Central Bank Tone and Currency Risk Premia

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Abstract

I analyze how the tone of central bank press conferences impacts risk premia in the currency market. I measure tone as the difference between the number of hawkish and dovish phrases made during a press conference. I consider two measures of risk premia. The first measure is implied risk aversion. This is based on the relationship between the option implied, or risk neutral distribution of returns, and the physical, or actual distribution of returns. I find that implied risk aversion increases when central banks are hawkish, and decreases when central banks are dovish. The second measure is the variance risk premium. This is the difference between option implied and realized variance, and reflects the cost of insuring against an unexpected increase in variance. I find that variance risk premia increase when central banks are hawkish, and decrease when central banks are dovish. The magnitudes are economically and statistically significant. A one standard deviation increase in the hawkishness of a press conference increases the one month variance risk premium by 4.7% per year, relative to the average of 28.9% per year.

1 Introduction

Central bank press conferences move markets. Press conferences are live, partially unscripted, and provide market participants clues on future policy actions. Press conferences

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can reveal news not previously available to the markets.¹ This paper asks how the tone of central bank press conferences impacts risk premia in the currency market.

I measure tone as the difference between the number of hawkish and dovish phrases made during a press conference, using the method in Apel & Grimaldi (2012).² I examine the impact of tone on two measures of risk premia. The first measure is implied risk aversion, as defined in Jackwerth (2000). It is based on the relationship between the option implied, or risk neutral distribution of returns, and the physical, or actual distribution of returns. The former is estimated using a cross section of option prices, while the latter is estimated using a historical time series of returns. I find that implied risk aversion increases when central banks are hawkish, and decreases when central banks are dovish. This is a contemporaneous result, meaning that central bank tone explains the contemporaneous change in implied risk aversion.

The second measure is the variance risk premium. This is the difference between option implied and realized variance. The variance risk premium reflects the cost of insuring against an increase in variance. Using the method in Carr & Wu (2009), I construct one, two, and three month variance risk premia for each currency. I find that variance risk premia increase when central banks are hawkish, and decrease when central banks are dovish. The magnitudes are economically and statistically significant. A one standard deviation increase in the hawkishness of a press conference increases the one month variance risk premium by 4.7% per year, relative to the average of 28.9% per year. This is a predictive result, meaning that central bank tone predicts future realized variance risk premia.

The two risk aversion measures are related in the following way. When implied risk aversion is higher, it means that options are more expensive, relative to their value if investors were risk neutral. When options are relatively expensive, the expected return from shorting a variance swap is higher. This intuition is confirmed by the empirical results. Hawkish

¹For example, Hansen & McMahon (2016) show that FOMC communication over future monetary policy decisions has a significant impact on both financial and real variables.

²A hawkish central bank is likely to increase interest rates or tighten monetary policy. A dovish central bank is likely to lower interest rates or loosen monetary policy.
central bank tone contemporaneously increases implied risk aversion, and also predicts higher realized variance risk premia.

This paper makes two contributions. The first is a joint analysis of the impact of central bank press conferences on risk premia across a range of countries and currencies. The second is the use of central bank tone to explain changes in implied risk aversion, and to predict variance risk premia. To the best of my knowledge, these contributions are novel.

This paper adds to the recent literature on the impact of central bank tone on financial markets. Schmeling & Wagner (2016) analyze the tone of European Central Bank press conferences, and find that positive tone is associate with higher bond yields, lower implied equity volatility, lower variance risk premia, and lower credit spreads. They use the method in Loughran & McDonald (2011) to measure tone, which based on the proportion of negative words contained in the text.\(^3\)

Why is central bank tone important for asset prices? It is well documented that central bank policy decisions impact asset prices.\(^4\) However, the impact of their words is relatively understudied. In part, this is because central bank use of words as a policy tool is relatively recent. Following the financial crisis of 2007-08, many countries lowered interest rates close to zero. Since then, they have increasingly relied on forward guidance as a policy tool. Forward guidance is communication to the public about the future course of monetary policy.\(^5\) Individuals, firms, and investors incorporate this information into their decisions. Consequently, forward guidance has an immediate impact on the economy and financial markets.\(^6\)

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\(^3\) Alternative approaches to analyze central bank text are in proposed Lucca & Trebbi (2009) and Acosta (2015).

\(^4\) For example, Lucca & Moench (2015) document large average excess returns on U.S. equities in anticipation of monetary policy decisions made at FOMC meetings. Cieslak et al. (2016) show that most of the U.S. equity risk premium is earned over the weeks corresponding to the FOMC cycle. Boyarchenko et al. (2016) show that Federal Reserve announcements impact markets independent of changes in conventional monetary policy.

\(^5\) In the early 2000s, the US Federal Reserve began using forward guidance. For example, in December 2008, the Fed lowered interest rates close to zero. Additionally, they stated that the Federal Funds rate would remain exceptionally low for some time due to weak economic conditions. By communicating its intention to keep future interest rates low, the Fed was hoping to influence then-prevailing decisions. Seven years later, in December 2015, the Fed raised interest rates. At the same time, they communicated their intention to raise interest rates over the coming year.

\(^6\) Campbell et al. (2012) and Filardo & Hofmann (2014) examine the impact of forward guidance on
Why do risk premia change in response to the tone of central bank press conferences? One explanation is that the tone of a press conference indicates to investors the likelihood of central bank intervention, conditional on the state of the economy. Suppose that the central bank has a reaction function defined over various future economic states, and this is not known to the investor. Instead, the investor has some expectations. These are then updated in response to new information, such as press conferences.

A hawkish central bank is less likely to provide monetary stimulus in bad states of the world. A dovish central bank is more likely to provide monetary stimulus in bad states of the world. For example, Belke & Klose (2010) compare how the Fed and the ECB reacted to the financial crisis of 2007-08. The Fed was more aggressive in easing monetary policy, relative to the ECB. This is partly attributed to the difference in their respective mandates. The Fed has a dual mandate of stable prices and maximum employment, whereas the ECB’s mandate is price stability. This means the Fed is more dovish than the ECB. As a result, the Fed puts a greater weight on the output gap, and is more likely to provide monetary stimulus in response to a crisis.

Following a press conference, suppose the investor believes that the central bank is more likely to provide monetary stimulus in bad states of the world, i.e. the central bank is dovish. Then the investor has less incentive to pay for insurance in those states, and risk premia decrease. Now suppose instead the investor believes that the central bank is less likely to provide monetary stimulus in bad states of the world, i.e. the central bank is hawkish. Then the investor has more incentive to pay for insurance in those states, and risk premia increase. A well known example of this phenomenon is the Greenspan put. Alan Greenspan, the former chairman of the Federal Reserve, would decrease interest rates when the stock market fell by a certain amount. The central bank essentially provided a put option to investors, protecting them when markets declined.\footnote{A put option’s payoff is decreasing in the price of the underlying asset. Index put options are often used}

\footnote{macroeconomic variables and asset prices. Del Negro et al. (2012) and McKay et al. (2016) show that the impact of forward guidance is small in practice, relative to theoretical predictions. Swanson (2017) shows that forward guidance has significant impacts on Treasury yields, stock prices, and exchange rates.}
Why are currencies the best channel to analyze the impact of central banks on risk premia? The first reason is data availability. I have access to option data traded on the Chicago Mercantile Exchange (CME). A prerequisite for this paper’s analysis is liquid option markets, and currencies meet this criteria. In addition, currencies allow the incorporation of data from multiple central banks, each corresponding to its own currency. As the CME is a US based exchange, for any other asset class, the CME option data is relevant only for the Fed, and not other central banks. For example, treasury bond options or S&P 500 options are not significantly impacted by foreign central banks. The Fed data consists of 20 press conferences, while the sample size of all central banks is 157 press conferences.

The second reason is that currencies are disproportionately affected by interest rates, and hence central bank behavior, relative to stocks or commodities. This holds true even if central banks do not directly attempt to influence exchange rates, as they may do with bonds or equities. Like currencies, bonds are also primarily impacted by interest rates and central bank behavior. However, they suffer from the data limitation discussed earlier. Currencies are impacted by the interest rate differential between the home and foreign currency. Currencies typically appreciate in response to a current or an expected future increase in interest rates. And they depreciate in response to a current or an expected future decrease in interest rates. Other macroeconomic data matter for currency markets, and can be interpreted through the lens of how it might impact central banks and interest rates. On the other hand, for stocks and commodities, interest rates matter, but they aren’t necessarily the most important factor.

The remainder of this paper is organized as follows: Section 2 describes the data. Section

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8Asset classes include stocks, bonds, currencies, and commodities.
9An important result in this literature is the forward premium puzzle, documented in Fama (1984) and Hansen & Hodrick (1980). The puzzle is that higher interest rates currencies earn excess returns over lower interest rate currencies.
10For example, if inflation or GDP growth is high, the central bank is likely to tighten monetary policy and increase interest rates. Alternatively, if inflation is low or the economy is weakening, the central bank is likely to loosen monetary policy and decrease interest rates.
11Stocks are impacted by expectations of future cash flows. Commodities are impacted by their own fundamentals.
3 presents the methodology. This includes the construction of central bank tone, implied risk aversion, and variance risk premia. An empirical example is presented for exposition, followed by the proposed regression specification. Section 4 presents and discusses the results. Section 5 concludes.

2 Data

This section describes the data. The data consist of currency futures and option contracts, and central bank press conference transcripts.

2.1 Currency Futures and Options

2.1.1 Currency Futures

Currency futures are traded on the Chicago Mercantile Exchange (CME). I use data on four currency futures contracts: the British pound (GBP), the Canadian dollar (CAD), the euro (EUR), and the Swiss franc (CHF). Prices are sampled at five minute intervals. The data come from DTN IQFeed. Prices are quoted as the number of US dollars (USD) per unit of foreign currency. Thus, a price increase is an appreciation of the foreign currency, and a depreciation of the US dollar. A price decrease is a depreciation of the foreign currency, and an appreciation of the US dollar. Returns on the US dollar are constructed as a weighted average of the returns on each of the currency contracts. The weights correspond to the proportions in the US dollar index DXY, and are as follows: 14.4% (GBP), 11.1% (CAD), 70.1% (EUR), and 4.4% (CHF). These are intended to reflect relative trading volumes of each currency to the dollar.

The currency futures market trades 23 hours per day, 5 days per week. Trading begins at 6.00pm EST on Sunday, and stops at 5.00pm EST on Friday. There is a 1 hour trading

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\textsuperscript{12}DTN IQFeed is an online provider of live and historical financial market data. Their currency futures data is sourced directly from the CME.
break from 5.00pm EST to 6.00pm EST each day. Closing prices are at 5.00pm EST from
Monday to Friday. Currency contracts trade in a quarterly cycle, with expiries in March,
June, September, and December each year. For all contracts other than the Canadian dollar,
they expire the business day preceding the third Tuesday of the contract month, which is
usually a Monday. The Canadian dollar contracts expire the business day preceding the
third Wednesday of the contract month, which is a usually a Tuesday.

The raw data take the form of continuous futures contracts. This is necessary in order to
ensure that returns are correctly calculated. Prices are back-adjusted to create a continuous
contract. This works by removing price gaps caused by a contract roll. The process starts at
the end of the price series, and works its way back. This leaves current prices intact. Prices
prior to the last roll date are adjusted. All currency contracts except for the Canadian dollar
are rolled two days prior to expiry. The Canadian dollar is rolled three days prior to expiry
to ensure that all contracts are rolled on the same day.

2.1.2 Currency Options

Options on the currency futures contracts also trade on the CME. These trade on a monthly
cycle. I use option data on each of the four currencies. The data come from OptionWorks
via Quandl.\textsuperscript{13} Option prices are sampled at the close of each trading day. The data start in
June 2009 and end in December 2015. The data take the form of one, two, and three month
implied volatility curves.

Implied volatility is a function of the strike price. First, the option price is converted to
an implied volatility, \( \sigma \), via the Black Scholes model. This is done across the range of traded
strike prices, using the Black-Scholes formula. Let \( F \) be the futures price, \( K \) be the strike
price, \( T \) be the time to maturity, \( \sigma \) be the implied volatility, and \( r \) be the interest rate. The
call option price \( C \) is given by:

\[
C = F N(d_1) - K e^{-rT} N(d_2)
\]

\textsuperscript{13}Quandl is online data provider of financial and economic data. OptionWorks is one of the databases
within Quandl that specializes in options on futures.
\[ C = e^{-rT}[FN(d_1) - KN(d_2)] \]
\[ d_1 \equiv \frac{\log(F/K) + (\sigma^2/2)T}{\sigma\sqrt{T}} \]
\[ d_2 \equiv d_1 - \sigma\sqrt{T} \]

Next, a polynomial of degree six is fitted to the data. This produces the implied volatility curve, where implied volatility is a function of the strike price. For convenience, the strike price \( K \), is expressed as moneyness \( M \), or the percentage deviation from the current futures price \( F \).

\[ M \equiv \log(K/F) \]
\[ \sigma(K) = b_0 + b_1M + b_2M^2 + b_3M^3 + b_4M^4 + b_5M^5 + b_6M^6 \]

The raw data consists of the closing futures price, the six model coefficients, the minimum and maximum moneyness, and the time to expiry. The minimum and maximum moneyness are upper and lower bounds. They reflect the fact that option prices only trade in a certain range of the current futures price. Typically, this includes the 5\(^{th}\) and 95\(^{th}\) quantile of the distribution.

Any strike and implied volatility pair can be converted to a call or put option price via the Black Scholes model. Using implied volatility curves does not require that Black Scholes assumptions hold. The implied volatility can be thought of as a normalized option price. It allows for a more intuitive comparison of option prices across strikes, time to maturity, or underlying currencies.

The curves are constructed for constant one month, two month, and three month maturities. Options trade on a monthly cycle. Constant maturity contracts are created by
interpolating across traded options with maturities less than and greater than the constant maturity. For example, the one month implied volatility curve is constructed using option prices expiring before and after one month. This is a standard procedure. For example, this method is used to calculate the VIX, the one month implied volatility of the S&P500 index.

2.2 Central Bank Press Conferences

Central bank announcements consist of two parts. The first part is a policy action. Usually, this is an overnight interest rate that is either lowered, raised, or held constant. Policy actions also include asset purchases. The second part is text. Examples of text include press conferences, interest rate decisions, meeting minutes, and economic outlook publications. The text contains useful information pertaining to the state of the economy and the future path of monetary policy. Press conferences tend to have the largest impact on asset prices. This is because they take place in real time and are partially unscripted.\(^\text{14}\)

I use press conference transcripts for five central banks: The Bank of England (BOE), the Bank of Canada (BOC), the European Central Bank (ECB), the Swiss National Bank (SNB), and the US Federal Reserve (FED). All the press conference data is publicly available on each central bank’s website. The Bank of England, Bank of Canada, and US Federal Reserve hold four press conferences per year. These coincide with alternate interest rate announcements that are made eight times per year. The European Central Bank holds eight press conferences per year, coinciding with each interest rate decision. Through December 2014, it held twelve press conferences per year. Now it holds eight press conferences per year. The Swiss National Bank holds two press conferences per year. These coincide with alternate interest rate announcements that are made four times per year. The total sample consists of 157 press conferences. The data start in June 2009 for all central banks excluding the Fed. The Fed data start in April 2011, at the time it started holding press conferences. All the data end in December 2015.

\(^{14}\)A press conference typically includes initial prepared remarks, followed by a live question and answer session.
3 Methodology

In this section, I present the methodology. First, I measure central bank tone, compute implied risk aversion, and compute variance risk premia. Then, I present an empirical example of a single observation. Finally, I use a regression to measure the impact of central bank tone on implied risk aversion and variance risk premia.

3.1 Central Bank Tone

Central bank tone is measured by the relative frequency of hawkish and dovish phrases. I use the method in Apel & Grimaldi (2012). Each phrase is a two word combination, consisting of an adjective followed by a noun. The nouns are common to both hawkish and dovish phrases, while the adjective is used to identify whether the phrase is hawkish or dovish. Table 1 lists the adjectives and nouns. A hawkish phrase consists of a hawkish adjective and a noun. A dovish phrase consists of a dovish adjective and a noun. Any combination of adjective and noun is considered a phrase. For example, increased inflation is a hawkish phrase, while slower growth is a dovish phrase.

For each press conference taking place at time $t$, I count the number of hawkish phrases, $\#Hawk_t$, and dovish phrases, $\#Dove_t$. I define the net index, $NI_t$, as the difference between the two.

$$NI_t = \#Hawk_t - \#Dove_t$$

When the net index is greater than zero, tone is hawkish. When the net index is less than zero, tone is dovish. The magnitude of the net index indicates how hawkish or dovish the tone is. Figure 1 plots the net index for each central bank.

Apel & Grimaldi (2012) propose this method to analyze the text in Swedish central bank minutes. First, they select a set of phrases that are either hawkish or dovish. Second, they count the number of hawkish and dovish phrases contained in the text. Their measure of
tone is based on the relative proportion of hawkish and dovish phrases contained in the text. They find that the tone of the Swedish central bank minutes is useful in predicting future interest rate decisions. Hawkish tone implies that the central bank is likely to tighten monetary policy in the future, while dovish tone implies that the central bank is likely to ease monetary policy in the future. The strength of the announcement depends on the numerical value for tone. They conclude that the minutes contain useful information not captured by observable macroeconomic variables.

In their paper, phrases associated with a stronger economy or higher inflation are hawkish, while phrases associated with a weaker economy or lower inflation are dovish. This is because a strong economy or high inflation means the central bank is more likely to tighten monetary policy. Conversely, if the economy is weak or inflation is low, the central bank is more likely to ease monetary policy.

The upside to this approach is that tone can be quantified and objectively calculated. It can later be used in a regression. The downside is that the full content of the announcement is not captured. Given that text is inherently subjective, there is an inevitable trade-off in objectively quantifying tone.

Why is this best method to measure central bank tone? Loughran & McDonald (2016) document that most methods to measure tone or sentiment rely on the frequency of certain words or phrases in the text. The relevant words are selected based on what the researcher wishes to measure. The method I use in this paper, based on Apel & Grimaldi (2012), differs in two ways from other common methods. First, it uses frequency of two word combinations rather a single word. This increases the precision of each phrase, at the expense of fewer phrases identified. Second, it uses two categories of phrases (hawkish and dovish), instead of one. Loughran & McDonald (2011) show that the negative words are better at measuring tone, relative to positive words, and so some studies use only one category of phrases. This is because positive words are more frequently negated, relative to negative words. This is

15 Alternatives include machine learning based approaches that are beyond the scope of this paper.
16 For example, Schmeling & Wagner (2016) analyze ECB press conferences using only negative words.
more likely to be a problem when analyzing single words rather than two word combinations. The use of two word combinations makes it easier to accurately identify two categories of phrases (hawkish and dovish).

Apel & Grimaldi (2012) apply their method to Swedish central bank minutes. The central bank publishes in Swedish, and the analysis is performed in Swedish. Is there a linguistic issue in applying this method to other central banks? Other than the Swiss National Bank, all the central banks analyzed in this paper publish in English (including the European Central Bank). The Swiss National Bank publishes English language versions of their statements; these are what I use. Even though this list of words is developed in the context of the Swedish central bank, all the words are commonly used in English. Further, these words are regularly used by economists and central bankers. There is no reason to believe that the list of words would be any different if the initial method was developed for an English medium central bank.

One limitation of using the net index to explain to market movements is the difficulty in capturing market expectations. A dovish press conference may not move the market at all if the market already expected it. Market movements should depend on how hawkish or dovish a press conference is relative to expectations, rather than on its own. In subsequent regressions, I get around this problem by controlling for the market reaction to a press conference. This is done by including the daily currency return and change in implied volatility over the press conference period in the regression.\footnote{Another possibility to control for market expectations is to predict the net index using its own lags and other market or macroeconomic data. This then forms the baseline for the market expectation, and hawkishness or dovishness can be measured relative to this. I do not employ this approach in this paper, due to data limitations. The number of press conferences for each central bank is too small to construct accurate forecasts. Macroeconomic data, the basis for central bank policy, is also available only at low frequencies.}

Note that Apel & Grimaldi (2012) calculate the net index differently. They take the difference between the number of phrases hawkish and dovish phrases, and divide by the total number of phrases. Their net index is the proportion of hawkish or dovish phrases, rather than raw value. I avoid this method so that the magnitude of the net index is more
meaningful. Suppose, for example, that the central bank makes nine dovish phrases and one hawkish phrase. The regular net index is $-8$, while the proportional net index is $-0.8$. In the next period, suppose that the central bank makes two dovish statements and no hawkish statements. The regular net index is $-2$, while the proportional net index is $-1$. Which of the two statements is more dovish? We get different answers depending on which measure we use. The main results are reported using the regular net index. As a robustness check, results are reported using the proportional net index.

A potential downside to not using the proportional net index is that results are affected by the length of the press conference. For example, a longer press conference implies a higher frequency of phrases, but not necessarily a higher proportion of phrases. This is only a problem if there is considerable variation in the length of press conferences. Table 2 reports the average length (in words) of each central bank’s press conferences, and the corresponding coefficient of variation (standard deviation divided by average length). First, note that there is considerable variation in average length across central banks. But within central banks, this is generally not the case. Other than the Bank of England, the coefficient of variation is low for each central bank. The standard deviation of the net index for each central bank tends to vary in line with the average length of the press conference. Central banks with longer press conferences have a larger standard deviation of the net index. In the regression analysis, observations for each central bank are pooled together. I control for the difference in press conference length by dividing each central bank’s net index by its own standard deviation. This makes the net index value comparable between central banks, in addition to a more intuitive interpretation.

### 3.2 Implied Risk Aversion

Implied risk aversion is identified from the risk neutral and physical densities of returns. This approach follows the method of Jackwerth (2000). Consider a complete market economy with a representative investor. The investor maximizes expected utility subject to a budget
constraint. Let $S$ denote the state, $p(S)$ the physical density, $q(S)$ the risk neutral density, $W(S)$ the investor’s wealth, and $U[W(S)]$ the investor’s utility function. The investor is endowed with one unit of wealth. Expected utility is given by the following equation:

$$\int p(S)U[W(S)] \, dS$$

In a complete market economy, the investor can purchase state contingent securities. The investor is endowed with one unit of wealth. The budget constraint is given by:

$$\int q(S)W(S) \, dS - 1$$

The investor maximizes expected utility subject to the budget constraint. Let $\lambda$ denote the Lagrange multiplier. The investor solves the following optimization problem:

$$\max \int p(S)U[W(S)] \, dS - \lambda \left( \int q(S)W(S) \, dS - 1 \right)$$

I solve this optimization problem by taking first order conditions. The investor chooses wealth in each state to equate the expected marginal utility of wealth with its relative price. The result is an expression for $U'[W(S)]$.

$$U'[W(S)] = \lambda \frac{q(S)}{p(S)}$$

Next, I differentiate this equation to compute an expression for $U''[W(S)]$.

$$U''[W(S)] = \lambda \left( \frac{p(S)q'(S) - q(S)p'(S)}{[p(S)]^2} \right)$$

Finally, I combine these two equations to get an expression for the Arrow-Pratt coefficient of absolute risk aversion, $ARA(S)$. The absolute risk aversion function is identified from the risk neutral and physical densities, as the Lagrange multiplier is no longer in the expression.
\[ ARA(S) = -\frac{U''[W(S)]}{U'[W(S)]} = \frac{p'(S)}{p(S)} - \frac{q'(S)}{q(S)} \]  

(1)

Closely related to absolute risk aversion function is the pricing kernel, \( m(S) \). This is the ratio of the risk neutral density to the physical density. Intuitively, this is the price of consumption in a given state, relative to the probability that the state occurs.

\[ m(S) = \frac{q(S)}{p(S)} \]

The absolute risk aversion function is proportional to the derivative of the pricing kernel. The slope of the pricing kernel tells us the sign of the absolute risk aversion function. When the pricing kernel is downward sloping, absolute risk aversion is positive. When the pricing kernel is upward sloping, absolute risk aversion is negative.

\[ ARA(S) = -\frac{m'(S)}{m(S)} \]  

(2)

To estimate the risk neutral density, I employ the method of Malz (2014). Recall from section 2 that each observation is an implied volatility curve, which is a function of the strike price. I convert implied volatilities into call option prices, via the Black-Scholes formula.\(^{18}\) Let \( F \) be the futures price, \( K \) be the strike price, \( T \) be the time to maturity, \( \sigma \) be the implied volatility, and \( r \) be the interest rate. The call option price \( C \) is given by:

\[
C = e^{-rT}[FN(d_1) - KN(d_2)] \\

d_1 \equiv \frac{\log(F/K) + (\sigma^2/2)T}{\sigma\sqrt{T}} \\

\sigma \sqrt{T} \\
\]

Using implied volatility curves does not require that Black Scholes assumptions hold. The implied volatility can be thought of as a normalized option price. It allows for a more intuitive comparison of prices across contracts and over time.
The call option price can be calculated for any strike price, \( K \). Define this as the call valuation function, \( C(K) \). The risk neutral CDF is the derivative of the call price with respect to the strike price. The risk neutral PDF is the derivative of the CDF with respect to the strike price. The derivatives are approximated by numerical differencing. I calculate the call price across a fine grid of strike prices. This effectively fills in the gaps between the prices of actual traded options. A discrete set of option prices becomes effectively continuous. This is necessary to compute a density function, that is also continuous. The step size of the grid is \( \Delta = 0.1\% \). The unit is log return, or the log difference between the strike price and current futures price. The risk neutral CDF \( Q(K) \) and PDF \( q(K) \) are given by:

\[
Q(K) \approx 1 + e^{-r_T} \frac{1}{\Delta} \left[ C\left(K + \frac{\Delta}{2}\right) - C\left(K - \frac{\Delta}{2}\right)\right]
\]

\[
q(K) \approx \frac{1}{\Delta} \left[ Q\left(K + \frac{\Delta}{2}\right) - Q\left(K - \frac{\Delta}{2}\right)\right]
\]

This procedure is valid for strikes within the minimum and maximum moneyness. The density is constructed only as far as actual options are traded. Appending tails to the density requires an extrapolation of option prices, rather than interpolation between prices. There are numerous methods to append tails to the distribution. Usually, it requires assuming a particular distribution to fit the tails, such as lognormal or generalized extreme value. I do not append tails to the distribution. Instead, I define the density and compute implied risk aversion only in the range of traded strike prices. This typically includes the 5\textsuperscript{th} and 95\textsuperscript{th} quantile of the distribution. Incorporating tails into the distribution does not have a material impact on calculation of implied risk aversion, and the subsequent results. Further, the results are a function only of traded option prices, rather than how the tails are appended.

The physical density is estimated using the Realized GARCH model of Hansen et al. (2012), combined with filtered historical simulation. It is constructed using a historical time series. The Realized GARCH model incorporates measurements of volatility based
on intraday high frequency data, and it allows for an asymmetric response of volatility to positive and negative shocks, i.e. leverage effects.\textsuperscript{19} Let $y_t$ be the daily return on the futures contract, $h_t$ be the latent volatility process, and $x_t$ be the daily realized volatility constructed from five minute returns. $\epsilon_t$ and $v_t$ are mean zero i.i.d. innovations. The model consists of three equations: the return equation, the GARCH equation, and the measurement equation.

\[
\begin{align*}
    y_t &= \mu + \sqrt{h_t} \epsilon_t \\
    \log h_t &= \omega + \sum_{i=1}^{q} \alpha_i \log h_{t-i} + \sum_{i=1}^{p} \beta_i \log x_{t-i} \\
    \log x_t &= \zeta + \delta \log h_t + \eta_1 \epsilon_t + \eta_2 (\epsilon_t^2 - 1) + v_t
\end{align*}
\]

I set $p = 1$ and $q = 2$. This is the preferred specification of Hansen \textit{et al.} (2012). I assume $\epsilon_t$ is student t distributed with variance one, and $v_t$ is normally distributed. For each density, the GARCH model is estimated using daily data.\textsuperscript{20} For exposition, table 3 presents estimates for a single observation. All estimates are computed out of sample, meaning that models are estimated using only data available at the time.

An alternative specification for the GARCH model is to include the net index as an explanatory variable in the GARCH equation. When doing so, the estimated coefficient on the net index is not statistically significant. One interpretation of this finding is that the impact of the net index is primarily captured through option prices and the risk neutral density, rather than the physical density. That said, an alternative explanation is that the sample size of press conference for each currency is too small, leading to limited statistical power.\textsuperscript{21} The statistical power of the net index comes from pooling the central bank observations together. Further, since the GARCH models are estimated out of sample, including the net index would make it difficult to construct a density forecast for the first few press conferences.

\textsuperscript{19}Leverage effects are statistically significant for currencies, as per the results in table 3.
\textsuperscript{20}Estimation is by maximum likelihood using the rugarch package in R.
\textsuperscript{21}The GARCH model is estimated separately for each currency.
Once the GARCH model is estimated, filtered historical simulation (FHS) is used to construct a density forecast one month ahead. This process is repeated for each date. The FHS procedure works as follows:

1. Sample $D$ standardized residuals with replacement from the model, where $D$ is the number of trading days in a month.

2. The residuals are fed iteratively through the GARCH model to construct a simulated monthly return.

3. Repeat this process $N$ times to construct $N$ simulated monthly returns. I set $N = 500,000$.

4. Apply a kernel density estimator on the simulated returns to construct the density. The bandwidth choice is based on the plug in method of Wand & Jones (1994).

Using the estimated risk neutral and physical densities, I compute risk aversion as a function of future states. The risk aversion function is proportional to the derivative of the pricing kernel, as per equation 2. One point to note is that the function is not smooth. This is because the physical density is estimated using a kernel smoother. The bandwidth is selected to ensure that the density is smooth. However, it does not ensure that the derivative of the density is smooth. Calculating the risk aversion function requires the derivative of the physical density. To get around this problem, I fit the risk aversion function to a polynomial of degree two.

To see how this works, let $r$ be the return on the currency futures contract. When $r$ is positive, the foreign currency appreciates relative to the US dollar. When $r$ is negative, the foreign currency depreciates relative to the US dollar. The polynomial coefficients can be interpreted as the level, slope, and curvature of the risk aversion function. Typically, the three coefficients capture 99% of the variation in the risk aversion function. Thus, a
quadratic polynomial is sufficient to capture the variation in the risk aversion function, without significant approximation errors.\(^{22}\)

\[
ARA(r) = a + br + cr^2
\]

In the majority of cases, risk aversion is positive in states where the foreign currency depreciates \((r < 0)\), and it is negative in states where the US dollar depreciates \((r > 0)\). A positive sign indicates a premium to holding the foreign currency. A negative sign indicates a premium to holding the US dollar. The implication is that there is hedging on both sides of the contract. Investors pay a premium to hedge against declines in the foreign currency as well as declines in the US dollar. This is equivalent to a U-shaped pricing kernel. The hedging demand on both sides isn’t necessarily the same. Net hedging, or the difference between the positive and negative values of risk aversion, need not be zero.

I define implied risk aversion as the probability weighted sum of the distance between the risk aversion function and zero. Implied risk aversion is at the one month horizon. The probabilities come from the physical density estimates. The absolute value of risk aversion tells us the degree of insurance or hedging demand. The sign of this number tells us the direction, i.e. demand for hedging the foreign or domestic currency. The best way to capture the total amount of risk aversion in single number is a weighted sum of the distance between the risk aversion function and zero. In the regression, I use the change in implied risk version over the course of the press conference at time \(t\).

\[
IRAt = \sum_r p(r)|ARA(r)|
\]

\[
\Delta IRAt = \log IRAt - \log IRAt-1
\]

To the best of my knowledge, this definition is not present in the literature. Prior studies,\(^{22}\) Gagnon & Power (2012) apply a similar approach to measure changes in risk aversion in the crude oil market.
such as Jackwerth (2000), assume that the return is a proxy for wealth. In that case, there is no justification for using the absolute value of implied risk aversion when aggregating across the distribution. This link between returns and wealth is a reasonable assumption when the underlying asset is a market index such as the S&P 500, rather than a currency futures contract. If the absolute value is not used, then positive and negative values of risk aversion cancel each other out. However, if positive and negative values of implied risk aversion actually represent hedging demand on both sides of the contract, it is the magnitude that matters. Then, the absolute value is the correct measure.

3.3 Variance Risk Premium

The variance risk premium is the difference between option implied and realized variance. It reflects the cost of insuring against an increase in variance. Suppose that variance is time varying and that investors dislike higher variance. Then, investors are willing to pay a premium to insure against an unexpected increase in variance. Currency variance risk premia have been found to predict future returns. Della Corte et al. (2016) find that low insurance-cost currencies outperform high insurance-cost currencies. Londono & Zhou (2016) find that currency variance risk premia predict future changes in exchange rates. Menkhoff et al. (2012) find a strong link between currency variance risk premia and returns from currency carry trades.

I use the method in Carr & Wu (2009) to quantify the variance risk premium. Their method constructs a variance swap using realized and option implied variance. They show that the variance swap rate is well approximated by a particular portfolio of options. Let $P_t$ be the currency futures price at time $t$, and $R_{t+1}$ be the daily return between time $t$ and $(t + 1)$. The realized variance, $RV_{t,t+\tau}$, is the average daily squared return between time $t$ and $(t + \tau)$. 
\[
R_{t+1} = \ln(P_{t+1}) - \ln(P_t)
\]

\[
RV_{t,t+\tau} = \tau^{-1} \sum_{i=1}^{\tau} R_{t+i}^2
\]

A variance swap is a forward contract on the realized variance of an underlying asset. Suppose a swap is initiated at time \( t \), and matures at time \( (t + \tau) \). \( RV_{t,t+\tau} \) is the realized variance over the life of the swap, and \( VS_{t,t+\tau} \) is the variance swap rate. I define the variance risk premium, \( VRP_{t,t+\tau} \), as the payoff to the holder of a short position in a variance swap. This is given by:

\[
VRP_{t,t+\tau} = VS_{t,t+\tau} - RV_{t,t+\tau}
\]

The variance swap rate is agreed at initiation of the contract, while the realized variance is determined over the life of the contract. The expected value of the variance swap is zero under the risk neutral measure \( Q \). Thus, the variance swap rate is the risk neutral expectation of realized variance between time \( t \) and \( (t + \tau) \).

\[
VS_{t,t+\tau} = E^Q_t[RV_{t,t+\tau}]
\]

The focus of this paper is on realized returns from entering into a variance swap. That said, there is an important distinction between the expected and realized return on a variance swap. The expected return, under the physical measure \( P \) at time \( t \) is given by:

\[
VRP^e_{t,t+\tau} = VS_{t,t+\tau} - E^P_t[RV_{t,t+\tau}]
\]

Note that the literature sometimes defines the variance risk premium as the payoff to the long position in variance swap. The benefit to defining it as I have here is simpler intuition. An increase in the variance risk premium is an increase in the cost of insurance.
for investors. The literature also sometimes uses volatility (square root of variance) swaps instead of variance swaps. Variance swaps have the advantage that they can be replicated with a static option portfolio, unlike volatility swaps that require a dynamic option portfolio. As a result, in the financial markets, variance swaps are more commonly traded. This is discussed further in appendix A.

### 3.4 Empirical Example

I now present an empirical example of the methodological procedure. This is a single observation in the dataset. On September 4, 2014, the ECB held a press conference. It lowered the deposit rate from -0.10% to -0.20%, and it announced the Bank’s intention to begin purchasing non-financial private sector assets. As part of the announcement, the Bank stressed that inflation remained well below its 2% target. A portion of the introductory statement of the ECB press conference is presented in appendix B. Relevant phrases for computing the net index are highlighted for exposition. The net index value of this press conference was $-6$, or $-1.3$ standard deviations. The example demonstrates how the net index captures the underlying tone of this particular press conference.

The one month implied risk aversion decreased by 12.0%. The one month, two month, and three month variance risk premia were 0.2%, $-24.1\%$, and $-23.5\%$, respectively. This is relative to the average one month, two month, and three month variance risk premia of 28.9%, 28.0%, and 28.9%, respectively.\(^23\) These numbers reflect the main result of a decrease in implied risk aversion, and lower than average variance risk premia. There is a significant drop in the variance risk premium in the first month following the announcement. The drop is even greater in the second and third month. The second and the third month may reflect persistent announcement affects. They may also be a result of the following month’s press conference by the ECB. That statement, on October 2, 2014, had a net index value of $-7$, or $-1.56$ standard deviations.

\(^{23}\)The two and three month average variance risk premia exclude the Swiss Franc outlier. This is discussed in appendix C.
Figure 2 presents the various steps involved in computing the option implied risk aversion. The top left figure plots the risk neutral density before and after the press conference. The top right figure plots the physical density before and after the announcement. The bottom left figure plots the pricing kernel before and after the press conference. From this picture, the impact of the press conference is a flatter pricing kernel, particularly in the tails of the distribution. The bottom right figure plots the absolute risk aversion function before and after the press conference. The flatter pricing kernel is reflected in the absolute risk aversion function that is now closer to zero following the press conference. The implied risk aversion is calculated as the probability weighted sum of the distance between the absolute risk aversion function and zero. This decreases as the absolute risk aversion function is closer to zero following the press conference.

3.5 Net Index Regressions

I run regressions to analyze the impact of the net index on the change in implied risk aversion and variance risk premia. \( Y_t \) is the dependent variable, and takes on four possibilities:

\[
Y_t \in \{ \Delta IRA_t, VRP_{t,t+30}, VRP_{t,t+60}, VRP_{t,t+90} \}
\]

The first is the change in the one month implied risk aversion, \( \Delta IRA_t \). The next three are the one, two, and three month variance risk premia, given by \( VRP_{t,t+30} \), \( VRP_{t,t+60} \), \( VRP_{t,t+90} \), respectively. Let \( t \) be the day of the press conference. \( \Delta IRA_t \) is the difference between implied risk aversion at the close of \( (t-1) \) and implied risk aversion at the close of \( t \). It is contemporaneous with respect to the press conference. The one month variance risk premium, \( VRP_{t,t+30} \), is measured from the close of \( t \) until the close of \( (t + 30) \), (i.e. for one month). Note that the calculation begins after the press conference has already occurred. An investor could enter into this short variance swap after observing the press conference. The same logic applies to the two and three month variance risk premia. The regression is
given by the following equation:

\[ Y_t = \alpha + \beta NI_t + \gamma_1 Ret_t + \gamma_2 \Delta IV_t + \gamma_3 VRP_{t-31,t-1} + \gamma_4 \Delta IV_{t-31,t-1} + \delta CB_t + \epsilon_t \]  

(3)

NI \_t is the net index observed during the press conference. Next, I include four control variables. The first two are the daily return, Ret\_t, and the daily change in implied volatility, \Delta IV\_t. Both these variables are measured from the close of the day prior to the press conference to the close of the day of the press conference. The daily return and change in implied volatility capture the market impact of the press conference. If the market was surprised by the press conference, these two variables can account for that. Then, the coefficient on the net index measures the additional information from the press conference not captured by market movements. The next two control variables are the prior month variance risk premium, VRP\_{t-31,t-1}, and the prior month change in implied volatility, \Delta IV_{t-31,t-1}. These are intended to capture persistence in the variance risk premium and implied volatility. Both these variables are measured from the close of (t − 31) until the close of (t − 1). This is the one month period before the press conference takes place.

Finally, I include central bank dummy variables. CB\_t consists of central bank dummy variables for the Bank of England (BOE\_t), Bank of Canada (BOC\_t), European Central Bank (ECB\_t), and the Swiss National Bank (SNB\_t). The intercept term corresponds to the US Federal Reserve (FED\_t). This is equivalent to central bank fixed effects.

Observations from all central banks are pooled together. Each central bank’s net index is divided by its own standard deviation. This makes the net index values across central banks directly comparable, and justifies pooling of observations. The pooling is critical to ensure sufficient power in hypothesis tests. The coefficient on the net index can be interpreted as the impact of a one standard deviation increase in hawkishness of a press conference.
4 Results

This section presents and discusses the results. I begin with summary statistics and a test of monotonicity in the net index of the dependent variables. Following that is a discussion of the regression results and their economic significance.

4.1 Summary Statistics

Figure 3 is a scatter plot of the net index against the four dependent variables (the change in implied risk aversion, and the one, two, and three month variance risk premia). A line of best fit is drawn and the correlation coefficient is reported. Each of the four dependent variables has a positive correlation with the net index.

Table 2 reports summary statistics for each central bank. The sample period is from June 2009 to December 2015. The statistics include the annual frequency of press conferences, the sample size, the average length (number of words) of each press conference, the corresponding coefficient of variation (standard deviation divided by average length), and the mean and standard deviation of the net index. The mean values of the net index are all negative, indicating that central banks are dovish on average. This is not surprising, given that the sample period was characterized by unprecedented global monetary easing. The standard deviation also varies considerably by central bank. Partly, this is due to the length of the announcement. Central banks with longer statements have a higher net index value, relative to central banks with shorter statements. For example, the ECB tends to have the longest press conferences, and has the highest standard deviation of the net index. In the regression, I divide each central bank’s net index by its own standard deviation. This allows for a more accurate comparison between central banks.

Tables 5 and 6 present summary statistics for the full sample, and subsamples of the net index. The subsamples consist of the net index above, equal to, and below zero. I report the average change in implied risk aversion, and average values of the one, two, and three
month variance risk premia. I also report the Sharpe Ratio corresponding to each value of
the variance risk premium. The Sharpe Ratio is the mean return divided by the standard
deviceation of returns from shorting the variance swap (i.e. earning the variance risk premium).
The Sharpe Ratios are approximately twice as large when the net index is positive, relative
to when it is negative.

Table 6 reports summary statistics including and excluding an outlier observation. On
January 15th, 2015, the Swiss National Bank abandoned its peg against the euro. It also
lowered interest rates from -0.25% to -0.75%, pushing further into negative territory. The
currency rose by 18% against the dollar in a single day. This is approximately 26 times the
daily the standard deviation, i.e. a 26 sigma event. This is discussed further in appendix
C. Regression results are reported without the outlier observation. When interpreting the
summary statistics and regression coefficients as a measure of central tendency, it is better
to exclude the outlier. The outlier is relevant only for the two and three month variance risk
premia, as it had been over a month since the previous press conference.

4.2 Monotonicity Test

Tables 5 and 6 show that the both the change in implied risk aversion and the variance risk
premia are decreasing in the net index. Patton & Timmermann (2010) propose a test for
monotonicity in returns or other financial variables. For this test, observations are sorted by
their net index value and split into three equal sized portfolios.\textsuperscript{24} The null hypothesis is that
the dependent variable is not monotonically increasing in the net index. The alternative is
that the dependent variable is monotonically increasing in the net index. Table 4 reports
p-values of this test for four dependent variables: the change in implied risk aversion, the one
month variance risk premium, the two month variance risk premium, and the three month
variance risk premium. The results indicate monotonicity in the net index for these variables.
This finding is consistent with the theory. Namely, that when central banks are hawkish, risk

\textsuperscript{24}Observations with a net index value equal to zero are removed. This is to ensure that the net index is
strictly decreasing across most observations. The Swiss Franc outlier is excluded from this test.
premia are higher. And when central banks are dovish, risk premia are lower. The results are strongest for the variance risk premia, and less strong for implied risk aversion.

4.3 Regression Results

The regression specification is given by equation 3. Table 7 reports regression results for the change in implied risk aversion. I use Newey West standard errors with four lags. Results are reported with and without central bank dummy variables. The sample period is June 2009 until December 2015. The first and second columns do not include the regressors \( Ret_t \) and \( \Delta IV_t \). In this case, I am not controlling for the market response to the press conference. The first and third columns do not include central bank dummy variables. Across all four specifications, the coefficient on the net index is positive and statistically significant. An increase in the net index (i.e. a hawkish press conference) results in an increase in implied risk aversion. The inclusion of \( Ret_t \) and \( \Delta IV_t \) modestly decrease the coefficient on the net index. This is to be expected, as some of the information coming from the press conference is captured by the market response. The inclusion of central bank dummy variables has no material impact on the magnitude of the coefficient. Based on the third specification, a one standard deviation increase in the net index results in a 0.8% increase in implied risk aversion.

Table 8 reports regression results for the one month variance risk premium. The specifications are identical to the previous case. Across all four specifications, the coefficient on the net index is positive and statistically significant. As before, the inclusion of \( Ret_t \) and \( \Delta IV_t \) modestly decrease the coefficient on the net index. The inclusion of central bank dummy variables has no material impact. Based on the third specification, a one standard deviation increase in the net index results in a 4.7% increase in the one month variance risk premium. This is economically significant, relative to the average one month variance risk premium of 28.9%.

25 Coefficients are reported with standard errors in parentheses. One, two, and three stars indicate p-values below 0.10, 0.05, and 0.01, respectively.
Table 9 reports regression results for the two month variance risk premium. The results follow a similar pattern to the one month case. A one standard deviation increase in the net index results in a 6.6% increase in the two month variance risk premium. This is economically significant and higher than the corresponding one month figure. Table 10 reports regression results for the three month variance risk premium. The results are quantitatively similar to the corresponding two month case. The standard errors on the net index coefficient are increasing in the horizon of the variance risk premium. Intuitively, the impact of a single press conference is more difficult to identify over longer time periods.\(^\text{26}\)

### 4.4 Robustness Checks

This section reports regression results for robustness checks. For all regressions, results are reported for the change in implied risk aversion and the one month variance risk premium. The regressors \(Rct_t\) and \(\Delta IV_t\) are included in the regression. The regressions are run with and without central bank dummy variables.

The original net index proposed by Apel & Grimaldi (2012) divides the difference between hawkish and dovish phrases by the total number of phrases. This is the proportional net index. The magnitude of the net index now represents the proportion of hawkish or dovish phrases, rather than the absolute number. Table 11 reports regression results using the proportional net index. The coefficient on implied risk aversion is positive and statistically significant, while the coefficient on the one month variance risk premium is positive but not statistically significant. As discussed in section 3.1, using the proportional net index can materially impact the relative magnitude across observations, and the results are sensitive to this.

Apel & Grimaldi (2012) propose the extended net index as a robustness exercise. The extended net index uses additional nouns to identify hawkish and dovish phrases.\(^\text{27}\) Table 12 reports regression results using the extended net index. The results follow the same pattern

\(^{26}\)The Swiss Franc outlier is excluded from all calculations. This is discussed further in appendix C.

\(^{27}\)The additional nouns are listed in table 1.
as the original results, but are slightly weaker. For the implied risk aversion regression, the
coefficient on the net index is unchanged. For the one month variance risk premium, the
coefficient is 4.2%, down from 4.7%.

As an additional robustness check, I separate implied risk aversion and the variance risk
premium into upside and downside components. The purpose of this exercise is to determine
whether the impact of the net index on implied risk aversion and the variance risk premium is
symmetric. Upside (downside) implied risk aversion is the weighted sum of the risk aversion
function conditional on it taking a positive (negative) value.

\[
IR^u_t = \sum_r p(r)|ARA(r)|\mathbb{1}_{[ARA(r)>0]}
\]
\[
IR^d_t = \sum_r p(r)|ARA(r)|\mathbb{1}_{[ARA(r)<0]}
\]

Upside (downside) variance is the expected squared return conditional on a positive
(negative) return. Upside and downside variance risk premium are thus defined as follows,
as per Feunou et al. (2017).

\[
RV^u_{t:t+\tau} = \tau^{-1} \sum_{i=1}^{\tau} R^2_{t+i-1:t+i} \mathbb{1}_{[R>0]}
\]
\[
RV^d_{t:t+\tau} = \tau^{-1} \sum_{i=1}^{\tau} R^2_{t+i-1:t+i} \mathbb{1}_{[R<0]}
\]
\[
VR^u_{t:t+\tau} = VS^u_{t:t+\tau} - RV^u_{t:t+\tau}
\]
\[
VR^d_{t:t+\tau} = VS^d_{t:t+\tau} - RV^d_{t:t+\tau}
\]

Table 13 reports regression results for the upside and downside change in implied risk
aversion. The impact of the net index is slightly higher on downside risk aversion, though the
difference is not statistically significant. Table 14 reports regression results for upside and
downside one month variance risk premium. The impact of the net index is slightly higher
on upside variance risk premium, but again the difference is not statistically significant. Both these results suggest that the impact of the net index on implied risk aversion and the variance risk premium is symmetric.

5 Conclusion

This paper asks how the tone of central bank press conferences impacts risk premia in the currency market. A hawkish press conference results in an increase in implied risk aversion and higher variance risk premia. A dovish press conference results in an decrease in implied risk aversion and lower variance risk premia. The results are economically and statistically significant, and robust to the inclusion of relevant control variables. The basic intuition of the result is as follows: The tone of a central bank press conference indicates to investors the likelihood of central bank intervention, conditional on the state of the economy. When a central bank is dovish, it is more likely to intervene in bad economic states, and investors pay less for insurance in those states. When a central bank is hawkish, it is less likely to intervene in bad economic states, and investors pay more for insurance in those states. Three broad themes emerge from this paper.

The first theme is that central banks have some ability to influence risk premia in markets. Central banks may have an incentive to choose their words in such a way as to generate a favorable market reaction. This paper treats central bank tone as exogenous. An avenue of a future research is to analyze the predictability of central bank tone itself, using historical financial and macroeconomic data.

The second theme is that investors should incorporate central bank tone into their portfolio decisions. The best case for this is the difference in the Sharpe ratios of shorting a variance swap for different values of the net index. The Sharpe ratio following a hawkish press conference is approximately double that of a dovish press conference. An example of simple trading strategy is to short variance swaps only if a central bank is hawkish, and stay
out of the market otherwise.

The third theme is the value of text based information. Most research in empirical finance deals with quantities, e.g. prices, returns, dividends, etc. Any point in time, an investor making a decision has access to qualitative and quantitative information. The qualitative information typically consists of text, e.g. central bank press conferences, news articles, etc. Text based information poses two challenges, relative to quantitative information The first is that historical data is not as easily available. The second is that there are multiple methods to quantify text, and quantification involves some loss of information. This paper employs a binary classification scheme for text, i.e. treating phrases as hawkish or dovish. It is encouraging that even a simple method produces valuable insights.
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A Variance and Volatility Swaps

There is an important distinction to be made between variance and volatility swaps. Volatility is the square root of variance, and is often more frequently quoted than variance in the context of options. It is theoretically possible to construct either a variance or volatility swap. In practice, variance swaps are traded more often than volatility swaps. Most variance swaps, including currency variance swaps, are traded in over the counter markets. One exception is S&P500 variance futures traded on the Chicago Board Options Exchange (CBOE).

The reason is variance swaps are preferred to volatility swaps is ease of replication. Demeterfi et al. (1999) show that a variance swap can be replicated with a static portfolio of options and dynamic hedging of the underlying asset. However, replicating a volatility swap requires a dynamic portfolio of options. In fact, from a pricing and replication perspective, a volatility swap is best thought of as a derivative of a variance swap.

As discussed, most of the literature on the variance risk premium has focused on its predictive power over future currency returns. If the variance risk premium is used only as a predictor, it does not matter how easy or difficult it is to replicate in the market. There is no reason to favor variance swaps over volatility swaps. Since this paper is focused on actual returns from variance swaps, there is a strong case for using variance swaps instead of volatility swaps. A trading strategy based on central bank announcements would be much easier to implement using variance swaps rather than volatility swaps.

B ECB Press Conference

This is a portion of the introductory statement of the ECB press conference on September 4, 2014. It contained six dovish phrases and no hawkish phrases. One of the dovish phrases appears in this portion, and is highlighted in blue.

Ladies and gentlemen, the Vice-President and I are very pleased to welcome you
to our press conference. We will now report on the outcome of today's meeting of the Governing Council, which was also attended by the Commission Vice-President, Mr Katainen.

Based on our regular economic and monetary analyses, the Governing Council decided today to lower the interest rate on the main refinancing operations of the Eurosystem by 10 basis points to 0.05% and the rate on the marginal lending facility by 10 basis points to 0.30%. The rate on the deposit facility was lowered by 10 basis points to -0.20%. In addition, the Governing Council decided to start purchasing non-financial private sector assets. The Eurosystem will purchase a broad portfolio of simple and transparent asset-backed securities (ABSs) with underlying assets consisting of claims against the euro area non-financial private sector under an ABS purchase programme (ABSPP). This reflects the role of the ABS market in facilitating new credit flows to the economy and follows the intensification of preparatory work on this matter, as decided by the Governing Council in June. In parallel, the Eurosystem will also purchase a broad portfolio of euro-denominated covered bonds issued by MFI domiciled in the euro area under a new covered bond purchase programme (CBPP3). Interventions under these programmes will start in October 2014. The detailed modalities of these programmes will be announced after the Governing Council meeting of 2 October 2014. The newly decided measures, together with the targeted longer-term refinancing operations which will be conducted in two weeks, will have a sizeable impact on our balance sheet.

These decisions will add to the range of monetary policy measures taken over recent months. In particular, they will support our forward guidance on the key ECB interest rates and reflect the fact that there are significant and increasing differences in the monetary policy cycle between major advanced economies. They will further enhance the functioning of the monetary policy transmission mechanism and support the provision of credit to the broad economy. In our analysis, we took into account the overall subdued outlook for inflation, the weakening in the euro area's growth momentum over the recent past and the continued subdued monetary and credit dynamics. Today's decisions, together with the other measures in place, have been taken with a view to underpinning the firm anchoring of medium to long-term inflation expectations, in line with our aim of maintaining inflation rates below, but close to, 2%. As our measures work their way through to the economy they will contribute to a return of inflation rates to levels closer to 2%. Should it become necessary to further address risks of too prolonged a
period of low inflation, the Governing Council is unanimous in its commitment to using additional unconventional instruments within its mandate.

C Swiss Franc Outlier

On January 15, 2015, the Swiss National Bank abandoned its peg against the euro. They also lowered interest rates from -0.25% to -0.75%, pushing further into negative territory. While they did not hold a press conference on that day, they did release a statement explaining why they abandoned the peg. That statement is reproduced below:

The Swiss National Bank (SNB) is discontinuing the minimum exchange rate of CHF 1.20 per euro. At the same time, it is lowering the interest rate on sight deposit account balances that exceed a given exemption threshold by 0.5 percentage points, to 0.75%. It is moving the target range for the three-month Libor further into negative territory, to between 1.25% and 0.25%, from the current range of between 0.75% and 0.25%.

The minimum exchange rate was introduced during a period of exceptional overvaluation of the Swiss franc and an extremely high level of uncertainty on the financial markets. This exceptional and temporary measure protected the Swiss economy from serious harm. While the Swiss franc is still high, the overvaluation has decreased as a whole since the introduction of the minimum exchange rate. The economy was able to take advantage of this phase to adjust to the new situation.

Recently, divergences between the monetary policies of the major currency areas have increased significantly – a trend that is likely to become even more pronounced. The euro has depreciated considerably against the US dollar and this, in turn, has caused the Swiss franc to weaken against the US dollar. In these circumstances, the SNB concluded that enforcing and maintaining the minimum exchange rate for the Swiss franc against the euro is no longer justified.

The SNB is lowering interest rates significantly to ensure that the discontinuation of the minimum exchange rate does not lead to an inappropriate tightening of monetary conditions. The SNB will continue to take account of the exchange rate situation in formulating its monetary policy in future. If necessary, it will
therefore remain active in the foreign exchange market to influence monetary conditions.

The currency rose by 18% against the dollar in a single day. This is approximately 26 times the daily the standard deviation, i.e. a 26 sigma event. There were other ramifications such as low liquidity in the Swiss Franc for a considerable period of time. Various foreign exchange brokers lost heavily, as client margin requirements did not cover such an extreme move. The outlier has a significant impact on the results. When interpreting the summary statistics and regression coefficients as a measure of central tendency, it is better to exclude the outlier. That said, outliers like this serve to illustrate the powerful impact of central banks on currency markets.
These figures plot the time series of the net index for each central bank. The net index is the difference between the number of hawkish and dovish phrases made during a press conference, i.e. $NI_t = \#Hawk_t - \#Dove_t$. 

$$NI_t = \#Hawk_t - \#Dove_t$$
Figure 2: Empirical Example - Implied Risk Aversion

(a) Risk Neutral Density

(b) Physical Density

(c) Pricing Kernel

(d) Absolute Risk Aversion Function

These four plots illustrate how the change in implied risk aversion is computed. The observation is the European Central Bank press conference on September 4, 2014. The net index value is -6, or -1.34 standard deviations. The top left figure plots the risk neutral density before and after the press conference. The top right figure plots the physical density before and after the announcement. The bottom left figure plots the pricing kernel before and after the press conference. From this picture, the impact of the press conference is a flatter pricing kernel, particularly in the tails of the distribution. The bottom right figure plots the absolute risk aversion function before and after the press conference. The flatter pricing kernel is reflected in the absolute risk aversion function that is now closer to zero following the press conference. Implied risk aversion is calculated as the probability weighted sum of the distance between the absolute risk aversion function and zero.
Figure 3: Net Index Scatter Plots

(a) \( NI_t & \Delta IRA_t, \rho = 0.26 \)

(b) \( NI_t & VRP_{t,t+30}, \rho = 0.19 \)

(c) \( NI_t & VRP_{t,t+60}, \rho = 0.22 \)

(d) \( NI_t & VRP_{t,t+90}, \rho = 0.19 \)

These figures plot the net index on the horizontal axis and the dependent variable on the vertical axis. Observations for all central banks are pooled together. Each central bank’s net index value is divided by its own standard deviation. The units for the net index is standard deviations, and the units for the dependent variable is percentage points. The four dependent variables are the change in implied risk aversion (top left), the one month variance risk premium (top right), the two month variance risk premium (bottom left), and the three month variance risk premium (bottom right). For each figure, a line of best fit is drawn, and the correlation coefficient \( \rho \) is reported in the header. The two and three month variance risk premia figures exclude the Swiss Franc outlier.
Table 1: Adjectives and Nouns

<table>
<thead>
<tr>
<th>Hawkish Adjectives</th>
<th>Dovish Adjectives</th>
<th>Nouns</th>
<th>Nouns Extended</th>
</tr>
</thead>
<tbody>
<tr>
<td>increased/increasing</td>
<td>decreased/decreasing</td>
<td>inflation</td>
<td>employment</td>
</tr>
<tr>
<td>fast/faster</td>
<td>slow/slower</td>
<td>cyclical position</td>
<td></td>
</tr>
<tr>
<td>strong/stronger</td>
<td>weak/weaker</td>
<td>growth</td>
<td>unemployment</td>
</tr>
<tr>
<td>high/higher</td>
<td>low/lower</td>
<td>price</td>
<td>recovery</td>
</tr>
<tr>
<td></td>
<td></td>
<td>wages</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>oil price</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>development</td>
<td></td>
</tr>
</tbody>
</table>

This table presents the adjectives and nouns used to construct the net index. The net index is calculated as the difference between the number of hawkish and dovish phrases made during a press conference. A hawkish phrase consists of a hawkish adjective and a noun. A dovish phrase consists of a dovish adjective and a noun. Any combination of adjective and noun is considered a phrase. For example, higher growth is a hawkish phrase, while lower inflation is a dovish phrase. The final column contains an additional list of nouns used to construct the extended net index.

Table 2: Central Bank Press Conference Summary Statistics

<table>
<thead>
<tr>
<th>Bank</th>
<th>PC/year</th>
<th>N</th>
<th>Avg Len</th>
<th>CV Len</th>
<th>Avg NI</th>
<th>Std Dev NI</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOE</td>
<td>4</td>
<td>26</td>
<td>11,206</td>
<td>0.516</td>
<td>−1.385</td>
<td>3.187</td>
</tr>
<tr>
<td>BOC</td>
<td>4</td>
<td>26</td>
<td>740</td>
<td>0.255</td>
<td>−0.615</td>
<td>1.041</td>
</tr>
<tr>
<td>ECB</td>
<td>8</td>
<td>73</td>
<td>6,749</td>
<td>0.110</td>
<td>−2.311</td>
<td>4.475</td>
</tr>
<tr>
<td>SNB</td>
<td>2</td>
<td>12</td>
<td>1,669</td>
<td>0.244</td>
<td>−0.583</td>
<td>1.256</td>
</tr>
<tr>
<td>FED</td>
<td>4</td>
<td>20</td>
<td>8,347</td>
<td>0.149</td>
<td>−1.000</td>
<td>1.817</td>
</tr>
</tbody>
</table>

This table reports summary statistics for central bank press conferences. The central banks are: Bank of England (BOE), Bank of Canada (BOC), European Central Bank (ECB), Swiss National Bank (SNB), US Federal Reserve (FED). The sample period is June 2009 until December 2015. The sample size is 157. The following statistics are reported for each central bank: the number of press conferences per year, the total sample size, the average length (number of words) of each press conference, the corresponding coefficient of variation (standard deviation divided by average length), the average value of the net index, and the corresponding standard deviation.
Table 3: Realized GARCH Parameter Estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu$</td>
<td>0.0152</td>
<td>0.0100</td>
</tr>
<tr>
<td>$\omega$</td>
<td>0.0063</td>
<td>0.0060</td>
</tr>
<tr>
<td>$\alpha_1$</td>
<td>0.0912***</td>
<td>0.0113</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>0.5548***</td>
<td>0.0070</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>0.3504***</td>
<td>0.0043</td>
</tr>
<tr>
<td>$\eta_1$</td>
<td>0.0037</td>
<td>0.0111</td>
</tr>
<tr>
<td>$\eta_2$</td>
<td>0.1481***</td>
<td>0.0131</td>
</tr>
<tr>
<td>$\delta$</td>
<td>1.0046***</td>
<td>0.0397</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.7297***</td>
<td>0.0412</td>
</tr>
<tr>
<td>$\nu$</td>
<td>9.5140***</td>
<td>1.9255</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>-0.1138**</td>
<td>0.0526</td>
</tr>
</tbody>
</table>

This table reports parameter estimates and robust standard errors of the Realized GARCH model for a single observation, the euro futures contract on September 4, 2014. One, two, and three stars indicate p-values below 0.10, 0.05, and 0.01, respectively. Estimation is by maximum likelihood using the rugarch package in R. The Realized GARCH model incorporates measurements of volatility based on intraday high frequency data, and it allows for an asymmetric response of volatility to positive and negative shocks, i.e. leverage effects. Let $y_t$ be the daily return on the futures contract, $h_t$ be the latent volatility process, and $x_t$ be the daily realized volatility constructed from five minute returns. $\epsilon_t$ and $v_t$ are mean zero i.i.d. innovations. The model consists of three equations: the return equation: $y_t = \mu + \sqrt{h_t} \epsilon_t$, the GARCH equation: $\log h_t = \omega + \sum_{i=1}^{q} \alpha_i \log h_{t-i} + \sum_{i=1}^{p} \beta_i \log x_{t-i}$, and the measurement equation: $\log x_t = \zeta + \delta \log h_t + \eta_1 \epsilon_t + \eta_2 (\epsilon_t^2 - 1) + v_t$. I set $p = 1$ and $q = 2$. This is the preferred specification of Hansen et al. (2012). I assume $\epsilon_t$ is student t distributed with variance one and shape $\nu$, and $v_t$ is normally distributed with variance $\lambda$.

Table 4: Monotonicity Test

<table>
<thead>
<tr>
<th>$\Delta IRA_t$</th>
<th>$VRP_{t,t+30}$</th>
<th>$VRP_{t,t+60}$</th>
<th>$VRP_{t,t+90}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-value</td>
<td>0.068</td>
<td>0.000</td>
<td>0.002</td>
</tr>
</tbody>
</table>

This table reports p-values from the Patton & Timmermann (2010) test of monotonicity in the four dependent variables: the change in implied risk aversion, the one month variance risk premium, the two month variance risk premium, and the three month variance risk premium. The null hypothesis is that the dependent variable is not monotonically increasing in the net index. The alternative is that the dependent variable is monotonically increasing in the net index. For this test, the observations are sorted by the net index value and split into three equal sized portfolios. Observations with a net index value equal to zero are removed. This is to ensure that the net index is strictly decreasing across most observations.
Table 5: Net Index Summary Statistics

<table>
<thead>
<tr>
<th></th>
<th>$\Delta IRA_t$</th>
<th>$VRP_{t,t+30}$</th>
<th>$SR_{t,t+30}$</th>
<th>$N$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Sample</td>
<td>0.092</td>
<td>28.909</td>
<td>0.560</td>
<td>157</td>
</tr>
<tr>
<td>$NI_t &gt; 0$</td>
<td>0.749</td>
<td>35.624</td>
<td>0.856</td>
<td>29</td>
</tr>
<tr>
<td>$NI_t = 0$</td>
<td>0.752</td>
<td>40.660</td>
<td>0.712</td>
<td>42</td>
</tr>
<tr>
<td>$NI_t &lt; 0$</td>
<td>-0.453</td>
<td>20.906</td>
<td>0.414</td>
<td>86</td>
</tr>
</tbody>
</table>

This is the first of two tables that reports summary statistics for the net index. The statistics are reported for the full sample, and three subsamples of the net index (positive, zero, negative). The sample period is June 2009 until December 2015. The summary statistics consist of the change in implied risk aversion, the one month variance risk premium, the one month Sharpe Ratio, and the sample size.

Table 6: Net Index Summary Statistics: Two and Three Month VRP

<table>
<thead>
<tr>
<th></th>
<th>$VRP_{t,t+60}$</th>
<th>$SR_{t,t+60}$</th>
<th>$VRP_{t,t+90}$</th>
<th>$SR_{t,t+90}$</th>
<th>$N$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Include Outlier</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Sample</td>
<td>13.750</td>
<td>0.074</td>
<td>19.349</td>
<td>0.142</td>
<td>157</td>
</tr>
<tr>
<td>$NI_t &gt; 0$</td>
<td>40.130</td>
<td>1.051</td>
<td>43.238</td>
<td>1.047</td>
<td>29</td>
</tr>
<tr>
<td>$NI_t = 0$</td>
<td>40.734</td>
<td>0.756</td>
<td>42.428</td>
<td>0.832</td>
<td>42</td>
</tr>
<tr>
<td>$NI_t &lt; 0$</td>
<td>-8.324</td>
<td>-0.034</td>
<td>0.023</td>
<td>0.000</td>
<td>86</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$VRP_{t,t+60}$</th>
<th>$SR_{t,t+60}$</th>
<th>$VRP_{t,t+90}$</th>
<th>$SR_{t,t+90}$</th>
<th>$N$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exclude Outlier</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Sample</td>
<td>27.965</td>
<td>0.515</td>
<td>28.916</td>
<td>0.442</td>
<td>156</td>
</tr>
<tr>
<td>$NI_t &gt; 0$</td>
<td>40.130</td>
<td>1.051</td>
<td>43.238</td>
<td>1.047</td>
<td>29</td>
</tr>
<tr>
<td>$NI_t = 0$</td>
<td>40.734</td>
<td>0.756</td>
<td>42.428</td>
<td>0.832</td>
<td>42</td>
</tr>
<tr>
<td>$NI_t &lt; 0$</td>
<td>17.489</td>
<td>0.307</td>
<td>17.354</td>
<td>0.230</td>
<td>85</td>
</tr>
</tbody>
</table>

This is the second of two tables that reports summary statistics for the net index. The statistics are reported for the full sample, and three subsamples of the net index (positive, zero, negative). The sample period is June 2009 until December 2015. The summary statistics consist of the two month variance risk premium, the two month Sharpe Ratio, the three month variance risk premium, the three month Sharpe Ratio, and the sample size. The top panel reports results including the outlier, and the bottom panel reports results excluding the outlier. The outlier is discussed further in appendix C.
Table 7: Regression Results: IRA

<table>
<thead>
<tr>
<th>Dependent Variable ($Y_t$)</th>
<th>$\Delta IRA_t$</th>
<th>$\Delta IRA_t$</th>
<th>$\Delta IRA_t$</th>
<th>$\Delta IRA_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.026</td>
<td>-1.416**</td>
<td>0.013</td>
<td>-1.284*</td>
</tr>
<tr>
<td></td>
<td>(0.533)</td>
<td>(0.699)</td>
<td>(0.514)</td>
<td>(0.682)</td>
</tr>
<tr>
<td>$NI_t$</td>
<td>0.903***</td>
<td>0.908***</td>
<td>0.845***</td>
<td>0.863***</td>
</tr>
<tr>
<td></td>
<td>(0.327)</td>
<td>(0.314)</td>
<td>(0.324)</td>
<td>(0.311)</td>
</tr>
<tr>
<td>$Ret_t$</td>
<td>0.084</td>
<td>0.055</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.436)</td>
<td>(0.450)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta IV_t$</td>
<td>0.035*</td>
<td>0.028</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.165)</td>
<td>(0.166)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$VRP_{t-31,t-1}$</td>
<td>0.023***</td>
<td>0.021***</td>
<td>0.027**</td>
<td>0.024***</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.008)</td>
<td>(0.008)</td>
<td>(0.008)</td>
</tr>
<tr>
<td>$\Delta IV_{t-31,t-1}$</td>
<td>-0.004</td>
<td>-0.005</td>
<td>0.002</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.009)</td>
<td>(0.010)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>CB Dummies</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.145</td>
<td>0.177</td>
<td>0.161</td>
<td>0.188</td>
</tr>
<tr>
<td>$N$</td>
<td>157</td>
<td>157</td>
<td>157</td>
<td>157</td>
</tr>
</tbody>
</table>

$Y_t = \alpha + \beta NI_t + \gamma_1 Ret_t + \gamma_2 \Delta IV_t + \gamma_3 VRP_{t-31,t-1} + \gamma_4 \Delta IV_{t-31,t-1} + \delta CB_t + \epsilon_t$

This table reports results from the above regression for the change in implied risk aversion. Each central bank’s net index is divided by its own standard deviation. Thus, the coefficient on the net index can be interpreted as the effect of a one standard deviation increase in hawkishness. Results are reported with and without central bank dummy variables. Coefficients are reported with Newey West standard errors in parentheses. One, two, and three stars indicate p-values below 0.10, 0.05, and 0.01, respectively. The sample period is June 2009 until December 2015. $NI_t$ is the net index, $Ret_t$ is the daily return, $\Delta IV_t$ is the daily change in implied volatility, $VRP_{t-31,t-1}$ is the prior month variance risk premium, and $\Delta IV_{t-31,t-1}$ is the prior month change in implied volatility. $CB_t$ consists of central bank dummy variables for the BOE, BOC, ECB, and SNB. In the first and second regressions, the restriction $\gamma_1 = \gamma_2 = 0$ is imposed. $\gamma_1$ and $\gamma_2$ are unrestricted in the third and fourth regressions. In the first and third regressions, the restriction $\delta = 0$ is imposed, meaning that each central bank has the same constant term. In the second and fourth regressions, $\delta$ is unrestricted, so the constant term corresponds to the FED. The dummy variable coefficients are not reported as they are insignificant.
Table 8: Regression Results: 1M VRP

<table>
<thead>
<tr>
<th>Dependent Variable ($Y_t$)</th>
<th>$VRP_{t,t+30}$</th>
<th>$VRP_{t,t+30}$</th>
<th>$VRP_{t,t+30}$</th>
<th>$VRP_{t,t+30}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>19.705***</td>
<td>10.036</td>
<td>19.776***</td>
<td>10.649</td>
</tr>
<tr>
<td>$NI_t$</td>
<td>5.757***</td>
<td>5.614**</td>
<td>4.703**</td>
<td>4.527**</td>
</tr>
<tr>
<td></td>
<td>(2.401)</td>
<td>(2.246)</td>
<td>(2.261)</td>
<td>(2.109)</td>
</tr>
<tr>
<td>$Ret_t$</td>
<td></td>
<td>5.463</td>
<td>5.882</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3.549)</td>
<td>(3.668)</td>
<td></td>
</tr>
<tr>
<td>$\Delta IV_t$</td>
<td></td>
<td>0.399**</td>
<td>0.376**</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.165)</td>
<td>(0.166)</td>
<td></td>
</tr>
<tr>
<td>$VRP_{t-31,t-1}$</td>
<td>0.515***</td>
<td>0.484***</td>
<td>0.552***</td>
<td>0.523***</td>
</tr>
<tr>
<td></td>
<td>(0.107)</td>
<td>(0.107)</td>
<td>(0.115)</td>
<td>(0.119)</td>
</tr>
<tr>
<td>$\Delta IV_{t-31,t-1}$</td>
<td>0.356***</td>
<td>0.325***</td>
<td>0.428***</td>
<td>0.397***</td>
</tr>
<tr>
<td></td>
<td>(0.105)</td>
<td>(0.105)</td>
<td>(0.103)</td>
<td>(0.109)</td>
</tr>
<tr>
<td>CB Dummies</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.163</td>
<td>0.178</td>
<td>0.177</td>
<td>0.190</td>
</tr>
<tr>
<td>$N$</td>
<td>157</td>
<td>157</td>
<td>157</td>
<td>157</td>
</tr>
</tbody>
</table>

$Y_t = \alpha + \beta NI_t + \gamma_1 Ret_t + \gamma_2 \Delta IV_t + \gamma_3 VRP_{t-31,t-1} + \gamma_4 \Delta IV_{t-31,t-1} + \delta CB_t + \epsilon_t$

This table reports results from the above regression for the one month variance risk premium. Each central bank’s net index is divided by its own standard deviation. Thus, the coefficient on the net index can be interpreted as the affect of a one standard deviation increase in hawkishness. Results are reported with and without central bank dummy variables. Coefficients are reported with Newey West standard errors in parentheses. One, two, and three stars indicate p-values below 0.10, 0.05, and 0.01, respectively. The sample period is June 2009 until December 2015. $NI_t$ is the net index, $Ret_t$ is the daily return, $\Delta IV_t$ is the daily change in implied volatility, $VRP_{t-31,t-1}$ is the prior month variance risk premium, and $\Delta IV_{t-31,t-1}$ is the prior month change in implied volatility. $CB_t$ consists of central bank dummy variables for the BOE, BOC, ECB, and SNB. In the first and second regressions, the restriction $\gamma_1 = \gamma_2 = 0$ is imposed. $\gamma_1$ and $\gamma_2$ are unrestricted in the third and fourth regressions. In the first and third regressions, the restriction $\delta = 0$ is imposed, meaning that each central bank has the same constant term. In the second and fourth regressions, $\delta$ is unrestricted, so the constant term corresponds to the FED. The dummy variable coefficients are not reported as they are insignificant.
This table reports results from the above regression for the two month variance risk premium. Each central bank’s net index is divided by its own standard deviation. Thus, the coefficient on the net index can be interpreted as the affect of a one standard deviation increase in hawkishness. Results are reported with and without central bank dummy variables. Coefficients are reported with Newey West standard errors in parentheses. One, two, and three stars indicate p-values below 0.10, 0.05, and 0.01, respectively. The sample period is June 2009 until December 2015. $NI_t$ is the net index, $Ret_t$ is the daily return, $\Delta IV_t$ is the daily change in implied volatility, $VRP_{t,t+31,t-1}$ is the prior month variance risk premium, and $\Delta IV_{t-31,t-1}$ is the prior month change in implied volatility. $CB_t$ consists of central bank dummy variables for the BOE, BOC, ECB, and SNB. In the first and second regressions, the restriction $\gamma_1 = \gamma_2 = 0$ is imposed. $\gamma_1$ and $\gamma_2$ are unrestricted in the third and fourth regressions. In the first and third regressions, the restriction $\delta = 0$ is imposed, meaning that each central bank has the same constant term. In the second and fourth regressions, $\delta$ is unrestricted, so the constant term corresponds to the FED. The dummy variable coefficients are not reported as they are insignificant. Results are reported without the Swiss Franc outlier, which is discussed further in appendix C.
### Table 10: Regression Results: 3M VRP

<table>
<thead>
<tr>
<th>Dependent Variable ($Y_t$)</th>
<th>$VRP_{t,t+90}$</th>
<th>$VRP_{t,t+90}$</th>
<th>$VRP_{t,t+90}$</th>
<th>$VRP_{t,t+90}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>16.875***</td>
<td>10.235</td>
<td>16.910***</td>
<td>10.082</td>
</tr>
<tr>
<td></td>
<td>(4.164)</td>
<td>(9.069)</td>
<td>(4.158)</td>
<td>(9.023)</td>
</tr>
<tr>
<td>$NI_t$</td>
<td>7.234**</td>
<td>7.240**</td>
<td>6.984*</td>
<td>6.513*</td>
</tr>
<tr>
<td></td>
<td>(3.194)</td>
<td>(3.216)</td>
<td>(3.933)</td>
<td>(3.633)</td>
</tr>
<tr>
<td>$Ret_t$</td>
<td>1.525</td>
<td>5.029</td>
<td>(7.815)</td>
<td>(5.636)</td>
</tr>
<tr>
<td>$\Delta IV_t$</td>
<td>0.080</td>
<td>0.191</td>
<td>(0.535)</td>
<td>(0.421)</td>
</tr>
<tr>
<td>$VRP_{t-31,t-1}$</td>
<td>0.668***</td>
<td>0.708***</td>
<td>0.723***</td>
<td>0.523***</td>
</tr>
<tr>
<td></td>
<td>(0.124)</td>
<td>(0.115)</td>
<td>(0.115)</td>
<td>(0.120)</td>
</tr>
<tr>
<td>$\Delta IV_{t-31,t-1}$</td>
<td>0.440***</td>
<td>0.465***</td>
<td>0.505***</td>
<td>0.407***</td>
</tr>
<tr>
<td></td>
<td>(0.155)</td>
<td>(0.130)</td>
<td>(0.227)</td>
<td>(0.173)</td>
</tr>
<tr>
<td>CB Dummies</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.172</td>
<td>0.216</td>
<td>0.172</td>
<td>0.219</td>
</tr>
<tr>
<td>$N$</td>
<td>156</td>
<td>156</td>
<td>156</td>
<td>156</td>
</tr>
</tbody>
</table>

This table reports results from the above regression for the three month variance risk premium. Each central bank’s net index is divided by its own standard deviation. Thus, the coefficient on the net index can be interpreted as the affect of a one standard deviation increase in hawkishness. Results are reported with and without central bank dummy variables. Coefficients are reported with Newey West standard errors in parentheses. One, two, and three stars indicate p-values below 0.10, 0.05, and 0.01, respectively. The sample period is June 2009 until December 2015. $NI_t$ is the net index, $Ret_t$ is the daily return, $\Delta IV_t$ is the daily change in implied volatility, $VRP_{t-31,t-1}$ is the prior month variance risk premium, and $\Delta IV_{t-31,t-1}$ is the prior month change in implied volatility. $CB_t$ consists of central bank dummy variables for the BOE, BOC, ECB, and SNB. In the first and second regressions, the restriction $\gamma_1 = \gamma_2 = 0$ is imposed. $\gamma_1$ and $\gamma_2$ are unrestricted in the third and fourth regressions. In the first and third regressions, the restriction $\delta = 0$ is imposed, meaning that each central bank has the same constant term. In the second and fourth regressions, $\delta$ is unrestricted, so the constant term corresponds to the FED. The dummy variable coefficients are not reported as they are insignificant. Results are reported without the Swiss Franc outlier, which is discussed further in appendix C.
Table 11: Regression Results: Proportional Net Index

<table>
<thead>
<tr>
<th>Dependent Variable ($Y_t$)</th>
<th>$\Delta IRA_t$</th>
<th>$\Delta IRA_{t-1}$</th>
<th>$VRP_{t,t+30}$</th>
<th>$VRP_{t,t+30}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>−0.178</td>
<td>−1.470**</td>
<td>17.817***</td>
<td>8.542</td>
</tr>
<tr>
<td></td>
<td>(0.501)</td>
<td>(0.676)</td>
<td>(4.810)</td>
<td>(12.917)</td>
</tr>
<tr>
<td>$NI_t^p$</td>
<td>0.622*</td>
<td>0.622*</td>
<td>2.820</td>
<td>2.750</td>
</tr>
<tr>
<td></td>
<td>(0.355)</td>
<td>(0.332)</td>
<td>(4.670)</td>
<td>(4.685)</td>
</tr>
<tr>
<td>$Ret_t$</td>
<td>0.111</td>
<td>0.086</td>
<td>5.940*</td>
<td>6.372*</td>
</tr>
<tr>
<td></td>
<td>(0.436)</td>
<td>(0.448)</td>
<td>(3.588)</td>
<td>(3.695)</td>
</tr>
<tr>
<td>$\Delta IV_t$</td>
<td>0.037*</td>
<td>0.030*</td>
<td>0.424**</td>
<td>0.401**</td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td>(0.019)</td>
<td>(0.169)</td>
<td>(0.170)</td>
</tr>
<tr>
<td>$VRP_{t-31,t-1}$</td>
<td>0.030***</td>
<td>0.027***</td>
<td>0.575***</td>
<td>0.546***</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.008)</td>
<td>(0.118)</td>
<td>(0.122)</td>
</tr>
<tr>
<td>$\Delta IV_{t-31,t-1}$</td>
<td>0.005</td>
<td>0.003</td>
<td>0.453***</td>
<td>0.422***</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.010)</td>
<td>(0.106)</td>
<td>(0.111)</td>
</tr>
<tr>
<td>CB Dummies</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.143</td>
<td>0.168</td>
<td>0.171</td>
<td>0.185</td>
</tr>
<tr>
<td>$N$</td>
<td>157</td>
<td>157</td>
<td>157</td>
<td>157</td>
</tr>
</tbody>
</table>

$Y_t = \alpha + \beta NI_t^p + \gamma_1 Ret_t + \gamma_2 \Delta IV_t + \gamma_3 VRP_{t-31,t-1} + \gamma_4 \Delta IV_{t-31,t-1} + \delta CB_t + \epsilon_t$

This table reports results from the above regression for two dependent variables: the change in implied risk aversion and the one month variance risk premium. It reproduces the results in the third and fourth columns of tables 7 and 8, using the proportional net index instead of the regular net index. The proportional net index is based on the proportion of hawkish or dovish phrases in a press conference, rather than the number of phrases. Results are reported with and without central bank dummy variables. Coefficients are reported with Newey West standard errors in parentheses. One, two, and three stars indicate p-values below 0.10, 0.05, and 0.01, respectively. The sample period is June 2009 until December 2015. $NI_t^p$ is the proportional net index, $Ret_t$ is the daily return, $\Delta IV_t$ is the daily change in implied volatility, $VRP_{t-31,t-1}$ is the prior month variance risk premium, and $\Delta IV_{t-31,t-1}$ is the prior month change in implied volatility. $CB_t$ consists of central bank dummy variables for the BOE, BOC, ECB, and SNB. In the first and third regressions, the restriction $\delta = 0$ is imposed, meaning that each central bank has the same constant term. In the second and fourth regressions, $\delta$ is unrestricted, so the constant term corresponds to the FED. The dummy variable coefficients are not reported as they are insignificant.
<table>
<thead>
<tr>
<th>Dependent Variable ($Y_t$)</th>
<th>$\Delta IRA_t$</th>
<th>$\Delta IRA_{t+30}$</th>
<th>$VRP_{t+30}$</th>
<th>$VRP_{t+30}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-0.073</td>
<td>-1.407***</td>
<td>19.257***</td>
<td>9.828</td>
</tr>
<tr>
<td></td>
<td>(0.498)</td>
<td>(0.684)</td>
<td>(4.659)</td>
<td>(12.908)</td>
</tr>
<tr>
<td>$NI_t^e$</td>
<td>0.768**</td>
<td>0.808***</td>
<td>4.205*</td>
<td>3.954*</td>
</tr>
<tr>
<td></td>
<td>(0.327)</td>
<td>(0.302)</td>
<td>(2.226)</td>
<td>(2.211)</td>
</tr>
<tr>
<td>$Ret_t$</td>
<td>0.103</td>
<td>0.069</td>
<td>5.585</td>
<td>6.013</td>
</tr>
<tr>
<td></td>
<td>(0.436)</td>
<td>(0.449)</td>
<td>(3.629)</td>
<td>(3.763)</td>
</tr>
<tr>
<td>$\Delta IV_t$</td>
<td>0.036*</td>
<td>0.029</td>
<td>0.406**</td>
<td>0.384**</td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td>(0.018)</td>
<td>(0.168)</td>
<td>(0.168)</td>
</tr>
<tr>
<td>$VRP_{t-31,t-1}$</td>
<td>0.028***</td>
<td>0.025***</td>
<td>0.559***</td>
<td>0.530***</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.008)</td>
<td>(0.115)</td>
<td>(0.118)</td>
</tr>
<tr>
<td>$\Delta IV_{t-31,t-1}$</td>
<td>0.003</td>
<td>0.000</td>
<td>0.432***</td>
<td>0.403***</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.010)</td>
<td>(0.103)</td>
<td>(0.106)</td>
</tr>
<tr>
<td>CB Dummies</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.155</td>
<td>0.183</td>
<td>0.176</td>
<td>0.189</td>
</tr>
<tr>
<td>$N$</td>
<td>157</td>
<td>157</td>
<td>157</td>
<td>157</td>
</tr>
</tbody>
</table>

$Y_t = \alpha + \beta NI_t^e + \gamma_1 Ret_t + \gamma_2 \Delta IV_t + \gamma_3 VRP_{t-31,t-1} + \gamma_4 \Delta IV_{t-31,t-1} + \delta CB_t + \epsilon_t$

This table reports results from the above regression for two dependent variables: the change in implied risk aversion and the one month variance risk premium. It reproduces the results in the third and fourth columns of tables 7 and 8, using the extended net index instead of the regular net index. The extended net index includes additional nouns, as presented in table 1, to identify hawkish and dovish phrases. Each central bank’s net index is divided by its own standard deviation. Thus, the coefficient on the net index can be interpreted as the affect of a one standard deviation increase in hawkishness. Results are reported with and without central bank dummy variables. Coefficients are reported with Newey West standard errors in parentheses. One, two, and three stars indicate p-values below 0.10, 0.05, and 0.01, respectively. The sample period is June 2009 until December 2015. $NI_t^e$ is the extended net index, $Ret_t$ is the daily return, $\Delta IV_t$ is the daily change in implied volatility, $VRP_{t-31,t-1}$ is the prior month variance risk premium, and $\Delta IV_{t-31,t-1}$ is the prior month change in implied volatility. $CB_t$ consists of central bank dummy variables for the BOE, BOC, ECB, and SNB. In the first and third regressions, the restriction $\delta = 0$ is imposed, meaning that each central bank has the same constant term. In the second and fourth regressions, $\delta$ is unrestricted, so the constant term corresponds to the FED. The dummy variable coefficients are not reported as they are insignificant.
Table 13: Regression Results: IRA upside & downside

<table>
<thead>
<tr>
<th>Dependent Variable ($Y_t$)</th>
<th>$\Delta IRA^u_t$</th>
<th>$\Delta IRA^d_t$</th>
<th>$\Delta IRA^u_{t-1}$</th>
<th>$\Delta IRA^d_{t-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-0.091</td>
<td>0.169</td>
<td>-1.173*</td>
<td>-1.440*</td>
</tr>
<tr>
<td></td>
<td>(0.437)</td>
<td>(0.632)</td>
<td>(0.601)</td>
<td>(0.786)</td>
</tr>
<tr>
<td>$NI_t$</td>
<td>0.815***</td>
<td>0.826***</td>
<td>0.879**</td>
<td>0.905**</td>
</tr>
<tr>
<td></td>
<td>(0.289)</td>
<td>(0.281)</td>
<td>(0.373)</td>
<td>(0.355)</td>
</tr>
<tr>
<td>$Ret_t$</td>
<td>0.216</td>
<td>-0.090</td>
<td>0.199</td>
<td>-0.134</td>
</tr>
<tr>
<td></td>
<td>(0.395)</td>
<td>(0.497)</td>
<td>(0.409)</td>
<td>(0.510)</td>
</tr>
<tr>
<td>$\Delta IV_t$</td>
<td>0.024</td>
<td>0.047**</td>
<td>0.019</td>
<td>0.038**</td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td>(0.020)</td>
<td>(0.019)</td>
<td>(0.019)</td>
</tr>
<tr>
<td>$VRP_{t-31,t-1}$</td>
<td>0.021***</td>
<td>0.019**</td>
<td>0.034***</td>
<td>0.031***</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.008)</td>
<td>(0.010)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>$\Delta IV_{t-31,t-1}$</td>
<td>-0.001</td>
<td>0.004</td>
<td>-0.003</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.012)</td>
<td>(0.009)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>CB Dummies</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.164</td>
<td>0.150</td>
<td>0.186</td>
<td>0.181</td>
</tr>
<tr>
<td>$N$</td>
<td>157</td>
<td>157</td>
<td>157</td>
<td>157</td>
</tr>
</tbody>
</table>

$Y_t = \alpha + \beta NI_t + \gamma_1 Ret_t + \gamma_2 \Delta IV_t + \gamma_3 VRP_{t-31,t-1} + \gamma_4 \Delta IV_{t-31,t-1} + \delta CB_t + \epsilon_t$

This table reports results from the above regression for two dependent variables: the change in upside implied risk aversion and the change in downside implied risk aversion. Each central bank’s net index is divided by its own standard deviation. Thus, the coefficient on the net index can be interpreted as the affect of a one standard deviation increase in hawkishness. Results are reported with and without central bank dummy variables. Coefficients are reported with Newey West standard errors in parentheses. One, two, and three stars indicate p-values below 0.10, 0.05, and 0.01, respectively. The sample period is June 2009 until December 2015. $NI_t$ is the net index, $Ret_t$ is the daily return, $\Delta IV_t$ is the daily change in implied volatility, $VRP_{t-31,t-1}$ is the prior month variance risk premium, and $\Delta IV_{t-31,t-1}$ is the prior month change in implied volatility. $CB_t$ consists of central bank dummy variables for the BOE, BOC, ECB, and SNB. In the first and third regressions, the restriction $\delta = 0$ is imposed, meaning that each central bank has the same constant term. In the second and fourth regressions, $\delta$ is unrestricted, so the constant term corresponds to the FED. The dummy variable coefficients are not reported as they are insignificant.
Table 14: Regression Results: 1M VRP upside & downside

<table>
<thead>
<tr>
<th>Dependent Variable ($Y_t$)</th>
<th>$VRP_{t,t+30}^u$</th>
<th>$VRP_{t,t+30}^u$</th>
<th>$VRP_{t,t+30}^d$</th>
<th>$VRP_{t,t+30}^d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>13.531***</td>
<td>3.232</td>
<td>10.231***</td>
<td>9.162**</td>
</tr>
<tr>
<td></td>
<td>(2.133)</td>
<td>(9.219)</td>
<td>(2.954)</td>
<td>(4.345)</td>
</tr>
<tr>
<td>$NI_t$</td>
<td>3.394**</td>
<td>3.133**</td>
<td>2.814*</td>
<td>2.856*</td>
</tr>
<tr>
<td></td>
<td>(1.577)</td>
<td>(1.474)</td>
<td>(1.575)</td>
<td>(1.531)</td>
</tr>
<tr>
<td>$Ret_t$</td>
<td>4.225*</td>
<td>4.325*</td>
<td>-1.430</td>
<td>-1.223</td>
</tr>
<tr>
<td></td>
<td>(2.466)</td>
<td>(2.596)</td>
<td>(2.310)</td>
<td>(2.245)</td>
</tr>
<tr>
<td>$\Delta IV_t$</td>
<td>0.464</td>
<td>0.398</td>
<td>-0.042</td>
<td>-0.039</td>
</tr>
<tr>
<td></td>
<td>(0.326)</td>
<td>(0.333)</td>
<td>(0.211)</td>
<td>(0.198)</td>
</tr>
<tr>
<td>$VRP_{t-31,t-1}$</td>
<td>0.124</td>
<td>0.115</td>
<td>0.438***</td>
<td>0.405***</td>
</tr>
<tr>
<td></td>
<td>(0.097)</td>
<td>(0.098)</td>
<td>(0.110)</td>
<td>(0.120)</td>
</tr>
<tr>
<td>$\Delta IV_{t-31,t-1}$</td>
<td>-0.026</td>
<td>-0.045</td>
<td>0.489***</td>
<td>0.445**</td>
</tr>
<tr>
<td></td>
<td>(0.143)</td>
<td>(0.148)</td>
<td>(0.171)</td>
<td>(0.180)</td>
</tr>
<tr>
<td>CB Dummies</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.050</td>
<td>0.077</td>
<td>0.110</td>
<td>0.130</td>
</tr>
<tr>
<td>$N$</td>
<td>157</td>
<td>157</td>
<td>157</td>
<td>157</td>
</tr>
</tbody>
</table>

$Y_t = \alpha + \beta NI_t + \gamma_1 Ret_t + \gamma_2 \Delta IV_t + \gamma_3 VRP_{t-31,t-1} + \gamma_4 \Delta IV_{t-31,t-1} + \delta CB_t + \epsilon_t$

This table reports results from the above regression for two dependent variables: the one month upside variance risk premium and the one month downside variance risk premium. Each central bank’s net index is divided by its own standard deviation. Thus, the coefficient on the net index can be interpreted as the affect of a one standard deviation increase in hawkishness. Results are reported with and without central bank dummy variables. Coefficients are reported with Newey West standard errors in parentheses. One, two, and three stars indicate p-values below 0.10, 0.05, and 0.01, respectively. The sample period is June 2009 until December 2015. $NI_t$ is the net index, $Ret_t$ is the daily return, $\Delta IV_t$ is the daily change in implied volatility, $VRP_{t-31,t-1}$ is the prior month variance risk premium, and $\Delta IV_{t-31,t-1}$ is the prior month change in implied volatility. $CB_t$ consists of central bank dummy variables for the BOE, BOC, ECB, and SNB. In the first and third regressions, the restriction $\delta = 0$ is imposed, meaning that each central bank has the same constant term. In the second and fourth regressions, $\delta$ is unrestricted, so the constant term corresponds to the FED. The dummy variable coefficients are not reported as they are insignificant.