ESSAYS ON EQUITY OPTION BEHAVIOR SURROUNDING MACROECONOMIC ANNOUNCEMENTS

by

Garrett T. DeSimone

A Dissertation submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Economics

Summer 2017

ESSAYS ON EQUITY OPTION BEHAVIOR SURROUNDING MACROECONOMIC ANNOUNCEMENTS

by

Garrett T. DeSimone

Approved: ______________________________
James Butkiewicz, Ph.D.
Chair of the Department of Economics

Approved: ______________________________
Bruce Weber, Ph.D.
Dean of the College of Business and Economics

Approved: ______________________________
Ann L. Ardis, Ph.D.
Senior Vice Provost for Graduate and Professional Education

I certify that I have read this Dissertation and that in my opinion it meets the academic and professional standard required by the University as a Dissertation for the degree of Doctor of Philosophy.

Signed: ______________________________

Paul Laux, Ph.D.
Professor in charge of Dissertation

I certify that I have read this Dissertation and that in my opinion it meets the academic and professional standard required by the University as a Dissertation for the degree of Doctor of Philosophy.

Signed: ______________________________

Stacie Beck, Ph.D.
Professor in charge of Dissertation

I certify that I have read this Dissertation and that in my opinion it meets the academic and professional standard required by the University as a Dissertation for the degree of Doctor of Philosophy.

Signed: ______________________________

James Butkiewicz , Ph.D.
Member of Dissertation committee

I certify that I have read this Dissertation and that in my opinion it meets the academic and professional standard required by the University as a Dissertation for the degree of Doctor of Philosophy.

Signed: ______________________________

William Latham, Ph.D.
Member of Dissertation committee

ACKNOWLEDGEMENTS

I would like to express my deepest thanks and appreciation to my co-advisers, Dr. Paul Laux and Dr. Stacie Beck, for their guidance throughout the entire process. They were both incredibly patient and tolerant. Both have personally invested many hours into assisting my development as a researcher. For this, I am truly grateful. I would also like to thank the members of my dissertation committee, Dr.James Butkiewicz and Dr.William Latham for their time and patience, as well as their willingness to fit me in their schedules on such short notice. Additionally, I want to thank my colleagues in the PhD Economics program that studied alongside me at the University of Delaware.

I would also like to express my sincerest gratitude to my family and friends. This dissertation would not have been possible without them. In particular, I want to thank my parents, Glenn and Linda, for providing their unconditional love and support throughout my doctoral pursuit. My brothers, Craig and Kyle, for reviewing my dissertation and offering brotherly advice. And all of my grandparents, for their many check-ins and their heartwarming phone calls.

Lastly, I want to thank the many friends that have shown immense support throughout my educational career. You all deserve to be listed by name, but that would quickly lead to an essay. Thank you to my first, close knit group friends from New York. You have been my wise, inner circle of advisers for longer than I can remember. Your friendship has been invaluable to me over the years. Thank you to my close fraternity brothers from UMBC SAE. I will always appreciate your hospitality during my random escapes to Baltimore. Finally, thank you to my great friends and roommates from UD. My graduate experience would not have been the same without you, or your willingness to renew leases with me and tolerate my various antics.

TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

This dissertation presents two empirical studies on equity option behavior around scheduled macroeconomic announcements. In the first essay, I analyze the predictive power of implied volatilities of S&P 500 options for underlying index returns on macroeconomic news days. I design a measure of uncertainty based on economist forecast dispersion. During high uncertainty announcements, the steepness of the implied volatility function strongly predicts negative next day returns on the S&P 500, implying that buying pressure on out-of-the-money puts precedes bad economic news. Firm-level implied volatilities for cyclical and high beta stocks also exhibit this behavior, indicating that options traders can predict the impact of announcements on individual stock returns. My findings are consistent with the notion that informed options traders can anticipate and capitalize on the upcoming macroeconomic news.

In the second essay, delta-neutral straddles have high returns when realized volatility is higher than expected, or when price jumps occur. This makes a straddle an effective proxy for studying variance and jump risk. In my second essay, I analyze returns on S&P 500 delta-neutral straddles to obtain the size and sign of the variance and jump risk premiums on macroeconomic announcement days. Announcement day returns comprise over 77% of the total negative annualized returns on straddles, implying a vastly larger premium for insuring against changes in volatility and jumps around systematically released market news. In particular, on days when the Consumer Price Index, Non-Farm Payrolls, Industrial Manufacturing, and Industrial Production are announced, average returns are strongly negative ranging from -1.3% to -2.5%. In comparison, non-announcement days have average straddle returns of -0.1%, indicating that insurance for volatility and jumps resulting from random economic news shocks can essentially be obtained for free. However, straddles earn highly positive returns

during Federal Open Market Committee (FOMC) meetings. This pattern of high returns to straddles is consistent with investor anticipation of sharp decreases in realized volatility as result of government put protection. High average returns compensate investors on FOMC days for bearing risks associated with stabilizing interventions.

OVERVIEW

This dissertation presents a set of empirical studies that has an overarching theme which focuses on equity option pricing behavior around scheduled macroeconomic announcements. The goal of this research is to further expand upon a developing macro-finance literature, which studies the impact of macroeconomic fundamentals on financial market prices.

I present two unique perspectives on the formation of option prices in anticipation of scheduled macroeconomic news, which naturally conforms to a two essay structure. These perspectives differ in theoretical motivation. Essay one of this dissertation studies the predictive ability of options prices for future stock returns in the context of informational inefficiency prior to announcements. This essay relies upon the notion that options markets are a preferred venue for traders possessing private information about economic news. Limits to arbitrage cause imperfect information flow between markets, leading to relevant information in option market prices which is not immediately reflected in underlying stock prices. This intuition is further built upon by classifying economic conditions that are likely to cause greater information asymmetry between these markets. This research extends upon a previous literature that uses options to predict event outcomes.

The second essay detaches from the informational inefficiency concept and instead seeks to characterize risk compensation as measured by option returns from announcements. Due to their unique characteristics, options provide exposures to higher-order risk characteristics that cannot be replicated by a simple stock. Risk compensation during announcements is measured by average returns to a particular type of options strategy, namely a delta-neutral straddle. This second essay explores how news about macroeconomic fundamentals influences the premiums for bearing certain types of risk measured by straddle returns.

Given the difference of these theoretical underpinnings, each essay in this paper can be read independently, with its own introduction, literature and theory review, data and conclusion. Chapter 1 contains the essay on informed trading during economic news, and Chapter 2 contains the essay on delta-neutral straddle returns around macroeconomic news.

Chapter 1

OPTIONS PRICES AND TRADING AROUND MACROECONOMIC NEWS

1.1 Introduction

A key topic in finance is how information is incorporated into prices. In a complete market, options are redundant securities and should not contain any new pricing information. However, equity options provide unique advantages to informed traders, such as high leverage and the ability to avoid short-sale constraints (Black, 1975). For these reasons, investors may choose options to capitalize on their private information first. If the flow of information is imperfect between these two markets, options prices will have predictive power for future stock returns.

A majority of this informed options research has concentrated on whether this market can anticipate the outcomes of firm-level announcements (Pan and Poteshman, 2006; Roll et al., 2010; Xing et al., 2010; Atilgan, 2014). Relatively few studies exist on how future macroeconomic news is incorporated into option prices. This is surprising, given that average returns are substantially larger on these days compared to others (Savor and Wilson, 2013). Therefore, I take this literature in new direction by empirically testing whether options prices contain information regarding future macroeconomic news. I hypothesize that under certain conditions, options prices can predict returns of their underlying equity resulting from macroeconomic news. My analysis has the benefit of a tight identification scheme that targets option pricing patterns on scheduled macroeconomic announcements.

This research makes several novel contributions to the literature. First, I establish that S&P 500 option prices predict index returns on announcement days. Specifically, a steep implied volatility (IV) skew precedes low return days. This predictive power is concentrated to news days where economists have greater disagreement regarding their forecasts. In this context, forecast disagreement serves as a reflection of overall market uncertainty for the outcome of a specific economic variable (Andersen et al., 2003). Pre-announcement disagreement is likely to create informational asymmetry between groups of traders. This notion is supported by several theoretical models of trade. In the Kim and Verrecchia (1994) model, information asymmetry between traders is larger when there is imperfect anticipation of the announcement. On the other hand, a perfectly anticipated announcement causes investor beliefs to converge leading to little price movement upon news arrival. Foster and Viswanathan (1996) demonstrate in a multi-period trading model that when information is highly heterogeneous, trading profits are larger. This is due to less aggressive trading by investors in early periods. As such, it is intuitive that options trades will carry relatively more informational value when uncertainty among market participants is highest. Empirically, Beber and Brandt (2009) find that high macroeconomic uncertainty is associated with greater trading activity prior to announcements.

Second, I find that macroeconomic information is incorporated into option prices differently based on announcement type. Weighted buying pressure on calls prior to Federal Open Market Committee (FOMC) days serves as a positive predictor of returns. In the case of other announcements, buying pressure in out-of-the-money (OTM) puts precedes low returns. This is likely due to the differences in information relayed during each type of announcement. However, I cannot entirely attribute the FOMC finding to the informed trading hypothesis.

Third, I confirm the economic significance of the IV skew result by backtesting a trading strategy. This strategy involves executing a series of trades on high uncertainty days. Fourth, firm-level options also embed future macroeconomic news in their prices. This is especially true for underlying stocks that are sensitive to business cycle factors, namely cyclical and high beta stocks. The IV skew for high beta stocks encompasses negative news for high and low uncertainty news days.

In this paper, I distinguish between FOMC and other types of announcements.

In general, FOMC meetings tend to have a calming impact on markets. Amengual and Xiu (2014) find that statements from the Fed are associated with downward volatility jumps, due to this policy uncertainty resolution. In comparison, other macro indicators are backward-looking since they are observed over a prior sampling period. My empirical results indicate that price pressure across weighted calls predicts high FOMC returns, whereas price pressure on out-of-the-money puts is a stronger indicator of low returns for other announcements. My research provides evidence that FOMC days are uniquely different than other days from an option pricing perspective. I leave exactly why these days are different as a direction for future research.

This analysis utilizes two established informed trading measures from the literature. First, the implied volatility (IV) skew is calculated as the difference in IVs between out-of-the-money (OTM) puts and at-the-money (ATM) calls (Xing et al., 2010). According to the constant volatility assumption of the Black and Scholes (1973) model, the implied volatility of an option should be constant across all strike prices and maturities. However, empirically observed implied volatility functions (IVFs) generally exhibit a downward sloping shape or "smile". Bollen and Whaley (2004) and Garleanu et al. (2009) attribute this to trading frictions and limits to arbitrage for market makers, leading to supply and demand factors dictating IVs. If informed traders anticipate that a news release will trigger a drop in price, then they will be likely to purchase OTM puts. In a market with trading frictions, this causes the price of OTM puts to increase relative to ATM calls.

Second, the IV spread (Atilgan, 2014) is calculated as the open interest weighted difference in IVs between matched calls and puts. It measures the relative buying pressure on calls and is a reflection of positive sentiment regarding future stock price movement. The implied volatility spread is a measure of the deviations from put-call parity between matched call and puts. If informed traders choose to express positive news regarding a stock, they will purchase calls. Due to the trading frictions mentioned previously, this can lead to the implied volatilites of calls to increase relative to puts. An increase in the spread implies an increase in expected future returns.

The remainder of this paper proceeds as follows: section 2 provides a literature review, section 3 gives a theoretical overview, section 4 discusses the data, section 5 documents a time-series methodology, section 6 discusses trading strategies, section 7 details a portfolio approach, and section 8 concludes.

1.2 Literature Review

In this section, I provide a review of the relevant literature related to informed options trading and the impact of macroeconomic announcements on security returns. First, I discuss research documenting the relationship between stock and options markets, which largely focuses on the predictive power of the options for firm-level news events. I also present supporting research for the informed options measures utilized in this paper.

Second, I provide an overview of the research related to the response of security markets to macroeconomic news events. This subsection is intended to demonstrate that macroeconomic news clearly impacts market returns and volatility, which makes them periods of interest for options traders. The issue of state dependence is also addressed. State dependence refers to the differing affects news has on market returns based on prevailing market conditions. The state dependence of returns will impact how options traders perceive the potential market reaction to news, which will induce them to trade or not to trade.

Third, I review indicators of macroeconomic uncertainty. These studies provide the basis for conditioning announcements on economists' forecasts. I provide a deeper theoretical discussion of the implications of economic uncertainty for the options trader in a later section.

1.2.1 Informed Trading in Options Markets

An extensive literature exists documenting the role of informed traders in the options market. Option markets provide the ideal environment for informed traders to act on private information due to the high leverage present and the ability to avoid short-sale constraints (Black, 1975). Under complete markets, options are redundant securities. In this setting, the only inputs required to model the price of an option are the underlying stocks price and volatility. However, if asymmetric information is present, informed traders may transact in the options market first resulting in relevant information not directly incorporated into stock price. Easley et al. (1998) develop an asymmetric information model in which traders can transact in options and equities markets or the pooling equilibrium. Their model predicts informational value in options volume, which they verify empirically by identifying a relationship between positive news and negative news volumes, and predictability for future stock returns. I cover the theoretical implications of this type of model for my research in later sections.

The early focus in this area has been on the lead-lag relationship between options and stock markets or on the informational role of option trading. The purpose of lead-lag research is to determine if price discovery occurs in options markets. Seminal papers such as Hasbrouck (1995) measure option market information share, or the proportion of price innovation variance that can be attributed to the options market. Chakravarty et al. (2004) research reinforces this finding, however they find that differences in price discovery based on moneyness. Specifically, out-of-the-money (OTM) options contribute to a greater portion of the information share.

Recent options studies have primarily focused on the predictability of options prices for returns as a result of firm-level annoucements. Diavatopoulos et al. (2012) find that changes in implied skewness and kurtosis from options prices are related to future returns surrounding earnings announcements. Atilgan (2014) document the pronounced predictability of implied volatility spreads for stock returns during announcement periods. Announcement return predictability is also stronger for more liquid options, a more asymmetric information environment, or stock liquidity is low. Xing et al. (2010) research the cross-sectional predictive power of the options volatility smirk for future stock returns. They find that firms with the steepest smirks have the worst negative earnings shocks, which is attributed to informed trading in options. Hao et al. (2013) use intraday transaction data to study the relationship between put-net volume and short sales. Their results show that in general short sales are more informative than put option volume. However, put option volume has more predictive power than short sales before negative unexpected earnings announcements. In a seminal paper, Roll et al. (2010) find that post announcement returns are positively related to option/stock trading volume ratio (O/S). Lin and Lu (2015) show that the predictive power of option IVs more than doubles around analyst announcements, implying that analysts tip option traders to the content of future announcement. Augustin et al. (2014) document wide-spread informed options trading prior to M&A announcements by studying abnormal volumes.

A relatively small group of papers concentrate on predictability around macroeconomic announcements. For example, Bernile et al. (2014) look for the presence of informed trading in E-Mini S&P 500 futures during FOMC news embargo periods. The authors find there is information contained in the abnormal order imbalances about following policy surprises. This paper seeks to contribute to this developing research on informed trading in options prior to macroeconomic news. In other words, I am looking to test whether options prices also embed information regarding macroeconomic fundamentals. In some ways, this is a more difficult research problem compared to firm-level studies. The interpretation of firm-level releases are generally unambiguous (surprise positive earnings leads to high returns). However, market responses to macroeconomic news vary based on the business cycle, making it more difficult to identify information in prices. This is the motivation behind conditioning announcements by uncertainty.

As documented in previous paragraphs, the informed options literature has mainly been dedicated to studying firm-level announcements. Although, the indicators used in these studies (implied volatility skew and spread) provide a useful tool for analyzing macroeconomic news. I detail these indicators in the following subsection.

1.2.1.1 Implied Volatility Skew

Xing et al. (2010) characterize the volatility skew as the difference in the IVs between OTM put options and ATM call options. The volatility smirk found in index options refers to the higher IVs for lower strike price puts and calls. Under the constant volatility assumption of the Black and Scholes (1973) model, IVs should be constant across all strikes and maturities. Therefore, the documented presence of the skew is a direct violation of standard options pricing models. The following paragraphs discuss possible explanations for the skew, as well implications of using market versus individual skews in empirical tests.

The most relevant explanation of the IV skew to this dissertation is the demand pressure argument. Bollen and Whaley (2004) and Garleanu et al. (2009) provide convincing evidence that supply and demand factors associated with different strike prices can explain non-constant IVFs. The presence of supply and demand factors in options market arises from limits to arbitrage and trading frictions. For example, market makers may not be willing to provide an unlimited number of contracts at fixed price due to volatility risk exposure and hedging costs. As compensation, market makers demand a higher premium to provide contracts at a given strike. Therefore, net buying pressure (difference between buyer and seller motivated contracts) can cause a deviations from standard model prices. If informed traders attempt to capitalize on their private knowledge by buying OTM puts or calls, this would lead to increased premiums for OTM options and higher IVs relative to at-the-money (ATM) options, and a steeper skew.

Another plausible explanation for the IV skew is compensation for negative jump risk. As probability or magnitude of negative jumps increases, an options seller should be compensated for bearing options sensitive to this risk. Theoretically, Bakshi et al. (1997) support the use of a stochastic volatility model with jumps for valuation of S&P 500 index options. Bates (1991) demonstrates that OTM puts were unusually expensive in the year prior to the October 1987 crash, meaning option market participants had expectations of impending negative price jump. Research has shown macroeconomic announcements can induce systematic intraday jumps in equities prices (Lee, 2011; Evans, 2011). Given this literature, the IV skew makes for an attractive measure of the probability and magnitude of negative price jumps occurring on announcement days.

An interesting empirical phenomena concerns the steeper slope observed in the index implied volatility function compared to the individual stock. Bollen and Whaley (2004) attribute the differential pricing of index options to institutional demand for OTM puts as a hedging instrument. Bakshi et al. (2003) argue that index and individual options have different risk neutral skewness. Buraschi et al. (2014) find that investor disagreement has explanatory power for the spread between index and individual volatility risk premia, as well as the difference in the implied volatility (IV) slopes between index and individual smiles, and the price of correlation risk. However, the theoretical specifics regarding the differential slopes observed in the IVF of individual and index options is not a central discussion of this dissertation. Although, it is important to acknowledge that the choice of option for this analysis could change the conclusions presented in this dissertation, for the reasons mentioned above. This is the motivation for using both in my empirical tests. Next, I address the properties of another options indicator, the implied volatility spread.

1.2.1.2 Implied Volatility Spread

Other literature has explored the relationship between future returns and deviations from the put-call parity. While deviations may represent market frictions or imperfections, informed traders transacting in the option market first may cause deviations that are not arbitraged away quickly. Cremers and Weinbaum (2010) classify the spread as the IV difference between matched strike calls and puts on American options. The authors employ American options since they can be subject to early exercise, therefore deviations from put-call do not necessarily imply arbitrage opportunities. Their theoretical justification for the positive relationship between IV spread and future stock returns is consistent with the price pressure argument. Atilgan (2014) extends this analysis to earnings announcements by utilizing changes in the spread. During the announcement window, stocks with relatively more expensive calls outperform those with relatively more expensive puts.

Next, I address the influence of macroeconomic news on security returns. If macroeconomic news is expected to trigger large price responses in underlying security, it should be reflected in the options prices prior to the release. The upcoming provides evidence that the stock market does in fact respond to news in announcements, which means options traders have incentive to gather information regarding macroeconomic fundamentals.

1.2.2 Macroeconomic Announcements and Security Returns

In this case, stock market returns should depend directly on state variables related to economic fundamentals. Prescheduled macroeconomic announcements provide agents with a relevant information regarding these fundamentals, and therefore levels of systematic risk.

A long line of literature examines the response of stock returns to changes in economic variables. For example, inflations negative relationship with stock returns has been studied extensively. Fama and Schwert (1977) show that this relationship holds for unexpected and expected changes in inflation. Schwert (1981) also documents that the stock market reacts negatively to unexpected changes in Consumer Price Index (CPI). This reaction only occurs on the announcement day, not when the CPI is being sampled. This suggests that the Bureau of Labor Statistics (BLS) assimilates prices into a single index number, which the market treats as new information. Pearce and Roley (1983) study daily stock price responses to inflation, money supply, and other economic variables in the context of the efficient market hypothesis. Their results indicate that surprise inflation announcements only have a limited impact on stock price returns. Flannery and Protopapadakis (2002) estimate a GARCH model where realized returns and conditional volatility depend on 17 macroeconomic announcements. They find the CPI , PPI, and the Monetary Aggregate are candidates for priced risk factors. Information regarding the future direction of monetary policy also plays a crucial role in influencing equity returns. Bernanke and Kuttner (2005) analyze the impact of surprise interest rate increases on stock returns. They are able to distinguish between expected and unexpected policy changes by using Federal Funds Futures. Utilizing a union consisting of meeting days of the Federal Open Market Committee (FOMC) and changes in the target funds rate, the authors find an unanticipated 25-point-basis cut is associated with a one percent increase of broad stock indices. However, the market responds little to anticipated rate changes. Other research has concentrated on market response to the tone communicated at FOMC meetings. Rosa (2011) finds that communications contained in FOMC announcements have a statistically significant impact on equity indices. Using intraday data, the author finds that 90 percent of the explainable variation in the S&P 500 is due to the unexpected component of the statement.

Several other pieces of research investigate unconditional stock market returns during FOMC announcements. An advantage of these studies is that they do not require assumptions about what classifies as good or bad news for stocks at a given period in time. Savor and Wilson (2013) empirically document the returns on announcement days for the CPI, PPI and FOMC. Their findings indicate that over 60 percent of the cumulative annual risk premium is earned on these days. According to the authors, this a clear indicator of the higher conditional risk of holding assets ahead of macroeconomic announcements.Lucca and Moench (2015) find that since 1994, the S&P500 has increased by 49 basis points on average prior to the announcement. Additionally, these returns do not exhibit any reversion. The authors have difficulty reconciling this finding with asset pricing theories or behavioral explanations.

There is also a price impact of scheduled releases on bond returns. Fleming and Remolona (1999) examine a "two-stage" process for which the U.S. Treasury market prices, trading volume, and bid-ask spreads respond to public news. Balduzzi et al. (2001) find that announcements significantly affect the price of Treasuries but this impact varies by maturity. This news is also incorporated into prices very rapidly, which implies jumps are a needed component of interest rate dynamics.

The literature presented above documents clearly that financial markets respond to macroeconomic news content. Since returns on options depend on the directional movement of their underlying asset, announcements that affect prices in the underlying asset will also affect options returns. A trader would have a strong incentive to gather information related to the news, so they can capitalize on the market reaction by taking an options position. However, markets react differently to certain kinds of economic news based on business cycle phases, meaning traders will weight news in announcements more heavily at certain periods. I address this state dependency in the next section.

1.2.3 State Dependence

State dependency refers to the asymmetric impacts announcements have returns based on economic conditions or other market factors. Basistha and Kurov (2008) document the cyclical variation of Fed policy on the stock market and find that firms with financial constraints (such as high debt) are asymmetrically affected by policy shocks in tight credit conditions. Kontonikas et al. (2013) examine the response of stock returns to Federal Funds Rate (FFR) changes in light of the recent financial crisis. The authors document that the stock market has a greater response to unexpected rate changes during recessions, bear markets, and tight credit conditions. Additionally, their research shows that markets did not respond positively to FFR cuts during the financial crisis of 07-08, which they attribute to investor perception of deteriorating economic conditions. Boyd et al. (2005) document that rising unemployment during expansions causes rising stock prices. The authors attribute this to implicit information bundled into unemployment announcements such as future interest rates, equity risk premium, and corporate earnings and dividends.

These studies demonstrate that the potential impact macroeconomic announcements on returns are considered more heavily by investors during specific market conditions. This It is likely some announcements in the sample will not illicit much of a stock price response, making these announcements relatively less important to traders. Therefore, I provide method of conditioning announcements by their potential response to news, namely economists' forecast uncertainty. Conditioning announcements ex-ante by forecast uncertainty, provides a way of classifying which announcements will attract the most informed traders. I discuss literature related to forecasting and uncertainty in the next subsection.

1.2.4 Macroeconomic Uncertainty

A recent set of literature seeks to obtain measures of macroeconomic uncertainty. The literature discussed in this section utilizes survey-based measures of disagreement, which provide support for implementation of the economists' forecast disagreement measure used in this paper. For example, Anderson et al. (2009) extract market uncertainty using disagreement among professional forecasters for macroeconomic variables. They find stronger empirical evidence for a uncertainty-return tradeoff than risk-return. Andersen et al. (2003) also finds that disperson among economic forecasts increases after the occurrence of bad economic news. Yu (2011) focuses on disagreement for individual stocks using earnings forecasts. The author documents a contemporaneous correlation between increase in uncertainty and a fall in the discount rate, along with a higher premium for value stocks with higher disagreement. Baker et al. (2013) develops a policy uncertainty index using newspaper coverage. They find that increases in policy uncertainty signal future declines in macro-level investment, output, and employment. Lastly, Buraschi et al. (2014) use analyst forecast data on future earnings to construct proxies for belief disagreement. These proxies have strong explanatory power for the difference between index and individual variance risk premia.

In summation, this research provides evidence that dispersion of economists' forecasts has explanatory power for future market returns related to macroeconomic news. The classification of announcements by uncertainty allows me to condition announcements by days that option traders likely have a large information advantage. The empirical results contained in this literature document a significant relationship between forecast dispersion and future returns. In the next section, I provide a detailed theoretical discussion of why forecast dispersion leads to greater informational-based trading in options markets.

1.3 Theoretical Models Of Information Asymmetry and Trade

The empirical setup in this paper is supported by early theoretical literature addressing the impact of informational asymmetry in options markets. Seminal in this area, Easley et al. (1998) develops an asymmetric information model in which informed agents may trade in both equities and options markets. There is also uninformed traders who trade for liquidity based reasons which are exogenous to the model. Uninformed traders are allowed to trade in both markets, for hedging or other non-speculative purposes. Orders arrive sequentially. Informed traders must decide which market to transact in as to maximize total profits. Informed traders are risk neutral, and allowed to buy or sell a stock, or buy or sell a call or put.

Easley et al. (1998) show an informed trader will choose to trade in both markets, or a pooling equilibrium, under certain conditions. This occurs when leverage in options is high, or when the liquidity in the options market is high relative to the stock market. Since this model only considers a only one matching call and put contract, leverage refers to the number of shares controlled by the option relative to the stock. Therefore, a cheap option relative to the stock would have higher leverage.

However, when option market depth is low or option leverage is low informed traders are deterred from the option market. If the only set of options available is of low leverage (deep ITM options), then informed traders would separate into the stock market. This is due to the higher profits available from trading in the stock market.

A consequence of their model is that different types of option trades provide information about future stock returns. Specifically, call buying or put selling indicates upcoming good news for returns, and put buying and call selling predicts bad news for returns. These results provide a theoretical backing for my empirical study of the implied volatility skew of S&P 500 index options. Specifically, OTM index put options are liquid, highly leveraged contracts, and therefore should contain the strongest predictive power for future stock price movements.

The predictive power of options prices also hinges on the idea that a market maker cannot fully hedge or identify informed trades, thereby creating informational inefficiencies. Biais and Hillion (1994) introduce a one-period model with a risk-neutral market maker takes orders from liquidity traders or informed traders, but is not aware of what trader she is transacting with. Liquidity traders trade for reasons not related to information about future payoffs, and submit trades exogenously. There are three final states of the world, which the informed trader knows with certainty (up, middle, and down). In a world with only stocks, the informed trader cannot earn profits, since all the contingent states cannot be spanned. However, introduction of an option enables the informed trader to make trades that are better suited to her information, since the middle state contingent claim of the world can now be traded. This completes the market. In order to provide camouflage, the informed trader will mimic liquidity trades as to not expose her information advantage. In this way, the market maker cannot fully identify informed trades from order flow.

The most relevant implication of this model is that option trading can reduce informational efficiency, even in a complete market. Current stock price (S) is the expected final value of the stock in state of the world (which is defined by θ), which is conditioned on the market makers order flow. The difference between this prior value and final realized state is the estimation error. The variance of this estimation error is the informational efficiency ($V(S - \theta)$). The informed trader engages in multiple types of trades that would appear to be liquidity driven, presenting a more difficult inference problem for the market maker. The order flow becomes less informative to the market maker, which drives S further away from the final state value, and increases the variance.

For example, if the informed trader had knowledge of a down state occurring in the next period, she could sell the stock or buy a put or sell a call. The market maker is uncertain as to which trader she is transacting with, and therefore increases the spread. trading camouflage can earn profits for informed traders, but will result in information in options trades not being fully revealing.

Another type of friction that could lead to price information not being fully revealed in stock prices is related to the inventory problem of the market maker. In a world where intermediaries can hedge perfectly, option prices follow Black and Scholes (1973) and are determined by no-arbitrage conditions. Alternatively, Garleanu et al. (2009) construct an option pricing model in which market-makers cannot perfectly hedge their inventories, due to the inability to trade continuously or transaction costs. Frictions in this model lead to option demand impacting option prices (an incomplete market).

The Garleanu et al. (2009) model contains dealers who trade contracts on the same underlying security in discrete time. The dealers trade with "end-users", or agents that have a need for option exposure. Dealers trade many contracts so some of the types of risk are netted out, or risk asset optimally hedged by taking a position in the underlying asset. However, there still exists an unhedgeable component of each dealers' trade. This an assumption of the model which is consistent micro-structure frictions of the options market (ex. Dealer cannot continuously hedge).The authors compute equilibrium prices for options that induce risk-averse dealers to supply the exact amount of options to meet end-users demand. Positive demand pressure from end-users enters into the pricing kernel of the dealer, which assigns high values to states of nature where the underlying asset pays off positively. This increases the price of the option, and entices the dealer to sell it.

While Garleanu et al. (2009) is agnostic about why the end-users demand options, a crucial assumption of my research is that option demand is prompted by informed trading. This paper argues that informed traders will demand certain options to exploit their private information, which will increase the price of these contracts. For example, an informed trader with information regarding negative news will prefer OTM puts due their leverage. Buying pressure on puts will increase the price the market maker sells these contracts for, which increases their IVs relative to other options. If the dealer makes inferences based on the direction of the trade, their response would still be to increase prices as risk of dealing to an informed trader increases.

The research discussed in the subsection not only presents evidence of informed traders in options markets, but also documents their ability to affect information flow and prices. But, simply being informed about upcoming news does not always induce a trader to transact in options. Profits from an options trade must exceed that of a stock trade. A condition for trading to occur in the option prior to news is that the announcement must generate a significant price movement in the underlying asset. Absent of a significant price movement, option positions initiated prior to the announcement may actually result in losses even when the direction of price change from the news was correctly anticipated. In the next subsection, I discuss the theoretical conditions that generate information gathering prior to news events, as well as micro-structure models which detail market price reponses to announcements.

1.3.1 Micro-structure models and Announcements

The research detailed in this section provides the theoretical justification for conditioning announcements based on uncertainty. Empirically, I classify news releases based on their ex-ante uncertainty measured by economist's forecast dispersion. This dispersion measures the standard deviation of economist forecasts, and therefore how widely their estimates differ. Forecast dispersion can serve as proxies for information heterogeneity, uncertainty, and differences of opinion– which lead to higher profits for informed traders, and greater incentives to gather information, and ability to cloak trades more effectively.

For example, the idea of greater profit potential to trading for uncertain announcements also holds for models with heterogeneously informed traders. Foster and Viswanathan (1996) analyze a multi-period trading model with differentially informed traders, a market maker, and a liquidity trader. The informed traders have noisy estimates of the asset value, and they receive signals with varying correlation structures. When trading begins, traders use the order flow and their own unique information to make a forecast of other informed traders' forecasts. In this model, the initial correlation structure of traders' private signals has a strong impact on total trading profits. When there are strong positive correlation in their initial signals, informed traders will trade aggressively in early periods, impounding information into price rapidly and reducing profits. However, when initial signals have a small positive correlation or negative correlation it reduces the amount of competition between traders, and incentivize traders to place smaller trades in early periods. This implies larger profits to informed traders for high levels of information heterogeneity.

In this sense, forecast dispersion can serve as a natural proxy for the correlation structure amongst traders' signals. When forecast dispersion is high, the correlation of traders' trading signals have low positive correlation, leading to higher trading profits during news announcements for options traders. All immediate information is not impounded into the underlying stock price. This leads to higher profit potential to options trades on high uncertainty news days, more informed trades in options, and greater predictability in options prices for underlying returns. Consistent with this theory, I find that options prices have stronger predictive power on these days.

Following the above logic, periods of uncertainty should also induce more information gathering. For example, Kim and Verrecchia (1991) use a three-period model to study the impact of anticipated public announcements on investor incentives on information gathering. The first period of the model investors trade on private signals that have varying precisions, the second period an announcement occurs, and in the third period investors consume. A relevant implication of this model is that the expected impact of the announcement influences the endogenous acquisition of information in the first period.

Specifically, the investor endogenously acquires costly information and chooses the precision of his private information signal ahead of the announcement. In the case of a perfectly anticipated announcement (no uncertainty), the arrival of the announcement barely stirs the market, and creates little trading opportunity. These types of news days would be of little interest to options traders since a significant price movement in the underlying would be unlikely. But, when there is large disagreement (high uncertainty) regarding an announcement, investors will have an incentive to gather information that is further away from the average expectation. An upcoming announcement that is highly uncertain will lead to options traders to developing a very precise private signal.

Under these conditions, informational asymmetry is large between stock and options markets, and options trades are relatively more informative.

This research is also clearly has ties to the theoretical literature on differences of opinions. Cao and Ou-Yang (2009) analyze a model in which investors have differences in opinion regarding public signals. Their model is dynamic, with a series of public signals for each market session, and a final payoff at time T. Investors disagree about the mean and precision about these public signals, causing differences in beliefs. The authors find that disagreement about the precision about a public signal for current and next-period information generate trading in the options market, and especially so during a large news event. When there are stronger differences in opinions regarding the stocks' payoff, trading volumes also increase in the options market. This is due to investors disagreeing on the options payoff more as well, which induces trades.

In the context of this paper, forecast dispersion serves as a proxy of differences of opinion. As such, options traders will be more active prior to announcements that have greater dispersion. In this model, belief differences generates option prices are consistent with Black and Scholes (1973). However, still can contain interesting implications for an informed trader. When beliefs are widely dispersed, the informed trader is able to hide trades more successfully amongst many other trades that have competing opinions regarding future market direction. This is due to a market maker not being able to identify informed traders in the presence of a large amount of speculative or liquidity trades. In contrast, a market-maker can easily identify trades that depart from the mean consensus regarding asset value when dispersion is low. Therefore, high uncertainty announcements will not only attract informed traders due price response, but also the ability to camouflage trades is easier.

1.3.2 Theoretical Motivation

This set of theoretical literature provides evidence of two important themes in my empirical setup. First, it formalizes the presence informed traders in the options market, and the conditions under which informed traders trade. Certain frictions prevent price from being fully realized in the stock market, namely the ability of option traders to camouflage amongst liquidity traders, and constraints such as transactions costs and inventory risk. This literature details why information may not flow evenly between markets, leading to options prices predicting certain stock price moves.

Second, it provides motivation for conditioning announcement news by forecast dispersion. The micro-structure models in the above subsection demonstrate that announcements of greater uncertainty increase incentives to gather information, increase the size of potential trading profits, and cause beliefs to become more heterogeneous across investors. Therefore, times of high uncertainty are periods where options trades will be executed more frequently, be driven by more private information, and have more predictive power for future stock returns. In the upcoming section, I implement time-series regressions involving uncertainty dummies motivated by this this theory.

1.4 Data

1.4.1 Option and Equity Data

My sample spans the period of January 2010 to December 2014. Daily option pricing data for individual options and indexes are available through the Ivy DB OptionMetrics database. OptionMetrics provides information such as end-of-day bid and ask quotes, volume, implied volatility surfaces, and option Greeks. Implied volatilities and Greeks are computed using the binomial tree model.

The steepness of the implied volatility (IV) skew for individual and index options are calculated using the methodology found in Xing et al. (2010). The IV skew has a negative relationship with future returns. This is due buying pressure on OTM puts from informed traders, which leads to increased OTM premiums and higher IVs relative to ATM options. Moneyness is defined using the strike-to-price ratio. OTM options have a ratio between .80 and .95 , while ATM options have a ratio between .95 and 1.05 . When multiple options exist daily within this range, they are weighted by volume. A standard series of filters is applied in order to ensure sufficient option liquidity.[1]

For this analysis, the IV skew is computed daily for the aggregate market or firm i on the day t as the difference between the implied volatility of OTM puts ($\sigma_{i,t}^{OTMP}$) and ATM calls ($\sigma_{i,t}^{ATMC}$). It is defined below as:

$$Skew_{i,t} = \sigma_{i,t}^{OTMP} - \sigma_{i,t}^{ATMC} \tag{1.1}$$

The next measure I utilize is the IV spread,which has a positive relationship with future stock returns and captures weighted deviations from put-call parity (Cremers and Weinbaum, 2010).

[1] To be included in the skew calculation, the option must satisfy these conditions:
i) The underlying stock's volume is positive for the day.
ii) The underlying stock's price is greater than \$5.
iii) The implied volatility of each option is between 3% and 200% .
iv) Option price (average of bid and ask) is greater than \$0.125 .
v) Option contract has positive open interest and non-missing volume.
vi) The option has a maturity between 10 and 60 days.

The IV spread is calculated daily for each firm i or index on day t. This calculation uses the same set of filters for option liquidity as in Equation 2.1. The spread represents the open-interest weighted differences in IVs between n matched calls and puts, defined below as:

$$spread_{i,t} = \sum_{j=1}^{n_{i,t}} w^{i}_{j,t}(\sigma^{i,call}_{i,t-1} - \sigma^{i,put}_{i,t-1}) \tag{1.2}$$

Table 1.1 provides summary statistics for stock returns, the IV skew and IV spread. The mean daily excess return for the S&P 500 is 0.054%. The return distribution over this period is slightly negatively skewed, and leptokurtic. The average daily skew is 0.115, implying that OTM put options are typically 11.5% more expensive than ATM calls. The daily average spread is 0.00025, meaning that when calls are weighted by their open interest, their implied volatilites make them 0.025% more expensive than matching puts. In the following section, I discuss the methodology for characterising announcement uncertainty and time series tests.

Table 1.1: Summary Statistics for Excess Returns and Implied Volatility Measures

This table represents daily summary statistics for S&P 500 index returns, the implied volatility skew, and the implied volatility spread on SPX options during the period of Jan 01, 2010 to Dec 31, 2014.

Variable	N	Mean	Std	Med.	Min	Max	Skew.	Kurt.
S&P500	1258	0.1238	0.0005	0.0007	-0.0663	0.04741	-0.3812	4.4565
Skew	1258	0.1146	0.2680	0.1120	0.05134	0.2505	0.7851	1.8229
Spread	1258	0.0003	0.3000	-0.0013	-0.0750	0.1441	1.05672	8.2021

Equity returns are from The Center for Research in Security Prices (CRSP). For individual stocks, general accounting data is available through Computstat. Major macroeconomic announcement dates and mean forecasts, standard deviation of forecasts, and surprise values are available through Bloomberg. In this study, I utilize eight different announcements of economic indicators. Table 1.2 provides sample statistics for each macroeconomic news event. My sample consists of 1258 trading days, with news events occurring on 455 days, making up roughly 33% percent of the total sample.

Table 1.2: Sample Statistics for Macroeconomic New Events

This table list macroeconomic type contained in the sample along with the number of occurrences during the period Jan 01, 2010 to Dec 31, 2014.

Event	Total In Sample
CPI MoM	60
Change in Nonfarm Payrolls	57
Consumer Confidence Index	60
Durable Goods Orders	60
FOMC Rate Decision (Upper Bound)	40
Housing Starts	60
ISM Manufacturing	59
Industrial Production MoM	60
New Home Sales MoM	60
PPI MoM	49
Total	565

Summary Statistics for Economists' Forecast Dispersions

This table represents summary statistic for economists' forecast dispersion (standard deviation) for macroeconomic indicators from Jan 01, 2010 to Dec 31 , 2014. The 20th percentile(P20) and 80th percentile(P80) are the cutoff values for the dummy variable uncertainty interactions for a low uncertainty announcement, and a high uncertainty announcement, respectively.

Event	Mean	Std	Min	Max	P20	P50	P80
CPI MoM	0.09	0.02	0.05	0.14	0.07	0.08	0.1
Payrolls	28.59	11.70	17.92	97.36	21.42	24.94	34.75
Consumer Confidence	1.72	0.43	0.95	2.65	1.34	1.67	2.075
Durable Goods	1.35	0.93	0.65	7.85	0.90	1.19	1.525
FOMC	0.00	0.01	0.00	0.03	0.00	0.00	0
Housing Starts	19.19	5.55	11.28	33.96	14.01	17.96	24.72
ISM Manufacturing	0.79	0.18	0.45	1.25	0.63	0.75	0.96
IP	0.19	0.05	0.11	0.33	0.16	0.19	0.22
New Home Sales	2.99	1.12	1.63	9.33	2.25	2.66	3.68
PPI	0.21	0.06	0.12	0.36	0.16	0.20	0.24

In the table above, I document statistic for economists' forecast dispersion for each macroeconomic event across the sample. An announcement whose forecast falls below the 20th percentile of economists' is considered a low uncertainty day. If the announcement is above the 80th percentile of forecasts it is considered a high uncertainty day. However, it is difficult to compare dispersion across different announcement because they are not standardized values.

Another important point to notice in that there is essentially no deviation among forecasters for FOMC meetings. The is due to the observed sample, which was a extended period of "Quantitative Easing". Since the committee pledged to keep rates near zero, there was no uncertainty regarding rate changes. This is a major reason why the FOMC announcement is separated into a different dummy variable. In the following section, I implement these uncertainty dummy variables in time-series regressions.

1.4.2 Time Series Regressions on Aggregate Market Returns

It is well established that asset returns respond only to the surprise component of announcements, since expectations are already embedded in security prices (Schwert, 1981; Pearce and Roley, 1983; Bernanke and Kuttner, 2005; Kontonikas et al., 2013). Therefore, option traders have little incentive to gather information on the outcomes of economic indicators which are near certain. From a theoretical perspective, Kim and Verrecchia (1994) develop a model in order to analyze how a public announcement changes investors incentives to gather information. According to their model, when the precision of announcement becomes small, investors have stronger incentives to gather information which is further away from the average expectation. In the case of a perfectly anticipated announcement the news release causes beliefs to converge, and little trading opportunity. On the other hand, uncertainty surrounding an announcement outcome should lead to heterogeneous beliefs amongst investors. In this environment options trades should be especially informative since payoffs from such trades are larger.

To test this hypothesis, I classify announcements into high and low uncertainty by economist forecast dispersion. Forecast dispersion values for each macroeconomic announcement are taken from Bloomberg, and are calculated as the standard deviation among economist estimates for each indicator. Forecast dispersion can interpreted as the level of disagreement amongst economists regarding a specific economic indicator (Andersen et al., 2003). I treat forecast dispersion as a proxy for macroeconomic uncertainty, with high(low) dispersion signaling high(low) uncertainty for that economic variable. If options traders have a significant information advantage regarding the outcomes of macroeconomic news events, then options prices should demonstrate increased predictability during periods of high uncertainty.

To classify announcements by their uncertainty, each announcement is sorted into quintiles based on its economist forecast dispersion over the entire sample. An announcement is considered "high uncertainty" if it falls within the highest quintile of forecast dispersion for that type of the announcement in the sample. An announcement is considered "low uncertainty" if it falls within the lowest quintile.

In addition to announcements being partitioned by uncertainty, I specifically target meeting days of the Federal Open Market Committee (FOMC). FOMC meetings are treated differentially as opposed to other announcements for two reasons. First, federal funds rate changes are infrequent. Therefore, when economists do forecast rate changes, the dispersion among them is very small making it difficult to classify high and low uncertainty days. Second, the literature has shown that asset prices not only respond to policy actions, but also communications relayed by the Fed regarding it's future policy tilt (Rosa, 2011). Even when a policy action is not imminent, option traders may have an advance understanding of the market response to the Fed's statement. If the option market does successfully anticipate stock market response to the meetings of the FOMC, the options proxies should display increased significance prior to these days.

In a set of time-series regressions I include dummy variables for high and low uncertainty announcements, FOMC days, and interaction terms. The specification takes the form:

$$\begin{aligned} Exret_{t+1} = \beta_o &+ (\beta_1 + \beta_2 HU_{t+1} + \beta_3 LU_{t+1} + \beta_4 F_{t+1}) * Skew_t \\ &+ (\beta_5 + \beta_6 HU_{t+1} + \beta_7 LU_{t+1} + \beta_8 F_{t+1}) * Spread_t \\ &+ \beta_9 HU_{t+1} + \beta_{10} LU_{t+1} + \beta_{11} F_{t+1} + \beta_{12} Ret_t + \epsilon_t \end{aligned} \quad (1.3)$$

where $Exret_{t+1}$ is the daily one day ahead excess return on the S&P 500 index, and $Skew_t$ and $Spread_t$ are measured using the same methodology as regression (1.3). HU_{t+1} is a dummy variable which takes on a value of 1 if the announcement on day *t+1* is in the highest quintile of forecast dispersions, 0 otherwise. LU_{t+1} is dummy a variable which takes on a value of 1 if that announcement on day *t+1* is in the lowest quintile of forecast dispersions, 0 otherwise.[2] F_{t+1} takes on a value of 1 if on day *t+1* a FOMC meeting occurs, 0 otherwise.

If the information asymmetry hypothesis is correct, then the coefficients on the interaction terms between option measures, high uncertainty days, and FOMC days ($\beta_2, \beta_6, \beta_4, \beta_8$) will display increased significance. Results for this regression are displayed in Table 1.3.

[2] For days with multiple macroeconomic announcements occurring, if the number of high uncertainty economic indicators is greater than number of low uncertainty economic indicators then HU_{t+1} takes a value of 1. If the number of high uncertainty announcements is less than low uncertainty indicators, LU_{t+1} takes a value of 1. If they are equal, both dummies take a value of 0. The results are quantitatively similar if days with multiple announcements are not classified by forecast dispersion.

1.4.3 Results

Model 1 in Table 1.3 lists the regression results utilizing the skew variables and interaction terms. The variables of in this table are the FOMC high and low uncertainty interactions (F,HU,LU, respectively). The interaction term for high uncertainty and skew has a coefficient of -0.129. This coefficient displays statistical significance very close to 5% across all three models. In models 3 and 5, the high uncertainty and skew coefficients have values -0.129 and -0.126, respectively. This is a strong indicator that when economic uncertainty is high, the skew predicts low announcement day returns.

In model 1, the coefficient on the high uncertainty (HU) variable is .015 with a t-stat of 2.04, which is statistically significant at a 5% confidence interval. The HU dummy variable indicates there is a positive relationship between announcement day returns and forecast uncertainty. The values for this variable do not significantly change across the three models for which it is included.

Taken collectively, these findings lend strong support to the notion that options prices have predictive power for macroeconomic news days. During periods of high uncertainty, options traders can successfully anticipate low returns caused by the arrival of negative news. Prior to the announcement, options traders bid up the prices of OTM puts and steepen the IV skew. The significance of the positive coefficient on the HU term also provides evidence that the skew result is information-driven. In other words, high uncertainty days normally predict high excess returns-except in the presence of large IV skew.

While it appears that options traders engage in OTM put buying ahead of bad news, there is no similar relationship between call buying and good news for Non-FOMC announcements.[3] The coefficients associated with the high and low uncertainty spread interactions are not statistically significant in any model.

Model 2 in Table 1.3 adds the F (FOMC) variable along with the skew and spread interaction terms. The coefficient on the $(F * spread)$ term is 0.154, with a highly significant t-statistic of 3.46, indicating that the spread positively predicts FOMC announcement day returns. This suggests that on the day prior to FOMC announcements, informed option

[3] In the context of security returns, bad news is synonymous with low returns, as is good news with high returns.

traders purchase calls in anticipation of positive returns. This finding remains consistent in both models 4 and 5 with coefficients of 0.154 and 0.158, respectively. Such a result carries and interesting implication for option pricing around FOMC days. However, The $(FOMC * skew)$ coefficient is insignificant across both models.

These findings of a significant skew closely relate to those of Xing et al. (2010), who find that the skew can predict negative returns for individual stocks. However, the authors conduct cross-sectional regressions using week-long holding period returns, whereas I investigate single day returns. The coefficient on the skew variable is also not significant in my results, meaning it cannot unconditionally predict returns. This is not surprising, since OTM puts are heavily trafficked by traders, and any predictive power is likely to arbitraged away quickly on non-announcement days. The positive coefficient on FOMC days is consistent with the results of Cremers and Weinbaum (2010), who find that buying pressure reflected in call IVs predicts positive stock returns. In the context of my results, the interaction coefficient on $(FOMC * spread)$ shows predictive power for positive FOMC announcement day returns, meaning informed traders purchase calls ahead of positive FOMC releases.

Given the significance of the time-series coefficients of the skew and spread, the natural next step is to test whether a strategy based on these measures can earn excess returns. In the following section, I test two strategies to determine the economic significance of the skew and the spread.

Table 1.3: Time-Series Regression Analysis with Forecast Dispersion Interactions

Model	C	Skew	HighU	LowU	Skew*HU	Skew*LU	FOMC	F*Skew	RetL	Spread	Spread*HU	Spread*LU	F*Spread	DF	R^2
1	-0.0017	0.0188	0.0153	-0.0010	-0.1290	0.0077	-0.0103	0.1068	-0.0602					1249	0.0094
	-0.7995	1.0115	2.0988**	-0.2350	-1.9540*	0.2093	-0.6803	0.7598	-1.3749						
	0.4241	0.3120	0.0360**	0.8143	0.0509*	0.8343	0.4964	0.4475	0.1694						
2	0.0005		0.0003	0.0000			0.0011		-0.0629	-0.0274	0.0655	0.0061	0.1530	1249	0.0066
	1.5197		0.2656	-0.0065			0.6491		-1.2741	-1.0352	0.7110	0.0839	2.9812***		
	0.1288		0.7906	0.9948			0.5164		0.2029	0.3008	0.4772	0.9331	0.0029***		
3	-0.0018	0.0207	0.0150	-0.0016	-0.1264	0.0132			-0.0659	-0.0086	0.0532	0.0009		1248	0.0108
	-0.9225	1.1705	2.0410**	-0.3529	-1.8880*	0.3469			-1.3158	-0.3326	0.5935	0.0119			
	0.3564	0.2420	0.0415**	0.7243	0.0593*	0.7287			0.1885	0.7395	0.5530	0.9905			
4	-0.0005	0.0092					-0.0123	0.1170	-0.0562	-0.0185			0.1538	1251	0.0122
	-0.2954	0.5572					-0.8512	0.8805	-1.2611	-0.7743			3.3167***		
	0.7677	0.5775					0.3948	0.3787	0.2075	0.4389			0.0009***		
5	-0.0015	0.0174	0.0152	-0.0006	-0.1294	0.0042	-0.0126	0.1196	-0.0571	-0.0223	0.0643	-0.0107	0.1583	1245	0.0181
	-0.7300	0.9456	2.0772	-0.1380	-1.9306*	0.1146	-0.8659	0.8960	-1.2880	-0.8520	0.7225	-0.1435	3.4605***		
	0.4655	0.3445	0.0380**	0.8903	0.0538*	0.9088	0.3867	0.3704	0.1980	0.3944	0.4701	0.8859	0.0006***		

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

1.5 Trading Strategies

In this section, I explore the economic significance of the informed options indicators by implementing a trading strategy for macroeconomic announcement days. Each strategy utilizes a simple set of filter rules or conditions that execute a long trade when satisfied.

1.5.1 Skew Strategy

The first strategy in this subsection focuses on the predictive power of the IV skew for high uncertainty announcements. This strategy takes a long position in the S&P 500 index if the conditions are met:

1. Trading day t is a macroeconomic announcement day (Non-FOMC).
2. The announcement falls into the highest uncertainty quintile.[4]
3. The IV skew on day t-1 is in upper 80th percentile of skew values.

The position is always closed at the end of each trading day. If the filter requirements are not met, the strategy is flat on that day. Table 1.4 and 1.5 list trade dates, S&P 500 returns, trade position (long or flat) and cumulative returns. The sample covers the period of January 2010 to December 2014. It is important to note that each trade executed is strictly based on information readily available to market participants at time t.

Long trades are executed a total of 50 times over the sample period. This strategy earns a highly negative cumulative return of -12.1%. While this strategy is tested over a period of five years, it is evident that a large negative return is earned only on very small portion of total trading days in the entire sample (approximately 4.0% of all days).

A possible explanation for the performance of the skew strategy is that high uncertainty days inherently have low returns. However, this notion would not be consistent with the fact that stock market average returns should be higher on announcement days due to higher conditional risk (Savor and Wilson, 2013). Nonetheless, I investigate this possibility using a simple strategy which always takes a long position on any high uncertainty news day, which occurs 101 times. Table 1.4 also lists the cumulative returns from the simple high

[4] Quintiles are formed based on the previous year's economist forecast deviations for each type of announcement

uncertainty strategy. It earns a small negative cumulative return of -0.11%. This provides evidence that simply trading on high uncertainty announcements does not provide significantly negative profits.

As a robustness check, I test the null hypothesis of equal mean returns between long and flat days using a Wilcoxon Rank-Sum Test. I choose this test over the standard T-Test due to the non-normality of returns and relatively small size of the sample distributions. The average return of the long strategy is -0.25% compared to 0.25% for flat days. The null hypothesis of equal means is rejected at 5% confidence interval with a p-value of 0.046.

1.5.1.1 Sharpe Ratios

In order to explore risk-adjusted returns, I calculate the daily Sharpe ratio for the skew strategy, the simple high uncertainty strategy and overall market during the sample period. However, these Sharpe ratios should be interpreted with caution, given the infrequency of the strategies.[5] The skew strategy has a daily Sharpe ratio of -0.040 compared to the simple high uncertainty strategy of 0.0012.

Taking a long position in the S&P 500 during this period would have yielded 0.054. This evidence also lends strong support to the information driven hypothesis, since the skew strategy generates significant negative returns during a largely bull market.[6]

These results demonstrate the large economic significance of the skew for macroeconomic announcement days. It is consistent with the notion that during periods when information asymmetry is large, informed traders with negative information regarding macroeconomic fundamentals trade out-of-the-money put options on the aggregate market.

---

[5] For example, under these filter rules the skew strategy takes a flat position during the entire year of 2012. Therefore, the Sharpe ratio may be misleading describing returns on a risk-adjusted basis.

[6] Modifying the skew strategy to take short positions on all days when the filter is met, and long positions on all other days outperforms the overall market with a ratio of 0.068.

Table 1.4: Returns from Skew Strategy and Simple High Uncertainty Strategy

Date	S%P 500 Ret.	Pos.	Skew. Strat	HighU Strat.
20-Jan-10	-0.01060	L	-0.01060	-0.01060
24-Mar-10	-0.00549	F	-0.01060	-0.01603
30-Mar-10	0.00004	F	-0.01060	-0.01599
23-Apr-10	0.00712	F	-0.01060	-0.00898
26-May-10	-0.00566	L	-0.01620	-0.01459
4-Jun-10	-0.03441	L	-0.05005	-0.04850
26-Jul-10	0.01120	L	-0.03941	-0.03784
25-Aug-10	0.00329	L	-0.03625	-0.03468
24-Sep-10	0.02119	L	-0.01583	-0.01422
27-Oct-10	-0.00269	F	-0.01583	-0.01687
24-Nov-10	0.01492	L	-0.00114	-0.00220
23-Dec-10	-0.00164	L	-0.00278	-0.00384
14-Jan-11	0.00738	F	-0.00278	0.00351
22-Feb-11	-0.02053	L	-0.02325	-0.01709
24-Feb-11	-0.00099	L	-0.02423	-0.01806
23-Mar-11	0.00291	F	-0.02423	-0.01520
29-Mar-11	0.00706	L	-0.01734	-0.00825
14-Apr-11	0.00008	L	-0.01725	-0.00817
15-Apr-11	0.00393	L	-0.01340	-0.00427
25-Apr-11	-0.00159	F	-0.01340	-0.00586
25-May-11	0.00318	F	-0.01340	-0.00269
31-May-11	0.01059	F	-0.01340	0.00787
1-Jun-11	-0.02278	L	-0.03588	-0.01509
15-Jun-11	-0.01743	F	-0.03588	-0.03226
1-Jul-11	0.01441	L	-0.02198	-0.01832
15-Jul-11	0.00555	F	-0.02198	-0.01287

Continued on next page

Table 1.4 – continued from previous page

Date	S%P 500 Ret.	Pos.	Skew Strat.	HighU Stra.	
26-Jul-11	-0.00410	F	-0.02198		-0.01692
18-Aug-11	-0.04459	L	-0.06560		-0.06076
24-Aug-11	0.01312	L	-0.05334		-0.04843
30-Aug-11	0.00235	L	-0.05112		-0.04620
1-Sep-11	-0.01187	L	-0.06238		-0.05752
14-Sep-11	0.01348	F	-0.06238		-0.04482
15-Sep-11	0.01719	F	-0.06238		-0.02840
28-Sep-11	-0.02069	L	-0.08178		-0.04851
3-Oct-11	-0.02845	L	-0.10791		-0.07558
15-Nov-11	0.00482	L	-0.10361		-0.07112
29-Nov-11	0.00221	L	-0.10162		-0.06907
16-Dec-11	0.00322	L	-0.09873		-0.06607
23-Dec-11	0.00904	F	-0.09873		-0.05764
27-Dec-11	0.00008	F	-0.09873		-0.05756
19-Jan-12	0.00494	F	-0.09873		-0.05291
26-Jan-12	-0.00575	F	-0.09873		-0.05835
12-Apr-12	0.01378	F	-0.09873		-0.04537
17-Apr-12	0.01549	F	-0.09873		-0.03059
13-Jun-12	-0.00702	F	-0.09873		-0.03740
14-Jun-12	0.01081	F	-0.09873		-0.02699
13-Jul-12	0.01650	F	-0.09873		-0.01094
17-Jul-12	0.00741	F	-0.09873		-0.00361
24-Aug-12	0.00645	F	-0.09873		0.00282
14-Sep-12	0.00396	F	-0.09873		0.00679
27-Sep-12	0.00965	F	-0.09873		0.01651
12-Oct-12	-0.00297	F	-0.09873		0.01349
16-Oct-12	0.01027	F	-0.09873		0.02390

Continued on next page

Table 1.4 – continued from previous page

Date	S%P 500 Ret.	Pos.	Skew Strat.	HighU Stra.	
25-Oct-12	0.00300	F	-0.09873		0.02697
14-Dec-12	-0.00414	F	-0.09873		0.02272
19-Dec-12	-0.00759	F	-0.09873		0.01496
27-Dec-12	-0.00122	F	-0.09873		0.01372
4-Jan-13	0.00487	L	-0.09435		0.01866
29-Jan-13	0.00511	F	-0.09435		0.02386
20-Feb-13	-0.01240	L	-0.10558		0.01116
26-Feb-13	0.00611	L	-0.10012		0.01734
15-Mar-13	-0.00162	L	-0.10158		0.01569
19-Mar-13	-0.00242	L	-0.10375		0.01323
26-Mar-13	0.00779	L	-0.09677		0.02112
5-Apr-13	-0.00429	L	-0.10065		0.01673
12-Apr-13	-0.00284	F	-0.10065		0.01385
30-Apr-13	0.00248	F	-0.10065		0.01637
16-May-13	-0.00501	F	-0.10065		0.01127
3-Jun-13	0.00594	F	-0.10065		0.01728
18-Jun-13	0.00779	F	-0.10065		0.02520
16-Jul-13	-0.00371	F	-0.10065		0.02140
17-Jul-13	0.00277	F	-0.10065		0.02423
24-Jul-13	-0.00381	F	-0.10065		0.02033
16-Aug-13	-0.00330	F	-0.10065		0.01696
23-Aug-13	0.00395	L	-0.09710		0.02097
26-Aug-13	-0.00404	L	-0.10075		0.01685
3-Sep-13	0.00416	L	-0.09701		0.02108
25-Sep-13	-0.00274	F	-0.09701		0.01829
1-Oct-13	0.00800	L	-0.08978		0.02643
1-Nov-13	0.00290	L	-0.08714		0.02941

Continued on next page

Table 1.4 – continued from previous page

Date	S%P 500 Ret.	Pos.	Skew Strat.	HighU Stra.	
26-Nov-13	0.00015	L	-0.08700		0.02956
2-Dec-13	-0.00272	L	-0.08949		0.02676
24-Dec-13	0.00292	L	-0.08683		0.02976
31-Dec-13	0.00396	L	-0.08322		0.03384
17-Jan-14	-0.00390	L	-0.08679		0.02981
7-Feb-14	0.01330	F	-0.08679		0.04351
14-Feb-14	0.00481	L	-0.08240		0.04853
19-Feb-14	-0.00652	L	-0.08838		0.04169
3-Mar-14	-0.00738	L	-0.09511		0.03400
25-Mar-14	0.00440	L	-0.09112		0.03855
4-Apr-14	-0.01254	F	-0.09112		0.02553
15-May-14	-0.00936	F	-0.09112		0.01593
23-May-14	0.00425	F	-0.09112		0.02025
6-Jun-14	0.00463	F	-0.09112		0.02497
24-Jul-14	0.00049	F	-0.09112		0.02547
26-Aug-14	0.00105	L	-0.09017		0.02655
25-Sep-14	-0.01617	L	-0.10488		0.00995
24-Oct-14	0.00705	F	-0.10488		0.01707
1-Dec-14	-0.00683	L	-0.11099		0.01013
15-Dec-14	-0.00634	L	-0.11663		0.00372
30-Dec-14	-0.00489	L	-0.12095		-0.00119

1.5.2 Spread Strategy

In this subsection I explore the economic significance of the implied volatility spread by implementing a trading strategy on FOMC days. Each strategy utilizes a simple set of filter rules or conditions in order for a trade on the news day to be executed.

I implement a trading strategy which focuses on the predictive power of the IV spread for FOMC announcements. This strategy takes a long position in the S&P 500 index if the conditions are met:

1. Trading day t is an FOMC announcement day.
2. The IV spread on day t-1 is in upper 60th percentile of spread values.[7]

The position is always closed at the end of each trading day. If the filter requirements are not met, the strategy is flat on that day. Table 1.5 list trade dates, S&P 500 returns, trade position (long or flat) and cumulative returns. The sample covers the period of January 2010 to December 2014. It is important to note that each trade executed is strictly based on information readily available to market participants at time t.

Table 1.6 displays summary statistics for returns to long and flat positions on FOMC days. Long trades are executed a total of 18 times during the sample. The average return for a long position is 0.41%, compared to 0.11% for a flat position. To test the significance of this result, I again apply a two-sided Wilcoxon Rank-Sum Test in order to determine whether mean returns are different across days. It has a two-sided p-value of .7778. Therefore, the null hypothesis of equal mean returns of long position and flat position days cannot be rejected. Given this evidence, I am unable to confirm the economic significance of the spread strategy.

However, the standard deviation of returns more than *doubles* across long days (1.66%) compared to flat position days (0.730%).[8] Therefore, it is possible that call buying pressure (or large deviations from put call parity) precede FOMC announcements that induce changes in realized volatility. However, I leave this as an open topic for further research.

---

[7] The 60th percentile is chosen as a cutoff in order to ensure a reasonable amount of trades occur throughout the sample.

[8] To add statistical rigor, an F-test rejects a null hypothesis of equal variances between the two samples for $p < .01$.

1.5.3 Pre-FOMC Option Explanations

In this subsection I propose several possible explanations for observed significance of the IV spread prior to FOMC meetings.The first is that the IV spread is correlated with priced risk factor that is primarily arises on these days. Given the much higher deviation of returns preceding large spread days, it is possible that the spread is correlated to higher-order moments of the return distribution. For example, Amengual and Xiu (2014) note that downward volatility jumps are due to resolution of policy uncertainty, through statements made during FOMC meetings. These jumps are priced with a positive premia, and calls would have a positive exposure to this type of risk. On the other hand, OTM puts have negative exposure to downside volatility. An investor is far less likely to be concerned with left-tail returns on days when downside volatility jumps are more common. My future research intends explore this idea further by controlling for different types of volatility premia.

Table 1.5: Returns from Spread FOMC Strategy

Date	S%P 500 Ret.	Position	Spread
27-Jan-10	0.00488	F	0.00492
16-Mar-10	0.00778	F	-0.00014
28-Apr-10	0.00646	F	-0.00873
23-Jun-10	-0.00299	F	0.00022
10-Aug-10	-0.00597	F	-0.01152
21-Sep-10	-0.00256	L	0.00611
3-Nov-10	0.00368	F	-0.00871
14-Dec-10	0.00091	L	0.01260
26-Jan-11	0.00422	F	-0.01263
15-Mar-11	-0.01120	L	0.01167
27-Apr-11	0.00625	F	-0.00469
22-Jun-11	-0.00647	L	0.00604
9-Aug-11	0.04741	L	0.02654
21-Sep-11	-0.02939	L	0.01589
2-Nov-11	0.01610	L	0.14410
13-Dec-11	-0.00869	L	0.00515
25-Jan-12	0.00867	F	-0.01480
13-Mar-12	0.01813	L	0.00742
25-Apr-12	0.01364	F	-0.01213
20-Jun-12	-0.00169	F	-0.00039
1-Aug-12	-0.00303	L	0.00734
13-Sep-12	0.01631	L	0.00634
24-Oct-12	-0.00309	L	0.01029
12-Dec-12	0.00045	F	0.00134
30-Jan-13	-0.00390	F	-0.00254
20-Mar-13	0.00670	L	0.01596
1-May-13	-0.00931	F	-0.01301

Continued on next page

Table 1.5 – continued from previous page

Date	S%P 500 Ret.	Position	Spread
19-Jun-13	-0.01385	F	0.00086
31-Jul-13	-0.00014	L	0.00592
18-Sep-13	0.01218	F	0.00271
30-Oct-13	-0.00488	F	-0.01018
18-Dec-13	0.01665	L	0.01775
29-Jan-14	-0.01021	F	-0.01367
19-Mar-14	-0.00613	L	0.00797
30-Apr-14	0.00299	F	-0.01231
18-Jun-14	0.00772	F	0.00383
30-Jul-14	0.00006	F	-0.00291
17-Sep-14	0.00130	L	0.01611
29-Oct-14	-0.00139	F	-0.02489
17-Dec-14	0.02035	L	0.03494

Table 1.6: Summary Statistics for FOMC Spread Strategy

This table lists summary statistics for the spread strategy on FOMC days during the period of Jan 01, 2010 to Dec 31, 2014. Long position days are taken when the spread on day $t-1$ is in the upper 60th percentile of previous spreads. Flat positions are taken when the spread is the lower 60th percentile of previous spreads.

P	N	Mean	Std	Min	Max	Skewness	Kurtosis
All FOMC	40	0.00245	0.0123	-0.0294	0.0474	0.9253	4.0442
Flat	22	0.0011	0.0073	-0.0138	0.0136	-0.2769	-0.5287
Long	18	0.0041	0.0166	-0.0294	0.0474	0.6835	1.9197

1.6 Portfolio Analysis

In this section, I analyze whether options prices have varying predictability based on a basket of options written on characteristic stock portfolios. While it may seem unnatural for an option trader to capitalize on macroeconomic information using firm-level options, these derivatives may be more attractive than index options. Options traders may look to transact in options whose underlying security is highly sensitive to information contained in news announcements, which present greater opportunities for excess returns. Two clear choices of underlying characteristics are based on stock sector and beta.

Individual option data is available through the Ivy DB Optionmetrics database. It is then matched with individual stock return data from CRSP. This analysis only utilizes firms that are constituents in the S&P 100.[9] Cyclical stocks are highly sensitive to macroeconomic announcements, therefore these stocks should attract more informed traders prior to the news releases. Industry classification for cyclical and defensive stocks is based on Boudoukh et al. (1994) and Beber and Brandt (2009). Cyclical industries include primary metals, transportation equipment, rubber and plastics, metal products, and electrical machinery. Defensive industries are food and beverage, tobacco, utilities, printing and publishing, and petroleum products.

The second part of the analysis explores whether options predictability differs based on underlying stock beta. Savor and Wilson (2014) show that stock market beta is strongly related to average returns on macroeconomic news days. In turn, trades in options that have higher underlying stock beta should be more reflective of their announcement day returns than returns in lower stock beta equities. First, all S&P 100 constituents are sorted into quintile portfolios based on daily beta over the previous 200 trading days. Portfolios are then rebalanced yearly.

Table 1.7 provides summary statistics for the underlying stock portfolios and option measures. This analysis uses equal weighted portfolio returns. The average daily firm IV skew is .053, which indicates that firm OTM put options are typically 5.3% more expensive than ATM calls. In comparison, the index IV skew is more than 2 times steeper on average,

[9] Beber and Brandt (2009) utilize a similar selection methodology. This is done to ensure individual option liquidity, since inclusion requires a liquid option market for that stock.

Table 1.7: Summary Statistics for Individual Options on S&P 100 Constituents

This table represents daily summary statistics for all SP 100 constituents. It lists statistics for grand returns, grand implied volatility skews, and grand implied volatility spreads during the period of Jan 01, 2010 to Dec 31, 2014.

Variable	N	Mean	STD	Min	Max	Skew	Kurtosis
Returns	141875	0.0007	0.0161	-0.2187	0.3409	0.1172	11.3787
IV Skew	121652	0.0532	0.0287	-0.2601	0.4245	0.8219	4.2601
O.I. Spread	138018	-0.0013	0.0185	-0.3734	0.4254	-0.1404	26.7111

at 10.9%. This is consistent with the empirical evidence of steeper index skews compared to individual options. The open interest spreads on average are -.13%, implying put options are more expensive than calls.

Table 1.8: Summary Statistics for Cyclical Portfolios

This table represents daily summary statistics for portfolios formed by cyclical and defensive sector. It lists statistics for portfolio returns, implied portfolio volatility skew, and the implied portfolio volatility spread during the period of Jan 01, 2010 to Dec 31, 2014. All equities are equal weighted within each portfolio.

Portfolio	Variable	N	Mean	STD	Min	Max
Cyclical	Returns	1258	0.0005	0.0132	-0.0848	0.1040
	IV Skew	1257	0.0514	0.02067	-0.0451	0.1490
	Spread	1257	0.0006	0.0118	-0.0706	0.1093
Defensive	Returns.	1258	0.0006	0.0084	-0.0513	0.0514
	IV Skew	1252	0.0486	0.0163	-0.0046	0.1173
	Spread	1257	-0.0025	0.0112	-0.0743	0.0926

1.6.1 Cyclical Stocks

In order to test the predictability of option prices on cyclical stock returns I adopt the same time series approach as in section 1.4. The same vector of uncertainty and event dummy variables is applied to each portfolio regression. However, to calculate a single skew and spread measure for each portfolio daily, the skews and spreads of each individual option within the portfolio are averaged together. Returns are equal-weighted within the portfolio. Table 1.8 contains descriptive statistics of the cyclical and defensive portfolios for the entire sample. Both portfolios have similar average daily returns at 0.054% and 0.059% for cyclical and defensive, respectively. However, the standard deviation of the cyclical portfolio is higher at 1.3%. The cyclical skew and defensive skew portfolio means are 5.1% and 4.9%, respectively. Spreads on cyclical stock options are much larger than defensive counterparts. Call options are 0.058% more expensive than puts for cyclical stocks, but puts are 0.25% more expensive for defensive stocks.

Table 1.10 details the composition of the cyclical and defensive portfolios on the final day of the sample. Although some firms are added and deleted from the the S&P 100, I do not provide a year-by-year description. Next I address the empirical setup for the portfolios.

Non-overlapping daily portfolio returns are then regressed on the informed options proxies augmented with dummy and interaction variables. It takes the following form:

$$\begin{aligned}Exret_{p,t+1} = \beta_o + (\beta_1 + \beta_2 HU_{t+1} + \beta_3 LU_{t+1} + \beta_4 F_{t+1}) * Skew_{p.t} \\ + (\beta_5 + \beta_6 HU_{t+1} + \beta_7 LU_{t+1} + \beta_8 F_{t+1}) * Spread_{p,t} \\ + \beta_9 HU_{t+1} + \beta_{10} LU_{t+1} + \beta_{11} F_{t+1} + \epsilon_t \quad (1.4)\end{aligned}$$

where $Exret_{p,t+1}$ is the daily one day ahead excess return on portfolio p (cyclical or defensive), and $Skew_{p,t}$ and $Spread_{p,t}$ represent daily averages of the skew and spread measures within that portfolio, HU_{t+1} is a dummy variable which takes on a value of 1 if the announcement on day *t+1* is in the highest quintile of forecast dispersions, 0 otherwise. LU_{t+1} is dummy a variable which takes on a value of 1 if that announcement on day *t+1* is in the lowest quintile of forecast dispersions, 0 otherwise. F_{t+1} takes on a value of 1 if on day *t+1* a FOMC meeting occurs, 0 otherwise. Again, the Newey and West (1986) adjustment is applied for autocorrelation and heteroskedascity.

Table 1.9 details the time series results for the cyclical portfolio regressions. The skew variable is highly positively significant (.082) with a p-value of 0.007. The HighU dummy coefficient of 0.0067 also displays significance at a 10% confidence level. Similar to the result found for the S&P 500 regressions, uncertainty and announcement day returns display a positive relationship.

However, when the skew variable is interacted with the HighU dummy it generates a negative coefficient of -0.12 and is significant at a 10% level. This is of similar magnitude to found aggregate market regressions (-0.13). It indicates that information regarding negative macroeconomic news is also contained in cyclical stock options for uncertainty announcements.

Moving to the FOMC terms, the FOMC dummy coeffcient displays strong positive significance (0.012). This is consistent with the finding that cyclical sector returns are responsive to FOMC announcements (Bernanke and Kuttner, 2005). The skew term prior to FOMC days is significant (-0.25) at a 1% level. In contrast, the same skew coefficient was not significant in the aggregate market regression. One possibility for this result is that investors in cyclical sectors are especially cognizant of downside risk in the event of unfavorable FOMC outcomes. Therefore, the skew would be more pronounced prior to FOMC days for only these types of securities. This explanation is consistent with the findings of (Beber and Brandt, 2009). The authors document only a small reduction of implied volatilities of the aggregate market upon release of highly uncertain announcements, which is due to the non-responsiveness of the non-cyclical components. However, when the broad market is disaggregated into portfolios, cyclical stocks display a pronounced reduction in volatility.

The $(FOMC * Spread)$ interaction term has a coefficient of 0.010, but is insignificant. The spread terms also do not display significance for HighU or LowU days. Therefore, I cannot conclude that call buying pressure precedes high returns days for these announcements.

For the defensive portfolio, the high uncertainty interaction terms are insignificant. This result is consistent with the fact that defensive stock returns do not generally exhibit a high sensitivity to macroeconomic news, therefore there should be no compelling reason for traders to open option positions prior to the announcement. On the other hand, the spread coefficient (0.20) on FOMC days is statistically significant at a 5% level. IV spreads on defensive stocks positively predict FOMC day returns. The spread does not predict other types of announcement day returns. Again, it is difficult to reconcile this finding with the informed trading hypothesis, since defensive stocks are not the ideal vechile to speculate on macroeconomic news.

It is possible that the spread in in this portfolio may be a serving as a proxy for other risk factors that manifest on FOMC days, such as variance risk or upside volatility.

To summarize, the findings of this analysis lend strong support to the hypothesis that informed trading also occurs in options on individual stocks sorted by industry prior to macroeconomic announcements. Options prices contain information regarding upcoming news, indicating that options traders are able to correctly anticipate the announcement. For cyclical stocks, the skew serves as a strong predictor of bad news before high uncertainty announcements and FOMC meetings. The predictability of the skew for these stocks is due to greater sensitivity of the underlying equity for bad FOMC news.

Table 1.9: Beta Portfolio Regressions

	C	Skew	Spread	HU	LU	Skew*HU	Skew*LU	Spread*HU	Spread*LU	F	F*Spread	F*Skew	N	R^2
Cyc.	-0.00376	0.08191	0.04576	0.00661	0.00340	-0.11825	-0.07986	-0.11927	0.08637	0.01223	0.09955	-0.25338	1240	0.0238
	-2.39664**	2.70572***	0.80856	1.91164*	0.70434	-1.87220*	-0.83069	-0.88747	0.69487	2.91326***	1.33617	-2.91197***		
	0.01669**	0.00691***	0.41892	0.05615*	0.48135	0.06141*	0.40631	0.37500	0.48727	0.00364***	0.18174	0.00366***		
Def.	-0.00034	0.01920	0.02737	0.00379	0.00292	-0.07021	-0.06255	-0.09753	-0.10639	0.00098	0.19707	-0.03017	1245	0.0128
	-0.33532	0.87277	0.92968	1.11983	1.19199	-1.00628	-1.10171	-1.42224	-1.20344	0.18316	2.30646**	-0.25962		
	0.73744	0.38296	0.35272	0.26300	0.23349	0.31448	0.27080	0.15521	0.22904	0.85470	0.02125**	0.79520		

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.10: Cyclical and Defensive Portfolio Composition

This table lists the composition of cyclical and defensive portfolios taken from S&P 100 constituents. It represents the remaining companies on the last day of the sample on Dec 31, 2014.

Portfolio	Companies
Cyclical	HONEYWELL INTERNATIONAL INC
	GENERAL DYNAMICS CORP
	GENERAL MOTORS CO
	NIKE INC
	CISCO SYSTEMS INC
	TEXAS INSTRUMENTS INC
	UNITED TECHNOLOGIES CORP
	QUALCOMM INC
	LOCKHEED MARTIN CORP
	EMERSON ELECTRIC CO
Defensive	CONOCO PHILLIPS
	TWENTY FIRST CENTURY FOX INC
	PHILIP MORRIS INTERNATIONAL INC
	EXELON CORP
	SOUTHERN CO
	ALTRIA GROUP INC

1.6.2 Beta Stocks

In this subsection, I employ the same empirical methodology using portfolios formed on underlying stock beta. Beta is estimated using daily returns from the previous year for all S&P 100 constituents. Stocks are then sorted into beta quintiles and rebalanced yearly. Firms that have a missing skew or spread variable on day *t-1* are dropped from the portfolio. Table 1.11 provides summary statistics at a daily frequency for each portfolio. Portfolio 0 represents stocks in the lowest quintile of betas. Portfolio 3 contains the largest average returns over the sample at 0.08%. As expected, the portfolio average returns indicate there is no discernible relationship between beta and returns at a daily frequency.

Average portfolio IV skews display similar magnitude to the daily all constituent average (.053). Daily skews have a higher standard deviation for higher beta porfolios. Curiously, the open interest spread monotonically increases from low to high beta portfolios. In the lowest beta quintile, puts in the average portfolio are 0.19% more expensive than calls. In the highest beta quintile, the average portfolio put is only 0.053% more expensive than its matching call. Similar to the previous subsubsection, Table 1.13 details the composition of each ranked beta portfolios on the final day of the sample.

Regression results for each beta portfolio are displayed in table 1.12. The $Skew * HU$ coefficient exhibits monotonic increasing significance with higher beta portfolios. Coefficients for portfolio 3 (-0.216) and portfolio 4 (-0.257) are statistically significant at the 10% and 5% level, respectively. For lower beta portfolios (0-3), these coefficients are insignificant. The dummy variable HU terms for portfolios 3 and 4 have positive coefficients, highlighting the positive uncertainty-return trade off.

Interestingly, the $Skew * LU$ terms also demonstrate significance for higher beta portfolios. This result does not appear in the aggregate market or cyclical portfolios. Portfolios 2 and 3 show the strongest significance at a 5% level with coefficients of -0.211 and -0.208. My results provide evidence that skews on high beta stocks can also anticipate bad news on low uncertainty days. Following my hypothesis, the greater high beta stock sensitivity to macroeconomic state variables than the aggregate market create more opportunities for profitable trades on all types of news days (high and low uncertainty). When considering the aggregate market regressions, it is likely that this same result does not appear for the LowU days due to the unresponsiveness of the low beta constituents.

Table 1.11: Summary Statistics for Beta Portfolios

This table represents daily summary statistics for portfolios formed by underlying stock beta. S&P 100 constituent firms are sorted into portfolios based on the previous year's daily returns. Portfolios are rebalanced yearly. Portfolio 0 contains the lowest quintile beta stocks in the S&P 100, and portfolio 4 contains the highest. It lists statistics for the portfolio returns, implied portfolio volatility skew, and the implied portfolio volatility spread during the period of Jan 01, 2010 to Dec 31, 2014. All equities are equal weighted within each portfolio.

Variable	Beta Portfolio	N	MEAN	STD	MIN	MAX
Portfolio Ret	0	1257	0.00051	0.00704	-0.04202	0.03405
	1	1257	0.00073	0.00888	-0.05232	0.03902
	2	1257	0.00068	0.01060	-0.06289	0.04798
	3	1257	0.00077	0.01288	-0.07903	0.05896
	4	1257	0.00037	0.01560	-0.10798	0.07951
IV Skew	0	1257	0.04932	0.01462	0.02094	0.12077
	1	1257	0.05321	0.01441	0.02335	0.11826
	2	1257	0.05482	0.01521	0.01486	0.16517
	3	1257	0.05349	0.01722	0.01767	0.14481
	4	1257	0.05311	0.01801	0.00779	0.17111
O.I. Spread	0	1257	-0.00193	0.00864	-0.04533	0.08863
	1	1257	-0.00147	0.00919	-0.05305	0.08397
	2	1257	-0.00092	0.01024	-0.09700	0.08263
	3	1257	-0.00076	0.01126	-0.09490	0.12583
	4	1257	-0.00053	0.01093	-0.10346	0.13396

In contrast, the only FOMC variable to display any statistical significance is the spread within portfolio 2. Given the lack of consistency across portfolios, I cannot conclude that options prices within beta portfolios also reflect future information found in FOMC announcements. Again, there is a possibility is that the spread in portfolio 2 proxies for a risk factor that arises on FOMC days.

My empirical findings are consistent with the notion that traders will concentrate their trades in options that have underlying securities that are most sensitive to announcement content. Therefore, IV skews on high beta stock portfolios contain information about upcoming macroeconomic news and predict low returns to these portfolios on during announcements, even for days with little uncertainty.

Table 1.12: Beta Portfolio Regressions

Beta	C	Skew	Spread	HU	LU	Skew*HU	Skew*LU	Spread*HU	Spread*LU	F	F*Spread	F*Skew	N	R
0	-0.00149	0.04177	0.07608	0.00170	0.00354	-0.03902	-0.06054	-0.08633	-0.18757	0.00160	0.10436	-0.01727	1245	0.01660
	-1.53104	1.95815*	2.35143**	0.54412	1.26337	-0.59692	-0.94328	-0.91503	-1.67870	0.25639	1.01094	-0.12593		
	0.12601	0.05044*	0.01886**	0.58646	0.20669	0.55067	0.34572	0.36035	0.09346	0.79769	0.31224	0.89981		
1	-0.00204	0.05117	0.03257	0.00558	0.00726	-0.09271	-0.14228	-0.07205	-0.15174	0.00333	0.19679	-0.04505	1245	0.01330
	-1.53642	1.90261*	0.72188	1.34624	1.61480	-1.14018	-1.50775	-0.61471	-1.21942	0.29943	1.61043	-0.18781		
	0.12469	0.05732*	0.47050	0.17847	0.10661	0.25443	0.13187	0.53886	0.22291	0.76466	0.10756	0.85105		
2	-0.00210	0.04947	0.01999	0.00851	0.01080	-0.13579	-0.21133	-0.04359	-0.14949	-0.00453	0.30942	0.07525	1245	0.01040
	-1.32350	1.59771	0.31136	1.58809	2.37418**	-1.31517	-2.28057**	-0.34123	-1.19737	-0.66411	3.22424***	0.54932		
	0.18591	0.11036	0.75558	0.11252	0.01774**	0.18870	0.02274**	0.73299	0.23139	0.50674	0.00130***	0.58288		
3	-0.00242	0.05996	0.06061	0.01197	0.01041	-0.21577	-0.20820	-0.07548	-0.19575	0.00927	0.20359	-0.18910	1245	0.02200
	-1.45848	1.74021*	0.83029	2.17368**	2.16514**	-1.95722*	-1.99654**	-0.48078	-1.24726	0.75565	1.45502	-0.72120		
	0.14496	0.08207*	0.40654	0.02992**	0.03057**	0.05054*	0.04609**	0.63076	0.21254	0.45000	0.14591	0.47092		
4	-0.00253	0.05124	0.03051	0.01511	0.01153	-0.25539	-0.23133	-0.13949	-0.27301	0.00615	0.28211	-0.05898	1245	0.02010
	-1.20664	1.16076	0.34096	2.32133**	1.87838*	-1.99110**	-1.68607*	-0.69782	-1.40176	0.35890	1.21982	-0.16211		
	0.22780	0.24596	0.73319	0.02043**	0.06056*	0.04669**	0.09203*	0.48542	0.16124	0.71973	0.22276	0.87125		

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.13: Beta Portfolio Composition

Portfolio	Composition
0	E M C CORP MA
	INTERNATIONAL BUSINESS MACHS COR
	PEPSICO INC
	APPLE INC
	PROCTER & GAMBLE CO
	SOUTHERN CO
	EXELON CORP
	JOHNSON & JOHNSON
	MERCK & CO INC NEW
	AMERICAN ELECTRIC POWER CO INC
	BAXTER INTERNATIONAL INC
	MCDONALDS CORP
	TARGET CORP
	WAL MART STORES INC
	VERIZON COMMUNICATIONS INC
	A T & T INC
	U S BANCORP DEL
	COSTCO WHOLESALE CORP NEW
1	MICROSOFT CORP
	COCA COLA CO
	EXXON MOBIL CORP
	ALTRIA GROUP INC
	CHEVRON CORP NEW
	LOCKHEED MARTIN CORP
	PFIZER INC
	3M CO

Continued on next page

Table 1.13 – continued from previous page

Portfolio	Composition
	RAYTHEON CO
	OCCIDENTAL PETROLEUM CORP
	LILLY ELI & CO
	NIKE INC
	INTEL CORP
	HOME DEPOT INC
	CISCO SYSTEMS INC
	QUALCOMM INC
	UNITED PARCEL SERVICE INC
	PHILIP MORRIS INTERNATIONAL INC
	UNITEDHEALTH GROUP INC
2	DU PONT E I DE NEMOURS & CO
	GENERAL DYNAMICS CORP
	GENERAL ELECTRIC CO
	FACEBOOK INC
	CONOCOPHILLIPS
	C V S HEALTH CORP
	CATERPILLAR INC
	COLGATE PALMOLIVE CO
	BRISTOL MYERS SQUIBB CO
	BOEING CO
	ABBOTT LABORATORIES
	WELLS FARGO & CO NEW
	APACHE CORP
	MEDTRONIC INC
	SIMON PROPERTY GROUP INC NEW

Continued on next page

Table 1.13 – continued from previous page

Portfolio	Composition
	NATIONAL OILWELL VARCO INC
	MONSANTO CO NEW
	ACCENTURE PLC IRELAND
	COMCAST CORP NEW
3	ORACLE CORP
	HONEYWELL INTERNATIONAL INC
	ABBVIE INC
	AMGEN INC
	TEXAS INSTRUMENTS INC
	UNITED TECHNOLOGIES CORP
	DISNEY WALT CO
	UNION PACIFIC CORP
	AMERICAN EXPRESS CO
	FEDEX CORP
	LOWES COMPANIES INC
	TIME WARNER INC NEW
	STARBUCKS CORP
	ALLSTATE CORP
	CAPITAL ONE FINANCIAL CORP
	EBAY INC
	DEVON ENERGY CORP NEW
	TWENTY FIRST CENTURY FOX INC
	MASTERCARD INC
	VISA INC
4	GENERAL MOTORS CO
	SCHLUMBERGER LTD

Continued on next page

Table 1.13 – continued from previous page

Portfolio	Composition
	DOW CHEMICAL CO
	EMERSON ELECTRIC CO
	HALLIBURTON COMPANY
	FORD MOTOR CO DEL
	JPMORGAN CHASE & CO
	BANK OF NEW YORK MELLON CORP
	BANK OF AMERICA CORP
	NORFOLK SOUTHERN CORP
	AMERICAN INTERNATIONAL GROUP INC
	MORGAN STANLEY DEAN WITTER & CO
	ANADARKO PETROLEUM CORP
	CITIGROUP INC
	GILEAD SCIENCES INC
	FREEPORT MCMORAN INC
	AMAZON COM INC
	GOLDMAN SACHS GROUP INC
	METLIFE INC

1.7 Conclusion

This paper examines the relationship between equity options prices and stock market returns during macroeconomic announcements. My analysis demonstrates that the options market contains information about future returns during macroeconomic news periods. Bad news is reflected is the IV skew of options and is concentrated to high uncertainty announcements as measured by economist forecast dispersion. Relative call buying pressure represented by the IV spread positively predicts FOMC day returns for the index. Portfolios formed on underlying firm industry and beta also exhibit similar results, as their IVs can anticipate returns resulting for news announcements. In fact, options on high beta stocks are able to predict next day returns for an even wider range of announcements than the index. I attribute this finding to greater sensitivity of high beta stocks to macroeconomic news releases. This lends strong support to the notion that investors will trade in individual assets to also exploit macroeconomic news. In summation, this paper contributes to the informed trading literature by demonstrating their predictive power of option prices also extends to economic fundamentals.

Further directions for my research will include addressing the unique behavior of options prices prior to FOMC days that is not exhibited before other announcements. One explanation I put forward is that during times of economic turmoil, the FOMC is likely to intervene and provide a backstop to falling asset prices. These actions could be anticipated by option market participants, and traded on in the form of call options. For other announcements, traders may be concerned with downside risk, and hedge by purchasing OTM puts.

Chapter 2

DELTA-NEUTRAL INDEX STRADDLE RETURNS SURROUNDING MACROECONOMIC ANNOUNCEMENTS

2.1 Introduction

A substantial literature has developed studying whether investors are willing to pay a premium to hedge against changes in higher-order moments of the return distribution such as stochastic variance and price jumps. In order to fully understand the pricing of these risks in markets, one must deviate from the assumptions of simple geometric Brownian motion found in the Black and Scholes (1973) (B-S) model. If the underlying price process is augmented with a stochastic variance and price jump component, an options portfolio will be sensitive to these risks also. Periods where there is an increased likelihood of a higher realized variance or a price jump will be incorporate these higher risk into options prices. Scheduled macroeconomic announcements are known points in time that are risky, since economic news can trigger a change in volatility or a jump in price. This intuition begs the question-is insurance for volatility risk and jump risk as measured by returns on an options portfolio substantially different on macroeconomic news days?

In this paper, I investigate the hypothesis of a significantly different risk premium paid by equity option buyers on macroeconomic news days compared to non-news days. Before diving deeper into this hypothesis, it is beneficial to layout the general economic intuition of a risk premium explained in the context of the Merton (1973) Intertemporal Capital Asset Pricing Model (ICAPM) model. The intertemporal nature of this model implies that current demands for assets are impacted by the possibility of an adverse change in the future investment opportunities set.[1] Assets that have high payoffs during periods of deteriorating

[1] The investment opportunities set is the complete array of investment choices available to an investor at a given time. Merton (1973) defines an "unfavorable shift" in an opportunities set variable such that future consumption will fall for a future level of given wealth.

investment opportunities (bad states) are hedges. Investors demand hedge assets to insure against bad states of the world, thereby driving up their prices, leading to low average returns. An investor would naturally want to hedge volatility and price jumps, since these are state variables for this investment set(Campbell, 1992; Bates, 2008). This is due to changes in volatility impacting the future risk-return tradeoff for investors, and the association of price jumps with market crashes.

Under the standard B-S model there would be no hedging motives for stochastic volatility or jumps. To facilitate understanding, it helps to lay out the underlying price process followed by B-S:

$$dS_t = \mu S_t dt + \sigma S_t dW_s \tag{2.1}$$

where S_t is stock price at time t, μ is the drift rate, σ is the volatility parameter, and dW_S is the standard Weiner process. This price process follows simple geometric Brownian motion-where sigma is constant and no jumps occur. Under geometric Brownian motion there would be no reason for an investor to try to hedge changes in volatility or jumps. But, if return volatility is uncertain (volatility parameter σ_t can vary through time) and jumps are introduced (driven by process dZ_t, and magnitude k), then an investor will have a desire to intertemporally hedge against changes in variance and jumps. The B-S model can be augmented to include these components, and takes the specification:

$$dS_t = \mu S_t dt + \sigma_t S_t dW_s + kdZ_t \tag{2.2}$$

The focus of this essay is on the size of the risk premium associated for insuring against changes in the volatility parameter σ_t and the dZ_t components of the price process across macroeconomic announcements.

My methodology for examining the behavior of these risk premiums surrounding news days uses a portfolio of S&P 500 index options called a delta-neutral straddle. A delta-neutral straddle involves simultaneously purchasing an at-the-money call and put option of the same maturity. Coval and Shumway (2001) demonstrate that straddles are sensitive to the higher-order factors of volatility and jump risk by comparing their actual average returns to the expected returns implied by the CAPM. The CAPM states that return on a straddle should be equal to:

$$E(r_s) = r_f + \beta_s E(R_m - r_f) + \epsilon \tag{2.3}$$

where r_s is the return on a straddle, r_f is the risk-free rate, R_m is the return on the market portfolio and β_s is the sensitivity of the straddle to the market portfolio. Since Coval and Shumway (2001) set the straddle to be market-neutral (similar to delta-neutral) meaning $\beta_s = 0$ and expected returns should be equal to the risk-free rate. However, their empirical results show that straddles have a -3% average weekly return, demonstrating that stochastic volatility and jumps are important pricing factors in straddle returns. This negative return represents the a premium paid by the straddle buyer for insuring against the volatility and jump factors. I use the intuition of Coval and Shumway (2001) in this paper to study the premiums for insuring against these risks on macroeconomic news days, as reflected by average straddle returns.

I hypothesize that the nature of scheduled macroeconomic news implies that there will be a substantially different risk premium on announcement days, which will be reflected in the holding-period average returns of straddles. This is because macroeconomic announcements are ex-ante identifiable days where news releases can trigger changes in the volatility or jump parameter in equation 2.1. This concept is supported by a set of literature that demonstrate financial market volatility and jumps responds to announcement news[2]. For example, Ederington and Lee (1993) find that macroeconomic news announcements are responsible for observed day-of-the-week volatility patterns in interest rates and futures markets. Anderson et al. (2009) find that macroeconomic news surprises produce jumps using high-frequency futures data. Vortelinos et al. (2015) determine that the surprise component of news announcements significantly positively affect realized volatility. Studies of this nature clearly

[2] While this literature provides clear evidence that volatility reacts to news, it is important to note that I am agnostic about the sensitivity of straddle returns to a specific type of surprise. Since returns are averaged across a large sample, overall announcement surprises should have mean zero. Large surprises in either direction should then net out, implying returns reflect receipt of an expected risk premia.

provide empirical evidence that realized volatility and price jumps react to information in announcements, making announcements known points in time of higher conditional risk. Since investors know about these days in advance, options straddles should be priced accordingly to account for higher risk on these days, which will be reflected in announcement day returns.

When average straddle returns are partitioned by announcement days, there are three striking results. First, my findings indicate that the average daily holding returns to delta-neutral straddles when the Consumer Price Index, Non-Farm Payrolls, ISM manufacturing, and Industrial Production are announced are strongly negative, ranging from -1.3% to -2.6%. When these days are aggregated, their average daily returns are -1.86% (-77% annualized), implying over 77 percent of the negative annualized returns on straddles is concentrated to 17% of all trading days. This finding is indicative of substantially higher premium for insuring against variance and jump risk on certain macroeconomic days as measured by straddle returns.

I find that on other days (except FOMC) average straddle returns are insignificantly different from zero, which is indicative of an extremely low variance and jump risk premium on these days. This means an investor can purchase a straddle to hedge against randomly occurring changes in volatility and jumps for free. To my knowledge, this is the first paper uncover an insignificant variance and jump risk premium for particular days. The findings in this paper contributes to a literature that studies the clustering of risk premium on specific trading days. Seminal in this area, Savor and Wilson (2013) demonstrate that macroeconomic announcements are days of high conditional directional risk to holding equities. I draw a parallel to their findings for premiums related to insurance against higher-order risks. I also highlight the importance of risk premia on two announcements not examined by Savor and Wilson (2013), Industrial Production and Industrial Manufacturing. My results also shed a different light on risk around FOMC days.

The third significant finding is that straddles held over Federal Open Market Committee (FOMC) meetings earn a large average significant positive return of 2.6%. This result highlights the unique relationship between FOMC meetings and market volatility. Specifically, the forward-looking nature of the FOMC disclosure makes these announcements inherently different than others. For example, Amengual and Xiu (2014) find that resolution of policy uncertainty from FOMC meetings are associated with rapid decreases in volatility.

The authors attribute rapid decreases in volatility to the "put protection" offered to the equity market by the Federal Reserve during times of crisis. FOMC meetings are scheduled days during which the Fed can systematically restore confidence and calm markets, which is anticipated by rational investors in the pricing of straddles. In terms of the ICAPM, FOMC statements specifically relay information regarding government guarantees, which reduce volatility. This is a "favorable shift" in the investment opportunities set. For FOMC days, the risk of heightened volatility is lower due to the likelihood of government put protection, since realized volatility typically drops in response to government guarantee news. When the future outlook on investments is optimistic due to likely government intervention (which are announced systematically on FOMC days), hedges will have low prices. However, when the FOMC does respond with the size of the guarantee expected by the market, volatility will be higher than expected, and straddles will earn high expected returns.[3] This paper contends that the positive returns to straddles on FOMC days are reflective of compensation due to a positive risk premium to government put protection. Another set of contributions of this research is to the pricing of government guarantees.

To provide robustness to my results, I conduct time-series regressions on straddle returns and a sub-period analysis of the financial crisis. These results provide supporting evidence of the unique patterns of straddle returns observed on announcement days, as well as proof that the significance of the announcement day results are not driven by the levels of extreme realized volatility from the crisis period.

In additional analysis, I disentangle the component sources of risk to straddles, variance and jump risk, and measure their contribution to the overall delta-neutral returns. Returns from variance and jumps risk can be isolated separately in straddle returns, by creating straddle portfolios that heavily weigh on one type or risk, while remaining neutral to the other. This can be achieved by utilizing a weighting scheme involving the option Greeks (to be defined later). An options portfolio that has large vega will be sensitive to underlying volatility, whereas a options portfolio with large gamma will be sensitive to underlying jumps(Cremers et al., 2015). Previous literature shows price jumps are more likely to occur

[3] For example, on the December 11th 2017 FOMC meeting the Fed dropped the fed funds rate by 25 b.p. The markets expected a 50 b.p. cut, and a result the S&P 500 ultimately dropped -2.5%.

around important news releases (Pan, 2002; Lee and Mykland, 2008). This makes announcements periods of higher risk to holding jump sensitive assets. If investors are willing to pay a large premium to hedge this type of risk during announcements, then an options portfolio designed to be sensitive to jumps should also demonstrate significantly different returns on announcement days. I test this hypothesis by forming straddle positions that are sensitive to gamma, as well as vega. Gamma is the second derivative of the options value with respect to underlying price, and measures the rate of change in delta. A high gamma options portfolio will be highly responsive to jumps in price. My results indicate that the premium for jump risk is the primary driver behind the observed announcement straddle returns.

These findings of this paper also provide a challenge to the pattern of positive firm-level straddle returns around earnings announcements documented by Xing and Zhang (2013). The authors attribute this to the behavioral based explanation of conservatism, in which investors are slow drawing inferences from new data and underestimate the uncertainty caused by the announcement.[4] I conclude that positive straddle returns on FOMC announcements are a compensation for risk associated with government guarantees.

This essay differs in theoretical implications from my first essay. In my first essay, I focus on elements of the options market that cause options prices to have predictive power for stock returns. This type of phenomena occurs because an informational inefficiency exists between options and stock markets, as a result of trading frictions. This inefficiency means information is embedded in options prices before stock prices. Using this intuition, I study whether an options market signal can predict future stock price under certain conditions. In contrast, my focus in this essay is related to the risk premium associated with straddle returns over a longer period of time, and less concerned with private information regarding specific outcomes of news events.

In the next section, I present a literature and theory review, which ties together the concepts of variance and jump risk premiums, underlying stochastic price processes, delta-neutral straddle returns, and announcements. Section 2.3 discusses data and straddle

[4] Earnings announcements also include a forward-looking statement in the form of "earnings guidance". It is possible that the positive returns to firm-level straddles around announcements documented by Xing and Zhang (2013) are a result of a managers' ability to provide a form of put protection on her future stock price.

returns, including regressions and sub-period analysis with gamma and vega-neutral options strategies, and section 2.4 concludes.

2.2 Related Literature and Theoretical Overview

The goal of this section is to provide an overview of theory and draw connections between risk premiums, price processes, straddle returns, and the implications of macroeconomic news. In the first section I discuss the concept of a risk premium in the context of Merton (1973) ICAPM, along with the ICAPM's predictions for straddle return patterns. This is intended to to provide the reader with a broader understanding of a risk premium. After the implications of the ICAPM are outlined, I review the specific literature related to the volatility and jump risk premium.

In section 2.2.2, I discuss modifications of the (B-S) underlying price process to include stochastic volatility and price jumps. These modifications are necessary in order to generate the observed variance risk premium and jump risk premiums, which contribute to the observed patterns of average straddle returns.

Section 2.2.3 provides an overview of straddle-related literature. I discuss the implications of the stochastic price process for these returns, and address the roles played by the options Greeks in the formation of portfolios that are sensitive to volatility and jump risk.

Section 2.2.4 addresses the impact of macroeconomic news on market volatility and price jumps. This sub-section also provides a discussion on the nature of FOMC announcements. I provide evidence that asset markets respond to macroeconomic announcements, making them days of higher ex-ante volatility and jump risk, which is incorporated in risk premiums, and reflected in average straddle returns.

2.2.1 ICAPM

The Merton (1973) ICAPM model provides a strong framework for analyzing straddle return patterns. The ICAPM is a consumption based asset pricing model in which an investor seeks to maximize lifetime utility of consumption, but also faces uncertainties in future investment opportunities set. Within the multi-period structure of this model investors seek to hedge against consumption shortfalls and changes in the investment opportunities set. The opportunities set is driven by a single stochastic state variable, which for the purpose of this research could be volatility or jumps.[5] The risk-averse utility maximizer will demand

[5] Merton (1973) uses a stochastic interest rate as the driver of investment opportunities. However, since volatility and jumps clearly alter the investment opportunities set

assets that hedge against changes in volatility or jumps, since an increase in volatility or negative price jump would represent an unfavorable shift in the investment opportunities set. Investors will demand more of the hedge asset, the more positively correlated its return is with volatility. As a result, if the opportunity set worsens the investor will be compensated by high returns to the hedge asset. Merton (1973) mathematically demonstrates that an expected return to any asset(in this case, a straddle) can be represented as:

$$\alpha_i - r = \frac{\sigma_i[\rho_{iM} - \rho_{in}\rho_{nM}]}{\sigma_M(1-\rho_{nM}^2)}(\alpha_M - r) + \frac{\sigma_i[\rho_{in} - \rho_{iM}\rho_{nM}]}{\sigma_n(1-\rho_{nM}^2)}(\alpha_n - r) \tag{2.4}$$

where α_i is the return on the straddle, α_M is the expected return on the market portfolio, α_n is the expected return on a portfolio that replicates market volatility or price jumps, r is the risk-free rate, and ρ terms represent covariances. This equation shows that an investor should will pay a premium for hedging risks associated with unfavorable shifts in investment opportunities, in addition to compensation for market risk. The construction of a delta-neutral position means that asset has no exposure to the market portfolio, setting $\rho_{iM} = 0$. Then the second term reduces to $\frac{\sigma_i}{\sigma_n}\rho_{in} = \beta_n$, namely a variance or jump beta. For straddles, $\beta_n > 0$ due their positive covariance with the volatility or jump portfolio. An extensive literature presented in the following section provides evidence that there is a negative premium associated with insuring against volatility and jump risk. The negativity of these premiums implies a negative return on a theoretical market volatility or jump portfolio. An investor purchasing these theoretical portfolios should expect negative average returns, or $(\alpha_n - r < 0)$. Since the straddle positively covaries to market volatility and jumps, straddles will have negative expected returns $(\alpha_i - r < 0)$.

The exception to this case would be the sign of the premium on FOMC days, which are actually positive. A positive premium for bearing these risks in tied to the put protection offered by the Fed. I provide a deeper argument for this case in section 2.4.4. Next, I discuss variance and jump premiums.

---

it also meets the conditions of a state variable.(Campbell, 1992) It is possible to enrich the modeling by adding additional state-variables, however a single-state variable model is sufficent for explaining returns to a straddle

2.2.1.1 Variance Risk Premium

Straddles are sensitive to the volatility of their underlying assets. The variance risk premium is the price investors are willing to pay in order to hedge against a change in the future volatility of the security. Below I present evidence of prior literature documenting the pricing of variance risk in markets, which sets the foundation for discussion of differences between expected returns to straddles between announcement and non-announcement days.

Seminal in this area, Bakshi and Kapadia (2003) show the existence of the variance risk premium by analyzing profits and losses from delta-hedged positions on the S&P 500. The authors setup a portfolio with a long call, which is hedged by a short position in the stock. By dynamically hedging this portfolio, the authors can infer returns from risk related only to volatility. Since the option is a redundant asset, then the delta-hedged position should have average returns equal to the risk-free rate. However, large losses on these positions provide evidence in support of a non-zero variance risk premium. An advantage of the Bakshi and Kapadia (2003) methodology is that it effectively explores the sign of the variance premium, without imposing a specific volatility process for the underlying asset. My research is similar in that I also study delta-hedged returns,but differs with respect to conclusions about the size of the premium on specific days. Employing delta-neutral straddles as a tool enables me to document the size and sign of the premium on announcement days, without committing to a parametrization of an underlying price process.

The presence of a negative variance risk premium has also been documented for more complex option portfolios. For example, Carr and Wu (2009) quantify the variance risk premium by using the market price on a synthetic variance swap. Variance swaps are created by using a linear combination of option prices, and have payoffs that are equal the difference between the realized variance and the swap rate implied by the options. The authors conclude that the returns on these contracts are on average strongly negative, implying a negative premium to variance. Although a variance swap uses a continuum of options prices, their finding of negative prices for variance still conceptually holds for ATM straddles.

My research also has ties to the components of variance risk for stocks, which are categorized into an upside and downside. Feunou et al. (2015) decomposes the variance risk premium into a downside and upside variance risk premium, and find the downside risk premium is the main component. These premiums refer to the market price of risk associated with bad uncertainty (downside) vs. good uncertainty (upside). Investors like good uncertainty, due to the higher likelihood of large gains. On the other hand, an investor will have a strong aversion to bad uncertainty, since it increases the possibility of extreme losses. Although this result was demonstrated for stock returns, it can also be extended to option returns as well. Since bad uncertainty is associated with periods of high realized volatility, then a straddle serves as a hedge to this type of downside risk. In contrast, good uncertainty corresponds to periods of lower realized volatility, causing a straddle to perform rather poorly during these periods of market optimism, making them riskier assets. If certain announcements have a greater probability of introducing bad uncertainty into the market, then one would expect the price of insurance against bad uncertainty to increase prior to these announcements. This explanation would be consistent with a higher price of straddles, and their lower average returns during Consumer Price Index, Non-Farm Payrolls, Industrial Production, and Industrial Manufacturing releases. However, the FOMC meeting presents an exception. These are days when good uncertainty is systematically released into the market. Straddles would then have lower prices, and higher average returns on these days.

Recently, Dew-Becker et al. (2015) analyze the term structure of variance swaps. Variance swaps are an over-the-counter derivatives that have payoffs which depend directly on realized volatility. The authors find that expected future market variance is not reflected in variance swap returns, which implies there is not a risk premium associated with news related to future variance. They find that only transitory and unexpected realized variance carries at significantly negative premium. At first glance, this may seem like a challenge to the results presented in this paper. However, I do not make a distinction between compensation driven by transitory variance and future variance in straddle returns patterns. Returns of straddles are volume weighted, and span from 10 days to expiration to 60 days. Therefore, it is possible that the large negative returns observed across announcements are a result of insurance against the possibility of high realized short-term volatility and not future variance. However, I leave this question to future research.

2.2.1.2 Jump Risk Premium

Returns to delta-neutral straddle are also sensitive to the possibility of a discontinuous jump occurring in the price of the underlying asset. Exposure to this risk also plays an important role in expected returns to straddles. The increased likelihood of a jump occurring on an announcement day will increase price of straddles. Jump risk can also be treated distinctly from volatility risk discussed in the previous subsection, since a jump in asset price can also be associated with crash-like events, as opposed to just heightened volatility. An investor looking to insulate herself from crashes can take long positions that have positive co-variation with price jumps.

A long literature presents evidence of the pricing of jump risk, and jumps as a result of macroeconomic news. Seminal in this area, Todorov (2009) utilize high-frequency synthetic variance swaps data to demonstrate that sources of variance risk can be generated by the presence of stochastic volatility and jumps. An important result of this paper is that price jumps are typically associated with a spike in stochastic volatility and the variance risk premium, but with quick reversion to the mean. Pan (2002) show that there is a significant premium associated with time-varying jump risk, using a joint time-series of the S&P 500 index and ATM short-dated options. This line of research is supportive of time-varying risk aversion for investors towards anticipated jumps. In the context of macroeconomic news, if upcoming news increases investor expectations of price jump, it should also increase the size of the jump premium required on announcement days, thereby leading to significantly different expected returns to jump sensitive assets on announcement days.

Recent research also links jump risks to disaster risk. For example, Santa-Clara and Yan (2010) use a pricing model to imply jump intensity from S&P 500 index options. Their model translates risk of jumps into an ex-ante jump risk premium. Their results indicate that, on average, compensation for jump risk is more than half of the total equity premium, and during periods of crisis it comes close to 100% of the premium. Bates (1991) demonstrates that OTM puts were unusually expensive relative to ATM calls in the year prior to the October 1987 crash. The author derives a jump-diffusion model in which the parameters demonstrated by options prices indicate an expected crash. These studies imply jump-sensitive assets should have large payoffs during times of crisis, but will command low expected returns on average. If investors attribute more weight to tail outcomes as a result of announcement news, then this will be reflected by higher premiums for jump risk. Although the events documented above are extreme events, they provide helpful insight into understanding why an investor would pay a large premiums to hedge price jumps.

Next,I transition into a discussion regarding price processes for option pricing models that can generate the documented variance and jumps risk premiums in options returns. These price processes are also compared to the price process of B-S, which is geometric Brownian motion. Under B-S investors have no hedging motives related to stochastic volatility or price jumps, so I provide a general model which includes these components.

2.2.2 Price Processes

In this subsection, I provide a theoretical overview and examples of price processes. This is presented in order to facilitate understanding of the role played by underlying stochastic volatility and jumps in option returns. However, the primary concern of this research is on documenting the size and the sign of the premia on macroeconomic announcement days; therefore I do not commit to any particular model (similar to Bakshi and Kapadia (2003)) from the class of models discussed here. This alleviates the issues of specifying a "correct" model to match observed option prices and a proper parametrization of that model. This non-commitment proves useful, since current options pricing models have difficulty explaining the empirical observation regarding positive straddle returns on FOMC announcement days found in this paper.

I begin with the standard Black and Scholes (1973) model, whose underlying price process has constant volatility and no jumps in price. Under this assumption, options are redundant, meaning option returns should incorporate the exact same set of risks as the underlying security. This redundancy means that higher moments of the return distribution, such as volatility and price jumps are not reflected in option returns. Under the standard B-S, price follows this process:

$$dS_t = \mu S_t dt + \sigma S_t dW_s \tag{2.5}$$

where S_t is stock price at time t, μ is the drift rate, σ is the volatility parameter, and dW_S is the standard Weiner process. B-S sets volatility (σ) as a constant and does not include a jump component.

However, current option pricing models generally accept stochastic volatility and jumps as a natural part of the underlying price process. These models are typically referred to as jump-diffusion models. This class of option pricing models have a general underlying price process of the form:

$$dS_t = \mu S_t dt + \sigma_t S_t dW_s + k dZ_t \tag{2.6}$$

where price is S_t, μ is the drift rate and dW is a standard Weiner process. In contrast to equation 2.4, instantaneous volatility σ_t and jumps dZ_t are now stochastic processes, which can be treated as i.i.d. based on model specifications. Specific examples include Merton (1976), who allow jumps to be driven by a Poisson process (dZ_t) with a Gaussian jump size (k). Other seminal papers such as Heston (1993) and Bates (1996) who specify a square-root process for σ_t.

Given the nature of the pre-scheduled announcements studied in this paper, Dubinsky et al. (2006) present a relevant underlying price process for studying the affect of certain macroeconomic announcements on options prices. In their model, jumps deterministically occur at the time of the announcement. For a single upcoming announcement, the authors define equation (2.5) exactly as:

$$dS_t = \mu S_t d_t + \sigma_t S_t dW_s + d(S_\tau - (e^z - 1)) \tag{2.7}$$

where S_t is stock price at time t, σ_t is stochastic volatility function, μ is the drift rate, and dW_S is the standard Weiner process. Price jumps occur deterministically at announcement time τ. For the sake of simplicity, I temporarily ignore the stochastic volatility, in order to provide straightforward pricing implications for options around certain announcements. If T is the time to option expiration, then the annualized implied volatility of an option the moment before an announcement is $\sigma^2_{t,T} = \sigma^2 + T_i^{-1}(\sigma)^2$, and after $\sigma^2_{t,T} = \sigma^2$. This model captures an important empirical observation for this paper – options IVs increase leading up to announcements (at a rate T_i^{-1}), and then experience a sharp drop off immediately after. This drop in IVs impacts both calls and puts, which negatively impacts straddle returns. Termed a "volatility crush" by practitioners, this reduction in implied volatility can explain the large losses on options positions after the release of anticipated news.

However, this model has difficulty explaining the empirically observed positive option returns for FOMC announcements. In addition, Xing and Zhang (2013) find that firm-level straddles formed prior to earnings also generate positive returns. Any option pricing model that attempts to explain this return pattern would likely need to be of higher complexity to include symmetric price jumps, as well as asymmetric volatility.[6] The asymmetry of price jumps refers the changing probability and expected magnitude of an upward jump versus a downward jump in price. Volatility can also experience asymmetric changes, by increasing or decreasing rapidly. Amengual and Xiu (2014) document that these sudden decreases in volatility are related to resolution of monetary policy uncertainty, which systematically occur on FOMC meetings days. The authors demonstrate that the likelihood of decreased volatility is priced in variance swaps. In the context of my findings, I hypothesize that if there a higher likelihood of upward volatility movements on Non-FOMC announcement days, this would result in higher prices (lower average returns) for straddles. If the probability of sharp decreases in volatility is more likely on FOMC days, then this would result in lower prices (higher average returns) for straddles. However, I leave the specification of an option pricing model which can match the positive returns documented here to future research.

In the next section, I discuss previous research regarding straddle return patterns and their relationship with jump-diffusion price processes. I also provide a detailed theoretical overview of the formation of a delta-neutral options portfolio, as well as a decomposition of its returns from variance and jump risk.

2.2.3 Straddle Sensitivity and Option Greeks

A simple straddle can be formed by simultaneously purchasing an ATM call option and ATM put option with the same strike price and same time to maturity. An investor purchasing a straddle pays the premium for both options, but theoretically benefits from unlimited upside potential if the underlying stock experiences drastic moves in either direction. A seller of a straddle collects a large premium for writing the call and put contracts, but can be exposed to unlimited losses.

Coval and Shumway (2001) demonstrate that when underlying returns follow a geometric Brownian motion, straddles should have no risk premium and earn the risk-free rate

[6] See Kou (2002) and Eraker (2004).

on average as dictated by the CAPM model. According to the CAPM, expected returns on a straddle should be:

$$E(r_s) = r_f + \beta_s E(R_m - r_f) + \epsilon \tag{2.8}$$

where r_f is the risk-free rate, R_m is the return on the market portfolio and β_s is the sensitivity of the straddle to the market portfolio. Coval and Shumway (2001) construct their option positions to be market-neutral (similar to delta-neutral), thereby setting beta of the position equal to 0. To explicitly test if the CAPM relationship holds, the authors study the returns patterns for straddles and test if they are on average equal to the risk-free rate. The authors document returns significantly lower than the risk-free rate to long straddle positions (-3% weekly), which is indicative of the incorporation of higher order risks relating to volatility and jumps in options prices. The adoption of a delta-neutral position enables me to study these risks independently of directional market risk.

2.2.3.1 Delta-Neutrality

A convenient method for analyzing returns contributed by higher order risk factors, while netting out returns due to directional movements involves constructing a delta-neutral position. Delta is the first derivative of the portfolio value (Π) with respect to the underlying price S.[7] It is the rate of change of the option price for a $1 change in underlying price. For example, ATM call options typically have deltas near .5, meaning a $1 increase in stock price will lead to a .50 increase in the value of the option. Correspondingly, at-the-money (ATM) puts have deltas close to -.5. Absolute delta is increasing in moneyness, so deep in-the-money (ITM) calls and puts will be more sensitive to changes in stock price.

The delta of a portfolio is equal to the weighted sum of each asset's delta. Using this fact, a combination of puts and calls can be selected so that the overall portfolio delta is 0. A straddle can be constructed to be delta neutral by solving the set of equations:

---

[7] Expressed as $\left(\frac{\delta \Pi}{\delta S}\right)$

$$0 = w_c \Delta_c + w_p \Delta_p$$
$$1 = w_c + w_p$$

with weights on calls and puts (w_c, w_p) and the Black and Scholes (1973) deltas (Δ_c, Δ_p) of matching strikes and time to maturity. As an empirical matter, it is possible to have several ATM straddles of varying maturities. This type of portfolio will be insensitive to small changes in the price of the underlying asset. However, it will still be exposed to changes in volatility or price jumps.

Straddle exposure to these risks can also be explained mathematically, by taking the derivative of the delta-neutral portfolio profits $(\Delta\Pi)$ with respect small changes in the underlying price S over time interval Δt. It is important to note that the Greeks in this paper are taken from Optionmetrics, which uses the Black and Scholes (1973) methodology, that assumes constant underlying volatility. While it does not provide an exact representation of profits and losses to a delta-hedged portfolio with an underlying stochastic volatility and jump process, over small periods (such as a day) profits and losses for the portfolios should be approximately the same.

The change in portfolio value will be a function of σ, S, and t. Using a Taylor series expansion yields:

$$\Delta\Pi = \frac{\delta\Pi}{\delta S}\Delta S + \frac{\delta\Pi}{\delta\sigma}\Delta\sigma + \frac{\delta\Pi}{\delta t}\Delta t + \frac{1}{2}\frac{\delta^2\Pi}{\delta S^2}\Delta S^2 + \frac{\delta^2\Pi}{\delta S\delta t}\Delta S\Delta t + ... \tag{2.9}$$

Imposing delta neutrality on the portfolio eliminates the first term, since the value of the portfolio is no longer dependent on the underlying price. The second term is the change in portfolio value with respect to volatility, or returns related to the Greek known as "vega". The third term is the change in portfolio value with respect to time, or theta.[8] This will be equal to the return on the risk-free rate. The fourth term is the second derivative of the

[8] Theta represents the loss in portfolio value due to the passage of time. It does not make sense to hedge this parameter, since there is no uncertainty regarding the expiration of the asset.

portfolio value with respect to S, or “gamma”. Since the portfolio is not set to be vega or gamma neutral, changes in these values can generate profits or losses for the delta-neutral portfolio. For the purpose of straddles, higher order terms in the expansion can be ignored. The above equation can be simplified as:

$$\Delta\Pi = \nu\Delta\sigma + \Theta\Delta t + \frac{1}{2}\Gamma\Delta S^2 \tag{2.10}$$

The profits and losses on a delta neutral position can be expressed as a linear combination of changes in vega, theta, and gamma. An increase in underlying volatility or significant increase in underlying stock price will lead to profits on a the delta-neutral portfolio. In the upcoming subsections I provide a deeper explanation of these Greeks.

2.2.3.2 Vega

Vega measures the rate of change in option value with respect to volatility of the underlying asset price. It refers to the term $\left(\frac{\delta\Pi}{\delta\sigma}\right)$ in equation 2.9. Vegas for long options strategies are generally positive, and increase in value with increasing volatility. If an option has a vega of .2, and volatility increases by 1%, then the option will increase in value by 0.20.

In the empirical section, I construct option portfolios that weigh heavily on vega, but are simultaneously delta-neutral and gamma-neutral. These portfolios purchase long maturity ATM straddles, and sell multiple short maturity straddles. I detail the formation of these options portfolio in a later subsection. This option strategy isolates the risk connected to potential changes of market volatility as a result of macroeconomic news, or changes in the σ_t term in equation 2.5. As an example, suppose a long maturity delta-neutral straddle has vega ν_l, and it is combined with a short maturity straddle ν_s with weight w_s. The total portfolio vega is:

$$w_s\nu_s + \nu_l$$

A position that sets $w_s = -\frac{\nu_l}{\nu_s}$ will make the portfolio vega-neutral. This methodology can also be applied in reverse, in order to make the portfolio gamma-neutral.

2.2.3.3 Gamma

Gamma is the second derivative of the option value with respect to the underlying price, or the rate of change of delta. It refers to the term $\left(\dfrac{\delta^2\Pi}{\delta S^2}\right)$ in equation 2.9. For example, if an option has a delta of .5 and a gamma of .1, then a \$1 increase in the underlying price will cause delta to increase by 10% to .55. Short maturity ATM options have the largest gammas, making these options extremely sensitive to movements in the underlying price. This characteristic of short-term ATM options makes their returns highly responsive to price jumps. However, as the option moves deeper in or out of the money, gamma becomes smaller.

Gamma also reflects the curvature of an options payoff. Options are leveraged assets, and have non-linear returns. As an example, suppose there is an ATM delta-neutral straddle at current stock price S. Assume there is a large upward price movement in underlying stock price from S to S'. At S', the call option is in-the-money, and has a larger delta than before. The put option has a smaller negative delta since it is out-of-the-money. The overall delta of the straddle is now positive, and exposed to directional risk. In order to keep the straddle at delta-zero, the put and call holdings must be rebalanced.

In the empirical section, I explore option portfolios that weigh heavily on gamma but are simultaneously delta-neutral and vega-neutral. This option strategy isolates the risk connected to potential price jumps as a result of macroeconomic news, or changes in the dZ_t term in equation 2.5. This is achieved by taking long positions in short term ATM straddles, and selling multiple long term straddles. The weighting scheme for this option portfolio is similar to the one discussed in the previous subsection.

Now that I have established the important conceptual and theoretical implications of a risk premium, a stochastic price process for variance and jumps, and the sensitivity of straddles to these factors,I can begin to address the impacts of anticipated macroeconomic news on the price process, and on straddle return patterns.

2.3 Asset Returns and Macroeconomic News

In this subsection, I present prior research demonstrating the response of prices and volatility to macroeconomic news content. This research provides evidence that investors holding financial assets during announcements are exposed systematically higher risk, since news day induce changes in volatility and price jumps. In equation 2.5, this would be an increased risk regarding a shift in the volatility parameter (σ_t), or higher risk of a large price jump (kdZ_t). These levels of higher risk are reflected in average lower returns to straddles on certain announcement days. However, this is not the case for FOMC days. I provide a risk-related explanation for FOMC day straddle returns later in the section.

2.3.1 Macroeconomic Announcements

A long literature focuses on announcement day realized volatility and returns. A consensus in the research has emerged that certain announcements typically increase intraday volatility. Ederington and Lee (1993) find that macroeconomic news announcements impact the volatility of interest rates and FX markets. They find that while most of the price change in these markets occurs within one minute, volatility can remain high for several hours after. Beber and Brandt (2006) study the effect of macroeconomic announcements on beliefs and preferences for investors in the U.S. treasury market by observing option-implied state-price densities prior to and after the announcement. They find announcements reduce uncertainty in the second moment of the state-price density function, but changes in higher order moments depend on whether the news was good or bad. Balduzzi et al. (2001) determine that surprises in release data explain a significant portion of volatility persistence in the U.S. Treasury market. Examples of this type of research provides evidence that asset prices and volatility respond to news. The scheduled nature of these announcements means investors can anticipate that these are days of higher ex-ante risk, meaning investors can systematically price this volatility risk into options ahead of announcements.

The literature also demonstrates that macroeconomic news leads to price jumps, and that they occur more often on news days compared to no-news days. For example, Lee and Mykland (2008) and Lee (2011) present strong evidence that macroeconomic announcement news triggers price jumps in the S&P 500 index. Evans (2011) also argue that about one-third of jumps are a result of macroeconomic news announcements. These jumps are large in nature, and contribute significantly to the total price variation. Huang (2015) also finds that there are significantly more jumps on macroeconomic news days than no-news days, and both volatility and jumps are affected by the news release surprises. This supporting set of research ties risk premiums and anticipation of price jumps; If investors are willing to pay a premium to insure against jump risk, announcement days with a higher probability of jumps will be days when investors pay more for jump insurance. Given that investors can anticipate jumps as a result of macroeconomic announcements, they would be willing to pay a higher price for jump protection, and therefore straddles. This is consistent with the finding of significantly negative returns to straddle positions formed prior to announcement days.

A portion of this referenced literature focuses on the conditional responses of prices to news (ex. do surprise CPI figures lead to positive or negative returns?). However, it is important to note that the particular focus of this paper is not how straddle returns respond to positive or negative economic news, but rather measurement of the a reflected risk premium to holding straddles over a wide range of announcements. In this manner, my research is closely related to Savor and Wilson (2013), who find that stock market returns are significantly higher on macroeconomic news days compared to non-news days. Their argument centers on risk compensation. Specifically investors require higher expected returns for bearing market risk on announcement days. In comparison, my paper focuses on compensation for insuring against higher order volatility, but makes a similar conclusion that premiums vary between days.

A point of divergence between my paper and Savor and Wilson (2013) regards the treatment of FOMC days. Savor and Wilson (2013) note that the sign of market risk premium should be large and positive on announcement days, however they do not distinguish between the FOMC and other types of macroeconomic news (ex. Consumer Price Index, Non-Farm Payrolls). I argue that variance and jump risk premium actually positive on FOMC days, compared to the largely negative premium on announcement days of the Consumer Price Index, Non-Farm Payrolls, Industrial Manufacturing and Industrial Production. This is due to the put protection offered by the Fed during periods of falling asset prices, which calms markets and reduces volatility, lowering the price of straddles. I detail the nature of FOMC announcements in the upcoming subsection.

2.3.1.1 FOMC Announcements

Before discussing FOMC meeting announcements, it is helpful to briefly addresses news related to other macroeconomic indicators. Most of these announcements provide relevant information regarding the state of the economy, but are backward-looking. For example, the Consumer Price Index calculation involves measuring changes in price of goods over the previous month from a market basket. While this information gives agents a pulse on the economy, it does not directly provide guidance for the path of prices, or precise policy responses to this new fundamental information. Investors must infer this type of information.

The nature of FOMC announcements is very different. Beginning in 1999, the FOMC began releasing balance of risk statements that accompanied fed funds rate target changes. It is a indicator of the committee's views for future risks of heightened inflation or economic weakness. These statements not only explain the logic behind a current policy action, but express an outlook on future policy stance and convey information (somewhat directly) to investors about the Fed's future policy tilt. For example, if the statement included the phrasing "the risks are mainly weighted towards conditions that may generate economic weakness in the future" it would be indicator of future lax policy. This communication regarding future policy path may even have a greater impact on stock indices than actual rate changes (Rosa, 2011).

The FOMC's ability to lower rates and provide forward guidance through the balance-of-risks statement in order to stabilize the economy in times of crisis makes this type of economic news unique, which I document further through examples and literature presented in the upcoming paragraphs. FOMC meetings are pre-scheduled periods that allow the committee to intervene in markets during times of high uncertainty by providing policy protection to falling asset prices (ex. pledging to keep rates low for an extended period of time). In turn, rational investors know ex-ante when this intervention will occur, and can incorporate these expectations into asset prices.

The clearest examples of this sort of government protection come from meetings leading up to and during the financial crisis. On September 18th, 2007 the FOMC decided to lower the target fed funds rate by 50 b.p. in response to tightening credit conditions. On October 28th, 2008 the Fed lowered the target fed funds rate by an another 50 b.p., and stated "coordinated interest rate cuts by central banks, extraordinary liquidity measures,official steps to strengthen financial systems, should help over time to improve credit conditions and promote a return to moderate economic growth." Policy actions like these lend support to the fact that the Fed will provide support to turbulent markets.

Similarly, several studies also demonstrate government guarantees are incorporated into financial market prices. For example, Kelly et al. (2011) document a reduction in aggregate tail risk from in the banking sector due to a government wide sector bailout insurance. Their findings indicate that the difference in costs of OTM puts between individual banks and the financial sector index increased four-fold from the pre-crisis level. In other words, the price of crash insurance (in the form of OTM puts) increased for individual banks, but decreased for the financial sector as whole due to anticipation of future government intervention. Government protection can also be seen in currency markets. Neely (2011) documents the intervention of the G-7 in the rapid appreciation of the Japanese yen after the Tohoku earthquake in March 2011. As a result of the earthquake, the yen's volatility increased substantially and propagated disorder throughout foreign exchange markets. In response to intervention, the yen depreciated and exhibited lower volatility. Bekaert et al. (2013) explore the links between risk, uncertainty and monetary policy using a VAR framework. Their intuition is that uncertainty alters the employment and output decisions of firms, leading a monetary authority to respond to high uncertainty in order to improve real economic conditions. The authors consistently find that lax policy decreases risk aversion, which reduces risk premiums and increases prices of assets. In converse, high uncertainty and risk aversion typically lead to lax policy. This lends support to a major theoretical point of this paper, which is that the FOMC contemporaneously looks at volatility in financial markets while setting monetary policy. These studies provide strong evidence of government intervention in financial markets during turbulent times, as well as pricing of this government insurance by investors.

The likelihood of government intervention is conceptually consistent with research that demonstrates that the variance risk premium is insignificantly different from zero or positive at the beginning of crisis. During the start of a crisis, a speedy government response is anticipated by investors, thereby reducing the hedging need for variance (Amengual and Xiu, 2014). Supportive of this, Bekaert and Hoerova (2014) evaluate several volatility forecasting models for conditional variance, and also note a similar result of positive variance premia for short amounts of time at the start of crisis periods. Although, even advanced volatility models such as these would have difficulty identifying positive premia over periods of a single day such as the FOMC announcements. My methodology has the advantage of being able to explore the sign of the premia on different types of days, without estimating or imposing a specific model.

The argument of this paper is that rational investors anticipate this intervention since FOMC meetings are scheduled. Investors demand lower prices for volatility or jump sensitive assets around meetings, since Fed action is likely to reduce volatility or cause positive price jumps. Lower prices of volatility and jumps lead to higher average returns during announcements as compensation for risk related to future lower volatility or positive price jumps. Straddles have higher payoffs when government intervention was smaller than expected (ex. rates cuts not a large as market expected, or rates were tightened unexpectedly). This theory can explain higher average straddle returns observed on FOMC days.

This literature review presented the reader with a discussion of the connections between the concepts of risk premia, stochastic processes, straddle returns, and macroeconomic news days. The goal of addressing topics relating to this literature was to provide evidence in support of the hypothesis of a substantially different variance and jump risk premia on announcement days, which is reflected on the average returns on straddles. Next, I formally test this hypothesis by forming option straddle portfolios.

2.4 Data and Delta-Neutral Straddle Returns

The central hypothesis of this paper is that premiums for volatility and jump risk should be substantially different on macroeconomic announcement days, as reflected by returns on delta-neutral straddles. In this data section, I test this hypothesis by forming straddle portfolios and aggregating their returns across different sets of announcement days. In order to further provide robustness to these results, I conduct regressions and sub-period analysis. In later sections, I form two options portfolio that independently sensitive to volatility or jump risk, and document their contribution to the observed delta-neutral straddle returns.

My sample period covers from January 1st, 2004 to December 31, 2014. Equity options data for S&P 500 index options are taken from the OptionMetrics database which includes option Greeks, implied volatilities, end-of-day bid and ask quotes, volume, and open interest. As in Xing and Zhang (2013), I apply a series of filters and to ensure the validity of the options quotes.[9] Upon straddle formation, only options with an absolute delta between 0.375 and 0.625 are used. To calculate daily returns on individual options mid-quote values are used. Moneyness is determined by the stock price over strike, and ATM options are required to be between 0.95 and 1.05.

Formation of each straddle involves purchasing a call and put at the same strike and maturity. To make the straddle delta-neutral, the calls and puts are weighted such that the total delta of the complete strategy equals zero. When multiple calls and puts exist on a single day, they are volume weighted. Straddles are then reformed on a daily basis.

As an example, assume at time t-1 the stock price S = 1000 and there are two ATM calls and puts with strikes of 1000 and 1005. The volume for the 1000 strike is 500, and the 1005 strike is 1500. Returns to the straddle are measured over a holding period of the

---

[9] To be included in straddle calculations, the option must satisfy these conditions:
i) Option price (average of bid and ask) is greater than \$0.125 .
iii) Option contract has non-missing volume.
iv) The option has a maturity between 10 and 60 days.
v) Option bid price > 0, bid $<$ offer.
vi) Put options must have a strike price >= bid and offer >= $max(0, strikeprice - stockprice)$
vii) Call options must have stock price >= bid and offer >= $max(0, stockprice - strikeprice)$

end-of-day at time t-1 to end-of-day at time t. The return on the 1000 straddle is weighted by 25% (500/2000), and the return on the 1005 straddle is weighted by 75% (1500/2000). Assume at the end of day t, the stock price is S'. New ATM straddles are chosen around S', weighted by volume, and returns are measured to end-of-day at t+1.

Table 2.1: Statistics for Daily Delta-Neutral Straddle Returns on SPX Options

This table provides summary statistics for daily Delta-neutral straddle returns on the full sample of Jan 01,2004 to Dec 31, 2014. Straddle positions are held from close-to-close, and are reformed daily. When multiple straddle exist on a single day, they are volume weighted.

N	Mean	Std	Min	Max	Skew.	Kurt.	T-stat	$Prob > \|t\|$
2768	-0.0040	0.0698	-0.1642	1.2876	4.3095	50.5939	-3.02	0.0025

Summary statistics for daily straddle returns are presented in table 2.1. On average, straddles have a highly significant mean negative daily return of -0.40%. This represents an cumulative annualized value of -100.8 %. The findings of are consistent with that of Coval and Shumway (2001), who document large negative returns to straddle positions and a negative price of volatility. Straddle returns have a standard deviation of 15.1%. The return distribution is positively skewed, and highly leptokurtic, which means extreme return values occur rather often.

Next, I partition straddle returns based on macroeconomic announcement day. I investigate a wide array of announcements during which assets sensitive to volatility may carry a significant premium. Table 2.2 presents average one-day returns on delta-neutral straddles for ten different types of announcements. My findings indicate that several news days generate highly negative holding period straddle returns. On days when the Consumer Price Index , Nonfarm Payroll, ISM Manufacturing, and Industrial Production are announced average returns are strongly negative and statistically significant at a 1% level. The average straddle returns on these days are -1.3%, -1.8%, -1.5% and -2.5%, respectively. I term this four announcement days as “A-days”. Savor and Wilson (2013) also use this term, however the A-days in this paper additionally contain ISM and IP, but omit FOMC.

It is rather intuitive that days on which macroeconomic information that systematically impacts volatility is directly conveyed should also be days on which volatility and jump premiums are largest. While implied volatility on these days has a tendency to fall, realized volatility can be mixed. Investors are willing to pay these larger premiums for variance and jumps due the risk of bad economic news causing higher volatility or negative price jumps. It is not the case that every announcement increases volatility, but rather an investor is averse to a chance that negative news may increase volatility or cause price jumps.

The other announcements have average returns have mixed signs, but not statistically different from zero at a 5% confidence level. This may be due to the limited impact the announcement could have on volatility, or the relative unimportance traders attach the information in the news release.

Now, I investigate aggregate returns from the A-days. Table 2.3 presents summary statistics for the partitioned sample of A-days versus non-news days (N-days). A-day straddles on average earn a highly significant return of -1.85%. This is a sharp contrast to other-day average returns of -0.1%, which is insignificant at any standard confidence level. To formally confirm that average returns are different across days, I conduct a standard t-test. A t-test rejects the null hypothesis of equal mean returns with significant T-stat of 5.52.

The highly negative average returns on announcement days indicates that on a remarkable portion of the risk premium attached to annualized straddle returns is paid on a relatively small amount of trading days. The cost to an investor purchasing straddles prior to A-days would be approximately -77.7% on an annualized basis.[10] This implies that over 77% of the annualized returns from holding daily delta-neutral straddles is earned on approximately 17% of all trading days in the sample. Therefore, the price of variance exposure is significantly more expensive on these announcement days.

[10] On average, these types of announcements occur 42 times a year. Therefore, the annualized return is $-1.85\% * 42 = -77.7\%$.

It follows that it is essentially free to insure against changes in aggregate volatility due to randomly occurring economic news on non-announcement days. This result is reflective of a substantially lower premium to insuring against volatility and jump risk on non-announcement days. Table 2.3 also lists summary statistics for daily returns on the S&P 500. Consistent with the results in Savor and Wilson (2013), average returns are higher on macroeconomic announcement days. The standard deviation of returns on A-days is only 1 b.p. higher than N-days. However, the return distribution on A-days exhibit a negative skewness of -1.12. This is an indicator that downside risk to owning stocks on A-days is larger. A risk-averse investor would be willing to pay substantially more to hedge against this type of risk that she experiences more-so on A-days.

Table 2.2: Statistics of Individual Announcement Day Delta-Neutral Straddle Returns on SPX Options

This table provides summary statistics for delta-neutral straddle returns for individual macroeconomic announcements from Jan 01, 2004 to Dec 31, 2014. Straddle positions are held from close-to-close, and are reformed daily.

Event	N	Mean	Stdev	Min	Max	Skew.	Kurt.	T-stat	$Prob < \|t\|$
CPI	132	-0.0135	0.0568	-0.0945	0.2973	2.3162	8.3294	-2.7289	0.007
Nonfarm Payroll	129	-0.0257	0.0730	-0.1329	0.4330	2.9063	13.4560	-4.005	0.0001
Consumer Conf.	132	0.0084	0.0602	-0.1046	0.3831	2.6301	11.7776	1.595	0.113
Durable Goods	132	-0.0016	0.0518	-0.1046	0.2415	1.9811	5.5551	-0.345	0.731
FOMC Decision	90	0.0264	0.0840	-0.0890	0.3149	1.4768	2.2482	2.981	0.004
Housing Starts	132	-0.0097	0.0630	-0.1249	0.2688	1.7905	4.7696	-1.772	0.079
ISM Manu.	132	-0.0184	0.0572	-0.1339	0.1882	1.1289	2.1787	-3.687	0.0003
Industrial Prod.	131	-0.0154	0.0499	-0.1325	0.1875	1.5143	3.794	-3.528	0.0006
Home Sales	103	0.0037	0.0496	-0.0623	0.2415	2.0066	5.5958	0.758	0.450
PPI	121	0.0026	0.0650	-0.0843	0.2836	2.0930	5.4845	0.448	0.655

Table 2.3: Aggregated Announcement Returns for S&P 500 Index and Delta-Neutral Straddles

This table provides summary statistics for delta-neutral straddle returns and returns on the S&P 500 index from Jan 01, 2004 to Dec 31, 2014. A-days represent the combined announcements of the CPI, ISM, IP, and NFP, and N-days no announcement occurs.

	Daytype	N	Mean	Std	Min	Max	Skewness	Kurt.	T-stat	$Prob > t$
Straddle Returns	N-days	2300	-0.0011	0.0712	-0.1642	1.2876	4.5692	54.6121	-0.7166	0.4737
	A-days	468	-0.0185	0.0604	-0.1339	0.4330	2.2822	10.0804	-6.6307	0.0000
S&P 500 Returns	N-days	2301	0.0002	0.0124	-0.0903	0.1158	0.1473	12.6361	0.9256	0.3547
	A-days	468	0.0006	0.0125	-0.0893	0.0514	-1.2124	8.3407	1.0309	0.3031

2.4.1 FOMC-Day Straddle Returns

An interesting empirical finding is the positive returns for straddles during FOMC announcement periods. On average, straddles held through FOMC days earn 2.6% with a highly significant T-stat of 2.24%. These positive returns contrast with the highly negative returns found on other announcement days. I attribute this to market anticipation of information regarding volatility in FOMC news releases.

The central difference between other macroeconomic news announcements and FOMC announcements is their forward-looking nature. FOMC announcements are accompanied by a balance of risks statement, in which the committee provides forward guidance regarding future economic policy. The Fed is able to able to react to developing economic risks and financial market uncertainty by providing commitments to keep policy lax. In recent literature, Amengual and Xiu (2014) find that resolution of policy uncertainty from FOMC meetings are associated with sharp decreases in volatility. These sharp decreases in volatility would clearly cause a long position on volatility to lose value, such as straddle. Rational investors should then be able to anticipate the implications of government intervention on returns

The impending risk of government intervention in markets lowers the price for insurance against variance and jumps, which is reflected in straddle prices. In terms of the ICAPM, a straddle will have low returns when volatility is lower than expected (positive shift in investment opportunities). If rational investors anticipate government intervention on FOMC meeting, straddles should have low prices and earn high expected returns. This is due to the expectation that FOMC tends to reduce volatility through its actions.

Another possibility is that the level of risk aversion differs between regular announcement days and FOMC days. If investors become more risk-averse prior to regular announcements by attributing larger weights to bad outcomes, then Bekaert et al. (2013) demonstrate in a VAR framework find that high uncertainty and risk aversion implicit in the VIX lead to lax policy in the short-term. However, I leave this theory open for future research.

In this next section, I provide further evidence of this phenomenon by conducting regression analysis on straddle returns and a sub-period analysis of the financial crisis. The intent of these studies is to provide robustness by demonstrating that average straddle returns for announcement days are significant in regressions, as well as showing the return patterns are not driven by extreme volatility outliers as a result of the financial crisis.

2.4.2 Regressions and Financial Crisis

In this section, I present further evidence of the significance of macroeconomic news announcements from regressions on delta-neutral straddle returns. Table 2.4 contains regression results for daily delta-neutral straddle returns on dummy variables and controls. Model 1 only includes the announcement day dummies representing the CPI, ISM, IP, NFP, and FOMC. These values take a value of 1 if that day is an announcement day, 0 otherwise. The coefficients for the CPI dummy is significantly negative at 5% level, with a T-stat of -2.2. The ISM, IP, and NFP are highly significantly negative at a 1% level. The signs and significance of these variables are consistent with previous findings of negative straddle returns on real announcement days. The FOMC dummy takes a positive coefficient with a strong significant T-stat of 3.16, which supports the finding of positive average straddle returns on these days.

Model 2 adds two additional control variables. VRP is the lagged one-day variance risk premium measured as the difference between the CBOE's VIX and 30- day realized volatility. When the premium is large, uncertainty about future variance is large, and/or risk aversion. These are states in which positions on variance are relatively more expensive. Inclusion of this variable is done to ensure the announcement day results are not only driven by periods of extreme volatility or risk aversion.

As expected, the coefficient on the VRP term is negative and significant at 5% level. As the premium increases, it becomes more costly for a variance buyer to insure against changes in volatility. During these periods, expected returns to a straddle are lower. The FC variable is a dummy variable for the Financial Crisis period, which takes a value of 1 if the date is within the NBER recession dates, 0 otherwise. It does not appear that the financial crisis significantly impacted straddle returns (in the presence of the VRP control). Inclusion of these controls does not alter the significance of the announcement coefficients by any large measure.

Ultimately, these regressions provide strong supporting evidence of the unique straddle return behavior during announcement periods. Using linear regressions with announcement day dummy variables, I document the strong significance that announcements have on straddle returns. These signs are consistent with the summary analysis of returns, and remain significant in the presence of control variables.

Table 2.4: Regression of Straddle Returns on Announcement Day Variables

The table below represents linear regression results for daily delta-neutral straddle returns from the period Jan 01,2004 to Dec 31, 2014. The CPI, ISM, IP , NFP represent dummy variables for their respective announcement days. The VRP term is defined as the lagged difference between the VIX and 30 day realized volatility. FC represents a dummy variable for returns with the 07-09 Financial Crisis period, as dated by NBER. Regressions use the Newey and West (1986) adjustment for autocorrelation and heteroskedascity.

Variable	Model 1	Model 2
Constant	-0.0023	-0.0019
	(-1.61)	(-0.94)
CPI	-0.0109	-0.0100
	(-2.1784)**	(-1.9901)**
ISM	-0.0175	-0.0155
	(-3.5047)***	(-3.0241)***
IP	-0.0120	-0.0108
	(-2.6300)***	(-2.3062)**
NFP	-0.0245	-0.0235
	(-3.8194)***	(-3.6356)***
FOMC	0.0278	0.0289
	(3.1615)***	(3.2692)***
VRP		-0.0005
		(-2.1027)**
FC		0.0034
		(0.8777)
Df	2763	2760
R-squared	1.40%	1.58%

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Next, I evaluate the patterns of straddle returns observed across the financial crisis. This analysis is conducted to demonstrate to the reader that the significance of the announcement days straddle returns are not driven by the extreme levels of realized volatility during the financial crisis. To address this issue, I partition my sample based on the Financial Crisis, shown in table 2.5. The Financial Crisis sample consists of the time period of the recession dated by the NBER.

The first two columns of this table represent the returns to straddle on Non-Announcement days. Average daily straddle returns during the recession were positive. The recession represented a period of higher volatility, and therefore straddles should have higher returns. For the FOMC days, it is apparent that straddles formed during the 15 committee meetings within the recession have higher returns at 5.0% compared to 2.16% outside of the recession. Although this sample is small, these findings are in line with the pricing of downward volatility. Periods in which the Fed is most likely to engage in actions that reduce market volatility also make delta-neutral straddles more risky. This is compensated by higher expected returns to straddle positions during FOMC days.

The last two columns present recession vs. non-recession mean straddle returns for aggregated NFP, CPI, ISM , IP announcements. Straddle returns for these announcements during the recession are -0.093%, compared to .021% for N-day recession returns. This represent a difference of -1.14%. Even during periods of high volatility and uncertainty, straddles still deliver consistently low returns during announcements. Therefore, exposure to upward volatility risk is systematically more expensive on real announcement days.

This sub-period analysis supports the risk compensation argument of upward volatility of real announcement days, and downward volatility on FOMC days. In the presence of put protection, FOMC announcements lead to higher expected returns on straddles due to their higher conditional risk. The real announcement days experience lower expected returns, as a premium charged for risks associated with information regarding a worsening economy. In the next section to further the investigation of straddle behavior, I decompose the two risk components of straddle returns, namely jump and volatility risk.

2.4.3 Gamma and Vega-Neutral Straddles

A potential problem with only evaluating the returns from a delta-neutral straddle is disentangling whether risk premia is driven by pure volatility or jump risk. Cremers et al. (2015) demonstrate that they are separately priced risk factors, and can explain the cross-sectional variation of returns. In the context of economic theory, investors seeking to hedge negative shifts in investment opportunities due to variance can weigh their portfolios towards assets that co-vary positively with equity market variance. Option portfolios with large vegas will be very sensitive to small changes in volatility. The option vega is a measure of the impact of a change in volatility of the underlying security on the option price. Since straddles have high sensitives to market variance (large vegas) on average, they deliver low expected returns.

Straddle holders are also exposed to jump risk. If the underlying asset experiences a large discontinuous jump in price, the straddle will no longer remain delta-neutral, and will be exposed to directional movements of the underlying asset. Option gamma is the rate of change the portfolio's delta with respect to the price of the underlying asset. An option portfolio with a large gamma will also be sensitive to underlying price jumps.A straddle will also have a high sensitivity to market jumps (high gammas).

A natural next step is to determine exactly which type of risk is the driver of observed straddle returns during specific macroeconomic news periods. This can be done by analyzing two other options strategies, the gamma-neutral, vega-positive straddle and a vega-neutral, gamma-positive strategy.[11] These options strategies create high exposures to volatility and jump risk respectively, and are orthogonal to one another (Cremers et al., 2015).

Creating the strictly vega-positive option portfolio involves purchasing one distant maturity straddle, and selling multiple short term straddles such that the total gamma of the portfolio is zero. To form a gamma-positive option portfolio, one short maturity straddle is purchased and multiple longer term straddles are sold in a ratio that nets a portfolio of vega zero. For both the strategies, I use short maturity options that expire the next calendar month, and longer term maturity options that expire in that calendar month following. When there are multiple viable ATM straddles, the largest total volume option straddle is chosen

[11] The overall strategy remains delta-neutral, since it involves combining multiple straddles that are already have a delta of zero.

Table 2.5: Summary Statistics for Straddle Returns partitioned by Recession

This table presents delta-neutral straddle returns aggregated by sub-sample (Recession vs. Non-Recession). The recession is classified as the Financial Crisis period, as dated by NBER.

	No News		FOMC		CPI, IP, ISM, NFP	
	Non-Rec.	Rec.	Non-Rec.	Rec.	Non-Rec.	Rec.
N	1902	319	75	15	402	66
Mean	-0.0027	0.0021	0.0216	0.0501	-0.0200	-0.0093
StdDev	0.0694	0.0775	0.0815	0.0951	0.0585	0.0703
Min	-0.1642	-0.1249	-0.0890	-0.0668	-0.1339	-0.1329
Max	1.2876	0.6443	0.3149	0.2973	0.4330	0.2973
Skew	5.1375	3.0349	1.5749	1.2080	2.4174	1.7026
Kurt	68.7024	16.8910	2.6336	2.0353	11.5620	5.2577
T- Stat	-1.71	0.48	2.30	2.04	-6.85	-1.08
P-value	.0887	.6297	.0242	.0606	$<$ .0001	.2840

in order to ensure liquidity. At the end of each trading day, a new set of ATM straddles is selected similar to the delta-neutral methodology.

The purpose of looking at separate gamma and vega portfolios is to identify whether variance or jump risk factor drives the observed delta neutral returns. For example, if gamma risk is priced more heavily in the straddle, then returns to the gamma portfolio should be larger in absolute value for announcement days.

Table 2.6 presents results for the gamma positive options strategy. Full sample average daily returns are -0.29%. This is consistent with previous research documenting a significantly negative price to jump risk. When mean returns are decomposed into N-days (-0.13%) and A-days (-1.09%), it is apparent that gamma portfolio has much lower returns on A-days. A t-test of means between the two day-types has a T-stat of 3.19, which rejects a null hypothesis of equal returns at 1% level. This makes a strong case for a higher price of jump risk on the real announcement days.

In the case of FOMC announcements, FOMC day returns to the gamma positive strategy are positive (1.75%). Besides providing evidence that the observed straddle returns on these days are not spurious, it also indicates that the jump component plays an important role in expected returns. A t-test of equal means of N-Days and FOMC-days a T-stat of 3.21, which rejects the null at a 1% confidence level. In other words, the high gamma risk in short term options are an important factor in the return behavior on macroeconomic news days.

Table 2.7 lists the returns to the vega positive strategy. It is immediately apparent that volatility risk does not play a large role in returns behavior exhibited on announcement days, or during the sample as a whole. The full sample daily average returns to the vega positive strategy is 0.1%, but is not statistically significant at any standard confidence interval. The A-days have a positive average return of 0.27%, but a two-sided test of means does not reject the null that hypothesis of equal average returns across N-days and A-days at any significant confidence level. The average FOMC-day return (-0.04%) is also not significant.

A possible reason for the insignificance of the vega straddle results compared to delta-neutral straddles involves the weighting scheme and calendar formation of the long and short positions. The delta-neutral straddles were created by volume weighting using a options that expire between 10 and 60 days. Therefore the longest dated options were at most 60 days, and possibly were assigned very small weights. In comparison, the vega strategy uses options expiring up to 90 days, and only selects a single straddle (by highest volume). Since this strategy only picks a single straddle to short and long respectively, return patterns are likely to be very noisy.

In summation, I conclude that jump risk is the central component of the returns to straddles during announcement and FOMC days. In other words, shorted dated options are the most sensitive to macroeconomic news events because of their high gammas. However, the absolute value of the gamma option portfolios are significantly smaller in magnitude than their delta-neutral counterparts. I attribute this the different weighting schemes of the two strategies, or the possibility of another type of priced risk factor. However, the extent to which volatility risk contributes to these return patterns cannot be determined from this analysis.

Table 2.6: Gamma Positive Option Strategy Returns

The table listed below displays summary statistics for daily straddles that are formed to be gamma positive and vega-neutral. To form a gamma positive option portfolio, one short maturity straddle is purchased and multiple longer term straddles are sold in a ratio that nets a portfolio of vega zero.

Daytype	N	Mean	StdDev	Min	Max	Skew	Kurt	T-Stat	P-value
All Days	2768	-0.0029	0.0657	-0.1655	0.8398	3.0319	20.7353	-1.62	.103
N-Days	2300	-0.0013	0.0679	-0.1655	0.8398	3.1051	21.1027	-.42	.674
CPI,NFP,ISM,IP	468	-0.0109	0.0528	-0.1350	0.2781	1.7835	6.2703	-4.06	$< .0001$
FOMC	90	0.0175	0.0964	-0.1350	0.4560	2.2957	7.2674	1.58	.117

Table 2.7: Vega Positive Option Strategy Returns

The table listed below displays summary statistics for daily straddles that are formed to be vega positive and gamma neutral. To form a vega positive option portfolio, one long maturity straddle is purchased and multiple shorter term straddles are sold in a ratio that nets a portfolio of vega zero.

Daytype	N	Mean	StdDev	Min	Max	Skew	Kurt	T-Stat	P-value
All-Days	2768	0.0010	0.0412	-0.3294	0.2988	-0.7240	8.2546	1.29	.194
N-Days	2221	0.0007	0.0404	-0.2897	0.2988	-0.4741	7.0716	.859	.392
CPI, NFP,ISM, IP	468	0.0027	0.0385	-0.2185	0.1426	-1.0047	8.1426	1.87	.131
FOMC	90	-0.0004	0.0662	-0.3294	0.2007	-1.6935	8.6436	-.0558	.95

2.5 Conclusion

In this paper I explore the return behavior of ATM delta-neutral straddles on S&P 500 options during macroeconomic news events. On average, delta-neutral straddles have negative returns since they hedge volatility. However, straddles exhibit unique behavior during several types of announcements. On days when the Consumer Price Index , Non-Farm Payrolls, Industrial Manufacturing ,and Industrial Production are announced average straddle returns are significantly more negative than on other days. Investors are willing to pay larger premiums on announcement days due the possibility of higher realized volatility as a result of negative economic news.

This paper also demonstrates that the premiums for hedging against variance and jump risk is close to zero on announcement days. This means an investor can hedge shocks to volatility and jumps from random economic news for free.

However, straddle returns on Federal Open Market Committee (FOMC) days are on average positive. This is likely due to the put protection offered by the Federal Reserve in times of turmoil. Statements made by the Fed tend to have a calming effect on markets, and lead to rapid decreases in volatility. Straddles have low payoffs when volatility is lower than expected, therefore they will have low prices during periods when government intervention in markets is likely. A risk-averse investor knows she will be exposed to higher risk of government put protection during FOMC meetings, and require higher expected returns to on variance-sensitive assets.

I show these findings hold in a sub-sample analysis of the Financial Crisis, and are robust in a regression analysis. I also investigate the contribution of straddle returns from their component risks of jump (gamma) and vega (volatility) risk. This is done by creating options portfolios that weigh heavily on one type of risk, but remain neutral to other. My results indicate that the observed returns on straddles during announcement days is primarily driven by gamma, or the short-dated options returns. The signs of average returns based on announcement day for the gamma portfolios are consistent with the broader delta-neutral portfolio, but of smaller absolute magnitudes. This is possibly a result of the portfolio construction, or the presence of another priced risk factor.

This essay opens the door to many future avenues of research. One such avenue would be an investigation as to whether straddles on individual options also also exhibit the same patterns of returns during announcements. Another would be specifying an option pricing model which can generate the pattern of option returns exhibiting around FOMC announcements.

Chapter 3

CONCLUDING SUMMARY

This dissertation presents a set of empirical studies with a unifying theme related to the the pricing of equity options around scheduled macroeconomic news. The goal of this research to contribute to an expanding set of literature that studies the incorporation of macroeconomic news on options pricing and implied volatility. However, these essays provide two slightly differing perspectives on the impact of macroeconomic news on options prices.

The results in the first essay find that option prices lead stock prices, in the sense that options prices contain information about future economic news before stock prices do. A profitable trading strategy can be created using this knowledge, implying that a market inefficiency exists. This inefficiency is a result of the characteristics of each market, as well as the effects of market micro-structure. An informed trader prefers options markets, because she is able to take levered positions and avoid short-sale constraints when trading. Factors such as trade camouflaging and transactions costs limit information flow between the options and stock market. I show this inefficiency exists in a high uncertainty environment. When the economic outlook is very uncertain, it leads to greater incentives for option information gathering. A central contribution of this first essay is demonstrating that during times of uncertainty, informational asymmetry increases, and informational efficiency decreases between options and stock markets.

The second essay focuses on measuring risk compensation for higher-order moments as measured by option returns. The central finding of this essay is that options prices incorporate the future increased risk of changing volatility or price jumps as a result of scheduled macroeconomic news. Premiums for insuring against these risks are larger around announcements, reflected by substantially different holding period returns on straddles compared to non-news days. Options markets also price the likelihood of government intervention, especially on FOMC days. Taken collectively, these results indicate that the options market efficiently incorporates risks related to volatility and jumps resulting from macroeconomic news.

Therefore, these essays address two different concepts of option pricing in relation to macroeconomic news, which can co-exist. The first essay takes the view that there are times when the stock market does not efficiently incorporate information from the options market, which are unidentified by using a set of conditional information. The second essay takes the perspective that options prices embed macroeconomic risks for higher-order moments, which is reflected by average returns to straddles over a long period unconditionally across announcement days.

This dissertation presents many directions for future research. In regards to the first essay, the exact reasons behind the predictive behavior of the implied volatility spread during FOMC days is still unresolved. An interesting study would be explore the IV spreads linkage with the higher-order moments on return days. Additionally, I would like to enhance the skew trading strategy to include volume data. By including volume as a filter, I can pinpoint announcements prior to which options traders are relatively more active.

There is also plenty of room for research into how variance and jump risk is compensated on macroeconomic announcement days. Since information from macroeconomic news likely drives returns to many individual stocks, an interesting research question would be whether the return patterns to individual straddles on macroeconomic news are similar to S&P 500 options. Compensation for other higher-order moment risks could also be explored using options, such correlation between an individual stocks and the index.

BIBLIOGRAPHY

Amengual, D. and D. Xiu (2014). Resolution of policy uncertainty and sudden declines in volatility. *Chicago Booth Research Paper* (13-78).

Andersen, T. G., T. Bollerslev, F. X. Diebold, and C. Vega (2003). Micro effects of macro announcements: Real-time price discovery in foreign exchange. *The American economic review 93*(1), 38–62.

Anderson, E. W., E. Ghysels, and J. L. Juergens (2009). The impact of risk and uncertainty on expected returns. *Journal of Financial Economics 94*(2), 233–263.

Atilgan, Y. (2014, 1). Volatility spreads and earnings announcement returns. *Journal of Banking & Finance 38*, 205–215.

Augustin, P., M. Brenner, and M. G. Subrahmanyam (2014). Informed options trading prior to m&a announcements: Insider trading? *Available at SSRN 2441606*.

Baker, S. R., N. Bloom, and S. J. Davis (2013). Measuring economic policy uncertainty. *Chicago Booth research paper* (13-02).

Bakshi, G., C. Cao, and Z. Chen (1997). Empirical performance of alternative option pricing models. *The Journal of Finance 52*(5), 2003–2049.

Bakshi, G. and N. Kapadia (2003). Delta-hedged gains and the negative market volatility risk premium. *Review of Financial Studies 16*(2), 527–566.

Bakshi, G., N. Kapadia, and D. Madan (2003). Stock return characteristics, skew laws, and the differential pricing of individual equity options. *Review of Financial Studies 16*(1), 101–143.

Balduzzi, P., E. J. Elton, and T. C. Green (2001). Economic news and bond prices: Evidence from the us treasury market. *Journal of financial and Quantitative analysis 36*(04), 523–543.

Basistha, A. and A. Kurov (2008). Macroeconomic cycles and the stock markets reaction to monetary policy. *Journal of Banking & Finance 32*(12), 2606–2616.

Bates, D. S. (1991, 07). The crash of '87: Was it expected? the evidence from options markets. *Journal of Finance 46*(3), 1009–1044. Update Code: 199203.

Bates, D. S. (1996). Jumps and stochastic volatility: Exchange rate processes implicit in deutsche mark options. *Review of financial studies 9*(1), 69–107.

Bates, D. S. (2008). The market for crash risk. *Journal of Economic Dynamics and Control 32*(7), 2291–2321.

Beber, A. and M. W. Brandt (2006). The effect of macroeconomic news on beliefs and preferences: Evidence from the options market. *Journal of Monetary Economics 53*(8), 1997–2039.

Beber, A. and M. W. Brandt (2009). Resolving macroeconomic uncertainty in stock and bond markets*. *Review of Finance 13*(1), 1–45.

Bekaert, G. and M. Hoerova (2014). The vix, the variance premium and stock market volatility. *Journal of Econometrics 183*(2), 181–192.

Bekaert, G., M. Hoerova, and M. L. Duca (2013). Risk, uncertainty and monetary policy. *Journal of Monetary Economics 60*(7), 771–788.

Bernanke, B. S. and K. N. Kuttner (2005). What explains the stock market's reaction to federal reserve policy? *The Journal of Finance 60*(3), 1221–1257.

Bernile, G., J. Hu, and Y. Tang (2014). Can information be locked-up? informed trading ahead of macro-news announcements. *Informed Trading Ahead of Macro-News Announcements (May 10, 2014)*.

Biais, B. and P. Hillion (1994). Insider and liquidity trading in stock and options markets. *Review of Financial Studies 7*(4), 743–780.

Black, F. (1975). Fact and fantasy in the use of options. *Financial Analysts Journal 31*(4), 36–41.

Black, F. and M. S. Scholes (1973, May). The pricing of options and corporate liabilities. *Journal of Political Economy 81*(3), 637–654.

Bollen, N. P. and R. E. Whaley (2004). Does net buying pressure affect the shape of implied volatility functions? *Journal of Finance*, 711–753.

Boudoukh, J., M. Richardson, and R. F. Whitelaw (1994). Industry returns and the fisher effect. *Journal of Finance 49*(5), 1595 – 1615.

Boyd, J. H., J. Hu, and R. Jagannathan (2005, 04). The stock market's reaction to unemployment news: Why bad news is usually good for stocks. *Journal of Finance 60*(2), 649–672. Update Code: 200505.

Buraschi, A., F. Trojani, and A. Vedolin (2014). When uncertainty blows in the orchard: Comovement and equilibrium volatility risk premia. *The Journal of Finance 69*(1), 101–137.

Campbell, J. Y. (1992). Intertemporal asset pricing without consumption data. Technical report, National Bureau of Economic Research.

Cao, H. H. and H. Ou-Yang (2009). Differences of opinion of public information and speculative trading in stocks and options. *Review of Financial Studies 22*(1), 299–335.

Carr, P. and L. Wu (2009). Variance risk premiums. *Review of Financial Studies 22*(3), 1311–1341.

Chakravarty, S., H. Gulen, and S. Mayhew (2004). Informed trading in stock and option markets. *The Journal of Finance 59*(3), 1235–1258.

Coval, J. D. and T. Shumway (2001). Expected option returns. *Journal of Finance 56*(3), 983 – 1009.

Cremers, M., M. Halling, and D. Weinbaum (2015). Aggregate jump and volatility risk in the cross-section of stock returns. *Journal of Finance 70*(2), 577 – 614.

Cremers, M. and D. Weinbaum (2010, 04). Deviations from put-call parity and stock return predictability. *Journal of Financial and Quantitative Analysis 45*(2), 335–367. Update Code: 201007.

Dew-Becker, I., S. Giglio, A. Le, and M. Rodriguez (2015). The price of variance risk. Technical report, National Bureau of Economic Research.

Diavatopoulos, D., J. S. Doran, A. Fodor, and D. R. Peterson (2012, 3). The information content of implied skewness and kurtosis changes prior to earnings announcements for stock and option returns. *Journal of Banking & Finance 36*(3), 786–802.

Dubinsky, A., M. Johannes, et al. (2006). Fundamental uncertainty, earning announcements and equity options. Technical report, Working paper.

Easley, D., M. O'Hara, and P. S. Srinivas (1998). Option volume and stock prices: Evidence on where informed traders trade. *The Journal of Finance 53*(2), 431–465.

Ederington, L. H. and J. H. Lee (1993). How markets process information: News releases and volatility. *The Journal of Finance 48*(4), 1161–1191.

Eraker, B. (2004). Do stock prices and volatility jump? reconciling evidence from spot and option prices. *The Journal of Finance 59*(3), 1367–1403.

Evans, K. P. (2011, 10). Intraday jumps and us macroeconomic news announcements. *Journal of Banking & Finance 35*(10), 2511–2527.

Fama, E. F. and G. W. Schwert (1977). Asset returns and inflation. *Journal of Financial Economics 5*(2), 115–146.

Feunou, B., M. R. Jahan-Parvar, and C. Okou (2015). Downside variance risk premium.

Flannery, M. J. and A. A. Protopapadakis (2002). Macroeconomic factors do influence aggregate stock returns. *Review of Financial Studies 15*(3), 751–782.

Fleming, M. J. and E. M. Remolona (1999). Price formation and liquidity in the us treasury market: The response to public information. *The journal of Finance 54*(5), 1901–1915.

Foster, F. D. and S. Viswanathan (1996). Strategic trading when agents forecast the forecasts of others. *The Journal of Finance 51*(4), 1437–1478.

Garleanu, N., L. H. Pedersen, and A. M. Poteshman (2009). Demand-based option pricing. *Review of Financial Studies 22*(10), 4259–4299.

Hao, X., E. Lee, and N. Piqueira (2013, 05). Short sales and put options: Where is the bad news first traded? *Journal of Financial Markets 16*(2), 308–330. Update Code: 201304.

Hasbrouck, J. (1995). One security, many markets: Determining the contributions to price discovery. *Journal of Finance*, 1175–1199.

Heston, S. L. (1993). A closed-form solution for options with stochastic volatility with applications to bond and currency options. *Review of financial studies 6*(2), 327–343.

Huang, X. (2015). Macroeconomic news announcements, systemic risk, financial market volatility and jumps. Technical report, Board of Governors of the Federal Reserve System (US).

Kelly, B. T., H. Lustig, and S. Van Nieuwerburgh (2011). Too-systemic-to-fail: What option markets imply about sector-wide government guarantees. Technical report, National Bureau of Economic Research.

Kim, O. and R. E. Verrecchia (1991). Market reaction to anticipated announcements. *Journal of Financial Economics 30*(2), 273 – 309.

Kim, O. and R. E. Verrecchia (1994). Market liquidity and volume around earnings announcements. *Journal of Accounting and Economics 17*(1-2), 41 – 67.

Kontonikas, A., R. MacDonald, and A. Saggu (2013, 11). Stock market reaction to fed funds rate surprises: State dependence and the financial crisis. *Journal of Banking & Finance 37*(11), 4025–4037.

Kou, S. G. (2002). A jump-diffusion model for option pricing. *Management science 48*(8), 1086–1101.

Lee, S. S. (2011). Jumps and information flow in financial markets. *Review of Financial Studies*, hhr084.

Lee, S. S. and P. A. Mykland (2008). Jumps in financial markets: A new nonparametric test and jump dynamics. *Review of Financial studies 21*(6), 2535–2563.

Lin, T.-C. and X. Lu (2015, 03). Why do options prices predict stock returns? evidence from analyst tipping. *Journal of Banking and Finance 52*, 17–28. Update Code: 201504.

Lucca, D. O. and E. Moench (2015). The prefomc announcement drift. *The Journal of Finance 70*(1), 329–371.

Merton, R. C. (1973). An intertemporal capital asset pricing model. *Econometrica: Journal of the Econometric Society*, 867–887.

Merton, R. C. (1976). Option pricing when underlying stock returns are discontinuous. *Journal of financial economics 3*(1-2), 125–144.

Neely, C. J. (2011). A foreign exchange intervention in an era of restraint. *Federal Reserve Bank of St. Louis Review 93*(5), 303–24.

Newey, W. K. and K. D. West (1986). A simple, positive semi-definite, heteroskedasticity and autocorrelationconsistent covariance matrix.

Pan, J. (2002). The jump-risk premia implicit in options: Evidence from an integrated time-series study. *Journal of financial economics 63*(1), 3–50.

Pan, J. and A. M. Poteshman (2006, Fall). The information in option volume for future stock prices. *Review of Financial Studies 19*(3), 871–908. Update Code: 200611.

Pearce, D. K. and V. V. Roley (1983, 09). The reaction of stock prices to unanticipated changes in money: A note. *Journal of Finance 38*(4), 1323–1333.

Roll, R., E. Schwartz, and A. Subrahmanyam (2010, 4). O/s: The relative trading activity in options and stock. *Journal of Financial Economics 96*(1), 1–17.

Rosa, C. (2011, 12). Words that shake traders: The stock market's reaction to central bank communication in real time. *Journal of Empirical Finance 18*(5), 915–934.

Santa-Clara, P. and S. Yan (2010). Crashes, volatility, and the equity premium: Lessons from s&p 500 options. *The Review of Economics and Statistics 92*(2), 435–451.

Savor, P. and M. Wilson (2013). How much do investors care about macroeconomic risk? evidence from scheduled economic announcements. *Journal of Financial and Quantitative Analysis 48*(02), 343–375.

Savor, P. and M. Wilson (2014). Asset pricing: A tale of two days. *Journal of Financial Economics 113*(2), 171–201.

Schwert, G. W. (1981, 03). The adjustment of stock prices to information about inflation. *Journal of Finance 36*(1), 15–29.

Todorov, V. (2009). Variance risk-premium dynamics: The role of jumps. *Review of Financial Studies*, hhp035.

Vortelinos, D. et al. (2015). The effect of macro news on volatility and jumps. *Annals of Economics and Finance 16*(2), 425–447.

Xing, Y. and X. Zhang (2013). Anticipating uncertainty: Straddles around earnings announcements. *Available at SSRN 2204549*.

Xing, Y., X. Zhang, and R. Zhao (2010, 06). What does the individual option volatility smirk tell us about future equity returns? *Journal of Financial and Quantitative Analysis 45*(3), 641–662. Update Code: 201010.

Yu, J. (2011). Disagreement and return predictability of stock portfolios. *Journal of Financial Economics 99*(1), 162–183.