Option-implied expectations and the (non) neutrality of money

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Abstract

In this paper we measure the impact of monetary policy shocks on the option-implied expectations for the US equity options market. More specifically, we proxy the expectations about the path of equity prices and tail risk (extreme returns) with the skewness and the kurtosis of the risk-neutral option-implied distribution for the S&P500 index. Our results show that the Fed can manage the option-implied expectations of US equity market for both long and short-term horizon. Specifically, our results clearly show that monetary policy shocks have the most significant impact on the long-end of the term structure of option-implied expectations about future equity prices and price jumps. More specifically, an expansionary monetary policy revises upward (downward) the long-term option-implied expectations regarding price (jump tail risk) in the US equity market.

Keywords: *Monetary policy, Option-implied moments, Implied expectations*

JEL Classification: E4, G1

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1.Introduction

In this paper we attempt to find in which extent the Fed can manage investors' expectations and fears about the future state of the economy. The risk-taking channel of monetary policy have been theoretically explained by (write the relevant literature). whether monetary policy is able to influence investors' beliefs about the short-term and long-term horizon. The last years, the links amongst stock market performance and monetary policy have been extensively examined. A vast relevant literature starting with Thornbecke (1997) document a strong reaction of aggregate stock market returns to corresponding monetary policy news (Bernarke and Kuttner, 2005; Rigobon and Sack, 2003; Savor and Wilson, 2014; Brusa *et al.*, 2015; Lucca and Moench, 2015; Cieslak *et al*., 2018; amongst others). Bernarke and Kuttner (2005) point out that stock market react to monetary policy shocks mainly because of revisions on expected future dividend and capital gain growths and not because of changes in the expected discount factor. While the Central's Bank target is traditionally inflation and unemployment, in many cases monetary policy decisions are made based on their expected impact on equities. In details, the recent findings in the relevant literature have identified the systematic intervention of the Fed in the stock-market during times of rising turbulence, volatility and meltdowns in the stock-market (Rigobon and Sack, 2003; Kurov *et al.*, 2019; Kurov *et al.*, 2016; Gu *et al.*, 2018; Cieslak and Vissing-Jorgensen, 2020). For example, Kurov et al. (2016) show that there is a This behaviour of the Fed is characterized as Fed put (or Greenspans put), since the Fed intervenes by cutting interest rates in a falling market to prevent a severe meltdown (just like a protective put option does). Notwithstanding the rich available findings in the relevant literature about the response of investors' expectations to monetary policy shocks, the extent in which Fed can manage investors' beliefs about the short-term and long-term horizon has yet

not answered. Specifically, there is an ongoing debate in the relevant literature of monetary economics about the famous "long-term money neutrality". While Lucas (1972) in his seminal work, set up a theoretical framework that explains the long-term money neutrality, many relevant studies empirically verify that monetary policy have affects real output variables and inflation expectations in both short-term and long-term horizon (Hanson and Stein, 2015; Kontonikas and Zekaite, 2018; Nakamura and Steinsson, 2018; amongst others).

In our analysis, we empirically examine the dynamic impact of monetary policy on the option-implied expectations in the US equity market, by using a Structural vector autoregressions (SVARs) models. We estimate the model-free version of option-implied moments (a model-free version of risk-neutral distribution), to proxy investors' expectations about the future state of the economy. Option-implied moments are widely used from many researchers as a proxy of investors' beliefs and fears, since option-implied information is inherently forward-looking and reflects investors' beliefs under the risk-neutral measure about the upcoming evolution of the underlying equities prices (Bates, 1991; Jackwerth and Rubinstein, 1996; Bakshi *et al.*., 1997). We use option data from the S&P 500 index to obtain higher option-implied moments of the return distribution[3], following the Bakshi *et al.* (2003) model-free methodology. Afterwards, we estimate the dynamic response of option-implied moments to monetary policy shocks, by using a Structural-VAR and reduced VAR models. In our analysis, we proxy the option-implied variance, skewness, and kurtosis of the return distribution of S&P 500 index, using option contracts with different maturities. Therefore, using risk neutral

[3] More specifically, we calculate the implied skewness and implied kurtosis of S&P 500 index return distribution. During this paper, we may refer to implied moments as moments of risk neutral density. In the next sections we are going to explain in more details the relevant theoretical concepts and issues that links the risk neutral density and option-implied moments.

densities of the US stock market that corresponds to varying horizons, we construct the term structure of option-implied moments, similarly with the term structure of interest rates. We follow this approach because it allows us to examine if monetary policy affects asymmetrically investors' expectations and fears for different horizons in the future.

Our study is related with a large body of the monetary policy and macro-finance literature. One strand of the literature finds a negative relationship between monetary policy changes and subsequent stock returns (Thorbecke, 1997; Patelis,1997; Goto and Valkanov, 2002; Rigobon and Sack, 2004; Gorodnichenko and Weber, 2016; Kuttner, 2001; Lucca and Moench, 2015). Other studies extend the findings of the relevant literature by documenting that an expansionary monetary policy revises upwardly the investors' expectations regarding the subsequent path of stock prices (Bernarke and Kuttner, 2005; Bekaert *et al.*., 2013; Triantafyllou and Dotsis, 2017; amongst others). In the same vein, there are some studies that empirically verifies the existence of "Greenspan put" phenomenon based on the impact of expansionary monetary policy on investors' expectations (Rigobon and Sack, 2003; Kurov *et al.*, 2019; Cieslak and Vissing-Jorgensen, 2020).

In addition, one other strand of the literature that is also related with our study, examines the impact of monetary policy decisions on stock market uncertainty (Bekaert *et al.*, 2013; Vahamma and Aijo, 2011; D'Amico and Farka, 2011; Rosa, 2011; Fernandez-Perez *et al.*, 2017; Jiang *et al.*, 2012; Gospodinov and Jamali, 2012; Clements, 2007; Du *et al.*, 2018), on risk aversion (Bekaert *et al.*, 2013; Adrian and Shin, 2008; Ioannidou *et al.*, 2015) and on jump tail risk (Hattori *et al.*, 2016; Beckmeyer *et al.*, 2019). Moreover, another strand of the macro-finance literature investigates the links between the monetary policy stance and the risk-taking behaviour of the financial

institutions and investors (risk-taking channel of monetary policy) (Adrian and Shin, 2008; Borio and Zhu, 2012; Bekaert *et al.*, 2013; Angeloni *et al.*, 2015). For instance, Bekaert *et al.* (2013) empirically verify the impact of monetary policy on stock-market uncertainty (proxied by the VIX index) and risk-aversion (proxied by the Variance Risk Premium).

Our paper diverges from the previous studies, since our analysis has a different scope and methodology approach. Firstly, whilst the effects of the monetary policy on the second moments of option-implied distribution of the stocks returns (implied volatility)[4] have been examined extensively in the prior literature, considerably less attention has been given to the impact of monetary policy on third and fourth moments of the distribution of option prices[5], that reflect a richer information set about investors' perception of subsequent stock market performance. Additionally, the inclusion of multiple risk neutral distributions for many different horizons, allow us to identify if the impact of monetary policy on implied moments differs across different maturities. In our analysis, we provide evidence that the long-term component of the term structure of option implied moments are much more responsive to monetary policy shocks than the short-end components.

The contribution of our paper in the relevant literature is twofold. Firstly, in line with the results on the relevant literature (Bernarke and Kuttner, 2005; Bekaert *et al.*., 2013; Triantafyllou and Dotsis, 2017; amongst others), our analysis shows that expansionary monetary policy revises upwardly the investors' expectations regarding the subsequent

[4] Implied volatility is used as a measure of investors' uncertainty. Bekaert *et al.*, 2013 decompose the VIX index into a pure uncertainty component and to a risk aversion component.
[5] There are only a few studies that investigate the impact of monetary policy shocks on higher moments of the returns distribution. For example, Hattori et al (2016) and Bechmeyer et al (2019) that identify the impact of monetary policy on option-implied kurtosis as a measure of jump tail risk are two examples of the relevant literature.

path of equity prices (risk neutral skewness becomes less negative). More specifically, when policy makers decide to follow a lax monetary policy to provide "protection" to financial markets, investors start revising upwardly their expectations about the subsequent stock market returns. While few other studies empirically verify the "Greenspan put" phenomenon (Rigobon and Sack, 2003; Kurov *et al.*, 2019; Cieslak and Vissing-Jorgensen, 2020), we are the first to show the impact of "Fed put" on investors' ex-ante expectations using higher moments of option-implied distribution of the S&P 500 index.

Secondly, we find empirical evidence which are at odds with the standard monetary theory. Concretely, we find that long-term expectations are more severely affected by monetary policy shocks when compared with the short-term ones, implicitly rejecting the 'long-term money neutrality' for the US equity options market[6]. Our results are in line with the findings of a few studies (Hanson and Stein, 2015; Kontonikas and Zekaite, 2018; Nakamura and Steinsson, 2018; amongst others) which also identify a long-term non-neutrality of money. For example, Kontonikas and Zekaite (2018) use a VAR specification and they find that monetary policy influence inflation expectations in the long-term horizon. Additionally, Hanson and Stein (2015) identify a stronger impact of monetary policy shocks on long-term real interest rates that is at odds with standard Keynesian theory. They attribute this phenomenon to "yield-oriented" investors, namely, they assume that increased trading volume on long-term yield bonds taking place when Fed's chair announces changes on short-term interest rates because

[6] Lucas (1972) in his Nobel-awarded work entitled "Expectations and Neutrality of money", uses a simple example of an open economy to explain how the response of the real output of an economy is neutral to monetary policy decisions in the long-term. He assumes that economic agents receive information about real and monetary disturbances only via changes in the prices, and therefore their subsequent "hedging behavior" to the price shifts during the following period, results in the well-known "long-term money neutrality". Since then, New Keynesian macro-models presume that monetary policy can influence real variables only in the short-term horizon in which goods prices cannot readjust to policy shocks, and therefore inflation expectations are neutral to monetary policy shocks in the long-term horizon.

investors need to readjust the portfolios positions. Despite the significant results of the relevant studies, Hanson and Stein (2015) emphasize that "none of our evidence directly refutes the long-run non-neutrality hypothesis that policy is somehow able to move expected real rates far out into future". Finally, Nakamura and Steinsson (2018) find that high-frequency monetary policy shocks affect both real interest rates of the long-end component of the term structure of interest rates, and forecasts of the output growth. They attempt to explain their empirical results, using a theoretical model in which policy makers cannot only influence expectations about monetary policy, but they also affect expectations about economic fundamentals.

2.1 Risk-neutral density

2.1.1 Risk-neutral moments and market expectations

There exists a line of research devoted to extract information embedded in option prices. Since options are priced considering an expiration period of τ days ahead (the option expiration or maturity), the information embedded in these prices is forward-looking, as opposed to historical data which is backward-looking. Therefore, not only is this information more informative, but it also reflects investors' expectations about future states of the economy, as investors incorporate their fears and expectations in the price of the options.

Working with option prices is also convenient because contrary to the stock prices, which only provide one realization of the price process, option prices are available for a spectrum of strike prices which allows us to infer the whole market's risk-neutral distribution, RND, over the underlying price (see Breeden and Litzenberger (1978)).

Furthermore, since options trade for different maturities, τ, option-implied information allows us to extract RNDs over different time horizons.

There exists a strand of the literature devoted to study the superior informational content of option-implied information about the future of the stock price process. Early works mainly focused on the study of the implied volatility as a measure of expected future volatility, see Poon and Granger (2003), among others. However, the implied volatility alone does not explain the expected risk of a market crash. As documented by Jackwerth and Rubinstein (1996) after the crash in 1987 RNDs became skewed and leptokurtic. Researchers have turned their attention to higher moments of the RNDs, that is skewness and kurtosis, which provide a greater insight about the shape of the distribution and its tails. For instance, when a RND presents negative skewness (that is, the left tail is more pronounced) this is an indicator that investors expect the market to decrease. Therefore, skewness has become a proxy for investors' expected tail risk of the return distribution. See the works of Rubinstein (1973), Kraus and Litzenberger (1976, 1983), Bates (1991), Jackwerth and Rubinstein (1996), Bakshi et al (1997), Bakshi et al (2003), amongst others.

2.1.2 Option contracts data

In order to extract the risk-neutral moments we use information embedded in the prices of financial options on the S&P500 index, which is a proxy for the U.S. market.

The dataset includes observations ranging from January 1996 to June 2019 which have been obtained from the volatility surface provided by Ivy DB OptionMetrics. As it is well accepted in the literature, the risk-free rate used is the zero-coupon yield provided by OptionMetrics.

dataset contains information about deltas, times to maturity, option premiums, implied-

volatilities and strike prices for call and put options on the S&P500 index. Using observations from the volatility surface has the main advantage that the information is consistent across observations, that is, for each day and type of option (call and put) the same delta range and times to maturity are available, which allows a more uniform and comparable analysis across maturities. The delta range includes deltas from 10% to 90% (for calls and puts) in increments of 5%. analysis covers a wide spectrum of horizons which includes maturities at 30, 60, 91, 122, 152, 182, 273 and 365 days. Those maturities shorter than 15 days and greater than 365 days have been removed from the analysis.

The filtering of the data is done as follows: those observations showing either negative implied volatilities, option premiums or strike prices have been discarded; as well as all those observations that violate the arbitrage bounds.

When working with option prices we need to deal with the presence of the dividends which represents a challenge because not only dividends cannot be observed, but they are also difficult to estimate. In order to overcome this issue we follow Aït-Sahalia and Lo (1998) and use forward quotes, F, as the underlying price instead of spot prices, S. Forward prices can be inferred from the put-call parity formula as follows,

$$F = (c - p)\, e^{r\tau} + K \qquad (1)$$

where c and p are the prices of the call and put options, respectively; r is the risk-free rate, τ is the time remaining to maturity of the option and K is the strike price. F prices are computed using pairs of at-the-money (ATM) put and call options. Should the ATM pair be unavailable, we use the put-call pair which is closer to ATM. In order to compute the forward prices at least two call and two put observations are required for each day.

2.1.3 Methodology: BKM higher moments estimation

This paper studies the ex-ante market expectations and how they react to monetary policy shocks.

As mentioned earlier, we can infer valuable information from the risk-neutral density and its higher moments about the market's expectations as well as future uncertainty for different time horizons. Bakshi *et al*. (2003) proposed an approach to derive the risk-neutral higher moments in a model-free manner, which has the advantage of not being subject to any pre-specified model and its assumptions.

Following Bakshi et al. (2003) we compute the higher moments (variance, skewness and kurtosis) of the risk-neutral distribution of the S&P500 index extracted from option prices (referred to as BKM moments heretofore).

The first challenge we encounter with the BKM approach is that it requires a continuum of strike prices. Because options trade at discrete prices this requires the use of interpolation techniques within the observed range of prices. The interpolation is done on an implied-volatility – delta space, following the lines of Figlewski (2008) and Neumann and Skiadopoulos (2013). Another challenge present when we work with option prices is the scarcity of extreme observations which form the tails of the distribution. In order to capture more area in the tail region, some researchers such as Buss and Vilkov (2012) extrapolate beyond the observed moneyness range to more extreme moneyness values of 1/3 to 3 assigning to these new observations the value of the last observed implied-volatitity value. However, this is equivalent to pasting lognormal tails to the center of the distribution and so imposing assumptions about the shape of the tails of the RND. In our analysis because the volatility surface provides observations for a delta range between 10% and 90% (for calls and puts), which covers

most of the tail area, we do not extrapolate beyond the observed range (10% to 90%) thus leaving the tails free from any imposed assumptions.

In order to interpolate between the observed deltas, we create a grid with 1, 000 delta points spanning between the highest (90%) and the lowest (10%) observed deltas for each day and maturity considered. The interpolation is done by fitting a cubic smoothing spline on the grid of deltas. A minimum of 4 observations per day and maturity are required to perform the interpolation.

The interpolation is performed over the domain of put deltas (Δput). Once the interpolation is fitted, we calculate the corresponding call delta (Δcall) counterpart as

Δcall = 1 + Δput. Once this is done, we translate the deltas into their corresponding moneyness which is needed to calculate the BKM moments.

As proposed in Bakshi et al. (2003) only out-of-the-money (OTM) call and put options are used. The use of data from the volatility surface ensures availability of the same number of call and put options, which provides a symmetric range of observations.5 In our analysis, 501 OTM calls and 501 OTM puts has been used each day to compute the BKM risk-neutral moments.

A full derivation of the BKM approach is provided in the Appendix A.

2.1.4 Term structure of risk-neutral moments

In our analysis, we calculate the implied moments for a wide spectrum of horizons as we discuss in the previous subsection. purpose is to use this wide spectrum of the estimated implied moments in order to construct the term structure of option-implied moments, similarly with the term structure of interest rates. We follow this approach,

because the term structure of option-implied moments will provide a rich information set about the varying response of the RND of contracts with different maturities to monetary policy shocks. In details, we calculate 4 components of the term structure of option-implied moments, the term spread, the level, the short-end and the long-end component. The term spread (of each implied moment) is calculated, as the difference of the 365 days maturity and the 30 days maturity implied moment. Additionally, we calculate the level, the short term and long-term components as the average of all the estimated implied moments for each maturity, as the average of the 1,2- and 3-months implied moments and the average of 6,9- and 12-months implied moments, respectively. In the next sections of this paper, for brevity we will use the terms implied skewness or implied kurtosis to correspond to the level of implied skewness or kurtosis. Similarly, we are going to use the terms short-end and long-end implied skewness(kurtosis), to correspond to the short-end and long-end components of the term structure of implied skewness(kurtosis). Finally, we use the abbreviations IV, IS and IK to refer to implied variance, implied skewness and implied kurtosis respectively.

2.2 Measuring monetary policy (MP) stance and shocks

In our analysis we mainly follow the empirical approach of Triantafyllou and Dotsis (2017) and Bekaert et al. (2013). Firstly, we estimate the measures of monetary policy stance. In details, we use four measures of monetary policy stance, the fed fund target rate (FFR), the real interest rate (RIR) that is the Fed funds rate target minus the CPWe annual inflation rate, the growth rate of the monetary aggregate M1 (M1growth) and the Taylor rule rate (TRD). The corresponding time series are obtained from the FRED database. The frequency of the measures of monetary policy stance are monthly, except the TRD measures that is quarterly. Our baseline measure of monetary policy stance is

the FFR (similarly with Triantafyllou and Dotsis (2017) and we use RIR, M1growth and TRD as alternative measures of monetary policy stance.

3.1. Long-term patterns and descriptive statistics

Figure 1 and **Figure 2** plot the contemporaneous movements of Fed Fund rate with the level of implied skewness (IS) and the level of implied kurtosis (IK) respectively.

Figure 1. The level of implied skewness and the Fed funds rate

In this figure, we plot the monthly time series of the level of option-implied skewness and the fed fund rate. The left vertical axis includes the values of the FFR and the right the values of the level of IS. The data covers the period from Jan/1996 to Jun/2019

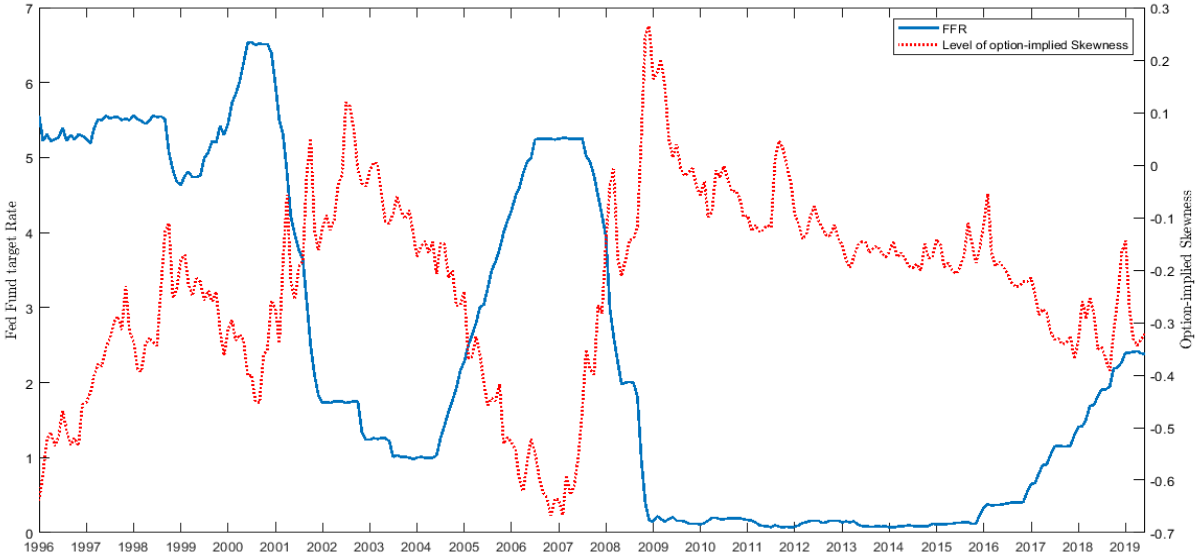
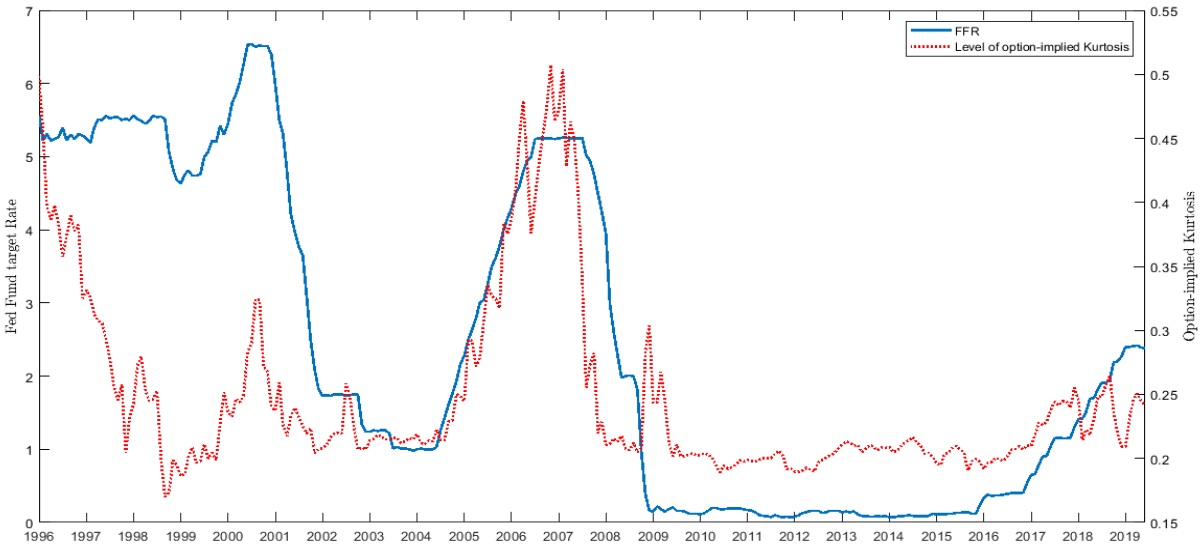


Figure 2. The level of implied kurtosis and the Fed funds rate

In this figure, we plot the monthly time series of the level of option-implied kurtosis and the fed fund rate. The left vertical axis includes the values of the FFR and the right the values of the level of IK. The data covers the period from Jan/1996 to Jun/2019



In general, we observe an opposite (analogue) direction movement between the Fed Fund rate and option-implied skewness (option-implied kurtosis). More specifically, the figures show that accommodative (contractionary) monetary policy is related to a higher (lower) level of option-implied skewness and a lower (higher) level of option-implied kurtosis. The pattern that we observe in **Figure 1** and **2**, is also documented in previous studies of the relevant literature, like the one conducted by Triantafyllou and Dotsis (2017) in which they find similar results about the relationship of option-implied skewness in commodities markets and monetary policy stance. Additionally, Hattori *et al.* (2016) find similar results about the impact of the unconventional monetary policy on the jump tail risk of the stock market.

Moreover, we provide two more figures, **Figure 3** and **Figure 4**, in which we include the short-end and long-end components of option-implied skewness and kurtosis instead of the level of IS and IK, respectively.

Figure 3. Short-end and long-end components of Implied skewness and the Fed funds rate

In this figure, we plot the monthly time series of the short-end and long-end components of option-implied skewness and the fed fund rate. The left vertical axis includes the values of the FFR and the right the values of IS. The data covers the period from Jan/1996 to Jun/2019

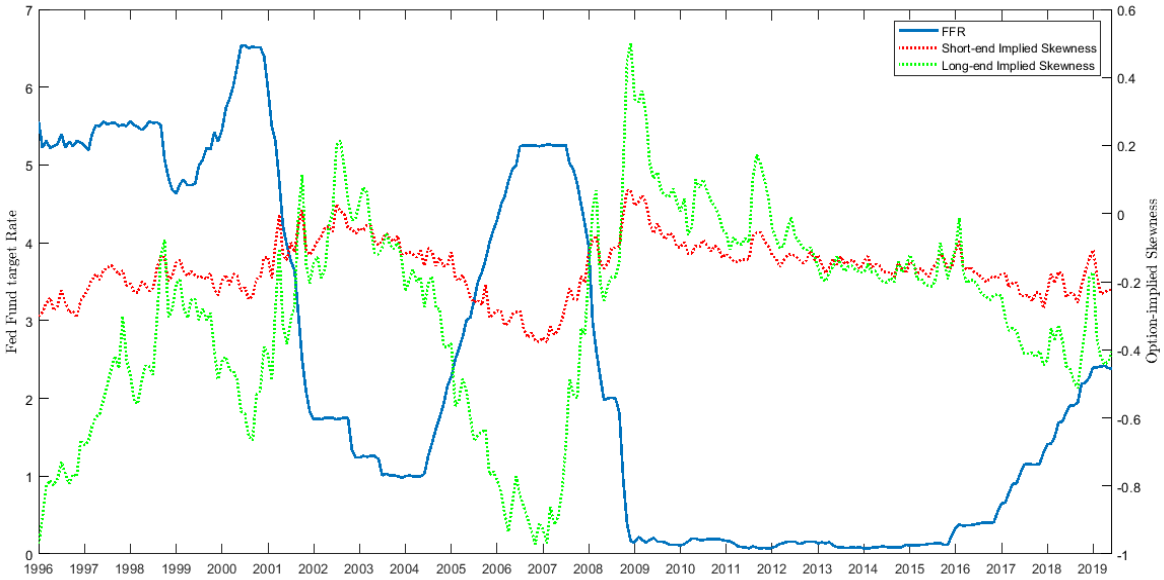
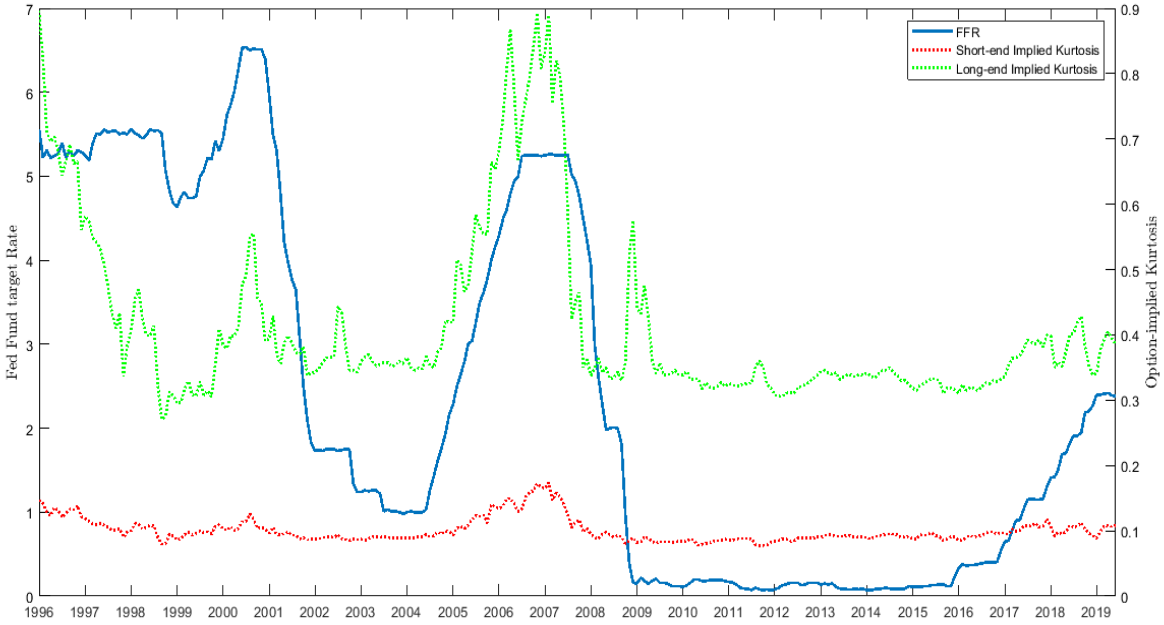


Figure 4. Short-end and long-end components of Implied skewness and the Fed funds rate

In this figure, we plot the monthly time series of the short-end and long-end components of option-implied kurtosis and the fed fund rate. The left vertical axis includes the values of the FFR and the right the values of IK. The data covers the period from Jan/1996 to Jun/2019



In **Figures 3** and **4**, we observe larger swings in the movement of the long-end components of option-implied moments (both implied skewness and kurtosis) compared to the movement of the short-end components, during periods that the level

of Fed Fund rate falls (or rises). This is a first indication that the long-end components of option-implied moments are more responsive to monetary policy shocks.

Finally, we present **Table 1** and **Table 2** that shows the descriptive statistics and the correlation respectively.

Table 1. Descriptive statistics

This table shows the descriptive statistics along with the ADF unit root tests for the explanatory variables which we include in the left-hand side of the forecasting regressions. With *, **, and *** we reject the hypothesis of a unit root for 10%, 5% and 1% confidence level respectively. All the time series have monthly frequency and cover the period from January 1990 till December 2017.

	FFR	M1growth	inflation	RIR	TDR	Skewness term spread	Skewness level	Skewness short-end	Skewness long-end	kurtosis term spread	Kurtosis level	Kurtosis short-end	kurtosis long-end	Variance term spread	Variance level	Variance short-end	Variance long-end	Industrial production growth	Term spread of yield curve
Mean	2.37	0.44	0.18	0.18	3.19	-0.20	-0.23	-0.16	-0.29	0.49	0.25	0.10	0.41	0.02	0.24	0.23	0.25	0.00	0.02
Median	6.54	5.75	1.22	40.01	6.33	0.70	0.26	0.07	0.50	1.14	0.51	0.17	0.90	0.20	1.42	1.71	1.13	0.02	0.04
Maximum	0.07	-3.32	-1.92	-3.68	-3.14	-0.97	-0.67	-0.38	-0.97	0.30	0.17	0.08	0.27	-1.08	0.08	0.06	0.09	-0.04	-0.01
Minimum	2.18	0.94	0.35	1.90	1.73	0.33	0.18	0.08	0.29	0.19	0.07	0.02	0.14	0.11	0.17	0.20	0.15	0.01	0.01
Std. Dev.	0.47	1.61	-0.89	0.35	-0.66	-0.40	-0.29	-0.07	-0.36	1.86	1.91	1.75	1.90	-5.09	3.11	3.58	2.56	-1.71	-0.06
Skewness	1.62	11.31	7.67	2.03	4.08	2.70	3.03	3.24	2.88	5.52	5.93	5.96	5.76	43.07	17.21	21.23	12.92	12.38	2.07
Kurtosis	2.37	0.44	0.18	0.18	3.19	-0.20	-0.23	-0.16	-0.29	0.49	0.25	0.10	0.41	0.02	0.24	0.23	0.25	0.00	0.02

Table 4.2. Correlation matrix

	FFR	M1growth	inflation	RIR	TDR	Skewness term spread	Skewness level	Skewness short-end	Skewness long-end	kurtosis term spread	Kurtosis level	Kurtosis short-end	kurtosis long-end	Variance term spread	Variance level	Variance short-end	Variance long-end	Industrial production growth	Term spread of yield curve
FFR	1.00																		
M1growth	-0.28	1.00																	
inflation	0.08	0.02	1.00																
RIR	0.95	-0.25	0.03	1.00															
TDR	0.06	-0.02	-0.09	0.16	1.00														
Skewness term spread	-0.71	0.31	-0.12	-0.59	0.04	1.00													
Skewness level	-0.77	0.31	-0.13	-0.67	-0.04	0.97	1.00												
Skewness short-end	-0.76	0.29	-0.11	-0.70	-0.12	0.86	0.96	1.00											
Skewness long-end	-0.76	0.31	-0.13	-0.65	-0.01	0.99	0.99	0.93	1.00										
kurtosis term spread	0.34	-0.31	0.15	0.23	-0.10	-0.80	-0.72	-0.59	-0.76	1.00									
Kurtosis level	0.43	-0.32	0.16	0.31	-0.11	-0.85	-0.79	-0.67	-0.82	0.99	1.00								
Kurtosis short-end	0.60	-0.35	0.14	0.49	-0.04	-0.91	-0.90	-0.83	-0.91	0.90	0.95	1.00							
kurtosis long-end	0.39	-0.32	0.16	0.28	-0.11	-0.83	-0.76	-0.63	-0.79	1.00	1.00	0.93	1.00						
Variance term spread	0.34	-0.18	0.09	0.32	0.33	-0.35	-0.49	-0.59	-0.43	-0.04	0.06	0.28	0.01	1.00					
Variance level	-0.04	0.17	-0.09	0.08	0.11	0.67	0.59	0.47	0.62	-0.62	-0.64	-0.63	-0.63	-0.38	1.00				
Variance short-end	-0.13	0.19	-0.09	-0.02	0.01	0.68	0.64	0.56	0.65	-0.53	-0.57	-0.62	-0.55	-0.58	0.97	1.00			
Variance long-end	0.06	0.13	-0.07	0.19	0.21	0.61	0.49	0.33	0.54	-0.68	-0.67	-0.59	-0.67	-0.13	0.97	0.88	1.00		
Industrial production growth	0.12	-0.10	0.01	0.18	0.29	-0.18	-0.21	-0.24	-0.19	0.13	0.12	0.14	0.12	0.18	-0.08	-0.12	-0.03	1.00	
Term spread of yield curve	-0.92	0.18	-0.06	-0.89	0.00	0.50	0.60	0.63	0.57	-0.13	-0.23	-0.41	-0.19	-0.27	-0.16	-0.07	-0.25	0.00	1.00

3.2. Empirical analysis of Vector Autoregressive models

3.2.1 Analytical forms of SVARs and VARs models

Our empirical analysis is comprised by a VAR framework. In details, we estimate several VAR and Structural VAR models in order to measure the impact of monetary policy stance on investors' expectations, following many relevant studies like Bekaert *et al.* (2013), Triantafyllou and Dotsis (2017), amongst others. Our baseline model is a structural bivariate VAR model similar with Triantafyllou and Dotsis (2017). The bivariate VAR model has the form $Y_t = [MP_t\ IM_t]$ (2), where MP_t is the corresponding measure of monetary policy stance (i.e. FFR or RIR) and IM_t is the corresponding component of the term structure of option-implied moments (i.e. the level of the option-implied skewness or the short-end component of option-implied kurtosis).

Additionally, we estimate multivariate SVAR and VAR models in order to provide robustness in our empirical results. Firstly, similarly with Bekaert *et al.* (2013), we estimate 4 variables SVAR model of the form $Y_t = [IPG_t\ MP_t\ IS_t\ IV_t]$[7] (3), and the form $Y_t = [IPG_t\ MP_t\ IK_t\ IV_t]$[8] (4), where IPG_t is the industrial production growth, MP_t is the monetary policy stance variable, IS_t(IK_t) is component of the term structure of option-implied skewness(kurtosis) (for example the level of implied skewness) and IV_t is the component of the term structure of option-implied variance. The industrial production growth is a business cycle indicator, and it is the most important control variable since it may affect simultaneously the monetary policy stance and the investors' expectations.

[7] Furthermore, we estimate the four variables SVAR model using a different ordering of the variables and different option-implied moments. For example, we use the same ordering as Triantafyllou and Dotsis (2017), or we replace the IS and IV with IK. we discuss the alternative ordering of the VAR specification in the robustness checks section.
[8] Furthermore, we estimate the four variables SVAR model using a different ordering of the variables and different option-implied moments. For example, we use the same ordering as Triantafyllou and Dotsis (2017), or we replace the IS and IV with IK. we discuss the alternative ordering of the VAR specification in the robustness checks section.

Notwithstanding the fact that Structural VAR analysis provide interesting empirical insights about the impact of monetary policy to option implied expectations, we additionally estimate a reduced-form VAR model without any specific restrictions, to ensure that the restrictions of the SVAR model do not influence the empirical results. Consequently, following Christiano *et al.* (1999) and Bekaert *et al.* (2013), we estimate a six variable monetary VAR model with the following ordering, first is the price level measure CPI, next is industrial production level (IPL), third is the fed fund rate, price level measure PPWe is placed forth, and the components of implied skewness (implied kurtosis) and implied variance are placed fifth and sixth respectively. The analytical form of the estimated six variable monetary VAR models, are the following: $Y_t = [CPI_t\ IPL_t\ FFR_t\ PPI_t\ IS_t\ IV_t]$ (5) and $Y_t = [CPI_t\ IPL_t\ FFR_t\ PPI_t\ IK_t\ IV_t]$ (6). In the estimated VAR specifications, the monetary policy variable is placed before the implied moments in order to capture the fact that asset markets are sensitive to monetary policy shocks, while the monetary authorities are neutral (or respond more sluggishly) to rising turbulence of the stock market. we estimate our SVAR models using short-run and long-run restrictions that we discuss in the next subsection. Since we use two and four variables in our SVAR models, we need to impose one and six restrictions respectively, for the exact identification of our models (we need N(N-1)/2 restrictions where N is the number of variables in each SVAR model).

3.2.2 Short-run and Long-run restrictions

Firstly, we estimate a SVAR model using short-run restrictions. Our short-run restrictions are that the market-based measures (option-implied moments) do not have a contemporaneous (short-run) effect on monetary policy and other macroeconomic variables. Our selected restrictions are based on the premise that macroeconomic variables (like industrial production growth) and monetary

policy have a sluggish response to changes in option-implied information. The SVAR models with the short run restriction are the following:

$$AY_t = \gamma + BY_{t-1} + \varepsilon_t \tag{7}$$

Where Y_t is the vector of variables (vectors described in equation 1 and 2), γ is the vector of constant terms and ε_t is the matrix with the independent structural shocks in our systems. Finally, A is a full rank matrix (2 x 2 or 4 x 4 depends on the model) which determines the endogeneity of the variables in each SVAR model and B is the short-run (feedback) response matrix in which we imply the contemporaneous restrictions, namely that option-implied moments do not have a short-run effect on monetary policy and macroeconomic variables. Consequently, the form of the feedback matrix based on the short-run restrictions is the following:

$$B = \begin{bmatrix} \beta_{11} & 0 & \cdots & 0 \\ \beta_{21} & & \ddots & \vdots \\ \vdots & & & 0 \\ \beta_{n1} & \beta_{n2} & \cdots & \beta_{n1} \end{bmatrix} \tag{8}$$

The long-run restrictions in our SVAR settings are based on the results of the relevant literature about the long-term money neutrality (Lucas, 1972; Barro, 1977; Bernarke and Mihov, 1998). More specifically, similarly with Triantafyllou and Dotsis (2017) and Bekaert *et al.* (2013), we restrict monetary policy to have zero long-run effect on real macroeconomic variables and option-implied moments. Following Blanchard and Quah (1989), the SVAR model with the long-run restrictions has the following long-run response matrix:

$$C = (I - A^{-1}B)^{-1}B^{-1} \quad (9)$$

Our results are based on structural-form Impulse Response Function (SIRFs thereafter) for which, we estimate the 90% bootstrapped confidence intervals based on 1000 replications. Finally, in our main analysis, we choose the optimal-length of our SVARs by following Akaike lag-length selection criterion (AIC).

3.3. SVAR analysis: The response of option implied moments to MP shocks

In this section we discuss the empirical results of the bivariate Structural VAR models, while the rest models are discussed in the robustness checks section. As we discussed in previous subsections, our main goal is to identify the response of investors' expectations to monetary policy stance, and more specifically, to find if the responses of the short-term and long-term investors' expectations to monetary policy, differ. Consequently, we focus our main analysis in the responsiveness of option-implied moments to monetary policy shocks and not the reverse response. we present the results about the response of monetary policy to shocks of option-implied moments, in the following subsection and we discuss the results. As we discussed in previous subsection, we use the term spread, the level, the short-end and long end components of each term structure of option-implied moments, to obtain information about the term structure of risk neutral densities.

we use four different measures of monetary policy stance, FFR, RIR, M1growth and TRD. Following the empirical approach of Triantafyllou and Dotsis (2017) in this section we use FFR

changes as measures of monetary policy shocks. In the robustness checks section, we present the results when we use the alternative measures of monetary policy stance and other subsamples (specifically samples before and after the recent financial crisis and the Zero-lower bound period).[9]

Firstly, we present **Table 3**, that shows the sign of the statistically significant Structural Impulse Response Functions (SIRFs) generated by a negative one standard deviation shock in FFR for each SVAR model as discussed in previous section. Additionally, **Table 3** includes the time period (the months) in which the estimated SIRFs are statistically significant in a 90% confidence interval.

Additionally, we report the graphs of the SIRFs that show the responses of the term spread, the level, the short-end and the long-end components of the term structure of option-implied moments, to a negative one standard deviation shock in FFR. Precisely**, Figure 5** demonstrate the SIRFs of the term spread and the level of the option-implied moments, while **Figure 6** plots the SIRFs of the short-end and long-end component of the option-implied moments.

Table 3. Structural-form Impulse Responses of the option-implied moments for bivariate SVARs

[9] we provide a subsample analysis in order to ensure that the different macroeconomic and monetary environment, and more specifically the Zero lower bound environment, does not affect the main results of our main analysis. In general, the main results and arguments are not affected by the subsample analysis.

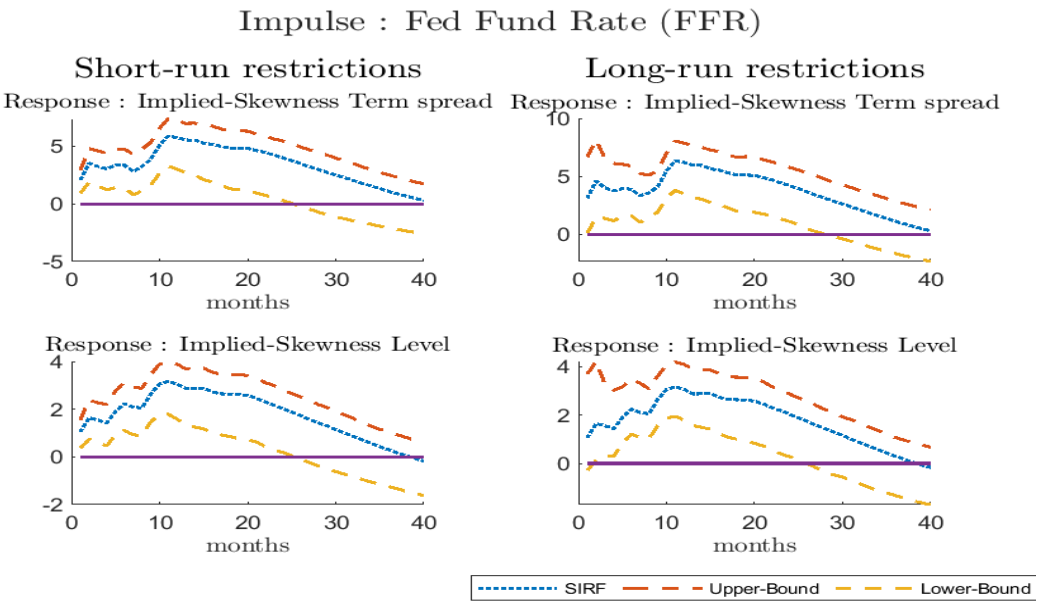
This table summarizes the results of the estimated bivariate SVAR models as we discussed in subsection 2.3. In details, Panel A (Panel B) present how many months the SIRFs that are generated by a negative (positive) one standard deviation shock in FFR (option-implied moment) are statistically significant in a 90% significance level. we estimate the bootstrapped standard errors of the computed SIRFS using 1000 replications. Additionally, we include the column sign, that indicates the sign of the statistically significant SIRFs.

The response of option-implied moments to a negative monetary policy shock			
Short-run restrictions		**Long-run restriction**	
n	**nificant from-to (month)**	**n**	**nificant from-to (month)**
Impulse: FFR, Response: Term spread of IS			
+	1-25	+	1-28
Impulse: FFR, Response: Level of IS			
+	1-25	+	1-25
Impulse: FFR, Response: Short-end of IS			
+	1-4,5-22	+	1-25
Impulse: FFR, Response: Long-end of IS			
+	1-26	+	1-26
Impulse: FFR, Response: Term spread of IK			
+	2-4	-	10-20
Impulse: FFR, Response: Level of IK			
-	8-15	-	7-20
Impulse: FFR, Response: Short-end of IK			
-	5,7-23	-	6-24
Impulse: FFR, Response: Long-end of IK			
+	2	-	9-21

Figure 5. SIRFs of the term spread and the level of implied skewness-kurtosis to negative FFR shocks (expansionary MP shocks), for the bivariate SVAR model

In this figure we plot the SIRFs of the term spread and the level of option-implied moments to a negative one standard deviation shock in FFR. In details, the left (right) column graphs include the estimated SIRFs from the SVAR models when we apply contemporaneous (long-run) restrictions. Additionally, the red and the yellow dotted lines are the upper and lower bounds of the 90% confidence interval respectively. Finally, panel A and B include the components of option-implied skewness and kurtosis respectively.

Panel A



Panel B

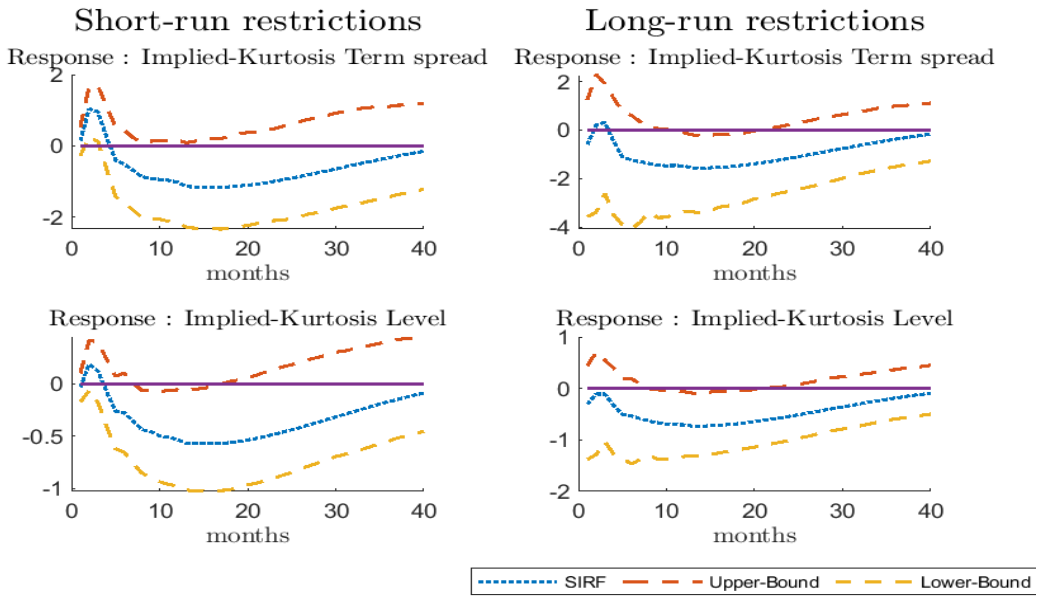
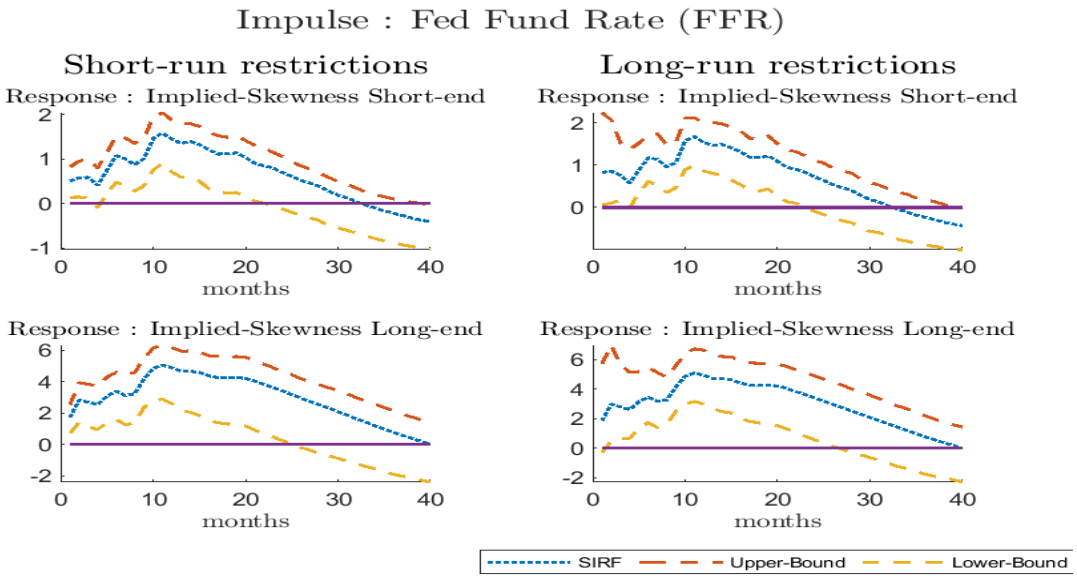


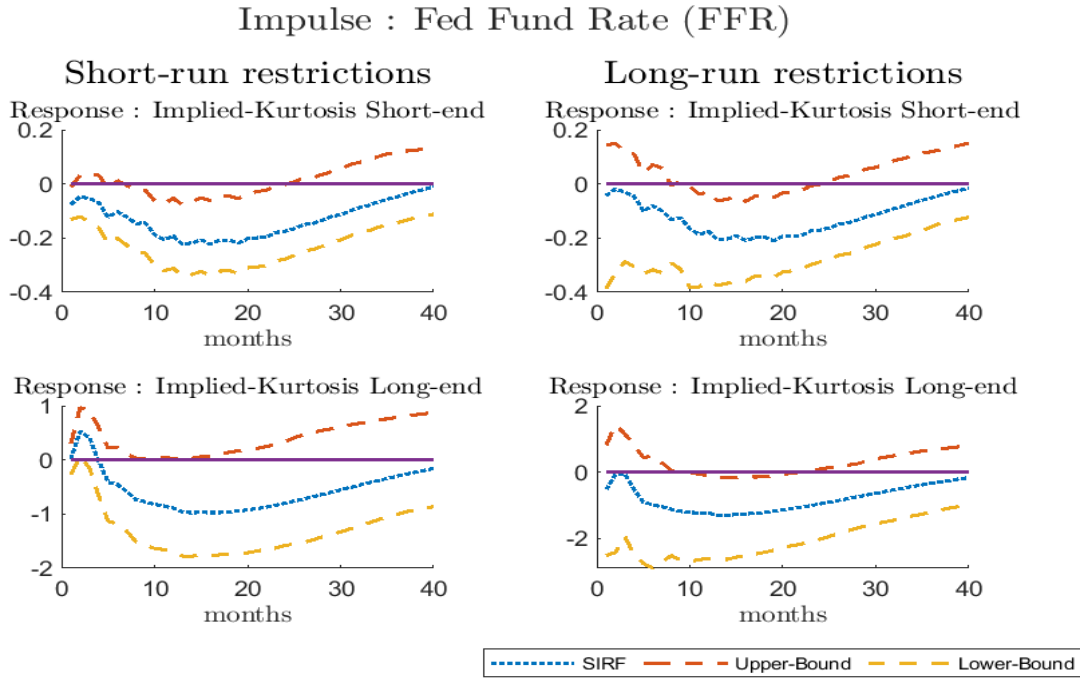
Figure 6. SIRFs of the short-end and the long-end implied skewness-kurtosis to negative FFR shocks (expansionary MP shocks), for the bivariate SVAR model

In this figure we plot the SIRFs of the short-end and the long-end components of option-implied moments to a negative one standard deviation shock in FFR. In details, the left (right) column graphs include the estimated SIRFs from the SVAR models when we apply contemporaneous (long-run) restrictions. Additionally, the red and the yellow dotted lines are the upper and lower bounds of the 90% confidence interval respectively. Finally, panel A and B include the components of option-implied skewness and kurtosis respectively.

Panel A



Panel B



We observe several interesting conclusions from the empirical results of the bivariate SVAR models. Initially, we notice that accommodative monetary policy (negative shock in FFR) results in an upward revision on investors' expectations about the subsequent stock market returns. Specifically, we find that the level of IS display an instant response (from the 1st month) to monetary policy shocks. The response is statistically significant for almost 2 years and reach its maximum value (2.5 basis points) after 11 months, for both models with short-run and long-run restrictions. This result is a first indication of the "Fed Put", since we find that accommodative monetary policy results in an upward revise of investors' expectations about the future state of the economy. Our results are in line with the results of several relevant studies which examine the existence of "Fed put" during periods of economic turbulence, as well as its impact to financial markets[10]. More importantly, Triantafyllou and Dotsis (2017) find similar results about the reaction of Implied skewness of agricultural commodities market to monetary policy shocks, and Stotz (2019) documents a higher option-implied expected returns of S&P 500 index after accommodative monetary policy shock[11].

Furthermore, we observe that an expansionary monetary policy shock has a statistically significant negative effect in the level of option-implied kurtosis, irrespective of the applied restrictions (short-run or long-run). When we apply contemporaneous restrictions, the impact of monetary policy on the level of IK is positive and statistically insignificant for the first 4 months after the initial shock and it turns to negative after the 5th month. Specifically, the level of IK decreases by maximum 0.56 basis points after 18 months, with the impact being significant between lags 7 and 18 lags. we find that implied kurtosis exhibits a slower response to monetary policy shocks

[10] For more details see Kurov et al (2016), Gu et al (2018), Cieslak and Vissing-Jorgensen (2020)
[11] Option-implied expected returns correspond to the mean of the risk neutral density, so it is correlated but not identical with the skewness of the risk neutral density.

compared to implied skewness. This result reveals that monetary policy actions influence investors' perception about the probability of an extreme event to occur, and more specifically, that accommodative monetary policy contributes to the reduction of the jump tail risk of the stock market. Hattori *et al.* (2017) conclude that unconventional monetary policy tools reduce the jump tail risk during the zero-lower bound period. Nevertheless, we are the first to show the long-term dynamic response of option-implied kurtosis to a negative monetary policy shock, using a SVAR analysis.

Furthermore, the responsiveness of the term spread of option-implied moments (IS and IK) to monetary policy shocks, is a first indication that monetary policy actions have a distinct impact on short-term and long-term components of option-implied moments. The Table 1 provides interesting results about the impact of monetary policy shocks on the term spread of IS. In details, we find that an expansionary shock in monetary policy, has an immediate positive statistical impact on the term spread of IS that lasts for almost 24 months, regardless of the chosen applied restrictions in our model. Uncomplicated, this result suggests that a negative one standard deviation shock in FFR, increases the difference between the IS of 1-year maturity and 30-days maturity, option contracts. Therefore, this result is an indication that the long-term investors' expectations about the future returns of the stock market (proxied by IS of 1-year maturity) are more upwardly revised than the short-term investors' expectations, when an expansionary monetary policy shock occurs.

When we estimate the responsiveness of the term spread of implied kurtosis to monetary policy shocks, the results are related to the applied restrictions of the SVAR model. When we apply short-

run/long-run restrictions in the bivariate SVAR model, the statistically significant impact of lax monetary policy shock on the term spread of IK, is positive/negative between lags 2-4/8-20[12].

In addition, **Figure 6** provides novel and detailed results about the asymmetric response of long-term and short-term components of option-implied moments to monetary policy shocks. Specifically, we observe that a negative monetary policy shock has a stronger (in magnitude) and more long-lasting impact to long-term IS compared to short-term IS. When we apply short-run restrictions in our SVAR model, one standard deviation accommodative monetary policy shock causes a 0.016/0.044 change in short-end/long-end IS after 11 months. Moreover, the impact of lax monetary policy shock on short-end and long-end IS remain statistically significant from months 1 to 22 (except 5th month) and from months 1 to 26 respectively. The results are likewise when long-run restrictions are applied to the SVAR model. The results about the asymmetric impact of monetary policy on short-run and long-run IK are puzzling. When we apply short-run restrictions in the bivariate model, we find a more long-lasting statistically significant response of short-end IK to monetary policy shocks in comparison to the long-term kurtosis. The response of long-term IK to an accommodative monetary policy shock is positive and statistically significant in the first 2 months, and in the following months it turns to negative and statistically insignificant. Notwithstanding, the results are altered when we apply long-term restrictions in our SVAR model. we observe that the responses of short-term and long-term IK to a negative monetary policy shock, are statistically significant for almost the same period, but the impact of monetary policy shock on long-term IK is almost 6 times stronger. In details, the impact of accommodative monetary policy

[12] In the robustness checks section, we find that multivariate SVAR model exhibit results more "persistent" about the impact of monetary policy on components of IK. we find negative statistically significant responses of the term spread of IK to expansionary monetary policy for both short-run and long-run SVAR models.

shock on Short-end/long-end IK, remains statistically significant from 6-24/9-21 months and the maximum values of the impact is 2/12 basis points after 15/17 months.

The main conclusion that emerges from Figure 6 is that the long-term components of the term structure of option-implied moments are more responsive to monetary policy shocks than the short-end components. While the theory of monetary economics assume that real macroeconomic variables are immune to monetary policy actions in the long term, we find that investors' expectations about the long-term horizon exhibit a statistically significant response to monetary policy shocks. Our empirical results provide a new perspective about the importance of monetary policy actions, since we find that policy makers can affect long-term investors' expectations.

3.4. SVAR analysis: The response of future monetary policy to option-implied expectations shocks

While it is not our target to empirically verify how monetary policy react to option-implied expectations, we provide results about the responsiveness of monetary policy to investors' expectations and fears about the future state of the economy. We present similar tables and figures with the previous subsection 3.3 , in order to show the impact of option-implied moments on monetary policy. In details, similarly with **Table 3, Table 4** shows the sign of the statistically significant Structural Impulse Response Functions (SIRFs) generated by a negative(positive) one standard deviation shock in components of IS (IK) for each SVAR model as discussed in previous section. Furthermore, it includes the time period (the months) in which the estimated SIRFs are statistically significant in a 90% confidence interval. Furthermore, we include **figures 7** and **8** that demonstrate the SIRFs that correspond to the impact of the term spread and the level of the option-

implied moments on monetary policy and the impact of the short-end and long-end components of the option implied moments on monetary policy respectively.

Table 4. Structural-form Impulse Responses of the Fed fund rate for bivariate SVARs

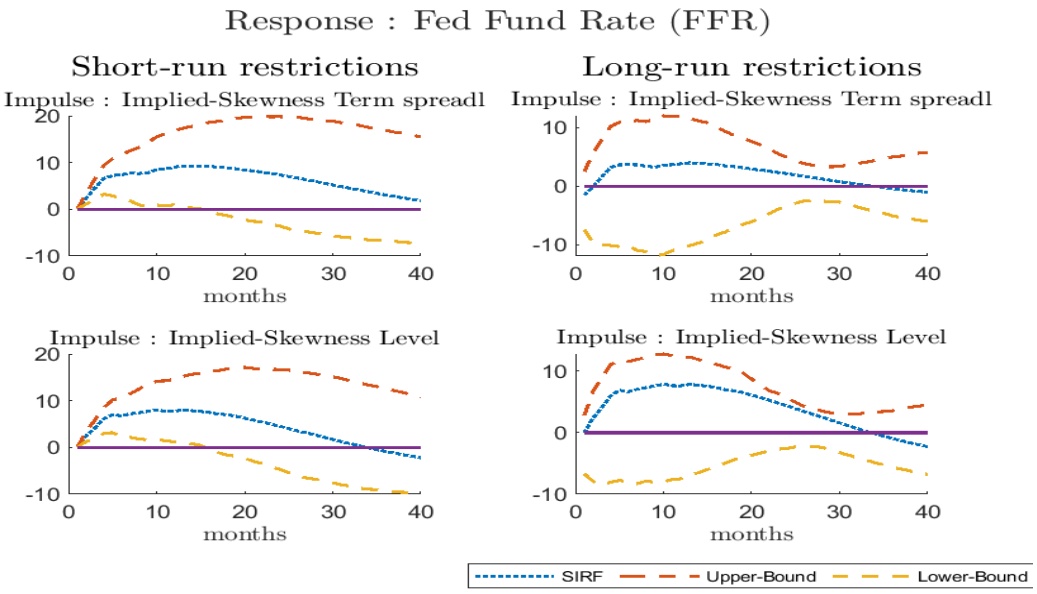
This table summarizes the results of the estimated bivariate SVAR models as we discussed in subsection 2.3. In details, the table present how many months the SIRFs that are generated by a negative (positive) one standard deviation shock in option-implied Skewness (kurtosis) are statistically significant in a 90% significance level. we estimate the bootstrapped standard errors of the computed SIRFS using 1000 replications. Additionally, we include the column sign, that indicates the sign of the statistically significant SIRFs.

The response of Fed Fund Rate to a negative/positive shock in IS/IK			
Short-run restrictions		**Long-run restriction**	
Sign	**Significant from-to (month)**	**Sign**	**Significant from-to (month)**
Impulse: Term spread of IS, Response: FFR			
-	1-15	\	\
Impulse: Level of IS, Response: FFR			
-	1-15	\	\
Impulse: Short-end of IS, Response: FFR			
-	1-18	\	\
Impulse: Long-end of IS, Response: FFR			
-	1-14	\	\
Impulse: Term spread of IK, Response: FFR			
+	1-20	\	\
Impulse: Level of IK, Response: FFR			
+	1-21	\	\
Impulse: Short-end of IK, Response: FFR			
+	1-16	\	\
Impulse: Long-end of IS, Response: FFR			
+	1-20	\	\

Figure 7. SIRFs of the FFR to a negative/positive shock of the term spread and the level of implied skewness/kurtosis, for the bivariate SVAR model

In this figure we plot the SIRFs of the FFR to a one standard deviation shock in the term spread and the level of option-implied moments. In details, the left (right) column graphs include the estimated SIRFs from the SVAR models when we apply contemporaneous (long-run) restrictions. Additionally, the red and the yellow dotted lines are the upper and lower bounds of the 90% confidence interval respectively. Finally, panel A and B include the components of option-implied skewness and kurtosis respectively.

Panel A



Panel B

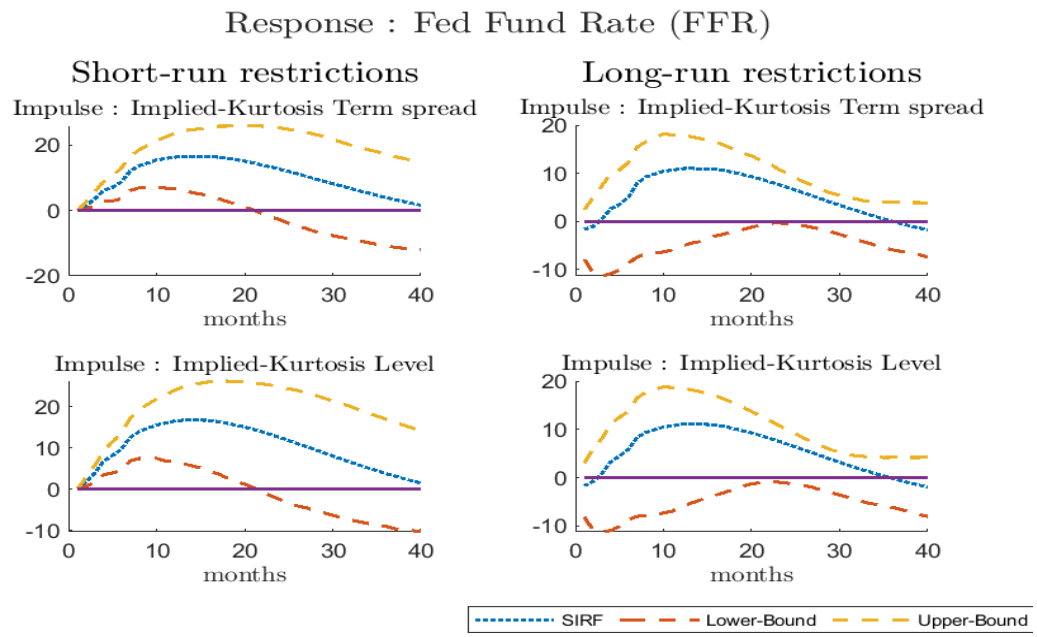
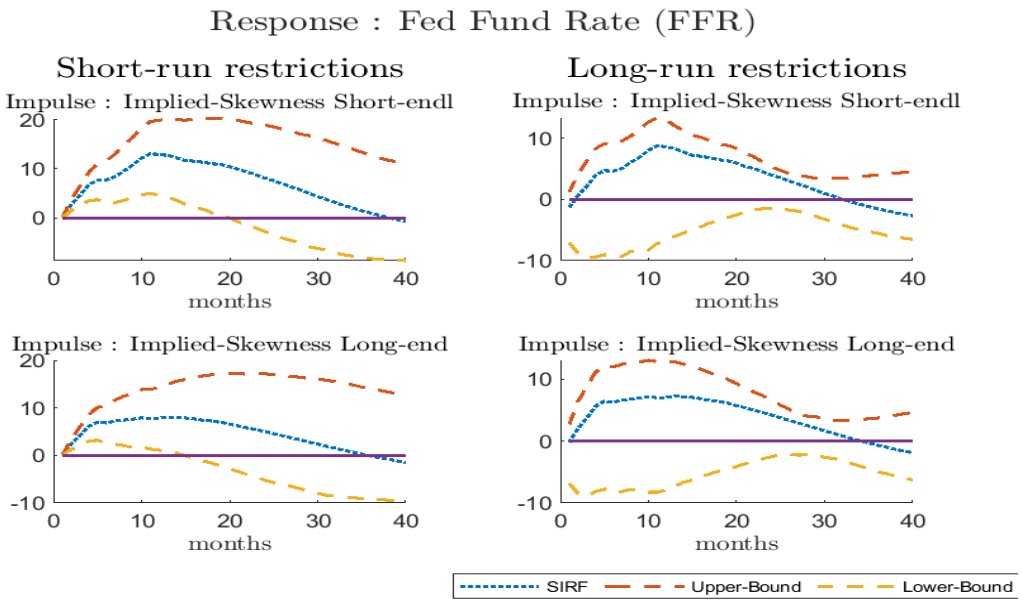


Figure 8. SIRFs of the FFR to a negative/positive shock of the short-end and the long-end of implied skewness/kurtosis, for the bivariate SVAR model

In this figure we plot the SIRFs of the FFR to a one standard deviation shock in the short-end and the long-end components of the option-implied moments. In details, the left (right) column graphs include the estimated SIRFs from the SVAR models when we apply contemporaneous (long-run) restrictions. Additionally, the red and the yellow dotted lines are the upper and lower bounds of the 90% confidence interval respectively. Finally, panel A and B include the components of option-implied skewness and kurtosis respectively.

Panel A



Panel B

Firstly, we observe that the SVAR model with the long-run restrictions does not provide statistically significant SIRFs of the monetary policy stance. Triantafyllou and Dotsis (2017) find similar results about the response of FFR to shocks derived from implied moments of the agricultural commodities market. Notwithstanding the non-statistically significant results of the model with the applied long-run restrictions, the estimated SVAR model with the short-run restrictions applied provide interesting results. Specifically, we find that a negative shock in IS (an indication that investors expect bearish stock market) results an immediate and statistically significant increase to FFR for up to 15 months ahead from the initial shock. Similarly, we document that a positive shock in IK (an indication that investors predict a higher possibility of an extreme event to occur) cause an immediate increase to FFR and we observe that this impact remains statistically significant till 20 months after the initial shock. These results are puzzling since they indicate that when investors expect a subsequent poor performance of the stock market, monetary policy tends to be contractionary. In order to explain our results, we follow the argument of the David and Veronesi (2014). In their paper, they find similar results about the impact of option-implied expectations on subsequent short-term interest rates (a measure of monetary policy). Specifically, they find that a positive shock in a measure of downside-risk (put-to-call ratio) results a statistically significant increase on future short-term interest rates for a long period after the initial shock. They provide a dynamic equilibrium model in order to explain this phenomenon, and they conclude that beliefs and expectations about economy drive both option prices and monetary policy stance through the forward-looking Taylor rule. In simple words, they claim that expectations about the future state of the economy drives both option prices and the conducted monetary policy, and consequently option prices lead monetary policy.

Finally, when it comes to the response of monetary policy to shocks in the short-end and long-end components of option-implied moments, we find similar results about the impact of short-end and long-end implied moments on FFR.

We discuss the empirical evidence of this subsection about the impact of implied-moments on monetary policy, in the following subsection in which we estimate a predicting regression model similar with Triantafyllou and Dotsis 2017. Our purpose is to ensure that the argument of David and Veronesi (2014) about the predictability of option-implied moments on subsequent monetary policy is robust and it is can explain the empirical results of this subsection. Additionally, we discuss more about the relevant results in the robustness checks section and in the appendix.

4. Predicting Subsequent monetary policy rate using option implied moments

As we mention in the previous subsection, we attempt to verify the claim of Veronesi and David (2014), by using a predicting regression analysis. we estimate a predicting regression model in which we predict the future monetary policy path using implied moments. we follow this empirical approach motivated by the seminal paper of David and Veronesi (2014). The predicting regression model is similar with Triantafyllou and Dotsis (2017) and has the following equation:

$$FFR_t = a + b_1 IV_{t-k} + b_1 IS_{t-k} + u_t \quad (10)$$

Where FFR is the Fed Fund rate at month t, IV_{t-k} is the component of the term structure of implied variance (for example the level of IV), the IS_{t-k} is the component of the implied skewness and finally k corresponds to the predicting horizon. In order to provide robustness in our empirical

results, we run a multivariate predicting regression model that we use macroeconomic indicators as control variables. Specifically, the multivariate model has the following form:

$$FFR_t = a + b_1 TS_{t-k} + b_1 IPG_{t-k} + b_1 INF_{t-k} + b_1 IV_{t-k} + b_1 IS_{t-k} + u_t \quad (11)$$

Where TS is the term spread of the yield curve, IPG is the industrial production growth and INF is the monthly inflation rate.

In the end, we estimate similar regression models with equations (10) and (11) but instead of the components of the IS we include the components of IK. The predicting models that include the implied kurtosis are described by the following equations:

$$FFR_t = a + b_1 IV_{t-k} + b_1 IK_{t-k} + u_t \quad (12)$$

$$FFR_t = a + b_1 TS_{t-k} + b_1 IPG_{t-k} + b_1 INF_{t-k} + b_1 IV_{t-k} + b_1 IK_{t-k} + u_t \quad (13)$$

In this section, we empirically verify that ex-ante investors' expectations can predict the subsequent level of the monetary policy rate, following the argument of David and Veronesi (2014) and Triantafyllou and Dotsis (2017). The following **Tables 5** and **6** includes the results of the estimated regression model of the equation (10), and equation (11), respectively.

Table 5. Predicting the monetary policy (Fed funds rate) with the level of implied variance and implied skewness

This table shows the predicting regressions on monthly monetary policy stance (Fed funds rate), using as explanatory variables lagged values of the level of implied variance and implied skewness. Our predicting horizon ranges from 1 to 24 months. IV is option-implied variance, IS option-implied skewness. The t-statistics reported in the relevant lines are corrected for autocorrelation and heteroscedasticity using the Newey-West (1987) estimator. we forecast the future monetary policy stance k months ahead (k = 1, 3, 6, 12, 24).

Horizon (k)		***k=1***	***k=3***	***k=6***	***k=12***	***k=24***
Const	Coef.	-2.453***	-2.407***	-2.288***	-1.596*	0.291
	t-stat	(-4.35)	(-3.81)	(-3.36)	(-1.81)	(0.19)
Level of IV	Coef.	7.596***	7.282***	6.871***	5.389**	2.068
	t-stat	(4.08)	(3.55)	(3.23)	(2.24)	(0.64)
Level of IS	Coef.	-13.19***	-13.25***	-13.01***	-11.28***	-5.862
	t-stat	(-14.40)	(-11.53)	(-9.24)	(-5.20)	(-1.52)
% R^2		70.9	72.9	72.1	57.6	18.7

Table 6. Predicting the monetary policy (Fed funds rate) with the level of implied variance, implied skewness and other macroeconomic factors.

This table shows the predicting regressions on monthly monetary policy stance (Fed funds rate), using as explanatory variables lagged values of the level of implied variance and implied skewness, the term spread of US yield curve, the industrial production growth of US and the monthly inflation rate. Our predicting horizon ranges from 1 to 24 months. The t-statistics reported in the relevant lines are corrected for autocorrelation and heteroscedasticity using the Newey-West (1987) estimator. we predict the future monetary policy stance k months ahead (k = 1, 3, 6, 12, 24).

Horizon (k)		***k=1***	***k=3***	***k=6***	***k=12***	***k=24***
Const	Coef.	-0.824	-1.063	-1.437	-1.877	-0.651
	t-stat	(-1.00)	(-1.15)	(-1.42)	(-1.58)	(-0.38)
Term spread	Coef.	-51.81***	-44.85**	-31.18	-0.0679	18.87
	t-stat	(-3.16)	(-2.43)	(-1.47)	(-0.00)	(0.37)
IPG	Coef.	32.02**	40.10***	48.62***	55.87***	54.08*
	t-stat	(2.23)	(3.33)	(3.82)	(2.88)	(1.80)
INF	Coef.	0.672**	0.696***	0.592***	0.396	0.216
	t-stat	(2.47)	(3.00)	(2.83)	(1.41)	(0.87)
Level of IV	Coef.	6.839***	6.791***	6.759***	6.106***	3.218
	t-stat	(4.71)	(4.15)	(3.72)	(2.89)	(1.15)
Level of IS	Coef.	-9.894***	-10.36***	-10.93***	-11.11***	-6.866*
	t-stat	(-7.28)	(-6.80)	(-6.30)	(-4.82)	(-1.82)
% R^2		74.9	76.8	75.4	60.7	22.1

The estimated results show that the IS (more specifically the level of the implied skewness) is a robust predictor of subsequent FFR. In details the predicting model that includes the level of IV and IS as predictors of future FFR explains the larger fraction of the variability of the subsequent FFR, since the estimated R^2 values are 70.2, 72.9, 72.1, 57.6 for a 1,3,6 and 12 months forecasting horizon respectively. The estimated coefficients of the level of IS are statistically significant in a 1% significance level for forecasting horizons ranging from 1 up to 12 months. Finally, we observe that even when we include macroeconomic control variables in our predicting model, the level of IS remain a highly statistically significant predictor of subsequent FFR.

Furthermore, **Table 7** and **8** include the results of the estimated regression models of the equation (12) and (13) respectively.

Table 7. Predicting the monetary policy (Fed funds rate) with the level of implied variance and implied kurtosis

This table shows the predicting regressions on monthly monetary policy stance (Fed funds rate), using as explanatory variables lagged values of the level of implied variance and implied kurtosis. Our predicting horizon ranges from 1 to 24 months. IV is option-implied variance and IK is option-implied kurtosis. The t-statistics reported in the relevant lines are corrected for autocorrelation and heteroscedasticity using the Newey-West (1987) estimator. we forecast the future monetary policy stance k months ahead (k = 1, 3, 6, 12, 24).

Horizon (k)		***k=1***	***k=3***	***k=6***	***k=12***	***k=24***
Const	Coef.	-2.697***	-2.698***	-2.581**	-1.650	0.823
	t-stat	(-3.40)	(-2.85)	(-2.50)	(-1.34)	(0.42)
Level of IV	Coef.	1.018	0.711	0.432	-0.244	-1.063
	t-stat	(0.59)	(0.35)	(0.20)	(-0.11)	(-0.53)
Level of IK	Coef.	19.46***	19.68***	19.33***	15.95***	6.177
	t-stat	(9.17)	(7.46)	(6.35)	(3.79)	(0.92)
% R^2		37.8	39.7	39.5	29.4	6.7

Table 8. Predicting the monetary policy (Fed funds rate) with the level of implied variance, implied kurtosis and other macroeconomic factors

This table shows the predicting regressions on monthly monetary policy stance (Fed funds rate), using as explanatory variables lagged values of the level of implied variance and implied kurtosis, the term spread of US yield curve, the industrial production growth of US and the monthly inflation rate. Our predicting horizon ranges from 1 to 24 months. The t-statistics reported in the relevant lines are corrected for autocorrelation and heteroscedasticity using the Newey-West (1987) estimator. we predict the future monetary policy stance k months ahead (k = 1, 3, 6, 12, 24).

Horizon (k)		***k=1***	***k=3***	***k=6***	***k=12***	***k=24***
Const	Coef.	1.236	1.103	1.012	1.168	2.241
	t-stat	(1.54)	(1.09)	(0.83)	(0.68)	(1.05)
Term spread	Coef.	-121.5***	-118.2***	-111.2***	-87.66**	-46.21
	t-stat	(-9.53)	(-7.02)	(-4.99)	(-2.43)	(-0.96)
IPG	Coef.	50.90***	59.60***	67.84***	75.13***	65.82**
	t-stat	(2.84)	(3.72)	(3.99)	(3.16)	(2.00)
INF	Coef.	0.651***	0.676***	0.579**	0.354	0.182
	t-stat	(2.61)	(3.15)	(2.50)	(1.02)	(0.52)
Level of IV	Coef.	2.467***	2.206**	1.878	1.019	-0.173
	t-stat	(2.65)	(2.07)	(1.58)	(0.67)	(-0.09)
Level of IK	Coef.	9.589***	10.06***	10.21***	8.729	2.347
	t-stat	(4.28)	(3.47)	(2.84)	(1.64)	(0.34)
% R^2		67	68.2	65.8	48.3	15

Our results show that the level of IK is a strong predictor of future FFR. The estimated coefficient of the level of IK are statistically significant in a 1% significance level for almost all the estimated predicting horizons, and the estimated R^2 values are 37.8, 39.7, 39.5, 29.4 for a 1,3,6 and 12 months forecasting horizon respectively. Furthermore, we find that the results remain unaltered in the inclusion of other macroeconomic control variables.

The estimated results of the predicting regression models are in line with the empirical results of the David and Veronesi (2014) and Triantafyllou and Dotsis (2017). In details, similarly with the estimated results of the SVAR model, we find that the level of the implied skewness/implied kurtosis predicts negatively/positively the subsequent FFR. In simple words this result means that when investors expect bearish stock market or they estimate a higher probability of extreme event to occur, policy makers conduct contractionary monetary policy.

Our results confirm the claim of David and Veronesi (2014) who emphasize that option prices embody a rich information content about the subsequent FFR.

5. Robustness checks

In this section we present further empirical evidence to provide robustness in our analysis. Firstly, we estimate identical SVAR models using alternative measures of monetary policy stance. Secondly, we conduct our analysis in different subsamples, in order to ensure that our empirical results are immune to changes in financial, macroeconomic or monetary conditions (like the zero lower bound period). Thirdly, we estimate a 4-variable SVAR and a 6-variable monetary VAR model, as we discussed in the subsection 3.2. In this section, we provide the results that derived from the robustness checks, which are related with the impact of monetary policy shocks on implied moments, while estimated results about the response of monetary policy to shocks of the implied moments, are included in the appendix.

5.1. Alternative measures of monetary policy stance

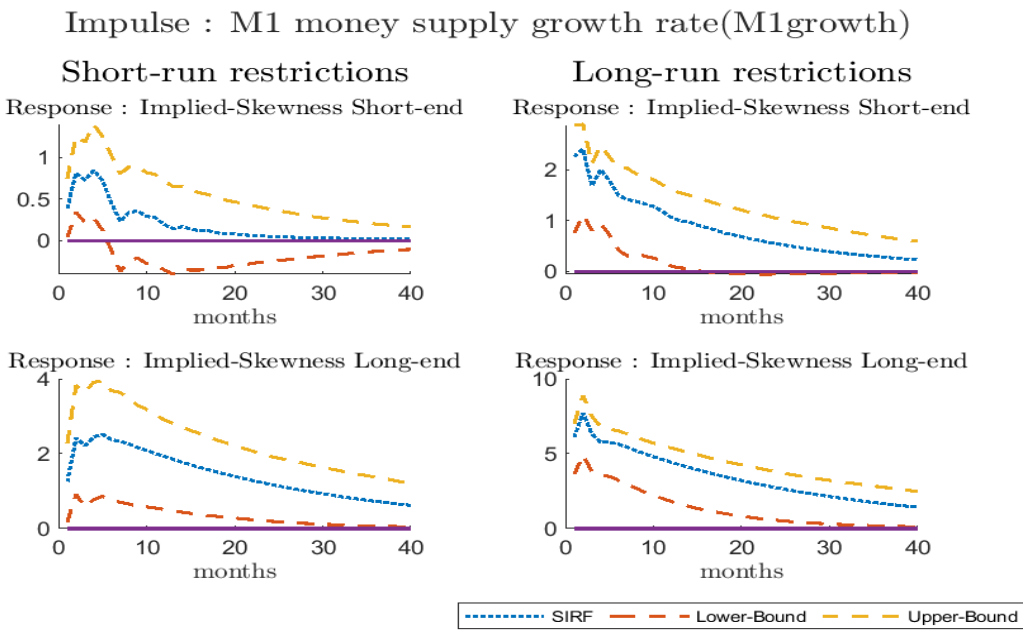
We estimate the same bivariate and multivariate SVAR and VAR models using different measures of monetary policy stance. For brevity, in this section we present only the figures that include the SIRFs of the short end and long end IS and IK to an expansionary one standard deviation monetary policy shock[13], while we include the rest results in the appendix. In details, **Figures 9** to **11** plot the responses of the components of IS and IK to an expansionary one standard deviation shock in M1 growth rate, Taylor rule rate, and real interest rate respectively.

[13] we use the term "expansionary", instead of the term "negative", for the monetary policy shock, because, in contrast with FFR, RIR or taylor rule rate, a negative shock in M1 growth rate is a contractionary monetary policy shock. Therefore, we estimate the responses of implied moments to a negative one standard deviation shock in FFR, RIR and taylor rule rate, and to a positive one standard deviation shock in M1 growth rate.

Figure 9 SIRFs of the short-end and the long-end implied skewness-kurtosis to positive M1growth shocks (expansionary MP shocks), for the bivariate SVAR model

In this figure we plot the SIRFs of the short-end and the long-end components of option-implied moments to a positive one standard deviation shock in M1 growth rate. In details, the left (right) column graphs include the estimated SIRFs from the SVAR models when we apply contemporaneous (long-run) restrictions. Additionally, the red and the yellow dotted lines are the upper and lower bounds of the 90% confidence interval respectively. Finally, panel A and B include the components of option-implied skewness and kurtosis respectively.

Panel A



Panel B

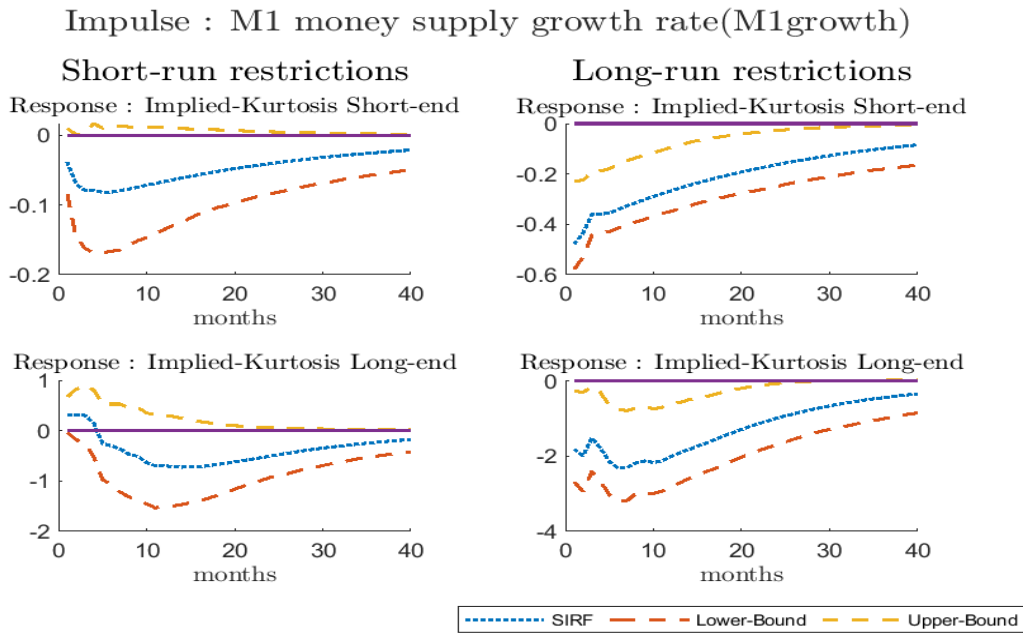
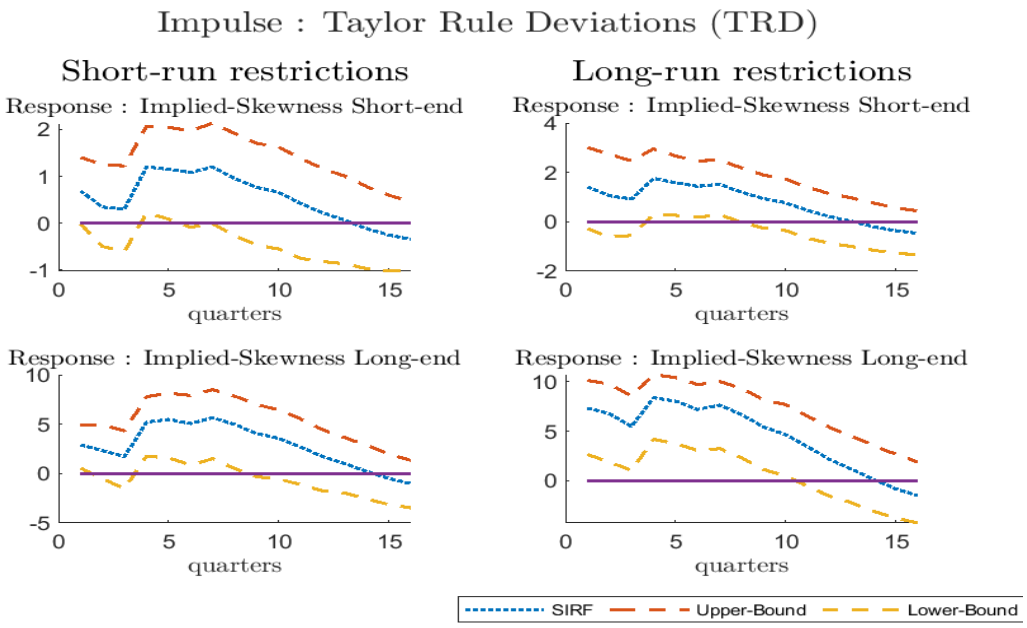


Figure 10. SIRFs of the short-end and the long-end implied skewness-kurtosis to negative TRD shocks (expansionary MP shocks), for the bivariate SVAR model

In this figure we plot the SIRFs of the short-end and the long-end components of option-implied moments to a negative one standard deviation shock in Taylor rule rate. In details, the left (right) column graphs include the estimated SIRFs from the SVAR models when we apply contemporaneous (long-run) restrictions. Additionally, the red and the yellow dotted lines are the upper and lower bounds of the 90% confidence interval respectively. Finally, panel A and B include the components of option-implied skewness and kurtosis respectively.

Panel A



Panel B

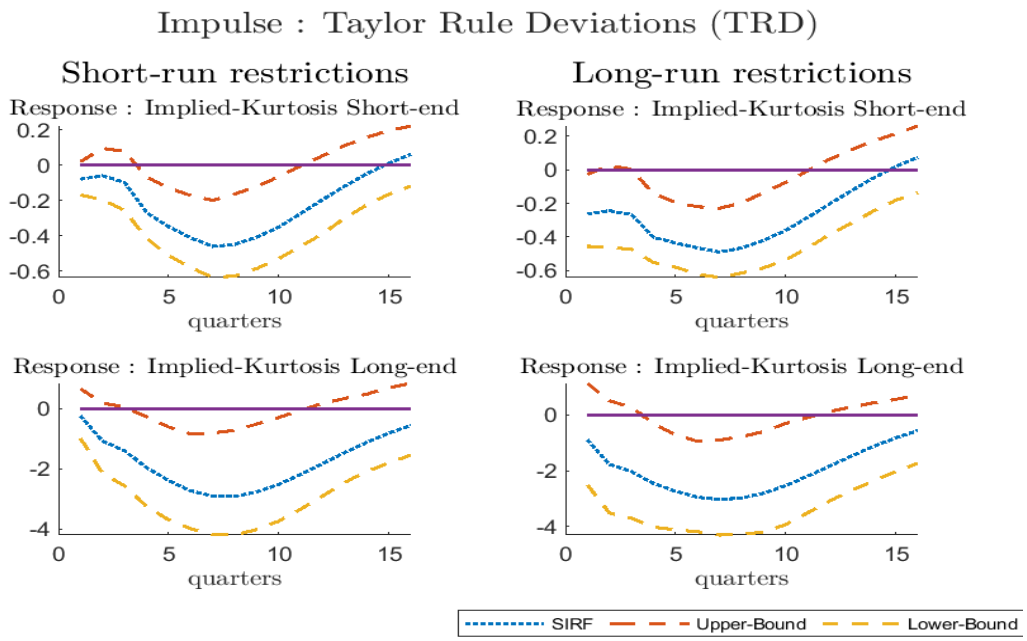
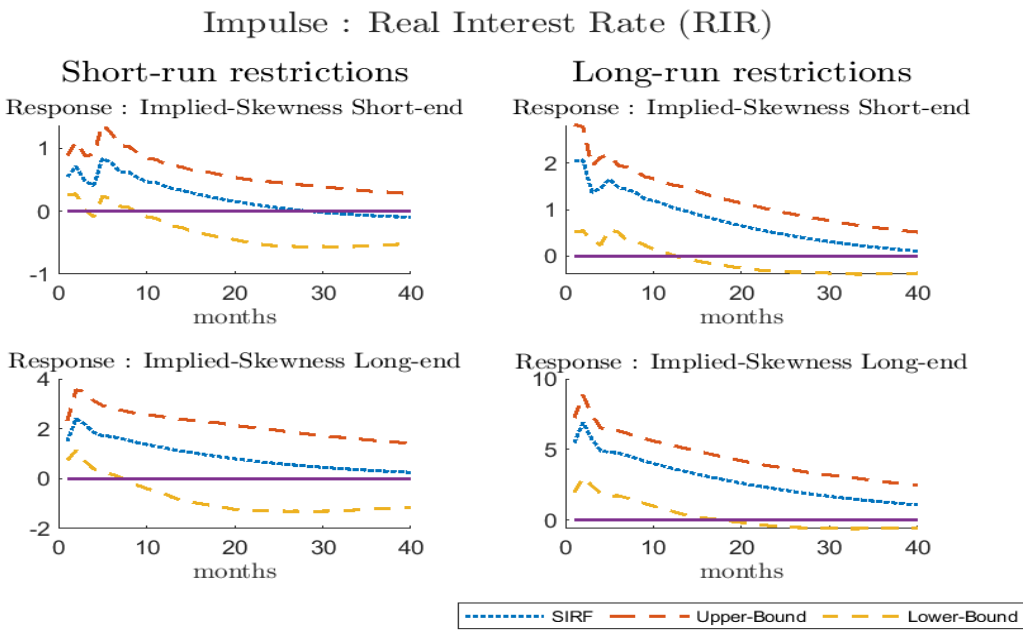


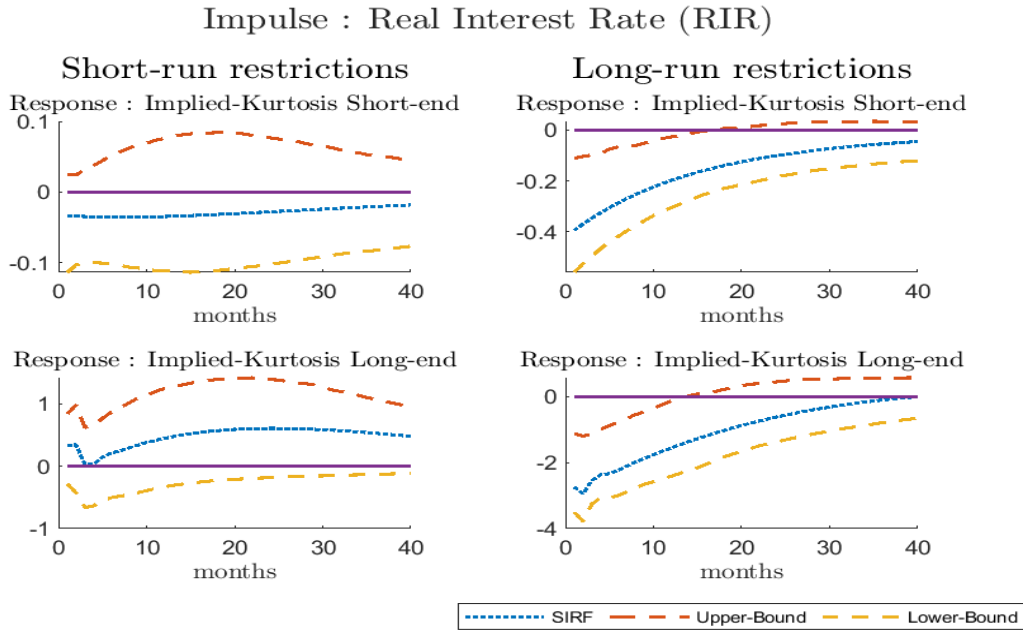
Figure 11. SIRFs of the short-end and the long-end implied skewness-kurtosis to negative RIR shocks (expansionary MP shocks), for the bivariate SVAR model

In this figure we plot the SIRFs of the short-end and the long-end components of option-implied moments to a negative one standard deviation shock in RIR. In details, the left (right) column graphs include the estimated SIRFs from the SVAR models when we apply contemporaneous (long-run) restrictions. Additionally, the red and the yellow dotted lines are the upper and lower bounds of the 90% confidence interval respectively. Finally, panel A and B include the components of option-implied skewness and kurtosis respectively.

Panel A



Panel B



Interestingly when we use the M1 growth rate as a proxy of monetary policy stance (**Figure 9**), we obtain remarkable evidence about the distinct response of the long-end and short-end components of IS to monetary policy shocks. More specifically, when we apply contemporaneous restrictions in our SVAR model, we notice that an expansionary shock in M1 growth rate causes an almost 3 times greater change in long-term IS than short-term IS after 5 months. Additionally, the estimated SIRFs of long-end IS remain statistically significant for up to 40 months after the initial shock, while the SIRFs of short-end IS remain statistically significant for up to 6 months. The empirical results are similar when long-run restrictions are applied to our SVAR model. In general, our empirical results remain unaltered irrespectively of the selected measure of monetary policy stance. Namely, we find that an expansionary monetary policy shock (decrease of FFR, RIR, TRD and increase in M1growth) results an increase in IS, decrease in IK, and additionally, the long-end components of the term structure of option-implied moments are more responsive to monetary policy shocks.

5.3. Subsample analysis

We split our sample in two subsamples, one that corresponds to the period before the recent financial crisis of 2007 (pre-crisis period), and one that covers the period afterwards (post-crisis period). Our purpose is to ensure that the response of the investors' expectations to monetary policy shocks remains statistically significant across the varying macroeconomic and monetary conditions. Specifically, during the period after the recent financial crisis of 2007, the Fed fund rate (the most common monetary policy tool during conventional periods) hits the zero-lower bound for almost 6 years, in which policy makers used unconventional monetary policy tools (like forward guidance and large asset purchases). Therefore, we estimate identical SVAR models in

both subsamples to ensure that our results are not driven by specific macroeconomic and monetary regimes.

Generally, we find that the main conclusions that emerge from the estimated SVAR models using all the available sample, are not distinct when we choose other subsample. In details, during the pre-crisis period we find a stronger in magnitude and a more long-lasting impact of monetary policy shocks on investors' expectations, even though monetary policy shocks increase/decrease the components of IS/IK, during both periods. The empirical results of the subsample analysis can be found in the appendix.

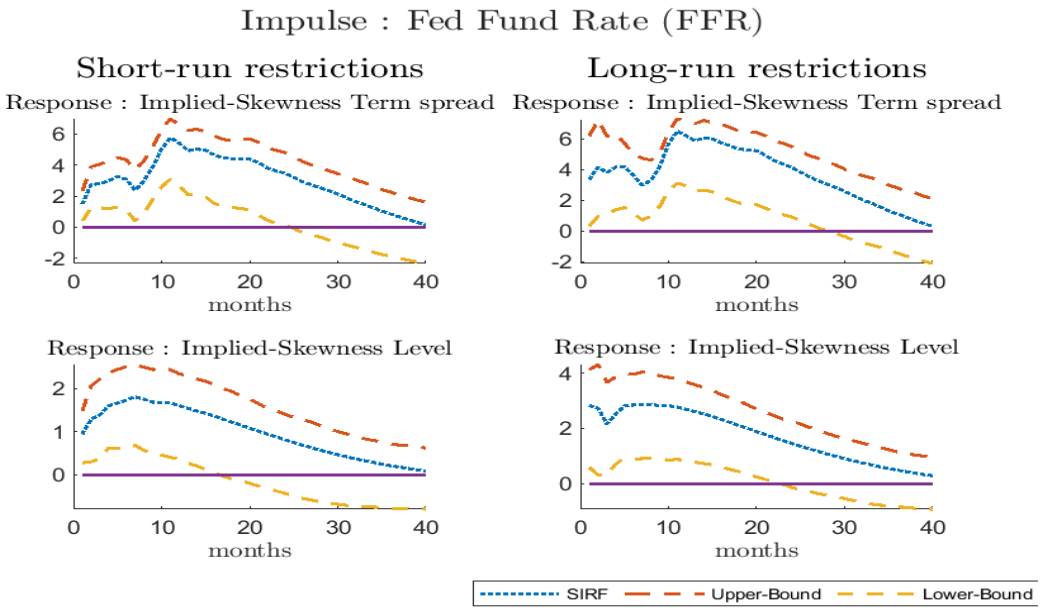
5.2. Multivariate analysis

We test whether our empirical results remain robust in the inclusion of other macroeconomic variables. In details, we estimate a 4-variable SVAR and a 6-variable VAR model as we discussed in previous subsection 3.3. Initially we estimate a 4-variable SVAR model as we described in equations (3) and (4). The **figure 12** presents the results of the estimated SIRFs of the components of the IS to an accommodative monetary policy shock when we run the model in equation (3). Similarly, the **figure 13** shows the corresponding results for the components of IK when we run the model in equation (4).

Figure 12. SIRFs of the components of the term structure of implied skewness to negative FFR shocks (expansionary MP shocks), for the multivariate SVAR model

In this figure we plot the SIRFs of the components of IS to a negative one standard deviation shock in FFR when we estimate the multivariate SVAR model (equation (3)). In details, the left (right) column graphs include the estimated SIRFs from the SVAR models when we apply contemporaneous (long-run) restrictions. Additionally, the red and the yellow dotted lines are the upper and lower bounds of the 90% confidence interval respectively. Finally, panel A includes the responses of the term spread and the level of IS to monetary policy shocks, while the panel B show the SIRFs of the short-end and long-end component of IS to a negative one standard deviation shock in FFR

Panel A



Panel B

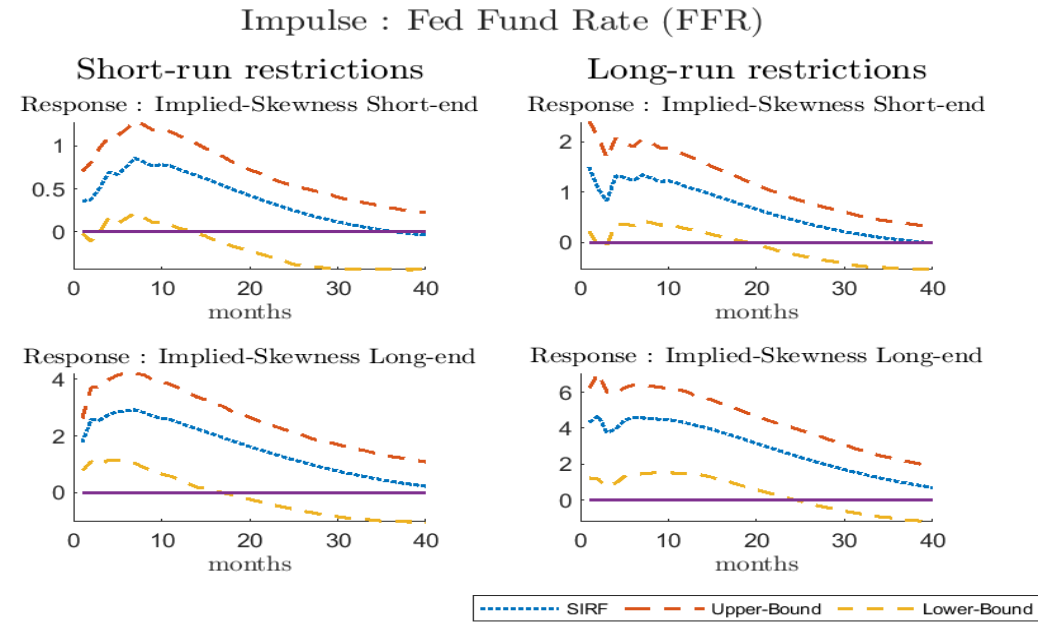
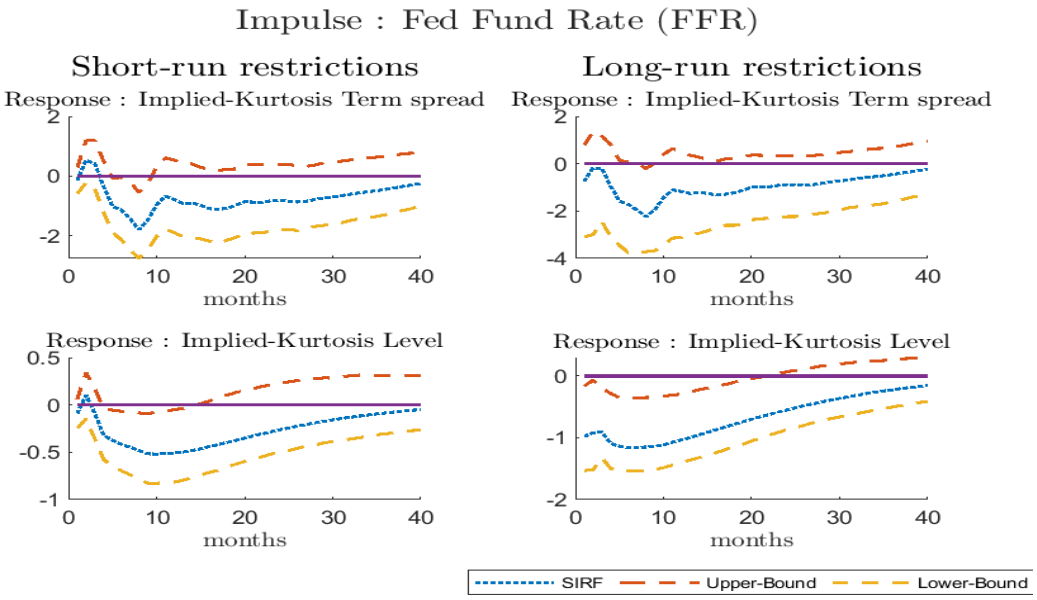


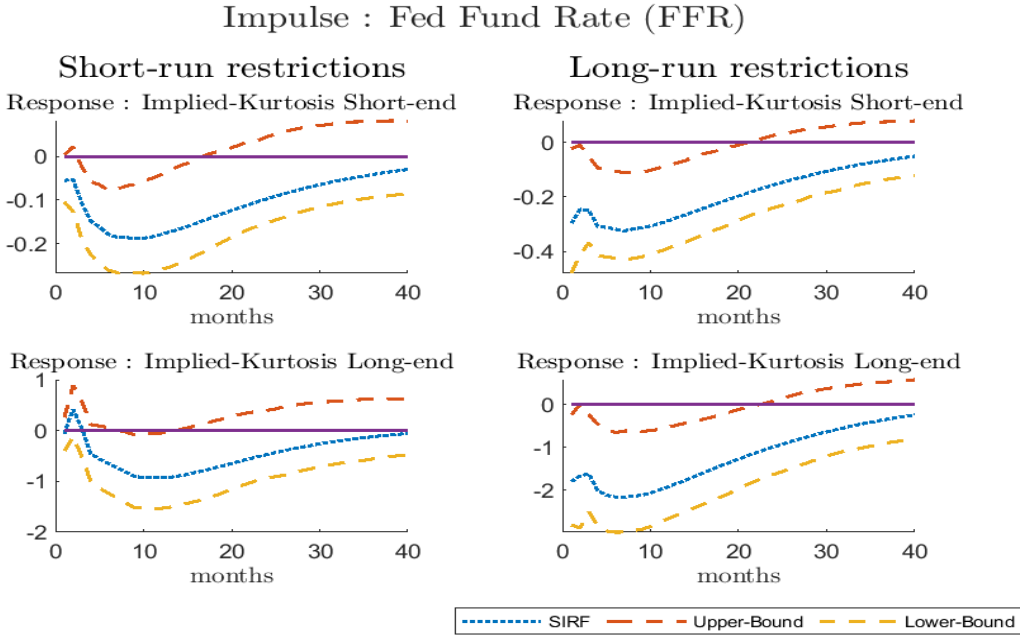
Figure 13. SIRFs of the components of the term structure of implied kurtosis to negative FFR shocks (expansionary MP shocks), for the multivariate SVAR model

In this figure we plot the SIRFs of the components of IK to a negative one standard deviation shock in FFR when we estimate the multivariate SVAR model (equation (4)). In details, the left (right) column graphs include the estimated SIRFs from the SVAR models when we apply contemporaneous (long-run) restrictions. Additionally, the red and the yellow dotted lines are the upper and lower bounds of the 90% confidence interval respectively. Finally, panel A includes the responses of the term spread and the level of IK to monetary policy shocks, while the panel B show the SIRFs of the short-end and long-end component of IK to a negative one standard deviation shock in FFR

Panel A



Panel B



The **figures 12** and **13** demonstrate that our empirical results in section 3 are robust. Interestingly, the estimated results of the multivariate SVAR models, provide more convincing evidence about the higher sensitivity of the long-term IK to monetary policy shocks. Specifically, while we observe similar results about the response of IS to monetary policy shocks, the estimated responses of long-term and short-term IK to monetary policy in the multivariate SVAR models, are more "persistent" compared to the corresponding results of the bivariate model. In the multivariate setting, lax monetary policy results a negative statistically significant change to long-end IK, regardless of the applied-restrictions on the 4-variable SVAR model, while in the bivariate setting, we find a positive statistically significant response of long-end IK to a negative shock in FFR, when short-run restrictions are applied. Additionally, we observe that the difference between the impact of FFR shocks on long-end and short-end IK is greater when we estimate the 4-variable SVAR model.

Finally, for brevity, we include in the appendix, a few other estimated multivariate models and specifications. we estimate a few modifications of the 4-variable SVAR model (equation (3)) and 6-variable monetary VAR models (equation 5 and 6), and the estimated results can be found in the appendix. The additional modifications that we apply in multivariate SVAR model are the following: 1) we estimate a multivariate model of the form $Y_t = [IPG_t\ MP_t\ IS_t\ IK_t]$ (14); 2) we change the ordering of the variables, specifically we use the ordering that Triantafyllou and Dotsis (2017) used in their empirical analysis. Specifically, the form of the SVAR models with different ordering are $Y_t = [MP_t\ IPG_t\ IV_t\ IS_t]$ (15) and $Y_t = [MP_t\ IPG_t\ IV_t\ IK_t]$ (16).

6. Conclusion

Briefly, in our paper we document the impact of monetary policy on investors' expectations and fears. Specifically, by using higher moments of the option-implied distribution, we find that lax monetary policy results in an upward revision on investors' expectations about the future state of the economy. we firmly believe that our empirical results provide further evidence about the risk-taking channel of monetary policy, and they clearly demonstrate that accommodative monetary policy contributes to investors' "irrational exuberance"[14].

More importantly, we provide novel results about the long-term non money neutrality on option markets. we are the first to show that policy makers are not only able to influence investors' expectations about the subsequent market performance, but more significantly, can shape expectations about the long-term horizon.

Our results have a potential important policy implementation, since we provide evidence that policy makers are qualified to influence not only ex-ante expectations about the short-term horizon, but mainly, investors' beliefs about the long-term horizons. Our novel results are partially at odds with the standard monetary theory, likewise a few other similar studies (Hanson and Stein 2015, Kontonikas and Zekaite 2018, Nakamura and Steinsson 2018).

[14] This term initially used by Shiller (2015) and is also known as "animal spirits".

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Appendix A: Computation of the BKM moments

Bakshi et al (2003) proposed a methodology to extract model-free risk-neutral moments from OTM option prices.

The τ-period return from time t is defined by Bakshi et al (2003) as: $R(t,\tau) \equiv ln[S(t,\tau)] - ln[S(t)]$, where $S(t,\tau)$ designates the price of the stock at time t which has τ time remaining to maturiy.

Bakshi et al (2003) show that under the martingale pricing measures, the risk-neural skewness and kurtosis can be inferred from OTM call and put options as,

$$\begin{aligned} SKEWNESS(t,\tau) \equiv & \quad \frac{\mathcal{E}_t^*\{(R(t,\tau)-\mathcal{E}_t^*[R(t,\tau)])^3\}}{\{\mathcal{E}_t^*\left(R(t,\tau)-\mathcal{E}_t^*[R(t,\tau)]\right)^2\}^{3/2}} \\ = & \quad \frac{e^{r\tau}W(t,\tau)-3\mu(t,\tau)e^{r\tau}V(t,\tau)+2\mu(t,\tau)^3}{[e^{r\tau}V(t,\tau)-\mu(t,\tau)^2]^{3/2}} \end{aligned} \tag{2}$$

$$\begin{aligned} KURTOSIS(t,\tau) \equiv & \quad \frac{\mathcal{E}_t^*\{(R(t,\tau)-\mathcal{E}_t^*[R(t,\tau)])^4\}}{\{\mathcal{E}_t^*\left(R(t,\tau)-\mathcal{E}_t^*[R(t,\tau)]\right)^2\}^2} = \\ = & \quad \frac{e^{r\tau}X(t,\tau)-4\mu(t,\tau)e^{r\tau}W(t,\tau)+6e^{r\tau}\mu(t,\tau)^2V(t,\tau)-3\mu(t,\tau)^4}{[e^{r\tau}V(t,\tau)-\mu(t,\tau)^2]^2} \end{aligned} \tag{3}$$

where $\mathcal{E}_t^*$ is the expectation operator under the risk-neutral density and $\mu(t,\tau)$ is defined as,

$$\mu(t,\tau) \equiv \mathcal{E}_t^* ln\left[\frac{S(t,\tau)}{S(t)}\right] = e^{r\tau} - 1 - \frac{e^{r\tau}}{2}V(t,\tau) - \frac{e^{r\tau}}{6}W(t,\tau) - \frac{e^{r\tau}}{24}X(t,\tau) \tag{4}$$

The volatility contract $V(t,\tau) \equiv \mathcal{E}_t^*\{e^{-r\tau}R(t,\tau)^2\}$, the cubic contract $W(t,\tau) \equiv \mathcal{E}_t^*\{e^{-r\tau}R(t,\tau)^3\}$ and the quartic contract $X(t,\tau) \equiv \mathcal{E}_t^*\{e^{-r\tau}R(t,\tau)^4\}$ payoffs are defined as,

$$\begin{aligned} V(t,\tau) \quad = & \int_{S(t)}^{\infty} \frac{2\left(1-ln\left[\frac{K}{S(t)}\right]\right)}{K^2} C(t,\tau;K)dK \\ & + \int_0^{S(t)} \frac{2\left(1+ln\left[\frac{S(t)}{K}\right]\right)}{K^2} P(t,\tau;K)dK \end{aligned} \tag{5}$$

$$\begin{aligned} W(t,\tau) \quad = & \int_{S(t)}^{\infty} \frac{6ln\left[\frac{K}{S(t)}\right]-3\left(ln\left[\frac{K}{S(t)}\right]\right)^2}{K^2} C(t,\tau;K)dK \\ & - \int_0^{S(t)} \frac{6ln\left[\frac{S(t)}{K}\right]+3\left(ln\left[\frac{S(t)}{K}\right]\right)^2}{K^2} P(t,\tau;K)dK \end{aligned} \tag{6}$$

$$X(t,\tau) = \int_{S(t)}^{\infty} \frac{12\left(ln\left[\frac{K}{S(t)}\right]\right)^2 - 4\left(ln\left[\frac{K}{S(t)}\right]\right)^3}{K^2} C(t,\tau;K)dK + \int_{0}^{S(t)} \frac{12ln\left(\left[\frac{S(t)}{K}\right]\right)^2 + 4\left(ln\left[\frac{S(t)}{K}\right]\right)^3}{K^2} P(t,\tau;K)dK \quad (7)$$

where K is the strike price, $S(t)$ is the underlying stock price at time t, and $C(t,\tau;K)$ and $P(t,\tau;K)$ represent the price of the European call and put, respectively, on day t, with τ days to maturity and strike price K.