Uncovering the Asymmetric Information Content of High-Frequency Options

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Abstract

We propose option realized semivariances and signed jumps as new "observable quantities" to summarize the asymmetric information contained in the sign of high-frequency options returns. These measures successfully capture the direction of the discontinuities related to the underlying asset and risk factor, resulting in additional incremental information not contained in the aggregate option realized measures. Using options data on S&P 500 ETF (SPY) and 15 individual equities, we find that the negative (positive) semivariance and signed jump of out-of-the-money call (put) options play a prominent role in predicting future variance, variance risk-premia, and excess monthly returns.

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1 Introduction

The state-contingent nature of the option payoff makes it highly informative about state prices and the price of risk. In addition, it is widely known that, beyond market return risk, investors require compensation for bearing variance and jump risks. Traditional approaches considering end-of-day option prices provide important insights about equity, variance, jump and tail risk premia.[1] However, the increasing availability of high-frequency option data affords the potential to convey accurate real-time information regarding investors' preferences, yielding a more comprehensive view of the joint dynamics between the realized and expected asset price. In other words, high-frequency option data capture information about investors' expectations and risk appetites' change in response to the intraday order flow and news arrivals, which are not contained in low-frequency data.[2]

In this paper, we propose (noise-robust) option realized signed measures to summarize the asymmetric information content of high-frequency option data. Our approach assumes that an option is an asset on its own (e.g., Coval and Shumway, 2001; Broadie et al., 2009), and therefore its variance is simply the variance of the option prices. Employing high-frequency econometric techniques, we first estimate the option realized variance and jump variation. We show that the jump component of the option quadratic variation captures discontinuities that are related to both the underlying asset and the underlying risk factor.[3] However, as the aggregate option realized variance and jump variation fail at capturing the information contained in the sign of the high-frequency option returns, we further decompose them into the option realized semivariances and signed jumps. These measures successfully capture the asymmetric dynamics of the high-frequency option returns, reflecting the down-

[1] An incomplete list of studies on these topics includes Bakshi et al. (2003), Christoffersen et al. (2012), Andersen et al. (2015, 2017), Bollerslev et al. (2015), among others.

[2] To illustrate, Figure 1, in Section 3, presents the intraday prices (underlying asset and options) of the market index and an individual equity on August 7, 2007. This day the Federal Reserve surprised the market by deciding to keep its target for the federal funds rate. This news triggered a negative market reaction that took about an hour to recover and is completely disregarded when considering end-of-day data.

[3] This result is in line with Andersen et al. (2015) who show that option prices, as functionals of the variance and jump intensity, inherit the behavior of these variables at small scales.

side and upside risk of option contracts which is off-set at the aggregate level.[4]

Our decomposition allows us to exploit the information within specific moneyness ranges, thereby capturing unique joint dynamics and investors' risk preferences across these states. As the call (put) option moves in the same (opposite) direction of the underlying asset, the asset downside risk is captured by the negative (positive) option realized semivariance or signed jump. Thus, we expect these measures to possess a richer and non-trivial information set compared to their aggregate measures.

We construct our option realized measures using a novel high-frequency option dataset, coupled with standard high-frequency econometric techniques that are both straightforward to estimate and computationally inexpensive. Our dataset comprises the SPDR S&P 500 ETF (SPY) as a proxy for the US stock market index, along with 15 individual US equities. The sample period ranges from January 2005 to December 2021 (January 2004 to December 2021) for SPY (individual equities). We assess the predictive ability of the option realized signed measures, estimated from out-of-the-money (OTM) calls and puts, for variance, variance risk premia and equity excess returns. In particular, in our empirical application, we examine whether the information content of our asymmetric measures improves upon that of the aggregate option and equity realized measures, as well as end-of-day option implied measures.

Our results can be summarized as follows. First, we find that the option realized signed measures are good predictors of future realized variance (RV) and variance risk-premia (VRP) at the daily, weekly, and monthly horizons. In specific, we show that the information content of our proposed signed measures are neither contained in the aggregate option realized measures nor in standard predictors usually employed in the literature. This suggests that the incremental information afforded by our option realized signed measures comple-

[4]The relevance of semivariances, and the broader class of downside risk measures, has a long history in finance and several studies have shown that the upside and downside risks are very distinct factors, where generally downside risk plays a more important role in explaining risk-premia (e.g., Hogan and Warren, 1974; Ang et al., 2006; Lettau et al., 2014; Kilic and Shaliastovich, 2019; Bollerslev et al., 2020; Almeida et al., 2022).

ments that of alternative predictors. Interestingly, the significance of our option realized signed measures also persists when controlling for signed measures constructed from the underlying assets. Second, the superior predictive power of the option realized signed jumps relative to the absence of any predictability afforded by the option realized jump, implies that our proposed decomposition successfully uncovers the distinct and rich information contained in the sign of the high-frequency option returns. In fact, we find that most of the predictive power is driven by the negative (positive) semivariance and signed jump of OTM call (put) options, confirming previous findings in the literature regarding the richer information content of downside risk measures (e.g., Ang et al., 2006; Lettau et al., 2014; Kilic and Shaliastovich, 2019). Third, we also assess the information content of the option realized measures to predict equity excess returns. We document a superior performance of the option realized signed measures relative to their aggregate counterparts, albeit their predictive ability is mostly confined to the monthly horizon. Finally, when considering the individual equities, we are able to capture option dynamics related to calls activities that are not uncovered in the equity index option dynamics.

The current high-frequency option pricing literature is very limited, focusing mainly on options written on indices (e.g., Andersen et al., 2015; Audrino and Fengler, 2015; Kapetanios et al., 2019; Amaya et al., 2022). The few exceptions considering options written on individual equities investigate issues related to market microstructure and trading costs (e.g., Anand et al., 2016; Muravyev and Pearson, 2020; Andersen et al., 2021). Thus, to the best of our knowledge, we are the first in studying the predictive information content of (noise-robust) option realized signed measures using high-frequency option data written on both the market index and individual equities.

The closest works to ours are Audrino and Fengler (2015) and Amaya et al. (2022), who employ high-frequency options written on the market index to construct an option realized variance. Audrino and Fengler (2015) examine the consistency of models by comparing the option realized variance against those implied by competing models. Amaya et al. (2022)

investigate the impact of market microstructure noise and the information content of the option realized variance. We extend and complement these studies in a number of ways.

First, besides the option realized variance, we examine the information content of the option realized jump, as a tool to capturing dynamics related to the underlying asset and risk factor in presence of discontinuities. Second, we propose asymmetric measures which can better capture the information contained in the sign of the high-frequency option returns.[5] Third, we shed new light on the pivotal impact of downside risk contained in the call and put options and precisely identified only when considering the asymmetric option realized measures. Finally, we examine the predictive information content of these measures by adopting an extended and more recent dataset encompassing both the market index and individual equities.

Our paper intersects with several strands of the literature on important areas in asset pricing and financial econometrics. We relate to the extensive literature identifying jumps from option prices (e.g., Bates, 1996; Duffie et al., 2000; Pan, 2002; Aït-Sahalia, 2002; Eraker et al., 2003; Bollerslev and Todorov, 2011a, 2014; Christoffersen et al., 2012; Andersen et al., 2020; Todorov, 2022), as well as to the strands of the literature explaining risk compensation for this additional source of risk in equity premia (e.g., Bali and Hovakimian, 2009; Santa-Clara and Yan, 2010; Andersen et al., 2015; Cremers et al., 2015; Andersen et al., 2017) and variance-risk premia (e.g., Bollerslev and Todorov, 2011b; Bollerslev et al., 2015; Andersen et al., 2015; Almeida et al., 2022). We also relate to the literature employing high-frequency data to better estimate variance and jump measures (e.g., Andersen et al., 2001, 2003; Barndorff-Nielsen and Shephard, 2004; Barndorff-Nielsen et al., 2010, *inter alia*). Finally, we touch upon the literature looking at the information content of decomposed risk measures (e.g., Ang et al., 2006; Feunou et al., 2013; Lettau et al., 2014; Bollerslev et al., 2015; Patton and Sheppard, 2015; Farago and Tédongap, 2018; Kilic and Shaliastovich, 2019; Bollerslev

[5]Consistent with economic intuition, large differences in the option realized semivariances and signed jumps are typically associated with macroeconomic announcements, highlighting the importance of discriminating between positive and negative option returns.

et al., 2020; Baruník et al., 2022).

The remainder of the paper is organized as follows. Section 2 presents the theoretical framework adopted for the construction of the option realized measures. Section 3 describes the data and the estimated option realized measures. In Sections 4, 5, and 6, we study the information content of the option realized measures with respect to future realized variances, variance risk premia, and excess equity returns, respectively. Section 7 concludes the paper. Additional results are relegated to the paper Appendix.

2 Theoretical Background

This section presents the construction of our proposed option realized measures. First, we define the theoretical framework and outline the option quadratic variation. In specific, we show that the option realized measures contain incremental information about (signed) jumps that stem from both the underlying asset and the underlying risk factor. Second, we present the option realized measures in their standard and noise-robust forms.

We assume that the price of an asset S and its underlying risk factor X, are two Itô semimartingale processes that evolve continuously under the objective measure $\mathbb{P}$, and are outlined by the following stochastic differential equations:

$$\frac{dS_t}{S_{t-}} = \mu_S(X_{t-})dt + \sum_{i=1}^{m} \sigma_{S,i}(X_{t-})dW_{i,t} + dJ^+_{S,t} + dJ^-_{S,t}, \tag{1}$$

$$dX_t = \mu_X(X_{t-})dt + \sum_{i=1}^{m} \sigma_{X,i}(X_{t-})dW_{i,t} + dJ^+_{X,t} + dJ^-_{X,t}, \tag{2}$$

where $\mu_S(X_{t-})$ and $\mu_X(X_{t-})$ are predictable drift coefficients for the respective price and underlying risk factor. $\{W_{i,t}\}_{t\geq 0, i\in\{1,\ldots,m\}}$ are independent standard Brownian motions under the measure $\mathbb{P}$, and $\{\sigma_{S,i}(X_{t-})\}_{i\in\{1,\ldots,m\}}$ and $\{\sigma_{X,i}(X_{t-})\}_{i\in\{1,\ldots,m\}}$ are diffusive coefficients for the same processes. $J^+_{S,t}$ and $J^-_{S,t}$ ($J^+_{X,t}$ and $J^-_{X,t}$) are two jump processes for the price (risk factor) that capture the positive and negative jump sizes and, of course, their sum equals the total jump part:

$$J_{S,t}^{+} = \sum_{n=1}^{N_{S,t}} Z_{S,n} \mathbb{I}_{\{Z_{S,n}>0\}}, \quad J_{S,t}^{-} = \sum_{n=1}^{N_{S,t}} Z_{S,n} \mathbb{I}_{\{Z_{S,n}<0\}}, \tag{3}$$

$$J_{X,t}^{+} = \sum_{n=1}^{N_{X,t}} Z_{X,n} \mathbb{I}_{\{Z_{X,n}>0\}}, \quad J_{X,t}^{-} = \sum_{n=1}^{N_{X,t}} Z_{X,n} \mathbb{I}_{\{Z_{X,n}<0\}}, \tag{4}$$

where $\{N_{S,t}\}_{t\geq 0}$ and $\{N_{X,t}\}_{t\geq 0}$ are Cox processes, $\{Z_{S,n}\}_{n=1}^{\infty}$ and $\{Z_{X,n}\}_{n=1}^{\infty}$ are the jump size of the price and risk factor, respectively. In addition, we assume the jump intensities are state dependent, i.e. $\lambda_S(X_{t-})$ and $\lambda_X(X_{t-})$, but the jump sizes are state independent.

Following standard conditions, the option price of the asset S at time t is given by $O_{t,k,\tau}$. Assuming frictionless trading in the options market (Andersen et al., 2015), the option prices are given by:

$$O_t \equiv O_{t,k,\tau}\left(S_t, X_t\right) = \begin{cases} \mathbb{E}^{\mathbb{Q}}\left[e^{-\int_t^{t+\tau} r_u du}(S_{t+\tau} - K)^{+}\Big|S_t, X_t\right], & \text{if } K > S_{t+\tau}, \\ \mathbb{E}^{\mathbb{Q}}\left[e^{-\int_t^{t+\tau} r_u du}(K - S_{t+\tau})^{+}\Big|S_t, X_t\right], & \text{if } K \leq S_{t+\tau}, \end{cases} \tag{5}$$

where τ is time-to-maturity, K is the strike price, $S_{t+\tau}$ is the spot price of the underlying asset at time $t+\tau$, $k = K/S_t$ is the average contract moneyness on day t, r_u is the risk-free rate, and $\mathbb{Q}$ is the risk-neutral probability measure.

As our aim is to construct measures of the option realized variance and semivariances, we start by deriving the option quadratic variation. Using Itô's lemma for semimartingale processes (for more details, see proposition 8.19 in Cont and Tankov, 2003), the quadratic variation of the option can be characterized as follows:[6]

$$
\begin{aligned}
[o, o]_t = & \underbrace{\sum_{i=1}^{m} \int_0^t \left(\frac{\partial o_u}{\partial s}(S_u, X_u) \right)^2 \sigma_{S,i}^2(X_{u-}) du + \sum_{i=1}^{m} \int_0^t \left(\frac{\partial o_u}{\partial x}(S_u, X_u) \right)^2 \sigma_{X,i}^2(X_{u-}) du + 2 \sum_{i=1}^{m} \int_0^t \left(\frac{\partial o_u}{\partial s}(S_u, X_u) \right) \left(\frac{\partial o_u}{\partial x}(S_u, X_u) \right) \sigma_{S,i}(X_{u-}) \sigma_{X,i}(X_{u-}) du}_{OCV_t} \\
& + \underbrace{\sum_{0 \le u \le t} \left[(o_u(S_u, X_u) - o_u(S_{u-}, X_{u-}))^+ \right]^2 + \sum_{0 \le u \le t} \left[(o_u(S_u, X_u) - o_u(S_{u-}, X_{u-}))^- \right]^2}_{OJV_t = OJV_t^+ + OJV_t^-} .
\end{aligned}
\tag{6}
$$

Proof: See Appendix B.

We use $(\,\cdot\,)^+$ and $(\,\cdot\,)^-$ to denote the positive and negative jump, respectively. As can be seen in equation (6), the evolution of the option quadratic variation depends on two components. The first component contains three terms that capture the diffusive or normal changes in the information set, while the second component relates to the rough arrival of information. It is important to note that the jump component of $[o, o]_t$ captures jumps that are related to both the underlying asset and the underlying risk-factor. In addition, equation (6) allows to differentiate the direction of the jumps, which is crucial for measuring downside risk. As noted by Andersen et al. (2015), negative price jumps and positive price jumps impact the option quadratic variation differently. This different impact is due to the leverage effect; negative returns correlate with increases in volatility, while positive returns correlate with reductions in volatility.

Although the option quadratic variation is not directly observable, it can be consistently estimated from high-frequency option data. The next subsection is devoted to this purpose.

[6] $o_t \equiv \log(O_t)$. To ease notation, we suppress the subscripts k and τ. In addition, we have purposely omitted $\frac{1}{o_s^2(S_{u-}, X_{u-})}$ from the three elements of the diffusive component. This term is obtained by taking the derivative of o_t w.r.t. x and s, and its quadratic form arises because of the quadratic variation.

2.1 Option Realized Measures

An option is an asset whose payoff depends on the value of another asset, i.e. the underlying asset. Despite this dependence, an option can be seen as an asset on its own, meaning that the variance of an option is simply the variance of the option prices. In other words, using high-frequency option data and the realized variance approach (e.g. Barndorff-Nielsen and Shephard, 2002; Andersen et al., 2003), we can consistently estimate the option quadratic variation for a specific level of moneyness and maturity:[7]

$$\mathcal{ORV}_t = \sum_{j=1}^{N} |r^o_{t,j}|^2 \xrightarrow{p} [o, o]_t, \tag{7}$$

where $r^o_{t,j} = \log(O_{t,j\Delta_N}) - \log(O_{t,(j-1)\Delta_N})$, $j = 1, 2, \ldots, N$ is the j-th high-frequency option return, $\Delta_N \equiv 1/N$ is the time interval and N is the total number of intraday increments per day. As the $\mathcal{ORV}$ is a consistent estimator of the option quadratic variation, the jump component of the $\mathcal{ORV}$ contains information about jumps in both the underlying asset and underlying risk factor, which suggests that the jump component of the $\mathcal{ORV}$ contains non trivial information as it is not possible to identify risk factor jumps using the realized variance of the underlying asset. Motivated by the incremental information of the jump component, we separate jumps from the diffusive part of the option quadratic variation as:

$$\mathcal{ORJ}_t = \max\left(\mathcal{ORV}_t - \mathcal{OBV}_t, 0\right) \xrightarrow{p} OJV_t, \tag{8}$$

where $\mathcal{OBV}_t = N/(N-1)(\pi/2)\sum_{j=2}^{N} |r^o_{t,j}||r^o_{t,j-1}|$, is the option bi-power variation, which is a consistent estimator of the diffusive component (e.g., Barndorff-Nielsen and Shephard, 2004).

The $\mathcal{ORV}_t$ and $\mathcal{OBV}_t$ rely on even functions of high-frequency option returns, i.e. squares and absolute values, which of course eliminate any information that may be con-

[7] Andersen et al. (2001, 2003) and Barndorff-Nielsen and Shephard (2002) show that under suitable conditions the realized variance is an unbiased and highly efficient estimator of the quadratic variation.

tained in the sign of these returns. To overcome this issue, we propose the option realized semivariance. As shown in Barndorff-Nielsen et al. (2010), these measures decompose the $\mathcal{ORV}$ into two components that relate only to positive and negative high-frequency option returns. The option realized semivariances, therefore, capture the downside and upside risk of an option contract. Since the call (put) option moves in the same (opposite) direction as the underlying asset, the downside risk of the underlying asset is captured by the negative (positive) option realized semivariance of a call (put) contract.

Let $p(x) = \max\{x, 0\}$ and $n(x) = \min\{x, 0\}$ denote the component-wise positive and negative of a real vector x. Then, the option realized semivariances can be outlined as:

$$\begin{aligned} \mathcal{ORV}_t^+ &= \sum_{j=1}^{N} p\left(r_{t,j}^o\right)^2 \xrightarrow{p} \frac{1}{2} OCV_t + OJV_t^+, \\ \mathcal{ORV}_t^- &= \sum_{j=1}^{N} n\left(r_{t,j}^o\right)^2 \xrightarrow{p} \frac{1}{2} OCV_t + OJV_t^-. \end{aligned} \tag{9}$$

These estimators provide a complete decomposition of $\mathcal{ORV} = \mathcal{ORV}^+ + \mathcal{ORV}^-$, and this decomposition holds for any N and in the limit. As shown in equation (9) the option realized semivariance includes variation due to both the continuous part of the option price process and the jump component. However, the continuous part is not decomposable into positive and negative components,[8] which suggests that this component can be removed by taking the difference between both option realized semivariances. The remaining component is what we define as the option realized signed jumps:

$$\mathcal{ORSJ}_t = \mathcal{ORV}_t^+ - \mathcal{ORV}_t^- \xrightarrow{p} OJV_t^+ - OJV_t^-. \tag{10}$$

Finally, we proceed by separating the positive and negative signed jumps as follows:

$$\mathcal{ORJ}_t^+ = p\left(\mathcal{ORSJ}_t\right), \quad \mathcal{ORJ}_t^- = n\left(\mathcal{ORSJ}_t\right). \tag{11}$$

[8]This implies that each of the option realized semivariances converges to one-half of the continuous part of the option quadratic variation plus the sum of squared signed jumps.

We use the decomposition of the option realized variance (equation (9)) and signed jumps (equation (11)) to gain new insights on the importance of the asymmetric variance and jump measures related to signed option returns. We refer to them as option realized signed measures.

2.2 Market Microstructure Noise

This section presents noise-robust estimates of our proposed option realized measures. It is well documented in the literature that standard high-frequency based volatility measures tend to be biased in the presence of market microstructure noise (e.g., Zhang et al., 2005; Hansen and Lunde, 2006; Aït-Sahalia and Xiu, 2019). Among other things, price discreteness forces the observed price to deviate from the "true" price (e.g., Gottlieb and Kalay, 1985; Easley and O'Hara, 1992). As a consequence, the observed volatility is upward biased vis-à-vis the true volatility by an amount that depends on the tick size and the sampling frequency. Thus, market microstructure noise may have a non-negligible impact even when sampling at the "optimal" five-minute returns (e.g., Andersen et al., 2001).[9]

We assume that the observed log option price, $o_t = \log(O_t)$, is a discontinuous Itô semimartingale, contaminated by additive microstructure noise:

$$o_t = o_t^* + u_t, \tag{12}$$

where o_t^* is the efficient option price and u_t is the noise component with $\mathbb{E}[u_t] = 0$ and $\mathbb{E}[u_t^2] = \omega^2$, and $o_t^* \perp u_t$. To estimate our noise-robust option realized measures, we rely on the subsampling approach of Zhang et al. (2005) based on five-minute frequency. We select this approach for two reasons. First, it has been shown to produce reasonable estimates of volatility with high accuracy in different empirical applications (e.g., Andersen et al., 2011).[10]

[9] The 5-minute sampling frequency is found to be reasonably free of market microstructure noise, as evidenced by the Hausmann tests of Aït-Sahalia and Xiu (2019) for market microstructure noise and first-order serial correlation.

[10] Christensen et al. (2014) show that when the aim is to estimate the quadratic variation, the subsampling

Second, the subsampling approach does not involve any overlapping, so we avoid having a single option return contributing to both positive and negative semivariances.[11]

For each trading day, we select option prices at a frequency $\Delta_N = 5$ minutes and construct $\theta = 3$ overlapping price grids at an inferior frequency, that is, $\delta = \theta\Delta_N$:

09:31:00	09:36:00	09:41:00
09:46:00	09:51:00	09:56:00
10:01:00	10:06:00	10:15:00
⋮	⋮	⋮

With observations sampled every 5 minutes, this estimator employs three overlapping grids constructed at a 15-minute frequency. The option subsampling realized measures are defined as the average of the standard measures over the θ grids defined above, that is:

$$\begin{aligned} \widehat{\mathcal{ORV}}_t &= \frac{1}{\theta}\sum_{i=1}^{\theta} \mathcal{ORV}_{t,i}(\delta), \qquad \widehat{\mathcal{OBV}}_t = \frac{1}{\theta}\sum_{i=1}^{\theta} \mathcal{OBV}_{t,i}(\delta), \\ \widehat{\mathcal{ORV}}_t^+ &= \frac{1}{\theta}\sum_{i=1}^{\theta} \mathcal{ORV}_{t,i}^+(\delta), \quad \widehat{\mathcal{ORV}}_t^- = \frac{1}{\theta}\sum_{i=1}^{\theta} \mathcal{ORV}_{t,i}^-(\delta). \end{aligned} \tag{13}$$

Similarly, the option subsampling realized jump and signed jumps are estimated as follows:

$$\begin{aligned} \widehat{\mathcal{ORJ}}_t &= \max\left(\widehat{\mathcal{ORV}}_t - \widehat{\mathcal{OBV}}_t, 0\right), \\ \widehat{\mathcal{ORJ}}_t^+ &= p\left(\widehat{\mathcal{ORSJ}}_t\right), \quad \widehat{\mathcal{ORJ}}_t^- = n\left(\widehat{\mathcal{ORSJ}}_t\right), \end{aligned} \tag{14}$$

where $\widehat{\mathcal{ORSJ}}_t = \widehat{\mathcal{ORV}}_t^+ - \widehat{\mathcal{ORV}}_t^-$.

In what follows, we rely on the option subsampling realized measures. Please note that

approach of Zhang et al. (2005) is to first-order equivalent to the realized kernel (Barndorff-Nielsen et al., 2008) and the preaveraging approach (Jacod et al., 2009). In addition, Amaya et al. (2022) show that the subsampling estimators, implemented using high-frequency options, based on 5-minute returns provide a good bias-variance trade-off, which is consistent with the work of Liu et al. (2015).

[11] The pre-averaging approach of Jacod et al. (2009) also provides noise-robust estimates of the variance. However, this estimator is less suitable for signed measures, as it considers overlapping returns, where returns with different signs contribute to the estimation of both positive and negative signed measures.

for ease of notation, we drop the hat from the measures when referring to these quantities.

3 Data

This section presents the data adopted in the study. Subsections 3.1 and 3.2 illustrate the respective high-frequency option and underlying data, together with the filtering procedure and cleaning processes implemented. Finally, subsection 3.3 depicts the option realized measures and their interaction with the underlying measures.

3.1 High-Frequency Options

Our data consists of high-frequency options written on the SPDR S&P 500 ETF (SPY) and on 15 individual equities provided by CBOE LiveVol. The raw option data include minute-by-minute bid-ask quotes and volumes over the trading day (09:31 to 16:00) for the period January 11, 2005 and December 31, 2021 for SPY.[12] For the individual equities, the data span from January 2, 2004 to December 31, 2021.[13]

As discussed in the introduction, high-frequency option data affords the potential of reflecting real-time information regarding investors' expectations in a more accurate manner than low-frequency data. To illustrate, Figure 1 presents in four panels the intraday prices (underlying asset and options) of SPY (top panels) and AAPL (bottom panels), at the 1-minute original interval. The day corresponds to an FOMC meeting, held on August 7, 2007, where the Federal Reserve decided to keep its target for the federal fund rates, in contrast to what the market had been anticipating.[14] The impact of this unexpected news triggered

[12] Options written on SPY are only available from January 11, 2005, and are the most liquid options on the market.

[13] The 15 individual equities are Apple Inc. (AAPL), Amazon Inc. (AMZN), Boeing Co (BA), Caterpillar Inc (CAT), Goldman Sachs Group Inc (GS), Home Depot Inc (HD), IBM Corp (IBM), Johnson & Johnson (JNJ), JP Morgan Chase and Co (JPM), The Coca Cola Co (KO), Microsoft Corp (MSFT), United Health Group (UNH), Verizon Communications Inc (VZ), Wells Fargo & Co (WFC) and Exxon Mobil Co (XOM).

[14] The Federal Open Market Committee decided on that day to keep its target for the federal funds rate at 5-1/4 percent. The Committee statement on forward-guidance was moderately suggesting for an expansion (e.g. "...the economy seems likely to continue to expand at a moderate pace over coming quarters, supported by solid growth in employment and incomes and a robust global economy.") However, there were policy

Figure 1: **High-Frequency Underlying and Option Prices around an FOMC Event**

Notes: This figure shows the time series of the underlying and options prices for the stock market index (SPY) and Apple Inc. (AAPL) equity during an FOMC meeting on August 7, 2007. The selected options are OTM calls ($K/S = 1.10$) and puts ($K/S = 0.9$). The data tick size is kept at the original 1-minute.

a negative (positive) jump for the underlying asset and the call price (put price) of both SPY and AAPL, with the prices reversing to previous levels after around one hour, i.e., 15:00h. This is one of the many examples that can be drawn from our dataset to highlight the importance of high-frequency option data in capturing these price joint dynamics that are related to news arrivals, which are otherwise ignored by end-of-day option data.

Following the low- and high-frequency option literature (e.g., Bakshi et al., 1997; Carr and Wu, 2011; Christoffersen et al., 2012; Andersen et al., 2021), we implement the following filters. We only consider bid and ask quotes between 09:31 and 16:00; we remove contracts with an average intraday mid-quote price smaller than 3/8; we remove contracts with nil

concerns mainly on the inflation pressures (e.g. "...a sustained moderation in inflation pressures has yet to be convincingly demonstrated", and "...the Committee's predominant policy concern remains the risk that inflation will fail to moderate as expected.")

daily open interest; we require the bid price to be higher than zero and lower than the ask price; we keep options with a maturity of at least 5 days and up to 120 days; we keep options that are at-the-money (ATM) and OTM;[15] we remove Mini option and Jumbo contracts as per consistency with other assets; we remove options that violate arbitrage conditions.[16]

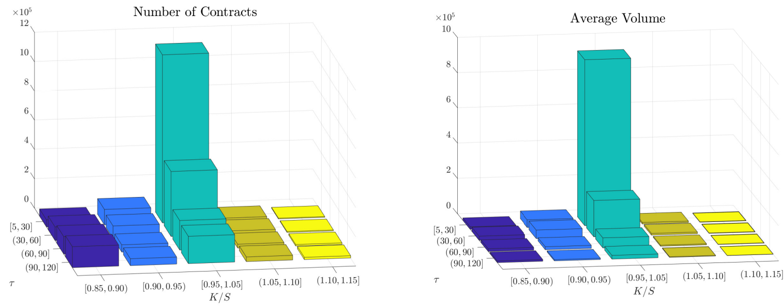
Figure 2 depicts, after implementing the filters, the number of contracts and average trading volume stratified by moneyness and maturity for respectively SPY and the average of the 15 individual equities. As can be seen, the shorter maturities $\tau \in [5, 30]$ concentrates the biggest proportion of contracts for both SPY and individual equities. The trading volume corroborates this finding. For instance, the number of contracts within this region is 1,325,516 –with an average trading volume of 201,936– for SPY, and 243,708 –with an average trading volume of 9,607– across the 15 individual equities.

For the shortest maturity region ($\tau \in [5, 30]$), the ATM range ($K/S \in [0.95, 1.05]$) concentrates the biggest proportion of contracts and trading volume for both SPY and the average of the individual equities. By contrast, the OTM range ($K/S \in [0.90, 0.95)$ and $K/S \in [1.05, 1.10)$) shows different features for SPY and the individual equities. Whereas SPY OTM put contracts account for 85% and 83% of all OTM contracts and average trading volume, respectively, these proportions drop to 60% and 45% for individual equities. The descriptive statistics suggest that put options written on SPY may contain a richer information set than calls. Conversely, the information content of option contracts on individual equities distribute more symmetrically across moneyness, implying that the measures estimated from either call or put options may be equally informative (e.g., Bakshi et al., 2003).

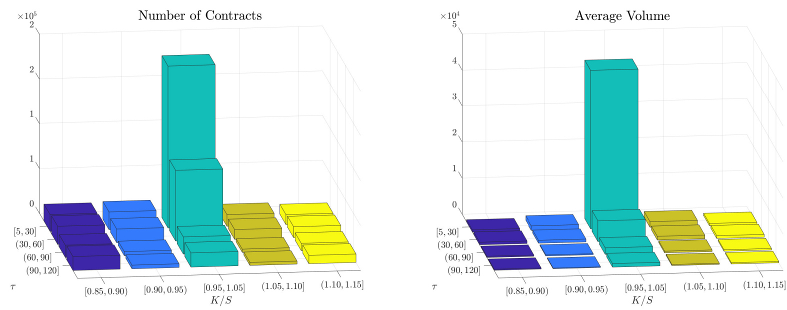
[15] We do not adjust for early exercise premia since we are working directly with option prices. However, Andersen et al. (2015) show that the early exercise premia of high-frequency options is always substantially smaller than bid-ask spreads and does not exceed 0.2% of an option price. Moreover, according to Bakshi et al. (2003), the magnitude of such premia in OTM options is negligible.

[16] Most of these filters are common in the option pricing literature. The open interest constraint ensures that there is genuine interest in the option contract (Carr and Wu, 2011). Options that are close to maturity or that have a very long expiration date are removed, consistently with Carr and Wu (2011) and Christoffersen et al. (2012), among others. We remove options with a negative bid-ask spread and that violate no-arbitrage constraints, as these option prices are invalid and inconsistent with theory. Finally, we remove in-the-money (ITM) contracts, as they tend to be more illiquid than OTM and ATM contracts (e.g., Christoffersen et al., 2012).

Figure 2: **Description of High-Frequency Option Data**



(a) **Market Index (SPY)**



(b) **Individual Equities**

Notes: This figure reports in two panels the number of option contracts and the average contracts volume for SPY and for the average of the individual equities. The descriptive are reported for all available contracts grouped across moneyness $K/S \in \{0.85, 0.90, 1.00, 1.10, 1.15\}$ and maturities $\tau \in \{30, 60, 90, 120\}$. The sample period is from January 11, 2005 to December 31, 2021, for SPY, and from January 2, 2004 to December 31, 2021 for the individual equities.

3.2 High-Frequency Underlying Data

We collect high-frequency equity data at the tick level from Refinitiv DataScope for SPY and 15 individual equities. The sample period matches the high-frequency options data, i.e. January 11, 2005 to December 31, 2021 for SPY, and January 2, 2004 to December 31, 2021 for the individual equities. In following Barndorff-Nielsen et al. (2008), the common cleaning process for high-frequency stock data is detailed as follows. We delete ticks with a time stamp outside 09:30–16:00h; if one or multiple transactions have occurred in that second, we calculate the volume-weighted average price within that second; for the volume-weighted average price, we use the entry from the nearest previous second; we delete entries for which the price deviated by more than 10 mean absolute deviations from a rolling centered median (excluding the observation under consideration) of 50 observations (25 observations before and 25 after). Finally, we employ the previous tick interpolation to aggregate our data using a 5-minute interval. The choice of the 5-minute interval for stock is customary in the literature and is motivated by the good bias-variance trade-off observed at this interval (e.g. Andersen et al., 2003; Liu et al., 2015).

3.3 Introducing the Option Realized Measures

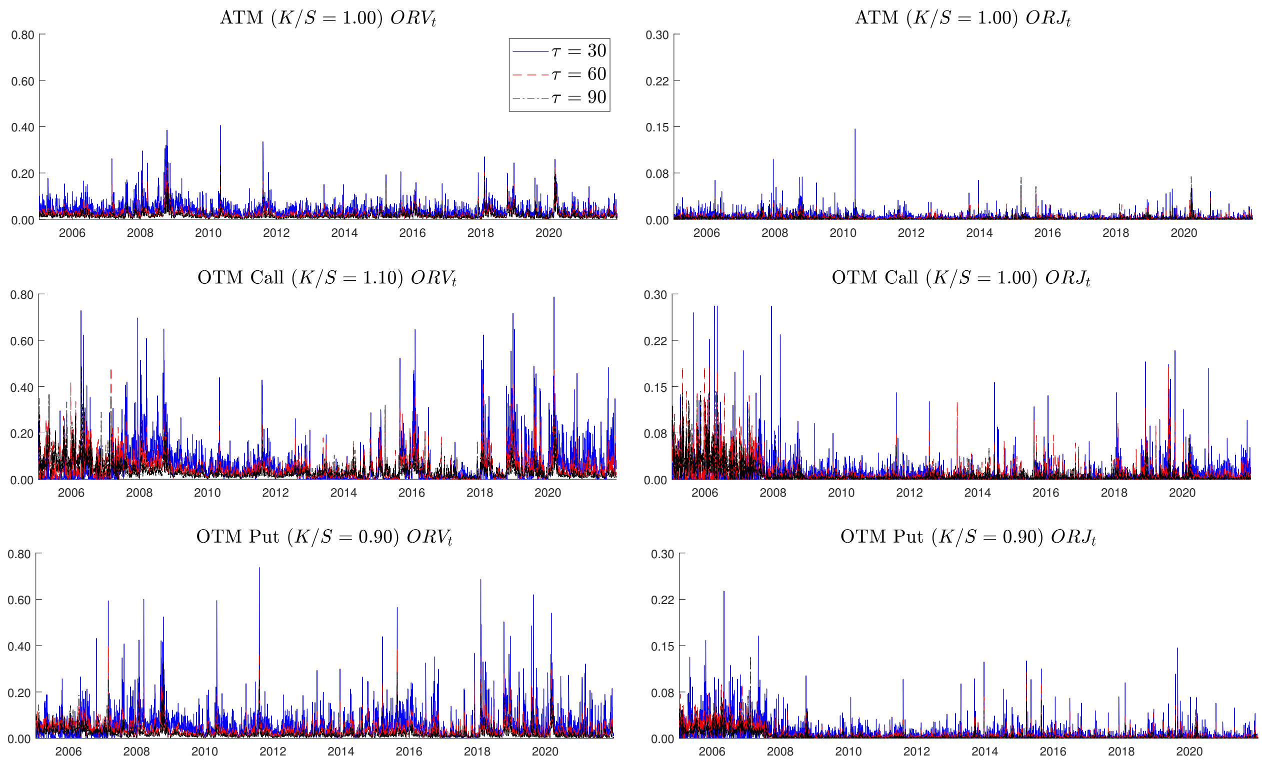
To deal with the large cross-section of option data spanning various maturities and moneyness levels, we construct a surface of option realized measures across both dimensions. In specific, for a given day, we collect an option realized measure, say $\mathcal{ORV}$, for all options in our dataset and perform a smoothed interpolation across moneyness levels and maturities.[17] Finally, we extract a daily balanced panel across moneyness and maturity with three equally spaced points over the moneyness dimension $K/S \in \{0.90,\ 1.00, 1.10\}$, corresponding to OTM puts, ATM and OTM calls, for maturities of $\tau \in \{30,\ 60,\ 90\}$.

Figure 3 depicts the SPY $\mathcal{ORV}$ and $\mathcal{ORJ}$ for the aforementioned levels of moneyness and maturities. Irrespective whether we look at the time series of the $\mathcal{ORV}$ or $\mathcal{ORJ}$, we observe that these measures share similar dynamics across both maturities and moneyness levels. As expected, the measures with shorter maturities display greater values. The time series of OTM option realized measures depict larger fluctuations relative to their ATM

[17] We perform a locally smoothing quadratic regression by adopting the Matlab Lowess procedure on the square root of $\mathcal{ORV}$ and then use these values to obtain a result in $\mathcal{ORV}$ units. The Matlab functions perform a local regression using weighted linear least squares with a second degree polynomial model which is robust to other choices of smoothing.

counterparts, particularly in turbulent times such as the global financial crisis and the Covid-19 pandemic.

Figure 3: **SPY Option Realized Measures**

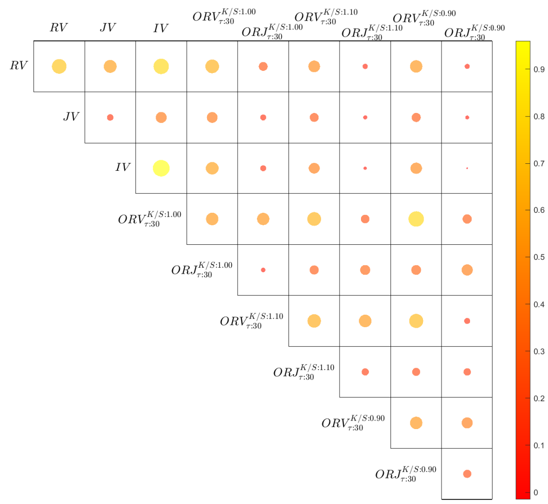


Notes: This figure shows the time series of the option realized measures namely $\mathcal{ORV}$ and $\mathcal{ORJ}$ with respect to SPY. The time series are presented for measures estimated across moneyness $K/S \in \{0.90,\ 1.00,\ 1.10\}$ and maturities $\tau \in \{30,\ 60,\ 90\}$. The sample period is from January 11, 2005 to December 31, 2021, at a daily frequency.

To rationalize the interaction between the option and the underlying realized measures, Figures 4 and 5 report the correlations and the AR(1) coefficient (main diagonal) for SPY and the average of the individual equities. For completeness, we also compare with the ATM implied volatility (IV), in variance form. For SPY, unsurprisingly, ATM $\mathcal{ORV}$ displays the highest level of correlation with both RV and IV, with values corresponding to 62% and 56%, respectively.[18] By contrast, when $\mathcal{ORV}$ is computed using OTM calls or puts, the

[18]The correlation between IV and RV equals 79%.

Figure 4: **SPY Correlations and AR(1) Coefficients**



Notes: This figure presents the correlations between RV, JV, IV, and selected $\mathcal{ORV}$ and $\mathcal{ORJ}$ variables for SPY. RV and JV are the underlying realized variance and jump component, respectively. IV is the 30-day implied variance. The selected maturity for the option realized measures corresponds to $\tau = 30$ days, while the selected moneyness corresponds to OTM call options ($K/S = 1.10$), ATM options ($K/S = 1.00$), and OTM put options ($K/S = 0.90$). RV and JV are computed from SPY 5-minute returns. The main diagonal entries report the AR(1) coefficient of the variables. The sample period is from January 11, 2005 to December 31, 2021, at a daily frequency.

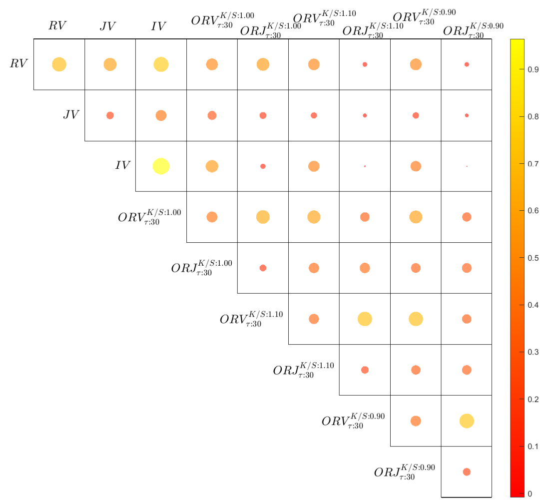
correlation with RV decreases to 46% and 52%, respectively. A qualitatively similar finding is observed when comparing OTM $\mathcal{ORV}$ and IV.

A plausible explanation for the decrease in the correlation level can be attributed to the fact that the OTM option realized jumps contribute more to the option quadratic variation and these jumps are not captured by the RV. The smaller AR(1) coefficient observed in OTM $\mathcal{ORV}$ supports this explanation as jumps dynamics are known to be much less persistent than continuous sample path dynamics (e.g., Andersen et al., 2007). Similar conclusions can be drawn from Figure 5 for the relationship between the option and the underlying realized measures of the individual equities.

Finally, Figure 6 plots the SPY option realized semivariances and signed jumps.[19] For

[19] For the sake of space, we plot the $\mathcal{ORSJ}$, which contains both signed jumps, namely $\mathcal{ORJ}^+$ and

Figure 5: **Individual Equity Correlations and AR(1) Coefficients**



Notes: This figure presents the correlations between RV, JV, IV, and selected $\mathcal{ORV}$ and $\mathcal{ORJ}$ variables for the average of the individual equities. RV and JV are the underlying realized variance and jump component, respectively. IV is the 30-day implied variance. The selected maturity for the option realized measures corresponds to $\tau = 30$ days, while the selected moneyness corresponds to OTM call options ($K/S = 1.10$), ATM options ($K/S = 1.00$), and OTM put options ($K/S = 0.90$). RV and JV are computed from 5-minute returns. The main diagonal entries report the AR(1) coefficient of the variables. The sample period is from January 2, 2004 to December 31, 2021, at a daily frequency.

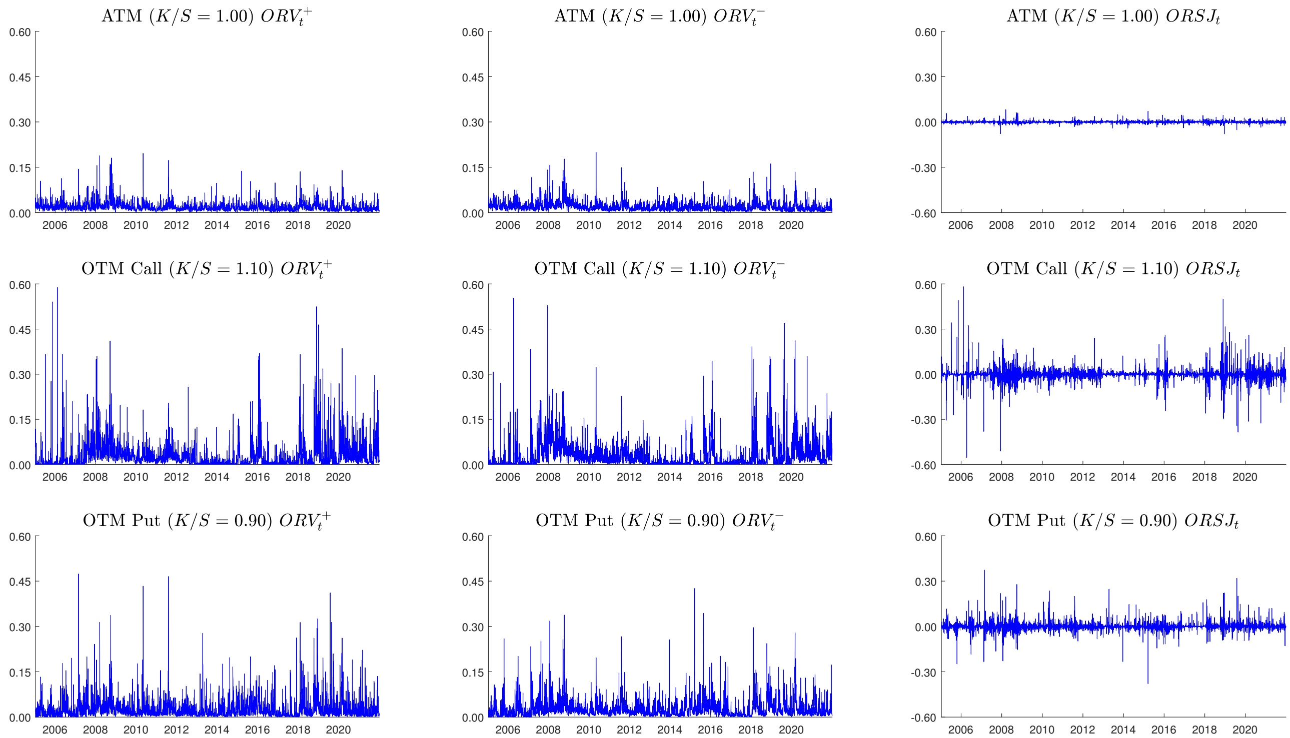
ease of presentation, and motivated by the graphical evidence in Figure 3, we focus on the dynamics of our estimates across the same levels of moneyness with a maturity of 30 days. We corroborate similar patterns even when the option realized measures are decomposed by sign. That is, OTM option realized semivariances and signed jumps fluctuate more than their ATM counterparts reaching, in absolute terms, higher values.

In summary, the previous descriptive analysis suggests that option realized measures estimated using OTM calls and puts within 30-day maturity afford a richer information set relative to measures based on alternative moneyness and maturity levels. Thus, in what follows, we focus on option realized measures estimated from OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$) with a maturity of 30 days.[20]

$\mathcal{ORJ}^-$, depicted above and below the zero value, respectively.

[20]Qualitatively similar results in all the subsequent sections are attained when considering option realized

Figure 6: **SPY Option Realized Signed Measures**



Notes: This figure shows the time series of the option realized semivariances ($\mathcal{ORV}^+$and $\mathcal{ORV}^-$) and signed jumps ($\mathcal{ORSJ}$) with respect to SPY. The time series are presented for measures estimated across moneyness $K/S \in \{0.90,\ 1.00,\ 1.10\}$ and maturity equal to $\tau \in 30$ days. The sample period is from January 11, 2005 to December 31, 2021, at a daily frequency.

4 Predicting the Realized Variance

This section is devoted to assessing the predictive information content of the option realized signed measures on future SPY and individual equity realized variances. We start by examining the predictive power of the option realized semivariances, to then focus our attention on the option realized signed jumps.

Our baseline model is an extension of the so-called HAR model of Corsi (2009), which

measures constructed from ATM options. Our ATM option realized measures are constructed by blending the ATM call and put as in Figlewski (2010). These results are available upon request.

incorporates a daily jump component (JV) and the OptionMetrics ATM 30-day implied volatility (IV), in variance form.[21] This framework encompasses several specifications that improve upon the standard HAR model (e.g., Andersen et al., 2007; Busch et al., 2011, *inter alia*). Therefore, this setup allows us to assess the incremental information of the option realized measures even after controlling for predictors that are commonly adopted in the literature. Let $RV_{t+1:t+h}$ define the multi-period normalized (scaled by the horizon) realized variance measures as the average of the corresponding one-period measures:

$$RV_{t+1:t+h} = h^{-1}\left[RV_{t+1} + RV_{t+2} + \cdots + RV_{t+h}\right],$$

where h corresponds to the forecasting horizon, i.e. $h \in \{1, 5, 22\}$ denoting one-day, one-week, and one-month ahead. The baseline model is outlined as:

$$RV_{t+1:t+h} = \beta_0 + \beta_d RV_t^{(\mathrm{d})} + \beta_w RV_t^{(\mathrm{w})} + \beta_m RV_t^{(\mathrm{m})} + \beta_{JV} JV_t + \beta_{IV} IV_t + \varepsilon_{t+1:t+h}, \qquad (15)$$

where $RV^{(d)}$, $RV^{(w)}$, and $RV^{(m)}$ are the respective past daily, weekly, and monthly RV as defined in Corsi (2009). JV is the jump component and IV is the implied volatility, in variance form. For individual equities, the baseline model is estimated using panel regressions with firm fixed effects.[22]

4.1 Option Realized Semivariances

To assess the predictive power of the option realized measures on future SPY and individual equities RV, we further augment the baseline model separately with the aggregate

[21]The stock jump variation is defined as $JV_t \equiv \max\left(RV_t - BV_t, 0\right)$ following Barndorff-Nielsen and Shephard (2004). IV is the average of the ATM call and put implies volatilities. OptionMetrics computes implied volatilities using a binomial tree, taking into account discrete dividend payments and the possibility of early exercise and using historical LIBOR/Eurodollar rates for interest rate inputs.

[22]To ease notation, we have suppressed the i subscript that characterizes the standard panel regression models. This applies to all the equations shown in our empirical exercises.

$\mathcal{ORV}$ and the option realized semivariances:

$$RV_{t+1:t+h} = \beta_0 + \beta_d RV_t^{(\mathrm{d})} + \beta_w RV_t^{(\mathrm{w})} + \beta_m RV_t^{(\mathrm{m})} + \beta_{JV} JV_t + \beta_{IV} IV_t + \beta_{\mathcal{ORV}} \mathcal{ORV}_t + \varepsilon_{t+1:t+h}, \tag{16}$$

$$RV_{t+1:t+h} = \beta_0 + \beta_d RV_t^{(\mathrm{d})} + \beta_w RV_t^{(\mathrm{w})} + \beta_m RV_t^{(\mathrm{m})} + \beta_{JV} JV_t + \beta_{IV} IV_t + \beta_{\mathcal{ORV}^+} \mathcal{ORV}^+{}_t + \beta_{\mathcal{ORV}^-} \mathcal{ORV}^-{}_t + \varepsilon_{t+1:t+h}, \tag{17}$$

where the $\mathcal{ORV}$ is the option realized variance, while $\mathcal{ORV}^+$ and $\mathcal{ORV}^-$ are respectively the positive and negative option realized semivariances. The remaining measures are defined as in equation (15).[23]

Tables 1 and 2 convey in three panels the regression results for SPY and the individual equities. Panels A, B, and C of each table report the one-day ($h = 1$), one-week ($h = 5$), and one-month ($h = 22$) coefficients and their corresponding robust t-statistics in parentheses. The t-statistics in Table 1 are estimated using Newey-West robust standard errors.[24] The regression results reported in Table 2 are estimated using a panel regression framework with firm fixed effects, and the t-statistics are estimated using clustered robust standard errors. Adjusted R^2s (R^2_{adj}) are reported in the last row of the tables. The first column of each panel presents the results for the baseline model. The other columns report the results with respect to the OTM call and put $\mathcal{ORV}$ and semivariances.

First, we focus on the stock market index results (Table 1). The coefficients of past RVs are generally significant, confirming the high persistence feature of RV. In addition, we find that whereas IV displays a strong and positive link with future RV, JV predicts negatively the future RV and is only significant at the daily horizon. The strong predictability of IV

[23] To avoid issues with extreme observations, throughout the study we winsorize the option realized measures at the 0.5% and 99.5% levels.

[24] The t-statistics are estimated using Newey and West (1987) HAC robust standard errors, with a lag-length equal to $\max\left[\left\lfloor 4\left(\frac{T}{100}\right)^{\frac{2}{9}}\right\rfloor, h\right]$. The first term corresponds to the optimal length of the Barlett kernel, and h denotes the forecast horizon.

decays as the forecasting horizon lengthens. However, it provides evidence on the importance of augmenting the HAR model with forward-looking information (e.g., Busch et al., 2011).

Turning our attention to models augmented with the option realized (semi)variances, we observe that whereas the OTM call $\mathcal{ORV}$ is generally insignificant, the OTM put $\mathcal{ORV}$ positively predicts future RV, albeit mostly at shorter horizons. In contrast, we document a significant predictive power afforded by the negative semivariance of a call ($\mathcal{ORV}^-$) and the positive semivariance of a put ($\mathcal{ORV}^+$). As the call (put) option moves in the same (opposite) direction of the underlying asset, the call $\mathcal{ORV}^-$ and the put $\mathcal{ORV}^+$ contain information about the underlying downside risk. In addition, the semivariances related to the underlying upside risk generally render negative and insignificant coefficients. This finding implies that only call $\mathcal{ORV}^-$ and put $\mathcal{ORV}^+$ carry a incremental information to predict future RV.

Although our decomposition uncovers a predictability for the call $\mathcal{ORV}^-$, our results suggest that, on average, the put $\mathcal{ORV}^+$ plays a more important role in predicting future RV. To illustrate, the coefficients of the call $\mathcal{ORV}^-$ are always significant at the 5% level, while those of the put $\mathcal{ORV}^+$ are significant at the 1% (5%) for $h = \{1, 5\}$ ($h = 22$). The positive coefficient of the downside semivariances imply that an increase in call $\mathcal{ORV}^-$ or put $\mathcal{ORV}^+$ raises the future SPY price variations. In other words, a 2-standard deviation increase in OTM put $\mathcal{ORV}^+(h = 1)$ predicts a rise of approximately 36% in the annual RV.

The results for the individual equities, reported in Table 2, confirm that past RV and IV are strong predictors of future RV. In contrast to the results for the index where only the put $\mathcal{ORV}$ is significant across all forecasting horizons, for the individual equities both call and put $\mathcal{ORV}$ are significant and positively related to future RV. In addition, we also corroborate the downside risk channel, as the call $\mathcal{ORV}^-$ and the put $\mathcal{ORV}^+$ subsume all the information contained in their corresponding aggregate $\mathcal{ORV}$. We document a consistent increase in the t-stats of the put $\mathcal{ORV}^+$ relative to its aggregate counterpart. For instance, the t-stat of the put $\mathcal{ORV}^+$ at $h = 1$ and $h = 22$ is 2.90 and 3.27, while for the same horizons the t-stats of the put $\mathcal{ORV}$ equal 2.31 and 2.63, respectively.

Table 1: Predicting SPY RV with Option Realized Semivariances

		Call ($K/S = 1.10$)		Put ($K/S = 0.90$)			Call ($K/S = 1.10$)		Put ($K/S = 0.90$)			Call ($K/S = 1.10$)		Put ($K/S = 0.90$)	
	Panel A: $h = 1$					Panel B: $h = 5$					Panel C: $h = 22$				
β_0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(−3.351)	(−3.708)	(−3.734)	(−3.945)	(−3.956)	(−1.917)	(−2.547)	(−2.549)	(−2.930)	(−2.746)	(2.825)	(1.343)	(1.172)	(0.434)	(0.549)
β_d	0.228	0.220	0.221	0.193	0.197	0.283	0.273	0.273	0.243	0.245	0.072	0.037	0.036	0.022	0.025
	(2.837)	(2.753)	(2.819)	(2.396)	(2.482)	(3.475)	(3.285)	(3.278)	(2.940)	(2.942)	(1.665)	(0.814)	(0.781)	(0.424)	(0.499)
β_w	0.402	0.403	0.409	0.406	0.409	0.374	0.376	0.380	0.379	0.382	0.291	0.296	0.300	0.296	0.299
	(3.177)	(3.179)	(3.243)	(3.228)	(3.275)	(2.342)	(2.356)	(2.387)	(2.409)	(2.439)	(2.122)	(2.181)	(2.213)	(2.197)	(2.214)
β_m	−0.310	−0.308	−0.303	−0.297	−0.291	−0.191	−0.188	−0.183	−0.176	−0.170	0.015	0.026	0.031	0.034	0.038
	(−2.709)	(−2.700)	(−2.696)	(−2.629)	(−2.599)	(−1.159)	(−1.136)	(−1.111)	(−1.065)	(−1.025)	(0.084)	(0.142)	(0.168)	(0.189)	(0.214)
β_{JV}	−1.260	−1.266	−1.243	−1.269	−1.253	−0.788	−0.796	−0.778	−0.799	−0.782	0.803	0.777	0.793	0.790	0.809
	(−2.036)	(−2.049)	(−2.040)	(−2.080)	(−2.049)	(−1.441)	(−1.476)	(−1.458)	(−1.507)	(−1.478)	(1.383)	(1.472)	(1.517)	(1.463)	(1.485)
β_{IV}	0.664	0.660	0.646	0.666	0.654	0.624	0.619	0.608	0.627	0.616	0.243	0.227	0.216	0.246	0.236
	(5.194)	(5.212)	(5.247)	(5.261)	(5.215)	(5.303)	(5.271)	(5.117)	(5.244)	(5.049)	(2.229)	(2.077)	(1.963)	(2.245)	(2.144)
β_{ORV}		0.065		0.233			0.090		0.269			0.285		0.330	
		(1.355)		(2.924)			(1.309)		(2.476)			(1.790)		(1.747)	
β_{ORV^+}			−0.209		0.532			−0.129		0.542			0.097		0.550
			(−1.802)		(3.407)			(−1.162)		(2.711)			(0.729)		(2.076)
β_{ORV^-}			0.349		−0.098			0.315		−0.004			0.508		0.100
			(2.442)		(−0.550)			(2.121)		(−0.020)			(2.113)		(0.495)
R^2_{adj}	63.434%	63.461%	63.646%	63.673%	63.802%	67.177%	67.228%	67.323%	67.455%	67.561%	47.678%	48.803%	48.990%	48.482%	48.166%

Notes: This table presents the results of the HAR regression models in the spirit of Corsi (2009), as illustrated in regression models 15, 16, and 17, where the dependent variable is the SPY realized variance over future horizons with $h \in (1, 5, 22)$ days ahead presented in Panel A, B, and C, respectively. $\mathcal{ORV}$ is the option realized variance for SPY OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). $\mathcal{ORV}^+$and $\mathcal{ORV}^-$are the option realized semivariances for SPY OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). $RV_t^{(d)}$, $RV_t^{(w)}$, and $RV_t^{(m)}$ are the daily, weekly, and monthly levels of realized variances. JV_t is the jump variation over the last day. IV is the ATM options implied volatility, in variance form, with a maturity of 30 days, over the last day. t-stats are reported in parentheses and reflect robust Newey-West standard errors. Adjusted-R^2 are reported in the last row (%). The sample period is from January 11, 2005 to December 31, 2021, at a daily frequency.

Table 2: Predicting Equity RV with Option Realized Semivariances

		Call ($K/S = 1.10$)		Put ($K/S = 0.90$)			Call ($K/S = 1.10$)		Put ($K/S = 0.90$)			Call ($K/S = 1.10$)		Put ($K/S = 0.90$)	
	Panel A: $h = 1$					Panel B: $h = 5$					Panel C: $h = 22$				
β_d	0.348	0.343	0.344	0.343	0.344	0.211	0.205	0.205	0.204	0.205	0.087	0.083	0.083	0.082	0.082
	(6.455)	(6.273)	(6.283)	(6.259)	(6.294)	(5.663)	(5.380)	(5.389)	(5.397)	(5.431)	(4.390)	(4.115)	(4.105)	(4.247)	(4.272)
β_w	0.151	0.151	0.151	0.151	0.152	0.246	0.246	0.246	0.246	0.247	0.131	0.131	0.130	0.131	0.131
	(1.698)	(1.691)	(1.692)	(1.692)	(1.706)	(3.596)	(3.577)	(3.578)	(3.582)	(3.588)	(4.425)	(4.411)	(4.407)	(4.429)	(4.453)
β_m	−0.077	−0.079	−0.078	−0.077	−0.076	0.027	0.026	0.026	0.028	0.028	0.173	0.171	0.171	0.173	0.173
	(−2.623)	(−2.646)	(−2.642)	(−2.598)	(−2.562)	(0.457)	(0.428)	(0.433)	(0.459)	(0.469)	(3.036)	(3.005)	(3.009)	(3.033)	(3.042)
β_{JV}	−0.294	−0.296	−0.296	−0.295	−0.295	−0.158	−0.161	−0.160	−0.159	−0.159	−0.030	−0.032	−0.031	−0.030	−0.030
	(−1.442)	(−1.456)	(−1.453)	(−1.448)	(−1.451)	(−1.403)	(−1.439)	(−1.431)	(−1.420)	(−1.423)	(−0.391)	(−0.418)	(−0.409)	(−0.399)	(−0.401)
β_{IV}	0.597	0.602	0.601	0.600	0.598	0.665	0.671	0.671	0.669	0.668	0.385	0.390	0.390	0.389	0.387
	(10.278)	(10.412)	(10.407)	(10.392)	(10.394)	(12.677)	(12.688)	(12.677)	(12.691)	(12.653)	(6.162)	(6.206)	(6.197)	(6.244)	(6.200)
β_{ORV}		0.105		0.152			0.136		0.177			0.097		0.149	
		(2.847)		(2.306)			(2.874)		(2.232)			(3.112)		(2.630)	
β_{ORV^+}			0.085		0.328			0.070		0.259			0.032		0.240
			(1.482)		(2.901)			(1.312)		(2.580)			(0.901)		(3.271)
β_{ORV^-}			0.108		−0.133			0.215		0.029			0.189		−0.003
			(2.039)		(−2.363)			(2.830)		(0.446)			(2.696)		(−0.051)
R^2_{adj}	57.396%	57.423%	57.418%	57.427%	57.443%	61.512%	61.554%	61.555%	61.550%	61.551%	52.039%	52.081%	52.091%	52.093%	52.099%

Notes: This table presents the results of the HAR regression models in the spirit of Corsi (2009), as illustrated in regression models 15, 16, and 17, where the dependent variable is the individual equity realized variance over future horizons with $h \in (1, 5, 22)$ days ahead presented in Panel A, B, and C, respectively. $\mathcal{ORV}$ is the option realized variance for the individual equities OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). $\mathcal{ORV}^+$and $\mathcal{ORV}^-$are the option realized semivariances for the individual equities OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). $RV_t^{(\mathrm{d})}$, $RV_t^{(\mathrm{w})}$, and $RV_t^{(\mathrm{m})}$ are the daily, weekly, and monthly levels of realized variances. JV_t is the jump variation over the last day. IV is the ATM options implied volatility, in variance form, with a maturity of 30 days, over the last day. The models are estimated in a panel framework with firms fixed effect. t-stats are reported in parentheses and reflect robust Newey-West standard errors. Adjusted-R^2 are reported in the last row (%). The sample period is from January 2, 2004 to December 31, 2021, at a daily frequency.

In sum, from this first empirical analysis, we document that most of the incremental information content of the option realized measures is attained by the (positive) negative semivariance of OTM put (call), subsuming most of the information in the aggregate $\mathcal{ORV}$. These results suggest that only the semivariances related to downside risk carry a positive and significant predictive power for future RV.

4.2 Option Realized Signed Jumps

Previous research reported that realized jumps extracted from stock data were only of limited value for forecasting RV (e.g. Andersen et al., 2007; Busch et al., 2011). This suggests that the impact of jumps depends critically on their sign, and such impact may be offset in a measure that does not distinguish between positive and negative jumps. Motivated by these findings, in this section we assess whether the option realized jumps and signed jumps contain incremental information to predict future RV. To do so, we adopt the following models:

$$RV_{t+1:t+h} = \beta_0 + \beta_d RV_t^{(\mathrm{d})} + \beta_w RV_t^{(\mathrm{w})} + \beta_m RV_t^{(\mathrm{m})} + \beta_{JV} JV_t + \beta_{IV} IV_t + \beta_{\mathcal{ORJ}} \mathcal{ORJ}_t + \varepsilon_{t+1:t+h}, \tag{18}$$

$$RV_{t+1:t+h} = \beta_0 + \beta_d RV_t^{(\mathrm{d})} + \beta_w RV_t^{(\mathrm{w})} + \beta_m RV_t^{(\mathrm{m})} + \beta_{JV} JV_t + \beta_{IV} IV_t + \beta_{\mathcal{ORJ}^+} \mathcal{ORJ}^+{}_t + \beta_{\mathcal{ORJ}^-} \mathcal{ORJ}^-{}_t + \varepsilon_{t+1:t+h}, \tag{19}$$

where the $\mathcal{ORJ}$ is the option realized jump component, and the $\mathcal{ORJ}^+$ and $\mathcal{ORJ}^-$ are the positive and negative option realized signed jumps. The remaining variables are defined as in equation (15).

Tables 3 and 4 report the SPY and individual equity results. The structure of the tables follows that presented in Section 4.1. As shown in Table 3, the option realized jump is always insignificant, irrespective of the option and forecasting horizon under analysis. This finding confirms our prior regarding that the impact of jumps depends critically on their sign, and in order to uncover their incremental information we need to discriminate between upside and downside jump risk.

The signed jumps display a similar pattern uncovered for the semivariances, confirming the stronger incremental information attained by the measures related to the underlying downside risk. That is, $\mathcal{ORJ}^-$ for calls and $\mathcal{ORJ}^+$ for puts are the main risk components containing predictive information about future RV at any horizon. Whereas the coefficient of the put $\mathcal{ORJ}^+$ is positive, the one of the call $\mathcal{ORJ}^-$ is negative. Please note that the $\mathcal{ORJ}^-$ is negative by construction, implying that a negative coefficient increases future RV. For instance, a 2-standard deviation increase (decrease) in the OTM put (call) $\mathcal{ORJ}^+$ ($\mathcal{ORJ}^-$) predicts a rise of approximately 42% (33%) of the next day ($h = 1$) annual RV. This result shows that the coefficient associated with the signed jumps reflect a greater effect vis-à-vis the semivariances in predicting RV when both are found to be significant.

The results for the individual equities (Table 4), the $\mathcal{ORJ}$ is still found to be insignificant across all forecasting horizons, while the option signed jumps show a strong predictive power documented through the downside risk channel. The differences between the aggregate and signed jumps are striking. To illustrate, focusing on $h = 22$, we find that the coefficient of the call and put $\mathcal{ORJ}$ are both indistinctly from zero with very insignificant t-stats (call $\beta_{ORJ} = 0.02$ with t-stat=0.47, and put $\beta_{ORJ} = 0.03$ with t-stat=0.51). By contrast, our proposed signed jumps show coefficients that are highly significant (call $\beta_{ORJ^-} = -0.14$ with t-stat=-2.22, and put $\beta_{ORJ^+} = 0.36$ with t-stat=4.14).

Although we document that the downside risk of calls and puts are important predictors of future RV, we find that the coefficient of the put $\mathcal{ORJ}^+$ is both larger, in absolute terms, and more significant than that of the call $\mathcal{ORJ}^-$. A plausible rationale for this finding is related to the fact that investors dislike bad uncertainty as it increases the likelihood of severe losses. The upside risk of a put option, captured by the $\mathcal{ORJ}^+$ component, better reflects this aversion, thereby leading to a greater future RV increase compared to the downside risk of a call option.

Table 3: Predicting SPY RV with Option Realized Signed Jumps

	Panel A: $h=1$	Call ($K/S=1.10$)		Put ($K/S=0.90$)		Panel B: $h=5$	Call ($K/S=1.10$)		Put ($K/S=0.90$)		Panel C: $h=22$	Call ($K/S=1.10$)		Put ($K/S=0.90$)	
β_0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(−3.351)	(−3.226)	(−3.512)	(−3.282)	(−3.652)	(−1.917)	(−1.863)	(−2.436)	(−1.934)	(−2.558)	(2.825)	(2.730)	(2.405)	(2.384)	(2.036)
β_d	0.228	0.227	0.223	0.227	0.213	0.283	0.285	0.279	0.281	0.272	0.072	0.070	0.062	0.072	0.056
	(2.837)	(2.799)	(2.804)	(2.805)	(2.742)	(3.475)	(3.475)	(3.405)	(3.476)	(3.264)	(1.665)	(1.587)	(1.431)	(1.580)	(1.242)
β_w	0.402	0.402	0.407	0.402	0.409	0.374	0.374	0.378	0.374	0.380	0.291	0.291	0.293	0.291	0.296
	(3.177)	(3.176)	(3.234)	(3.178)	(3.304)	(2.342)	(2.344)	(2.372)	(2.341)	(2.414)	(2.122)	(2.123)	(2.152)	(2.124)	(2.181)
β_m	−0.310	−0.310	−0.304	−0.310	−0.294	−0.191	−0.191	−0.186	−0.191	−0.178	0.015	0.016	0.021	0.015	0.029
	(−2.709)	(−2.714)	(−2.700)	(−2.708)	(−2.637)	(−1.159)	(−1.162)	(−1.126)	(−1.158)	(−1.071)	(0.084)	(0.087)	(0.114)	(0.084)	(0.161)
β_{JV}	−1.260	−1.259	−1.243	−1.259	−1.262	−0.788	−0.788	−0.776	−0.787	−0.788	0.803	0.804	0.801	0.803	0.793
	(−2.036)	(−2.038)	(−2.034)	(−2.037)	(−2.056)	(−1.441)	(−1.439)	(−1.442)	(−1.444)	(−1.459)	(1.383)	(1.387)	(1.446)	(1.383)	(1.416)
β_{IV}	0.664	0.664	0.649	0.665	0.651	0.624	0.624	0.614	0.627	0.613	0.243	0.243	0.232	0.243	0.235
	(5.194)	(5.189)	(5.254)	(5.182)	(5.211)	(5.303)	(5.301)	(5.138)	(5.301)	(5.065)	(2.229)	(2.230)	(2.104)	(2.212)	(2.134)
β_{ORJ}		0.061		0.090			−0.083		0.147			0.148		0.011	
		(0.380)		(0.645)			(−0.580)		(0.748)			(0.799)		(0.042)	
β_{ORJ^+}			−0.028		0.846			−0.012		0.688			0.249		0.727
			(−0.271)		(3.168)			(−0.111)		(2.482)			(1.354)		(2.055)
β_{ORJ^-}			−0.530		−0.080			−0.409		−0.027			−0.615		−0.254
			(−2.267)		(−0.394)			(−1.914)		(−0.129)			(−2.135)		(−0.937)
R^2_{adj}	63.434%	63.427%	63.697%	63.428%	63.857%	67.177%	67.172%	67.304%	67.175%	67.417%	47.678%	47.683%	48.264%	47.665%	48.166%

Notes: This table presents the results of the HAR regression models in the spirit of Corsi (2009), as illustrated in regression models 15, 18, and 19, where the dependent variable is the SPY realized variance over future horizons with $h \in (1, 5, 22)$ days ahead presented in Panel A, B, and C, respectively. $\mathcal{ORJ}$ is the option realized jump component for SPY OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). $\mathcal{ORJ}^+$and $\mathcal{ORJ}^-$are the option realized signed jumps for SPY OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). $RV_t^{(\mathrm{d})}$, $RV_t^{(\mathrm{w})}$, and $RV_t^{(\mathrm{m})}$ are the daily, weekly, and monthly levels of realized variances. JV_t is the jump variation over the last day. IV is the ATM options implied volatility, in variance form, with a maturity of 30 days, over the last day. t-stats are reported in parentheses and reflect robust Newey-West standard errors. Adjusted-R^2 are reported in the last row (%). The sample period is from January 11, 2005 to December 31, 2021, at a daily frequency.

Table 4: Predicting Equity RV with Option Realized Signed Jumps

	Panel A: $h = 1$	Call ($K/S = 1.10$)		Put ($K/S = 0.90$)		Panel B: $h = 5$	Call ($K/S = 1.10$)		Put ($K/S = 0.90$)		Panel C: $h = 22$	Call ($K/S = 1.10$)		Put ($K/S = 0.90$)	
β_d	0.348	0.347	0.346	0.347	0.344	0.211	0.210	0.209	0.210	0.208	0.087	0.087	0.086	0.087	0.084
	(6.455)	(6.390)	(6.351)	(6.406)	(6.363)	(5.663)	(5.610)	(5.543)	(5.626)	(5.569)	(4.390)	(4.343)	(4.275)	(4.354)	(4.283)
β_w	0.151	0.151	0.151	0.151	0.153	0.246	0.246	0.246	0.246	0.247	0.131	0.131	0.131	0.131	0.132
	(1.698)	(1.695)	(1.694)	(1.697)	(1.712)	(3.596)	(3.591)	(3.589)	(3.594)	(3.605)	(4.425)	(4.426)	(4.420)	(4.424)	(4.468)
β_m	−0.077	−0.078	−0.078	−0.077	−0.075	0.027	0.027	0.027	0.027	0.029	0.173	0.172	0.172	0.173	0.174
	(−2.623)	(−2.625)	(−2.634)	(−2.620)	(−2.539)	(0.457)	(0.452)	(0.454)	(0.458)	(0.475)	(3.036)	(3.034)	(3.033)	(3.036)	(3.050)
β_{JV}	−0.294	−0.296	−0.296	−0.295	−0.295	−0.158	−0.160	−0.159	−0.159	−0.159	−0.030	−0.030	−0.030	−0.030	−0.031
	(−1.442)	(−1.454)	(−1.450)	(−1.446)	(−1.459)	(−1.403)	(−1.419)	(−1.412)	(−1.408)	(−1.421)	(−0.391)	(−0.395)	(−0.394)	(−0.392)	(−0.408)
β_{IV}	0.597	0.599	0.600	0.598	0.597	0.665	0.667	0.667	0.666	0.665	0.385	0.386	0.386	0.385	0.386
	(10.278)	(10.295)	(10.352)	(10.292)	(10.353)	(12.677)	(12.647)	(12.589)	(12.666)	(12.669)	(6.162)	(6.142)	(6.138)	(6.153)	(6.161)
β_{ORJ}		0.130		0.118			0.116		0.099			0.021		0.028	
		(1.597)		(1.206)			(1.618)		(1.251)			(0.465)		(0.514)	
β_{ORJ^+}			0.156		0.518			0.086		0.344			0.022		0.361
			(1.866)		(2.979)			(1.057)		(2.752)			(0.457)		(4.143)
β_{ORJ^-}			−0.193		0.003			−0.191		0.004			−0.141		−0.073
			(−2.528)		(0.042)			(−2.112)		(0.078)			(−2.216)		(−1.229)
R^2_{adj}	57.396%	57.404%	57.411%	57.399%	57.456%	61.512%	61.518%	61.519%	61.513%	61.535%	52.039%	52.039%	52.045%	52.039%	52.090%

Notes: This table presents the results of the HAR regression models in the spirit of Corsi (2009), as illustrated in regression models 15, 18, and 19, where the dependent variable is the individual equity realized variance over future horizons with $h \in (1, 5, 22)$ days ahead presented in Panel A, B, and C, respectively. $\mathcal{ORJ}$ is the option realized jump component for the individual equities OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). $\mathcal{ORJ}^+$and $\mathcal{ORJ}^-$are the option realized signed jumps for the individual equities OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). $RV_t^{(d)}$, $RV_t^{(w)}$, and $RV_t^{(m)}$ are the daily, weekly, and monthly levels of realized variances. JV_t is the jump variation over the last day. IV is the ATM options implied volatility, in variance form, with a maturity of 30 days, over the last day. The models are estimated in a panel framework with firms fixed effect. t-stats are reported in parentheses and reflect robust Newey-West standard errors. Adjusted-R^2 are reported in the last row (%). The sample period is from January 2, 2004 to December 31, 2021, at a daily frequency.

In sum, we document that our option realized signed jumps related to the downside risk of call and put options possess strong predictive power for the future RV, across all forecasting horizons, while the aggregate option realized jump is always insignificant. Hence, failing to properly disentangle the upside from the downside risk leads to uninformative option realized jumps.

4.3 Robustness Checks

There is ample empirical evidence that the volatility of positive and negative returns is not necessarily equivalent (Bollerslev, 2022). Building on this rationale, Patton and Sheppard (2015) proposed an extension of the HAR model, which replaces the daily RV with the positive and negative semivariances. Motivated by their framework, this section investigates whether our option realized measures, specifically the option realized signed measures, offer additional incremental information compared to the signed measures estimated under the physical measure using high-frequency equity data.[25] To do so, we replace the daily RV (JV) with the positive and negative semivariances (signed jumps) in models (16) and (17) ((18) and (19)).

The robustness results are presented in Tables C1–C4. We begin by examining the SHAR model, which replaces the daily RV with their semivariances (RV^+ and RV^-). The results for SPY and individual equities are reported in Tables C1 and C2, respectively. As can be seen, the option realized semivariances, related to the downside risk of the underlying asset, are significant across all forecasting horizons for both SPY and individual stocks. In contrast, the predictive power of the aggregate option realized variance yields mixed results, primarily showing significance for short horizons. Noteworthy, for SPY, we observe that the coefficient of the underlying negative semivariance (β_d^-) is always significant in the benchmark SHAR model. However, it renders insignificant once the model is augmented with the option realized semivariances. This finding underscores the richer information content of the option realized

[25] The estimation of the underlying realized semivariances and signed jumps is conducted using equations (9) and (11), respectively, applied to high-frequency equity data sampled at 5-minute intervals.

semivariances, as they encompass and surpass the information contained in the underlying semivariance measures.

The results for the option realized signed jumps are outlined in Tables C3–C4 for SPY and individual equity, respectively. This benchmark model replaces the underlying jump variation with its positive and negative signed jumps (JV^+ and JV^-). The findings exhibit qualitatively similarities to those reported for the semivariances. However, the option aggregate jump component is typically insignificant across all forecasting horizons. In contrast, the option realized signed jumps are consistently significant irrespective of the horizon. Notably, for SPY, the underlying negative jump also becomes insignificant after the inclusions of the option realized signed jumps. This finding reveals the non-trivial predictive power of the option realized signed measures, supporting the downside risk channel.

Finally, as an additional robustness check, we also consider the Corsi and Renò (2012) HAR leverage model, which incorporates the daily, weekly and monthly values of the negative returns. Our results remain both qualitatively and quantitatively similar. For sake of brevity, these results are available upon request.

5 Predicting the Variance Risk Premium

There is vast evidence supporting that both past "realized" price jumps and volatility play an important role in explaining the variance risk-premium (e.g. Todorov, 2010). In addition, Bollerslev et al. (2015) show that a large fraction of the variance risk premium comes from compensation demanded by investors for bearing downside risk. Motivated by these findings, this section examines whether our option realized signed measures can explain future VRP. We define the VRP as the difference between the ex-ante risk-neutral expectation of the future return variance and ex-post realized return variance over the interval $[t+1, t+h]$:[26]

$$VRP_{t+1:t+h} = \frac{1}{h}\left(\mathrm{E}_t^{\mathbb{Q}}\left[RV_{t+1:t+h}\right] - RV_{t+1:t+h}\right),$$

where the risk-neutral expectation is proxied by the 30-day IV in variance form scaled at the daily level and the RV is the daily realized variance estimated using 5-min return.

We study the predictability of the future index and individual equity variance risk premia, as measured by VRP, over forecasting horizons of one-day ($h = 1$), one-week ($h = 5$) and one-month ($h = 22$) ahead. Our baseline model is outlined as:

$$VRP_{t+1:t+h} = \beta_0 + \beta_{RV} RV_t + \beta_{JV} JV_t + \beta_{VRP} VRP_t + \varepsilon_{t+1:t+h}, \tag{20}$$

where RV, JV are the realized variance and jump variation at time t, and VRP is the daily variance risk-premium computed as the difference between the daily implied and realized variance at time t. For individual equities, the baseline model is estimated using panel regressions with firm fixed effects.[27]

5.1 Option Realized Semivariances

Focusing first on the information content of the realized (semi)variances, we augment the baseline models by adding the aggregate $\mathcal{ORV}$ and the option realized semivariances into

[26] We compute the risk premia as a short position in a variance swap, namely, as the difference between risk neutral and physical expectations of returns (e.g. Bollerslev et al., 2009; Bekaert and Hoerova, 2014). Other studies follow the definition as in Carr and Wu (2008), namely, as the difference between physical and risk neutral expectations of return variation. The same definition is applied in Kilic and Shaliastovich (2019).

[27] To avoid multicollinearity issues, we consider the RV and IV separately in the regression model. Results for IV are qualitatively similar and are reported in Appendix C.

the baseline model as follows:

$$VRP_{t+1:t+h} = \beta_0 + \beta_{RV} RV_t + \beta_{JV} JV_t + \beta_{VRP} VRP_t + \beta_{\mathcal{ORV}} \mathcal{ORV}_t + \varepsilon_{t+1:t+h}, \tag{21}$$

$$\begin{aligned} VRP_{t+1:t+h} = \beta_0 + \beta_{RV} RV_t + \beta_{JV} JV_t + \beta_{VRP} VRP_t + \beta_{\mathcal{ORV}^+} \mathcal{ORV}_t^+ \\ + \beta_{\mathcal{ORV}^-} \mathcal{ORV}_t^- + \varepsilon_{t+1:t+h}, \end{aligned} \tag{22}$$

where $\mathcal{ORV}$ is the aggregate option realized variance, and $\mathcal{ORV}^+$ and $\mathcal{ORV}^-$ are respectively the positive and negative option realized semivariances. The remaining variables are defined as in equation (20). Tables 5 and 6 report in three panels the regression results for SPY and the individual equities. Panels A, B, and C of each table convey the one-day ($h = 1$), one-week ($h = 5$), and one-month ($h = 22$) coefficients and their corresponding robust t-statistics in parentheses. The t-statistics in Table 5 are estimated using Newey-West robust standard errors,[28] while for Table 6 the t-statistics are estimated using clustered robust standard errors. The last row reports the adjusted R^2 (R^2_{adj}). The first column of each panel presents the results for the baseline model, while the other columns report the results with the respect to the OTM call and put $\mathcal{ORV}$ and semivariances ($\mathcal{ORV}^+$ and $\mathcal{ORV}^-$).

The results for SPY (Table 5) show that the lagged VRP is strongly significant across all forecasting horizons. This result is not surprising as the VRP is also a very persistent measure. As per the RV and JV, we find that the sign of their coefficients is horizon dependent, and they are only significant when predicting one-month and one-day VRP, respectively. In addition, we note that from the aggregate $\mathcal{ORV}$s, only the put $\mathcal{ORV}$ significantly predicts future VRP. In contrast, when we decompose the $\mathcal{ORV}$s, we find that the call $\mathcal{ORV}^-$ and put $\mathcal{ORV}^+$ emerge as significant predictors of future VRP, which is in line with the results documented for RV. These relations are statistically significant at the 5% level for calls and at the 1% level for puts. The incremental information content afforded by the option realized semivariances is also clear from the adjusted R^2 (R^2_{adj}) of the regressions. For in-

[28] We refer to Section 4.1 for more details on the lags for the HAC standard errors.

stance, for the one-day ahead predictions, the R^2_{adj} associated with the baseline model and the model augmented with put $\mathcal{ORV}$ is 13.19% and 13.69%, respectively, while for the mode augmented with the put semivariances the R^2_{adj} is 14.20%, outperforming the baseline model by 100 basis points.

However, it is interesting to note that our measures now display a negative coefficient. We rationalize this finding using $\mathcal{ORV}$ as follows. As noted in Section 4, $\mathcal{ORV}$ positively predict future RV (see Tables 1 and 2). Thereby, an increase in the $\mathcal{ORV}$, *ceteris paribus*, would increase the RV, this quantity would then enter the VRP equation with a negative sign, yielding a decrease in future VRP.[29]

The results for the individual equities, reported in Table 6, confirm the relevance of both call- and put-based option realized measures to predict future VRP, with these relations being always significant, at least, at the 5% level. The option realized semivariances of either calls and puts significantly predict future VRP also through the downside risk channel previously discussed for SPY. More importantly, while the role of the aggregate $\mathcal{ORV}$'s declines as the horizon lengthens, as noted by a decrease in their t-statistics, the significance of the coefficient of the put $\mathcal{ORV}^+$ and call $\mathcal{ORV}^-$ increases with the forecasting horizon, suggesting that our proposed decomposition can better capture the information contained in the dynamics of the high-frequency option returns.

[29]Please note that if VRP is estimated as in Carr and Wu (2008), Kilic and Shaliastovich (2019) and Amaya et al. (2022), the relationship between future VRP and the proposed option realized measures will be reversed.

Table 5: Predicting SPY VRP with Option Realized Semivariances

		Call ($K/S=1.10$)		Put ($K/S=0.90$)			Call ($K/S=1.10$)		Put ($K/S=0.90$)			Call ($K/S=1.10$)		Put ($K/S=0.90$)	
	Panel A: $h=1$					Panel B: $h=5$					Panel C: $h=22$				
β_0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(3.569)	(3.972)	(4.025)	(4.241)	(4.254)	(4.119)	(4.542)	(4.567)	(4.669)	(4.543)	(3.373)	(4.057)	(4.047)	(3.724)	(3.723)
β_{RV}	−0.052	−0.048	−0.045	−0.035	−0.037	0.053	0.055	0.058	0.068	0.067	0.201	0.211	0.213	0.212	0.211
	(−0.666)	(−0.610)	(−0.567)	(−0.449)	(−0.471)	(0.619)	(0.626)	(0.657)	(0.793)	(0.783)	(4.334)	(4.620)	(4.705)	(4.769)	(4.760)
β_{JV}	1.225	1.227	1.208	1.234	1.219	0.759	0.761	0.744	0.768	0.754	−0.140	−0.132	−0.142	−0.134	−0.143
	(2.719)	(2.728)	(2.737)	(2.784)	(2.731)	(1.599)	(1.602)	(1.582)	(1.630)	(1.592)	(−0.731)	(−0.721)	(−0.777)	(−0.738)	(−0.772)
β_{VRP}	0.349	0.349	0.355	0.335	0.341	0.484	0.484	0.489	0.472	0.476	0.394	0.395	0.398	0.385	0.388
	(3.194)	(3.202)	(3.312)	(3.109)	(3.179)	(5.536)	(5.533)	(5.614)	(5.401)	(5.466)	(6.800)	(6.905)	(7.041)	(6.623)	(6.715)
β_{ORV}		−0.003		−0.021			−0.001		−0.019			−0.007		−0.013	
		(−0.607)		(−2.930)			(−0.241)		(−2.381)			(−1.167)		(−1.890)	
β_{ORV^+}			0.023		−0.057			0.020		−0.052			0.005		−0.031
			(2.030)		(−3.796)			(2.359)		(−3.435)			(0.746)		(−2.920)
β_{ORV^-}			−0.029		0.022			−0.023		0.018			−0.021		0.007
			(−2.347)		(1.369)			(−1.953)		(1.764)			(−2.102)		(1.113)
R^2_{adj}	13.190%	13.185%	13.619%	13.692%	14.200%	23.627%	23.614%	24.032%	24.206%	24.810%	34.677%	35.090%	35.473%	35.404%	35.778%

Notes: This table presents the results of the regression models 20, 21, and 22, where the dependent variable is the SPY variance risk premium defined as: $VRP_{t+1:t+h} = \frac{1}{h}\left(\mathrm{E}_t^{\mathbb{Q}}\left[RV_{t+1:t+h}\right] - RV_{t+1:t+h}\right)$, over future horizons with $h \in (1, 5, 22)$ days ahead presented in Panel A, B, and C, respectively. $\mathcal{ORV}$ is the option realized variance for SPY OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). $\mathcal{ORV}^+$and $\mathcal{ORV}^-$are the option realized semivariances for SPY OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). RV, is the daily level of realized variances. JV_t is the jump variation over the last day. VRP is the variance risk premium over the previous day. t-stats are reported in parentheses and reflect robust Newey-West standard errors. Adjusted-R^2 are reported in the last row (%). The sample period is from January 11, 2005 to December 31, 2021, at a daily frequency.

Table 6: Predicting Equity VRP with Option Realized Semivariances

		Call ($K/S=1.10$)		Put ($K/S=0.90$)			Call ($K/S=1.10$)		Put ($K/S=0.90$)			Call ($K/S=1.10$)		Put ($K/S=0.90$)	
	Panel A: $h=1$					Panel B: $h=5$					Panel C: $h=22$				
β_{RV}	−0.054	−0.053	−0.053	−0.052	−0.053	0.015	0.016	0.017	0.017	0.016	0.090	0.091	0.091	0.091	0.091
	(−1.276)	(−1.244)	(−1.246)	(−1.234)	(−1.244)	(0.412)	(0.448)	(0.451)	(0.458)	(0.449)	(3.883)	(3.914)	(3.919)	(3.914)	(3.904)
β_{JV}	0.217	0.219	0.218	0.217	0.217	0.085	0.087	0.086	0.085	0.085	0.044	0.045	0.045	0.045	0.045
	(1.158)	(1.172)	(1.169)	(1.165)	(1.167)	(0.753)	(0.781)	(0.774)	(0.767)	(0.767)	(0.523)	(0.537)	(0.532)	(0.527)	(0.527)
β_{VRP}	0.348	0.345	0.346	0.345	0.346	0.337	0.334	0.334	0.334	0.335	0.252	0.251	0.251	0.251	0.251
	(12.511)	(12.404)	(12.413)	(12.376)	(12.447)	(7.842)	(7.723)	(7.731)	(7.739)	(7.754)	(14.730)	(14.582)	(14.614)	(14.673)	(14.729)
β_{ORV}		−0.009		−0.014			−0.010		−0.013			−0.005		−0.006	
		(−2.578)		(−2.164)			(−3.061)		(−2.268)			(−2.230)		(−2.164)	
β_{ORV^+}			−0.007		−0.031			−0.004		−0.020			−0.002		−0.013
			(−1.194)		(−2.754)			(−1.015)		(−2.515)			(−0.570)		(−2.921)
β_{ORV^-}			−0.010		0.012			−0.018		−0.001			−0.010		0.004
			(−1.948)		(1.457)			(−2.972)		(−0.280)			(−2.746)		(1.939)
R^2_{adj}	15.352%	15.395%	15.387%	15.410%	15.442%	14.133%	14.215%	14.221%	14.207%	14.211%	12.925%	12.978%	12.989%	12.965%	12.986%

Notes: This table presents the results of the regression models 20, 21, and 22, where the dependent variable is the individual equity variance risk premium defined as: $VRP_{t+1:t+h} = \frac{1}{h}\left(\mathrm{E}_t^{\mathbb{Q}}\left[RV_{t+1:t+h}\right] - RV_{t+1:t+h}\right)$, over future horizons with $h \in (1, 5, 22)$ days ahead presented in Panel A, B, and C, respectively. $\mathcal{ORV}$ is the option realized variance for individual equities OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). $\mathcal{ORV}^+$and $\mathcal{ORV}^-$ are the option realized semivariances for the individual equities OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). RV, is the daily level of realized variances. JV_t is the jump variation over the last day. VRP is the variance risk premium over the previous day. t-stats are reported in parentheses and reflect robust Newey-West standard errors. Adjusted-R^2 are reported in the last row (%). The sample period is from January 2, 2004 to December 31, 2021, at a daily frequency.

5.2 Option Realized Signed Jumps

The previous section shows that the role of past RV and JV is limited to the month and daily horizon, respectively, while the option realized semivariances are strong predictors of future VRP. Thus, in this section we assess whether the option realized (signed) jumps can further explain future VRP by employing the following models:

$$VRP_{t+1:t+h} = \beta_0 + \beta_{RV} RV_t + \beta_{JV} JV_t + \beta_{VRP} VRP_t + \beta_{\mathcal{ORJ}} \mathcal{ORJ}_t + \varepsilon_{t+1:t+h}, \tag{23}$$

$$\begin{aligned} VRP_{t+1:t+h} = {} & \beta_0 + \beta_{RV} RV_t + \beta_{JV} JV_t + \beta_{VRP} VRP_t + \beta_{\mathcal{ORJ}^+} \mathcal{ORJ}_t^+ \\ & + \beta_{\mathcal{ORJ}^-} \mathcal{ORJ}_t^- + \varepsilon_{t+1:t+h}, \end{aligned} \tag{24}$$

where $\mathcal{ORJ}$ is the aggregate option realized jump and the $\mathcal{ORJ}^+$ and $\mathcal{ORJ}^-$ are the positive and negative option realized signed jumps. The remaining variables are defined as in equation (20). The results for SPY and individual equities are reported respectively in Tables 7 and 8. The tables are structured as in Section 5.1.

Several conclusion can be drawn from these results. First, we corroborate that past RV and JV only predict future VRP to a limited extent. Second, while the aggregate option realized jump shows no predictive power at all forecasting horizons, the option realized signed jumps related to the downside risk of calls and upside risk of puts emerge as a strong predictor of future VRP irrespective of the forecasting horizon. Third, the incremental information afforded by the option realized signed jumps is directly reflected in a greater R^2_{adj}. To illustrate, when the baseline model, for SPY, is augmented with option signed jumps estimated using OTM puts, the R^2_{adj} of the models outperform that of the benchmark by 139, 112 and 87 basis points at the daily, weekly and monthly horizon, respectively. Finally, these results unambiguously show that the richer information content of the option price jumps can only be uncovered using measures that successfully capture the option dynamics pertaining to the positive and negative option returns.

Table 7: Predicting SPY VRP with Option Realized Signed Jumps

		Call ($K/S = 1.10$)		Put ($K/S = 0.90$)			Call ($K/S = 1.10$)		Put ($K/S = 0.90$)			Call ($K/S = 1.10$)		Put ($K/S = 0.90$)	
	Panel A: $h = 1$					Panel B: $h = 5$					Panel C: $h = 22$				
β_0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(3.569)	(3.486)	(3.780)	(3.555)	(3.840)	(4.119)	(4.033)	(4.540)	(4.109)	(4.471)	(3.373)	(3.465)	(4.108)	(3.255)	(3.523)
β_{RV}	−0.052	−0.051	−0.042	−0.052	−0.044	0.053	0.053	0.060	0.053	0.058	0.201	0.202	0.207	0.201	0.204
	(−0.666)	(−0.661)	(−0.551)	(−0.667)	(−0.567)	(0.619)	(0.616)	(0.695)	(0.616)	(0.674)	(4.334)	(4.355)	(4.548)	(4.321)	(4.513)
β_{JV}	1.225	1.224	1.211	1.225	1.228	0.759	0.760	0.746	0.759	0.756	−0.140	−0.140	−0.143	−0.140	−0.139
	(2.719)	(2.725)	(2.731)	(2.721)	(2.757)	(1.599)	(1.598)	(1.580)	(1.602)	(1.593)	(−0.731)	(−0.732)	(−0.770)	(−0.740)	(−0.750)
β_{VRP}	0.349	0.348	0.355	0.348	0.344	0.484	0.484	0.489	0.481	0.482	0.394	0.394	0.397	0.392	0.392
	(3.194)	(3.184)	(3.315)	(3.184)	(3.204)	(5.536)	(5.532)	(5.610)	(5.462)	(5.558)	(6.800)	(6.792)	(6.946)	(6.652)	(6.812)
β_{ORJ}		−0.009		−0.005			0.004		−0.021			−0.005		−0.018	
		(−0.677)		(−0.422)			(0.364)		(−1.383)			(−0.471)		(−1.393)	
β_{ORJ^+}			0.002		−0.089			0.007		−0.065			−0.005		−0.038
			(0.299)		(−3.312)			(1.047)		(−2.964)			(−0.569)		(−2.286)
β_{ORJ^-}			0.050		0.005			0.035		−0.011			0.028		0.000
			(2.280)		(0.258)			(2.005)		(−0.703)			(2.274)		(0.026)
R^2_{adj}	13.190%	13.263%	13.909%	13.254%	14.577%	23.627%	23.684%	24.174%	23.732%	24.749%	34.677%	34.735%	35.382%	34.811%	35.547%

Notes: This table presents the results of the regression models 20, 23, and 24, where the dependent variable is the SPY variance risk premium defined as: $VRP_{t+1:t+h} = \frac{1}{h}\left(\mathrm{E}_t^{\mathbb{Q}}\left[RV_{t+1:t+h}\right] - RV_{t+1:t+h}\right)$, over future horizons with $h \in (1, 5, 22)$ days ahead presented in Panel A, B, and C, respectively. $\mathcal{ORJ}$ is the option realized jump component for SPY OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). $\mathcal{ORJ}^+$and $\mathcal{ORJ}^-$are the option realized signed jumps for SPY OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). RV, is the daily level of realized variances. JV_t is the jump variation over the last day. VRP is the variance risk premium over the previous day. t-stats are reported in parentheses and reflect robust Newey-West standard errors. Adjusted-R^2 are reported in the last row (%). The sample period is from January 11, 2005 to December 31, 2021, at a daily frequency.

Table 8: Predicting Equity VRP with Option Realized Signed Jumps

		Call ($K/S=1.10$)		Put ($K/S=0.90$)			Call ($K/S=1.10$)		Put ($K/S=0.90$)			Call ($K/S=1.10$)		Put ($K/S=0.90$)	
	Panel A: $h=1$					Panel B: $h=5$					Panel C: $h=22$				
β_{RV}	−0.054	−0.054	−0.054	−0.054	−0.054	0.015	0.015	0.015	0.015	0.015	0.090	0.090	0.090	0.090	0.090
	(−1.276)	(−1.281)	(−1.284)	(−1.277)	(−1.273)	(0.412)	(0.404)	(0.404)	(0.408)	(0.415)	(3.883)	(3.873)	(3.881)	(3.878)	(3.887)
β_{JV}	0.217	0.218	0.218	0.217	0.218	0.085	0.086	0.085	0.085	0.086	0.044	0.045	0.044	0.045	0.045
	(1.158)	(1.171)	(1.167)	(1.162)	(1.177)	(0.753)	(0.767)	(0.760)	(0.757)	(0.764)	(0.523)	(0.531)	(0.524)	(0.525)	(0.530)
β_{VRP}	0.348	0.347	0.346	0.348	0.345	0.337	0.336	0.336	0.337	0.336	0.252	0.252	0.252	0.252	0.252
	(12.511)	(12.303)	(12.408)	(12.359)	(12.446)	(7.842)	(7.758)	(7.747)	(7.800)	(7.779)	(14.730)	(14.510)	(14.603)	(14.601)	(14.706)
β_{ORJ}		−0.013		−0.012			−0.012		−0.011			−0.006		−0.005	
		(−1.597)		(−1.230)			(−1.861)		(−1.332)			(−1.176)		(−0.789)	
β_{ORJ^+}			−0.013		−0.050			−0.006		−0.026			−0.001		−0.016
			(−1.676)		(−2.855)			(−1.001)		(−2.531)			(−0.224)		(−3.256)
β_{ORJ^-}			0.019		0.003			0.018		−0.003			0.006		−0.006
			(2.292)		(0.288)			(2.152)		(−0.515)			(1.540)		(−1.725)
R^2_{adj}	15.352%	15.369%	15.378%	15.358%	15.471%	14.133%	14.155%	14.153%	14.139%	14.180%	12.925%	12.940%	12.929%	12.928%	12.981%

Notes: This table presents the results of the regression models 20, 23, and 24, where the dependent variable is the individual equity variance risk premium defined as: $VRP_{t+1:t+h} = \frac{1}{h}\left(\mathrm{E}_t^{\mathbb{Q}}\left[RV_{t+1:t+h}\right] - RV_{t+1:t+h}\right)$, over future horizons with $h \in (1, 5, 22)$ days ahead presented in Panel A, B, and C, respectively. $\mathcal{ORJ}$ is the option realized jump component for the individual equities OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). $\mathcal{ORJ}^+$ and $\mathcal{ORJ}^-$ are the option realized signed jumps for the individual equities OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). RV, is the daily level of realized variances. JV_t is the jump variation over the last day. VRP is the variance risk premium over the previous day. t-stats are reported in parentheses and reflect robust Newey-West standard errors. Adjusted-R^2 are reported in the last row (%). The sample period is from January 2, 2004 to December 31, 2021, at a daily frequency.

5.3 Robustness Checks

The baseline model employed in the previous sections, motivated by the findings in Todorov (2010), considers mainly controls estimated under the physical measure. Thus, we now assess the predictability of the option realized measures after controlling for other variables specially related to the options market, asset distribution asymmetry and tail risk. In particular, we consider the ATM 30-day implied volatility (IV), in variance form, as defined in Section 4, the risk-neutral skewness (RNS) (Bakshi et al., 2003) and the Jump-Tail Index (JTI) (Du and Kapadia, 2012).[30]

Tables C5 and C7 (Tables C6 and C8), in Appendix C, report the results for the SPY (individual equities) option realized semivariances and signed jumps, respectively. As can be seen, our previous findings are robust to controlling for the different measures extracted from option data. In particular, we find that only the option realized semivariances and signed jump measures related to the underlying downside risk are consistently significant across all forecasting horizons.[31] In contrast, we find that the sign and the significance of the new controls are horizon dependent. This holds true for SPY and the individual equities, and irrespective whether we consider the option realized semivariances or signed jumps.

In sum, we document that our proposed option realized signed measures possess strong predictive power for the variance risk-premium of both the SPY and individual equities. In addition, we find that the informational content of our proposed option realized signed measures is robust to controlling for standard predictors normally employed in the literature.[32] This suggests that our proposed measures contain non-trivial information, which successfully complement that of standard predictors related to both aggregate and downside risk

[30] More details about these variables can be found in Appendix A.

[31] The results in terms of predictive power for the option realized (signed) measures remain qualitatively and quantitatively unchanged when we replace the RNS with the $Skew$ (or $SPRD$) in our regressions. For more details about these variables, see Appendix A.

[32] For the sake of completeness, we have also replaced the aggregate underlying RV and JV with the corresponding semivariances and signed jumps as we showed when predicting future RV in subsection 4.3. The significance of our option realized measures hold, and the results are qualitatively and quantitatively similar.

extracted from low-frequency options data.

6 Predicting Excess Returns

Hitherto, we have shown that the option realized (signed) measures are good determinants of RV and VRP. Furthermore, there is extensive empirical evidence that, at relatively low-frequencies (monthly or longer), measures of volatility and downside risk strongly predict future excess returns. However, although from a risk-return perspective we should expect a positive relation, the low-frequency literature have documented both a positive and negative relation giving rise to the so-called volatility puzzle hypothesis (e.g. Ang et al., 2006; Stambaugh et al., 2015; Hou and Loh, 2016, *inter alia*). In this section, we aim at shedding light on this relation, in the short-term, by assessing the informational content of our option realized signed measures to predict excess returns for horizons of up to one month.

Thus, our predictive model considers a number of additional explanatory variables and firm characteristics commonly employed in the literature. These include the weekly reversal (REV) (e.g. Lehmann, 1990; Jegadeesh, 1990), momentum (MoM) (e.g. Jegadeesh and Titman, 1993), illiquidity (Illiq) (e.g. Amihud, 2002), stock market value (Size) (e.g., Fama and French, 1993), and option volume (OptV) (e.g. Pan and Poteshman, 2006). The construction of each of these variables follow standard procedures, as further detailed in Appendix A. We construct the controls for both SPY and the individual equities. Our baseline model is outlined as:

$$R_{t+1:t+h} = \alpha + \beta_{RV} RV_t + \beta_{JV} JV_t + \beta_{IV} IV_t + \beta_{REV} REV_t + \beta_{MoM} MoM_t + \beta_{Illiq} Illiq_t + \beta_{Size} Size_t + \beta_{OptV} OptV_t + \varepsilon_{t+1:t+h}, \quad (25)$$

where $R_{t+1:t+h}$ is the (log) excess return, and we use one-month T-bill rate as a proxy for the risk-free rate; as usual, $h \in (1, 5, 22)$ is our predictive horizon, and for forecasts larger than one day, we cumulate the excess return from $t+1$ to $t+h$ (scaled by the horizon) as in Bollerslev et al. (2009, 2014). RV, JV and IV are the respective past daily realized variance, jump variation and the OptionMetrics ATM 30-day implied volatility, in variance form. For the individual equities, the baseline model is estimated panel regressions with firm fixed effects.[33]

6.1 Option Realized Semivariances

We start by first focusing on the predictive power of the option realized semivariances. Thus, we augment the baseline model as follows:

$$R_{t+1:t+h} = \alpha + \mathbf{\Lambda}'\mathbf{\Pi}_t + \beta_{\mathcal{ORV}}\mathcal{ORV}_t + \varepsilon_{t+1:t+h}, \tag{26}$$

$$R_{t+1:t+h} = \alpha + \mathbf{\Lambda}'\mathbf{\Pi}_t + \beta_{\mathcal{ORV}^+}\mathcal{ORV}^+{}_t + \beta_{\mathcal{ORV}^-}\mathcal{ORV}^-{}_t + \varepsilon_{t+1:t+h}, \tag{27}$$

where $\mathcal{ORV}$ is the option realized variance, while $\mathcal{ORV}^+$ and $\mathcal{ORV}^-$ are the positive and negative option realized semivariances, respectively. $\mathbf{\Pi}$ is the matrix of predictors outlined in equation (25), and $\mathbf{\Lambda}$ is the vector of coefficients. Tables 9 and 10 report in three panels the predictive regression results for SPY and the individual equities. Panels A, B, and C of each table convey the one-day ($h = 1$), one-week ($h = 5$), and one-month ($h = 22$) coefficients and their corresponding robust t-statistics in parentheses. The t-statistics in Table 9 are estimated using Newey-West robust standard errors;[34] for Table 10 the t-statistics are estimated using clustered robust standard errors.

Several conclusions can be drawn from Tables 9 and 10. First, besides RV, for SPY, and REV and $OptV$, for individual equities, none of the controls are significant across all forecasting horizons. This implies that the impact of controls on future excess return is horizon-dependent. Second, we find a negative relation between the option realized semivariances and future excess returns.

[33] Our results are qualitatively similar irrespective whether we consider close-to-close or open-to-close returns.

[34] We refer to Section 4.1 for more details on the lags for the HAC standard errors.

We interpret this as follows. As the put $\mathcal{ORV}^+$ and the call $\mathcal{ORV}^-$ capture information about the underlying downside risk, an increase in either of these measures triggers a moment of distress that persists over the short horizon, thereby producing negative realizations of future excess return. Third, while this negative relation is predominantly significant at the month horizon for SPY, we note that for individual equities the semivariances of the call (put) play a more important role at shorter (longer) horizons. More importantly, we corroborate the superior information content afforded by the option realized semivariances related to downside risk, i.e. put $\mathcal{ORV}^+$ and call $\mathcal{ORV}^-$, with the put $\mathcal{ORV}^+$ being significant at the 1% level for both SPY and individual equities at the month horizon. In fact, we observe that the R^2_{adj}s of the models that include the option realized measures are generally larger, especially for those including semivariances.

6.2 Option Realized Signed Jumps

We now turn to the relationship between the option realized signed jumps and excess returns. To do so, we rely on the following models:

$$R_{t+1:t+h} = \alpha + \mathbf{\Lambda}'\mathbf{\Pi}_t + \beta_{\mathcal{ORJ}}\mathcal{ORJ}_t + \varepsilon_{t+1:t+h}, \tag{28}$$

$$R_{t+1:t+h} = \alpha + \mathbf{\Lambda}'\mathbf{\Pi}_t + \beta_{\mathcal{ORJ}^+}\mathcal{ORJ}^+{}_t + \beta_{\mathcal{ORJ}^-}\mathcal{ORJ}^-{}_t + \varepsilon_{t+1:t+h}, \tag{29}$$

where $\mathcal{ORJ}$ is the aggregate option realized jump, and the $\mathcal{ORJ}^+$ and $\mathcal{ORJ}^-$ are the positive and negative option realized signed jumps, respectively. The remaining variables are defined as in equation (25). Tables 11 and 12 report the results for SPY and the individual equities respectively. The structure of the tables are identical to that outlined for Tables 9 and 10.

Table 9: Predicting SPY Excess Return with Option Realized Semivariances

		Call ($K/S = 1.10$)		Put ($K/S = 0.90$)			Call ($K/S = 1.10$)		Put ($K/S = 0.90$)			Call ($K/S = 1.10$)		Put ($K/S = 0.90$)	
	Panel A: $h = 1$					Panel B: $h = 5$					Panel C: $h = 22$				
α	−0.006	−0.005	−0.005	−0.004	−0.004	−0.001	0.000	0.000	0.001	0.001	0.002	0.003	0.003	0.003	0.003
	(−1.064)	(−0.857)	(−0.827)	(−0.707)	(−0.617)	(−0.187)	(0.024)	(0.051)	(0.152)	(0.150)	(0.547)	(0.892)	(0.942)	(1.017)	(1.036)
β_{RV}	−4.831	−4.433	−4.501	−4.224	−3.875	−3.938	−3.598	−3.585	−3.404	−3.522	−1.946	−1.592	−1.614	−1.453	−1.504
	(−2.077)	(−1.897)	(−1.925)	(−1.750)	(−1.611)	(−2.604)	(−2.344)	(−2.323)	(−2.177)	(−2.240)	(−3.177)	(−2.620)	(−2.632)	(−2.347)	(−2.413)
β_{JV}	15.068	15.741	15.601	15.745	15.614	8.994	9.570	9.580	9.590	9.404	−6.505	−5.907	−5.961	−5.956	−6.117
	(0.479)	(0.497)	(0.492)	(0.497)	(0.498)	(0.843)	(0.921)	(0.924)	(0.919)	(0.902)	(−1.543)	(−1.621)	(−1.661)	(−1.588)	(−1.606)
β_{IV}	5.626	5.474	5.527	4.960	4.683	2.006	1.876	1.864	1.420	1.505	1.871	1.736	1.753	1.331	1.364
	(2.079)	(2.036)	(2.053)	(1.737)	(1.642)	(0.760)	(0.718)	(0.712)	(0.534)	(0.567)	(1.600)	(1.524)	(1.546)	(1.123)	(1.157)
β_{REV}	−0.029	−0.030	−0.031	−0.032	−0.032	−0.019	−0.020	−0.020	−0.022	−0.023	−0.002	−0.003	−0.004	−0.005	−0.005
	(−2.205)	(−2.282)	(−2.330)	(−2.417)	(−2.389)	(−2.081)	(−2.181)	(−2.203)	(−2.382)	(−2.437)	(−0.671)	(−1.022)	(−1.260)	(−1.659)	(−1.871)
β_{MoM}	0.002	0.002	0.002	0.002	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(1.218)	(1.077)	(1.065)	(1.068)	(0.992)	(0.323)	(0.198)	(0.186)	(0.188)	(0.200)	(0.178)	(−0.013)	(−0.034)	(−0.007)	(−0.007)
β_{Illiq}	0.681	0.670	0.672	0.763	0.804	1.752	1.742	1.752	1.824	1.821	0.417	0.408	0.413	0.484	0.487
	(0.514)	(0.507)	(0.508)	(0.576)	(0.605)	(1.633)	(1.627)	(1.638)	(1.712)	(1.713)	(0.707)	(0.702)	(0.709)	(0.822)	(0.829)
β_{Size}	0.502	0.402	0.387	0.343	0.304	0.013	−0.073	−0.084	−0.127	−0.128	−0.190	−0.279	−0.292	−0.319	−0.325
	(1.025)	(0.830)	(0.801)	(0.690)	(0.613)	(0.030)	(−0.170)	(−0.196)	(−0.286)	(−0.290)	(−0.717)	(−1.043)	(−1.091)	(−1.158)	(−1.178)
β_{OptV}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(−0.494)	(−0.099)	(−0.062)	(0.008)	(0.151)	(1.768)	(2.269)	(2.295)	(2.207)	(2.240)	(3.633)	(4.394)	(4.389)	(4.055)	(4.144)
β_{ORV}		−0.424		−0.549			−0.363		−0.483			−0.377		−0.445	
		(−1.357)		(−1.154)			(−1.639)		(−1.635)			(−2.009)		(−2.131)	
β_{ORV^+}			−0.129		−0.150			−0.336		−0.852			−0.231		−0.691
			(−0.220)		(−0.197)			(−1.078)		(−1.738)			(−1.240)		(−2.700)
β_{ORV^-}			−0.758		−1.472			−0.448		−0.082			−0.579		−0.238
			(−1.199)		(−1.487)			(−1.050)		(−0.163)			(−2.245)		(−0.945)
R^2_{adj}	0.458%	0.501%	0.486%	0.485%	0.522%	1.334%	1.487%	1.474%	1.453%	1.455%	4.934%	6.195%	6.281%	5.726%	5.821%

Notes: This table presents the results of the regression models 25, 26, and 28, where the dependent variable is the SPY excess return defined as the SPY (log) excess returns over future horizons with $h \in (1, 5, 22)$ days ahead presented in Panel A, B, and C, respectively. $\mathcal{ORV}$ is the option realized variance for SPY OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). $\mathcal{ORJ}$ is the option realized jump component for SPY OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). RV, is the daily level of realized variances. JV_t is the jump variation over the last day. RV_t is the past daily realized variance, JV_t is the jump variation over the previous day, IV_t is the ATM 30-day implied volatility (in variance form), REV is the weekly reversal (e.g. Lehmann, 1990; Jegadeesh, 1990), MoM is the medium-term price momentum (see Jegadeesh and Titman, 1993), $Illiq$ is the illiquidity ratio by Amihud (2002), $Size$ is the stock's market value, and $OptV$ is the option total trading volume (e.g. Pan and Poteshman, 2006). t-stats are reported in parentheses and reflect robust Newey-West standard errors. Adjusted-R^2 are reported in the last row (%). The sample period is from January 11, 2005 to December 31, 2021, at a daily frequency.

Table 10: Predicting Equity Excess Returns with Option Realized Semivariances

	Panel A: $h=1$					Panel B: $h=5$					Panel C: $h=22$				
		Call ($K/S=1.10$)		Put ($K/S=0.90$)			Call ($K/S=1.10$)		Put ($K/S=0.90$)			Call ($K/S=1.10$)		Put ($K/S=0.90$)	
β_{RV}	−0.127	−0.065	−0.077	−0.025	−0.052	−0.482	−0.454	−0.452	−0.437	−0.448	−0.419	−0.421	−0.417	−0.409	−0.416
	(−0.239)	(−0.120)	(−0.143)	(−0.047)	(−0.096)	(−1.115)	(−1.028)	(−1.025)	(−1.006)	(−1.025)	(−4.978)	(−5.057)	(−4.954)	(−4.908)	(−4.959)
β_{JV}	10.181	10.206	10.181	10.187	10.193	2.919	2.931	2.922	2.922	2.925	−0.006	−0.007	−0.007	−0.005	−0.005
	(2.084)	(2.093)	(2.090)	(2.097)	(2.093)	(1.857)	(1.860)	(1.856)	(1.852)	(1.856)	(−0.014)	(−0.015)	(−0.016)	(−0.012)	(−0.011)
β_{IV}	0.832	0.790	0.800	0.756	0.774	1.454	1.434	1.434	1.420	1.428	0.829	0.831	0.828	0.822	0.827
	(1.294)	(1.222)	(1.231)	(1.179)	(1.197)	(3.411)	(3.322)	(3.319)	(3.309)	(3.307)	(5.044)	(5.018)	(4.978)	(4.905)	(4.939)
β_{REV}	−0.016	−0.016	−0.017	−0.017	−0.017	−0.014	−0.014	−0.014	−0.014	−0.014	−0.004	−0.004	−0.004	−0.004	−0.004
	(−3.267)	(−3.253)	(−3.428)	(−3.365)	(−3.372)	(−4.472)	(−4.462)	(−4.565)	(−4.557)	(−4.566)	(−3.905)	(−3.922)	(−4.034)	(−4.057)	(−4.100)
β_{MoM}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(−0.298)	(−0.268)	(−0.261)	(−0.234)	(−0.249)	(−0.581)	(−0.570)	(−0.564)	(−0.557)	(−0.559)	(−1.222)	(−1.224)	(−1.220)	(−1.212)	(−1.211)
β_{Illiq}	−0.008	−0.007	−0.007	−0.007	−0.007	−0.008	−0.007	−0.007	−0.007	−0.007	0.007	0.007	0.008	0.008	0.007
	(−0.802)	(−0.772)	(−0.768)	(−0.734)	(−0.750)	(−0.772)	(−0.748)	(−0.742)	(−0.729)	(−0.742)	(1.413)	(1.408)	(1.411)	(1.409)	(1.401)
β_{Size}	−0.010	0.002	−0.001	−0.006	−0.009	−0.082	−0.076	−0.076	−0.080	−0.081	0.018	0.017	0.018	0.018	0.018
	(−0.075)	(0.014)	(−0.008)	(−0.047)	(−0.070)	(−0.490)	(−0.464)	(−0.464)	(−0.483)	(−0.491)	(0.112)	(0.109)	(0.115)	(0.115)	(0.115)
β_{OptV}	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001
	(−1.995)	(−1.991)	(−1.995)	(−1.926)	(−1.931)	(−3.552)	(−3.601)	(−3.604)	(−3.574)	(−3.564)	(−3.328)	(−3.319)	(−3.301)	(−3.306)	(−3.307)
β_{ORV}		−0.133		−0.312			−0.061		−0.138			0.005		−0.032	
		(−1.695)		(−2.248)			(−1.392)		(−2.254)			(0.216)		(−0.958)	
β_{ORV^+}			0.148		−0.283			0.043		−0.161			0.025		−0.083
			(1.052)		(−1.449)			(0.836)		(−1.770)			(1.005)		(−2.610)
β_{ORV^-}			−0.473		−0.182			−0.221		−0.044			−0.045		0.065
			(−2.306)		(−0.717)			(−2.036)		(−0.405)			(−1.326)		(1.493)
R^2_{adj}	0.448%	0.452%	0.460%	0.464%	0.456%	0.761%	0.764%	0.770%	0.771%	0.767%	1.072%	1.071%	1.073%	1.075%	1.078%

Notes: This table presents the results of the regression models 25, 26, and 28, where the dependent variable is the individual equity's excess return defined as the equity (log) excess returns over future horizons with $h \in (1,5,22)$ days ahead presented in Panel A, B, and C, respectively. $\mathcal{ORV}$ is the option realized variance for the individual equities OTM calls ($K/S=1.10$) and OTM puts ($K/S=0.90$). $\mathcal{ORJ}$ is the option realized jump component for the individual equities OTM calls ($K/S=1.10$) and OTM puts ($K/S=0.90$). RV, is the daily level of realized variances. JV_t is the jump variation over the last day. RV_t is the past daily realized variance, JV_t is the jump variation over the previous day, IV_t is the ATM 30-day implied volatility (in variance form), REV is the weekly reversal (e.g. Lehmann, 1990; Jegadeesh, 1990), MoM is the medium-term price momentum (see Jegadeesh and Titman, 1993), $Illiq$ is the illiquidity ratio by Amihud (2002), $Size$ is the stock's market value, and $OptV$ is the option total trading volume (e.g. Pan and Poteshman, 2006). The models are estimated in a panel framework with firms fixed effect. t-stats are reported in parentheses and reflect robust Newey-West standard errors. Adjusted-R^2 are reported in the last row (%). The sample period is from 11th January 2005 to 31st December 2021, at a daily frequency. The sample period is from January 2, 2004 to December 31, 2021, at a daily frequency.

Table 11: Predicting SPY Excess Return with Option Realized Signed Jumps

		Call ($K/S = 1.10$)		Put ($K/S = 0.90$)			Call ($K/S = 1.10$)		Put ($K/S = 0.90$)			Call ($K/S = 1.10$)		Put ($K/S = 0.90$)	
	Panel A: $h = 1$					Panel B: $h = 5$					Panel C: $h = 22$				
α	−0.006	−0.007	−0.006	−0.007	−0.007	−0.001	−0.001	−0.001	−0.001	0.001	0.002	0.002	0.002	0.001	0.003
	(−1.064)	(−1.147)	(−1.071)	(−1.233)	(−1.181)	(−0.187)	(−0.216)	(−0.106)	(−0.196)	(0.103)	(0.547)	(0.622)	(0.707)	(0.461)	(0.912)
β_{RV}	−4.831	−4.923	−4.926	−5.017	−4.905	−3.938	−3.974	−3.828	−3.952	−3.773	−1.946	−1.892	−1.869	−1.992	−1.796
	(−2.077)	(−2.115)	(−2.096)	(−2.153)	(−2.057)	(−2.604)	(−2.630)	(−2.524)	(−2.610)	(−2.460)	(−3.177)	(−3.133)	(−3.168)	(−3.279)	(−2.982)
β_{JV}	15.068	15.070	14.757	15.122	14.767	8.994	8.995	9.418	8.998	9.617	−6.505	−6.506	−6.162	−6.492	−5.983
	(0.479)	(0.478)	(0.466)	(0.480)	(0.465)	(0.843)	(0.842)	(0.894)	(0.843)	(0.917)	(−1.543)	(−1.550)	(−1.585)	(−1.535)	(−1.507)
β_{IV}	5.626	5.714	5.724	5.957	5.796	2.006	2.040	1.878	2.031	1.657	1.871	1.821	1.770	1.954	1.578
	(2.079)	(2.104)	(2.080)	(2.153)	(2.053)	(0.760)	(0.775)	(0.712)	(0.760)	(0.625)	(1.600)	(1.569)	(1.523)	(1.642)	(1.358)
β_{REV}	−0.029	−0.029	−0.029	−0.028	−0.028	−0.019	−0.019	−0.020	−0.019	−0.022	−0.002	−0.002	−0.003	−0.002	−0.004
	(−2.205)	(−2.189)	(−2.223)	(−2.148)	(−2.064)	(−2.081)	(−2.074)	(−2.131)	(−2.096)	(−2.362)	(−0.671)	(−0.702)	(−1.006)	(−0.622)	(−1.315)
β_{MoM}	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
	(1.218)	(1.220)	(1.232)	(1.189)	(1.231)	(0.323)	(0.324)	(0.266)	(0.321)	(0.281)	(0.178)	(0.177)	(0.081)	(0.167)	(0.127)
β_{Illiq}	0.681	0.670	0.634	0.528	0.616	1.752	1.747	1.852	1.740	1.883	0.417	0.424	0.521	0.379	0.526
	(0.514)	(0.504)	(0.481)	(0.394)	(0.464)	(1.633)	(1.630)	(1.734)	(1.628)	(1.769)	(0.707)	(0.718)	(0.886)	(0.651)	(0.886)
β_{Size}	0.502	0.533	0.511	0.580	0.565	0.013	0.025	−0.021	0.019	−0.112	−0.190	−0.208	−0.231	−0.170	−0.290
	(1.025)	(1.099)	(1.034)	(1.187)	(1.148)	(0.030)	(0.057)	(−0.049)	(0.043)	(−0.255)	(−0.717)	(−0.786)	(−0.874)	(−0.632)	(−1.077)
β_{OptV}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(−0.494)	(−0.553)	(−0.549)	(−0.525)	(−0.668)	(1.768)	(1.738)	(2.020)	(1.760)	(2.079)	(3.633)	(3.706)	(4.192)	(3.600)	(3.994)
β_{ORJ}		0.753		1.311			0.289		0.099			−0.436		0.327	
		(0.640)		(0.899)			(0.495)		(0.138)			(−1.370)		(0.974)	
β_{ORJ^+}			0.449		0.708			−0.617		−1.367			−0.503		−1.060
			(0.487)		(0.665)			(−1.418)		(−1.991)			(−1.822)		(−2.671)
β_{ORJ^-}			−0.004		−0.305			0.542		0.695			0.776		0.643
			(−0.005)		(−0.191)			(0.925)		(0.983)			(2.476)		(1.543)
R^2_{adj}	0.458%	0.449%	0.655%	0.458%	0.658%	1.334%	1.318%	1.608%	1.311%	1.690%	4.934%	5.024%	5.862%	4.947%	5.815%

Notes: This table presents the results of the regression models 25, 27, and 29, where the dependent variable is the SPY excess return defined as the SPY (log) excess returns over future horizons with $h \in (1, 5, 22)$ days ahead presented in Panel A, B, and C, respectively. $\mathcal{ORV}^+$and $\mathcal{ORV}^-$are the option realized semivariances for SPY OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). $\mathcal{ORJ}^+$and $\mathcal{ORJ}^-$are the option realized signed jumps for SPY OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). RV, is the daily level of realized variances. JV_t is the jump variation over the last day. RV_t is the past daily realized variance, JV_t is the jump variation over the previous day, IV_t is the ATM 30-day implied volatility (in variance form), REV is the weekly reversal (e.g. Lehmann, 1990; Jegadeesh, 1990), MoM is the medium-term price momentum (see Jegadeesh and Titman, 1993), $Illiq$ is the illiquidity ratio by Amihud (2002), $Size$ is the stock's market value, and $OptV$ is the option total trading volume (e.g. Pan and Poteshman, 2006). t-stats are reported in parentheses and reflect robust Newey-West standard errors. Adjusted-R^2 are reported in the last row (%). The sample period is from January 11, 2005 to December 31, 2021, at a daily frequency.

Table 12: Predicting Equity Excess Returns with Option Realized Signed Jumps

	Panel A: $h=1$	Call ($K/S=1.10$)		Put ($K/S=0.90$)		Panel B: $h=5$	Call ($K/S=1.10$)		Put ($K/S=0.90$)		Panel C: $h=22$	Call ($K/S=1.10$)		Put ($K/S=0.90$)	
β_{RV}	-0.127	-0.121	-0.135	-0.112	-0.129	-0.482	-0.485	-0.487	-0.481	-0.466	-0.419	-0.425	-0.420	-0.422	-0.414
	(-0.239)	(-0.227)	(-0.251)	(-0.211)	(-0.242)	(-1.115)	(-1.116)	(-1.116)	(-1.113)	(-1.076)	(-4.978)	(-4.989)	(-4.948)	(-5.008)	(-4.908)
β_{JV}	10.181	10.190	10.166	10.189	10.186	2.919	2.915	2.912	2.920	2.927	-0.006	-0.014	-0.008	-0.008	-0.002
	(2.084)	(2.083)	(2.082)	(2.087)	(2.085)	(1.857)	(1.853)	(1.856)	(1.856)	(1.860)	(-0.014)	(-0.032)	(-0.019)	(-0.017)	(-0.004)
β_{IV}	0.832	0.826	0.833	0.813	0.835	1.454	1.457	1.457	1.453	1.435	0.829	0.835	0.830	0.833	0.823
	(1.294)	(1.286)	(1.281)	(1.271)	(1.283)	(3.411)	(3.400)	(3.384)	(3.406)	(3.357)	(5.044)	(5.045)	(5.019)	(5.040)	(4.972)
β_{REV}	-0.016	-0.016	-0.017	-0.016	-0.017	-0.014	-0.014	-0.014	-0.014	-0.014	-0.004	-0.004	-0.004	-0.004	-0.004
	(-3.267)	(-3.272)	(-3.451)	(-3.280)	(-3.326)	(-4.472)	(-4.490)	(-4.588)	(-4.470)	(-4.538)	(-3.905)	(-3.936)	(-4.066)	(-3.889)	(-4.083)
β_{MoM}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(-0.298)	(-0.291)	(-0.294)	(-0.281)	(-0.290)	(-0.581)	(-0.584)	(-0.580)	(-0.579)	(-0.565)	(-1.222)	(-1.233)	(-1.222)	(-1.227)	(-1.209)
β_{Illiq}	-0.008	-0.008	-0.008	-0.008	-0.008	-0.008	-0.008	-0.008	-0.008	-0.008	0.007	0.007	0.007	0.007	0.008
	(-0.802)	(-0.800)	(-0.799)	(-0.778)	(-0.804)	(-0.772)	(-0.778)	(-0.775)	(-0.768)	(-0.752)	(1.413)	(1.406)	(1.413)	(1.402)	(1.415)
β_{Size}	-0.010	-0.006	-0.012	-0.007	-0.009	-0.082	-0.084	-0.083	-0.081	-0.082	0.018	0.014	0.017	0.017	0.018
	(-0.075)	(-0.044)	(-0.089)	(-0.055)	(-0.068)	(-0.490)	(-0.500)	(-0.493)	(-0.489)	(-0.495)	(0.112)	(0.086)	(0.110)	(0.108)	(0.113)
β_{OptV}	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	(-1.995)	(-1.998)	(-2.004)	(-2.002)	(-1.989)	(-3.552)	(-3.539)	(-3.552)	(-3.554)	(-3.580)	(-3.328)	(-3.309)	(-3.320)	(-3.333)	(-3.272)
β_{ORJ}		-0.072		-0.287			0.037		-0.019			0.069		0.062	
		(-0.652)		(-1.806)			(0.392)		(-0.154)			(1.429)		(1.389)	
β_{ORJ^+}			0.200		-0.139			0.091		-0.206			0.030		-0.126
			(1.287)		(-0.610)			(1.663)		(-1.694)			(1.239)		(-3.012)
β_{ORJ^-}			0.461		-0.205			0.159		0.129			0.062		-0.018
			(2.250)		(-0.628)			(1.446)		(0.953)			(2.202)		(-0.428)
R^2_{adj}	0.448%	0.446%	0.454%	0.449%	0.446%	0.761%	0.759%	0.762%	0.759%	0.763%	1.072%	1.079%	1.074%	1.074%	1.083%

Notes: This table presents the results of the regression models 25, 27, and 29, where the dependent variable is the individual equity's excess return defined as the equity (log) excess returns over future horizons with $h \in (1, 5, 22)$ days ahead presented in Panel A, B, and C, respectively. $\mathcal{ORV}^+$and $\mathcal{ORV}^-$are the option realized semivariances for the individual equities OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). $\mathcal{ORJ}^+$and $\mathcal{ORJ}^-$are the option realized signed jumps for individual equities OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). RV, is the daily level of realized variances. JV_t is the jump variation over the last day. RV_t is the past daily realized variance, JV_t is the jump variation over the previous day, IV_t is the ATM 30-day implied volatility (in variance form), REV is the weekly reversal (e.g. Lehmann, 1990; Jegadeesh, 1990), MoM is the medium-term price momentum (see Jegadeesh and Titman, 1993), $Illiq$ is the illiquidity ratio by Amihud (2002), $Size$ is the stock's market value, and $OptV$ is the option total trading volume (e.g. Pan and Poteshman, 2006). t-stats are reported in parentheses and reflect robust Newey-West standard errors. Adjusted-R^2 are reported in the last row (%). The sample period is from January 2, 2004 to December 31, 2021, at a daily frequency.

The controls display a very similar behavior to that documented in Section 6.1. That is, none of the controls are consistently significant across all the forecasting horizons, and their sign is generally horizon-dependent.

In line with our previous findings, the option realized jump is a poor predictor of future excess return, irrespective of the forecasting horizon. In contrast, the put $\mathcal{ORJ}^+$ and the call $\mathcal{ORJ}^-$ are important determinants of the future monthly excess returns, which are found to be significant at the 1% and 5% levels, respectively. We also detect a negative relation between the option realized signed jumps and future excess return. The negative relation of the option signed jumps and future excess returns suggests that the economic channel between the two has been characterized by the presence of different episodes in our sample in which increases in risk measures are followed by decreases in equity returns.

6.3 Robustness Checks

To further assess the information content of the option realized measures, we perform a robustness analysis that considers various popular equity premium predictors beyond those employed in the equation (25). To this end, we focus on predictors computed from historical returns and option data that are commonly associated with asymmetric behavior of stock prices and option distributions, therefore improving the completeness of our model. We consider the VRP as defined in Section 5 (e.g., Bollerslev et al., 2009; Bekaert and Hoerova, 2014), implied volatility skew (Skew) (Xing et al., 2010), volatility spread (SPRD) (Bali and Hovakimian, 2009), the maximum return (Max), the minimum return (Min) of Bali et al. (2011),[35] the risk-neutral variance (RNV) and risk-neutral skewness (RNS) of Bakshi et al. (2003), the jump tail index (JTI) of Du and Kapadia (2012), and the left tail variation of Bollerslev et al. (2015).[36] These measures are described in more detail in Appendix A.

[35] Since we carry out the robustness exercise focusing on the monthly horizon ($h = 22$), we compute the monthly Max and Min measures. However, our results are robust to the inclusion of weekly Max and Min.

[36] While we compute controls for both SPY and the individual equities, we only consider the left tail variation for the index obtained from www.tailindex.com. We refrain from computing the LTV for individual equities as for many days the strike price grid does not fulfill the required extreme moneyness.

For the sake of brevity, and given that at shorter horizons, equity premia are mainly driven by their noisy component (e.g. Stambaugh, 1999; Andersen et al., 2020), we perform our robustness exercise on monthly predictive regressions. Due to the larger number of variables adopted in this robustness exercise, Tables C9–C16 present separate results for calls and puts, from which we can draw several conclusions.

First, for SPY, we find that our previous findings are robust to controlling for popular important predictors such as VRP, LTV, Min, and RNS. This holds true irrespective whether we consider the option realized semivariances or signed jump. Second, we find that the significance of our measures is either of similar magnitude or stronger after including these new controls. This finding reaffirms that our measures provide complementary information about excess returns. Third, we also confirm the negative relation between our option realized measures and future excess returns. However, we also detect the same negative relation for other measures of downside risk, such as the LTV and Min. The fact that these measures also display a negative relation provides additional evidence that our sample is characterized by the presence of different episodes in which increases in risk measures are followed by decreases in equity returns. Finally, for the individual equities, we also confirm the robustness of our measures, and confirm that the call $\mathcal{ORJ}^-$ plays a more important for predicting equity excess return than the call $\mathcal{ORV}^-$.

In sum, we document that our option realized (signed) measures contain incremental information to predict equity premia at the month horizon. These effects are robust to several measures of volatility, jump risk, measures of asymmetry, indicating that our proposed measures provide complementary information regarding equity premia. In particular, we find that only the signed jump measures related to the underlying downside risk remain significant, suggesting that the informational content of signed jumps capture specific dynamics related to the direction of the jumps contained in both the underlying asset and risk factor, which is crucial to predict future equity premia.

7 Conclusion

In this paper, we introduce option realized semivariances and signed jumps to summarize the information contained in the sign of high-frequency option returns. Our asymmetric measures are able to capture the downside and upside risk pertaining to call and put options, thereby reflecting in a more timely manner the joint dynamics between the realized and expected asset price. We use these measures to shed light on the role of downside and upside risk of call and puts options for predicting variance, variance risk-premium, and excess returns.

Using high-frequency options written on the SPDR S&P 500 ETF (SPY) and on 15 individual equities, we find that the information content of the option realized variance is limited, and the aggregate option realized jump shows no predictive power. In contrast, our proposed option realized signed measures are important determinants of future variance, variance risk-premium, and excess returns at the month horizon. In specific, the incremental information of the option realized signed measures is found in the negative (positive) semivariances and jumps of OTM call (put) options. This result is in line with an underlying downside risk channel, as the call (put) option moves in the same (opposite) direction of the underlying asset. Thereby, the asset downside risk is related with the downside (upside) risk of a call (put) contract, which is captured by the negative (positive) option realized semivariances or signed jumps.

Finally, we show that the incremental information content afforded by our proposed option realized signed measures is robust to controlling for standard predictors estimated from stock and option data. This suggests that our measures contain complementary information about variance, variance risk-premia and monthly excess returns.

References

Aït-Sahalia, Y. (2002). Telling from discrete data whether the underlying continuous-time model is a diffusion. *The Journal of Finance 57*(5), 2075–2112.

Aït-Sahalia, Y. and D. Xiu (2019). A hausman test for the presence of market microstructure noise in high frequency data. *Journal of Econometrics 211*(1), 176–205.

Almeida, C., G. Freire, R. Garcia, and R. Hizmeri (2022). Tail risk and asset prices in the short-term. *Available at SSRN 4216981*.

Amaya, D., J.-F. Bégin, and G. Gauthier (2022). The informational content of high-frequency option prices. *Management Science 68*(3), 2166–2201.

Amihud, Y. (2002). Illiquidity and stock returns: cross-section and time-series effects. *Journal of Financial Markets 5*(1), 31–56.

Anand, A., J. Hua, and T. McCormick (2016). Make-take structure and market quality: Evidence from the US options markets. *Management Science 62*(11), 3271–3290.

Andersen, T., I. Archakov, L. Grund, N. Hautsch, Y. Li, S. Nasekin, I. Nolte, M. C. Pham, S. Taylor, and V. Todorov (2021). A descriptive study of high-frequency trade and quote option data. *Journal of Financial Econometrics 19*(1), 128–177.

Andersen, T. G., T. Bollerslev, and F. X. Diebold (2007). Roughing it up: Including jump components in the measurement, modeling, and forecasting of return volatility. *The Review of Economics and Statistics 89*(4), 701–720.

Andersen, T. G., T. Bollerslev, F. X. Diebold, and H. Ebens (2001). The distribution of realized stock return volatility. *Journal of Financial Economics 61*(1), 43–76.

Andersen, T. G., T. Bollerslev, F. X. Diebold, and P. Labys (2001). The distribution of realized exchange rate volatility. *Journal of the American Statistical Association 96*(453), 42–55.

Andersen, T. G., T. Bollerslev, F. X. Diebold, and P. Labys (2003). Modeling and forecasting realized volatility. *Econometrica 71*(2), 579–625.

Andersen, T. G., T. Bollerslev, and N. Meddahi (2011). Realized volatility forecasting and market microstructure noise. *Journal of Econometrics 160*(1), 220–234.

Andersen, T. G., O. Bondarenko, V. Todorov, and G. Tauchen (2015). The fine structure of equity-index option dynamics. *Journal of Econometrics 187*(2), 532–546.

Andersen, T. G., N. Fusari, and V. Todorov (2015). The risk premia embedded in index options. *Journal of Financial Economics 117*(3), 558–584.

Andersen, T. G., N. Fusari, and V. Todorov (2017). Short-term market risks implied by weekly options. *The Journal of Finance 72*(3), 1335–1386.

Andersen, T. G., N. Fusari, and V. Todorov (2020). The pricing of tail risk and the equity premium: evidence from international option markets. *Journal of Business & Economic Statistics 38*(3), 662–678.

Ang, A., J. Chen, and Y. Xing (2006). Downside risk. *The Review of Financial Studies 19*(4), 1191–1239.

Ang, A., R. J. Hodrick, Y. Xing, and X. Zhang (2006). The cross-section of volatility and expected returns. *The Journal of Finance 61*(1), 259–299.

Audrino, F. and M. R. Fengler (2015). Are classical option pricing models consistent with observed option second-order moments? Evidence from high-frequency data. *Journal of Banking & Finance 61*, 46–63.

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

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

Bali, T. G., N. Cakici, and R. F. Whitelaw (2011). Maxing out: Stocks as lotteries and the cross-section of expected returns. *Journal of Financial Economics 99*(2), 427–446.

Bali, T. G. and A. Hovakimian (2009). Volatility spreads and expected stock returns. *Management Science 55*(11), 1797–1812.

Barndorff-Nielsen, O., P. R. Hansen, A. Lunde, and N. Shephard (2008). Realised kernels in practice: Trades and quotes. *Econometrics Journal 4*, 1–32.

Barndorff-Nielsen, O. E., S. Kinnebrock, and N. Shephard (2010). Measuring downside risk–realised semivariance. In T. Bollerslev, J. Russell, and M. Watson (Eds.), *Volatility and Time Series Econometrics: Essays in Honor of Robert F. Engle*, Chapter 7, pp. 117–136. New York: Oxford University Press.

Barndorff-Nielsen, O. E. and N. Shephard (2002). Estimating quadratic variation using realized variance. *Journal of Applied Econometrics 17*(5), 457–477.

Barndorff-Nielsen, O. E. and N. Shephard (2004). Power and bipower variation with stochastic volatility and jumps. *Journal of Financial Econometrics 2*(1), 1–37.

Baruník, J., M. Bevilacqua, and R. Tunaru (2022). Asymmetric network connectedness of fears. *Review of Economics and Statistics 104*(6), 1304–1316.

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

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

Bollerslev, T. (2022). Realized semi (co) variation: Signs that all volatilities are not created equal. *Journal of Financial Econometrics 20*(2), 219–252.

Bollerslev, T., S. Z. Li, and B. Zhao (2020). Good volatility, bad volatility, and the cross section of stock returns. *Journal of Financial and Quantitative Analysis 55*(3), 751–781.

Bollerslev, T., J. Marrone, L. Xu, and H. Zhou (2014). Stock return predictability and variance risk premia: Statistical inference and international evidence. *Journal of Financial and Quantitative Analysis 49*(3), 633–661.

Bollerslev, T., G. Tauchen, and H. Zhou (2009). Expected stock returns and variance risk premia. *The Review of Financial Studies 22*(11), 4463–4492.

Bollerslev, T. and V. Todorov (2011a). Estimation of jump tails. *Econometrica 79*(6), 1727–1783.

Bollerslev, T. and V. Todorov (2011b). Tails, fears, and risk premia. *The Journal of Finance 66*(6), 2165–2211.

Bollerslev, T. and V. Todorov (2014). Time-varying jump tails. *Journal of Econometrics 183*(2), 168–180.

Bollerslev, T., V. Todorov, and L. Xu (2015). Tail risk premia and return predictability. *Journal of Financial Economics 118*(1), 113–134.

Broadie, M., M. Chernov, and M. Johannes (2009). Understanding index option returns. *The Review of Financial Studies 22*(11), 4493–4529.

Busch, T., B. J. Christensen, and M. Ø. Nielsen (2011). The role of implied volatility in forecasting future realized volatility and jumps in foreign exchange, stock, and bond markets. *Journal of Econometrics 160*(1), 48–57.

Carr, P. and L. Wu (2008). Variance risk premiums. *The Review of Financial Studies 22*(3), 1311–1341.

Carr, P. and L. Wu (2011). A simple robust link between American puts and credit protection. *The Review of Financial Studies 24*(2), 473–505.

Christensen, K., R. C. Oomen, and M. Podolskij (2014). Fact or friction: Jumps at ultra high frequency. *Journal of Financial Economics 114*(3), 576–599.

Christoffersen, P., K. Jacobs, and C. Ornthanalai (2012). Dynamic jump intensities and risk premiums: Evidence from S&P 500 returns and options. *Journal of Financial Economics 106*(3), 447–472.

Cont, R. and P. Tankov (2003). *Financial modelling with jump processes*. Chapman and Hall/CRC.

Corsi, F. (2009). A simple approximate long-memory model of realized volatility. *Journal of Financial Econometrics 7*(2), 174–196.

Corsi, F. and R. Renò (2012). Discrete-time volatility forecasting with persistent leverage effect and the link with continuous-time volatility modeling. *Journal of Business & Economic Statistics 30*(3), 368–380.

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

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

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

Du, J. and N. Kapadia (2012). The tail in the volatility index. *U. Massachusetts, Amherst Working paper*.

Duffie, D., J. Pan, and K. Singleton (2000). Transform analysis and asset pricing for affine jump-diffusions. *Econometrica 68*(6), 1343–1376.

Easley, D. and M. O'Hara (1992). Time and the process of security price adjustment. *The Journal of Finance 47*(2), 577–605.

Eraker, B., M. Johannes, and N. Polson (2003). The impact of jumps in volatility and returns. *The Journal of Finance 58*(3), 1269–1300.

Fama, E. F. and K. R. French (1993). Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics 33*(1), 3–56.

Farago, A. and R. Tédongap (2018). Downside risks and the cross-section of asset returns. *Journal of Financial Economics 129*(1), 69–86.

Feunou, B., M. R. Jahan-Parvar, and R. Tédongap (2013). Modeling market downside volatility. *Review of Finance 17*(1), 443–481.

Figlewski, S. (2010). Estimating the implied risk newutral density for the U.S. market portfolio. In T. Bollerslev, J. Russell, and M. Watson (Eds.), *Volatility and Time Series Econometrics: Essays in Honor of Robert F. Engle*, Chapter 15, pp. 323–353. New York: Oxford University Press.

Gottlieb, G. and A. Kalay (1985). Implications of the discreteness of observed stock prices. *The Journal of Finance 40*(1), 135–153.

Hansen, P. R. and A. Lunde (2006). Realized variance and market microstructure noise. *Journal of Business & Economic Statistics 24*(2), 127–161.

Hogan, W. W. and J. M. Warren (1974). Toward the development of an equilibrium capital-market model based on semivariance. *Journal of Financial and Quantitative Analysis 9*(1), 1–11.

Hou, K. and R. K. Loh (2016). Have we solved the idiosyncratic volatility puzzle? *Journal of Financial Economics 121*(1), 167–194.

Jacod, J., Y. Li, P. A. Mykland, M. Podolskij, and M. Vetter (2009). Microstructure noise in the continuous case: the pre-averaging approach. *Stochastic Processes and their Applications 119*(7), 2249–2276.

Jegadeesh, N. (1990). Evidence of predictable behavior of security returns. *The Journal of Finance 45*(3), 881–898.

Jegadeesh, N. and S. Titman (1993). Returns to buying winners and selling losers: Implications for stock market efficiency. *The Journal of Finance 48*(1), 65–91.

Kapetanios, G., E. Konstantinidi, M. Neumann, and G. Skiadopoulos (2019). Jumps in option prices and their determinants: Real-time evidence from the E-mini S&P 500 options market. *Journal of Financial Markets 46*, 100506.

Kilic, M. and I. Shaliastovich (2019). Good and bad variance premia and expected returns. *Management Science 65*(6), 2522–2544.

Lehmann, B. N. (1990). Fads, martingales, and market efficiency. *The Quarterly Journal of Economics 105*(1), 1–28.

Lettau, M., M. Maggiori, and M. Weber (2014). Conditional risk premia in currency markets and other asset classes. *Journal of Financial Economics 114*(2), 197–225.

Liu, L. Y., A. J. Patton, and K. Sheppard (2015). Does anything beat 5-minute RV? a comparison of realized measures across multiple asset classes. *Journal of Econometrics 187*(1), 293–311.

Muravyev, D. and N. D. Pearson (2020). Options trading costs are lower than you think. *The Review of Financial Studies 33*(11), 4973–5014.

Newey, W. K. and K. D. West (1987). A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica 55*(3), 703–708.

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

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

Patton, A. J. and K. Sheppard (2015). Good volatility, bad volatility: Signed jumps and the persistence of volatility. *Review of Economics and Statistics 97*(3), 683–697.

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

Stambaugh, R. F. (1999). Predictive regressions. *Journal of Financial Economics 54*(3), 375–421.

Stambaugh, R. F., J. Yu, and Y. Yuan (2015). Arbitrage asymmetry and the idiosyncratic volatility puzzle. *The Journal of Finance 70*(5), 1903–1948.

Todorov, V. (2010). Variance risk-premium dynamics: The role of jumps. *The Review of Financial Studies 23*(1), 345–383.

Todorov, V. (2022). Nonparametric jump variation measures from options. *Journal of Econometrics 230*(2), 255–280.

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

Zhang, L., P. A. Mykland, and Y. Aït-Sahalia (2005). A tale of two time scales: Determining integrated volatility with noisy high-frequency data. *Journal of the American Statistical Association 100*(472), 1394–1411.

Appendices

A Controls Definitions

Our empirical investigations rely on the following explanatory variables and firm characteristics.

- Reversal (REV): following Jegadeesh (1990) and Lehmann (1990), the short-term reversal variable is defined as the weekly return over the previous week from day $t-4$ to day t.

- Momentum (MoM): following Jegadeesh and Titman (1993), the momentum variable at the end of day t is defined as the compound gross return from day $t-252$ through day $t-21$, skipping the short-term reversal month.

- Illiquidity (Illiq): following Amihud (2002) the illiquidity for stock i at the end of day t is measured as the average daily ratio of the absolute stock return to the dollar trading volume from day $t-4$ through day t:

$$\text{Illiq}_{i,t} = \frac{1}{N}\sum_{d}\left(\frac{|r_{i,d}|}{\text{volume}_{\ i,d} \times \ \text{price}_{\ i,d}}\right),$$

  where volume $_{i,d}$ is the daily trading volume, $\text{price}_{i,d}$ is the daily price, and other variables are as previously defined. We further transform the illiquidity measure by its natural logarithm to reduce skewness.

- Firm's market value (Size): following Fama and French (1993), a firm's size is measured by its market value of equity, that is, the product of the closing price and the number of shares outstanding (in millions of dollars). Following common practice, we also transform the size variable by its natural logarithm to reduce skewness.

- Total Option Volume (OptV): the measure of total option volume as proxy for the total trading activity in the options market for each stock in the previous day (e.g. Pan and Poteshman, 2006).

- Variance Risk Premium (VRP): we compute the variance risk premium as a short position in a variance swap, namely, as the difference between risk neutral and physical expectations of returns (e.g. Bollerslev et al., 2009; Bekaert and Hoerova, 2014).

- Implied Volatility Skew (Skew): following Xing et al. (2010), we define the implied volatility skew as the difference between the out-of-the-money put implied volatility (with delta of -0.20) and at-the-money call implied volatility (with delta of 0.50), both using maturities of 30 days.

- Volatility Spread (SPRD): following Bali and Hovakimian (2009) and Cremers and Weinbaum (2010), the implied volatility spread is computed as the difference between the at-the-money call implied volatility (with delta of 0.50) and at-the-money put implied volatility (with delta of -0.50), using options with maturity of 30 days.

- Maximum daily return (Max): the Max variable is defined as the largest total daily raw return observed over the previous month (see Bali et al., 2011).

- Minimum daily return (Min): the Min variable is defined as the smallest total daily raw return observed over the previous month (see Bali et al., 2011).

- Risk-Neutral Variance (RNV): the RNV is the Bakshi et al. (2003) risk-neutral variance extracted model-free from options by considering a volatility contract that simultaneously involves a long position in out of the money calls and a long position in out of the money puts.

- Risk-Neutral Skewness (RNS): the RNS is the Bakshi et al. (2003) risk-neutral skewness extracted model-free from options by considering a cubic contract that simultaneously involves a long position in out of the money calls and a short position in out of the money puts.

- Jump Tail Index (JTI): the jump tail index proposed by Du and Kapadia (2012). The JTI is defined as difference between the price of the variance contract Bakshi et al. (2003) and the integrated variance (under the $\mathbb{Q}$ measure).

- Left Tail Variation (LTV): the left tail variation proposed by Bollerslev et al. (2015) is an option implied measure of short-horizon downside tail risk obtained from short-dated OTM put options. The measure is obtained from `www.tailindex.com`.

B Option Quadratic Variation

To derive the option quadratic variation (OQV) outlined in equation (6), we assume that $o_t \equiv \log(O_t)$, where $O_t \equiv O_{t,k,\tau}(S_t, X_t)$ is the option price at time t, is twice continuously differentiable. Thus, Itô's lemma for semimartingale processes can be used to derive the OQV as follows (see, Proposition 8.19 in Cont and Tankov, 2003):

$$\begin{aligned}
o_t(S_t, X_t) - o_0(S_0, X_0) = & \int_0^t \frac{\partial o_u}{\partial u}(S_u, X_u)du + \int_0^t \frac{\partial o_u}{\partial s}\left(S_{u-}, X_{u-}\right)dS_u + \int_0^t \frac{\partial o_u}{\partial x}\left(S_{u-}, X_{u-}\right)dX_u \\
& + \frac{1}{2}\int_0^t \frac{\partial^2 o_u}{\partial s^2}(S_{u-}, X_{u-})d\left[S,S\right]_u^c + \frac{1}{2}\int_0^t \frac{\partial^2 o_u}{\partial x^2}(S_{u-}, X_{u-})d\left[X,X\right]_u^c \\
& + \int_0^t \frac{\partial o_u}{\partial sx}(S_{u-}, X_{u-})d\left[S,X\right]_u^c \\
& + \sum_{0 \le u \le t}\left[o_u(S_u, X_u) - (o_u(S_{u-}, X_{u-}))^+ + o_u(S_u, X_u) - (o_u(S_{u-}, X_{u-}))^-\right] \\
& - \sum_{o \le u \le t}\left[\frac{\partial o_u}{\partial s}(S_{u-}, X_{u-})(S_u - S_{u-})^+ + \frac{\partial o_u}{\partial s}(S_{u-}, X_{u-})(S_u - S_{u-})^-\right] \\
& - \sum_{o \le u \le t}\left[\frac{\partial o_u}{\partial x}(S_{u-}, X_{u-})(X_u - X_{u-})^+ + \frac{\partial o_u}{\partial x}(S_{u-}, X_{u-})(X_u - X_{u-})^-\right],
\end{aligned}$$

where $(\cdot)^+$ and $(\cdot)^-$ denote respectively the positive and negative jumps.

Replacing equations (1) and (2), we get:

$$\begin{aligned}
o_t(S_t, X_t) - o_0(S_0, X_0) = & \int_0^t \frac{\partial o_u}{\partial u}(S_{u-}, X_{u-})du \\
& + \int_0^t \frac{\partial o_u}{\partial s}(S_{u-}, X_{u-})\left[\mu_S(X_{u-})du + \sum_{i=1}^m \sigma_{S,i}(X_{u-})dW_{i,u} + dJ_{S,u}^+ + dJ_{S,u}^-\right] \\
& + \int_0^t \frac{\partial o_u}{\partial x}(S_{u-}, X_{u-})\left[\mu_X(X_{u-})du + \sum_{i=1}^m \sigma_{X,i}(X_{u-})dW_{i,u} + dJ_{X,u}^+ + dJ_{X,u}^-\right] \\
& + \frac{1}{2}\int_0^t \frac{\partial^2 o_u}{\partial s^2}(S_{u-}, X_{u-})\sum_{i=1}^m \sigma_{S,i}^2(X_{u-})du + \frac{1}{2}\int_0^t \frac{\partial^2 o_u}{\partial x^2}(S_{u-}, X_{u-})\sum_{i=1}^m \sigma_{X,i}^2(X_{u-})du \\
& + \int_0^t \sum_{i=1}^m \frac{\partial o_u}{\partial sx}(S_{u-}, X_{u-})\sigma_{S,i}(X_{u-})\sigma_{X,i}(X_{u-})du \\
& + \sum_{0 \le u \le t}\left(o_u(S_{u-}, X_{u-}) - o_u(S_{u-}, X_{u-})^+\right) + \sum_{0 \le u \le t}\left(o_u(S_{u-}, X_{u-}) - o_u(S_{u-}, X_{u-})^-\right) \\
& - \int_0^t \frac{\partial o_u}{\partial s}(S_{u-}, X_{u-})dJ_{S,u}^+ - \int_0^t \frac{\partial o_u}{\partial s}(S_{u-}, X_{u-})dJ_{S,u}^- \\
& - \int_0^t \frac{\partial o_u}{\partial x}(S_{u-}, X_{u-})dJ_{X,u}^+ - \int_0^t \frac{\partial o_u}{\partial x}(S_{u-}, X_{u-})dJ_{X,u}^-.
\end{aligned}$$

Rearranging terms yields:

$$
\begin{aligned}
&o_t(S_t, X_t) - o_0(S_0, X_0) = \\
&= \int_0^t \left[\begin{array}{c} \frac{\partial o_u}{\partial u}(S_u, X_u) + \frac{\partial o_u}{\partial s}(S_{u-}, X_{u-})\mu_S(X_{u-}) + \frac{\partial o_u}{\partial x}(S_{u-}, X_{u-})\mu_X(X_{u-}) \\ + \sum_{i=1}^m \left(\frac{1}{2}\frac{\partial^2 o_u}{\partial s^2}(S_{u-}, X_{u-})\sigma_{S,i}^2(X_{u-}) + \frac{1}{2}\frac{\partial^2 o_u}{\partial x^2}(S_{u-}, X_{u-})\sigma_{X,i}^2(X_{u-}) \right. \\ \left. + \frac{\partial^2 o_u}{\partial sx}(S_u, X_u)\sigma_{S,i}(X_{u-})\sigma_{X,i}(X_{u-}) \right) \end{array} \right] du \\
&+ \sum_{i=1}^m \int_0^t \frac{\partial o_u}{\partial s}(S_{u-}, X_{u-})\sigma_{S,i}(X_{u-}) dW_{i,u} + \sum_{i=1}^m \int_0^t \frac{\partial o_u}{\partial x}(S_{u-}, X_{u-})\sigma_{X,i}(X_{u-}) dW_{i,u} \\
&+ \sum_{0 \le u \le t} \left(o_u(S_u, X_u) - o_u(S_{u-}, X_{u-}) \right)^+ + \sum_{0 \le u \le t} \left(o_u(S_u, X_u) - o_u(S_{u-}, X_{u-}) \right)^- .
\end{aligned}
$$

Finally, the option quadratic variation is given by the following expression:[37]

$$
\begin{aligned}
[o, o]_t = &\sum_{i=1}^m \int_0^t \left(\frac{\partial o_u}{\partial s}(S_u, X_u) \right)^2 \sigma_{S,i}^2(X_{u-}) du + \sum_{i=1}^m \int_0^t \left(\frac{\partial o_u}{\partial x}(S_u, X_u) \right)^2 \sigma_{X,i}^2(X_{u-}) du \\
&+ 2 \sum_{i=1}^m \int_0^t \left(\frac{\partial o_u}{\partial s}(S_u, X_u) \right) \left(\frac{\partial o_u}{\partial x}(S_u, X_u) \right) \sigma_{S,i}(X_{u-})\sigma_{X,i}(X_{u-}) du \\
&+ \sum_{0 \le u \le t} \left[\left(o_u(S_u, X_u) - o_u(S_{u-}, X_{u-}) \right)^+ \right]^2 + \sum_{0 \le u \le t} \left[\left(o_u(S_u, X_u) - o_u(S_{u-}, X_{u-}) \right)^- \right]^2 .
\end{aligned}
$$

□

[37] We have purposely omitted $\frac{1}{O_u^2(S_{u-}, X_{u-})}$ from the three elements of the diffusive component. This term is obtained by taking the derivative of O_u w.r.t. s and x, and its quadratic form arises because of the quadratic variation.

C Additional Results and Robustness Checks

Table C1: Predicting SPY RV with Option Realized Variance using the SHAR Model

		Call $(K/S = 1.10)$		Put $(K/S = 0.90)$			Call $(K/S = 1.10)$		Put $(K/S = 0.90)$			Call $(K/S = 1.10)$		Put $(K/S = 0.90)$	
	Panel A: $h = 1$					Panel B: $h = 5$					Panel C: $h = 22$				
β_0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(−4.322)	(−4.871)	(−4.952)	(−5.636)	(−5.767)	(−2.491)	(−2.853)	(−2.894)	(−3.359)	(−3.294)	(1.398)	(1.213)	(1.202)	(1.666)	(2.069)
β_{d^+}	0.019	−0.055	0.226	−0.173	0.154	0.206	0.166	0.363	0.041	0.332	0.537	0.440	0.641	0.531	0.937
	(0.099)	(−0.259)	(0.819)	(−0.850)	(0.528)	(0.810)	(0.570)	(1.073)	(0.153)	(0.931)	(1.325)	(1.004)	(1.250)	(1.196)	(1.478)
β_{d^-}	0.329	0.263	−0.065	−0.090	−0.421	0.474	0.438	0.219	0.114	−0.197	0.557	0.470	0.238	0.544	0.171
	(1.890)	(1.583)	(−0.246)	(−0.510)	(−1.379)	(2.311)	(2.127)	(1.059)	(0.545)	(−0.773)	(2.019)	(1.813)	(0.976)	(1.720)	(0.620)
β_w	0.571	0.567	0.570	0.538	0.540	0.579	0.577	0.579	0.551	0.551	0.325	0.320	0.322	0.324	0.329
	(6.186)	(6.102)	(6.119)	(5.765)	(5.772)	(4.137)	(4.102)	(4.109)	(3.900)	(3.914)	(2.949)	(2.874)	(2.878)	(2.874)	(2.871)
β_m	−0.390	−0.385	−0.386	−0.351	−0.351	−0.288	−0.285	−0.286	−0.254	−0.253	0.002	0.009	0.009	0.003	0.001
	(−3.234)	(−3.201)	(−3.193)	(−3.037)	(−3.027)	(−1.507)	(−1.491)	(−1.496)	(−1.359)	(−1.358)	(0.010)	(0.052)	(0.048)	(0.016)	(0.003)
β_{JV}	−0.798	−0.811	−0.789	−0.885	−0.859	−0.247	−0.254	−0.238	−0.322	−0.301	0.823	0.805	0.822	0.821	0.830
	(−1.402)	(−1.427)	(−1.424)	(−1.522)	(−1.481)	(−0.712)	(−0.739)	(−0.707)	(−0.876)	(−0.827)	(1.947)	(1.924)	(1.982)	(1.900)	(1.964)
β_{IV}	0.711	0.725	0.727	0.791	0.789	0.643	0.650	0.651	0.711	0.712	0.091	0.109	0.111	0.094	0.089
	(5.468)	(5.718)	(5.711)	(6.346)	(6.383)	(4.548)	(4.687)	(4.684)	(5.069)	(4.988)	(0.786)	(0.938)	(0.955)	(0.781)	(0.725)
β_{ORV}		0.009		0.043			0.005		0.037			0.011		0.001	
		(1.821)		(4.765)			(0.646)		(3.275)			(0.930)		(0.096)	
β_{ORV^+}			−0.201		0.820			−0.155		0.734			−0.093		0.439
			(−1.242)		(3.316)			(−1.041)		(2.739)			(−0.523)		(1.805)
β_{ORV^-}			0.409		0.057			0.261		0.045			0.344		−0.495
			(2.344)		(0.213)			(1.776)		(0.163)			(1.897)		(−1.275)
R^2_{adj}	62.438%	62.518%	62.677%	63.002%	63.133%	66.107%	66.107%	66.228%	66.496%	66.609%	49.644%	49.762%	49.883%	49.633%	49.990%

Notes: This table presents the results of the SHAR regression models, where the dependent variable is the SPY RV over future horizons with $h \in (1, 5, 22)$ days ahead presented in Panel A, B, and C, respectively. In following Patton and Sheppard (2015), the SHAR model replaces the daily RV by the positive and negative daily realized semivariances, and their coefficients are respectively denoted by β_d^+ and β_d^-. $\mathcal{ORV}$ is the option realized variance, while $\mathcal{ORV}^+$ and $\mathcal{ORV}^-$ are the option realized semivariances for SPY OTM calls $(K/S = 1.10)$ and OTM puts $(K/S = 0.90)$. $RV_t^{(w)}$, and $RV_t^{(m)}$ are the daily, weekly, and monthly levels of realized variances. JV_t is the jump variation over the last day. IV is the ATM options implied volatility, in variance form, with a maturity of 30 days, over the last day. t-stats are reported in parentheses and reflect robust Newey-West standard errors. Adjusted-R^2 are reported in the last row (%). The sample period is from January 11, 2005 to December 31, 2021, at a daily frequency.

Table C2: Predicting Equity RV with Option Realized Semivariances using the SHAR Model

		Call ($K/S=1.10$)		Put ($K/S=0.90$)			Call ($K/S=1.10$)		Put ($K/S=0.90$)			Call ($K/S=1.10$)		Put ($K/S=0.90$)	
	Panel A: $h=1$					Panel B: $h=5$					Panel C: $h=22$				
β_{d^+}	0.170	0.111	0.109	0.143	0.190	0.383	0.358	0.367	0.373	0.395	0.480	0.295	0.308	0.483	0.510
	(2.424)	(1.468)	(1.426)	(1.935)	(2.579)	(3.427)	(3.073)	(3.162)	(3.275)	(3.353)	(4.540)	(2.822)	(2.972)	(4.475)	(4.652)
β_{d^-}	0.249	0.226	0.234	0.182	0.149	0.494	0.485	0.477	0.469	0.451	0.480	0.511	0.495	0.486	0.456
	(2.806)	(2.425)	(2.464)	(1.708)	(1.272)	(5.729)	(5.462)	(5.245)	(4.937)	(4.822)	(5.126)	(4.558)	(4.353)	(5.013)	(4.838)
β_w	0.402	0.396	0.396	0.396	0.397	0.384	0.381	0.381	0.381	0.382	0.174	0.194	0.194	0.174	0.175
	(6.505)	(6.358)	(6.367)	(6.322)	(6.369)	(4.888)	(4.854)	(4.857)	(4.846)	(4.855)	(7.096)	(8.360)	(8.372)	(7.255)	(7.234)
β_m	−0.182	−0.179	−0.179	−0.175	−0.175	−0.066	−0.064	−0.064	−0.063	−0.063	0.105	0.138	0.138	0.105	0.105
	(−6.132)	(−5.962)	(−5.968)	(−5.677)	(−5.701)	(−0.929)	(−0.904)	(−0.904)	(−0.882)	(−0.881)	(1.671)	(2.351)	(2.354)	(1.654)	(1.665)
β_{JV}	0.369	0.357	0.358	0.359	0.360	0.163	0.157	0.158	0.159	0.159	0.025	0.102	0.102	0.026	0.026
	(2.095)	(2.063)	(2.068)	(2.079)	(2.085)	(2.544)	(2.481)	(2.493)	(2.510)	(2.521)	(0.430)	(1.578)	(1.577)	(0.446)	(0.448)
β_{IV}	0.701	0.713	0.713	0.711	0.708	0.678	0.684	0.684	0.682	0.681	0.344	0.386	0.387	0.343	0.342
	(7.160)	(7.111)	(7.108)	(7.097)	(7.109)	(13.689)	(13.658)	(13.661)	(13.570)	(13.576)	(5.024)	(5.949)	(5.952)	(5.033)	(5.005)
β_{ORV}		0.207		0.303			0.093		0.113			0.055		−0.025	
		(2.901)		(2.320)			(2.603)		(1.902)			(2.195)		(−0.739)	
β_{ORV^+}			0.211		0.451			0.066		0.192			0.025		0.101
			(2.775)		(2.481)			(1.541)		(2.402)			(0.747)		(2.690)
β_{ORV^-}			0.177		0.014			0.122		−0.015			0.103		−0.177
			(1.979)		(0.181)			(2.375)		(−0.271)			(2.107)		(−2.837)
R^2_{adj}	54.331%	54.435%	54.492%	54.448%	54.484%	61.127%	61.188%	61.287%	61.181%	61.294%	52.343%	52.251%	53.254%	53.427%	53.482%

Notes: This table presents the results of the SHAR regression models, where the dependent variable is the individual equity RV over future horizons with $h \in (1,5,22)$ days ahead presented in Panel A, B, and C, respectively. In following Patton and Sheppard (2015), the SHAR model replaces the daily RV by the positive and negative daily realized semivariances, and their coefficients are respectively denoted by β_d^+ and β_d^-. $\mathcal{ORV}$ is the option realized variance, while $\mathcal{ORV}^+$ and $\mathcal{ORV}^-$ are the option realized semivariances for SPY OTM calls ($K/S=1.10$) and OTM puts ($K/S=0.90$). $RV_t^{(w)}$, and $RV_t^{(m)}$ are the daily, weekly, and monthly levels of realized variances. JV_t is the jump variation over the last day. IV is the ATM options implied volatility, in variance form, with a maturity of 30 days, over the last day. The models are estimated in a panel framework with firms fixed effect. t-stats are reported in parentheses and reflect clustered robust standard errors. Adjusted-R^2 are reported in the last row (%). The sample period is from January 2, 2004 to December 31, 2021, at a daily frequency.

Table C3: Predicting SPY RV with Option Realized Signed Jumps using the SHAR Model

		Call ($K/S = 1.10$)		Put ($K/S = 0.90$)			Call ($K/S = 1.10$)		Put ($K/S = 0.90$)			Call ($K/S = 1.10$)		Put ($K/S = 0.90$)	
	Panel A: $h = 1$					Panel B: $h = 5$					Panel C: $h = 22$				
β_0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(−3.222)	(−3.056)	(−3.268)	(−3.065)	(−3.413)	(−2.010)	(−1.915)	(−2.227)	(−1.935)	(−2.375)	(2.254)	(2.236)	(1.919)	(2.013)	(1.890)
β_d	0.149	0.148	0.142	0.148	0.125	0.232	0.233	0.226	0.230	0.214	0.124	0.124	0.115	0.127	0.111
	(1.286)	(1.264)	(1.212)	(1.266)	(1.067)	(2.949)	(2.946)	(2.879)	(2.929)	(2.699)	(2.949)	(2.945)	(2.813)	(2.833)	(2.653)
β_w	0.432	0.431	0.430	0.431	0.429	0.393	0.393	0.392	0.393	0.392	0.283	0.283	0.280	0.284	0.283
	(3.184)	(3.187)	(3.174)	(3.187)	(3.216)	(2.421)	(2.427)	(2.411)	(2.418)	(2.434)	(2.053)	(2.055)	(2.039)	(2.064)	(2.066)
β_m	−0.309	−0.309	−0.312	−0.309	−0.304	−0.191	−0.191	−0.194	−0.191	−0.188	0.031	0.031	0.028	0.032	0.034
	(−2.494)	(−2.496)	(−2.499)	(−2.492)	(−2.483)	(−1.106)	(−1.107)	(−1.113)	(−1.107)	(−1.085)	(0.177)	(0.177)	(0.156)	(0.179)	(0.192)
β_{JV^+}	−0.964	−0.996	−1.139	−0.986	−1.621	−0.245	−0.202	−0.271	−0.281	−0.391	1.318	1.317	1.031	1.367	1.358
	(−1.961)	(−1.887)	(−2.142)	(−1.907)	(−2.167)	(−0.450)	(−0.368)	(−0.482)	(−0.503)	(−0.585)	(1.269)	(1.273)	(1.049)	(1.292)	(1.289)
β_{JV^-}	−0.771	−0.743	−0.008	−0.748	0.561	−0.511	−0.550	0.158	−0.473	0.730	−1.275	−1.274	−0.374	−1.327	−0.254
	(−1.857)	(−1.833)	(−0.018)	(−1.738)	(1.208)	(−0.989)	(−1.076)	(0.322)	(−0.920)	(1.526)	(−1.803)	(−1.806)	(−0.640)	(−1.819)	(−0.439)
β_{IV}	0.649	0.651	0.666	0.652	0.692	0.613	0.611	0.626	0.617	0.644	0.186	0.186	0.208	0.182	0.209
	(4.534)	(4.487)	(4.534)	(4.477)	(4.619)	(4.682)	(4.668)	(4.738)	(4.661)	(4.928)	(1.715)	(1.720)	(1.890)	(1.651)	(1.918)
β_{ORJ}		0.007		0.008			−0.010		0.012			0.000		−0.017	
		(0.404)		(0.424)			(−0.719)		(0.628)			(0.022)		(−0.589)	
β_{ORJ^+}			0.080		0.930			−0.013		0.867			0.146		0.714
			(0.773)		(2.769)			(−0.133)		(2.822)			(0.917)		(1.858)
β_{ORJ^-}			−0.491		−0.463			−0.436		−0.038			−0.577		0.103
			(−1.795)		(−1.383)			(−1.851)		(−0.143)			(−1.905)		(0.589)
R^2_{adj}	62.631%	62.625%	62.772%	62.624%	62.940%	66.863%	66.860%	66.959%	66.859%	67.088%	47.335%	47.323%	47.675%	47.337%	47.641%

Notes: This table presents the results of the SHAR regression models, where the dependent variable is the SPY RV over future horizons with $h \in (1, 5, 22)$ days ahead presented in Panel A, B, and C, respectively. In following Patton and Sheppard (2015), the SHAR model replaces the daily JV by the positive and negative daily realized signed jumps, and their coefficients are respectively denoted by β_{JV^+} and β_{JV^-}. $\mathcal{ORJ}$ is the option realized jump, while $\mathcal{ORJ}^+$ and $\mathcal{ORJ}^-$ are the option realized signed jumps for SPY OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). $RV_t^{(w)}$, and $RV_t^{(m)}$ are the daily, weekly, and monthly levels of realized variances. JV_t is the jump variation over the last day. IV is the ATM options implied volatility, in variance form, with a maturity of 30 days, over the last day. t-stats are reported in parentheses and reflect robust Newey-West standard errors. Adjusted-R^2 are reported in the last row (%). The sample period is from January 11, 2005 to December 31, 2021, at a daily frequency.

Table C4: Predicting Equity RV with Option Realized Signed Jumps using the SHAR Model

	Panel A: $h=1$					Panel B: $h=5$					Panel C: $h=22$				
		Call ($K/S=1.10$)		Put ($K/S=0.90$)			Call ($K/S=1.10$)		Put ($K/S=0.90$)			Call ($K/S=1.10$)		Put ($K/S=0.90$)	
β_d	0.325	0.325	0.324	0.325	0.322	0.193	0.197	0.197	0.193	0.192	0.076	0.084	0.084	0.076	0.075
	(7.808)	(7.861)	(7.847)	(7.753)	(7.754)	(5.503)	(5.432)	(5.371)	(5.469)	(5.415)	(3.841)	(3.827)	(3.777)	(3.821)	(3.775)
β_w	0.160	0.158	0.158	0.159	0.160	0.253	0.250	0.250	0.253	0.253	0.136	0.133	0.133	0.136	0.136
	(1.860)	(1.849)	(1.852)	(1.859)	(1.861)	(3.737)	(3.702)	(3.699)	(3.736)	(3.740)	(4.868)	(4.569)	(4.563)	(4.874)	(4.883)
β_m	−0.078	−0.078	−0.078	−0.078	−0.076	0.022	0.026	0.026	0.022	0.023	0.164	0.172	0.172	0.164	0.165
	(−2.694)	(−2.738)	(−2.747)	(−2.691)	(−2.595)	(0.375)	(0.445)	(0.446)	(0.376)	(0.388)	(2.817)	(3.029)	(3.030)	(2.816)	(2.830)
β_{JV^+}	−0.322	−0.559	−0.684	−0.329	−0.364	0.294	−0.085	−0.110	0.290	0.293	0.789	0.551	0.558	0.793	0.803
	(−1.937)	(−2.577)	(−2.748)	(−1.972)	(−2.070)	(1.361)	(−0.612)	(−0.870)	(1.343)	(1.306)	(3.613)	(3.567)	(3.446)	(3.595)	(3.533)
β_{JV^-}	−0.476	−0.311	−0.284	−0.466	−0.351	−0.744	−0.271	−0.240	−0.739	−0.681	−0.988	−0.869	−0.831	−0.993	−0.926
	(−2.185)	(−1.155)	(−1.032)	(−2.115)	(−1.390)	(−2.823)	(−1.867)	(−1.554)	(−2.775)	(−2.465)	(−4.230)	(−4.257)	(−4.001)	(−4.209)	(−3.911)
β_{IV}	0.590	0.597	0.599	0.591	0.594	0.652	0.665	0.666	0.652	0.653	0.367	0.381	0.381	0.366	0.367
	(9.522)	(9.652)	(9.660)	(9.514)	(9.453)	(12.585)	(12.496)	(12.442)	(12.556)	(12.536)	(5.524)	(5.943)	(5.933)	(5.499)	(5.527)
β_{ORJ}		0.140		0.095			0.115		0.048			0.011		−0.047	
		(1.697)		(0.964)			(1.628)		(0.630)			(0.247)		(−0.770)	
β_{ORJ^+}			0.247		0.411			0.106		0.200			0.006		0.191
			(2.435)		(2.353)			(1.389)		(1.808)			(0.118)		(4.234)
β_{ORJ^-}			−0.094		−0.184			−0.143		0.016			−0.089		0.094
			(−1.738)		(−1.275)			(−1.689)		(0.237)			(−1.714)		(1.212)
R^2_{adj}	57.395%	57.370%	57.485%	57.397%	57.598%	61.565%	61.503%	61.503%	61.564%	62.571%	52.350%	52.084%	52.855%	52.351%	53.029%

Notes: This table presents the results of the SHAR regression models, where the dependent variable is the individual equity RV over future horizons with $h \in (1, 5, 22)$ days ahead presented in Panel A, B, and C, respectively. In following Patton and Sheppard (2015), the SHAR model replaces the daily JV by the positive and negative daily realized signed jumps, and their coefficients are respectively denoted by β_{JV^+} and β_{JV^-}. $\mathcal{ORJ}$ is the option realized jump, while $\mathcal{ORJ}^+$ and $\mathcal{ORJ}^-$ are the option realized signed jumps for SPY OTM calls ($K/S = 1.10$) and OTM puts ($K/S = 0.90$). $RV_t^{(w)}$, and $RV_t^{(m)}$ are the daily, weekly, and monthly levels of realized variances. JV_t is the jump variation over the last day. IV is the ATM options implied volatility, in variance form, with a maturity of 30 days, over the last day. The models are estimated in a panel framework with firms fixed effect. t-stats are reported in parentheses and reflect clustered robust standard errors. Adjusted-R^2 are reported in the last row (%). The sample period is from January 2, 2004 to December 31, 2021, at a daily frequency.

Table C5: Predicting SPY Variance Risk-Premium with Option Realized Semivariances

	Call ($K/S = 1.10$)						Put ($K/S = 0.90$)					
	Panel A: $h = 1$											
β_0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(3.972)	(4.025)	(3.277)	(3.308)	(1.464)	(1.513)	(4.241)	(4.254)	(3.509)	(3.402)	(2.279)	(2.305)
β_{IV}	−0.048	−0.045	−0.056	−0.053	0.281	0.298	−0.035	−0.037	−0.044	−0.045	0.319	0.313
	(−0.610)	(−0.567)	(−0.704)	(−0.663)	(1.130)	(1.195)	(−0.449)	(−0.471)	(−0.560)	(−0.575)	(1.306)	(1.285)
β_{JV}	1.227	1.208	1.212	1.192	1.105	1.080	1.234	1.219	1.216	1.202	1.097	1.080
	(2.728)	(2.737)	(2.700)	(2.708)	(2.441)	(2.441)	(2.784)	(2.731)	(2.754)	(2.701)	(2.496)	(2.434)
β_{VRP}	0.398	0.400	0.393	0.395	0.352	0.352	0.370	0.378	0.365	0.372	0.315	0.323
	(6.848)	(6.931)	(6.733)	(6.808)	(5.348)	(5.272)	(6.159)	(6.296)	(6.030)	(6.168)	(4.500)	(4.601)
β_{RNS}			0.000	0.000					0.000	0.000		
			(1.982)	(2.033)					(2.108)	(2.006)		
β_{JTI}					−0.196	−0.204					−0.213	−0.210
					(−1.724)	(−1.780)					(−1.886)	(−1.870)
β_{ORV}	−0.003		−0.003		−0.011		−0.021		−0.021		−0.031	
	(−0.607)		(−0.784)		(−1.564)		(−2.930)		(−3.011)		(−3.225)	
β_{ORV^+}		0.023		0.022		0.016		−0.057		−0.057		−0.066
		(2.030)		(1.964)		(1.124)		(−3.796)		(−3.808)		(−4.427)
β_{ORV^-}		−0.029		−0.030		−0.041		0.022		0.021		0.008
		(−2.347)		(−2.438)		(−3.750)		(1.369)		(1.268)		(0.380)
R^2_{adj}	13.185%	13.619%	13.294%	13.735%	14.974%	15.527%	13.692%	14.200%	13.829%	14.320%	15.846%	16.299%
	Panel B: $h = 5$											
β_0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(4.542)	(4.567)	(2.438)	(2.469)	(1.517)	(1.557)	(4.669)	(4.543)	(2.946)	(2.785)	(2.242)	(2.262)
β_{IV}	0.055	0.058	0.049	0.052	0.369	0.382	0.068	0.067	0.062	0.061	0.408	0.405
	(0.626)	(0.657)	(0.566)	(0.596)	(1.317)	(1.359)	(0.793)	(0.783)	(0.717)	(0.711)	(1.525)	(1.518)
β_{JV}	0.761	0.744	0.750	0.733	0.644	0.623	0.768	0.754	0.755	0.742	0.637	0.620
	(1.602)	(1.582)	(1.574)	(1.554)	(1.352)	(1.324)	(1.630)	(1.592)	(1.600)	(1.563)	(1.372)	(1.329)
β_{VRP}	0.429	0.432	0.426	0.428	0.386	0.386	0.403	0.408	0.399	0.405	0.350	0.356
	(5.491)	(5.487)	(5.371)	(5.363)	(3.807)	(3.757)	(5.058)	(5.115)	(4.943)	(4.999)	(3.391)	(3.429)
β_{RNS}			0.000	0.000					0.000	0.000		
			(1.125)	(1.160)					(1.303)	(1.219)		
β_{JTI}					−0.187	−0.193					−0.204	−0.203
					(−1.428)	(−1.464)					(−1.617)	(−1.610)
β_{ORV}	−0.001		−0.002		−0.009		−0.019		−0.019		−0.029	
	(−0.241)		(−0.345)		(−1.134)		(−2.381)		(−2.471)		(−3.206)	
β_{ORV^+}		0.020		0.020		0.014		−0.052		−0.052		−0.060
		(2.359)		(2.257)		(1.126)		(−3.435)		(−3.452)		(−4.365)
β_{ORV^-}		−0.023		−0.024		−0.035		0.018		0.017		0.005
		(−1.953)		(−2.048)		(−3.212)		(1.764)		(1.610)		(0.283)
R^2_{adj}	23.614%	24.032%	23.685%	24.108%	25.865%	26.399%	24.206%	24.810%	24.309%	24.898%	26.955%	27.520%
	Panel C: $h = 22$											
β_0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(4.057)	(4.047)	(0.923)	(0.994)	(1.633)	(1.664)	(3.724)	(3.723)	(1.114)	(0.995)	(1.963)	(1.982)
β_{IV}	0.211	0.213	0.212	0.214	0.339	0.349	0.212	0.211	0.213	0.212	0.339	0.336
	(4.620)	(4.705)	(4.706)	(4.776)	(2.072)	(2.149)	(4.769)	(4.760)	(4.857)	(4.856)	(2.148)	(2.118)
β_{JV}	−0.132	−0.142	−0.131	−0.140	−0.180	−0.192	−0.134	−0.143	−0.132	−0.140	−0.183	−0.192
	(−0.721)	(−0.777)	(−0.728)	(−0.787)	(−0.946)	(−1.020)	(−0.738)	(−0.772)	(−0.746)	(−0.779)	(−0.983)	(−1.021)
β_{VRP}	0.185	0.185	0.185	0.186	0.167	0.166	0.174	0.177	0.174	0.178	0.154	0.158
	(6.124)	(6.143)	(6.094)	(6.121)	(4.560)	(4.515)	(5.639)	(5.777)	(5.642)	(5.768)	(4.295)	(4.331)
β_{RNS}			0.000	0.000					0.000	0.000		
			(−0.147)	(−0.119)					(−0.153)	(−0.201)		
β_{JTI}					−0.076	−0.080					−0.077	−0.075
					(−0.979)	(−1.041)					(−1.004)	(−0.978)
β_{ORV}	−0.007		−0.007		−0.011		−0.013		−0.013		−0.017	
	(−1.167)		(−1.183)		(−1.786)		(−1.890)		(−1.935)		(−2.928)	
β_{ORV^+}		0.005		0.005		0.002		−0.031		−0.031		−0.034
		(0.746)		(0.764)		(0.294)		(−2.920)		(−2.930)		(−3.557)
β_{ORV^-}		−0.021		−0.021		−0.026		0.007		0.008		0.002
		(−2.102)		(−2.141)		(−3.014)		(1.113)		(1.199)		(0.303)
R^2_{adj}	35.090%	35.473%	35.079%	35.461%	35.996%	36.473%	35.404%	35.778%	35.393%	35.771%	36.335%	36.669%

Notes: Everything is defined as in Table 5. The IV is the ATM implied volatility (in variance form), RNS is the risk-neutral skewness of Bakshi et al. (2003), and the JTI is the jump-tail index of Du and Kapadia (2012).

Table C6: Predicting Equity Variance Risk-Premium with Option Realized Semivariances

	Call ($K/S = 1.10$)						Put ($K/S = 0.90$)					
						Panel A: $h = 1$						
β_{IV}	−0.053	−0.053	−0.052	−0.052	0.166	0.165	−0.052	−0.053	−0.051	−0.052	0.168	0.166
	(−1.244)	(−1.246)	(−1.234)	(−1.234)	(2.242)	(2.238)	(−1.234)	(−1.244)	(−1.219)	(−1.230)	(2.261)	(2.243)
β_{JV}	0.219	0.218	0.217	0.217	0.183	0.182	0.217	0.217	0.216	0.216	0.181	0.181
	(1.172)	(1.169)	(1.165)	(1.162)	(1.033)	(1.029)	(1.165)	(1.168)	(1.157)	(1.160)	(1.022)	(1.027)
β_{VRP}	0.398	0.398	0.397	0.398	0.361	0.361	0.397	0.399	0.396	0.398	0.359	0.361
	(13.480)	(13.503)	(13.392)	(13.411)	(33.451)	(33.318)	(13.539)	(13.619)	(13.377)	(13.456)	(30.589)	(31.043)
β_{RNS}			0.000	0.000					0.000	0.000		
			(1.719)	(1.731)					(1.888)	(1.908)		
β_{JTI}					−0.063	−0.063					−0.063	−0.063
					(−2.667)	(−2.665)					(−2.679)	(−2.670)
β_{ORV}	−0.009		−0.009		−0.013		−0.014		−0.015		−0.022	
	(−2.578)		(−2.670)		(−3.430)		(−2.313)		(−2.345)		(−2.495)	
β_{ORV^+}		−0.007		−0.006		−0.009		−0.031		−0.032		−0.036
		(−1.189)		(−1.144)		(−1.848)		(−2.750)		(−2.762)		(−2.646)
β_{ORV^-}		−0.010		−0.011		−0.017		0.012		0.012		0.004
		(−1.952)		(−1.988)		(−2.423)		(1.451)		(1.413)		(0.725)
R^2_{adj}	15.395%	15.387%	15.413%	15.405%	17.164%	17.151%	15.410%	15.442%	15.434%	15.466%	17.201%	17.217%
						Panel B: $h = 5$						
β_{IV}	0.016	0.017	0.018	0.018	0.087	0.087	0.017	0.016	0.019	0.018	0.088	0.087
	(0.448)	(0.451)	(0.498)	(0.503)	(1.621)	(1.623)	(0.458)	(0.449)	(0.517)	(0.507)	(1.614)	(1.597)
β_{JV}	0.087	0.086	0.084	0.083	0.075	0.074	0.085	0.085	0.082	0.083	0.073	0.074
	(0.781)	(0.774)	(0.759)	(0.752)	(0.702)	(0.693)	(0.767)	(0.767)	(0.746)	(0.746)	(0.684)	(0.686)
β_{VRP}	0.317	0.317	0.316	0.316	0.305	0.305	0.317	0.318	0.315	0.316	0.305	0.306
	(13.715)	(13.715)	(13.508)	(13.499)	(9.575)	(9.578)	(13.452)	(13.512)	(13.148)	(13.209)	(9.341)	(9.414)
β_{RNS}			0.000	0.000					0.000	0.000		
			(2.491)	(2.516)					(2.536)	(2.543)		
β_{JTI}					−0.020	−0.020					−0.020	−0.020
					(−1.737)	(−1.739)					(−1.727)	(−1.713)
β_{ORV}	−0.010		−0.010		−0.012		−0.013		−0.015		−0.016	
	(−3.064)		(−3.250)		(−2.958)		(−2.268)		(−2.308)		(−2.128)	
β_{ORV^+}		−0.004		−0.003		−0.005		−0.020		−0.022		−0.022
		(−1.009)		(−0.835)		(−1.174)		(−2.514)		(−2.519)		(−2.427)
β_{ORV^-}		−0.018		−0.019		−0.020		−0.001		−0.002		−0.004
		(−2.986)		(−3.082)		(−2.795)		(−0.279)		(−0.415)		(−0.635)
R^2_{adj}	14.215%	14.221%	14.331%	14.340%	14.474%	14.481%	14.207%	14.211%	14.341%	14.345%	14.471%	14.469%
						Panel C: $h = 22$						
β_{IV}	0.091	0.091	0.091	0.091	0.090	0.091	0.091	0.091	0.091	0.091	0.091	0.090
	(3.915)	(3.919)	(3.949)	(3.956)	(2.095)	(2.099)	(3.914)	(3.904)	(3.955)	(3.946)	(2.073)	(2.063)
β_{JV}	0.045	0.045	0.045	0.044	0.045	0.045	0.045	0.045	0.044	0.044	0.045	0.045
	(0.537)	(0.532)	(0.527)	(0.522)	(0.544)	(0.539)	(0.527)	(0.527)	(0.516)	(0.517)	(0.534)	(0.535)
β_{VRP}	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.161	0.160	0.160	0.160	0.161
	(14.337)	(14.321)	(14.102)	(14.075)	(11.598)	(11.587)	(14.345)	(14.460)	(13.984)	(14.090)	(11.384)	(11.478)
β_{RNS}			0.000	0.000					0.000	0.000		
			(1.085)	(1.115)					(1.178)	(1.190)		
β_{JTI}					0.000	0.000					0.000	0.000
					(0.011)	(0.007)					(0.009)	(0.019)
β_{ORV}	−0.005		−0.005		−0.005		−0.006		−0.006		−0.006	
	(−2.233)		(−2.333)		(−2.267)		(−2.165)		(−2.212)		(−1.910)	
β_{ORV^+}		−0.002		−0.001		−0.002		−0.013		−0.013		−0.013
		(−0.561)		(−0.479)		(−0.573)		(−2.921)		(−2.943)		(−2.753)
β_{ORV^-}		−0.010		−0.010		−0.010		0.004		0.004		0.004
		(−2.768)		(−2.847)		(−2.674)		(1.938)		(1.818)		(1.956)
R^2_{adj}	12.979%	12.989%	13.009%	13.021%	12.977%	12.988%	12.965%	12.986%	13.002%	13.024%	12.963%	12.985%

Notes: Everything is defined as in Table 6. The IV is the ATM implied volatility (in variance form), RNS is the risk-neutral skewness of Bakshi et al. (2003), and the JTI is the jump-tail index of Du and Kapadia (2012).

Table C7: Predicting SPY Variance Risk-Premium with Option Realized Signed Jumps

	Call ($K/S = 1.10$)						Put ($K/S = 0.90$)					
							Panel A: $h = 1$					
β_0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(3.486)	(3.780)	(3.059)	(3.297)	(1.164)	(1.415)	(3.555)	(3.840)	(3.084)	(3.335)	(1.155)	(1.677)
β_{IV}	−0.051	−0.042	−0.060	−0.051	0.239	0.287	−0.052	−0.044	−0.061	−0.053	0.233	0.280
	(−0.661)	(−0.551)	(−0.764)	(−0.663)	(1.081)	(1.290)	(−0.667)	(−0.567)	(−0.774)	(−0.679)	(1.059)	(1.244)
β_{JV}	1.224	1.211	1.208	1.194	1.106	1.082	1.225	1.228	1.209	1.212	1.108	1.105
	(2.725)	(2.731)	(2.695)	(2.701)	(2.421)	(2.446)	(2.721)	(2.757)	(2.690)	(2.731)	(2.415)	(2.506)
β_{VRP}	0.400	0.397	0.396	0.393	0.365	0.357	0.400	0.388	0.396	0.383	0.367	0.345
	(6.755)	(6.717)	(6.658)	(6.612)	(5.925)	(5.695)	(6.731)	(6.475)	(6.615)	(6.356)	(5.920)	(5.376)
β_{RNS}			0.000	0.000					0.000	0.000		
			(1.928)	(2.107)					(1.943)	(2.098)		
β_{JTI}					−0.178	−0.201					−0.176	−0.198
					(−1.743)	(−1.931)					(−1.725)	(−1.885)
β_{ORJ}	−0.009		−0.011		−0.019		−0.005		−0.010		−0.010	
	(−0.677)		(−0.821)		(−1.528)		(−0.422)		(−0.852)		(−0.798)	
β_{ORJ^+}		0.002		0.001		−0.009		−0.089		−0.091		−0.104
		(0.299)		(0.111)		(−0.844)		(−3.312)		(−3.368)		(−4.089)
β_{ORJ^-}		0.050		0.051		0.066		0.005		0.008		0.026
		(2.280)		(2.356)		(3.336)		(0.258)		(0.456)		(1.172)
R^2_{adj}	13.181%	13.807%	13.285%	13.938%	14.768%	15.758%	13.172%	14.477%	13.277%	14.609%	14.727%	16.399%
							Panel B: $h = 5$					
β_0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(4.033)	(4.540)	(2.292)	(2.653)	(1.168)	(1.408)	(4.109)	(4.471)	(2.485)	(2.589)	(1.255)	(1.624)
β_{IV}	0.053	0.060	0.047	0.053	0.330	0.368	0.053	0.058	0.046	0.052	0.330	0.361
	(0.616)	(0.695)	(0.550)	(0.621)	(1.313)	(1.453)	(0.616)	(0.674)	(0.539)	(0.603)	(1.321)	(1.415)
β_{JV}	0.760	0.746	0.749	0.734	0.646	0.625	0.759	0.756	0.746	0.745	0.646	0.641
	(1.598)	(1.580)	(1.569)	(1.551)	(1.343)	(1.328)	(1.602)	(1.593)	(1.572)	(1.567)	(1.347)	(1.363)
β_{VRP}	0.431	0.429	0.429	0.426	0.399	0.392	0.428	0.424	0.424	0.420	0.396	0.384
	(5.517)	(5.485)	(5.416)	(5.384)	(4.273)	(4.134)	(5.469)	(5.316)	(5.350)	(5.201)	(4.266)	(3.935)
β_{RNS}			0.000	0.000					0.000	0.000		
			(1.073)	(1.237)					(1.216)	(1.190)		
β_{JTI}					−0.170	−0.188					−0.171	−0.185
					(−1.433)	(−1.564)					(−1.446)	(−1.532)
β_{ORJ}	0.004		0.003		−0.005		−0.021		−0.025		−0.026	
	(0.364)		(0.250)		(−0.411)		(−1.383)		(−1.660)		(−1.858)	
β_{ORJ^+}		0.007		0.006		−0.003		−0.065		−0.066		−0.079
		(1.047)		(0.905)		(−0.279)		(−2.964)		(−3.057)		(−4.063)
β_{ORJ^-}		0.035		0.036		0.050		−0.011		−0.008		0.009
		(2.005)		(2.119)		(3.621)		(−0.703)		(−0.524)		(0.404)
R^2_{adj}	23.612%	24.085%	23.677%	24.171%	25.622%	26.455%	23.660%	24.660%	23.747%	24.743%	25.693%	26.986%
							Panel C: $h = 22$					
β_0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(3.465)	(4.108)	(0.584)	(0.834)	(1.298)	(1.556)	(3.255)	(3.523)	(0.703)	(0.800)	(1.319)	(1.548)
β_{IV}	0.202	0.207	0.203	0.208	0.294	0.321	0.201	0.204	0.202	0.206	0.293	0.310
	(4.355)	(4.548)	(4.502)	(4.661)	(1.872)	(2.052)	(4.321)	(4.513)	(4.454)	(4.627)	(1.864)	(2.002)
β_{JV}	−0.140	−0.143	−0.137	−0.141	−0.178	−0.188	−0.140	−0.139	−0.138	−0.137	−0.178	−0.179
	(−0.732)	(−0.770)	(−0.734)	(−0.778)	(−0.904)	(−0.983)	(−0.740)	(−0.750)	(−0.746)	(−0.753)	(−0.910)	(−0.937)
β_{VRP}	0.193	0.190	0.193	0.191	0.182	0.176	0.191	0.188	0.191	0.189	0.180	0.174
	(6.024)	(6.038)	(5.962)	(5.985)	(4.993)	(4.886)	(5.899)	(5.906)	(5.825)	(5.867)	(4.975)	(4.785)
β_{RNS}			0.000	0.000					0.000	0.000		
			(−0.269)	(−0.172)					(−0.201)	(−0.220)		
β_{JTI}					−0.057	−0.070					−0.057	−0.065
					(−0.752)	(−0.921)					(−0.748)	(−0.864)
β_{ORJ}	−0.005		−0.005		−0.008		−0.018		−0.017		−0.019	
	(−0.471)		(−0.470)		(−0.880)		(−1.393)		(−1.541)		(−1.709)	
β_{ORJ^+}		−0.005		−0.005		−0.009		−0.038		−0.038		−0.043
		(−0.569)		(−0.569)		(−1.098)		(−2.286)		(−2.338)		(−3.104)
β_{ORJ^-}		0.028		0.028		0.034		0.000		0.000		0.007
		(2.274)		(2.325)		(3.250)		(0.026)		(−0.019)		(0.739)
R^2_{adj}	34.674%	35.305%	34.673%	35.296%	35.214%	36.089%	34.750%	35.471%	34.743%	35.465%	35.286%	36.154%

Notes: Everything is defined as in Table 7. The IV is the ATM implied volatility (in variance form), RNS is the risk-neutral skewness of Bakshi et al. (2003), and the JTI is the jump-tail index of Du and Kapadia (2012).

Table C8: Predicting Equity Variance Risk-Premia with Option Realized Signed Jumps

	Call ($K/S = 1.10$)						Put ($K/S = 0.90$)					
	Panel A: $h = 1$											
β_{IV}	−0.054	−0.054	−0.053	−0.054	0.160	0.160	−0.054	−0.054	−0.053	−0.053	0.160	0.163
	(−1.281)	(−1.284)	(−1.269)	(−1.272)	(2.181)	(2.189)	(−1.278)	(−1.273)	(−1.266)	(−1.260)	(2.188)	(2.207)
β_{JV}	0.218	0.218	0.217	0.217	0.183	0.182	0.217	0.219	0.216	0.217	0.182	0.183
	(1.171)	(1.167)	(1.164)	(1.160)	(1.034)	(1.028)	(1.162)	(1.177)	(1.155)	(1.169)	(1.024)	(1.038)
β_{VRP}	0.401	0.400	0.400	0.400	0.366	0.365	0.402	0.399	0.401	0.398	0.367	0.363
	(13.967)	(13.834)	(13.855)	(13.722)	(34.159)	(33.871)	(14.079)	(14.050)	(13.934)	(13.888)	(34.565)	(33.418)
β_{RNS}			0.000	0.000					0.000	0.000		
			(1.735)	(1.733)					(1.795)	(1.935)		
β_{JTI}					−0.062	−0.062					−0.062	−0.062
					(−2.628)	(−2.636)					(−2.633)	(−2.651)
β_{ORJ}	−0.013		−0.013		−0.014		−0.012		−0.013		−0.015	
	(−1.600)		(−1.682)		(−1.970)		(−1.230)		(−1.337)		(−1.572)	
β_{ORJ^+}		−0.013		−0.013		−0.015		−0.050		−0.051		−0.057
		(−1.678)		(−1.676)		(−2.100)		(−2.856)		(−2.856)		(−2.725)
β_{ORJ^-}		0.019		0.019		0.024		0.003		0.004		0.011
		(2.325)		(2.357)		(2.717)		(0.300)		(0.424)		(1.090)
R^2_{adj}	15.369%	15.378%	15.388%	15.397%	17.086%	17.104%	15.358%	15.471%	15.379%	15.497%	17.076%	17.222%
	Panel B: $h = 5$											
β_{IV}	0.015	0.015	0.016	0.017	0.081	0.082	0.015	0.015	0.017	0.017	0.082	0.083
	(0.404)	(0.404)	(0.454)	(0.456)	(1.526)	(1.538)	(0.408)	(0.415)	(0.459)	(0.469)	(1.530)	(1.545)
β_{JV}	0.086	0.085	0.084	0.083	0.075	0.074	0.085	0.086	0.083	0.083	0.074	0.074
	(0.767)	(0.760)	(0.746)	(0.738)	(0.689)	(0.682)	(0.757)	(0.764)	(0.737)	(0.744)	(0.678)	(0.685)
β_{VRP}	0.321	0.321	0.320	0.319	0.310	0.310	0.322	0.321	0.320	0.319	0.311	0.309
	(13.911)	(13.807)	(13.682)	(13.578)	(9.918)	(9.832)	(13.932)	(13.703)	(13.663)	(13.411)	(9.925)	(9.714)
β_{RNS}			0.000	0.000					0.000	0.000		
			(2.490)	(2.507)					(2.504)	(2.511)		
β_{JTI}					−0.019	−0.019					−0.019	−0.019
					(−1.663)	(−1.674)					(−1.667)	(−1.679)
β_{ORJ}	−0.012		−0.012		−0.013		−0.011		−0.013		−0.011	
	(−1.869)		(−2.108)		(−1.940)		(−1.331)		(−1.543)		(−1.417)	
β_{ORJ^+}		−0.007		−0.005		−0.007		−0.026		−0.029		−0.028
		(−1.006)		(−0.911)		(−1.082)		(−2.531)		(−2.519)		(−2.418)
β_{ORJ^-}		0.018		0.019		0.020		−0.003		0.000		0.000
		(2.179)		(2.273)		(2.162)		(−0.510)		(−0.075)		(−0.068)
R^2_{adj}	14.155%	14.153%	14.274%	14.275%	14.391%	14.392%	14.139%	14.180%	14.264%	14.310%	14.375%	14.422%
	Panel C: $h = 22$											
β_{IV}	0.090	0.090	0.090	0.091	0.088	0.088	0.090	0.090	0.091	0.091	0.088	0.089
	(3.873)	(3.881)	(3.908)	(3.918)	(2.039)	(2.045)	(3.878)	(3.887)	(3.915)	(3.928)	(2.042)	(2.050)
β_{JV}	0.045	0.044	0.044	0.044	0.045	0.045	0.045	0.045	0.044	0.044	0.045	0.045
	(0.531)	(0.524)	(0.521)	(0.514)	(0.541)	(0.534)	(0.525)	(0.530)	(0.515)	(0.520)	(0.534)	(0.539)
β_{VRP}	0.162	0.162	0.161	0.162	0.162	0.162	0.162	0.162	0.162	0.161	0.162	0.162
	(14.710)	(14.724)	(14.428)	(14.433)	(11.901)	(11.862)	(14.835)	(14.767)	(14.487)	(14.397)	(11.948)	(11.783)
β_{RNS}			0.000	0.000					0.000	0.000		
			(1.101)	(1.121)					(1.121)	(1.175)		
β_{JTI}					0.001	0.000					0.001	0.000
					(0.057)	(0.054)					(0.057)	(0.041)
β_{ORJ}	−0.006		−0.006		−0.006		−0.005		−0.005		−0.005	
	(−1.181)		(−1.243)		(−1.179)		(−0.790)		(−0.898)		(−0.790)	
β_{ORJ^+}		−0.001		−0.001		−0.001		−0.016		−0.017		−0.016
		(−0.226)		(−0.146)		(−0.223)		(−3.256)		(−3.266)		(−2.965)
β_{ORJ^-}		0.006		0.006		0.006		−0.006		−0.005		−0.006
		(1.565)		(1.659)		(1.477)		(−1.722)		(−1.519)		(−1.696)
R^2_{adj}	12.940%	12.929%	12.971%	12.962%	12.939%	12.928%	12.928%	12.981%	12.962%	13.018%	12.927%	12.980%

Notes: Everything is defined as in Table 8. The IV is the ATM implied volatility (in variance form), RNS is the risk-neutral skewness of Bakshi et al. (2003), and the JTI is the jump-tail index of Du and Kapadia (2012).

Table C9: Predicting SPY Monthly Excess Return with OTM Call Option Realized Semivariances

	Call ($K/S = 1.10$)																	
α	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.003	0.004
	(0.919)	(0.969)	(1.000)	(1.045)	(0.943)	(0.991)	(0.904)	(0.952)	(1.057)	(1.092)	(0.920)	(0.969)	(0.733)	(0.784)	(0.700)	(0.741)	(1.079)	(1.134)
β_{RV}			−1.768	−1.786	−1.630	−1.652	−1.619	−1.640	−1.813	−1.830	−1.455	−1.475	−1.547	−1.568	−1.443	−1.456	−1.487	−1.530
			(−3.055)	(−3.057)	(−2.638)	(−2.650)	(−2.577)	(−2.584)	(−3.017)	(−3.008)	(−2.376)	(−2.387)	(−2.579)	(−2.589)	(−2.426)	(−2.414)	(−2.220)	(−2.261)
β_{JV}	−5.602	−5.667	−6.009	−6.061	−6.242	−6.290	−5.896	−5.949	−5.737	−5.787	−6.035	−6.088	−5.980	−6.036	−6.281	−6.359	−5.167	−5.250
	(−1.772)	(−1.809)	(−1.703)	(−1.742)	(−1.741)	(−1.781)	(−1.616)	(−1.655)	(−1.728)	(−1.764)	(−1.655)	(−1.696)	(−1.652)	(−1.695)	(−1.772)	(−1.816)	(−1.219)	(−1.253)
β_{IV}			2.533	2.530	1.794	1.810	2.217	2.216	3.758	3.740			1.678	1.694	3.056	3.152	2.346	2.383
			(1.955)	(1.958)	(1.558)	(1.579)	(1.378)	(1.375)	(2.822)	(2.823)			(1.491)	(1.512)	(1.046)	(1.085)	(1.561)	(1.594)
β_{REV}	−0.003	−0.004	−0.003	−0.003	−0.003	−0.003	−0.002	−0.003	−0.001	−0.002	−0.003	−0.004	−0.003	−0.004	−0.003	−0.004	−0.005	−0.006
	(−1.013)	(−1.239)	(−0.876)	(−1.108)	(−0.938)	(−1.181)	(−0.546)	(−0.738)	(−0.395)	(−0.571)	(−1.059)	(−1.295)	(−0.970)	(−1.216)	(−0.972)	(−1.214)	(−1.328)	(−1.636)
β_{MoM}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(−0.060)	(−0.079)	(0.138)	(0.114)	(−0.010)	(−0.031)	(−0.068)	(−0.086)	(0.087)	(0.069)	(−0.130)	(−0.152)	(0.285)	(0.267)	(0.197)	(0.186)	(−0.223)	(−0.239)
β_{Illiq}	0.454	0.458	0.385	0.390	0.397	0.403	0.429	0.434	0.637	0.638	0.439	0.445	0.264	0.268	0.434	0.442	0.458	0.463
	(0.634)	(0.639)	(0.659)	(0.667)	(0.685)	(0.692)	(0.766)	(0.771)	(1.101)	(1.100)	(0.765)	(0.772)	(0.444)	(0.450)	(0.749)	(0.759)	(0.819)	(0.825)
β_{Size}	−0.282	−0.296	−0.295	−0.308	−0.291	−0.304	−0.278	−0.292	−0.315	−0.325	−0.286	−0.299	−0.158	−0.171	−0.240	−0.252	−0.319	−0.332
	(−1.076)	(−1.123)	(−1.103)	(−1.147)	(−1.090)	(−1.137)	(−1.046)	(−1.093)	(−1.180)	(−1.215)	(−1.065)	(−1.112)	(−0.581)	(−0.626)	(−0.876)	(−0.916)	(−1.202)	(−1.255)
β_{OptV}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(5.046)	(4.997)	(4.619)	(4.631)	(4.366)	(4.360)	(4.410)	(4.405)	(4.494)	(4.480)	(4.383)	(4.384)	(4.470)	(4.473)	(4.061)	(4.073)	(4.840)	(4.855)
β_{VRP}	1.616	1.638																
	(2.706)	(2.725)																
β_{Skew}			−0.007	−0.007														
			(−0.994)	(−0.961)														
β_{SPRD}					0.006	0.005												
					(1.147)	(1.124)												
β_{Max}							−0.007	−0.007										
							(−0.374)	(−0.361)										
β_{Min}									0.030	0.030								
									(1.835)	(1.823)								
β_{RNV}											0.058	0.058						
											(1.275)	(1.293)						
β_{RNS}													0.001	0.001				
													(1.604)	(1.641)				
β_{JTI}															−0.815	−0.864		
															(−0.560)	(−0.598)		
β_{LTV}																	−0.043	−0.043
																	(−2.089)	(−2.081)
β_{ORV}	−0.374		−0.360		−0.374		−0.371		−0.307		−0.376		−0.415		−0.408		−0.339	
	(−2.024)		(−1.865)		(−1.990)		(−1.970)		(−1.747)		(−2.008)		(−2.287)		(−2.352)		(−1.845)	
β_{ORV^+}		−0.227		−0.216		−0.227		−0.229		−0.187		−0.233		−0.265		−0.258		−0.144
		(−1.261)		(−1.146)		(−1.222)		(−1.223)		(−1.021)		(−1.266)		(−1.453)		(−1.455)		(−0.769)
β_{ORV^-}		−0.576		−0.556		−0.574		−0.568		−0.472		−0.574		−0.627		−0.621		−0.598
		(−2.239)		(−2.086)		(−2.226)		(−2.225)		(−2.021)		(−2.221)		(−2.514)		(−2.622)		(−2.297)
R^2_{adj}	6.210%	6.296%	6.359%	6.434%	6.229%	6.312%	6.231%	6.312%	7.362%	7.404%	6.044%	6.127%	6.578%	6.676%	6.288%	6.387%	6.570%	6.748%

Notes: Everything is defined as in Table 9. VRP is the variance risk-premium as defined in Section 5, $Skew$ is the volatility skewness, $SPRD$ is the call-put ATM volatility spread, Max and Min are the Bali et al. (2011) maximum and minimum daily returns, RNV and RNS are the Bakshi et al. (2003) risk-neutral variance and skewness, JTI is the jump-tail risk of Du and Kapadia (2012), and LTV is the left tail variation of Bollerslev et al. (2015). The left tail variation is obtained from www.tailindex.com and the sample size is from January 11, 2005 to December 31, 2019. All these measures are defined in Appendix A.

Table C10: Predicting SPY Monthly Excess Return with OTM Put Option Realized Semivariances

	Put ($K/S = 0.90$)																	
α	0.003	0.003	0.004	0.004	0.004	0.004	0.003	0.003	0.004	0.004	0.003	0.004	0.003	0.003	0.003	0.003	0.003	0.003
	(1.031)	(1.046)	(1.124)	(1.139)	(1.074)	(1.092)	(1.034)	(1.052)	(1.122)	(1.140)	(1.051)	(1.069)	(0.892)	(0.912)	(0.896)	(0.917)	(0.974)	(0.980)
β_{RV}			−1.655	−1.707	−1.496	−1.549	−1.486	−1.540	−1.748	−1.819	−1.318	−1.371	−1.422	−1.470	−1.369	−1.420	−1.500	−1.545
			(−2.805)	(−2.878)	(−2.378)	(−2.445)	(−2.338)	(−2.402)	(−2.823)	(−2.902)	(−2.129)	(−2.190)	(−2.329)	(−2.388)	(−2.378)	(−2.409)	(−2.256)	(−2.294)
β_{JV}	−6.223	−6.421	−6.068	−6.219	−6.339	−6.501	−5.940	−6.099	−5.816	−5.925	−6.055	−6.219	−6.035	−6.205	−6.169	−6.334	−4.994	−5.153
	(−1.919)	(−1.928)	(−1.677)	(−1.691)	(−1.716)	(−1.732)	(−1.585)	(−1.601)	(−1.697)	(−1.715)	(−1.618)	(−1.637)	(−1.614)	(−1.633)	(−1.741)	(−1.772)	(−1.169)	(−1.186)
β_{IV}			2.225	2.252	1.399	1.434	1.902	1.942	3.535	3.601			1.271	1.302	2.043	2.065	2.042	2.066
			(1.614)	(1.648)	(1.170)	(1.206)	(1.183)	(1.212)	(2.549)	(2.575)			(1.079)	(1.112)	(0.700)	(0.708)	(1.292)	(1.317)
β_{REV}	−0.005	−0.005	−0.004	−0.005	−0.004	−0.005	−0.004	−0.004	−0.002	−0.003	−0.005	−0.006	−0.005	−0.005	−0.005	−0.005	−0.006	−0.006
	(−1.459)	(−1.643)	(−1.464)	(−1.678)	(−1.561)	(−1.778)	(−0.971)	(−1.140)	(−0.750)	(−0.946)	(−1.703)	(−1.916)	(−1.633)	(−1.848)	(−1.659)	(−1.876)	(−1.620)	(−1.766)
β_{MoM}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.035)	(0.041)	(0.160)	(0.160)	(−0.005)	(−0.004)	(−0.074)	(−0.074)	(0.110)	(0.118)	(−0.111)	(−0.111)	(0.236)	(0.237)	(0.111)	(0.109)	(−0.093)	(−0.089)
β_{Illiq}	0.445	0.442	0.455	0.457	0.472	0.474	0.508	0.510	0.700	0.703	0.515	0.517	0.375	0.378	0.501	0.504	0.581	0.585
	(0.620)	(0.619)	(0.768)	(0.774)	(0.802)	(0.809)	(0.889)	(0.896)	(1.189)	(1.197)	(0.886)	(0.892)	(0.617)	(0.623)	(0.856)	(0.863)	(1.000)	(1.005)
β_{Size}	−0.315	−0.320	−0.334	−0.339	−0.333	−0.339	−0.318	−0.324	−0.338	−0.344	−0.328	−0.334	−0.223	−0.228	−0.298	−0.304	−0.298	−0.300
	(−1.175)	(−1.192)	(−1.214)	(−1.233)	(−1.210)	(−1.231)	(−1.163)	(−1.183)	(−1.239)	(−1.260)	(−1.187)	(−1.206)	(−0.790)	(−0.810)	(−1.052)	(−1.074)	(−1.106)	(−1.114)
β_{OptV}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(4.777)	(4.834)	(4.299)	(4.377)	(4.034)	(4.123)	(4.085)	(4.177)	(4.182)	(4.262)	(4.067)	(4.153)	(4.095)	(4.191)	(3.820)	(3.912)	(4.411)	(4.447)
β_{VRP}	1.436	1.483																
	(2.336)	(2.397)																
β_{Skew}			−0.008	−0.008														
			(−1.118)	(−1.110)														
β_{SPRD}					0.006	0.006												
					(1.344)	(1.360)												
β_{Max}							−0.008	−0.008										
							(−0.463)	(−0.468)										
β_{Min}									0.031	0.031								
									(1.877)	(1.877)								
β_{RNV}											0.042	0.044						
											(0.911)	(0.946)						
β_{RNS}													0.001	0.001				
													(1.170)	(1.179)				
β_{JTI}															−0.449	−0.441		
															(−0.310)	(−0.303)		
β_{LTV}																	−0.041	−0.040
																	(−1.889)	(−1.867)
β_{ORV}	−0.444		−0.421		−0.443		−0.439		−0.324		−0.456		−0.466		−0.462		−0.329	
	(−2.140)		(−1.974)		(−2.118)		(−2.120)		(−1.784)		(−2.211)		(−2.277)		(−2.480)		(−1.714)	
β_{ORV^+}		−0.687		−0.670		−0.692		−0.690		−0.610		−0.701		−0.710		−0.704		−0.510
		(−2.742)		(−2.584)		(−2.697)		(−2.719)		(−2.655)		(−2.757)		(−2.808)		(−2.956)		(−1.942)
β_{ORV^-}		−0.241		−0.203		−0.229		−0.222		−0.043		−0.251		−0.268		−0.260		−0.178
		(−0.963)		(−0.795)		(−0.915)		(−0.876)		(−0.179)		(−1.005)		(−1.080)		(−1.097)		(−0.703)
R^2_{adj}	5.743%	5.837%	5.927%	6.017%	5.778%	5.874%	5.785%	5.881%	6.953%	7.067%	5.624%	5.717%	5.960%	6.058%	5.740%	5.834%	5.974%	6.005%

Notes: Everything is defined as in Table 9. VRP is the variance risk-premium as defined in Section 5, $Skew$ is the implied skewness, $SPRD$ is the call-put ATM volatility spread, Max and Min are the Bali et al. (2011) maximum and minimum daily returns, RNV and RNS are the Bakshi et al. (2003) risk-neutral variance and skewness, JTI is the jump-tail risk of Du and Kapadia (2012), and LTV is the left tail variation of Bollerslev et al. (2015). The left tail variation is obtained from www.tailindex.com and the sample size is from January 11, 2005 to December 31, 2019. All these measures are defined in Appendix A.

Table C11: Predicting Individual Equity Monthly Excess Return with OTM Call Option Realized Semivariances

	Call ($K/S = 1.10$)															
β_{RV}			−0.421	−0.416	−0.416	−0.412	−0.422	−0.420	−0.420	−0.413	−0.483	−0.479	−0.439	−0.435	−0.510	−0.505
			(−5.136)	(−5.076)	(−4.906)	(−4.805)	(−5.035)	(−4.835)	(−4.973)	(−4.570)	(−5.451)	(−5.348)	(−5.440)	(−5.325)	(−5.451)	(−5.335)
β_{JV}	0.755	0.805	−0.008	−0.010	−0.075	−0.076	−0.010	−0.018	0.001	0.030	0.030	0.029	0.018	0.018	0.056	0.056
	(1.711)	(1.844)	(−0.018)	(−0.024)	(−0.178)	(−0.182)	(−0.022)	(−0.041)	(0.003)	(0.070)	(0.065)	(0.065)	(0.040)	(0.039)	(0.124)	(0.124)
β_{IV}			0.833	0.835	0.826	0.824	0.904	1.121	0.913	1.191			0.817	0.814	0.344	0.346
			(4.759)	(3.666)	(4.830)	(4.790)	(4.599)	(3.416)	(5.298)	(4.132)			(5.285)	(5.244)	(1.120)	(1.124)
β_{REV}	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004	−0.003	−0.002	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004
	(−4.228)	(−4.379)	(−3.923)	(−3.979)	(−3.659)	(−3.756)	(−3.766)	(−2.205)	(−3.984)	(−4.297)	(−3.996)	(−4.110)	(−4.224)	(−4.332)	(−4.019)	(−4.118)
β_{MoM}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(−1.686)	(−1.676)	(−1.224)	(−1.218)	(−1.235)	(−1.231)	(−1.309)	(−1.565)	(−1.247)	(−1.319)	(−1.278)	(−1.273)	(−1.244)	(−1.240)	(−1.434)	(−1.427)
β_{Illiq}	0.010	0.010	0.007	0.008	0.008	0.008	0.008	0.008	0.008	0.010	0.008	0.008	0.007	0.007	0.009	0.009
	(2.013)	(2.017)	(1.409)	(1.414)	(1.395)	(1.397)	(1.488)	(1.731)	(1.533)	(1.924)	(1.607)	(1.609)	(1.501)	(1.504)	(1.889)	(1.885)
β_{Size}	−0.031	−0.030	0.017	0.018	0.009	0.010	0.014	0.006	0.019	0.025	0.006	0.006	−0.011	−0.010	−0.016	−0.015
	(−0.179)	(−0.168)	(0.110)	(0.117)	(0.057)	(0.062)	(0.090)	(0.038)	(0.119)	(0.163)	(0.035)	(0.040)	(−0.066)	(−0.061)	(−0.098)	(−0.090)
β_{OptV}	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001
	(−1.945)	(−1.929)	(−3.350)	(−3.416)	(−3.363)	(−3.347)	(−3.248)	(−2.985)	(−3.200)	(−2.738)	(−3.127)	(−3.110)	(−3.199)	(−3.182)	(−2.924)	(−2.909)
β_{VRP}	0.445	0.462														
	(5.802)	(5.922)														
β_{Skew}			0.000	0.000												
			(−0.072)	(−0.053)												
β_{SPRD}					0.006	0.006										
					(3.497)	(3.490)										
β_{Max}							−0.002	−0.008								
							(−1.492)	(−1.461)								
β_{Min}									0.003	0.013						
									(1.578)	(1.518)						
β_{RNV}											0.032	0.032				
											(5.945)	(5.891)				
β_{RNS}													0.000	0.000		
													(−2.287)	(−2.281)		
β_{JTI}															0.154	0.152
															(2.422)	(2.400)
β_{ORV}	0.011		0.005		0.003		0.007		0.008		0.006		0.002		0.016	
	(0.486)		(0.228)		(0.156)		(0.337)		(0.363)		(0.295)		(0.082)		(0.763)	
β_{ORV^+}		0.031		0.025		0.023		0.030		0.029		0.027		0.018		0.032
		(1.208)		(1.069)		(0.925)		(1.180)		(1.157)		(1.083)		(0.841)		(1.293)
β_{ORV^-}		−0.037		−0.045		−0.045		−0.029		−0.021		−0.044		−0.042		−0.030
		(−1.055)		(−1.408)		(−1.327)		(−0.869)		(−0.635)		(−1.291)		(−1.204)		(−0.928)
R^2_{adj}	0.874%	0.886%	1.069%	1.071%	1.125%	1.128%	1.114%	1.247%	1.141%	1.383%	1.136%	1.137%	1.210%	1.211%	1.222%	1.221%

Notes: Everything is defined as in Table 10. VRP is the variance risk-premium as defined in Section 5, $Skew$ is the implied skewness, $SPRD$ is the call-put ATM volatility spread, Max and Min are the Bali et al. (2011) maximum and minimum daily returns, RNV and RNS are the Bakshi et al. (2003) risk-neutral variance and skewness, and JTI is the jump-tail risk by Du and Kapadia (2012). All these measures are defined in Appendix A.

Table C12: Predicting Individual Equity Monthly Excess Return with OTM Put Option Realized Semivariances

	Put ($K/S = 0.90$)															
β_{RV}			−0.409	−0.414	−0.403	−0.410	−0.409	−0.417	−0.408	−0.412	−0.471	−0.478	−0.430	−0.437	−0.497	−0.503
			(−5.005)	(−5.124)	(−4.737)	(−4.791)	(−4.891)	(−4.860)	(−4.830)	(−4.585)	(−5.370)	(−5.386)	(−5.359)	(−5.391)	(−5.357)	(−5.361)
β_{JV}	0.766	0.809	−0.006	−0.008	−0.074	−0.074	−0.008	−0.015	0.003	0.033	0.031	0.032	0.019	0.019	0.058	0.059
	(1.758)	(1.857)	(−0.014)	(−0.018)	(−0.179)	(−0.178)	(−0.018)	(−0.034)	(0.007)	(0.077)	(0.069)	(0.070)	(0.041)	(0.042)	(0.130)	(0.131)
β_{IV}			0.823	0.833	0.817	0.822	0.894	1.118	0.903	1.192			0.811	0.816	0.344	0.346
			(4.642)	(3.627)	(4.717)	(4.748)	(4.496)	(3.402)	(5.169)	(4.103)			(5.181)	(5.217)	(1.114)	(1.122)
β_{REV}	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004	−0.003	−0.003	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004
	(−4.390)	(−4.441)	(−4.067)	(−4.071)	(−3.794)	(−3.836)	(−3.919)	(−2.260)	(−4.104)	(−4.346)	(−4.105)	(−4.147)	(−4.343)	(−4.371)	(−4.094)	(−4.143)
β_{MoM}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(−1.677)	(−1.665)	(−1.212)	(−1.208)	(−1.223)	(−1.221)	(−1.295)	(−1.551)	(−1.235)	(−1.309)	(−1.264)	(−1.263)	(−1.235)	(−1.234)	(−1.416)	(−1.415)
β_{Illiq}	0.010	0.010	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.010	0.008	0.008	0.007	0.007	0.009	0.009
	(2.013)	(2.005)	(1.411)	(1.405)	(1.397)	(1.388)	(1.488)	(1.719)	(1.532)	(1.914)	(1.604)	(1.597)	(1.498)	(1.489)	(1.879)	(1.874)
β_{Size}	−0.031	−0.029	0.018	0.018	0.010	0.009	0.015	0.007	0.020	0.026	0.007	0.007	−0.010	−0.010	−0.014	−0.014
	(−0.174)	(−0.166)	(0.115)	(0.117)	(0.062)	(0.061)	(0.097)	(0.043)	(0.126)	(0.170)	(0.041)	(0.041)	(−0.063)	(−0.063)	(−0.086)	(−0.086)
β_{OptV}	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001
	(−1.909)	(−1.917)	(−3.340)	(−3.431)	(−3.351)	(−3.353)	(−3.231)	(−2.977)	(−3.189)	(−2.749)	(−3.106)	(−3.109)	(−3.178)	(−3.177)	(−2.908)	(−2.907)
β_{VRP}	0.433	0.459														
	(5.544)	(5.838)														
β_{Skew}			0.000	0.000												
			(−0.042)	(−0.052)												
β_{SPRD}					0.006	0.006										
					(3.477)	(3.485)										
β_{Max}							−0.002	−0.008								
							(−1.473)	(−1.463)								
β_{Min}									0.003	0.013						
									(1.558)	(1.521)						
β_{RNV}											0.032	0.032				
											(5.826)	(5.843)				
β_{RNS}													0.000	0.000		
													(−2.256)	(−2.257)		
β_{JTI}															0.151	0.152
															(2.366)	(2.384)
β_{ORV}	−0.025		−0.032		−0.035		−0.029		−0.027		−0.028		−0.022		−0.015	
	(−0.712)		(−0.972)		(−1.038)		(−0.899)		(−0.858)		(−0.904)		(−0.686)		(−0.497)	
β_{ORV^+}		−0.079		−0.083		−0.087		−0.080		−0.074		−0.079		−0.070		−0.067
		(−2.485)		(−2.713)		(−2.626)		(−2.571)		(−2.697)		(−2.512)		(−2.307)		(−2.227)
β_{ORV^-}		0.076		0.065		0.065		0.079		0.096		0.065		0.070		0.077
		(1.658)		(1.548)		(1.490)		(1.908)		(2.456)		(1.560)		(1.582)		(1.898)
R^2_{adj}	0.876%	0.892%	1.074%	1.077%	1.131%	1.135%	1.117%	1.254%	1.143%	1.391%	1.139%	1.142%	1.212%	1.216%	1.221%	1.226%

Notes: Everything is defined as in Table 10. VRP is the variance risk-premium as defined in Section 5, $Skew$ is the implied skewness, $SPRD$ is the call-put ATM volatility spread, Max and Min are the Bali et al. (2011) maximum and minimum daily returns, RNV and RNS are the Bakshi et al. (2003) risk-neutral variance and skewness, and JTI is the jump-tail risk by Du and Kapadia (2012). All these measures are defined in Appendix A.

Table C13: Predicting SPY Monthly Excess Return with OTM Call Option Realized Signed Jumps

	Call ($K/S = 1.10$)																	
α	0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.002	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.003
	(0.629)	(0.713)	(0.774)	(0.849)	(0.686)	(0.765)	(0.647)	(0.723)	(0.875)	(0.933)	(0.650)	(0.734)	(0.491)	(0.555)	(0.579)	(0.595)	(0.767)	(0.852)
β_{RV}			−2.098	−2.063	−1.935	−1.909	−1.922	−1.894	−2.083	−2.048	−1.771	−1.740	−1.882	−1.853	−1.873	−1.802	−1.818	−1.754
			(−3.743)	(−3.770)	(−3.147)	(−3.187)	(−3.115)	(−3.132)	(−3.523)	(−3.519)	(−2.866)	(−2.891)	(−3.142)	(−3.180)	(−3.187)	(−3.147)	(−2.757)	(−2.666)
β_{JV}	−6.662	−6.377	−6.600	−6.261	−6.906	−6.538	−6.479	−6.145	−6.185	−5.909	−6.618	−6.278	−6.598	−6.241	−6.573	−6.372	−5.240	−5.063
	(−1.906)	(−1.951)	(−1.641)	(−1.679)	(−1.671)	(−1.708)	(−1.545)	(−1.580)	(−1.665)	(−1.700)	(−1.578)	(−1.615)	(−1.574)	(−1.610)	(−1.713)	(−1.744)	(−1.142)	(−1.182)
β_{IV}			2.821	2.721	1.890	1.835	2.461	2.303	4.115	3.941			1.787	1.724	2.031	2.471	2.323	2.366
			(2.159)	(2.086)	(1.615)	(1.564)	(1.545)	(1.441)	(2.932)	(2.868)			(1.548)	(1.492)	(0.697)	(0.857)	(1.502)	(1.566)
β_{REV}	−0.002	−0.003	−0.002	−0.003	−0.002	−0.003	−0.001	−0.002	0.000	−0.001	−0.002	−0.003	−0.002	−0.003	−0.002	−0.003	−0.004	−0.005
	(−0.618)	(−0.885)	(−0.532)	(−0.832)	(−0.595)	(−0.906)	(−0.235)	(−0.519)	(−0.114)	(−0.349)	(−0.742)	(−1.044)	(−0.655)	(−0.959)	(−0.735)	(−1.010)	(−1.032)	(−1.365)
β_{MoM}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.198)	(0.113)	(0.356)	(0.254)	(0.178)	(0.083)	(0.093)	(0.016)	(0.249)	(0.165)	(0.066)	(−0.031)	(0.400)	(0.341)	(0.226)	(0.204)	(−0.025)	(−0.111)
β_{Illiq}	0.401	0.490	0.394	0.490	0.411	0.509	0.452	0.543	0.682	0.751	0.449	0.549	0.326	0.411	0.428	0.540	0.511	0.594
	(0.554)	(0.678)	(0.664)	(0.828)	(0.697)	(0.865)	(0.794)	(0.952)	(1.165)	(1.276)	(0.770)	(0.947)	(0.536)	(0.676)	(0.728)	(0.924)	(0.891)	(1.034)
β_{Size}	−0.205	−0.228	−0.232	−0.254	−0.223	−0.246	−0.208	−0.231	−0.263	−0.281	−0.215	−0.238	−0.119	−0.125	−0.200	−0.208	−0.244	−0.265
	(−0.797)	(−0.884)	(−0.875)	(−0.958)	(−0.846)	(−0.929)	(−0.793)	(−0.878)	(−1.006)	(−1.069)	(−0.809)	(−0.896)	(−0.442)	(−0.469)	(−0.747)	(−0.776)	(−0.906)	(−0.992)
β_{OptV}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(4.473)	(5.014)	(3.986)	(4.459)	(3.689)	(4.172)	(3.748)	(4.215)	(4.168)	(4.455)	(3.674)	(4.160)	(3.711)	(4.224)	(3.526)	(3.906)	(4.262)	(4.701)
β_{VRP}	1.882	1.854																
	(3.182)	(3.175)																
β_{Skew}			−0.009	−0.008														
			(−1.298)	(−1.239)														
β_{SPRD}					0.007	0.006												
					(1.406)	(1.309)												
β_{Max}							−0.009	−0.007										
							(−0.514)	(−0.422)										
β_{Min}									0.034	0.032								
									(2.005)	(1.940)								
β_{RNV}											0.062	0.060						
											(1.346)	(1.289)						
β_{RNS}													0.000	0.001				
													(1.006)	(1.269)				
β_{JTI}															−0.129	−0.432		
															(−0.087)	(−0.296)		
β_{LTV}																	−0.041	−0.043
																	(−1.917)	(−2.068)
β_{ORJ}	−0.437		−0.399		−0.432		−0.432		−0.336		−0.442		−0.464		−0.441		−0.493	
	(−1.373)		(−1.199)		(−1.351)		(−1.359)		(−1.095)		(−1.402)		(−1.491)		(−1.481)		(−1.486)	
β_{ORJ^+}		−0.503		−0.489		−0.497		−0.495		−0.430		−0.507		−0.550		−0.525		−0.453
		(−1.819)		(−1.760)		(−1.808)		(−1.777)		(−1.620)		(−1.854)		(−2.092)		(−2.075)		(−1.683)
β_{ORJ^-}		0.775		0.751		0.770		0.758		0.643		0.773		0.829		0.803		0.839
		(2.476)		(2.359)		(2.459)		(2.460)		(2.300)		(2.473)		(2.792)		(2.825)		(2.670)
R^2_{adj}	5.044%	5.659%	5.299%	5.888%	5.083%	5.689%	5.106%	5.690%	6.607%	7.036%	4.886%	5.498%	5.199%	5.906%	5.004%	5.652%	5.645%	6.312%

Notes: Everything is defined as in Table 11. VRP is the variance risk-premium as defined in Section 5, $Skew$ is the implied skewness, $SPRD$ is the call-put ATM volatility spread, Max and Min are the Bali et al. (2011) maximum and minimum daily returns, RNV and RNS are the Bakshi et al. (2003) risk-neutral variance and skewness, JTI is the jump-tail risk of Du and Kapadia (2012), and LTV is the left tail variation of Bollerslev et al. (2015). The left tail variation is obtained from www.tailindex.com and the sample size is from January 11, 2005 to December 31, 2019. All these measures are defined in Appendix A.

Table C14: Predicting SPY Monthly Excess Return with OTM Put Option Realized Signed Jumps

	Put ($K/S = 0.90$)																	
α	0.001	0.003	0.002	0.003	0.002	0.003	0.002	0.003	0.002	0.004	0.002	0.003	0.001	0.002	0.001	0.003	0.002	0.003
	(0.470)	(0.912)	(0.619)	(1.043)	(0.525)	(0.974)	(0.488)	(0.933)	(0.707)	(1.099)	(0.497)	(0.942)	(0.321)	(0.783)	(0.431)	(0.830)	(0.612)	(0.980)
β_{RV}			−2.206	−1.997	−2.035	−1.839	−2.022	−1.828	−2.189	−2.023	−1.866	−1.673	−1.991	−1.782	−1.980	−1.757	−1.917	−1.706
			(−3.917)	(−3.574)	(−3.296)	(−3.002)	(−3.263)	(−2.957)	(−3.693)	(−3.396)	(−2.993)	(−2.723)	(−3.311)	(−2.986)	(−3.342)	(−3.001)	(−2.884)	(−2.557)
β_{JV}	−6.575	−6.458	−6.589	−6.097	−6.899	−6.386	−6.465	−5.966	−6.160	−5.803	−6.607	−6.081	−6.581	−6.061	−6.538	−6.099	−5.178	−4.666
	(−1.869)	(−1.957)	(−1.629)	(−1.605)	(−1.659)	(−1.631)	(−1.531)	(−1.509)	(−1.650)	(−1.645)	(−1.565)	(−1.533)	(−1.557)	(−1.528)	(−1.695)	(−1.645)	(−1.126)	(−1.082)
β_{IV}			2.999	2.541	2.024	1.648	2.599	2.201	4.312	3.854			1.934	1.538	2.097	1.966	2.439	2.128
			(2.255)	(1.922)	(1.688)	(1.406)	(1.626)	(1.380)	(3.042)	(2.772)			(1.636)	(1.331)	(0.711)	(0.679)	(1.553)	(1.373)
β_{REV}	−0.002	−0.004	−0.001	−0.003	−0.002	−0.004	−0.001	−0.003	0.000	−0.002	−0.002	−0.004	−0.002	−0.004	−0.002	−0.004	−0.004	−0.005
	(−0.556)	(−1.099)	(−0.442)	(−1.135)	(−0.512)	(−1.208)	(−0.169)	(−0.712)	(−0.021)	(−0.608)	(−0.670)	(−1.358)	(−0.569)	(−1.273)	(−0.658)	(−1.352)	(−0.962)	(−1.498)
β_{MoM}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.177)	(0.196)	(0.352)	(0.302)	(0.168)	(0.128)	(0.084)	(0.047)	(0.237)	(0.212)	(0.055)	(0.021)	(0.386)	(0.357)	(0.205)	(0.202)	(−0.008)	(−0.028)
β_{Illiq}	0.367	0.455	0.345	0.493	0.366	0.512	0.408	0.551	0.633	0.753	0.408	0.554	0.278	0.427	0.382	0.535	0.495	0.627
	(0.509)	(0.630)	(0.589)	(0.826)	(0.629)	(0.865)	(0.726)	(0.958)	(1.090)	(1.273)	(0.709)	(0.946)	(0.460)	(0.696)	(0.658)	(0.908)	(0.874)	(1.073)
β_{Size}	−0.169	−0.282	−0.195	−0.311	−0.187	−0.306	−0.172	−0.290	−0.225	−0.330	−0.179	−0.298	−0.080	−0.200	−0.165	−0.278	−0.209	−0.299
	(−0.647)	(−1.080)	(−0.724)	(−1.151)	(−0.693)	(−1.135)	(−0.640)	(−1.083)	(−0.846)	(−1.233)	(−0.662)	(−1.102)	(−0.291)	(−0.723)	(−0.603)	(−1.002)	(−0.757)	(−1.107)
β_{OptV}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(4.418)	(4.819)	(3.904)	(4.278)	(3.584)	(3.981)	(3.643)	(4.030)	(4.128)	(4.261)	(3.562)	(3.980)	(3.603)	(4.006)	(3.445)	(3.745)	(4.151)	(4.496)
β_{VRP}	1.987	1.765																
	(3.309)	(3.000)																
β_{Skew}			−0.009	−0.008														
			(−1.371)	(−1.255)														
β_{SPRD}					0.007	0.007												
					(1.430)	(1.424)												
β_{Max}							−0.009	−0.009										
							(−0.521)	(−0.507)										
β_{Min}									0.035	0.033								
									(2.045)	(1.970)								
β_{RNV}											0.067	0.053						
											(1.414)	(1.144)						
β_{RNS}													0.000	0.000				
													(0.973)	(1.050)				
β_{JTI}															−0.088	−0.241		
															(−0.058)	(−0.165)		
β_{LTV}																	−0.041	−0.040
																	(−1.908)	(−1.889)
β_{ORJ}	0.332		0.359		0.329		0.325		0.432		0.292		0.367		0.329		0.143	
	(1.029)		(1.055)		(0.977)		(0.965)		(1.353)		(0.876)		(1.072)		(0.956)		(0.423)	
β_{ORJ^+}		−1.044		−1.029		−1.059		−1.055		−0.934		−1.076		−1.079		−1.069		−0.907
		(−2.736)		(−2.571)		(−2.671)		(−2.686)		(−2.646)		(−2.736)		(−2.756)		(−2.881)		(−2.299)
β_{ORJ^-}		0.636		0.601		0.637		0.623		0.390		0.662		0.674		0.660		0.666
		(1.532)		(1.425)		(1.534)		(1.490)		(1.037)		(1.608)		(1.647)		(1.727)		(1.576)
R^2_{adj}	4.969%	5.599%	5.248%	5.841%	5.010%	5.653%	5.031%	5.667%	6.602%	7.044%	4.799%	5.475%	5.117%	5.782%	4.926%	5.581%	5.493%	6.080%

Notes: Everything is defined as in Table 11. VRP is the variance risk-premium as defined in Section 5, $Skew$ is the implied skewness, $SPRD$ is the call-put ATM volatility spread, Max and Min are the Bali et al. (2011) maximum and minimum daily returns, RNV and RNS are the Bakshi et al. (2003) risk-neutral variance and skewness, JTI is the jump-tail risk of Du and Kapadia (2012), and LTV is the left tail variation of Bollerslev et al. (2015). The left tail variation is obtained from www.tailindex.com and the sample size is from January 11, 2005 to December 31, 2019. All these measures are defined in Appendix A.

Table C15: Predicting Equity Monthly Excess Return with OTM Call Option Realized Signed Jumps

	Call ($K/S = 1.10$)															
β_{RV}			−0.424	−0.419	−0.420	−0.415	−0.425	−0.420	−0.423	−0.412	−0.486	−0.482	−0.443	−0.438	−0.509	−0.504
			(−5.090)	(−5.132)	(−4.847)	(−4.802)	(−4.960)	(−4.817)	(−4.881)	(−4.476)	(−5.424)	(−5.387)	(−5.379)	(−5.313)	(−5.297)	(−5.250)
β_{JV}	0.752	0.803	−0.016	−0.012	−0.082	−0.077	−0.017	−0.018	−0.006	0.030	0.023	0.029	0.011	0.017	0.050	0.056
	(1.720)	(1.853)	(−0.035)	(−0.028)	(−0.194)	(−0.184)	(−0.038)	(−0.042)	(−0.013)	(0.070)	(0.051)	(0.063)	(0.023)	(0.037)	(0.110)	(0.124)
β_{IV}			0.838	0.837	0.831	0.825	0.908	1.120	0.917	1.189			0.822	0.816	0.348	0.346
			(4.773)	(3.681)	(4.857)	(4.829)	(4.612)	(3.422)	(5.299)	(4.116)			(5.316)	(5.282)	(1.131)	(1.120)
β_{REV}	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004	−0.003	−0.003	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004
	(−4.244)	(−4.405)	(−3.939)	(−4.009)	(−3.676)	(−3.788)	(−3.789)	(−2.222)	(−3.995)	(−4.324)	(−4.004)	(−4.142)	(−4.255)	(−4.364)	(−4.017)	(−4.145)
β_{MoM}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(−1.695)	(−1.675)	(−1.233)	(−1.220)	(−1.243)	(−1.233)	(−1.316)	(−1.562)	(−1.254)	(−1.317)	(−1.287)	(−1.275)	(−1.253)	(−1.242)	(−1.440)	(−1.425)
β_{Illiq}	0.010	0.010	0.007	0.008	0.008	0.008	0.008	0.008	0.008	0.010	0.008	0.008	0.007	0.007	0.009	0.009
	(2.019)	(2.026)	(1.407)	(1.416)	(1.394)	(1.400)	(1.488)	(1.737)	(1.534)	(1.928)	(1.608)	(1.612)	(1.500)	(1.506)	(1.886)	(1.887)
β_{Size}	−0.035	−0.030	0.014	0.018	0.005	0.009	0.011	0.006	0.015	0.025	0.002	0.006	−0.014	−0.011	−0.019	−0.015
	(−0.194)	(−0.168)	(0.087)	(0.113)	(0.035)	(0.057)	(0.068)	(0.038)	(0.097)	(0.164)	(0.014)	(0.037)	(−0.087)	(−0.066)	(−0.113)	(−0.090)
β_{OptV}	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001
	(−1.912)	(−1.926)	(−3.335)	(−3.425)	(−3.355)	(−3.367)	(−3.230)	(−2.986)	(−3.181)	(−2.730)	(−3.116)	(−3.127)	(−3.161)	(−3.192)	(−2.906)	(−2.917)
β_{VRP}	0.446	0.461														
	(5.675)	(5.877)														
β_{Skew}			0.000	0.000												
			(−0.092)	(−0.060)												
β_{SPRD}					0.005	0.006										
					(3.480)	(3.482)										
β_{Max}							−0.002	−0.008								
							(−1.487)	(−1.460)								
β_{Min}									0.003	0.013						
									(1.574)	(1.513)						
β_{RNV}											0.032	0.032				
											(6.004)	(5.967)				
β_{RNS}													0.000	0.000		
													(−2.285)	(−2.274)		
β_{JTI}															0.153	0.152
															(2.419)	(2.399)
β_{ORJ}	0.069		0.070		0.067		0.071		0.071		0.067		0.067		0.075	
	(1.382)		(1.433)		(1.389)		(1.440)		(1.473)		(1.384)		(1.547)		(1.528)	
β_{ORJ^+}		0.028		0.030		0.028		0.034		0.031		0.032		0.022		0.033
		(1.159)		(1.301)		(1.149)		(1.436)		(1.276)		(1.297)		(1.093)		(1.372)
β_{ORJ^-}		0.072		0.062		0.062		0.047		0.043		0.063		0.059		0.058
		(2.505)		(2.254)		(2.190)		(1.708)		(1.688)		(2.199)		(1.971)		(2.114)
R^2_{adj}	0.881%	0.888%	1.077%	1.072%	1.133%	1.129%	1.122%	1.249%	1.149%	1.384%	1.143%	1.139%	1.218%	1.212%	1.230%	1.223%

Notes: Everything is defined as in Table 12. VRP is the variance risk-premium as defined in Section 5, $Skew$ is the implied skewness, $SPRD$ is the call-put ATM volatility spread, Max and Min are the Bali et al. (2011) maximum and minimum daily returns, RNV and RNS are the Bakshi et al. (2003) risk-neutral variance and skewness, and JTI is the jump-tail risk by Du and Kapadia (2012). All these measures are defined in Appendix A.

Table C16: Predicting Equity Monthly Excess Return with OTM Put Option Realized Signed Jumps

	Put ($K/S = 0.90$)															
β_{RV}			−0.422	−0.412	−0.417	−0.408	−0.422	−0.413	−0.420	−0.406	−0.483	−0.475	−0.442	−0.434	−0.506	−0.497
			(−5.116)	(−5.126)	(−4.861)	(−4.753)	(−4.979)	(−4.779)	(−4.897)	(−4.455)	(−5.449)	(−5.366)	(−5.411)	(−5.309)	(−5.304)	(−5.229)
β_{JV}	0.760	0.809	−0.009	−0.005	−0.075	−0.071	−0.010	−0.011	0.001	0.037	0.029	0.035	0.016	0.022	0.056	0.061
	(1.740)	(1.872)	(−0.020)	(−0.011)	(−0.179)	(−0.172)	(−0.023)	(−0.026)	(0.002)	(0.085)	(0.064)	(0.077)	(0.036)	(0.049)	(0.126)	(0.138)
β_{IV}			0.836	0.829	0.829	0.818	0.906	1.113	0.915	1.184			0.822	0.812	0.348	0.343
			(4.767)	(3.635)	(4.850)	(4.778)	(4.607)	(3.400)	(5.284)	(4.081)			(5.322)	(5.241)	(1.127)	(1.110)
β_{REV}	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004	−0.003	−0.003	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004	−0.004
	(−4.213)	(−4.412)	(−3.893)	(−4.044)	(−3.634)	(−3.821)	(−3.736)	(−2.260)	(−3.947)	(−4.354)	(−3.958)	(−4.138)	(−4.201)	(−4.360)	(−3.969)	(−4.146)
β_{MoM}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(−1.689)	(−1.659)	(−1.227)	(−1.206)	(−1.237)	(−1.219)	(−1.310)	(−1.547)	(−1.248)	(−1.304)	(−1.280)	(−1.260)	(−1.250)	(−1.231)	(−1.432)	(−1.410)
β_{Illiq}	0.010	0.010	0.007	0.008	0.008	0.008	0.008	0.008	0.008	0.010	0.008	0.008	0.007	0.007	0.009	0.009
	(2.017)	(2.029)	(1.403)	(1.419)	(1.390)	(1.402)	(1.483)	(1.739)	(1.528)	(1.927)	(1.602)	(1.612)	(1.494)	(1.504)	(1.877)	(1.887)
β_{Size}	−0.031	−0.029	0.017	0.018	0.009	0.009	0.014	0.007	0.019	0.025	0.006	0.006	−0.012	−0.010	−0.015	−0.014
	(−0.177)	(−0.166)	(0.109)	(0.116)	(0.056)	(0.059)	(0.090)	(0.042)	(0.120)	(0.169)	(0.035)	(0.040)	(−0.072)	(−0.063)	(−0.092)	(−0.086)
β_{OptV}	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001
	(−1.929)	(−1.874)	(−3.361)	(−3.379)	(−3.379)	(−3.319)	(−3.254)	(−2.928)	(−3.206)	(−2.692)	(−3.139)	(−3.076)	(−3.191)	(−3.139)	(−2.928)	(−2.868)
β_{VRP}	0.443	0.454														
	(5.700)	(5.809)														
β_{Skew}			0.000	0.000												
			(−0.078)	(−0.052)												
β_{SPRD}					0.005	0.006										
					(3.470)	(3.519)										
β_{Max}							−0.002	−0.008								
							(−1.486)	(−1.461)								
β_{Min}									0.003	0.013						
									(1.569)	(1.513)						
β_{RNV}											0.032	0.032				
											(6.004)	(5.921)				
β_{RNS}													0.000	0.000		
													(−2.297)	(−2.250)		
β_{JTI}															0.152	0.151
															(2.408)	(2.381)
β_{ORJ}	0.052		0.062		0.054		0.063		0.064		0.057		0.082		0.065	
	(1.180)		(1.386)		(1.233)		(1.402)		(1.430)		(1.289)		(1.865)		(1.434)	
β_{ORJ^+}		−0.131		−0.126		−0.132		−0.123		−0.113		−0.122		−0.108		−0.112
		(−2.983)		(−3.115)		(−3.043)		(−2.961)		(−3.074)		(−2.936)		(−2.675)		(−2.704)
β_{ORJ^-}		−0.008		−0.019		−0.017		−0.028		−0.052		−0.019		−0.031		−0.020
		(−0.186)		(−0.439)		(−0.410)		(−0.674)		(−1.418)		(−0.462)		(−0.713)		(−0.486)
R^2_{adj}	0.875%	0.897%	1.072%	1.081%	1.128%	1.139%	1.116%	1.258%	1.143%	1.393%	1.138%	1.147%	1.215%	1.219%	1.224%	1.229%

Notes: Everything is defined as in Table 12. VRP is the variance risk-premium as defined in Section 5, $Skew$ is the implied skewness, $SPRD$ is the call-put ATM volatility spread, Max and Min are the Bali et al. (2011) maximum and minimum daily returns, RNV and RNS are the Bakshi et al. (2003) risk-neutral variance and skewness, and JTI is the jump-tail risk by Du and Kapadia (2012). All these measures are defined in Appendix A.