.8844)
Panel D: Sharpe Ratio Difference (%)												
High - Medium	**14.3603**	**14.3180**	3.7728	0.0625	-7.6239	**-16.9517**	**-19.0042**	**-19.3344**	**-19.2697**	**-19.0859**	**-18.1699**	**15.0288**
	(0.0067)	(0.0057)	(0.4518)	(0.9906)	(0.1648)	(0.0018)	(0.0003)	(0.0005)	(0.0003)	(0.0003)	(0.0004)	(0.0042)
High - Low	**12.7518**	**12.0436**	2.0628	-4.6461	-5.3472	**-13.7557**	**-16.2138**	**-16.7289**	**-17.1461**	**-17.8525**	**-19.2705**	**13.7920**
	(0.0118)	(0.0155)	(0.6928)	(0.3818)	(0.3218)	(0.0079)	(0.0018)	(0.0023)	(0.0023)	(0.0032)	(0.0024)	(0.0078)
Medium - Low	-1.6085	-2.2744	-1.7100	-4.7086	2.2767	3.1960	2.7904	2.6055	2.1236	1.2335	-1.1006	-1.2368
	(0.7605)	(0.6508)	(0.7470)	(0.3362)	(0.6733)	(0.5710)	(0.6244)	(0.6577)	(0.7515)	(0.8277)	(0.8614)	(0.8088)

Notes: The table reports the summary statistics from out-of-sample trades in short-term zero-beta straddles in the DJX options market from October 1, 2004 to March 6, 2015. On each trading day, market agents fit past 252 observations of CIV or VXD in an ARMA(1,1) model, and use estimated parameters of the ARMA model to forecast today's CIV or VXD, then use the CIV/VXD forecast to obtain a price forecast for the zero-beta straddle by using the Black-Scholes Model. The proportions for the call and put options in the straddle also depend on the CIV forecast. They enter their positions in the market by buying (selling) the aforementioned option portfolio if the portfolio is underpriced (overpriced). On the next day, they close their positions of the previous day by an offsetting order so that they can rebalance their portfolio everyday. Only options with maturities that are between 7 to 60 days are traded. If an option traded on the previous day cannot be found on the next day, the rate of return for that option during this period is recorded as -1. The profit of the zero-beta straddle is calculated as:

$$\text{profit} = \frac{-C\beta_c + S}{P\beta_c - C\beta_c + S} r_c + \frac{P\beta_c}{P\beta_c - C\beta_c + S} r_p \quad (10)$$

where C and P are put and call option prices. S is the underlying index level; r_c and r_p are return on the call and put options, respectively. β_c is the market beta for the call option, and is defined as $\beta_c = \frac{S}{C}\Delta_c$, where Δ_c is the call option delta. The rate of return π can then be calculated. We allow market agents to borrow at the risk-free rate and to invest all profits from option trades into risk-free assets. Therefore, we deduct (add) a risk-free rate from (to) the rate of return of the zero-beta-straddle. No transaction cost is considered. The return sample is divided into three subsamples: high-, medium- and low-volatility period subsamples, according to realized volatility calculated from historical index levels. p-values for the mean and mean difference are based on Efron & Tibshirani (1993) and Efron (1979) via a transformation of original returns, and p-values for the Sharpe ratio are based on Opdyke (2007). All p-values are calculated through a bootstrap t-test. The t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. In parentheses are p-values. Numbers in bold indicate significance at 5% significance level.

Table 15. Mean Rate of Return Differences from Out-of-Sample Option Trades before Transaction Costs (Zero-Beta Straddles)

		B										
		CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}
	Whole Periods											
A	CIV_1	0.0704										
		(0.8351)										
	CIV_5	0.0452	-0.0252									
		(0.8941)	(0.9380)									
	CIV_{10}	0.3944	0.3241	0.3493								
		(0.2348)	(0.3304)	(0.2956)								
	CIV_{15}	0.5784	0.5081	0.5333	0.1840							
		(0.0824)	(0.1336)	(0.1033)	(0.5883)							
	CIV_{20}	0.1173	0.0469	0.0721	-0.2772	-0.4611						
		(0.7252)	(0.8857)	(0.8273)	(0.4072)	(0.1684)						
	CIV_{25}	0.0802	0.0098	0.0350	-0.3143	-0.4983	-0.0371					
		(0.8097)	(0.9769)	(0.9188)	(0.3392)	(0.1290)	(0.9100)					
	CIV_{30}	0.1252	0.0548	0.0800	-0.2693	-0.4532	0.0079	0.0450				
		(0.7050)	(0.8657)	(0.8101)	(0.4232)	(0.1746)	(0.9823)	(0.8943)				
	CIV_{35}	0.1335	0.0632	0.0884	-0.2609	-0.4449	0.0162	0.0533	0.0083			
		(0.6781)	(0.8462)	(0.7908)	(0.4298)	(0.1756)	(0.9620)	(0.8719)	(0.9821)			
	CIV_{40}	0.1492	0.0788	0.1041	-0.2452	-0.4292	0.0319	0.0690	0.0240	0.0157		
		(0.6595)	(0.8147)	(0.7506)	(0.4597)	(0.1851)	(0.9231)	(0.8340)	(0.9415)	(0.9628)		
	CIV_{45}	0.1849	0.1145	0.1397	-0.2096	-0.3935	0.0676	0.1047	0.0597	0.0514	0.0357	
		(0.5849)	(0.7331)	(0.6691)	(0.5251)	(0.2386)	(0.8376)	(0.7495)	(0.8499)	(0.8759)	(0.9136)	
	VXD	0.1258	0.0554	0.0806	-0.2687	-0.4527	0.0085	0.0456	0.0006	-0.0078	-0.0234	-0.0591
		(0.7126)	(0.8728)	(0.8101)	(0.4236)	(0.1692)	(0.9813)	(0.8880)	(0.9992)	(0.9779)	(0.9434)	(0.8574)
	High-Volatility Periods											
A	CIV_1	0.0516										
		(0.9406)										
	CIV_5	-0.8215	-0.8730									
		(0.2376)	(0.2130)									
	CIV_{10}	-0.8246	-0.8762	-0.0031								
		(0.2387)	(0.2180)	(0.9972)								
	CIV_{15}	-0.9160	-0.9675	-0.0945	-0.0914							
		(0.1981)	(0.1632)	(0.8958)	(0.8972)							
	CIV_{20}	**-2.2031**	**-2.2546**	**-1.3816**	-1.3785	-1.2871						
		(0.0023)	(0.0024)	(0.0493)	(0.0522)	(0.0635)						
	CIV_{25}	**-2.4269**	**-2.4785**	**-1.6055**	**-1.6023**	**-1.5109**	-0.2238					
		(0.0014)	(0.0008)	(0.0218)	(0.0203)	(0.0335)	(0.7509)					
	CIV_{30}	**-2.3991**	**-2.4507**	**-1.5776**	**-1.5745**	**-1.4831**	-0.1960	0.0278				
		(0.0007)	(0.0009)	(0.0242)	(0.0239)	(0.0332)	(0.7800)	(0.9660)				
	CIV_{35}	**-2.3978**	**-2.4493**	**-1.5763**	**-1.5732**	**-1.4818**	-0.1947	0.0291	0.0013			
		(0.0013)	(0.0004)	(0.0253)	(0.0251)	(0.0314)	(0.7898)	(0.9654)	(0.9984)			
	CIV_{40}	**-2.3969**	**-2.4485**	**-1.5755**	**-1.5723**	**-1.4809**	-0.1938	0.0300	0.0022	0.0009		
		(0.0014)	(0.0014)	(0.0276)	(0.0251)	(0.0330)	(0.7849)	(0.9638)	(0.9983)	(0.9989)		
	CIV_{45}	**-2.4027**	**-2.4542**	**-1.5812**	**-1.5781**	**-1.4867**	-0.1996	0.0242	-0.0036	-0.0049	-0.0058	
		(0.0018)	(0.0014)	(0.0278)	(0.0308)	(0.0370)	(0.7811)	(0.9720)	(0.9956)	(0.9951)	(0.9946)	
	VXD	0.2242	0.1727	1.0457	1.0488	1.1402	**2.4273**	**2.6512**	**2.6233**	**2.6220**	**2.6212**	**2.6269**
		(0.7488)	(0.8060)	(0.1331)	(0.1385)	(0.1041)	(0.0007)	(0.0005)	(0.0005)	(0.0002)	(0.0007)	(0.0004)
	Medium-Volatility Periods											
A	CIV_1	0.0414										
		(0.9277)										
	CIV_5	0.4419	0.4005									
		(0.3509)	(0.3904)									
	CIV_{10}	0.7846	0.7432	0.3427								
		(0.0955)	(0.1143)	(0.4664)								
	CIV_{15}	**1.4268**	**1.3854**	**0.9849**	0.6422							
		(0.0023)	(0.0026)	(0.0349)	(0.1706)							
	CIV_{20}	**1.4256**	**1.3842**	**0.9837**	0.6410	-0.0013						
		(0.0020)	(0.0038)	(0.0317)	(0.1707)	(0.9964)						
	CIV_{25}	**1.4567**	**1.4153**	**1.0148**	0.6721	0.0298	0.0311					
		(0.0021)	(0.0028)	(0.0288)	(0.1505)	(0.9467)	(0.9469)					
	CIV_{30}	**1.4960**	**1.4545**	**1.0541**	0.7113	0.0691	0.0704	0.0393				
		(0.0010)	(0.0026)	(0.0243)	(0.1238)	(0.8796)	(0.8862)	(0.9333)				
	CIV_{35}	**1.4825**	**1.4411**	**1.0406**	0.6979	0.0557	0.0570	0.0258	-0.0134			
		(0.0013)	(0.0020)	(0.0233)	(0.1245)	(0.9021)	(0.8963)	(0.9579)	(0.9760)			
	CIV_{40}	**1.4612**	**1.4198**	**1.0193**	0.6766	0.0343	0.0356	0.0045	-0.0348	-0.0214		
		(0.0023)	(0.0027)	(0.0255)	(0.1327)	(0.9392)	(0.9400)	(0.9911)	(0.9378)	(0.9626)		
	CIV_{45}	**1.4071**	**1.3657**	**0.9652**	0.6225	-0.0197	-0.0185	-0.0496	-0.0889	-0.0754	-0.0541	
		(0.0029)	(0.0028)	(0.0356)	(0.1729)	(0.9646)	(0.9659)	(0.9125)	(0.8446)	(0.8633)	(0.9016)	
	VXD	0.0900	0.0486	-0.3518	-0.6946	**-1.3368**	**-1.3355**	**-1.3666**	**-1.4059**	**-1.3925**	**-1.3711**	**-1.3170**
		(0.8542)	(0.9216)	(0.4517)	(0.1413)	(0.0037)	(0.0060)	(0.0041)	(0.0025)	(0.0021)	(0.0029)	(0.0050)
	Low-Volatility Periods											
A	CIV_1	0.1181										
		(0.8313)										
	CIV_5	0.5150	0.3969									
		(0.3362)	(0.4591)									
	CIV_{10}	**1.2233**	**1.1052**	0.7083								
		(0.0240)	(0.0401)	(0.1869)								
	CIV_{15}	**1.2244**	**1.1063**	0.7094	0.0011							
		(0.0234)	(0.0393)	(0.1800)	(0.9984)							
	CIV_{20}	**1.1294**	1.0113	0.6143	-0.0940	-0.0950						
		(0.0378)	(0.0627)	(0.2485)	(0.8596)	(0.8607)						
	CIV_{25}	**1.2107**	**1.0926**	0.6957	-0.0126	-0.0137	0.0814					
		(0.0257)	(0.0435)	(0.2002)	(0.9814)	(0.9795)	(0.8747)					
	CIV_{30}	**1.2787**	**1.1606**	0.7637	0.0554	0.0543	0.1493	0.0680				
		(0.0197)	(0.0304)	(0.1512)	(0.9137)	(0.9144)	(0.7734)	(0.8964)				
	CIV_{35}	**1.3158**	**1.1977**	0.8007	0.0924	0.0914	0.1864	0.1051	0.0371			
		(0.0153)	(0.0247)	(0.1326)	(0.8609)	(0.8625)	(0.7215)	(0.8390)	(0.9462)			
	CIV_{40}	**1.3834**	**1.2653**	0.8683	0.1600	0.1590	0.2540	0.1726	0.1047	0.0676		
		(0.0107)	(0.0203)	(0.1021)	(0.7592)	(0.7556)	(0.6240)	(0.7411)	(0.8410)	(0.8954)		
	CIV_{45}	**1.5503**	**1.4322**	1.0353	0.3270	0.3259	0.4209	0.3396	0.2716	0.2345	0.1669	
		(0.0055)	(0.0092)	(0.0548)	(0.5318)	(0.5450)	(0.4249)	(0.5091)	(0.5966)	(0.6520)	(0.7367)	
	VXD	0.0630	-0.0551	-0.4521	**-1.1604**	**-1.1614**	**-1.0664**	**-1.1478**	**-1.2157**	**-1.2528**	**-1.3204**	**-1.4873**
		(0.9118)	(0.9198)	(0.4060)	(0.0264)	(0.0338)	(0.0488)	(0.0345)	(0.0278)	(0.0206)	(0.0149)	(0.0067)

Notes: The table reports the differences between mean rates of returns from option trades that are based on different pairs of CIVs, and respective two-sided p-values for the mean difference in parentheses. The mean difference is calculated as $\bar{\pi}_A - \bar{\pi}_B$, where $\bar{\pi}_A$ and $\bar{\pi}_B$ are mean rates of returns from option trades that are based on CIVs in A and B, respectively. p-values for the mean difference are based on Efron & Tibshirani (1993) and Efron (1979), and are calculated based on a bootstrap t-test. The null hypothesis of the test is that there is no difference between the mean rates of returns for the zero-beta straddles based on different CIVs. The bootstrap t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. Numbers in bold indicate significance at 5% significance level.

Table 16. Sharpe Ratio Differences from Out-of-Sample Option Trades before Transaction Costs (Zero-Beta Straddles)

		B										
		CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}
	Whole Periods											
	CIV_1	0.6125										
		(0.3892)										
	CIV_5	0.3993	-0.2132									
		(0.8407)	(0.9022)									
	CIV_{10}	3.4623	2.8498	3.0629								
		(0.1756)	(0.2549)	(0.0750)								
	CIV_{15}	5.0974	4.4849	4.6981	1.6352							
		(0.1445)	(0.1816)	(0.1098)	(0.4755)							
	CIV_{20}	1.0490	0.4365	0.6496	-2.4133	**-4.0484**						
		(0.7939)	(0.9069)	(0.8477)	(0.4152)	(0.0376)						
A	CIV_{25}	0.7285	0.1160	0.3291	-2.7338	**-4.3690**	-0.3205					
		(0.8490)	(0.9726)	(0.9231)	(0.3544)	(0.0381)	(0.6772)					
	CIV_{30}	1.1346	0.5221	0.7353	-2.3276	-3.9628	0.0857	0.4062				
		(0.7641)	(0.8916)	(0.8227)	(0.4291)	(0.0548)	(0.9132)	(0.0695)				
	CIV_{35}	1.2170	0.6045	0.8177	-2.2452	-3.8804	0.1681	**0.4886**	0.0824			
		(0.7481)	(0.8702)	(0.8153)	(0.4435)	(0.0656)	(0.8514)	(0.0340)	(0.4002)			
	CIV_{40}	1.3615	0.7490	0.9622	-2.1007	-3.7359	0.3125	0.6331	0.2269	0.1445		
		(0.7227)	(0.8428)	(0.7721)	(0.4793)	(0.0729)	(0.7269)	(0.0848)	(0.3912)	(0.4003)		
	CIV_{45}	1.6313	1.0188	1.2319	-1.8310	-3.4661	0.5823	0.9028	0.4966	0.4142	0.2697	
		(0.6526)	(0.7820)	(0.7096)	(0.5344)	(0.1012)	(0.6062)	(0.2298)	(0.4486)	(0.4646)	(0.5016)	
	VXD	1.0894	0.4769	0.6901	-2.3728	-4.0080	0.0404	0.3610	-0.0452	-0.1276	-0.2721	-0.5419
		(0.1048)	(0.5642)	(0.7311)	(0.3624)	(0.2399)	(0.9909)	(0.9250)	(0.9919)	(0.9749)	(0.9449)	(0.8811)
	High-Volatility Periods											
	CIV_1	0.3843										
		(0.7195)										
	CIV_5	-5.8930	-6.2773									
		(0.1046)	(0.0793)									
	CIV_{10}	-5.9097	-6.2940	-0.0167								
		(0.2182)	(0.1759)	(0.9954)								
	CIV_{15}	-6.5633	-6.9476	-0.6703	-0.6536							
		(0.2062)	(0.1646)	(0.8629)	(0.8038)							
	CIV_{20}	**-15.8424**	**-16.2267**	-9.9494	**-9.9327**	**-9.2791**						
		(0.0072)	(0.0064)	(0.0664)	(0.0249)	(0.0334)						
A	CIV_{25}	**-17.4763**	**-17.8606**	**-11.5833**	**-11.5666**	**-10.9130**	-1.6339					
		(0.0013)	(0.0013)	(0.0186)	(0.0113)	(0.0136)	(0.4566)					
	CIV_{30}	**-17.2771**	**-17.6614**	**-11.3840**	**-11.3673**	**-10.7137**	-1.4347	0.1993				
		(0.0013)	(0.0018)	(0.0220)	(0.0138)	(0.0123)	(0.4988)	(0.2544)				
	CIV_{35}	**-17.2573**	**-17.6416**	**-11.3643**	**-11.3476**	**-10.6940**	-1.4149	0.2190	0.0197			
		(0.0015)	(0.0009)	(0.0200)	(0.0117)	(0.0137)	(0.4971)	(0.3181)	(0.8355)			
	CIV_{40}	**-17.2058**	**-17.5901**	**-11.3128**	**-11.2961**	**-10.6425**	-1.3634	0.2705	0.0713	0.0516		
		(0.0010)	(0.0011)	(0.0207)	(0.0127)	(0.0161)	(0.5251)	(0.4499)	(0.7812)	(0.7465)		
	CIV_{45}	**-17.0091**	**-17.3934**	**-11.1161**	**-11.0994**	**-10.4458**	-1.1667	0.4672	0.2680	0.2482	0.1967	
		(0.0013)	(0.0009)	(0.0193)	(0.0148)	(0.0136)	(0.5775)	(0.5080)	(0.6640)	(0.6382)	(0.5924)	
	VXD	1.6271	1.2428	7.5201	7.5368	8.1904	**17.4695**	**19.1034**	**18.9042**	**18.8844**	**18.8329**	**18.6362**
		(0.3123)	(0.4308)	(0.0624)	(0.1349)	(0.1235)	(0.0041)	(0.0006)	(0.0008)	(0.0004)	(0.0005)	(0.0006)
	Medium-Volatility Periods											
	CIV_1	0.4266										
		(0.8381)										
	CIV_5	4.6945	4.2679									
		(0.2183)	(0.1639)									
	CIV_{10}	8.3881	7.9615	3.6936								
		(0.1001)	(0.0704)	(0.2148)								
	CIV_{15}	**15.4209**	**14.9943**	**10.7264**	7.0328							
		(0.0252)	(0.0187)	(0.0460)	(0.0917)							
	CIV_{20}	**15.4697**	**15.0430**	10.7752	7.0816	0.0487						
		(0.0462)	(0.0383)	(0.0836)	(0.1669)	(0.9904)						
A	CIV_{25}	**15.8883**	**15.4616**	11.1938	7.5002	0.4673	0.4186					
		(0.0404)	(0.0341)	(0.0744)	(0.1391)	(0.8964)	(0.5057)					
	CIV_{30}	**16.4177**	**15.9911**	11.7232	8.0296	0.9968	0.9480	0.5294				
		(0.0366)	(0.0290)	(0.0625)	(0.1249)	(0.7863)	(0.2246)	(0.3553)				
	CIV_{35}	**16.3727**	**15.9461**	11.6782	7.9846	0.9518	0.9030	0.4844	-0.0450			
		(0.0344)	(0.0285)	(0.0632)	(0.1242)	(0.8053)	(0.2934)	(0.4250)	(0.8408)			
	CIV_{40}	**16.2405**	**15.8139**	11.5460	7.8524	0.8196	0.7708	0.3522	-0.1772	-0.1322		
		(0.0370)	(0.0304)	(0.0667)	(0.1291)	(0.8372)	(0.4941)	(0.6937)	(0.7772)	(0.7358)		
	CIV_{45}	**15.5212**	**15.0945**	10.8267	7.1331	0.1002	0.0515	-0.3671	-0.8965	-0.8515	-0.7193	
		(0.0365)	(0.0309)	(0.0759)	(0.1612)	(0.9793)	(0.9795)	(0.8355)	(0.5696)	(0.5266)	(0.4615)	
	VXD	0.9587	0.5320	-3.7358	-7.4294	**-14.4623**	-14.5110	-14.9296	**-15.4590**	**-15.4140**	**-15.2818**	**-14.5625**
		(0.3114)	(0.8057)	(0.3429)	(0.1498)	(0.0338)	(0.0558)	(0.0534)	(0.0474)	(0.0433)	(0.0461)	(0.0485)
	Low-Volatility Periods											
	CIV_1	1.0925										
		(0.1997)										
	CIV_5	4.7960	3.7035									
		(0.0958)	(0.1728)									
	CIV_{10}	**11.4882**	**10.3957**	**6.6922**								
		(0.0049)	(0.0079)	(0.0306)								
	CIV_{15}	11.5357	10.4431	6.7397	0.0474							
		(0.1125)	(0.1475)	(0.3186)	(0.9929)							
	CIV_{20}	10.6651	9.5726	5.8691	-0.8231	-0.8705						
		(0.1733)	(0.2218)	(0.4255)	(0.8950)	(0.7813)						
A	CIV_{25}	11.4893	10.3968	6.6933	0.0011	-0.0463	0.8242					
		(0.1551)	(0.1867)	(0.3682)	(0.9998)	(0.9880)	(0.2350)					
	CIV_{30}	12.2037	11.1112	7.4077	0.7155	0.6680	1.5385	0.7144				
		(0.1339)	(0.1643)	(0.3255)	(0.9180)	(0.8353)	(0.0767)	(0.1982)				
	CIV_{35}	12.6406	11.5481	7.8446	1.1524	1.1049	**1.9755**	**1.1513**	0.4369			
		(0.1268)	(0.1573)	(0.2982)	(0.8641)	(0.7375)	(0.0479)	(0.0494)	(0.0823)			
	CIV_{40}	13.3985	12.3060	8.6025	1.9103	1.8628	**2.7334**	**1.9092**	1.1948	0.7579		
		(0.1089)	(0.1315)	(0.2676)	(0.7815)	(0.5868)	(0.0385)	(0.0431)	(0.0781)	(0.0811)		
	CIV_{45}	15.0133	13.9207	10.2172	3.5250	3.4776	**4.3481**	3.5239	2.8096	2.3726	1.6147	
		(0.0808)	(0.1037)	(0.2080)	(0.6179)	(0.3578)	(0.0467)	(0.0589)	(0.0902)	(0.0970)	(0.0997)	
	VXD	0.5869	-0.5056	-4.2091	**-10.9013**	-10.9487	-10.0782	-10.9024	-11.6167	-12.0537	-12.8116	-14.4263
		(0.3391)	(0.4886)	(0.1270)	(0.0065)	(0.1390)	(0.1911)	(0.1652)	(0.1489)	(0.1393)	(0.1187)	(0.0943)

Notes: The table reports the differences between Sharpe ratios from option trades that are based on different pairs of CIVs, and respective two-sided p-values for the Sharpe ratio difference in parentheses. The Sharpe ratio difference is calculated as $Sharpe_A - Sharpe_B$, where $Sharpe_A$ and $Sharpe_B$ are Sharpe ratios from option trades that are based on CIVs in A and B, respectively. p-values for the Sharpe ratio difference are based on Ledoit & Wolf (2008) for non i.i.d. returns. The null hypothesis is that there is no difference between the Sharpe ratios for the zero-beta straddles based on different CIVs. The bootstrap t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. Numbers in bold indicate significance at 5% significance level.

Table 17. Returns of Out-of-Sample Trades in Short-Term At-the-Money Zero-Beta Straddles after Transaction Costs

	CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}	VXD
Panel A: Daily returns from option trades												
Whole Periods												
Number of + (-) returns	601(1769)	628(1742)	737(1633)	861(1509)	993(1377)	1012(1358)	1018(1352)	1017(1353)	1014(1356)	1009(1361)	1026(1344)	614(1756)
Mean (%)	-3.1170	**-3.0505**	**-3.0915**	**-2.7650**	**-2.6071**	**-3.0783**	**-3.1238**	**-3.0805**	**-3.0743**	**-3.0623**	**-3.0354**	**-2.9910**
Mean p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
St.Dev (%)	11.0694	11.0711	11.1803	11.4466	11.9000	12.1116	12.1759	12.1341	12.0949	12.0778	12.2917	11.0297
Skewness	3.0992	2.9736	1.6006	0.8705	-1.7909	-4.1958	-4.6698	-4.7560	-4.8704	-5.0675	-5.5353	3.2075
Kurtosis	28.8437	28.7564	29.4557	30.5449	39.4803	40.6661	42.4062	43.6935	45.5707	49.0603	59.1004	28.7484
Sharpe ratio (%)	**-28.1587**	**-27.5535**	**-27.6511**	**-24.1554**	**-21.9088**	**-25.4163**	**-25.6559**	**-25.3876**	**-25.4186**	**-25.3549**	**-24.6945**	**-27.1180**
Sharpe ratio p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
High-Volatility Periods												
Number of + (-) returns	237(553)	248(542)	274(516)	301(489)	328(462)	317(473)	317(473)	316(474)	316(474)	313(477)	319(471)	242(548)
Mean (%)	**-2.0613**	**-2.0151**	**-2.9055**	**-2.9310**	**-3.0339**	**-4.3285**	**-4.5727**	**-4.5463**	**-4.5467**	**-4.5487**	**-4.5614**	**-1.8359**
Mean p-value	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0005
St.Dev (%)	13.4281	13.4344	13.7436	14.3124	14.4218	14.6545	14.8704	14.8727	14.8988	14.9899	15.4337	13.3042
Skewness	2.8418	2.8054	0.9067	0.1299	-0.5775	-3.3455	-4.0718	-4.1370	-4.2361	-4.4285	-5.0237	3.0574
Kurtosis	25.3385	25.2581	26.1198	26.7632	27.0997	28.0103	29.4722	30.3123	31.6973	34.5985	45.0402	25.5303
Sharpe ratio (%)	**-15.3508**	**-14.9996**	**-21.1405**	**-20.4788**	**-21.0368**	**-29.5366**	**-30.7502**	**-30.5684**	**-30.5171**	**-30.3451**	**-29.5549**	**-13.7992**
Sharpe ratio p-value	0.0330	0.0364	0.0063	0.0051	0.0029	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0473
Medium-Volatility Periods												
Number of + (-) returns	184(606)	196(594)	238(552)	277(513)	327(463)	342(448)	348(442)	351(439)	350(440)	350(440)	347(443)	190(600)
Mean (%)	**-3.6577**	**-3.6203**	**-3.2356**	**-2.9144**	**-2.2933**	**-2.3046**	**-2.2758**	**-2.2381**	**-2.2534**	**-2.2780**	**-2.3399**	**-3.5683**
Mean p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
St.Dev (%)	9.1323	9.1421	9.1726	9.2101	9.1889	9.4401	9.3769	9.2970	9.2105	9.1210	9.2132	9.1374
Skewness	2.4624	1.9267	1.3864	0.8324	-0.5176	-3.1702	-3.0249	-3.2410	-3.2565	-3.2573	-3.1585	2.4261
Kurtosis	19.4881	19.2129	18.5388	18.0720	19.8474	27.1694	27.6370	28.2651	28.8455	29.4135	28.4164	19.3059
Sharpe ratio (%)	**-40.0528**	**-39.6001**	**-35.2752**	**-31.6434**	**-24.9569**	**-24.4131**	**-24.2700**	**-24.0734**	**-24.4654**	**-24.9750**	**-25.3974**	**-39.0516**
Sharpe ratio p-value	0.0004	0.0003	0.0002	0.0002	0.0003	0.0001	0.0003	0.0002	0.0002	0.0001	0.0001	0.0007
Low-Volatility Periods												
Number of + (-) returns	180(610)	184(606)	225(565)	283(507)	338(452)	353(437)	353(437)	350(440)	348(442)	346(444)	360(430)	182(608)
Mean (%)	**-3.6319**	**-3.5161**	**-3.1333**	**-2.4495**	**-2.4943**	**-2.6019**	**-2.5230**	**-2.4572**	**-2.4230**	**-2.3603**	**-2.2048**	**-3.5690**
Mean p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
St.Dev (%)	10.1252	10.1166	10.1112	10.1775	11.5096	11.5836	11.5280	11.4541	11.3644	11.2595	11.2716	10.1379
Skewness	3.4605	3.4487	3.1337	2.7819	-4.4528	-5.6538	-5.7368	-5.8541	-6.0016	-6.2267	-6.5216	3.4412
Kurtosis	30.7196	30.7074	30.5468	29.7819	60.7271	60.6419	62.0030	63.8753	66.3217	70.1238	75.2571	30.4501
Sharpe ratio (%)	**-35.8703**	**-34.7559**	**-30.9886**	**-24.0677**	**-21.6713**	**-22.4615**	**-21.8862**	**-21.4523**	**-21.3205**	**-20.9623**	**-19.5604**	**-35.2043**
Sharpe ratio p-value	0.0045	0.0040	0.0050	0.0098	0.0012	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0037
Panel B: Mean Difference (%)												
High - Medium	**1.5964**	**1.6052**	0.3302	-0.0166	-0.7406	**-2.0238**	**-2.2969**	**-2.3082**	**-2.2933**	**-2.2707**	**-2.2215**	**1.7324**
	(0.0081)	(0.0057)	(0.5798)	(0.9783)	(0.2306)	(0.0013)	(0.0004)	(0.0005)	(0.0007)	(0.0006)	(0.0017)	(0.0029)
High - Low	**1.5706**	**1.5010**	0.2279	-0.4815	-0.5396	**-1.7266**	**-2.1496**	**-2.0892**	**-2.1237**	**-2.1885**	**-2.3567**	**1.7331**
	(0.0097)	(0.0129)	(0.7055)	(0.4413)	(0.4199)	(0.0102)	(0.0019)	(0.0012)	(0.0014)	(0.0014)	(0.0008)	(0.0034)
Medium - Low	-0.0258	-0.1042	-0.1023	-0.4649	0.2010	0.2972	0.2473	0.2191	0.1696	0.0823	-0.1351	0.0007
	(0.9582)	(0.8227)	(0.8283)	(0.3354)	(0.7037)	(0.5723)	(0.6368)	(0.6763)	(0.7421)	(0.8727)	(0.8041)	(0.9988)
Panel C: Sharpe Ratio Difference (%)												
High - Medium	**24.7019**	**24.6006**	14.1347	11.1646	3.9200	-5.1235	-6.4802	-6.4951	-6.0517	-5.3701	-4.1575	**25.2524**
	(0.0070)	(0.0039)	(0.0600)	(0.1133)	(0.5457)	(0.2373)	(0.0898)	(0.0906)	(0.1187)	(0.1728)	(0.3033)	(0.0034)
High - Low	**20.5195**	**19.7563**	9.8481	3.5888	0.6344	-7.0751	**-8.8640**	**-9.1161**	**-9.1965**	**-9.3827**	**-9.9945**	**21.4051**
	(0.0176)	(0.0205)	(0.2148)	(0.6382)	(0.9017)	(0.0812)	(0.0203)	(0.0157)	(0.0160)	(0.0120)	(0.0080)	(0.0112)
Medium - Low	-4.1824	-4.8442	-4.2866	-7.5758	-3.2856	-1.9516	-2.3838	-2.6210	-3.1448	-4.0126	-5.8370	-3.8473
	(0.6509)	(0.5901)	(0.6068)	(0.3381)	(0.5937)	(0.5991)	(0.5090)	(0.4658)	(0.3880)	(0.2907)	(0.1314)	(0.6577)

Notes: The table reports the summary statistics from out-of-sample trades in short-term zero-beta straddles in the DJX options market from October 1, 2004 to March 6, 2015. On each trading day, market agents fit past 252 observations of CIV or VXD in an ARMA(1,1) model, and use estimated parameters of the ARMA model to forecast today's CIV or VXD, then use the CIV/VXD forecast to obtain a price forecast for the zero-beta straddle by using the Black-Scholes Model. The proportions for the call and put options in the straddle also depend on the CIV. They enter their positions in the market by buying (selling) the aforementioned option portfolio if the portfolio is underpriced (overpriced). On the next day, they close their positions of the previous day by an offsetting order so that they can rebalance their portfolio everyday. Only options with maturities that are between 7 to 60 days are traded. If an option traded on the previous day cannot be found on the next day, the rate of return for that option during this period is recorded as -1. The profit of the zero-beta straddle is calculated as:

$$\text{profit} = \frac{-C\beta_c + S}{P\beta_c - C\beta_c + S} r_c + \frac{P\beta_c}{P\beta_c - C\beta_c + S} r_p \qquad (11)$$

where C and P are put and call option prices. S is the underlying index level; r_c and r_p are return on the call and put options, respectively. β_c is the market beta for the call option, and is defined as $\beta_c = \frac{S}{C}\Delta_c$, where Δ_c is the call option delta. The rate of return π can then be calculated. We allow market agents to borrow at the risk-free rate and to invest all profits from option trades into risk-free assets. Therefore, we deduct (add) a risk-free rate from (to) the rate of return of the zero-beta-straddle. Transaction costs include a 25% effective bid-ask spread and a 0.5% commission fee; see (Hull 2012, Table 9.1) for a typical commission fee scheme in the options markets. Commission fees are payable both upon entering and exiting a position since an offsetting order is used to close out positions in the market. The return sample is divided into three subsamples: high-, medium- and low-volatility period subsamples, according to realized volatility calculated from historical index levels. p-values for the mean and mean difference are based on Efron & Tibshirani (1993) and Efron (1979) via a transformation of original returns, and p-values for the Sharpe ratio are based on Opdyke (2007). All p-values are calculated through a bootstrap t-test. The t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. In parentheses are p-values. Numbers in bold indicate significance at 5% significance level.

Table 18. Mean Rate of Return Differences from Out-of-Sample Option Trades after Transaction Costs (Zero-Beta Straddles)

		B										
		CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}
	Whole Periods											
	CIV_1	0.0665										
		(0.8369)										
	CIV_5	0.0255	-0.0410									
		(0.9360)	(0.9023)									
	CIV_{10}	0.3520	0.2855	0.3265								
		(0.2854)	(0.3812)	(0.3239)								
	CIV_{15}	0.5099	0.4433	0.4843	0.1578							
		(0.1272)	(0.1783)	(0.1488)	(0.6354)							
	CIV_{20}	0.0387	-0.0278	0.0132	-0.3133	-0.4712						
		(0.9111)	(0.9389)	(0.9673)	(0.3578)	(0.1696)						
A	CIV_{25}	-0.0068	-0.0733	-0.0324	-0.3589	-0.5167	-0.0455					
		(0.9835)	(0.8320)	(0.9251)	(0.2879)	(0.1428)	(0.9035)					
	CIV_{30}	0.0365	-0.0300	0.0109	-0.3156	-0.4734	-0.0022	0.0433				
		(0.9137)	(0.9283)	(0.9766)	(0.3615)	(0.1822)	(0.9940)	(0.9014)				
	CIV_{35}	0.0426	-0.0239	0.0171	-0.3094	-0.4672	0.0040	0.0495	0.0062			
		(0.8989)	(0.9453)	(0.9593)	(0.3717)	(0.1854)	(0.9916)	(0.8902)	(0.9854)			
	CIV_{40}	0.0547	-0.0118	0.0292	-0.2973	-0.4552	0.0160	0.0615	0.0182	0.0120		
		(0.8688)	(0.9691)	(0.9282)	(0.3869)	(0.1921)	(0.9619)	(0.8578)	(0.9575)	(0.9716)		
	CIV_{45}	0.0816	0.0151	0.0561	-0.2704	-0.4282	0.0429	0.0885	0.0452	0.0390	0.0269	
		(0.8040)	(0.9637)	(0.8653)	(0.4319)	(0.2295)	(0.8982)	(0.8070)	(0.9002)	(0.9144)	(0.9381)	
	VXD	0.1259	0.0594	0.1004	-0.2261	-0.3839	0.0873	0.1328	0.0895	0.0833	0.0713	0.0443
		(0.6902)	(0.8599)	(0.7499)	(0.4869)	(0.2471)	(0.7942)	(0.6922)	(0.7874)	(0.8059)	(0.8325)	(0.8903)
	High-Volatility Periods											
	CIV_1	0.0462										
		(0.9502)										
	CIV_5	-0.8441	-0.8904									
		(0.2117)	(0.2009)									
	CIV_{10}	-0.8697	-0.9159	-0.0256								
		(0.2186)	(0.1870)	(0.9716)								
	CIV_{15}	-0.9726	-1.0188	-0.1284	-0.1029							
		(0.1607)	(0.1511)	(0.8541)	(0.8879)							
	CIV_{20}	**-2.2671**	**-2.3134**	**-1.4230**	-1.3974	-1.2946						
		(0.0019)	(0.0019)	(0.0464)	(0.0536)	(0.0806)						
A	CIV_{25}	**-2.5114**	**-2.5576**	**-1.6672**	**-1.6417**	**-1.5388**	-0.2442					
		(0.0015)	(0.0008)	(0.0220)	(0.0268)	(0.0367)	(0.7450)					
	CIV_{30}	**-2.4850**	**-2.5312**	**-1.6409**	**-1.6153**	**-1.5125**	-0.2179	0.0263				
		(0.0011)	(0.0006)	(0.0223)	(0.0270)	(0.0399)	(0.7639)	(0.9718)				
	CIV_{35}	**-2.4854**	**-2.5316**	**-1.6412**	**-1.6157**	**-1.5128**	-0.2182	0.0260	-0.0003			
		(0.0012)	(0.0009)	(0.0252)	(0.0273)	(0.0419)	(0.7673)	(0.9712)	(0.9995)			
	CIV_{40}	**-2.4874**	**-2.5336**	**-1.6433**	**-1.6177**	**-1.5148**	-0.2202	0.0240	-0.0024	-0.0020		
		(0.0012)	(0.0004)	(0.0248)	(0.0299)	(0.0393)	(0.7638)	(0.9763)	(0.9978)	(0.9980)		
	CIV_{45}	**-2.5001**	**-2.5463**	**-1.6560**	**-1.6304**	**-1.5275**	-0.2330	0.0113	-0.0151	-0.0147	-0.0127	
		(0.0011)	(0.0008)	(0.0271)	(0.0314)	(0.0422)	(0.7591)	(0.9878)	(0.9858)	(0.9856)	(0.9872)	
	VXD	0.2255	0.1792	1.0696	1.0951	1.1980	**2.4926**	**2.7368**	**2.7105**	**2.7108**	**2.7128**	**2.7256**
		(0.7395)	(0.7893)	(0.1142)	(0.1145)	(0.0898)	(0.0010)	(0.0005)	(0.0005)	(0.0006)	(0.0005)	(0.0004)
	Medium-Volatility Periods											
	CIV_1	0.0375										
		(0.9369)										
	CIV_5	0.4221	0.3846									
		(0.3615)	(0.4034)									
	CIV_{10}	0.7433	0.7059	0.3213								
		(0.1110)	(0.1270)	(0.4890)								
	CIV_{15}	**1.3645**	**1.3270**	**0.9424**	0.6211							
		(0.0033)	(0.0044)	(0.0413)	(0.1760)							
	CIV_{20}	**1.3531**	**1.3156**	**0.9310**	0.6098	-0.0114						
		(0.0051)	(0.0043)	(0.0467)	(0.1988)	(0.9829)						
A	CIV_{25}	**1.3820**	**1.3445**	**0.9599**	0.6386	0.0175	0.0289					
		(0.0036)	(0.0045)	(0.0395)	(0.1698)	(0.9713)	(0.9517)					
	CIV_{30}	**1.4196**	**1.3822**	**0.9975**	0.6763	0.0552	0.0665	0.0377				
		(0.0035)	(0.0037)	(0.0319)	(0.1451)	(0.9037)	(0.8882)	(0.9368)				
	CIV_{35}	**1.4043**	**1.3669**	**0.9822**	0.6610	0.0399	0.0512	0.0224	-0.0153			
		(0.0032)	(0.0037)	(0.0325)	(0.1515)	(0.9343)	(0.9123)	(0.9637)	(0.9762)			
	CIV_{40}	**1.3798**	**1.3423**	**0.9577**	0.6364	0.0153	0.0267	-0.0022	-0.0399	-0.0246		
		(0.0034)	(0.0033)	(0.0378)	(0.1640)	(0.9733)	(0.9535)	(0.9961)	(0.9348)	(0.9606)		
	CIV_{45}	**1.3178**	**1.2804**	0.8957	0.5745	-0.0466	-0.0353	-0.0641	-0.1018	-0.0865	-0.0619	
		(0.0043)	(0.0070)	(0.0521)	(0.2179)	(0.9192)	(0.9432)	(0.8911)	(0.8228)	(0.8512)	(0.8958)	
	VXD	0.0894	0.0520	-0.3327	-0.6539	**-1.2750**	**-1.2637**	**-1.2925**	**-1.3302**	**-1.3149**	**-1.2903**	**-1.2284**
		(0.8461)	(0.9106)	(0.4659)	(0.1570)	(0.0063)	(0.0076)	(0.0082)	(0.0058)	(0.0057)	(0.0059)	(0.0086)
	Low-Volatility Periods											
	CIV_1	0.1158										
		(0.8174)										
	CIV_5	0.4986	0.3828									
		(0.3273)	(0.4549)									
	CIV_{10}	**1.1824**	**1.0666**	0.6838								
		(0.0194)	(0.0394)	(0.1798)								
	CIV_{15}	**1.1377**	1.0218	0.6390	-0.0448							
		(0.0392)	(0.0622)	(0.2364)	(0.9348)							
	CIV_{20}	1.0301	0.9143	0.5315	-0.1524	-0.1076						
		(0.0636)	(0.0938)	(0.3324)	(0.7759)	(0.8538)						
A	CIV_{25}	**1.1089**	0.9931	0.6103	-0.0736	-0.0288	0.0788					
		(0.0461)	(0.0699)	(0.2688)	(0.8934)	(0.9624)	(0.8918)					
	CIV_{30}	**1.1748**	1.0589	0.6762	-0.0077	0.0371	0.1447	0.0659				
		(0.0363)	(0.0556)	(0.2151)	(0.9892)	(0.9519)	(0.8099)	(0.9088)				
	CIV_{35}	**1.2090**	**1.0931**	0.7104	0.0265	0.0713	0.1789	0.1001	0.0342			
		(0.0297)	(0.0450)	(0.1907)	(0.9567)	(0.8900)	(0.7518)	(0.8630)	(0.9514)			
	CIV_{40}	**1.2717**	**1.1558**	0.7731	0.0892	0.1340	0.2416	0.1628	0.0969	0.0627		
		(0.0211)	(0.0324)	(0.1574)	(0.8733)	(0.8188)	(0.6779)	(0.7849)	(0.8698)	(0.9111)		
	CIV_{45}	**1.4272**	**1.3113**	0.9286	0.2447	0.2895	0.3971	0.3183	0.2524	0.2182	0.1555	
		(0.0104)	(0.0212)	(0.0941)	(0.6556)	(0.6297)	(0.4957)	(0.5813)	(0.6554)	(0.7041)	(0.7886)	
	VXD	0.0630	-0.0529	-0.4356	**-1.1195**	-1.0747	-0.9671	-1.0459	**-1.1118**	**-1.1460**	**-1.2087**	**-1.3642**
		(0.8978)	(0.9151)	(0.4051)	(0.0301)	(0.0519)	(0.0759)	(0.0587)	(0.0452)	(0.0360)	(0.0256)	(0.0136)

Notes: The table reports the differences between mean rates of returns from option trades that are based on different pairs of CIVs, and respective two-sided p-values for the mean difference in parentheses. The mean difference is calculated as $\bar{\pi}_A - \bar{\pi}_B$, where $\bar{\pi}_A$ and $\bar{\pi}_B$ are mean rates of returns from option trades that are based on CIVs in A and B, respectively. p-values for the mean difference are based on Efron & Tibshirani (1993) and Efron (1979), and are calculated based on a bootstrap t-test. The null hypothesis of the test is that there is no difference between the mean rates of returns for the zero-beta straddles based on different CIVs. The bootstrap t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. Numbers in bold indicate significance at 5% significance level.

Table 19. Sharpe Ratio Differences from Out-of-Sample Option Trades after Transaction Costs (Zero-Beta Straddles)

		B										
		CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}
	Whole Periods											
	CIV_1	0.6051										
		(0.4108)										
	CIV_5	0.5076	-0.0975									
		(0.7976)	(0.9541)									
	CIV_{10}	4.0032	3.3981	**3.4956**								
		(0.1227)	(0.1614)	(0.0303)								
	CIV_{15}	6.2499	5.6448	**5.7423**	2.2467							
		(0.0603)	(0.0784)	(0.0357)	(0.2645)							
	CIV_{20}	2.7424	2.1372	2.2348	-1.2609	**-3.5075**						
		(0.4488)	(0.5558)	(0.4823)	(0.6291)	(0.0459)						
A	CIV_{25}	2.5028	1.8977	1.9952	-1.5004	**-3.7471**	-0.2396					
		(0.5047)	(0.6007)	(0.5357)	(0.5863)	(0.0436)	(0.6954)					
	CIV_{30}	2.7711	2.1660	2.2635	-1.2321	-3.4788	0.0287	0.2683				
		(0.4517)	(0.5463)	(0.4772)	(0.6535)	(0.0534)	(0.9596)	(0.1271)				
	CIV_{35}	2.7401	2.1350	2.2325	-1.2631	-3.5098	-0.0023	0.2373	-0.0310			
		(0.4533)	(0.5522)	(0.4840)	(0.6445)	(0.0567)	(0.9960)	(0.2637)	(0.7482)			
	CIV_{40}	2.8038	2.1987	2.2962	-1.1994	-3.4461	0.0614	0.3010	0.0327	0.0637		
		(0.4439)	(0.5396)	(0.4693)	(0.6637)	(0.0631)	(0.9279)	(0.3876)	(0.9046)	(0.7034)		
	CIV_{45}	3.4642	2.8590	2.9566	-0.5391	-2.7857	0.7218	0.9614	0.6931	0.7241	0.6604	
		(0.3373)	(0.4141)	(0.3571)	(0.8512)	(0.1527)	(0.4572)	(0.1999)	(0.3140)	(0.2256)	(0.1321)	
	VXD	1.0407	0.4355	0.5330	-2.9626	-5.2092	-1.7017	-1.4621	-1.7304	-1.6994	-1.7631	-2.4235
		(0.0708)	(0.5920)	(0.7826)	(0.2498)	(0.1150)	(0.6505)	(0.6833)	(0.6370)	(0.6476)	(0.6213)	(0.5001)
	High-Volatility Periods											
	CIV_1	0.3513										
		(0.7425)										
	CIV_5	-5.7897	-6.4109									
		(0.1092)	(0.0769)									
	CIV_{10}	-5.1280	-5.4793	0.6617								
		(0.2398)	(0.1915)	(0.8096)								
	CIV_{15}	-5.6860	-6.0373	0.1037	-0.5580							
		(0.2403)	(0.2108)	(0.9797)	(0.8172)							
	CIV_{20}	**-14.1858**	**-14.5371**	-8.3961	**-9.0578**	**-8.4998**						
		(0.0126)	(0.0081)	(0.0988)	(0.0349)	(0.0357)						
A	CIV_{25}	**-15.3994**	**-15.7506**	**-9.6097**	**-10.2714**	**-9.7134**	-1.2136					
		(0.0043)	(0.0032)	(0.0499)	(0.0170)	(0.0169)	(0.4444)					
	CIV_{30}	**-15.2176**	**-15.5689**	-9.4279	**-10.0896**	**-9.5316**	-1.0318	0.1818				
		(0.0034)	(0.0028)	(0.0560)	(0.0202)	(0.0214)	(0.4873)	(0.3640)				
	CIV_{35}	**-15.1662**	**-15.5175**	-9.3766	**-10.0383**	**-9.4802**	-0.9804	0.2331	0.0514			
		(0.0041)	(0.0038)	(0.0571)	(0.0214)	(0.0208)	(0.5153)	(0.4686)	(0.7447)			
	CIV_{40}	**-14.9942**	**-15.3455**	-9.2046	**-9.8663**	**-9.3083**	-0.8084	0.4051	0.2234	0.1720		
		(0.0034)	(0.0035)	(0.0692)	(0.0250)	(0.0241)	(0.6108)	(0.5097)	(0.6354)	(0.5823)		
	CIV_{45}	**-14.2041**	**-14.5553**	-8.4144	-9.0761	**-8.5181**	-0.0182	1.1953	1.0135	0.9622	0.7902	
		(0.0078)	(0.0069)	(0.1086)	(0.0588)	(0.0341)	(0.9937)	(0.4537)	(0.4755)	(0.4657)	(0.4137)	
	VXD	1.5516	1.2004	7.3413	6.6796	7.2376	**15.7375**	**16.9510**	**16.7692**	**16.7179**	**16.5459**	**15.7557**
		(0.2946)	(0.4286)	(0.0606)	(0.1469)	(0.1491)	(0.0068)	(0.0017)	(0.0014)	(0.0009)	(0.0017)	(0.0035)
	Medium-Volatility Periods											
	CIV_1	0.4526										
		(0.8328)										
	CIV_5	4.7775	4.3249									
		(0.2248)	(0.1741)									
	CIV_{10}	8.4093	7.9567	3.6318								
		(0.1050)	(0.0745)	(0.2499)								
	CIV_{15}	**15.0959**	**14.6433**	10.3184	6.6866							
		(0.0277)	(0.0222)	(0.0517)	(0.0963)							
	CIV_{20}	**15.6396**	**15.1870**	10.8621	7.2303	0.5437						
		(0.0361)	(0.0280)	(0.0693)	(0.1206)	(0.8601)						
A	CIV_{25}	**15.7827**	**15.3301**	11.0052	7.3734	0.6868	0.1431					
		(0.0355)	(0.0269)	(0.0651)	(0.1256)	(0.8251)	(0.8073)					
	CIV_{30}	**15.9794**	**15.5268**	11.2019	7.5701	0.8835	0.3398	0.1967				
		(0.0341)	(0.0289)	(0.0636)	(0.1116)	(0.7683)	(0.6336)	(0.6740)				
	CIV_{35}	**15.5874**	**15.1348**	10.8099	7.1781	0.4915	-0.0522	-0.1953	-0.3920			
		(0.0338)	(0.0303)	(0.0661)	(0.1305)	(0.8838)	(0.9496)	(0.7213)	(0.0572)			
	CIV_{40}	**15.0778**	**14.6252**	10.3003	6.6685	-0.0181	-0.5618	-0.7049	-0.9016	-0.5096		
		(0.0385)	(0.0376)	(0.0744)	(0.1440)	(0.9957)	(0.5446)	(0.3401)	(0.0786)	(0.0892)		
	CIV_{45}	**14.6554**	**14.2027**	9.8778	6.2460	-0.4405	-0.9842	-1.1274	-1.3240	-0.9320	-0.4224	
		(0.0381)	(0.0350)	(0.0812)	(0.1668)	(0.8879)	(0.4703)	(0.3590)	(0.2120)	(0.2816)	(0.4747)	
	VXD	1.0012	0.5486	-3.7764	-7.4081	**-14.0947**	**-14.6384**	**-14.7815**	**-14.9782**	**-14.5862**	-14.0766	-13.6542
		(0.3435)	(0.8098)	(0.3430)	(0.1579)	(0.0378)	(0.0449)	(0.0469)	(0.0427)	(0.0460)	(0.0534)	(0.0540)
	Low-Volatility Periods											
	CIV_1	1.1144										
		(0.2239)										
	CIV_5	4.8817	3.7673									
		(0.1169)	(0.1950)									
	CIV_{10}	**11.8026**	**10.6882**	**6.9209**								
		(0.0077)	(0.0121)	(0.0251)								
	CIV_{15}	**14.1990**	13.0846	9.3173	2.3964							
		(0.0412)	(0.0573)	(0.1365)	(0.6137)							
	CIV_{20}	13.4088	12.2944	8.5271	1.6061	-0.7903						
		(0.0864)	(0.1044)	(0.2057)	(0.7774)	(0.7609)						
A	CIV_{25}	13.9841	12.8697	9.1024	2.1814	-0.2150	0.5753					
		(0.0698)	(0.0910)	(0.1722)	(0.7108)	(0.9365)	(0.3224)					
	CIV_{30}	14.4180	13.3036	9.5363	2.6153	0.2189	1.0092	0.4339				
		(0.0613)	(0.0831)	(0.1651)	(0.6524)	(0.9356)	(0.1502)	(0.3237)				
	CIV_{35}	14.5498	13.4354	9.6681	2.7471	0.3507	1.1410	0.5657	0.1318			
		(0.0592)	(0.0728)	(0.1568)	(0.6350)	(0.8977)	(0.1124)	(0.1617)	(0.3843)			
	CIV_{40}	14.9080	13.7936	10.0263	3.1053	0.7089	1.4992	0.9239	0.4900	0.3582		
		(0.0516)	(0.0668)	(0.1373)	(0.5918)	(0.7964)	(0.0768)	(0.1046)	(0.2386)	(0.1816)		
	CIV_{45}	**16.3099**	**15.1955**	11.4282	4.5072	2.1108	**2.9011**	2.3258	1.8919	1.7601	**1.4019**	
		(0.0289)	(0.0403)	(0.0873)	(0.4434)	(0.4814)	(0.0388)	(0.0540)	(0.0748)	(0.0635)	(0.0459)	
	VXD	0.6660	-0.4484	-4.2157	**-11.1366**	-13.5330	-12.7427	-13.3180	-13.7519	-13.8837	-14.2419	**-15.6439**
		(0.3277)	(0.5602)	(0.1609)	(0.0122)	(0.0552)	(0.0948)	(0.0790)	(0.0722)	(0.0671)	(0.0618)	(0.0349)

Notes: The table reports the differences between Sharpe ratios from option trades that are based on different pairs of CIVs, and respective two-sided p-values for the Sharpe ratio difference in parentheses. The Sharpe ratio difference is calculated as $\text{Sharpe}_A - \text{Sharpe}_B$, where Sharpe_A and Sharpe_B are Sharpe ratios from option trades that are based on CIVs in A and B, respectively. p-values for the Sharpe ratio difference are based on Ledoit & Wolf (2008) for non i.i.d. returns. The null hypothesis is that there is no difference between the Sharpe ratios for the zero-beta straddles based on different CIVs. The bootstrap t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. Numbers in bold indicate significance at 5% significance level.

Supplemental Tables to the Manuscript entitled

”The information content of corridor implied variances and their economic difference in the DJX options market” by Shan Lu

Description

This documentation provides supplemental tables to Section *6.4 Alternative Strategies* of the manuscript entitled ”The information content of corridor implied variances and their economic difference in the DJX options market”. After considering the length of the manuscript, we have decided not to insert tables in this file into the manuscript. We have briefly summarized the results of tables in this file in Section *6.4 Alternative Strategies* of the manuscript since results of tables in this file are a robustness check for the results presented in Section *6. Economic Analysis* of the manuscript. The detailed procedure of simulations are described in the footnotes of each table in this file.

Table 1. Returns of Short-Term At-the-Money Delta-Hedged Puts before Transaction Costs

	CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}	VXD
Panel A: Summary Statistics of Option Trades												
Whole Periods												
Long (short) put trades	2530(92)	2398(224)	1471(1151)	502(2120)	136(2486)	39(2583)	8(2614)	1(2621)	1(2621)	1(2621)	0(2622)	2518(104)
Average number of futures hedged	0.4922	0.4926	0.4933	0.4939	0.4945	0.4951	0.4957	0.4964	0.4972	0.4983	0.5001	0.4923
Number of + (-) returns	970(1652)	1004(1618)	1274(1348)	1560(1062)	1656(966)	1685(937)	1692(930)	1694(928)	1695(927)	1702(920)	1713(909)	965(1657)
Mean (%)	-0.2342	-0.2862	0.2934	0.3575	0.2210	0.3941	0.4181	0.4329	0.4524	**0.4853**	**0.5503**	-0.3014
Mean p-value	0.3288	0.2246	0.2175	0.1304	0.3529	0.1038	0.0772	0.0671	0.0589	0.0447	0.0313	0.2043
St.Dev (%)	12.2310	12.2227	12.2075	12.1948	12.1914	12.1857	12.1913	12.2118	12.2649	12.4127	12.9716	12.2279
Skewness	3.6926	3.6109	2.2658	-1.1763	-3.8739	-3.8114	-3.7634	-3.7701	-3.7480	-3.7051	-3.5669	3.6956
Kurtosis	40.6214	40.6905	40.1768	40.5489	40.6227	40.8320	40.7506	40.5755	40.2033	39.3418	36.4001	40.6339
Sharp ratio (%)	-1.9146	-2.3412	2.4038	2.9313	1.8128	3.2342	3.4294	3.5450	3.6885	3.9099	4.2423	-2.4647
Sharpe ratio p-value	0.3075	0.2552	0.1005	0.2093	0.3205	0.1819	0.1693	0.1645	0.1438	0.1434	0.1191	0.2399
High-Volatility Periods												
Long (short) put trades	825(49)	764(110)	401(473)	101(773)	30(844)	7(867)	1(873)	0(874)	0(874)	0(874)	0(874)	820(54)
Average number of futures hedged	0.4892	0.4897	0.4907	0.4916	0.4925	0.4934	0.4943	0.4955	0.4968	0.4986	0.5017	0.4893
Number of + (-) returns	341(533)	349(525)	444(430)	532(342)	537(337)	541(333)	546(328)	544(330)	543(331)	544(330)	548(326)	340(534)
Mean (%)	0.7135	0.4870	0.5523	0.0391	**-0.9242**	-0.8415	-0.8389	-0.7988	-0.7649	-0.7090	-0.5853	0.6556
Mean p-value	0.1152	0.2815	0.2207	0.9275	0.0434	0.0610	0.0644	0.0754	0.0892	0.1128	0.2072	0.1426
St.Dev (%)	13.2761	13.2736	13.2423	13.2270	13.1733	13.1606	13.1444	13.1368	13.1474	13.2160	13.5821	13.2778
Skewness	3.3452	3.2603	2.6802	0.5999	-3.6481	-3.6420	-3.6133	-3.5822	-3.5391	-3.4849	-3.4333	3.3516
Kurtosis	30.5141	30.5833	30.3776	30.4246	29.3820	29.0903	28.6885	28.2171	27.5852	26.7263	25.5087	30.5548
Sharp ratio (%)	**5.3743**	3.6687	4.1710	0.2955	**-7.0155**	**-6.3939**	**-6.3824**	**-6.0808**	**-5.8181**	-5.3646	-4.3097	4.9375
Sharpe ratio p-value	0.0355	0.3351	0.0839	0.7838	0.0160	0.0065	0.0070	0.0278	0.0558	0.1311	0.3109	0.0887
Medium-Volatility Periods												
Long (short) put trades	849(25)	808(66)	542(332)	206(668)	52(822)	15(859)	3(871)	1(873)	1(873)	1(873)	0(874)	839(35)
Average number of futures hedged	0.4935	0.4938	0.4944	0.4950	0.4955	0.4960	0.4965	0.4971	0.4979	0.4988	0.5003	0.4935
Number of + (-) returns	313(561)	328(546)	416(458)	513(361)	559(315)	570(304)	572(302)	577(297)	577(297)	574(300)	572(302)	312(562)
Mean (%)	-0.5694	-0.5425	0.2307	0.2135	0.6098	0.6983	0.7804	0.8159	0.8286	**0.8494**	0.8688	-0.6252
Mean p-value	0.1634	0.1890	0.5786	0.6053	0.1410	0.0889	0.0636	0.0531	0.0516	0.0471	0.0520	0.1263
St.Dev (%)	11.9550	11.9515	11.9564	11.9558	11.9445	11.9492	11.9644	11.9991	12.0720	12.2523	12.8655	11.9469
Skewness	5.3603	5.2673	3.0644	-3.6647	-5.6111	-5.6679	-5.5846	-5.6183	-5.6342	-5.6088	-5.3307	5.3583
Kurtosis	69.8411	69.9620	69.1974	70.2490	71.9298	72.6940	73.3647	73.8634	74.0359	73.2621	67.4330	69.7754
Sharp ratio (%)	-4.7632	-4.5392	1.9294	1.7855	5.1051	5.8442	6.5228	6.7996	6.8636	6.9325	6.7531	-5.2330
Sharpe ratio p-value	0.2549	0.2818	0.0915	0.5614	0.2458	0.2208	0.2044	0.1892	0.1922	0.1881	0.1865	0.2469
Low-Volatility Periods												
Long (short) put trades	856(18)	826(48)	528(346)	195(679)	54(820)	17(857)	4(870)	0(874)	0(874)	0(874)	0(874)	859(15)
Average number of futures hedged	0.4940	0.4943	0.4948	0.4952	0.4955	0.4958	0.4962	0.4966	0.4970	0.4975	0.4982	0.4940
Number of + (-) returns	316(558)	327(547)	414(460)	515(359)	560(314)	574(300)	574(300)	573(301)	575(299)	584(290)	593(281)	313(561)
Mean (%)	**-0.8466**	**-0.8030**	0.0973	**0.8198**	**0.9774**	**1.3255**	**1.3128**	**1.2816**	**1.2935**	**1.3156**	**1.3674**	**-0.9345**
Mean p-value	0.0253	0.0398	0.8106	0.0317	0.0109	0.0007	0.0011	0.0012	0.0008	0.0006	0.0011	0.0165
St.Dev (%)	11.3388	11.3386	11.3572	11.3246	11.3131	11.2845	11.3043	11.3483	11.4326	11.6425	12.3743	11.3338
Skewness	2.1840	2.1174	0.6041	-1.0200	-2.0999	-1.7986	-1.7696	-1.8119	-1.7905	-1.7719	-1.7590	2.1888
Kurtosis	20.9246	20.7465	19.7138	19.9652	20.2219	20.2556	19.8626	19.3702	18.6900	17.6050	15.5705	21.0198
Sharp ratio (%)	-7.4662	-7.0816	0.8570	7.2394	8.6395	**11.7461**	11.6132	11.2937	11.3143	11.2996	11.0505	-8.2456
Sharpe ratio p-value	0.1292	0.1356	0.0954	0.1308	0.0990	0.0459	0.0504	0.0533	0.0551	0.0520	0.0500	0.1142
Panel B: Mean Difference (%)												
High - Medium	**1.2829**	1.0295	0.3216	-0.1744	**-1.5339**	**-1.5398**	**-1.6194**	**-1.6147**	**-1.5935**	**-1.5584**	**-1.4542**	**1.2808**
	(0.0360)	(0.0882)	(0.5955)	(0.7770)	(0.0095)	(0.0108)	(0.0066)	(0.0062)	(0.0075)	(0.0086)	(0.0219)	(0.0335)
High - Low	**1.5601**	**1.2899**	0.4550	-0.7807	**-1.9016**	**-2.1670**	**-2.1517**	**-2.0805**	**-2.0585**	**-2.0245**	**-1.9528**	**1.5901**
	(0.0089)	(0.0287)	(0.4401)	(0.1904)	(0.0015)	(0.0004)	(0.0003)	(0.0008)	(0.0009)	(0.0007)	(0.0016)	(0.0073)
Medium - Low	0.2771	0.2605	0.1334	-0.6064	-0.3676	-0.6272	-0.5324	-0.4658	-0.4649	-0.4662	-0.4986	0.3093
	(0.6201)	(0.6419)	(0.8202)	(0.2779)	(0.5136)	(0.2576)	(0.3426)	(0.4143)	(0.4046)	(0.4155)	(0.4034)	(0.5757)
Panel C: Sharpe Ratio Difference (%)												
High - Medium	**10.1374**	8.2079	2.2416	-1.4900	**-12.1206**	**-12.2381**	**-12.9053**	**-12.8804**	**-12.6817**	**-12.2971**	**-11.0628**	**10.1705**
	(0.0383)	(0.0969)	(0.6186)	(0.7493)	(0.0134)	(0.0142)	(0.0138)	(0.0134)	(0.0158)	(0.0180)	(0.0327)	(0.0397)
High - Low	**12.8405**	**10.7504**	3.3140	-6.9439	**-15.6550**	**-18.1400**	**-17.9957**	**-17.3745**	**-17.1324**	**-16.6642**	**-15.3602**	**13.1830**
	(0.0088)	(0.0292)	(0.4794)	(0.1608)	(0.0008)	(0.0004)	(0.0003)	(0.0004)	(0.0006)	(0.0009)	(0.0016)	(0.0070)
Medium - Low	2.7030	2.5424	1.0724	-5.4539	-3.5344	-5.9019	-5.0904	-4.4941	-4.4507	-4.3670	-4.2974	3.0125
	(0.6179)	(0.6309)	(0.8195)	(0.2710)	(0.4959)	(0.2750)	(0.3463)	(0.4119)	(0.4204)	(0.4308)	(0.4390)	(0.5694)

Notes: The table reports the summary statistics from trades in short-term at-the-money delta-hedged puts in the DJX options market from October 1, 2004 to March 6, 2015. On each trading day, market agents use CIVs to obtain a price forecast for the at-the-money put option by using the Black-Scholes Model. They enter their positions in the market by buying (selling) one put contract if the option portfolio is underpriced (overpriced), and simultaneously buying (selling) a number of futures on the DJIA index which is equal to the option's delta. On the next day, they close their positions of the previous day by an offsetting order so that they can rebalance their portfolio everyday. Only options with maturities that are between 7 to 60 days are traded. Futures that has the a maturity that is closest to the put option is chosen. If a put option traded on the previous day cannot be found on the next day, the rate of return for that contract during this period is recorded as -1. The rate of return of the delta-hedged puts is calculated as, if an put contract is bought:

$$\pi = \frac{(P_{\text{close}} - P_{\text{open}}) + |\Delta_p|(F_{\text{close}} - F_{\text{open}})}{P_{\text{open}}} \tag{1}$$

and if an put option contract is sold:

$$\pi = -\frac{(P_{\text{close}} - P_{\text{open}}) + |\Delta_p|(F_{\text{close}} - F_{\text{open}})}{P_{\text{open}}} \tag{2}$$

where P is the put option price. Δ_p is the put option delta. We allow market agents to borrow at the risk-free rate and to invest all profits from option trades into risk-free assets. Therefore, we deduct (add) a risk-free rate from (to) the rate of return of the delta-hedged puts. No transaction cost is considered. The return sample is divided into three subsamples: high-, medium- and low-volatility period subsamples, according to realized volatility calculated from historical index levels. p-values for the mean and mean difference are based on Efron & Tibshirani (1993) and Efron (1979), and p-values for the Sharpe ratio are based on Opdyke (2007). All p-values are calculated through a bootstrap t-test. The t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. In parentheses are p-values. Numbers in bold indicate significance at 5% significance level.

Table 2. Mean Rate of Return Differences from Option Trades before Transaction Costs (Delta-Hedged Puts)

		B										
		CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}
	Whole Periods											
	CIV_1	-0.0520										
		(0.8759)										
	CIV_5	0.5276	0.5796									
		(0.1219)	(0.0865)									
	CIV_{10}	0.5916	0.6436	0.0640								
		(0.0867)	(0.0573)	(0.8455)								
	CIV_{15}	0.4552	0.5072	-0.0724	-0.1365							
		(0.1813)	(0.1319)	(0.8234)	(0.6772)							
	CIV_{20}	0.6283	**0.6803**	0.1007	0.0366	0.1731						
		(0.0650)	(0.0444)	(0.7604)	(0.9103)	(0.6043)						
A	CIV_{25}	0.6523	**0.7043**	0.1246	0.0606	0.1971	0.0240					
		(0.0540)	(0.0367)	(0.7113)	(0.8590)	(0.5610)	(0.9415)					
	CIV_{30}	**0.6671**	**0.7191**	0.1395	0.0754	0.2119	0.0388	0.0148				
		(0.0488)	(0.0349)	(0.6707)	(0.8202)	(0.5251)	(0.9097)	(0.9670)				
	CIV_{35}	**0.6866**	**0.7385**	0.1589	0.0949	0.2314	0.0583	0.0343	0.0195			
		(0.0462)	(0.0296)	(0.6379)	(0.7731)	(0.4948)	(0.8629)	(0.9223)	(0.9529)			
	CIV_{40}	**0.7195**	**0.7715**	0.1919	0.1279	0.2643	0.0912	0.0672	0.0524	0.0329		
		(0.0364)	(0.0242)	(0.5741)	(0.7107)	(0.4445)	(0.7957)	(0.8438)	(0.8779)	(0.9228)		
	CIV_{45}	**0.7845**	**0.8365**	0.2569	0.1928	0.3293	0.1562	0.1322	0.1174	0.0979	0.0650	
		(0.0222)	(0.0173)	(0.4685)	(0.5835)	(0.3402)	(0.6605)	(0.7063)	(0.7347)	(0.7705)	(0.8516)	
	VXD	-0.0672	-0.0152	-0.5948	**-0.6588**	-0.5224	**-0.6955**	**-0.7195**	**-0.7343**	**-0.7538**	**-0.7867**	**-0.8517**
		(0.8421)	(0.9651)	(0.0782)	(0.0488)	(0.1253)	(0.0387)	(0.0349)	(0.0315)	(0.0254)	(0.0199)	(0.0136)
	High-Volatility Periods											
	CIV_1	-0.2265										
		(0.7204)										
	CIV_5	-0.1612	0.0654									
		(0.8001)	(0.9135)									
	CIV_{10}	-0.6744	-0.4479	-0.5132								
		(0.2867)	(0.4794)	(0.4199)								
	CIV_{15}	**-1.6377**	**-1.4111**	**-1.4765**	-0.9633							
		(0.0128)	(0.0256)	(0.0243)	(0.1301)							
	CIV_{20}	**-1.5550**	**-1.3285**	**-1.3938**	-0.8806	0.0827						
		(0.0171)	(0.0355)	(0.0284)	(0.1650)	(0.8996)						
A	CIV_{25}	**-1.5524**	**-1.3259**	**-1.3913**	-0.8780	0.0852	0.0025					
		(0.0169)	(0.0349)	(0.0271)	(0.1680)	(0.8956)	(0.9967)					
	CIV_{30}	**-1.5123**	**-1.2858**	**-1.3512**	-0.8379	0.1253	0.0427	0.0401				
		(0.0189)	(0.0415)	(0.0334)	(0.1868)	(0.8402)	(0.9452)	(0.9520)				
	CIV_{35}	**-1.4784**	**-1.2519**	**-1.3173**	-0.8040	0.1592	0.0765	0.0740	0.0339			
		(0.0215)	(0.0499)	(0.0374)	(0.2086)	(0.8052)	(0.9015)	(0.9077)	(0.9605)			
	CIV_{40}	**-1.4225**	-1.1960	**-1.2613**	-0.7481	0.2152	0.1325	0.1299	0.0898	0.0559		
		(0.0266)	(0.0610)	(0.0499)	(0.2414)	(0.7393)	(0.8391)	(0.8396)	(0.8835)	(0.9336)		
	CIV_{45}	**-1.2988**	-1.0723	-1.1377	-0.6244	0.3388	0.2561	0.2536	0.2135	0.1796	0.1236	
		(0.0447)	(0.0923)	(0.0751)	(0.3305)	(0.5987)	(0.6964)	(0.6848)	(0.7492)	(0.7865)	(0.8522)	
	VXD	-0.0579	0.1686	0.1033	0.6165	**1.5798**	**1.4971**	**1.4945**	**1.4544**	**1.4205**	**1.3646**	1.2409
		(0.9274)	(0.7866)	(0.8695)	(0.3188)	(0.0133)	(0.0188)	(0.0180)	(0.0230)	(0.0269)	(0.0311)	(0.0508)
	Medium-Volatility Periods											
	CIV_1	0.0269										
		(0.9615)										
	CIV_5	0.8001	0.7732									
		(0.1674)	(0.1794)									
	CIV_{10}	0.7829	0.7560	-0.0172								
		(0.1768)	(0.1874)	(0.9743)								
	CIV_{15}	**1.1792**	**1.1523**	0.3791	0.3963							
		(0.0421)	(0.0505)	(0.5072)	(0.4995)							
	CIV_{20}	**1.2678**	**1.2408**	0.4677	0.4849	0.0886						
		(0.0296)	(0.0309)	(0.4141)	(0.4024)	(0.8754)						
A	CIV_{25}	**1.3499**	**1.3229**	0.5497	0.5669	0.1706	0.0821					
		(0.0201)	(0.0245)	(0.3486)	(0.3193)	(0.7686)	(0.8859)					
	CIV_{30}	**1.3853**	**1.3584**	0.5852	0.6024	0.2061	0.1176	0.0355				
		(0.0202)	(0.0220)	(0.3093)	(0.3005)	(0.7179)	(0.8468)	(0.9533)				
	CIV_{35}	**1.3980**	**1.3711**	0.5979	0.6151	0.2188	0.1302	0.0482	0.0127			
		(0.0174)	(0.0201)	(0.2965)	(0.2915)	(0.7140)	(0.8231)	(0.9300)	(0.9845)			
	CIV_{40}	**1.4188**	**1.3919**	0.6187	0.6359	0.2396	0.1511	0.0690	0.0335	0.0208		
		(0.0194)	(0.0193)	(0.2877)	(0.2699)	(0.6845)	(0.7929)	(0.8995)	(0.9548)	(0.9736)		
	CIV_{45}	**1.4383**	**1.4113**	0.6381	0.6553	0.2590	0.1705	0.0884	0.0529	0.0402	0.0194	
		(0.0195)	(0.0218)	(0.2862)	(0.2768)	(0.6735)	(0.7776)	(0.8872)	(0.9314)	(0.9451)	(0.9703)	
	VXD	-0.0558	-0.0827	-0.8559	-0.8387	**-1.2350**	**-1.3235**	**-1.4056**	**-1.4411**	**-1.4538**	**-1.4746**	**-1.4940**
		(0.9203)	(0.8861)	(0.1379)	(0.1452)	(0.0349)	(0.0239)	(0.0166)	(0.0134)	(0.0151)	(0.0122)	(0.0145)
	Low-Volatility Periods											
	CIV_1	0.0436										
		(0.9337)										
	CIV_5	0.9439	0.9003									
		(0.0840)	(0.0983)									
	CIV_{10}	**1.6664**	**1.6228**	0.7225								
		(0.0016)	(0.0032)	(0.1851)								
	CIV_{15}	**1.8240**	**1.7804**	0.8801	0.1576							
		(0.0011)	(0.0013)	(0.1015)	(0.7660)							
	CIV_{20}	**2.1721**	**2.1284**	**1.2282**	0.5057	0.3481						
		(0.0006)	(0.0002)	(0.0207)	(0.3475)	(0.5300)						
A	CIV_{25}	**2.1594**	**2.1157**	**1.2155**	0.4930	0.3354	-0.0127					
		(0.0001)	(0.0002)	(0.0256)	(0.3635)	(0.5425)	(0.9823)					
	CIV_{30}	**2.1282**	**2.0846**	**1.1843**	0.4618	0.3042	-0.0438	-0.0311				
		(0.0001)	(0.0001)	(0.0320)	(0.3937)	(0.5777)	(0.9328)	(0.9513)				
	CIV_{35}	**2.1401**	**2.0965**	**1.1962**	0.4737	0.3161	-0.0320	-0.0193	0.0119			
		(0.0002)	(0.0002)	(0.0261)	(0.3869)	(0.5663)	(0.9509)	(0.9718)	(0.9828)			
	CIV_{40}	**2.1621**	**2.1185**	**1.2182**	0.4957	0.3382	-0.0090	0.0028	0.0339	0.0220		
		(0.0003)	(0.0004)	(0.0271)	(0.3707)	(0.5393)	(0.9855)	(0.9964)	(0.9478)	(0.9690)		
	CIV_{45}	**2.2140**	**2.1704**	**1.2701**	0.5476	0.3900	0.0419	0.0546	0.0858	0.0739	0.0519	
		(0.0002)	(0.0005)	(0.0243)	(0.3386)	(0.4980)	(0.9431)	(0.9189)	(0.8742)	(0.8963)	(0.9257)	
	VXD	-0.0880	-0.1316	-1.0319	**-1.7544**	**-1.9119**	**-2.2600**	**-2.2473**	**-2.2162**	**-2.2281**	**-2.2501**	**-2.3020**
		(0.8722)	(0.8074)	(0.0546)	(0.0016)	(0.0006)	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0003)	(0.0001)

Notes: The table reports the differences between mean rates of returns from option trades that are based on different pairs of CIVs, and respective two-sided p-values for the mean difference in parentheses. The mean difference is calculated as $\bar{\pi}_A - \bar{\pi}_B$, where $\bar{\pi}_A$ and $\bar{\pi}_B$ are mean rates of returns from option trades that are based on CIVs in A and B, respectively. p-values for the mean difference are based on Efron & Tibshirani (1993) and Efron (1979), and are calculated based on a bootstrap t-test. The null hypothesis of the test is that there is no difference between the mean rates of returns for the zero-beta straddles based on different CIVs. The bootstrap t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. Numbers in bold indicate significance at 5% significance level.

Table 3. Sharpe Ratio Differences from Option Trades before Transaction Costs (Delta-Hedged Puts)

		B										
		CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}
	Whole Periods											
	CIV_1	-0.4266										
		(0.5822)										
	CIV_5	**4.3184**	**4.7451**									
		(0.0236)	(0.0122)									
	CIV_{10}	4.8459	5.2726	0.5275								
		(0.1136)	(0.0857)	(0.8107)								
	CIV_{15}	3.7274	4.1540	-0.5911	-1.1185							
		(0.3015)	(0.2565)	(0.8478)	(0.5959)							
	CIV_{20}	5.1488	5.5755	0.8304	0.3029	1.4215						
		(0.1727)	(0.1418)	(0.7865)	(0.8899)	(0.0727)						
A	CIV_{25}	5.3440	5.7707	1.0256	0.4981	1.6166	0.1952					
		(0.1645)	(0.1404)	(0.7423)	(0.8235)	(0.0776)	(0.6726)					
	CIV_{30}	5.4596	5.8862	1.1411	0.6136	1.7322	0.3107	0.1155				
		(0.1648)	(0.1233)	(0.7216)	(0.7975)	(0.0960)	(0.6561)	(0.8326)				
	CIV_{35}	5.6031	6.0297	1.2846	0.7572	1.8757	0.4542	0.2590	0.1435			
		(0.1475)	(0.1187)	(0.6940)	(0.7455)	(0.0796)	(0.5409)	(0.6529)	(0.1622)			
	CIV_{40}	5.8245	6.2511	1.5060	0.9786	2.0971	0.6756	0.4804	0.3649	0.2214		
		(0.1376)	(0.0928)	(0.6287)	(0.6729)	(0.0660)	(0.4026)	(0.4553)	(0.1731)	(0.1833)		
	CIV_{45}	6.1569	6.5836	1.8385	1.3110	2.4295	1.0081	0.8129	0.6974	0.5539	0.3325	
		(0.1111)	(0.0815)	(0.5630)	(0.5773)	(0.0607)	(0.3264)	(0.3463)	(0.2535)	(0.2773)	(0.3322)	
	VXD	-0.5501	-0.1234	**-4.8685**	-5.3960	-4.2775	-5.6989	-5.8941	-6.0096	-6.1531	-6.3745	-6.7070
		(0.1315)	(0.8713)	(0.0115)	(0.0848)	(0.2428)	(0.1431)	(0.1304)	(0.1258)	(0.1183)	(0.0886)	(0.0751)
	High-Volatility Periods											
	CIV_1	-1.7055										
		(0.2467)										
	CIV_5	-1.2033	0.5022									
		(0.6963)	(0.8736)									
	CIV_{10}	-5.0787	-3.3732	-3.8754								
		(0.2889)	(0.4646)	(0.2965)								
	CIV_{15}	**-12.3898**	-10.6842	**-11.1865**	-7.3110							
		(0.0360)	(0.0595)	(0.0259)	(0.0826)							
	CIV_{20}	**-11.7682**	-10.0627	**-10.5649**	-6.6895	0.6216						
		(0.0359)	(0.0798)	(0.0354)	(0.1029)	(0.5607)						
A	CIV_{25}	**-11.7567**	-10.0512	**-10.5534**	-6.6780	0.6330	0.0115					
		(0.0447)	(0.0791)	(0.0382)	(0.1115)	(0.5609)	(0.9745)					
	CIV_{30}	**-11.4551**	-9.7495	**-10.2518**	-6.3764	0.9347	0.3131	0.3016				
		(0.0492)	(0.0854)	(0.0451)	(0.1258)	(0.3993)	(0.4382)	(0.1365)				
	CIV_{35}	**-11.1924**	-9.4868	-9.9891	-6.1137	1.1974	0.5758	**0.5643**	**0.2627**			
		(0.0456)	(0.0928)	(0.0524)	(0.1503)	(0.2866)	(0.1986)	(0.0226)	(0.0229)			
	CIV_{40}	-10.7389	-9.0334	-9.5356	-5.6602	1.6509	1.0293	**1.0178**	**0.7162**	**0.4535**		
		(0.0547)	(0.1115)	(0.0586)	(0.1737)	(0.1669)	(0.0782)	(0.0174)	(0.0199)	(0.0205)		
	CIV_{45}	-9.6840	-7.9784	-8.4807	-4.6052	2.7058	**2.0842**	**2.0728**	**1.7711**	**1.5084**	**1.0549**	
		(0.0785)	(0.1596)	(0.0859)	(0.2713)	(0.0531)	(0.0265)	(0.0124)	(0.0166)	(0.0149)	(0.0158)	
	VXD	-0.4368	1.2687	0.7665	4.6419	**11.9530**	**11.3314**	**11.3199**	**11.0183**	10.7556	10.3021	9.2472
		(0.4213)	(0.4090)	(0.8038)	(0.3118)	(0.0310)	(0.0399)	(0.0425)	(0.0451)	(0.0532)	(0.0637)	(0.0931)
	Medium-Volatility Periods											
	CIV_1	0.2240										
		(0.8757)										
	CIV_5	6.6925	6.4686									
		(0.0968)	(0.0894)									
	CIV_{10}	6.5487	6.3247	-0.1439								
		(0.3135)	(0.3185)	(0.9742)								
	CIV_{15}	9.8683	9.6443	3.1757	3.3196							
		(0.1931)	(0.2013)	(0.5775)	(0.2728)							
	CIV_{20}	10.6074	10.3834	3.9148	4.0587	0.7391						
		(0.1853)	(0.1866)	(0.5025)	(0.2138)	(0.5221)						
A	CIV_{25}	11.2860	11.0620	4.5935	4.7373	1.4177	0.6786					
		(0.1583)	(0.1677)	(0.4624)	(0.1789)	(0.4255)	(0.5724)					
	CIV_{30}	11.5628	11.3388	4.8702	5.0141	1.6945	0.9554	0.2768				
		(0.1569)	(0.1552)	(0.4254)	(0.1505)	(0.3375)	(0.4374)	(0.1901)				
	CIV_{35}	11.6267	11.4028	4.9342	5.0780	1.7584	1.0194	0.3407	0.0640			
		(0.1564)	(0.1632)	(0.4247)	(0.1408)	(0.3258)	(0.4072)	(0.3085)	(0.7179)			
	CIV_{40}	11.6957	11.4717	5.0031	5.1470	1.8274	1.0883	0.4097	0.1329	0.0690		
		(0.1527)	(0.1581)	(0.4262)	(0.1339)	(0.3177)	(0.4074)	(0.4941)	(0.7677)	(0.8064)		
	CIV_{45}	11.5163	11.2923	4.8237	4.9676	1.6480	0.9089	0.2303	-0.0465	-0.1105	-0.1794	
		(0.1498)	(0.1555)	(0.4354)	(0.1507)	(0.4258)	(0.5813)	(0.8425)	(0.9650)	(0.9017)	(0.7624)	
	VXD	-0.4699	-0.6938	-7.1624	-7.0186	-10.3382	-11.0773	-11.7559	-12.0327	-12.0966	-12.1656	-11.9862
		(0.4785)	(0.6062)	(0.0726)	(0.2853)	(0.1796)	(0.1635)	(0.1489)	(0.1495)	(0.1479)	(0.1425)	(0.1438)
	Low-Volatility Periods											
	CIV_1	0.3846										
		(0.6881)										
	CIV_5	**8.3232**	7.9386									
		(0.0407)	(0.0520)									
	CIV_{10}	**14.7056**	**14.3210**	6.3824								
		(0.0130)	(0.0138)	(0.0883)								
	CIV_{15}	**16.1057**	**15.7212**	7.7826	1.4001							
		(0.0213)	(0.0218)	(0.1324)	(0.7176)							
	CIV_{20}	**19.2123**	**18.8277**	10.8891	4.5067	3.1065						
		(0.0102)	(0.0086)	(0.0519)	(0.2906)	(0.1168)						
A	CIV_{25}	**19.0794**	**18.6949**	10.7563	4.3738	2.9737	-0.1328					
		(0.0082)	(0.0079)	(0.0502)	(0.2979)	(0.1305)	(0.8389)					
	CIV_{30}	**18.7599**	**18.3753**	10.4367	4.0543	2.6542	-0.4524	-0.3195				
		(0.0134)	(0.0104)	(0.0565)	(0.3596)	(0.2793)	(0.8100)	(0.8566)				
	CIV_{35}	**18.7805**	**18.3959**	10.4573	4.0749	2.6747	-0.4318	-0.2990	0.0205			
		(0.0125)	(0.0121)	(0.0591)	(0.3533)	(0.2960)	(0.8250)	(0.8727)	(0.9262)			
	CIV_{40}	**18.7658**	**18.3812**	10.4426	4.0601	2.6600	-0.4465	-0.3137	0.0058	-0.0147		
		(0.0123)	(0.0094)	(0.0575)	(0.3560)	(0.3165)	(0.8369)	(0.8700)	(0.9910)	(0.9722)		
	CIV_{45}	**18.5167**	**18.1321**	10.1935	3.8111	2.4110	-0.6956	-0.5627	-0.2432	-0.2638	-0.2490	
		(0.0098)	(0.0114)	(0.0621)	(0.3955)	(0.4140)	(0.7829)	(0.8025)	(0.8459)	(0.7948)	(0.7157)	
	VXD	-0.7794	-1.1639	**-9.1025**	**-15.4850**	**-16.8851**	**-19.9916**	**-19.8588**	**-19.5393**	**-19.5598**	**-19.5451**	**-19.2961**
		(0.2592)	(0.2583)	(0.0282)	(0.0092)	(0.0176)	(0.0088)	(0.0080)	(0.0095)	(0.0104)	(0.0083)	(0.0093)

Notes: The table reports the differences between Sharpe ratios from option trades that are based on different pairs of CIVs, and respective two-sided p-values for the Sharpe ratio difference in parentheses. The Sharpe ratio difference is calculated as $Sharpe_A - Sharpe_B$, where $Sharpe_A$ and $Sharpe_B$ are Sharpe ratios from option trades that are based on CIVs in A and B, respectively. p-values for the Sharpe ratio difference are based on Ledoit & Wolf (2008) for non i.i.d. returns. The null hypothesis is that there is no difference between the Sharpe ratios for the zero-beta straddles based on different CIVs. The bootstrap t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. Numbers in bold indicate significance at 5% significance level.

Table 4. Returns of Short-Term At-the-Money Delta-Hedged Puts after Transaction Costs

	CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}	VXD
Panel A: Daily returns from option trades												
Whole Periods												
Number of + (-) returns	534(2088)	544(2078)	730(1892)	871(1751)	905(1717)	920(1702)	922(1700)	924(1698)	940(1682)	957(1665)	991(1631)	525(2097)
Mean (%)	**-4.4269**	**-4.4844**	**-3.9392**	**-3.9202**	**-4.0765**	**-3.9097**	**-3.8939**	**-3.8863**	**-3.8664**	**-3.8323**	**-3.7702**	**-4.5004**
Mean p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
St.Dev (%)	11.7049	11.7808	12.2014	12.5925	12.9989	12.9998	13.0440	13.1267	13.1776	13.3204	13.8944	11.6927
Skewness	3.1941	3.0221	1.1507	-2.1539	-4.2833	-4.2289	-4.1665	-4.1475	-4.1192	-4.0623	-3.8744	3.2077
Kurtosis	39.3633	38.5710	39.4943	40.7770	42.6251	42.6895	42.1147	41.3118	40.8587	39.8693	36.4733	39.4706
Sharpe ratio (%)	**-37.8204**	**-38.0656**	**-32.2851**	**-31.1313**	**-31.3602**	**-30.0755**	**-29.8521**	**-29.6057**	**-29.3405**	**-28.7704**	**-27.1345**	**-38.4889**
Sharpe ratio p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
High-Volatility Periods												
Number of + (-) returns	214(660)	212(662)	268(606)	308(566)	302(572)	308(566)	306(568)	308(566)	311(563)	320(554)	328(546)	210(664)
Mean (%)	**-3.1953**	**-3.4290**	**-3.3961**	**-3.9578**	**-4.9343**	**-4.8561**	**-4.8739**	**-4.8349**	**-4.8017**	**-4.7466**	**-4.6237**	**-3.2707**
Mean p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
St.Dev (%)	12.7105	12.8668	13.1136	13.5356	14.1959	14.1721	14.2481	14.2420	14.2521	14.3181	14.6713	12.6853
Skewness	2.7526	2.5232	1.7566	-0.3772	-3.8728	-3.8761	-3.8144	-3.7866	-3.7483	-3.6978	-3.6382	2.7906
Kurtosis	28.4943	27.6069	25.7414	26.3897	30.3150	30.1486	29.1571	28.7400	28.1870	27.4266	26.3119	28.7564
Sharpe ratio (%)	**-25.1390**	**-26.6497**	**-25.8973**	**-29.2400**	**-34.7583**	**-34.2651**	**-34.2074**	**-33.9479**	**-33.6913**	**-33.1508**	**-31.5153**	**-25.7833**
Sharpe ratio p-value	0.0050	0.0043	0.0028	0.0003	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0069
Medium-Volatility Periods												
Number of + (-) returns	169(705)	177(697)	242(632)	270(604)	294(580)	300(574)	300(574)	301(573)	308(566)	308(566)	320(554)	166(708)
Mean (%)	**-4.8120**	**-4.7906**	**-4.0479**	**-4.1097**	**-3.7377**	**-3.6565**	**-3.5768**	**-3.5414**	**-3.5282**	**-3.5062**	**-3.5016**	**-4.8690**
Mean p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
St.Dev (%)	11.5889	11.6591	11.7770	12.1444	12.4124	12.4630	12.4973	12.5321	12.6057	12.7867	13.4938	11.5921
Skewness	5.1737	4.9755	2.5381	-4.1509	-5.6885	-5.6826	-5.5875	-5.6167	-5.6271	-5.5967	-5.2629	5.1545
Kurtosis	69.5392	68.0425	65.7184	69.0525	70.6595	70.3570	70.5355	70.9561	71.0466	70.2352	63.1130	69.1878
Sharpe ratio (%)	**-41.5223**	**-41.0890**	**-34.3715**	**-33.8408**	**-30.1124**	**-29.3388**	**-28.6203**	**-28.2584**	**-27.9889**	**-27.4204**	**-25.9497**	**-42.0027**
Sharpe ratio p-value	0.0102	0.0119	0.0086	0.0004	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0104
Low-Volatility Periods												
Number of + (-) returns	151(723)	155(719)	220(654)	293(581)	309(565)	312(562)	316(558)	315(559)	321(553)	329(545)	343(531)	149(725)
Mean (%)	**-5.2733**	**-5.2337**	**-4.3737**	**-3.6931**	**-3.5575**	**-3.2166**	**-3.2311**	**-3.2825**	**-3.2692**	**-3.2443**	**-3.1853**	**-5.3615**
Mean p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
St.Dev (%)	10.6342	10.6498	11.6533	12.0537	12.2715	12.2372	12.2529	12.4920	12.5685	12.7636	13.4586	10.6199
Skewness	1.2668	1.1882	-1.1927	-2.5934	-3.3391	-3.1256	-3.0893	-3.1031	-3.0526	-2.9657	-2.7510	1.2695
Kurtosis	16.3900	16.1684	32.2070	32.7402	32.4786	32.6896	32.1638	30.3691	29.3519	27.4945	23.2183	16.4900
Sharpe ratio (%)	**-49.5880**	**-49.1436**	**-37.5315**	**-30.6386**	**-28.9901**	**-26.2855**	**-26.3696**	**-26.2770**	**-26.0106**	**-25.4182**	**-23.6670**	**-50.4847**
Sharpe ratio p-value	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0002	0.0001	0.0002	0.0001	0.0001	0.0001
Panel C: Mean Difference (%)												
High - Medium	**1.6167**	**1.3616**	0.6519	0.1519	-1.1966	-1.1996	**-1.2971**	**-1.2935**	**-1.2735**	-1.2404	-1.1221	**1.5983**
	(0.0047)	(0.0190)	(0.2789)	(0.8103)	(0.0597)	(0.0607)	(0.0463)	(0.0424)	(0.0477)	(0.0559)	(0.0937)	(0.0055)
High - Low	**2.0780**	**1.8048**	0.9776	-0.2647	**-1.3767**	**-1.6395**	**-1.6428**	**-1.5523**	**-1.5326**	**-1.5023**	**-1.4384**	**2.0908**
	(0.0003)	(0.0014)	(0.0974)	(0.6617)	(0.0293)	(0.0104)	(0.0099)	(0.0145)	(0.0174)	(0.0215)	(0.0327)	(0.0005)
Medium - Low	0.4613	0.4431	0.3257	-0.4167	-0.1801	-0.4399	-0.3457	-0.2588	-0.2591	-0.2619	-0.3164	0.4924
	(0.3895)	(0.4118)	(0.5694)	(0.4765)	(0.7624)	(0.4628)	(0.5735)	(0.6681)	(0.6714)	(0.6789)	(0.6311)	(0.3594)
Panel D: Sharpe Ratio Difference (%)												
High - Medium	16.3832	14.4393	8.4742	4.6008	-4.6459	-4.9263	-5.5872	-5.6895	-5.7023	-5.7303	-5.5655	16.2194
	(0.1392)	(0.1813)	(0.3458)	(0.4568)	(0.2670)	(0.2135)	(0.1597)	(0.1461)	(0.1427)	(0.1319)	(0.1262)	(0.1491)
High - Low	**24.4489**	**22.4939**	11.6342	1.3987	-5.7683	**-7.9796**	**-7.8378**	**-7.6709**	**-7.6806**	**-7.7326**	**-7.8482**	**27.7014**
	(0.0017)	(0.0047)	(0.0871)	(0.7929)	(0.1187)	(0.0290)	(0.0318)	(0.0258)	(0.0252)	(0.0197)	(0.0156)	(0.0020)
Medium - Low	8.0657	8.0546	3.1600	-3.2021	-1.1224	-3.0533	-2.2506	-1.9814	-1.9783	-2.0022	-2.2827	8.4820
	(0.4483)	(0.4450)	(0.7078)	(0.5730)	(0.8008)	(0.4838)	(0.6014)	(0.6403)	(0.6340)	(0.6280)	(0.5531)	(0.4350)

Notes: The table reports the summary statistics from trades in short-term at-the-money delta-hedged puts in the DJX options market from October 1, 2004 to March 6, 2015. On each trading day, market agents use CIVs to obtain a price forecast for the at-the-money put option by using the Black-Scholes Model. They enter their positions in the market by buying (selling) one put contract if the option portfolio is underpriced (overpriced), and simultaneously buying (selling) a number of futures on the DJIA index which is equal to the option's delta. On the next day, they close their positions of the previous day by an offsetting order so that they can rebalance their portfolio everyday. Only options with maturities that are between 7 to 60 days are traded. Futures that has the a maturity that is closest to the put option is chosen. If a put option traded on the previous day cannot be found on the next day, the rate of return for that contract during this period is recorded as -1. The rate of return of the delta-hedged puts is calculated as, if an put contract is bought:

$$\pi = \frac{(P_{\text{close}} - P_{\text{open}}) + |\Delta_p|(F_{\text{close}} - F_{\text{open}})}{P_{\text{open}}} \quad (3)$$

and if an put option contract is sold:

$$\pi = -\frac{(P_{\text{close}} - P_{\text{open}}) + |\Delta_p|(F_{\text{close}} - F_{\text{open}})}{P_{\text{open}}} \quad (4)$$

where P is the put option price. Δ_p is the put option delta. We allow market agents to borrow at the risk-free rate and to invest all profits from option trades into risk-free assets. Therefore, we deduct (add) a risk-free rate from (to) the rate of return of the delta-hedged puts. Transaction costs include a 25% effective bid-ask spread and a 0.5% commission fee for option contracts [see (Hull 2012, Table 9.1) for a typical commission fee scheme in the options markets], and a $0.05 bid-ask spread for futures contracts [see Harvey & Whaley (1992)]. Commission fees are payable both upon entering and exiting a position since an offsetting order is used to close out positions in the market. The return sample is divided into three subsamples: high-, medium- and low-volatility period subsamples, according to realized volatility calculated from historical index levels. p-values for the mean and mean difference are based on Efron & Tibshirani (1993) and Efron (1979), and p-values for the Sharpe ratio are based on Opdyke (2007). All p-values are calculated through a bootstrap t-test. The t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. In parentheses are p-values. Numbers in bold indicate significance at 5% significance level.

Table 5. Mean Rate of Return Differences from Option Trades after Transaction Costs (Delta-Hedged Puts)

		B										
		CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}
	Whole Periods											
	CIV_1	-0.0576										
		(0.8643)										
	CIV_5	0.4876	0.5452									
		(0.1471)	(0.0977)									
	CIV_{10}	0.5066	0.5642	0.0190								
		(0.1310)	(0.0929)	(0.9534)								
	CIV_{15}	0.3504	0.4079	-0.1373	-0.1563							
		(0.3106)	(0.2376)	(0.6960)	(0.6562)							
	CIV_{20}	0.5171	0.5747	0.0295	0.0105	0.1667						
		(0.1274)	(0.0980)	(0.9344)	(0.9750)	(0.6502)						
A	CIV_{25}	0.5330	0.5905	0.0453	0.0263	0.1826	0.0158					
		(0.1239)	(0.0837)	(0.8939)	(0.9412)	(0.6085)	(0.9654)					
	CIV_{30}	0.5406	0.5982	0.0530	0.0340	0.1902	0.0235	0.0077				
		(0.1195)	(0.0841)	(0.8815)	(0.9277)	(0.6035)	(0.9498)	(0.9822)				
	CIV_{35}	0.5605	0.6181	0.0729	0.0539	0.2101	0.0434	0.0275	0.0199			
		(0.1028)	(0.0729)	(0.8377)	(0.8874)	(0.5572)	(0.9026)	(0.9373)	(0.9584)			
	CIV_{40}	0.5945	0.6521	0.1069	0.0879	0.2441	0.0774	0.0616	0.0539	0.0340		
		(0.0849)	(0.0603)	(0.7599)	(0.8094)	(0.4964)	(0.8322)	(0.8621)	(0.8840)	(0.9228)		
	CIV_{45}	0.6567	**0.7142**	0.1690	0.1500	0.3063	0.1396	0.1237	0.1161	0.0962	0.0622	
		(0.0657)	(0.0478)	(0.6413)	(0.6791)	(0.4105)	(0.7071)	(0.7343)	(0.7606)	(0.7998)	(0.8708)	
	VXD	-0.0735	-0.0160	-0.5612	-0.5802	-0.4239	-0.5906	-0.6065	-0.6141	-0.6340	-0.6680	**-0.7302**
		(0.8170)	(0.9572)	(0.0843)	(0.0825)	(0.2129)	(0.0881)	(0.0806)	(0.0761)	(0.0631)	(0.0572)	(0.0393)
	High-Volatility Periods											
	CIV_1	-0.2336										
		(0.7034)										
	CIV_5	-0.2008	0.0329									
		(0.7427)	(0.9576)									
	CIV_{10}	-0.7625	-0.5288	-0.5617								
		(0.2269)	(0.4134)	(0.3752)								
	CIV_{15}	**-1.7390**	**-1.5053**	**-1.5382**	-0.9765							
		(0.0093)	(0.0257)	(0.0183)	(0.1390)							
	CIV_{20}	**-1.6608**	**-1.4271**	**-1.4600**	-0.8983	0.0782						
		(0.0116)	(0.0291)	(0.0274)	(0.1705)	(0.9058)						
A	CIV_{25}	**-1.6786**	**-1.4449**	**-1.4778**	-0.9161	0.0604	-0.0178					
		(0.0102)	(0.0259)	(0.0231)	(0.1604)	(0.9304)	(0.9781)					
	CIV_{30}	**-1.6396**	**-1.4059**	**-1.4388**	-0.8771	0.0994	0.0212	0.0390				
		(0.0141)	(0.0365)	(0.0282)	(0.1894)	(0.8819)	(0.9784)	(0.9526)				
	CIV_{35}	**-1.6064**	**-1.3728**	**-1.4056**	-0.8439	0.1326	0.0544	0.0722	0.0332			
		(0.0126)	(0.0357)	(0.0334)	(0.2017)	(0.8429)	(0.9379)	(0.9144)	(0.9637)			
	CIV_{40}	**-1.5513**	**-1.3176**	**-1.3505**	-0.7888	0.1877	0.1095	0.1273	0.0883	0.0551		
		(0.0184)	(0.0477)	(0.0379)	(0.2401)	(0.7803)	(0.8723)	(0.8496)	(0.9007)	(0.9316)		
	CIV_{45}	**-1.4284**	-1.1947	-1.2276	-0.6659	0.3106	0.2324	0.2502	0.2112	0.1780	0.1229	
		(0.0315)	(0.0729)	(0.0658)	(0.3341)	(0.6478)	(0.7317)	(0.7206)	(0.7569)	(0.8001)	(0.8567)	
	VXD	-0.0754	0.1583	0.1254	0.6871	**1.6636**	**1.5854**	**1.6032**	**1.5642**	**1.5310**	**1.4759**	**1.3530**
		(0.9008)	(0.8044)	(0.8366)	(0.2786)	(0.0113)	(0.0139)	(0.0145)	(0.0190)	(0.0192)	(0.0237)	(0.0416)
	Medium-Volatility Periods											
	CIV_1	0.0214										
		(0.9683)										
	CIV_5	0.7641	0.7427									
		(0.1680)	(0.1867)									
	CIV_{10}	0.7022	0.6809	-0.0618								
		(0.2192)	(0.2318)	(0.9174)								
	CIV_{15}	1.0743	1.0529	0.3103	0.3721							
		(0.0641)	(0.0710)	(0.5964)	(0.5214)							
	CIV_{20}	**1.1555**	1.1341	0.3914	0.4532	0.0812						
		(0.0488)	(0.0557)	(0.5105)	(0.4453)	(0.8937)						
A	CIV_{25}	**1.2352**	**1.2138**	0.4712	0.5330	0.1609	0.0798					
		(0.0383)	(0.0432)	(0.4200)	(0.3674)	(0.7876)	(0.8879)					
	CIV_{30}	**1.2706**	**1.2492**	0.5066	0.5684	0.1963	0.1152	0.0354				
		(0.0327)	(0.0337)	(0.3940)	(0.3412)	(0.7431)	(0.8501)	(0.9542)				
	CIV_{35}	**1.2838**	**1.2624**	0.5197	0.5815	0.2095	0.1283	0.0485	0.0131			
		(0.0279)	(0.0313)	(0.3759)	(0.3277)	(0.7195)	(0.8299)	(0.9400)	(0.9844)			
	CIV_{40}	**1.3058**	**1.2844**	0.5418	0.6036	0.2315	0.1503	0.0706	0.0352	0.0220		
		(0.0305)	(0.0292)	(0.3672)	(0.3060)	(0.7058)	(0.8051)	(0.9122)	(0.9550)	(0.9697)		
	CIV_{45}	**1.3104**	**1.2890**	0.5463	0.6081	0.2361	0.1549	0.0751	0.0397	0.0266	0.0046	
		(0.0332)	(0.0358)	(0.3798)	(0.3332)	(0.7069)	(0.8039)	(0.9067)	(0.9484)	(0.9616)	(0.9958)	
	VXD	-0.0570	-0.0784	-0.8211	-0.7593	-1.1313	**-1.2125**	**-1.2922**	**-1.3276**	**-1.3408**	**-1.3628**	**-1.3674**
		(0.9180)	(0.8884)	(0.1390)	(0.1879)	(0.0548)	(0.0399)	(0.0261)	(0.0256)	(0.0257)	(0.0244)	(0.0262)
	Low-Volatility Periods											
	CIV_1	0.0396										
		(0.9420)										
	CIV_5	0.8996	0.8601									
		(0.0935)	(0.1097)									
	CIV_{10}	**1.5802**	**1.5406**	0.6806								
		(0.0045)	(0.0048)	(0.2266)								
	CIV_{15}	**1.7158**	**1.6762**	0.8161	0.1356							
		(0.0016)	(0.0028)	(0.1487)	(0.8217)							
	CIV_{20}	**2.0567**	**2.0171**	**1.1570**	0.4765	0.3409						
		(0.0002)	(0.0002)	(0.0472)	(0.4109)	(0.5595)						
A	CIV_{25}	**2.0422**	**2.0027**	**1.1426**	0.4620	0.3265	-0.0144					
		(0.0003)	(0.0003)	(0.0461)	(0.4314)	(0.5761)	(0.9774)					
	CIV_{30}	**1.9907**	**1.9512**	1.0911	0.4106	0.2750	-0.0659	-0.0515				
		(0.0001)	(0.0006)	(0.0582)	(0.4885)	(0.6444)	(0.9144)	(0.9283)				
	CIV_{35}	**2.0041**	**1.9646**	1.1045	0.4239	0.2884	-0.0525	-0.0381	0.0134			
		(0.0006)	(0.0005)	(0.0566)	(0.4820)	(0.6377)	(0.9324)	(0.9471)	(0.9822)			
	CIV_{40}	**2.0290**	**1.9894**	1.1294	0.4488	0.3132	-0.0277	-0.0132	0.0382	0.0249		
		(0.0009)	(0.0004)	(0.0552)	(0.4539)	(0.6019)	(0.9633)	(0.9819)	(0.9467)	(0.9693)		
	CIV_{45}	**2.0880**	**2.0485**	**1.1884**	0.5078	0.3723	0.0314	0.0458	0.0973	0.0839	0.0590	
		(0.0006)	(0.0006)	(0.0451)	(0.4071)	(0.5559)	(0.9593)	(0.9433)	(0.8732)	(0.8917)	(0.9254)	
	VXD	-0.0882	-0.1277	-0.9878	**-1.6684**	**-1.8039**	**-2.1448**	**-2.1304**	**-2.0789**	**-2.0923**	**-2.1172**	**-2.1762**
		(0.8630)	(0.8078)	(0.0654)	(0.0019)	(0.0009)	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0003)	(0.0001)

Notes: The table reports the differences between mean rates of returns from option trades that are based on different pairs of CIVs, and respective two-sided p-values for the mean difference in parentheses. The mean difference is calculated as $\bar{\pi}_A - \bar{\pi}_B$, where $\bar{\pi}_A$ and $\bar{\pi}_B$ are mean rates of returns from option trades that are based on CIVs in A and B, respectively. p-values for the mean difference are based on Efron & Tibshirani (1993) and Efron (1979), and are calculated based on a bootstrap t-test. The null hypothesis of the test is that there is no difference between the mean rates of returns for the zero-beta straddles based on different CIVs. The bootstrap t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. Numbers in bold indicate significance at 5% significance level.

Table 6. Sharpe Ratio Differences from Option Trades after Transaction Costs (Delta-Hedged Puts)

		B										
		CIV_0	CIV_1	CIV_5	CIV_{10}	CIV_{15}	CIV_{20}	CIV_{25}	CIV_{30}	CIV_{35}	CIV_{40}	CIV_{45}
	Whole Periods											
	CIV_1	-0.2452										
		(0.7446)										
	CIV_5	**5.5353**	**5.7805**									
		(0.0058)	(0.0028)									
	CIV_{10}	**6.6891**	**6.9343**	1.1538								
		(0.0369)	(0.0287)	(0.5827)								
	CIV_{15}	6.4602	6.7054	0.9249	-0.2289							
		(0.0828)	(0.0738)	(0.7366)	(0.9038)							
	CIV_{20}	**7.7449**	**7.9901**	2.2096	1.0558	1.2847						
		(0.0471)	(0.0402)	(0.4461)	(0.5852)	(0.0772)						
A	CIV_{25}	**7.9683**	**8.2135**	2.4330	1.2791	1.5081	0.2234					
		(0.0445)	(0.0381)	(0.4002)	(0.5274)	(0.0728)	(0.5918)					
	CIV_{30}	**8.2147**	**8.4599**	2.6794	1.5255	1.7545	0.4698	0.2464				
		(0.0418)	(0.0350)	(0.3717)	(0.4582)	(0.0671)	(0.4385)	(0.6244)				
	CIV_{35}	**8.4799**	**8.7251**	2.9446	1.7908	**2.0197**	0.7350	0.5116	**0.2653**			
		(0.0350)	(0.0311)	(0.3307)	(0.3908)	(0.0351)	(0.2491)	(0.2853)	(0.0044)			
	CIV_{40}	**9.0500**	**9.2952**	3.5147	2.3609	**2.5898**	1.3051	**1.0817**	**0.8354**	**0.5701**		
		(0.0246)	(0.0207)	(0.2554)	(0.2706)	(0.0149)	(0.0652)	(0.0373)	(0.0018)	(0.0010)		
	CIV_{45}	**10.6859**	**10.9311**	5.1506	3.9968	**4.2257**	**2.9410**	**2.7176**	**2.4712**	**2.2060**	**1.6359**	
		(0.0132)	(0.0097)	(0.0961)	(0.0675)	(0.0010)	(0.0040)	(0.0016)	(0.0006)	(0.0004)	(0.0002)	
	VXD	-0.6685	-0.4233	**-6.0238**	**-7.3576**	-7.1287	**-8.4134**	**-8.6367**	**-8.8831**	**-9.1484**	**-9.7185**	**-11.3544**
		(0.0870)	(0.5808)	(0.0024)	(0.0222)	(0.0624)	(0.0330)	(0.0301)	(0.0274)	(0.0260)	(0.0189)	(0.0104)
	High-Volatility Periods											
	CIV_1	-1.5107										
		(0.3016)										
	CIV_5	-0.7583	0.7524									
		(0.8018)	(0.8001)									
	CIV_{10}	-4.1009	-2.5902	-3.3427								
		(0.3599)	(0.5682)	(0.3239)								
	CIV_{15}	-9.6193	-8.1086	-8.8610	-5.5184							
		(0.0793)	(0.1394)	(0.0614)	(0.1304)							
	CIV_{20}	-9.1261	-7.6154	-8.3678	-5.0251	0.4932						
		(0.1012)	(0.1695)	(0.0855)	(0.1630)	(0.6152)						
A	CIV_{25}	-9.0684	-7.5577	-8.3101	-4.9675	0.5509	0.0577					
		(0.1026)	(0.1743)	(0.0791)	(0.1660)	(0.5840)	(0.8325)					
	CIV_{30}	-8.8088	-7.2981	-8.0506	-4.7079	0.8105	0.3172	0.2596				
		(0.1149)	(0.1912)	(0.0919)	(0.2012)	(0.4070)	(0.3402)	(0.1483)				
	CIV_{35}	-8.5522	-7.0415	-7.7940	-4.4513	1.0671	0.5738	0.5162	0.2566			
		(0.1279)	(0.2095)	(0.1068)	(0.2150)	(0.2974)	(0.1454)	(0.0520)	(0.0544)			
	CIV_{40}	-8.0117	-6.5010	-7.2535	-3.9108	1.6076	**1.1143**	**1.0567**	**0.7971**	**0.5405**		
		(0.1577)	(0.2569)	(0.1464)	(0.2883)	(0.1552)	(0.0496)	(0.0251)	(0.0264)	(0.0123)		
	CIV_{45}	-6.3762	-4.8655	-5.6180	-2.2753	**3.2431**	**2.7498**	**2.6922**	**2.4326**	**2.1760**	**1.6355**	
		(0.2700)	(0.4018)	(0.2617)	(0.5395)	(0.0196)	(0.0061)	(0.0032)	(0.0022)	(0.0018)	(0.0009)	
	VXD	-0.6443	0.8664	0.1140	3.4567	8.9750	8.4818	8.4241	8.1646	7.9080	7.3675	5.7320
		(0.2079)	(0.5530)	(0.9716)	(0.4438)	(0.0992)	(0.1262)	(0.1359)	(0.1518)	(0.1642)	(0.1912)	(0.3295)
	Medium-Volatility Periods											
	CIV_1	0.4333										
		(0.7668)										
	CIV_5	7.1508	6.7175									
		(0.0931)	(0.0913)									
	CIV_{10}	7.6815	7.2482	0.5307								
		(0.2436)	(0.2563)	(0.9022)								
	CIV_{15}	11.4098	10.9766	4.2590	3.7283							
		(0.1518)	(0.1543)	(0.4436)	(0.1579)							
	CIV_{20}	12.1835	11.7502	5.0327	4.0520	0.7736						
		(0.1450)	(0.1399)	(0.3738)	(0.1157)	(0.4602)						
A	CIV_{25}	12.9020	12.4687	5.7512	5.2205	1.4921	0.7185					
		(0.1260)	(0.1266)	(0.3303)	(0.0979)	(0.3508)	(0.5304)					
	CIV_{30}	13.2639	12.8306	6.1131	5.5824	1.8541	1.0804	0.3619				
		(0.1143)	(0.1144)	(0.3039)	(0.0787)	(0.2517)	(0.3456)	(0.0746)				
	CIV_{35}	13.5333	13.1001	6.3825	5.8518	2.1235	1.3499	**0.6314**	0.2694			
		(0.1151)	(0.1200)	(0.2880)	(0.0647)	(0.2043)	(0.2443)	(0.0336)	(0.0693)			
	CIV_{40}	14.1019	13.6686	6.9511	**6.4203**	2.6920	1.9184	**1.1999**	**0.8380**	**0.5685**		
		(0.1029)	(0.1047)	(0.2505)	(0.0443)	(0.1246)	(0.1241)	(0.0306)	(0.0462)	(0.0358)		
	CIV_{45}	15.5726	15.1393	8.4217	**7.8910**	**4.1627**	**3.3891**	**2.6706**	**2.3087**	**2.0392**	**1.4707**	
		(0.0903)	(0.0926)	(0.1890)	(0.0286)	(0.0448)	(0.0360)	(0.0293)	(0.0354)	(0.0381)	(0.0427)	
	VXD	-0.4804	-0.9137	-7.6313	-8.1620	-11.8903	-12.6639	-13.3824	-13.7443	-14.0138	-14.5823	-16.0530
		(0.4952)	(0.5129)	(0.0683)	(0.2305)	(0.1359)	(0.1290)	(0.1126)	(0.1058)	(0.1044)	(0.0949)	(0.0837)
	Low-Volatility Periods											
	CIV_1	0.4444										
		(0.6771)										
	CIV_5	**12.0565**	**11.6121**									
		(0.0015)	(0.0015)									
	CIV_{10}	**18.9493**	**18.5050**	**6.8928**								
		(0.0003)	(0.0004)	(0.0359)								
	CIV_{15}	**20.5979**	**20.1535**	8.5414	1.6486							
		(0.0024)	(0.0015)	(0.0538)	(0.6005)							
	CIV_{20}	**23.3024**	**22.8581**	**11.2459**	4.3531	2.0745						
		(0.0006)	(0.0007)	(0.0210)	(0.2307)	(0.1191)						
A	CIV_{25}	**23.2183**	**22.7740**	**11.1618**	4.2690	2.6204	-0.0841					
		(0.0008)	(0.0011)	(0.0205)	(0.2422)	(0.1349)	(0.8870)					
	CIV_{30}	**23.3110**	**22.8666**	**11.2545**	4.3617	2.7131	0.0086	0.0927				
		(0.0016)	(0.0009)	(0.0260)	(0.2653)	(0.2122)	(0.9946)	(0.9450)				
	CIV_{35}	**23.5773**	**23.1330**	**11.5208**	4.6280	2.9794	0.2749	0.3590	0.2663			
		(0.0007)	(0.0009)	(0.0257)	(0.2399)	(0.1771)	(0.8641)	(0.8122)	(0.0946)			
	CIV_{40}	**24.1698**	**23.7254**	**12.1133**	5.2205	3.5719	0.8674	0.9515	0.8588	**0.5925**		
		(0.0008)	(0.0008)	(0.0194)	(0.1863)	(0.1203)	(0.6215)	(0.5539)	(0.0603)	(0.0434)		
	CIV_{45}	**25.9209**	**25.4766**	**13.8644**	6.9716	**5.3230**	2.6185	2.7026	**2.6099**	**2.3436**	**1.7511**	
		(0.0001)	(0.0002)	(0.0089)	(0.0970)	(0.0444)	(0.2159)	(0.1760)	(0.0263)	(0.0200)	(0.0134)	
	VXD	-0.8967	-1.3411	**-12.9532**	**-19.8461**	**-21.4947**	**-24.1992**	**-24.1151**	**-24.2078**	**-24.4741**	**-25.0665**	**-26.8177**
		(0.2495)	(0.2415)	(0.0006)	(0.0005)	(0.0014)	(0.0006)	(0.0007)	(0.0008)	(0.0004)	(0.0004)	(0.0003)

Notes: The table reports the differences between Sharpe ratios from option trades that are based on different pairs of CIVs, and respective two-sided p-values for the Sharpe ratio difference in parentheses. The Sharpe ratio difference is calculated as $Sharpe_A - Sharpe_B$, where $Sharpe_A$ and $Sharpe_B$ are Sharpe ratios from option trades that are based on CIVs in A and B, respectively. p-values for the Sharpe ratio difference are based on Ledoit & Wolf (2008) for non i.i.d. returns. The null hypothesis is that there is no difference between the Sharpe ratios for the zero-beta straddles based on different CIVs. The bootstrap t-test is based on the empirical distribution of returns. The empirical distribution of returns is obtained from 10000 nonparametric bootstrap repetitions of the return sample. Each repetition is obtained by drawing daily rates of returns with replacement. Numbers in bold indicate significance at 5% significance level.

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