Intra-day Behavior of Treasury Sector Index Option Implied Volatilities around Macroeconomic Announcements

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Abstract

If option implied volatility is an unbiased, efficient forecast of future return volatility in the underlying asset, then we should be able to predict its path around macroeconomic announcements from responses in cash markets. Regressions show that volatilities rise the afternoon before announcements that move cash markets, and that post-announcement volatilities return to normal as rapidly as cash prices do. Although implied volatilities are predictable, the Treasury options market is efficient since informed traders do not earn arbitrage profits once we account for trading costs.

Keywords: implied volatility, macroeconomic announcements, market efficiency

JEL Classification: G14

1. Introduction

Option implied volatility should be an unbiased, efficient forecast of future return volatility in the underlying cash asset (e.g., Black and Scholes, 1973; Merton, 1973;...
We analyze transaction data on Treasury sector index options before and after scheduled events to determine how option implied volatility reacts around predictable disturbances in cash market returns. To our knowledge, we are the first to use transaction data to study the link between option prices and expected near term volatility in the underlying cash market.

Our findings contribute to the finance literature in three distinct but related ways:

1. Treasury sector index option implied standard deviations (ISDs) rise significantly in advance of anticipated short-term disturbances in underlying cash markets. This increase supports the theoretical notion that option implied volatility conveys information about future price changes in cash markets.

2. The ISDs drop quickly after the scheduled release of macroeconomic information. The rapid adjustment suggests that options markets process information as quickly and efficiently as do the underlying cash markets.

3. The traders who possess public knowledge about this predictable behavior of option prices are not able to earn arbitrage profits once transactions costs are considered. This result indicates that Treasury sector index options markets are efficient during periods of unusual volatility in cash markets.

2. Background studies

Several studies (e.g. Manaster and Rendleman, 1982; Day and Lewis, 1992; Lamoureux and Lastrapes, 1993; Fleming, 1998; among others) show that implied volatilities contain information about the conditional variance of stock returns. Recent work by Mayhew and Stivers (2001) demonstrates that forecast properties of option implied volatilities are stronger for firms with substantial options trading volume. Ferson, Heuson, and Su (2001) extend the analysis to consider the relation between realized unconditional volatility in stock returns and ISDs estimated from option prices.

Canina and Figlewski (1993) question the long-term relation between implied and realized volatility. Christensen and Prabhala (1998) verify that option implied volatility is related to realized volatility over long horizons, but the intra-day effects of predictable volatility in cash markets on option implied volatilities have not yet been studied. We use scheduled macroeconomic announcements to examine the short-term relation between option ISDs and predictable uncertainty in underlying asset prices.

Several studies show how prices in the U.S. government bond market react to the information in scheduled economic announcements. Jones, Lamont, and Lumsdaine (1998) analyze changes in the level and volatility of daily closing yields on hypothetical Treasury securities before, on, and after release days for Non-farm Payroll and Producer Price Indexes. They find that bond market volatility increases significantly around scheduled news but that announcement shocks do not persist beyond the day of the actual release.

Balduzzi, Elton, and Green (2001) use transaction data to examine the intra-day response of Treasury markets to a variety of news releases. They show that
Payroll and Producer Price Index series cause the largest responses across the entire maturity spectrum. Surprises in several other releases (notably the Consumer Price Index, Durable Goods Orders, Housing Starts, Initial Jobless Claims, and Retail Sales) also have a significant impact in longer-maturity segments of the Treasury market. The response ends in less than one minute in most cases and always ends within 25 minutes.

Fleming and Remolona (1999) analyze the pattern of on-the-run Treasury transaction prices immediately after economic news is released. They identify a two-stage reaction to employment and inflation reports. The first stage, which lasts from one minute before until two minutes after an announcement is made, has dramatic price movements, wide bid/ask spreads, and low trading volume. These are classic microstructure responses to the release of public information on which no party can profitably trade. The second stage, which lasts for up to an hour, includes increased price volatility and trading volume, and lower spreads, as individual traders resolve the differences in their private views.

Since cash market prices and interest rates respond to scheduled macroeconomic releases, it is not surprising that many papers study the reactions of derivatives markets to scheduled releases. In the first of a series of related papers, Ederington and Lee (1993) analyze transaction data on Eurodollar, Treasury bond, and deutsche mark futures to determine when market participants respond to 19 macroeconomic releases. They find that most of the significant impact on return volatility occurs in the first minute after distribution. Variability is higher than normal for approximately 15 minutes after major releases (slightly more for the Non-farm Payroll report) and slightly higher for several hours on release days.

In later work Ederington and Lee (1995) refine their analysis and discover that futures price changes start about ten seconds after a release and last about 30 seconds. Return volatility peaks at around 30 seconds post-release. They find that the variance of returns is larger for the more important announcements, namely Non-farm Payroll and Producer and Consumer Price Indexes.

Ederington and Lee (1996) also evaluate the behavior of the ISDs embedded in the prices of put and call options on Treasury bond and Eurodollar futures contracts across release days. When they compare closing prices on the pre-announcement day and the announcement day, they find that ISDs rise before and fall after scheduled releases. The change in ISDs is larger for shorter-lived options and larger for the Payroll release than it is for either inflation series. Ederington and Lee attribute the systematic decline in ISDs and the corresponding decline in option prices to the publication of macroeconomic data that decreases the uncertainty remaining over an option’s life.

Since the timing of releases is known, the pre-announcement rise and post-announcement decline in option prices are predictable and could lead to riskless trading profits. Ederington and Lee (1996) explore this potential arbitrage by using daily data to trade delta-neutral portfolios of short calls and short puts. These short straddles generate losses. Ederington and Lee note that the release of economic information
causes such dramatic changes in the underlying cash market that the delta-neutrality of the arbitrages is destroyed as an explanation for the lack of profits.

3. Empirical predictions of ISD behavior

Theoretical option pricing models emphasize the role of ISDs as predictors of future disturbances in asset returns. Studies of government bond markets show that prices respond to macroeconomic announcements but until now no research has measured how intra-day options prices react in advance of this impending variability in cash markets. Here, we develop a series of hypotheses that come from integrating empirical results with option pricing theory, describe our data set, and discuss preliminary statistical results.

3.1. Hypotheses

Since we know that macroeconomic announcements lead to temporary volatility in Treasury cash markets, we propose the following hypotheses about the expected behavior of Treasury sector index option ISDs.

(H.1) ISDs should increase in advance of the scheduled announcements that are known to move Treasury cash prices.

(H.2) The increases in ISDs should be larger for the announcements that are known to have a greater impact on cash market volatility.

(H.3) Treasury option ISDs should return to a new equilibrium level within 20 minutes after the announcements are released.

(H.4) Actions by options dealers should preclude arbitrage opportunities on delta-hedged volatility straddles around scheduled announcements.

We derive Hypotheses 1 and 2 from analytics in Ederington and Lee (1996). They show how the estimated volatility parameter in the discrete analog of the time-varying volatility models of Merton (1973) and Hull and White (1987) behaves as a temporary source of uncertainty approaches. When an option has a finite life, ISDs rise as a release nears because pre-announcement trading intervals with lower than average volatility are removed from the long-run average, but a high-volatility trading interval, the announcement period, remains. This argument, which is supported by empirical results in Christensen and Prabhala (1998), motivates the belief that ISDs should increase in advance of scheduled announcements (Hypothesis 1) and that the size of the increase should be positively related to the importance of the announcement (Hypothesis 2).

We use transaction data to test our hypothesis that the response to economic news is as rapid in the options market as in the cash market, (Hypothesis 3). Given this documented predictability in options prices, we then evaluate the efficiency of the Treasury sector index options market. We concentrate on the profitability of arbitrage trading strategies that have the greatest chance of success because they focus on the
period of greatest upheaval in the options markets but expect that reactions by dealers will preclude arbitrage opportunities (Hypothesis 4).

3.2. Identifying announcements that move Treasury cash markets

We run a dummy variable regression similar to the one used in Jones, Lamont, and Lumsdaine (1998) to identify which announcements move the cash market. We expect that these releases will also have a significant impact on Treasury sector index option ISDs (Hypothesis 1) and that our regression coefficients will rank their importance (Hypothesis 2).

Our dependent variable is the natural logarithm of the square of the daily difference between 5-, 10-, and 30-year constant maturity Treasury returns and corresponding three-month Treasury bill returns for various time-based samples. The Treasury uses a proprietary algorithm to estimate a smooth curve from the yields of heavily traded securities and to interpolate values for the constant maturity time series. We obtain daily yields for the 90-day and 5-, 10-, and 30-year maturities from the Federal Reserve Bank of St. Louis web site, (www.stls.frb.org). In our return calculation we assume that a bond or note carries a coupon rate equal to the closing constant maturity yield on day \((t - 1)\) and is priced to sell at the next trading day’s \((t)\) closing constant maturity yield. Therefore, day \((t)\) is the announcement day. All of the announcements that we use are released at 8:30 a.m. or 9:15 a.m. Eastern Standard Time on day \((t)\). We consider accrued interest and the actual number of trading days between observations in the return calculations.

Our binary independent variables are one on announcement days for seven different macroeconomic series that are known to cause cash market reactions, and zero otherwise. The seven macroeconomic series are: the Consumer Price Index (CPI), Durable Goods Orders (DUR), Housing Starts (HSE), Industrial Production (IND), Non-farm Payroll and Unemployment (PAY) (which are always released at the same time), the Producer Price Index (PPI), and Retail Sales (RET). Announcement dates are supplied by Money Market Services Incorporated, an organization that generates forecast values for the major announcements via a survey of practicing economists.

The regression equation estimated is:

\[
\ln(\text{TYCMn}_{t} - \text{TB90t})^2 = \alpha_{\text{CMn}} + \beta_{1,\text{CMn}} \text{CPI}_t + \beta_{2,\text{CMn}} \text{DUR}_t + \beta_{3,\text{CMn}} \text{HSE}_t \\
+ \beta_{4,\text{CMn}} \text{IND}_t + \beta_{5,\text{CMn}} \text{PAY}_t + \beta_{6,\text{CMn}} \text{PPI}_t \\
+ \beta_{7,\text{CMn}} \text{RET}_t + \epsilon_{n,t} \tag{1}
\]

where:

\[
\ln(\text{TYCMn}_{t} - \text{TB90t})^2 \] is the natural logarithm of the square of the difference between the daily Treasury Constant Maturity return for maturity \((n)\) and the daily three-month Treasury bill return for day \((t)\)
\( \alpha_{CMn} \) is a maturity-specific constant term (\( n = 5, 10, \) and 30 years)

CPI\(_t\) is a binary variable that is one on days when the Consumer Price Index is released

DUR\(_t\) is a binary variable that is one on days when the Durable Goods Index is released

HSE\(_t\) is a binary variable that is one on days when Housing Starts are released

IND\(_t\) is binary variable that is one on days when the Industrial Production Index is released

PAY\(_t\) is a binary variable that is one on days when Non-farm Payroll and the Unemployment Rate are released

PPI\(_t\) is a binary variable that is one on days when the Producer Price Index is released

RET\(_t\) is a binary variable that is one on days when the Retail Sales Index is released

\( \varepsilon_{n,t} \) is a mean-zero error term.

Table 1 displays the regression results for 24 and 60 sets of monthly announcements before the option data begins in July 1994. We include a sample of 180 sets of monthly announcements that starts well before the period studied here and extends much later to show that the same releases cause cash market responses over time.

Since 50 of the 63 binary variable coefficients (more than 75%) and the \( F \)-statistics for each of the nine regressions are significant at the 5% level, we can be confident that these announcements move cash Treasury prices. In addition, all of the significant binary variable coefficients in Table 1 are positive, which indicates that announcement day returns are more volatile than non-announcement day returns. Each of the releases is significant in at least one of the nine regressions. However, responses to Industrial Production are typically weak, and responses to Durable Goods Orders, Housing Starts, and Retail Sales releases are not as great as reactions to Consumer and Producer Price Indexes and Non-farm Payroll/Unemployment Rate information.

The estimated coefficients on the Non-farm Payroll/Unemployment Rate and the Producer Price Index are much larger than the coefficients on the other explanatory variables for the long-term sample (the March 1983 to March 1998 columns in the table). However, the CPI coefficients are as large or larger than PPI coefficients in the short-horizon regressions (the January 1990 to December 1994 and January 1993 to

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1 The values in the table are not appreciably different from various ARCH or GARCH regressions that are available from the authors. Jones, Lamont, and Lumsdaine (1998) also found a strong correlation between OLS results and more sophisticated empirics.

2 Tests show that the 12 months between July 1994 and June 1995 (the period covered by the options transactions data available to us) are not statistically different from the 1993–1994, 1990–1994, or 1983–1998 samples. These results are available from the authors.
Table 1

Regressions of volatility in returns on Treasury securities against dummy variables for announcement dates

The dependent variables are the squared values of the natural logarithm of the excess of the 5-, 10-, and 30-year constant maturity Treasury returns over the corresponding three-month Treasury bill returns on the same trading day. Independent variables are binary variables that are one on each month’s announcement date for the Consumer Price Index (CPI), Durable Goods Orders (DUR), Housing Starts (HSE), Industrial Production (IND), Non-farm Payroll and Unemployment (PAY), the Producer Price Index (PPI), and Retail Sales (RET). Positive significant announcement coefficients indicate that Treasury returns are more volatile on announcement days than on non-announcement days.

Coefficients and t-Statistics

<table>
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<tr>
<td></td>
<td>5Yr</td>
<td>10 Yr</td>
<td>30 Yr</td>
</tr>
<tr>
<td>CPI</td>
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<td>1.27*</td>
<td>1.30*</td>
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<td>DUR</td>
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<td>0.68*</td>
<td>0.77*</td>
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<td>0.85*</td>
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<td>-0.04</td>
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<tr>
<td>PAY</td>
<td>2.17*</td>
<td>2.09*</td>
<td>2.13*</td>
</tr>
<tr>
<td>PPI</td>
<td>7.33</td>
<td>6.56</td>
<td>6.95</td>
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<tr>
<td>RET</td>
<td>0.77*</td>
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<td></td>
<td>-196.9</td>
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<td>0.07</td>
<td>0.08</td>
</tr>
<tr>
<td>D.W.</td>
<td>1.96</td>
<td>1.96</td>
<td>2.07</td>
</tr>
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* Indicates statistical significance at the 0.05 level.

We assume a one-tailed critical value because all coefficients are expected to be positive. There are 1250, 500, and 3760 observations in the respective data sets.
December 1994 columns). Therefore, in the months before our sector index options sample begins in July 1994, market participants appear to have reacted more to CPI releases than to PPI releases.

The results in Table 1 let us refine Hypotheses (1) and (2) to argue that we expect Non-farm Payroll releases to cause the greatest pre-announcement response in ISDs. Consumer and Producer Price Index announcements should lead to intermediate strength reactions, and Housing Starts, Durable Goods Orders, Retail Sales, and Industrial Production releases to small reactions.

Hypothesis 3 refers to post-announcement declines in sector index option ISDs. Implied volatility should decrease after scheduled news releases because moving beyond a period of high uncertainty, such as an announcement, reduces the average expected variation during the option’s remaining life.

Hypothesis 4 focuses on the profit potential of arbitrage trades. Profit potential is based on expected increases in the prices of both put and call options due to a temporary increase in ISDs. By using transaction data, we can evaluate the results of trading strategies that capture the increase in option prices more precisely than can the previous studies that use daily data. If trades around macroeconomic releases produce arbitrage profits, then option prices are not efficient.

4. Pre- and post-announcement behavior of ISDs

4.1. The data

The Chicago Board Options Exchange (CBOE) introduced trading on sector index options in the fall of 1992. By the spring of 1993, options were trading for ten different sectors. Additional sectors have been added since that time. Treasury note and bond index options have open interest in the thousands of contracts and daily trading volume in the mid-hundreds of contracts. Thus these are liquid markets that should contain efficient mechanisms for setting prices.

We obtain our intra-day trading data from the Berkeley Options Database. Our available sample covers July 1994 to June 1995 (12 sets of monthly announcements), and contains records of bid-ask price quotations and transactions time-stamped to the nearest second. Updated underlying index levels are also included in each record. We analyze prices for option contracts on 5- and 10-year Treasury notes and 30-year Treasury bonds, FVX, TNX, and TYX index options, respectively.

4.2. Estimating trading interval ISDs

The implied volatility measure derived from the observed price of an option is a function of the theoretical valuation model used to describe the evolution of option prices over time. To avoid potential biases due to nonconstant volatility, we estimate option implied volatilities using Hull and White’s (1987) stochastic volatility
approach. This specification assumes that the returns of the underlying asset follow one stochastic process but the variance of the returns follows another, possibly correlated, stochastic process.

We also replicate our empirical tests using Black-Scholes implied volatility estimates and find similar results. This agreement is not surprising because we estimate our ISDs from short-term, at-the-money options where biases in Black-Scholes prices are less severe.

To be sure that we are estimating ISDs from option prices in liquid markets, we limit our attention to near-the-money puts and calls that have six months or less to maturity. We adapt Whaley’s (1982) approach so that we can use all options transactions in a given trading interval. We follow a three-step procedure to compute the ISDs that we wish to use in further analysis:

1. We divide each day into 80 five-minute trading intervals.
2. To avoid the bid/ask bounce bias inherent in transaction data, we compute bid/ask midpoints for each put and call option quote that occurs in a given interval.
3. We use a grid search routine to generate a single ISD for each of the three sector index options (5-, 10-, and 30-year Treasuries) for each of the 80 five-minute intervals in each trading day in the sample, which gives us 240 ISDs per day.

4.3. Time series behavior of ISDs: Hypotheses (1), (2), and (3)

We combine the ISD estimates for the 5-, 10-, and 30-year Treasury sector index options in each of the 80 five-minute trading intervals each day to examine the pre- and post-announcement effects addressed in Hypotheses (1), (2), and (3). We run 80 of the following binary variable regressions to determine whether, and when, option ISDs rise on the day before and the day of each of the seven macroeconomic announcements \((a)\) in our sample:

\[
ISD_{i,t,m} = \alpha + \sum_{a \in A} \beta_{\text{pre},a} D_{\text{pre},a} + \sum_{a \in A} \beta_{\text{pst},a} D_{\text{pst},a} + \beta_5 D_5 + \beta_{10} D_{10} + \epsilon_t
\]

where:

- \(ISD_{i,t,m}\) defines the ISDs that minimize the sum of the squared deviations between the set of theoretical Hull-White option prices and the actual quote midpoints for each of the three sector index options \((m)\), in each of the 80 five-minute trading intervals \((i)\) for each of trading day \((t)\) in the sample.
- \(A\) is the set of seven announcements = \{CPI, DUR, HSE, IND, PAY, PPI, RET\}
- \(D_{\text{pre},a}\) is a binary variable that is one if day \((t)\) is the day before a given announcement \((a)\) will be made.
D_{pst,a} is a binary variable that is one if day \((t)\) is the day a given announcement \((a)\) will be made.

D_5 is a binary variable that is one if the interval ISD is computed from the set of trade prices for 5-year Treasury sector index options (FVX).

D_{10} is a binary variable that is one if the interval ISD is computed from the set of trade prices for 10-year Treasury sector index options (TNX) and

\(\varepsilon_t\) is an error-term with the desired statistical properties.

We expect the coefficients of the binary variables D_{pre,a} to be positive and increasing over the trading day \((t - 1)\) if the ISDs that we compute from prices of the Treasury sector index options rise with the approach of a macroeconomic announcement that will lead to volatility in the price of the cash asset. Theoretical options pricing models predict this result when implied volatility is an unbiased, efficient forecast of future return volatility in the underlying asset.

Seven of the announcements (Consumer Prices, Durable Goods, Housing Starts, Payroll and Unemployment, Producer Prices, and Retail Sales) are released at 8:30 a.m. Eastern Standard Time (EST) but Industrial Production is released at 9:15 a.m. EST. Trading hours for the sector index options are from 7:20 a.m. to 2:00 p.m. Central Standard Time (CST) so the options market opens ten minutes prior to most releases. In the tests that follow, we recognize the later announcement time for Industrial Production but for ease of illustration we display the results as if the information was released at 8:30 a.m. EST.

D_{pst,a} will be positive at the open on the trading day \((t - 0)\) but decay quickly after the second five-minute interval (8:25 a.m. to 8:30 a.m. EST or 7:25 a.m. to 7:30 a.m. CST) if Treasury index option ISDs deflate rapidly as cash prices complete their reaction to the information in macroeconomic releases. The coefficients of the binary variables D_5 and D_{10}, which we include as controls for maturity effects on ISDs, should be negative. D_5 will be more negative than D_{10} if the implied volatility of an option is positively related to the price elasticity of the underlying asset (the 30-year maturity is the omitted class). The coefficients on the binary variables for Non-farm Payroll/Unemployment Rate and Consumer Price Index announcements should exceed the coefficients for other announcements because these releases lead to the largest absolute excess returns in the Treasury market prior to and during the sample period (see Table 1).

Results for each of the regressions detailed above are available from the authors on request. To conserve space, we summarize our findings for specific macroeconomic announcements in Figure 1. The figure shows the \(t\)-statistics for the D_{pre,a} and D_{pst,a} coefficients for each announcement across the trading intervals of the pre-announcement day and the morning of the announcement day.

The heavy lines in Figure 1 represent the 1.645 critical value for a one-tailed test of positive significance at the 5% level. Positive significant coefficients in Figure 1
Figure 1

The pre-event day and event day responses of Treasury sector index ISDs to macroeconomic announcements

This figure plots the parametric $t$-statistics for the regression coefficients on the dummy variables $D_{pre,i}$ and $D_{pst,i}$ in the equation: $ISD = \alpha + \sum_{a \in A} \beta_{pre,a} D_{pre,a} + \sum_{a \in A} \beta_{pst,a} D_{pst,a} + \beta_5 D_5 + \beta_10 D_{10} + \epsilon_t$. The regression tests for differences between the average pre-event ($D_{pre,i}$) or post-release ($D_{pst,i}$) ISD for seven macroeconomic announcements ($a$) and the average nonevent ISD during the same five-minute trading interval. A positive significant $t$-statistic suggests that the average event ISD is significantly higher than the nonevent ISD, where $a \in A = \{\text{CPI, DUR, HSE, IND, PAY, PPI, RET}\}$, and $D_5$ and $D_{10}$ are 5- and 10-year ISD dummies. The sample period covers from July 1994 to June 1995. The heavy horizontal lines mark the 1.645 critical value of a $t$-statistic for a one-tailed test. The thin horizontal lines are drawn at zero. The vertical line on the right-hand side indicates the 8:30 a.m EST announcement release.
indicate that option ISDs are elevated before and just after the release of important macroeconomic announcements (Hypothesis 1). In addition, Consumer Price Index and Non-farm Payroll/Unemployment Rate releases cause more significant reactions than any other news studied here. The relative importance of these two series supports Hypothesis 2 because these announcements lead to the greatest changes in the natural logarithm of squared excess returns in the Treasury cash market before the options sample begins (see the July 1989–June 1994 and July 1992–June 1994 columns in Table 1).

As evidence in support of Hypothesis 3, we note that Treasury sector index option ISDs remain significantly elevated for only 20 minutes after these two announcements are published. ISDs subsequent to Industrial Production, Producer Price Index, and Retail Sales releases are higher than normal for only ten minutes post-release and ISDs are marginally higher only at the open on days when Durable Goods and Housing Starts are announced.

When we rerun the regressions using the Yule-Walker correction for autocorrelation in the residuals or White’s (1980) adjustment for heteroscedasticity it does not alter the results. In addition, coefficients for D5 and D10 are never positive and significant. They are negative and significant, as expected, in about 50% of the regressions.

Figure 1 illustrates significant pre-announcement increases in option implied volatilities for a variety of macroeconomic releases. The figure shows that the effects are especially profound for Consumer Price and Payroll releases. However, it is not possible to determine the size of the actual increases in ISDs from the figure. Our analysis of the individual regression results shows that the estimated coefficients for the Consumer Price Index variable average 0.4% with a maximum of 1% over the interval between noon on the pre-announcement day and 8:50 a.m. on the release day. The respective coefficients for the Non-farm Payroll/Unemployment Rate variable average 0.5% with a maximum of 0.9% for the same period.

Figure 2 illustrates the increase and subsequent post-announcement decline in ISDs for a specific option (the 5-year Treasury note index option, FVX) and a specific release (Non-farm Payroll/Unemployment Rate). It compares the average pre-release and release-day ISDs to the corresponding nonevent day averages for the pre-announcement day and the first 70 minutes of the announcement day. The mean announcement ISD begins to exceed the non-announcement ISD at noon on the pre-release day and remains elevated for some 20 minutes post-release. This pattern matches the significance of the t-statistics in Figure 1.

We can use a numerical example to highlight the relation between increases in ISDs and changes in option prices. For a six-month at-the-money call option, a 0.8% increase in volatility from 17% to 17.8% (reasonable levels given the regression results summarized in Figure 1 and the characteristics of our sample) increases the Hull-White call price by 4% and put price by 6% when the risk-free rate is 5%. The increases are significant and predictable in the price of a liquid option.
5. Arbitrage tests: Hypothesis 4

Predictable significant increases in implied volatilities in the afternoons before the scheduled release of macroeconomic news and predictable declines on the mornings of release days lead us to investigate the profitability of arbitrage strategies. We can vary the time of day for entry and exit and consider the trading costs faced by arbitragers by using transaction data. These enhancements provide a more direct test of pricing efficiency in the sector index options markets.

One approach is to buy options before implied volatilities increase and liquidate the positions just before announcements are released. In addition, we can replicate the Ederington and Lee (1996) strategy but refine it by writing when implied volatilities are high and covering after economic news is published and ISDs have fallen. Transaction data solve the portfolio rebalancing problem that compromises the tests that use daily data because option positions can be offset both before and after announcements are released and cash prices adjust. Therefore, we provide a much stronger test of efficiency in the options market around scheduled news announcements known to cause volatility in underlying cash markets (Hypothesis 4).

Figure 1 shows that Payroll/Unemployment and Consumer Price Index announcements lead to the most significant sustained increases in Treasury sector option
ISDs. Therefore, our arbitrage analysis focuses on trades around these releases. We note that although we would like to test the arbitrage trading strategies on a hold-out sample of announcement days that were not part of the data used to identify significant increases in option ISDs, data constraints prohibit this approach. However, the long-term regression results in Table 1 suggest that cash market responses to these economic announcements have occurred for many years. Therefore, our findings should be applicable to broader time periods.

We use delta-hedged call and put option portfolios, i.e. volatility straddles, to evaluate the profit potential of three trading strategies. The first two strategies require the option trader to buy \( \frac{N(d_1)}{N(-d_1)} \) puts for each call purchased, where \( N(d_1) \) and \( N(-d_1) \) are the well-known Black and Scholes (1973) hedge ratios for call and put options, respectively. Our option trader establishes the long positions at 11:00 a.m EST on the day before the announcements \((t-1)\) prior to the first significant increase in ISDs in Figure 1. By using transaction data, we can assume that the trader sells the option portfolios either at the end of the pre-announcement day (3:00 p.m. EST), or just prior to the announcement (8:30 a.m. EST). Both of these liquidation points occur before the release of economic news moves cash market prices and erases the delta neutrality of the straddle.

The third strategy requires the option trader to write \( \frac{N(d_1)}{N(-d_1)} \) put contracts for each call written at 8:30 a.m. EST on the announcement day \((t-0)\). The trader covers the short positions at noon on the same day. Using this strategy, we can let the trader offset the short volatility straddle soon after macroeconomic information is released and ISDs decline.

Table 2 reports the average arbitrage trading profits around the 12 Payroll/Unemployment and Consumer Price Index announcements for each of the three trading strategies. Strategy S1 purchases put and call options at 11:00 a.m. EST on the pre-announcement day \((t-1)\) and liquidates the positions at the market close (3:00 p.m. EST), on \((t-1)\). This strategy is a prerelease intra-day, long volatility straddle.

Strategy S2 also buys contracts at 11:00 a.m. EST on the pre-announcement day \((t-1)\) but holds the positions until the economic news is released at 8:30 a.m. EST on the announcement day \((t-0)\). This strategy is a prerelease, overnight, long volatility straddle.

In contrast, strategy S3 writes puts and calls at the release (8:30 a.m. EST) on the announcement day \((t-0)\) and then covers the short positions at noon on the same day, thus creating an intra-day short volatility straddle containing the release period on the announcement day. S1 and S2 will capture the profits from ISD increases on the pre-announcement day and S3 targets post-announcement ISD declines.

We look at two possible sets of trade prices when executing these strategies to measure the impact of dealer spreads. This extension lets us separate the effect of trading costs on arbitrage profits from the effect of cash market price movements that corrupt the delta-neutrality of the straddles. In Table 2, the columns labeled “Midpoint” assume that all trades occur at the bid/ask midpoint. The columns labeled
Table 2

Trading profits from option straddles around the release of selected economic announcements

We use the pattern in volatility changes around macroeconomic announcements to simulate three volatility straddle trading strategies (S1, S2, and S3). Our goal is to trade delta-neutral portfolios whose prices are sensitive only to volatility changes. We focus our attention on Consumer Price Index (CPI) and Unemployment and Non-farm Payroll (PAY) announcements because these two releases cause the most significant reactions in ISDs. Under strategy S1 we purchase \( \frac{N(d_1)}{N(-d_1)} \) put contracts for each call bought at 11:00 a.m. EST on the pre-announcement day \((t-1)\) and liquidate the position at the market close (3:00 p.m. EST) on the pre-announcement day \((t-1)\). Under strategy S2 we purchase \(\frac{N(d_1)}{N(-d_1)}\) put contracts for each call bought at 11:00 a.m. EST on the pre-announcement day \((t-1)\) and liquidate the position at the news release, 8:30 a.m. EST on the announcement day \((t-0)\). Under strategy S3 we sell \(\frac{N(d_1)}{N(-d_1)}\) put contracts for each call written at the 8:30 a.m. EST release on the announcement day \((t-0)\) and cover the positions at noon on the same day \((t-0)\). Strategies S1 and S2 capture profits from ISD increases on pre-announcement days and strategy S3 focuses on post-announcement ISD declines. We consider two cases when executing trades. Columns labeled “Midpoint” assume trades occur at the bid/ask mid point and columns labeled “Bid-Ask” assume that purchases (sales) occur at the ask (bid) quotes. We report average trading profits, quoted in dollars on a per share basis, for each set of the three Treasury sector index options on trades between July 1994 and June 1995.

<table>
<thead>
<tr>
<th>Sector indexes</th>
<th>Consumer Price Index</th>
<th>Unemployment and Non-farm Payroll</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Midpoint</td>
<td>Bid-Ask</td>
</tr>
<tr>
<td></td>
<td>S1</td>
<td>S2</td>
</tr>
<tr>
<td>5-Year Treasury</td>
<td>0.06</td>
<td>0.07</td>
</tr>
<tr>
<td>10-Year Treasury</td>
<td>0.05</td>
<td>0.07</td>
</tr>
<tr>
<td>30-Year Treasury</td>
<td>0.06*</td>
<td>0.08*</td>
</tr>
</tbody>
</table>

* Indicates statistical significance at the 0.05 level.

"Bid-Ask" record option purchases at the ask quote and contract sales at the bid quote. We report average trading profits, quoted in dollars on a per share basis, for the 12 trades under each strategy for each of the three Treasury sector index options.

The "Midpoint" columns for each announcement show that mean profits are positive and sometimes significant when trades occur at the bid/ask midpoint. The values become negative and significant for both announcements and all three options once we incorporate the bid/ask spread. These losses lead us to conclude that traders with knowledge of the timing of announcements and the patterns in implied volatility changes illustrated in Figure 1 cannot earn arbitrage profits around the news releases. We can also conclude that the Treasury sector index options markets are efficient even when underlying cash markets are volatile. However, the existence of significant positive profits for some midpoint strategies suggests that dealer reactions in advance of news events, not the upheavals in cash markets, stymie arbitragers.

An alternative arbitrage strategy is to implement a delta and gamma neutral hedge, which immunizes the hedge ratio of the option trade. This strategy requires the speculator to both buy and write similar options. As a result, the trader is both long and short in the implied volatility premium. In addition, trading twice as many options increases transactions costs. Therefore, it is not surprising that the gamma hedge equivalents of Table 2 do not exhibit positive profits.

6. Summary and conclusions

To our knowledge, our paper is the first to use transaction data on sector index options to document changes in implied volatility in advance of economic announcements known to generate temporary disturbances in underlying cash markets. We build on the theoretical argument that implied volatilities represent the market’s forecast of future realized variation in returns on the underlying asset. Our research makes three contributions to the finance literature.

First, we use a set of announcements known to move cash markets to propose and confirm hypotheses about which announcements will increase ISDs on sector index options on Treasury securities, when the effects will occur, and which announcements should lead to the most dramatic adjustments in option prices. We find that there are strong cash market responses to Non-farm Payroll/Unemployment, Consumer Price, and Producer Price releases, and weaker reactions to Durable Goods, Housing Starts, Retail Sales, and Industrial Production announcements. Option ISDs rise in the afternoon for all seven releases, but the increases are more dramatic and sustained for the three announcements that cause the greatest reactions in cash prices.

Second, our findings on the speed of the post-announcement decline in implied option volatilities suggest that options markets respond to economic information within 20 minutes after the news is released. This speed of adjustment is strong evidence supporting information efficiency in an important derivatives market at a time when Treasury prices are volatile.

Third, once the execution cost of the options trading is considered, traders who possess public knowledge about the timing of scheduled macroeconomic
announcements and related increases and decreases in option implied volatilities are unable to earn arbitrage profits. Our arbitrage tests use actual transaction prices instead of relying on a single daily closing price. Since the trades are timed to maximize the potential for arbitrage profits and still result in losses, we provide a strong test of pricing efficiency in the Treasury sector index option markets.

References


