The Leverage Effect and Expected Option Returns*

Hitesh Doshi Kris Jacobs Saim Ayberk Sert†

July 22, 2026

Abstract

We use a reduced-form model to study how the market leverage effect, the correlation between index returns and variance innovations, affects expected index option returns. This impact consists of four components, respectively operating through the option's equity and variance loadings, and the market equity and variance risk premiums. The model predicts a negative (positive) relation between the leverage effect and expected call (put) returns. Treating risk premiums as exogenous reverses the predicted sign for puts. We confirm these theoretical predictions using weekly S&P 500 index option returns. The empirical results are very robust and hold across formation days, maturities, and holding periods. We extend the analysis to delta-hedged and delevered returns.

Keywords: Leverage effect; Return-variance correlation; S&P 500 index options; Expected option returns; Pricing Kernel; Stochastic Volatility Model; Factor loadings; Variance risk premium; Equity risk premium; Skewness.

JEL Classification: G12, G13

*This work was completed in part with resources provided by the Research Computing Data Core at the University of Houston.

†C.T. Bauer College of Business, University of Houston. Doshi: hdoshi@bauer.uh.edu; Jacobs: kjacobs@bauer.uh.edu; Sert: sasert@bauer.uh.edu.

1 Introduction

The negative correlation between stock returns and changes in variance is one of the most robust empirical regularities in equity and stock index markets (Black, 1976; Christie, 1982; Duffee, 1995). Das and Sundaram (1999) and Neuberger and Payne (2021) show that this correlation, commonly labeled the leverage effect, results in negative skewness in the return distribution, which is in turn related to the implied volatility skew observed in option markets (Heston, 1993). The option pricing literature contains extensive evidence on the measurement of the parameters governing this correlation (e.g., Bates, 2000; Pan, 2002; Christoffersen, Heston, and Jacobs, 2009). However, in spite of the central place of the leverage effect in the option pricing literature, its role in the determination of expected option returns has not received much attention.

Options are nonlinear functions of the underlying return distribution, and a parameter that governs the asymmetry of that distribution should be reflected in their expected returns. The return-variance correlation is a natural candidate for proxying this asymmetry. Existing work typically measures asymmetry using risk-neutral skewness or with lottery-style proxies, and finds that higher skewness predicts lower option returns (Bali and Murray, 2013; Boyer and Vorkink, 2014; Byun and Kim, 2016). Conceptually, the return-variance correlation is a natural alternative to these existing measures given the structural relation with skewness (Das and Sundaram, 1999; Neuberger and Payne, 2021). Moreover, from an empirical perspective, it may be easier to measure this proxy precisely compared to skewness, which is particularly difficult to measure precisely using short windows (Bali, Engle, and Murray, 2016; Doshi, Jacobs, and Sert, 2026). These theoretical and empirical properties make the return-variance correlation well-suited as an asymmetry proxy and hence a predictor of expected option returns.

This paper studies the relation between the leverage effect and expected index option returns, both theoretically and empirically. Our theoretical analysis relies on the stochastic volatility framework of Heston (1993) and the variance-dependent exponential-affine pricing kernel in Heston, Jacobs, and Kim (2024b). This kernel yields equity and variance risk premiums that are both linear in the variance level and that depend explicitly on the return-variance correlation. In this setup, the expected option return can be decomposed into four components. Two of these components capture how a change in the leverage effect alters the option's equity and variance loadings through the risk-neutral distribution. The other two components capture how a change in the leverage effect alters the equity and variance risk premiums themselves. This decomposition allows us to characterize these four components and to quantify their relative contribution to the overall expected option return. A critical aspect of this framework is that we incorporate not only the impact of leverage on the exposures to the risk premiums, but also its impact on the risk premiums themselves.

Our theoretical analysis of the relation between the leverage effect and expected option returns yields three main results. First, the effect of the leverage effect on expected option returns is negative for calls and positive for puts. These signs are consistent with the intuition that a more negative correlation tilts the return distribution further to the left, thereby increasing the compensation required for holding calls and decreasing the compensation required for holding puts. Second, the magnitude of these effects is larger for out-of-the-money contracts than for at-the-money contracts for calls, but lower for puts. Third, the risk premium channel is critical. Treating risk premiums as exogenous, which is standard in much of the option returns literature, eliminates this channel and reverses the sign of the theoretically predicted relation between the leverage effect and expected put returns.

We test the theoretical predictions empirically using weekly S&P 500 index option returns from January 1996 through December 2023. Pooled predictive regressions estimate a negative and statistically significant coefficient on the leverage effect for calls and a positive and statistically significant coefficient for puts. The signs hold across three near-the-money moneyness intervals and for univariate and multivariate specifications with controls. A one-standard-deviation increase in the return-variance correlation lowers weekly call returns by roughly two to four-and-a-half percentage points and raises weekly put returns by roughly two to five percentage points. The estimated relation strengthens for out-of-the-money calls and is weaker in magnitude for out-of-the-money puts, with the differential larger for calls than for puts. The results are robust to the choice of formation day and to excluding expiration weeks (Garcia-Ares, 2023). They are also robust when we use samples of longer-maturity options and to a monthly holding period.

We extend our analysis to two different types of returns often used in the literature. First, we examine delta-hedged returns, which isolate the variance channel. In this case, the decomposition predicts a positive impact of the leverage effect on delta-hedged call returns, and a sign change across moneyness for delta-hedged put returns. Our empirical results align with both these predictions. Second, we examine delevered returns, which scale option payoffs by the underlying price rather than by the option price and have become standard in the literature that studies factor models for option returns (Büchner and Kelly, 2022; Fournier, Jacobs, and Orłowski, 2024; Duarte, Jones, and Wang, 2024; Dickerson, Fournier, Jacobs, and Orłowski, 2025). Similar to the analysis of raw returns, the impact of the leverage effect on expected delevered option returns can also be decomposed into four components. Our empirical results once again match the predictions of the theory.

Our analysis and empirical results highlight the role of endogenous risk premia. Much of the option returns literature treats the equity and variance risk premiums as exogenous or controls for equity risk premium by delta-hedging (e.g., Bakshi and Kapadia, 2003; Goyal and Saretto, 2009; Cao and Han, 2013; Bali, Beckmeyer, Moerke, and Weigert, 2023). Our decomposition shows that the risk premium channels are critical, and that ignoring them would reverse the sign of the predicted effect for puts. The return-variance correlation affects not only the option's exposures (loadings) but also the risk premiums it is exposed to.

Our paper contributes to several other strands of literature. We connect the literature on the leverage effect in option pricing (e.g., Heston, 1993; Christoffersen et al., 2009) to the literature on option returns, thereby characterizing and quantifying the role of a central option pricing parameter in the determination of expected option returns. We also contribute to the literature on option returns. There is an extensive literature on the properties of index option returns (Coval and Shumway, 2001; Bakshi and Kapadia, 2003; Broadie, Chernov, and Johannes, 2009; Carr and Wu, 2009; Constantinides, Jackwerth, and Savov, 2013; Chambers, Foy, Liebner, and Lu, 2014) and on the cross-section of option returns, which links option returns to various types of volatility risk (Goyal and Saretto, 2009; Cao and Han, 2013; Vasquez, 2017; Hu and Jacobs, 2020; Ruan, 2020; Cao, Vasquez, Xiao, and Zhan, 2023; Aretz, Lin, and Poon, 2023; Schlag and Sichert, 2026), risk-neutral and historical skewness (Bali and Murray, 2013; Boyer and Vorkink, 2014; Byun and Kim, 2016), and an array of underlying equity and option characteristics (Ramachandran and Tayal, 2021; Vasquez and Xiao, 2024; Heston, Jones, Khorram, Li, and Mo, 2023; Bali et al., 2023; Jeon, Kan, and Li, 2025).

Our work is also related to the classical literature on the relation between skewness and expected stock returns, and the relation between higher moments of returns and stock returns more in general. A large body of research shows that investors have preferences over the skewness of returns and require compensation for holding assets with negative skewness, giving rise to a skewness risk premium (Arditti, 1967; Kraus and Litzenberger, 1976; Conine Jr and Tamarkin, 1981; Harvey and Siddique, 2000; Mitton and Vorkink, 2007; Barberis and Huang, 2008). A recurring challenge in this literature is that skewness-related risk is difficult to measure. Several studies therefore propose alternative approaches based on historical returns, option prices, or firm characteristics.[1]

It is also worth emphasizing that our analysis and empirical results critically differ from the existing literature on skewness and option returns (see Bali and Murray, 2013; Boyer and Vorkink, 2014; Byun and Kim, 2016). First, our modeling approach explicitly relies on a stochastic discount factor and we investigate index option returns, while existing papers examine the cross-section of individual equity option returns. The magnitudes of the leverage effect and equity and variance risk premia on the underlying stocks, as well as the determinants of these risk premia can significantly differ from index markets. Second, the variables used in these studies to capture asymmetry differ from the leverage effect. Bali and Murray (2013) rely on risk-neutral skewness and Boyer and Vorkink (2014) on an ex ante skewness measure, while Byun and Kim (2016) use the maximum past stock return (MAX) of Bali et al. (2011), which is highly correlated with idiosyncratic volatility. The return-variance correlation we analyze determines the sign of skewness under the physical measure, but may contain different information. Moreover, it provides us with the opportunity to anchor and guide the empirical results with a theoretical analysis.

The remainder of the paper is organized as follows. Section 2 presents the model and the decomposition and discusses the theoretical predictions. Section 3 describes the data and the benchmark empirical results. Section 4 reports robustness exercises. Section 5 extends the analysis to delta-hedged and delevered returns, and Section 6 concludes.

[1]See, among others, Boyer, Mitton, and Vorkink (2010), Bali, Cakici, and Whitelaw (2011), Amaya, Christoffersen, Jacobs, and Vasquez (2015), Xing, Zhang, and Zhao (2010), Cremers and Weinbaum (2010), Conrad, Dittmar, and Ghysels (2013), Stilger, Kostakis, and Poon (2017), Kim and Park (2018), Langlois (2020), Jiang, Wu, Zhou, and Zhu (2020), Bollerslev, Li, and Zhao (2020), Huang and Li (2019), Kozhan, Neuberger, and Schneider (2013), Pederzoli (2026), and Doshi et al. (2026).

2 The Leverage Effect and Expected Option Returns

In this section, we present a standard model we use to decompose expected option returns into four components. We then derive theoretical predictions on how the return-variance correlation affects each of these components and the overall (combined) expected option return. We derive these results as a function of option type (call versus put) and moneyness.

2.1 Decomposing Expected Option Returns

We build on the one-factor stochastic volatility model (Heston, 1993) to provide a tractable framework for analyzing how the correlation between stock return and variance shocks affects option returns. The spot index level $S(t)$ and variance $v(t)$ evolve under the physical measure as follows:

$$\frac{dS(t)}{S(t)} = (\mu + r)dt + \sqrt{v(t)}dW_1(t), \tag{1}$$

$$dv(t) = \kappa(\theta - v(t))dt + \sigma\sqrt{v(t)}dW_2(t), \tag{2}$$

where $dW_1(t)$ and $dW_2(t)$ are Wiener processes with correlation ρ; μ is the equity risk premium; r is the constant risk-free rate; and κ, θ, and σ are the speed of mean-reversion, long-run variance, and volatility of variance, respectively.

Let $O(t, S(t), v(t))$ denote the time-t value of an option written on $S(t)$. Applying Itô's lemma to $O(t, S(t), v(t))$ and using Equations (1)–(2) yields the following decomposition of the option's instantaneous expected excess return into compensation for equity and variance risk (Duarte et al., 2024):

$$\mathrm{E}\left[\frac{dO}{O}\right] - rdt = \mu\beta_S dt + \lambda\beta_v dt, \tag{3}$$

where $\beta_S = SO_S/O$ is the option's leverage, $\beta_v = O_v/O$ is the option's exposure to variance, and $\lambda = \kappa(\theta - v) - \kappa^{\mathbb{Q}}(\theta^{\mathbb{Q}} - v)$ is the variance risk premium.[2] Equation (3) shows that the expected excess return of an option can be thought of as consisting of four components: the

[2] O_S and O_v denote the option's delta and its sensitivity to the variance state, respectively. O_v relates to conventional vega via $\partial O/\partial\sqrt{v} = 2\sqrt{v}\,O_v$. $\kappa^{\mathbb{Q}}$ and $\theta^{\mathbb{Q}}$ denote the speed of mean-reversion and long-run variance under risk neutral measure.

equity (underlying) risk premium, the option's equity exposure, the variance risk premium, and the option's variance exposure.

In much of the option return literature, the equity and variance risk premia in equation (3) are treated as exogenous (e.g., Broadie et al. (2009), Hu and Jacobs (2020), Duarte et al. (2024), and Schlag and Sichert (2026)). Our analysis on the other hand aims to take into account how the return-variance correlation shapes expected option returns through its effect on both premiums. That is, we endogenize these premiums by allowing them to depend on the variance level. We adopt the exponential-affine pricing kernel of Heston et al. (2024b), which is monotonic in the state variables:

$$\frac{dM}{M} = -rdt - \gamma\sqrt{v(t)}dW_1(t) + \xi\sigma\sqrt{v(t)}dW_2(t), \tag{4}$$

where $\gamma > 0$ and $\xi > 0$ ensure that marginal utility is decreasing in wealth and increasing in variance. Under this kernel, the expected option excess return is

$$\begin{aligned} \mathrm{E}\left[\frac{dO}{O}\right] - rdt &= -\mathrm{Cov}\left(\frac{dO}{O}, \frac{dM}{M}\right) \\ &= \left[\beta_S(\gamma - \rho\sigma\xi)v(t) + \beta_v(\gamma\rho\sigma - \xi\sigma^2)v(t)\right] dt, \end{aligned} \tag{5}$$

where β_S and β_v are as defined in Equation (3). Note that this pricing kernel yields state-dependent risk premia for the underlying index:

$$\mathrm{ERP} \equiv \mu(v(t)) = (\gamma - \rho\sigma\xi)v(t), \tag{6}$$

$$\mathrm{VRP} \equiv \lambda(v(t)) = (\gamma\rho\sigma - \xi\sigma^2)v(t), \tag{7}$$

where ERP and VRP denote the equity and variance risk premiums, respectively. Both risk premia are linear in $v(t)$, with a scaling factor jointly determined by the parameters characterizing the pricing kernel and the return dynamics, γ, ξ, ρ, and σ. Equation (5) is the basis for our theoretical predictions. It provides a framework in which the equity and variance risk premia in Equation (3) are determined by underlying parameters and preferences rather than exogenous.

Our setup differs from most existing analyses and empirical studies in several subtle ways. First, note that the kernel in Equation (4) prices two sources of risk, the return shock $dW_1(t)$

and the variance shock $dW_2(t)$, with prices of risk governed by γ and ξ. The return-variance correlation ρ enters both premiums not as a separate priced factor but as the correlation between these two shocks. It is, by construction, a parameter of the joint return-variance dynamics. This feature distinguishes our setting from the typical approach used in a factor model of option returns. The loadings β_S and β_v are model-implied ratios of option Greeks to the option price, not betas estimated from factor realizations. Furthermore, ρ is the primitive whose effect is structurally determined, rather than a return exposure. Second, the existing literature typically controls for the effects of dynamic risk premiums by either employing delta-hedged option returns or by assuming that these premiums are exogenous (e.g., Goyal and Saretto (2009), Cao and Han (2013), Hu and Jacobs (2020), Bali et al. (2023), and Schlag and Sichert (2026)). In contrast, our framework in Equation (5) explicitly characterizes and disentangles the channels through which ρ influences expected option returns. In Section 2.2, we use this decomposition to construct theoretical predictions for how ρ shapes expected option returns and each of the return components.

2.2 The Leverage Effect and Expected Option Returns

We now examine how ρ shapes expected option returns. Taking the derivative of Equation (5) with respect to ρ yields four separate terms:

$$\frac{\partial \mathrm{EER}}{\partial \rho} = \left[\frac{\partial \beta_S}{\partial \rho}\mu(v(t)) + \beta_S \frac{\partial \mu(v(t))}{\partial \rho} + \frac{\partial \beta_v}{\partial \rho}\lambda(v(t)) + \beta_v \frac{\partial \lambda(v(t))}{\partial \rho}\right] dt, \tag{8}$$

where EER denotes the expected excess option return $\left(\mathrm{E}\left[\frac{dO}{O}\right] - r dt\right)$. $\frac{\partial \beta_S}{\partial \rho}$ and $\frac{\partial \beta_v}{\partial \rho}$ capture how changes in ρ affect the option's equity and variance loadings through the risk-neutral distribution, whereas $\frac{\partial \mu(v(t))}{\partial \rho}$ and $\frac{\partial \lambda(v(t))}{\partial \rho}$ reflect the direct effect of ρ on risk premiums through the pricing kernel.

The underlying risk premiums have closed form derivatives with respect to ρ in the stochastic volatility model. Differentiating the premiums yields

$$\frac{\partial \mu(v(t))}{\partial \rho} = -\sigma \xi v(t) \leq 0, \tag{9}$$

$$\frac{\partial \lambda(v(t))}{\partial \rho} = \gamma \sigma v(t) \geq 0, \tag{10}$$

where the signs follow from $\gamma > 0$ and $\xi > 0$. These effects of ρ on the risk premiums in Equations (9) and (10) are consistent with economic intuition and results in the literature. A higher ρ lowers the equity premium by making the return distribution less left-skewed, in line with the extensive skewness risk premium literature (Arditti, 1967; Kraus and Litzenberger, 1976; Conine Jr and Tamarkin, 1981; Harvey and Siddique, 2000; Mitton and Vorkink, 2007; Barberis and Huang, 2008). Conversely, a higher ρ raises the variance risk premium by increasing the co-movement between variance shocks and the pricing kernel (Pyun, 2019; Hu, Jacobs, and Seo, 2022). However, the derivatives of the factor loadings $\partial\beta_S/\partial\rho$ and $\partial\beta_v/\partial\rho$ with respect to ρ depend on the characteristic function and need to be solved numerically. In our baseline analysis we use $\{\kappa, \theta, \sigma, \rho, \gamma, \xi\} = \{2.9862, 0.0372, 0.4500, -0.7458, 2.0527, 1.6599\}$, based on the estimates in Heston, Jacobs, and Kim (2024a).[3] See the Appendix for implementation details.

Figure 1 documents the resulting theoretical predictions for the effect of ρ on expected returns of options with 30 days to maturity, using a one-week holding period. We use 30-day options to avoid contracts close to expiration, consistent with the standard implementation in the option returns literature (Goyal and Saretto, 2009; Cao and Han, 2013). Panel A of Figure 1 plots the partial derivatives with respect to ρ in Equation (8) across moneyness. The sensitivities of risk premiums (red lines) are constant across moneyness, confirming the closed-form results. The sensitivities of loadings (blue lines) however vary substantially with moneyness and do not always have the same sign. For in-the-money calls, $\partial\beta_S/\partial\rho$ is positive, indicating that a higher ρ increases the equity loading, while $\partial\beta_v/\partial\rho$ is negative over the same range. Both sensitivities switch sign near the money and become large and negative for out-of-the-money calls. For near-the-money puts, $\partial\beta_S/\partial\rho$ and $\partial\beta_v/\partial\rho$ are both negative and large. For out-of-the-money puts, $\partial\beta_v/\partial\rho$ turns positive and $\partial\beta_S/\partial\rho$ becomes large and negative. We conclude that the sensitivities of the loadings depend on moneyness and option type, while the sensitivities of risk premiums are constant.

Panel B of Figure 1 builds on Panel A and plots the four components in Equation (8) together with the total (combined) sensitivity of expected option return with respect to ρ. For calls, the total effect of ρ on expected returns is negative and becomes more negative for out-of-the-money options. Using the baseline parameter values, a one-standard-

[3]We adjust κ and σ so that the Feller condition holds, and set the variance risk aversion ξ so that the equity risk premium retains its estimated value in Heston et al. (2024a).

deviation[4] increase in ρ reduces weekly call expected excess returns by 0.12 percentage points at $K/S = 0.8$ and by 5.36 percentage points at $K/S = 1.2$. The two variance-related components $(\partial\beta_v/\partial\rho) \cdot \mathrm{VRP}$ and $(\partial\mathrm{VRP}/\partial\rho) \cdot \beta_v$ (in dashed lines) are positive and become more positive for out-of-the-money options, except that $(\partial\beta_v/\partial\rho)\cdot\mathrm{VRP}$ turns slightly negative near the money. The equity components $(\partial\beta_S/\partial\rho) \cdot \mathrm{ERP}$ and $(\partial\mathrm{ERP}/\partial\rho) \cdot \beta_S$ (in solid lines) are both negative, with the loading term turning slightly positive for in-the-money options. In summary, the total effect of ρ on expected call returns remains negative across all strikes, with the variance terms partially offsetting the negative equity contribution.

For puts, the resulting total (combined) effect of ρ on expected returns is positive. A one-standard-deviation increase in ρ increases weekly put expected excess returns by 0.07 percentage points at $K/S = 1.2$ and by 0.23 percentage points at $K/S = 1.0$. The two premium terms $(\partial\mathrm{ERP}/\partial\rho)\cdot\beta_S$ and $(\partial\mathrm{VRP}/\partial\rho)\cdot\beta_v$ (in red) are both positive and become more positive for out-of-the-money options. On the other hand, the exposure terms $(\partial\beta_S/\partial\rho)\cdot\mathrm{ERP}$ and $(\partial\beta_v/\partial\rho) \cdot \mathrm{VRP}$ (in blue) are variable in sign, particularly at-the-money, and become negative for at-the-money and out-of-the-money options. Overall, the total effect is positive for puts, driven by the effect of ρ on risk premiums, while its effect on loadings operates in the opposite direction.

In Section 4.5, we report robustness exercises for the total effect of ρ on expected at-the-money option returns by varying ρ, the variance level v, the volatility of variance σ, the equity risk aversion γ, and the variance risk aversion ξ. Our findings that the sign of $\partial\mathrm{EER}/\partial\rho$ is negative for calls and positive for puts are robust. As expected, the magnitudes of course scale with v, σ, and ξ, but the qualitative implications of the leverage effect for expected call and put returns are not sensitive to the choice of parameter values.

Overall, these results indicate that the theory predicts that ρ affects expected option returns. For calls, the equity channel dominates and lowers expected returns as ρ increases. The effect on expected call returns is more negative for out-of-the-money options. For puts, the premium terms are both positive and dominate the loading terms in magnitude, so expected put returns decrease as ρ decreases. In both cases, these predictions are consistent with the intuition that a more negative ρ tilts the return distribution further to the left. Calls deliver low payoffs in the left tail and command higher expected returns as compensation, while puts hedge those same states and earn lower expected returns. Note that treating risk

[4] We take the empirical standard deviation of ρ to be 0.277.

premiums as constant, as is often done in the literature, eliminates the premium channel entirely. For calls, this omission is less consequential, but for puts, it can reverse the predicted sign. The premium channel dominates, and ignoring it leads to the incorrect conclusion that a more negative ρ increases expected put returns.

3 The Leverage Effect and Expected Option Returns: Empirical Results

We first discuss the data. We then start with results for at-the-money options, followed by results across moneyness.

3.1 Data and Descriptive Statistics

We obtain end-of-day S&P 500 index (SPX) option data from OptionMetrics Ivy DB, covering the period from January 1996 through December 2023. OptionMetrics provides option mid-prices, bid and ask quotes, open interest, trading volume, implied volatilities, and option Greeks. SPX index levels are also sourced from OptionMetrics for consistency.

Before computing weekly option returns, we apply a series of standard filters at the formation date to avoid look-ahead bias (Duarte et al., 2024): (i) call and put prices must satisfy no-arbitrage bounds; (ii) implied volatility and delta must be non-missing; (iii) bid price is strictly positive and strictly below the ask; (iv) mid-price is at least \$0.125; (v) relative bid-ask spread does not exceed 50%; (vi) minimum dollar spread is at least \$0.05 for options priced below \$3.00 and \$0.10 otherwise; and (vii) trading volume and open interest are strictly positive. We further restrict the baseline sample to options with between 15 and 55 calendar days to expiration and moneyness between 0.95 and 1.05 at formation.[5] In Section 3.3 below, we extend the moneyness range to 0.80-1.20 to further examine how the effect of ρ differs across strikes.

We construct daily realized variance from 5-minute prices of S&P 500 index futures obtained from Tick Data Inc., using the forward month contract as the most liquid contract at each point in time. The sample uses S&P 500 futures through December 2011 and E-mini

[5] This filter for a sample of at-the-money options follows the existing literature (Goyal and Saretto, 2009; Doran, Fodor, and Jiang, 2013; Vasquez, 2017; Hu and Jacobs, 2020).

S&P 500 futures from January 2012 onward. Daily realized variance is the sum of squared 5-minute log returns within each trading day. Realized variance and the correlation between returns and variance changes are then computed over a 30-day rolling window ending on each formation date, requiring at least 20 daily observations. The correlation is estimated between daily S&P 500 returns obtained from CRSP and daily changes in realized variance over the same window.

We form weekly option positions on Wednesday of each week, with a holding period ending on the following Wednesday. Friday is the expiration day for standard SPX options, and forming positions on that day could in principle expose the results to expiration-related effects, weekly liquidity patterns, or end-of-week price pressures. We therefore reserve the Friday-to-Friday specification for a robustness check.[6] The raw return on a long option position, with $j \in \{C, P\}$ denoting calls and puts, is

$$R^j_{t_0,t_N} = \frac{O^j_{t_N} - O^j_{t_0}}{O^j_{t_0}}, \tag{11}$$

where $O^j_{t_0}$ and $O^j_{t_N}$ are the mid-prices at formation (t_0) and at the end of the holding period (t_N). The final sample, after applying all filters and merging with the realized variance and correlation data, consists of 1,457 formation dates, 233,783 calls, and 230,014 puts.[7]

Table 1 reports summary statistics for SPX call and put options across five moneyness bins. Put option returns increase monotonically with the strike price, ranging from -11.165% to -3.484%. Call option returns are positive in-the-money and near-the-money, ranging from 1.272% to 1.717%, but become negative out-of-the-money, consistent with prior findings of non-monotonic call returns (Constantinides et al., 2013; Coval and Shumway, 2001; Bakshi, Madan, and Panayotov, 2010; Hu and Jacobs, 2020). Implied volatility decreases monotonically with moneyness for both calls and puts, ranging from 0.205 to 0.153 for calls and from 0.213 to 0.166 for puts, reflecting the well-known volatility skew. Realized volatility averages 0.112 across all bins and option types, uniformly below implied volatility, consistent with a negative variance risk premium. The return-variance correlation ρ is uniformly negative

[6] Garcia-Ares (2023) documents that option returns are partly driven by expiration day price pressures. As robustness checks, we re-examine our results when excluding expiration weeks or forming positions on Friday, and find that our conclusions are unchanged.

[7] We obtain 325,012 calls and 475,052 puts after extending the moneyness interval to 0.80-1.20.

across all bins, averaging around -0.316, with a standard deviation of 0.277, consistent with the leverage effect. Trading volume peaks near the money, consistent with the concentration of liquidity in at-the-money options. Finally, average time to expiration is approximately 31 days across all moneyness intervals.

3.2 Baseline Results

In this subsection we present our baseline results on how the return-variance correlation ρ is related to expected option returns. The theory in Section 2.2 predicts that expected call returns decrease and expected put returns increase as ρ increases. We test these predictions using weekly SPX option returns. Our baseline analysis focuses on near-the-money options, which are more actively traded and least affected by microstructure noise, which improves the precision of the estimates. Specifically, we estimate pooled regressions of weekly option returns on ρ, separately for calls and puts and within four moneyness bins: $[0.95, 1.05]$, $[0.95, 0.99]$, $(0.99, 1.01]$, and $(1.01, 1.05]$.[8] For each moneyness bin and option type, we estimate the following pooled regression:

$$R^j_{i,t,t+1} = a + b\,\rho_t + c' X_{i,t} + \varepsilon_{i,t,t+1}, \tag{12}$$

where $R^j_{i,t,t+1}$ is the weekly return on option contract i of type $j \in \{C, P\}$ from formation date t to $t+1$, ρ_t is the lagged correlation between daily index returns and daily variance innovations computed over the 30 days ending on date t, and $X_{i,t}$ is a vector of controls computed at the formation date. The controls include the lagged control variables–one-month realized volatility and realized quarticity, days to expiration, moneyness, option delta, gamma, vega, option volume, option relative spread, option leverage, option's exposure to variance, the VIX level, IV smirk, and the one-week and one-month market returns, following the literature (Coval and Shumway, 2001; Hu and Jacobs, 2020). We use Newey-West standard errors with five lags to adjust for serial correlation and heteroskedasticity in the residuals.

Table 2 reports the results. Panel A presents the estimates for calls. Specifications I, III, V, and VII report the univariate regressions, while specifications II, IV, VI, and VIII

[8] We estimate Equation (12) as a pooled regression because the correlation ρ_t is common to all contracts on a given formation date; within a moneyness bin, b estimates the average sensitivity for that bin.

include the full set of controls. The coefficient on ρ is negative and statistically significant in all eight specifications. In the univariate specifications, the coefficients range from -0.127 to -0.094, with t-statistics between -13.011 and -6.779. These estimates imply that a one-standard-deviation increase in ρ lowers weekly call returns by roughly 2.6 to 3.5 percentage points. In the multivariate specifications, the coefficients range from -0.158 to -0.101, with t-statistics between -12.310 and -6.196, implying that a one-standard-deviation increase in ρ lowers weekly call returns by roughly 2.8 to 4.4 percentage points.

Panel B presents the estimates for puts. The coefficient on ρ is now positive and statistically significant across all eight specifications, with t-statistics between 3.784 and 12.548. The univariate coefficients lie between 0.066 and 0.109, and the multivariate coefficients between 0.079 and 0.175. In terms of economic magnitudes, these estimates imply that a one-standard-deviation increase in ρ raises weekly put returns by 1.8 to 3.0 percentage points in the univariate specifications and by 2.2 to 4.8 percentage points in the multivariate specifications. Consistent with the theory, the economic magnitude of the effect differs clearly between calls and puts for out-of-the-money options.

Overall, the estimated signs are consistent with the predictions of the theory. Expected call returns decrease as ρ increases and expected put returns increase. This finding holds across the moneyness bins for both option types and is robust to including an extensive set of controls.

3.3 The Leverage Effect and Expected Returns: Moneyness Effects

The baseline results focus on at-the-money options. The theoretical predictions in Section 2.2 suggest that the strength of the effect also depends on moneyness, with out-of-the-money options more sensitive to ρ than at-the-money options for calls but less sensitive for puts. This subsection tests that prediction by extending the sample to contracts with moneyness between 0.80 and 1.20 and by formally comparing the results for out-of-the-money contracts with results for other options.

We present two sets of results for the predictive regressions. The first set of results separates the sample by moneyness and estimates Equation (12) within each subsample. The at-the-money subsample includes contracts with moneyness between 0.95 and 1.05, and the out-of-the-money subsample includes contracts with moneyness between 1.05 and 1.20 for calls and between 0.80 and 0.95 for puts. The second set of results pools the full sample and specifies an out-of-the-money indicator and its interaction with ρ:

$$R^j_{i,t,t+1} = a + b_1\rho_t + b_2\mathrm{OTM}_{i,t} + b_3\,\rho_t \times \mathrm{OTM}_{i,t} + c'X_{i,t} + \varepsilon_{i,t,t+1}, \tag{13}$$

where OTM_i equals one for out-of-the-money contracts and zero otherwise. The coefficient b_3 measures the differential impact of ρ on out-of-the-money returns relative to the impact on at-the-money and in-the-money returns. $X_{i,t}$ denotes the same set of control variables used in the baseline analysis.

Table 3 reports the results of the predictive regressions in Equation (13). Panel A presents the results for calls and Panel B for puts. Specifications I and II restrict the sample to at-the-money contracts, specifications III and IV use out-of-the-money contracts, and specifications V and VI use the full sample while including the interaction term.

For calls, the coefficient on ρ is -0.126 in the at-the-money sample and -0.284 in the out-of-the-money sample once controls are included. Both estimates are significant at the 1% level. The coefficient is roughly 2 times larger in absolute value for out-of-the-money contracts, indicating that the negative effect of ρ on call returns strengthens for out-of-the-money calls. The interaction term in the full sample specification confirms this result. The coefficient on $\rho \times \mathrm{OTM}$ is -0.161 with a t-statistic of -9.835. The interaction term implies an effect of ρ on out-of-the-money call returns of -0.280, roughly twice the effect on at-the-money and in-the-money contracts. A one-standard-deviation increase in ρ therefore lowers weekly returns on out-of-the-money calls by an additional 4.5 percentage points relative to at-the-money and in-the-money contracts.

For puts, the same statistical pattern carries the opposite economic meaning. The coefficient on ρ is 0.149 in the at-the-money sample and 0.057 in the out-of-the-money sample with controls. The interaction term in the full sample specification is -0.037 with a t-statistic of -2.665. In economic terms, a one-standard-deviation increase in ρ raises weekly out-of-the-money put returns by 1 percentage point less than at-the-money and in-the-money put returns. The differential is smaller in magnitude for puts than for calls, as suggested by the theory.

These results confirm the theoretical prediction that the sensitivity of expected option returns to ρ varies with moneyness. For calls, the effect is more pronounced for out-of-the-money contracts, whereas for puts it is less pronounced. The differential is larger for calls than for puts, also consistent with the theory.

4 Robustness

In this section we assess the robustness of the baseline results. We present results for alternative formation days, excluding expiration weeks, longer option maturities, and monthly holding periods. For all these robustness exercises, the relation between ρ and option returns yields signs and magnitudes similar to the baseline analysis. The results also remain statistically significant. We also present an extensive robustness analysis of the theoretical predictions with respect to the assumed parameter values in the pricing kernel and the stochastic volatility dynamics.

4.1 Friday-to-Friday Returns

The baseline analysis computes weekly option returns from Wednesday to Wednesday. To verify that the baseline results are not specific to the choice of formation day, we re-estimate the regressions using weekly returns computed from Friday to Friday. We construct weekly returns using mid prices on consecutive Friday and re-estimate the same specifications used in the benchmark, separately for calls and puts and within the four near-the-money moneyness bins, and one out-of-the-money moneyness bin.

Table 4 reports the results. The coefficient on ρ remains negative for calls and positive for puts and is statistically significant in all specifications. The coefficients are close to those obtained with Wednesday-to-Wednesday returns. The relation between ρ and option returns is therefore not driven by the choice of formation day.

4.2 Excluding Expiration Weeks

A second potential concern is that option-return predictability can be concentrated around expiration days. Garcia-Ares (2023) documents that rollover-driven order imbalances around the third Friday of the month generate large price distortions, with more than half of monthly anomaly returns realized during the two-day expiration window. If the relation between ρ and option returns is driven by these mechanical effects rather than by the channels identified in the theory, the benchmark results would be misleading. To address this concern, we re-estimate the benchmark regressions on a sample that excludes any week for which the formation date, holding period, or end date falls on or contains the third Friday of the month. The exclusion removes both the expiration week itself and the rollover pressures documented by Garcia-Ares (2023).

Table 5 reports the results. The coefficient on ρ is significant across all specifications. In the multivariate regressions it is negative for calls (between -0.101 and -0.067 for the near-the-money bins and -0.272 for the out-of-the-money bin) and positive for puts (between 0.101 and 0.194 for the near-the-money bins and 0.059 for the out-of-the-money bin). The only coefficient that departs from this sign pattern is the univariate out-of-the-money put regression. Once controls are included, the out-of-the-money put coefficient is again positive. The magnitudes are comparable to those in Table 2, indicating that the relation between ρ and option returns is not driven by expiration-day frictions and effects.

4.3 Maturity Effects

The baseline analysis focuses on contracts with on average a one-month maturity, which are the most actively traded contracts in the SPX option market. The theoretical predictions in Section 2.2 are also calibrated to one-month maturity, but the underlying mechanism applies to longer-dated contracts as well. We extend the analysis to contracts with longer maturities to verify that the documented patterns hold beyond the baseline window. We split the longer-maturity sample into two intervals: contracts with $56 \leq \text{DTE} \leq 95$ and contracts with $96 \leq \text{DTE} \leq 135$, where DTE stands for days to expiration. Within each interval, we estimate the same specifications used in the baseline analysis, separately for calls and puts and within the three near-the-money moneyness bins.

Table 6 reports the results. The coefficient on ρ is negative for calls and positive for puts across all twelve specifications of each type. It is significant in every specification for the 56-95 day maturity range, and in the 96-135 day range it remains significant in all but two of the multivariate specifications. The sign of the relation between ρ and option returns is therefore not specific to short-dated contracts and continues to hold for longer-dated contracts, though the effect attenuates at the longest maturities.

4.4 Monthly Returns

The baseline empirical analysis uses weekly returns. While the model prediction is for instantaneous option returns, it is well-known that measured option returns are noisy, and this problem intensifies with very short holding periods. We therefore avoid daily returns, which are very noisy. Weekly returns are typically considered to be the shortest holding period that can be reliably constructed from end-of-day data and is therefore the closest empirical counterpart to the instantaneous returns in the model. To verify that the relation between ρ and option returns also holds at lower frequencies, we extend the analysis to monthly returns.

We construct monthly returns over the standard option expiration cycle. The formation date is the Monday following the third Friday of each month and the end date is the third Friday of the following month. This convention aligns the holding period with the standard expiration cycle of SPX options. We restrict the sample to contracts with $56 \leq \text{DTE} \leq 95$ at formation. This constraint ensures that options do not expire during the holding period, while keeping the contracts close enough to expiration to remain in the most liquid part of the option market. Using these criteria, we estimate the same specifications used in the baseline analysis, separately for calls and puts and within the four near-the-money moneyness bins and an out-of-the-money bin.

The monthly results are consistent with the results for weekly returns. Table 7 reports that the coefficient on ρ is negative for calls (multivariate estimates between -0.306 and -0.244 for the near-the-money bins and -0.746 for the out-of-the-money bin) and positive for puts (between 0.130 and 0.236 for the near-the-money bins and 0.500 for the out-of-the-money bin), and statistically significant. The larger absolute magnitudes relative to the weekly results are mechanical and due to the longer holding period.

4.5 Model Parameters and Theoretical Predictions

This subsection examines whether the conclusions in Section 2.2 are sensitive to the choice of model parameter values. We vary the assumptions on the return-variance correlation ρ, the variance level v, the volatility of variance σ, and the preference parameters γ and ξ one at a time, holding the remaining parameters at their baseline values. For each parameter, we compute the total sensitivity $\partial \text{EER}/\partial \rho$ and its four components from Equation (8) at at-the-money strikes ($K/S = 1$) for options with 30 days to maturity and a one-week holding period.

4.5.1 The Leverage Parameter

Figure A.1 plots $\partial\text{EER}/\partial\rho$ and its four components for $\rho \in [-0.95, 0.95]$, with the baseline value $\rho = -0.7458$ marked by a vertical dashed line. The total sensitivity is negative for calls and positive for puts across the entire range of ρ, with magnitudes that remain very similar. The four components are also stable in sign and relative size. For calls, the equity loading term $(\partial\beta_S/\partial\rho) \cdot \text{ERP}$ dominates throughout, and the variance components partially offset. For puts, the two premium terms remain positive across the full range, and the loading terms remain modest and stable. The qualitative conclusions in Section 2.2 are therefore not driven by the specific value of ρ.

4.5.2 Variance and Volatility of Variance

Figure A.2 varies the variance level v (in Panel A) and the volatility of variance σ (in Panel B). Higher v scales both risk premiums and amplifies the absolute magnitude of $\partial\text{EER}/\partial\rho$. The sign of the total sensitivity does not change. For calls, $\partial\text{EER}/\partial\rho$ becomes more negative as v rises, with the equity loading term driving the increase. For puts, $\partial\text{EER}/\partial\rho$ rises with v, with the premium terms accounting for most of the change. Panel B shows that higher σ amplifies both the equity and variance channels but again preserves the sign. The total sensitivity for calls becomes increasingly negative in σ, while the total sensitivity for puts increases and then flattens out. In all cases the qualitative implications of the model remain the same.

4.5.3 Risk Aversion Parameters

Figure A.3 varies the variance risk aversion ξ (in Panel A) and the equity risk aversion γ (in Panel B). Higher ξ amplifies the magnitude of $\partial\text{EER}/\partial\rho$ in both directions, monotonically for calls (more negative) and for puts (more positive), with the equity loading term responsible for most of the increase for calls and most of the increase for puts due to the equity premium term. The sensitivity to γ in Panel B is smaller in absolute terms. For calls, $\partial\text{EER}/\partial\rho$ is essentially flat in γ. For puts, $\partial\text{EER}/\partial\rho$ declines somewhat as γ increases but remains positive throughout. The conclusions of Section 2.2 are therefore robust to a wide range of preference parameters.

5 Extensions

We next examine the implications of the theory for two different return definitions that are often used in the literature: delta-hedged returns, which isolate the variance channel by removing the equity channel, and delevered returns, which rescale the four channels of the raw-return decomposition.

5.1 Predictions for Delta-Hedged Returns

The benchmark analysis uses raw option returns. The expected raw return reflects both the option's exposure to the underlying and its exposure to variance, as shown by the decomposition in Equation (5). The exposure to the underlying is typically the dominant component for short-dated options, which can obscure the role of the variance channel through which ρ also operates. A common approach in the literature is to hedge the exposure to the underlying security and study delta-hedged returns, thereby isolating the variance component (e.g., Bakshi and Kapadia, 2003, Goyal and Saretto, 2009, Cao and Han, 2013, Bali et al., 2023 and Vasquez and Xiao, 2024). In this section, we extend the analysis to delta-hedged returns, thereby assessing how ρ influences expected option returns through the variance channel alone.

We construct a delta-hedged option position by combining a long position in the option with a short position of O_S units of the underlying stock, where O_S is the option delta. This portfolio has value $\Pi(t) = O(t, S(t), v(t)) - O_S\, S(t)$ and is, by construction, instantaneously insensitive to changes in the underlying. Applying Itô's lemma to $\Pi(t)$ and using Equations (1)-(2), the instantaneous return on the delta-hedged position scaled by the option price is

$$\mathrm{EER}_{\mathrm{dh}} = \mathrm{E}\left[\frac{d\Pi}{O}\right] - r\,\frac{\Pi}{O}\,dt = \beta_v\,\lambda(v(t))\,dt = \beta_v\,(\gamma\rho\sigma - \xi\sigma^2)\,v(t)\,dt, \tag{14}$$

where $\beta_v = O_v/O$ is vega-per-dollar and $\lambda(v(t))$ is the variance risk premium under Heston et al. (2024b) pricing kernel of Equation (4). The expected delta-hedged return depends on

ρ only through the variance loading β_v and the variance risk premium $\lambda(v(t))$. The equity loading β_S and the equity risk premium $\mu(v(t))$, which together drive a large part of the raw-return sensitivity to ρ, are absent here. Differentiating Equation (14) with respect to ρ gives

$$\frac{\partial \mathrm{EER_{dh}}}{\partial \rho} = \frac{\partial \beta_v}{\partial \rho}\lambda(v(t)) + \beta_v \frac{\partial \lambda(v(t))}{\partial \rho}, \tag{15}$$

which retains only the variance loading term and the variance risk premium term from the four-term decomposition in Equation (8). Delta-hedging therefore provides a test of the variance channel, isolated from the underlying channel that dominates raw call returns and partially offsets the premium effect for raw put returns. Figure 2 plots the sensitivity of the expected delta-hedged option returns to ρ across moneyness, together with the two components of the decomposition in Equation (15). The figure uses the same parameter values as in Section 2.2 and corresponds to a one-week holding period for options with 30 days to maturity.

For calls, the effect of ρ is positive across all moneyness levels while the effect is almost zero for in-the-money options. Scaling by the empirical standard deviation of ρ (0.277), a one-standard-deviation increase in ρ raises weekly delta-hedged call returns by under one basis point in-the-money, by 8.7 basis points at-the-money, and by up to 8.3 percentage points out-of-the-money. The decomposition shows that the out-of-the-money effect is driven by the loading channel, with the premium channel contributing a small positive amount.

The pattern for puts changes sign across moneyness. A one-standard-deviation increase in ρ lowers weekly delta-hedged in-the-money put returns by around one basis point and raises out-of-the-money put returns by roughly 27 basis points. The loading and premium channels offset each other throughout: the loading channel is negative for out-of-the-money puts and turns positive near-the-money. The pattern is opposite for the premium channel.

We test these predictions empirically using SPX delta-hedged returns. For the delta-hedged return, we construct a portfolio that is long one option and short $\Delta^j_{t_n}$ units of the index, with the residual invested or borrowed at the risk-free rate. The hedge is rebalanced daily; Tian and Wu (2023) estimate that daily rebalancing eliminates over 90% of directional risk compared to roughly 70% for a one-time hedge. The total delta-hedged gain over the holding period is

$$\Pi^{j,\mathrm{DH}}_{t_0,t_N} = O^j_{t_N} - O^j_{t_0} - \sum_{n=0}^{N-1} \Delta^j_{t_n}\left[S_{t_{n+1}} - S_{t_n}\right] - \sum_{n=0}^{N-1} \frac{a_n r_{t_n}}{365}\left[O^j_{t_n} - \Delta^j_{t_n} S_{t_n}\right], \tag{16}$$

where S_{t_n} is the index level, $\Delta^j_{t_n}$ is the delta from OptionMetrics, r_{t_n} is the annualized risk-free rate, and a_n is the number of calendar days between t_n and t_{n+1}. We normalize $\Pi^{j,\mathrm{DH}}_{t_0,t_N}$ by the option price at formation, $O^j_{t_0}$, to obtain the delta-hedged return $R^{j,\mathrm{DH}}_{t_0,t_N} = \Pi^{j,\mathrm{DH}}_{t_0,t_N}/O^j_{t_0}$, consistent with our model. The recent literature commonly scales by the initial portfolio cost net of the delta position (Cao and Han, 2013; Zhan, Han, Cao, and Tong, 2022; Bali et al., 2023); results are robust to this alternative normalization.

Table 1 reports summary statistics of returns on SPX call and put options across five moneyness bins. Delta-hedged returns are negative across all bins for both calls and puts, implied by a negative variance risk premium. The magnitudes are largest for deep out-of-the-money options of both types, consistent with Bakshi and Kapadia (2003).

Table 8 reports the results of the same specifications estimated in the baseline analysis using weekly delta-hedged returns as the dependent variable. Panel A presents the results for calls. In the in-the-money bin $[0.95, 0.99]$, the coefficients are small and statistically indistinguishable from zero. The coefficient turns positive and significant near the money and grows out of the money, reaching 0.054 in the $(1.01, 1.05]$ bin. Panel B presents the results for puts. In multivariate regressions, the coefficient on ρ is positive and significant in the out-of-the-money and at-the-money bins, with coefficients between 0.008 and 0.017, and turns negative and significant in the in-the-money bin $(1.01, 1.05]$, with a multivariate estimate of -0.010.

These empirical results align with the predictions of the theory. For calls, the sensitivity to ρ is essentially zero in-the-money and becomes positive out of the money. For puts, the model predicts a sign change near-the-money: the effect is slightly positive out-of-the-money and slightly negative in-the-money. The empirical results confirm the change in sign, but the empirical magnitudes exceed the theoretical predictions.

We assess the robustness of the delta-hedged results at the at-the-money interval and one-month maturity. The coefficient on ρ stays significantly positive when we exclude expiration weeks and when we use different formation dates. Table A.1 reports the full results.

5.2 Predictions for Delevered Returns

We next study the effect of ρ on delevered option returns. The definition of raw option returns has the option price at formation in the denominator, which introduces measurement noise since option prices are subject to substantial bid-ask spreads, particularly for deep out-of-the-money options. Delevered returns address this by scaling option gains by the price of the underlying instead, which is observed precisely and does not vary across contracts within the same underlying at a given date (Duarte et al., 2024). This normalization is increasingly adopted in the option factor model literature (Büchner and Kelly, 2022; Fournier et al., 2024; Duarte et al., 2024; Dickerson et al., 2025).

The expected delevered option return follows directly from Equation (5) by scaling each term by O/S:

$$\mathrm{EER}_{\mathrm{dlv}} = \frac{O}{S}\left(\mathrm{E}\left[\frac{dO}{O}\right] - r\,dt\right) = \left[\Delta\left(\gamma - \rho\sigma\xi\right)v(t) + \frac{O_v}{S}\left(\gamma\rho\sigma - \xi\sigma^2\right)v(t)\right]dt, \tag{17}$$

where the equity loading becomes Δ and the variance loading scaled by leverage becomes O_v/S. Differentiating with respect to ρ gives the following decomposition for delevered returns:

$$\frac{\partial \mathrm{EER}_{\mathrm{dlv}}}{\partial\rho} = \frac{\partial\Delta}{\partial\rho}\,\mu(v(t)) + \Delta\,\frac{\partial\mu(v(t))}{\partial\rho} + \frac{\partial(O_v/S)}{\partial\rho}\,\lambda(v(t)) + \frac{O_v}{S}\,\frac{\partial\lambda(v(t))}{\partial\rho}, \tag{18}$$

which retains the same structural form as Equation (8) but replaces the per-dollar-of-option exposures β_S and β_v with per-dollar-of-underlying exposures Δ and O_v/S. Delevering therefore rescales the four components but does not eliminate any of them, unlike delta-hedging which shuts off the underlying channel entirely.

Figure 3 plots the sensitivity of the expected delevered return to ρ across moneyness, together with the four components of Equation (18). The figure uses the same setup as in Section 2.2. For calls, the effect of ρ is negative in-the-money, attenuates toward the money, and turns slightly positive out-of-the-money. Scaling by the empirical standard deviation of ρ of 0.277, a one-standard-deviation increase in ρ lowers weekly delevered call returns by 1.38 basis points in-the-money, by 1 basis point at-the-money, and increases by less than one basis point out-of-the-money. For puts, the effect is positive throughout and grows monotonically as the option moves in-the-money, raising weekly delevered put returns by under one basis point out-of-the-money and by 1.52 basis points in-the-money. In both cases the equity premium channel dominates, while the remaining three terms contribute small offsetting amounts.

The theoretical predictions are an order of magnitude smaller than for raw returns. Delevering strips out the leverage-induced amplification of the underlying-driven variation across moneyness, but the sign pattern (negative for calls, positive for puts) and the dominance of the equity premium channel survive.

We now test these predictions using delevered option returns. We compute delevered option returns as follows:

$$R^{j,\mathrm{DL}}_{t_0,t_N} = R^{j}_{t_0,t_N} \times \frac{O^{j}_{t_0}}{S_{t_0}}. \tag{19}$$

.

Table 1 reports summary statistics of returns on SPX call and put options across five moneyness bins. Delevered returns decrease monotonically in moneyness. For calls, they decrease from 0.063% to -0.009%, and for puts, they become more negative, decreasing from -0.101% to -0.172%. In the Black and Scholes (1973) and Merton (1973) (BSM) models, this monotonicity is expected since expected delevered returns are proportional to delta, which is monotonic in moneyness. In the Heston (1993) model with priced variance risk, it is not guaranteed. The variance channel loads on vega, which is hump-shaped in K/S, and can either reinforce or offset the equity channel's slope. Constantinides et al. (2013) document a similar pattern using leverage-adjusted index option portfolios.

Table 9 reports the results of the predictive regressions in Equation (12) estimated on weekly delevered returns. For calls, the coefficient on ρ is negative and significant at the 1% level across all specifications, with multivariate point estimates between -0.004 and -0.001. For puts, the coefficient is positive and significant, with multivariate estimates between 0.001 and 0.002. The signs match the predictions of the theory. The magnitudes are an order of magnitude smaller than for raw returns, which is the expected mechanical consequence of delevering and also consistent with the theoretical predictions in Figure 3.

We examine the robustness of the results. We find the same patterns at the at-the-money interval and one-month maturity, when expiration weeks are dropped and when the formation date is changed. Table A.2 reports the results.

6 Conclusion

This paper examines how the leverage effect affects expected index option returns. We rely on the Heston (1993) stochastic volatility framework and the exponential-affine pricing kernel in Heston et al. (2024b) to characterize the relation between the return-variance correlation and expected index call and put returns. We show that the overall impact can be decomposed into four components operating through the impact of the leverage effect on the option's equity and variance loadings and through the equity and variance risk premiums. The analysis clarifies that it is critical to endogenize the equity and variance risk premiums. The risk premium channels have a material impact on expected returns, and reverse the predicted sign for puts. Much of the option returns literature ignores or removes the equity risk premium channel by delta-hedging, and our decomposition shows the implications of this assumption.

The theoretical analysis predicts a negative (positive) relation between the market leverage effect and call (put) expected returns, and the magnitudes of these relations increase for out-of-the-money contracts for calls. We confirm these theoretical predictions using a long sample of weekly S&P 500 index option returns. The estimated signs are robust across alternative formation days, the exclusion of expiration weeks, longer maturities, and a monthly holding period aligned with the option expiration cycle, and the results remain statistically significant.

We extend the theoretical analysis to investigate how the leverage effect affects delta-hedged and delevered option returns. These extensions sharpen the evidence on the variance channel. Delta-hedged returns isolate that channel and the sign of the relation with the leverage effect depends on moneyness, consistent with the model predictions. The theoretical structure of the leverage effect's impact on delevered expected returns on the other hand is similar to that of raw returns, and the empirical results indeed yield similar signs.

Our results identify the leverage effect as a determinant of expected option returns that operates through both factor loadings and risk premiums. A natural next step is to study the implications of the leverage effect for the cross-section of equity (stock) option returns, which is characterized by substantial cross-sectional variation in the leverage effect across firms.

References

Amaya, Diego, Peter Christoffersen, Kris Jacobs, and Aurelio Vasquez, 2015, Does realized skewness predict the cross-section of equity returns?, *Journal of Financial Economics* 118, 135–167.

Arditti, Fred D, 1967, Risk and the required return on equity, *The Journal of Finance* 22, 19–36.

Aretz, Kevin, Ming-Tsung Lin, and Ser-Huang Poon, 2023, Moneyness, underlying asset volatility, and the cross-section of option returns, *Review of Finance* 27, 289–323.

Bakshi, Gurdip, and Nikunj Kapadia, 2003, Delta-hedged gains and the negative market volatility risk premium, *The Review of Financial Studies* 16, 527–566.

Bakshi, Gurdip, Dilip Madan, and George Panayotov, 2010, Returns of claims on the upside and the viability of u-shaped pricing kernels, *Journal of Financial Economics* 97, 130–154.

Bali, Turan G, Heiner Beckmeyer, Mathis Moerke, and Florian Weigert, 2023, Option return predictability with machine learning and big data, *The Review of Financial Studies* 36, 3548–3602.

Bali, Turan G, Nusret Cakici, and Robert F Whitelaw, 2011, Maxing out: Stocks as lotteries and the cross-section of expected returns, *Journal of Financial Economics* 99, 427–446.

Bali, Turan G, Robert F Engle, and Scott Murray, 2016, *Empirical asset pricing: The cross section of stock returns* (John Wiley & Sons).

Bali, Turan G, and Scott Murray, 2013, Does risk-neutral skewness predict the cross-section of equity option portfolio returns?, *Journal of Financial and Quantitative Analysis* 48, 1145–1171.

Barberis, Nicholas, and Ming Huang, 2008, Stocks as lotteries: The implications of probability weighting for security prices, *American Economic Review* 98, 2066–2100.

Bates, David S, 2000, Post-'87 crash fears in the S&P 500 futures option market, *Journal of Econometrics* 94, 181–238.

Black, Fischer, 1976, Studies of stock price volatility changes, in *Proceedings from the American Statistical Association, Business and Economic Statistics Section*, 177.

Black, Fischer, and Myron Scholes, 1973, The pricing of options and corporate liabilities, *Journal of Political Economy* 81, 637–654.

Bollerslev, Tim, Sophia Zhengzi Li, and Bingzhi Zhao, 2020, Good volatility, bad volatility, and the cross section of stock returns, *Journal of Financial and Quantitative Analysis* 55, 751–781.

Boyer, Brian, Todd Mitton, and Keith Vorkink, 2010, Expected idiosyncratic skewness, *The Review of Financial Studies* 23, 169–202.

Boyer, Brian H, and Keith Vorkink, 2014, Stock options as lotteries, *The Journal of Finance* 69, 1485–1527.

Broadie, Mark, Mikhail Chernov, and Michael Johannes, 2009, Understanding index option returns, *The Review of Financial Studies* 22, 4493–4529.

Byun, Suk-Joon, and Da-Hea Kim, 2016, Gambling preference and individual equity option returns, *Journal of Financial Economics* 122, 155–174.

Büchner, Matthias, and Bryan Kelly, 2022, A factor model for option returns, *Journal of Financial Economics* 143, 1140–1161.

Cao, Jie, and Bing Han, 2013, Cross section of option returns and idiosyncratic stock volatility, *Journal of Financial Economics* 108, 231–249.

Cao, Jie Jay, Aurelio Vasquez, Xiao Xiao, and Xintong Eunice Zhan, 2023, Why does volatility uncertainty predict equity option returns?, *The Quarterly Journal of Finance* 13, 2350005.

Carr, Peter, and Liuren Wu, 2009, Variance risk premiums, *The Review of Financial Studies* 22, 1311–1341.

Chambers, Donald R, Matthew Foy, Jeffrey Liebner, and Qin Lu, 2014, Index option returns: Still puzzling, *The Review of Financial Studies* 27, 1915–1928.

Christie, Andrew A, 1982, The stochastic behavior of common stock variances: Value, leverage and interest rate effects, *Journal of Financial Economics* 10, 407–432.

Christoffersen, Peter, Steven Heston, and Kris Jacobs, 2009, The shape and term structure of the index option smirk: Why multifactor stochastic volatility models work so well, *Management Science* 55, 1914–1932.

Conine Jr, Thomas E, and Maurry J Tamarkin, 1981, On diversification given asymmetry in returns, *The Journal of Finance* 36, 1143–1155.

Conrad, Jennifer, Robert F Dittmar, and Eric Ghysels, 2013, Ex ante skewness and expected stock returns, *The Journal of Finance* 68, 85–124.

Constantinides, George M, Jens Carsten Jackwerth, and Alexi Savov, 2013, The puzzle of index option returns, *Review of Asset Pricing Studies* 3, 229–257.

Coval, Joshua D, and Tyler Shumway, 2001, Expected option returns, *The Journal of Finance* 56, 983–1009.

Cremers, Martijn, and David Weinbaum, 2010, Deviations from put-call parity and stock return predictability, *Journal of Financial and Quantitative Analysis* 45, 335–367.

Das, Sanjiv Ranjan, and Rangarajan K Sundaram, 1999, Of smiles and smirks: A term structure perspective, *Journal of Financial and Quantitative Analysis* 34, 211–239.

Dickerson, Alexander, Mathieu Fournier, Kris Jacobs, and Piotr Orłowski, 2025, Systematic variance risk everywhere in equity option markets, Working Paper.

Doran, James S, Andy Fodor, and Danling Jiang, 2013, Call-put implied volatility spreads and option returns, *Review of Asset Pricing Studies* 3, 258–290.

Doshi, Hitesh, Kris Jacobs, and Saim Ayberk Sert, 2026, Betting on the leverage effect, Working Paper, University of Houston.

Duarte, Jefferson, Christopher S Jones, and Junbo L Wang, 2024, Very noisy option prices and inference regarding the volatility risk premium, *The Journal of Finance* 79, 3581–3621.

Duffee, Gregory R, 1995, Stock returns and volatility a firm-level analysis, *Journal of Financial Economics* 37, 399–420.

Fournier, Mathieu, Kris Jacobs, and Piotr Orłowski, 2024, Modeling conditional factor risk premia implied by index option returns, *The Journal of Finance* 79, 2289–2338.

Garcia-Ares, Pedro Angel, 2023, Equity option return predictability and expiration days, *Available at SSRN 4595840* .

Goyal, Amit, and Alessio Saretto, 2009, Cross-section of option returns and volatility, *Journal of Financial Economics* 94, 310–326.

Harvey, Campbell R, and Akhtar Siddique, 2000, Conditional skewness in asset pricing tests, *The Journal of Finance* 55, 1263–1295.

Heston, Steven, Kris Jacobs, and Hyung Joo Kim, 2024a, A new closed-form discrete-time option pricing model with stochastic volatility, in *Proceedings of the EUROFIDAI-ESSEC Paris December Finance Meeting*.

Heston, Steven L, 1993, A closed-form solution for options with stochastic volatility with applications to bond and currency options, *The Review of Financial Studies* 6, 327–343.

Heston, Steven L, Kris Jacobs, and Hyung Joo Kim, 2024b, Volatility risk and monotonic pricing kernels, *Available at SSRN 3997905* .

Heston, Steven L, Christopher S Jones, Mehdi Khorram, Shuaiqi Li, and Haitao Mo, 2023, Option momentum, *The Journal of Finance* 78, 3141–3192.

Hu, Guanglian, and Kris Jacobs, 2020, Volatility and expected option returns, *Journal of Financial and Quantitative Analysis* 55, 1025–1060.

Hu, Guanglian, Kris Jacobs, and Sang Byung Seo, 2022, Characterizing the variance risk premium: The role of the leverage effect, *The Review of Asset Pricing Studies* 12, 500–542.

Huang, Tao, and Junye Li, 2019, Option-implied variance asymmetry and the cross-section of stock returns, *Journal of Banking & Finance* 101, 21–36.

Jeon, Yoontae, Raymond Kan, and Gang Li, 2025, Stock return autocorrelations and expected option returns, *Management Science* 71, 4895–4914.

Jiang, Lei, Ke Wu, Guofu Zhou, and Yifeng Zhu, 2020, Stock return asymmetry: Beyond skewness, *Journal of Financial and Quantitative Analysis* 55, 357–386.

Kim, Tong Suk, and Heewoo Park, 2018, Is stock return predictability of option-implied skewness affected by the market state?, *Journal of Futures Markets* 38, 1024–1042.

Kozhan, Roman, Anthony Neuberger, and Paul Schneider, 2013, The skew risk premium in the equity index market, *The Review of Financial Studies* 26, 2174–2203.

Kraus, Alan, and Robert H Litzenberger, 1976, Skewness preference and the valuation of risk assets, *The Journal of Finance* 31, 1085–1100.

Langlois, Hugues, 2020, Measuring skewness premia, *Journal of Financial Economics* 135, 399–424.

Merton, Robert C., 1973, The theory of rational option pricing, *Bell Journal of Economics and Management Science* 4, 141–183.

Mitton, Todd, and Keith Vorkink, 2007, Equilibrium underdiversification and the preference for skewness, *The Review of Financial Studies* 20, 1255–1288.

Neuberger, Anthony, and Richard Payne, 2021, The skewness of the stock market over long horizons, *The Review of Financial Studies* 34, 1572–1616.

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

Pederzoli, Paola, 2026, The crash risk in individual stocks embedded in skewness swap returns, *Journal of Financial and Quantitative Analysis* 61, 1036–1072.

Pyun, Sungjune, 2019, Variance risk in aggregate stock returns and time-varying return predictability, *Journal of Financial Economics* 132, 150–174.

Ramachandran, Lakshmi Shankar, and Jitendra Tayal, 2021, Mispricing, short-sale constraints, and the cross-section of option returns, *Journal of Financial Economics* 141, 297–321.

Ruan, Xinfeng, 2020, Volatility-of-volatility and the cross-section of option returns, *Journal of Financial Markets* 48, 100492.

Schlag, Christian, and Tobias Sichert, 2026, Volatility risk exposure and the cross-section of expected option returns, Working Paper.

Stilger, Przemysław S, Alexandros Kostakis, and Ser-Huang Poon, 2017, What does risk-neutral skewness tell us about future stock returns?, *Management Science* 63, 1814–1834.

Tian, Meng, and Liuren Wu, 2023, Limits of arbitrage and primary risk-taking in derivative securities, *The Review of Asset Pricing Studies* 13, 405–439.

Vasquez, Aurelio, 2017, Equity volatility term structures and the cross section of option returns, *Journal of Financial and Quantitative Analysis* 52, 2727–2754.

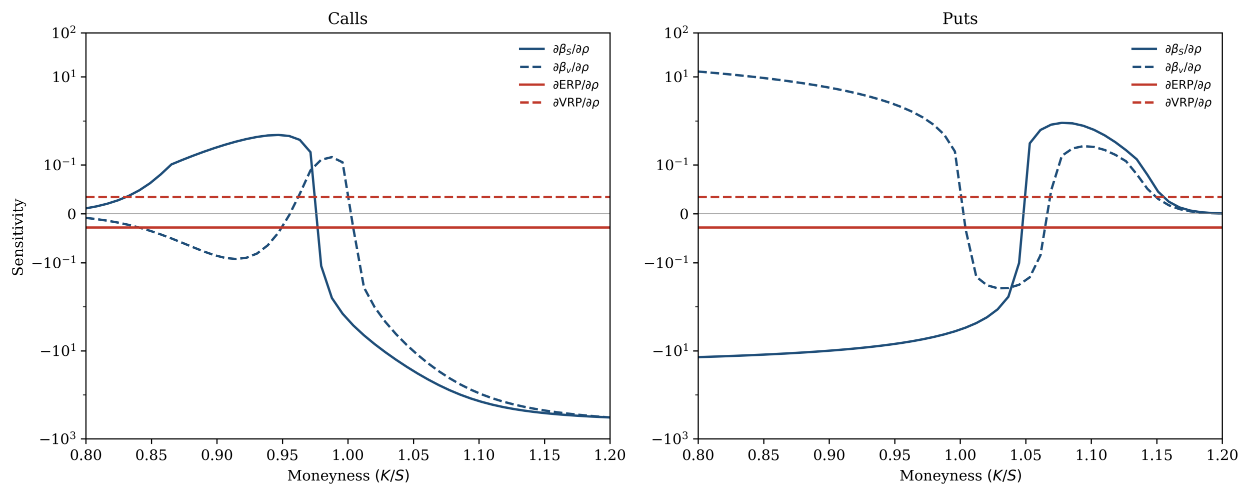
Vasquez, Aurelio, and Xiao Xiao, 2024, Default risk and option returns, *Management science* 70, 2144–2167.

Xing, Yuhang, Xiaoyan Zhang, and Rui Zhao, 2010, What does the individual option volatility smirk tell us about future equity returns?, *Journal of Financial and Quantitative Analysis* 45, 641–662.

Zhan, Xintong (Eunice), Bing Han, Jie Cao, and Qing Tong, 2022, Option return predictability, *The Review of Financial Studies* 35, 1394–1442.

Figure 1: The Leverage Effect and Expected Option Returns. This figure plots the sensitivity of expected option returns to the leverage effect, ρ, for options with 30 days to maturity and a one-week holding period, across moneyness $K/S \in [0.80, 1.20]$. The left columns report results for calls and the right columns for puts. Panel A plots the four partial derivatives in Equation (8): the sensitivities of the equity and variance loadings, $\partial\beta_S/\partial\rho$ (solid blue) and $\partial\beta_v/\partial\rho$ (dashed blue), and the sensitivities of the equity and variance risk premiums, $\partial\text{ERP}/\partial\rho$ (solid red) and $\partial\text{VRP}/\partial\rho$ (dashed red). Panel B plots the total sensitivity of the expected excess return, $\partial\text{EER}/\partial\rho$ (solid black), together with its four components from Equation (8). Model parameters are set to $\{\kappa, \theta, \sigma, \rho, \gamma, \xi\} = \{2.9862, 0.0372, 0.4500, -0.7458, 2.0527, 1.6599\}$. The figures use symmetric log scale.

Panel A: Sensitivity of Option Loadings and Risk Premiums



Panel B: Total Sensitivity of Expected Returns and Its Components

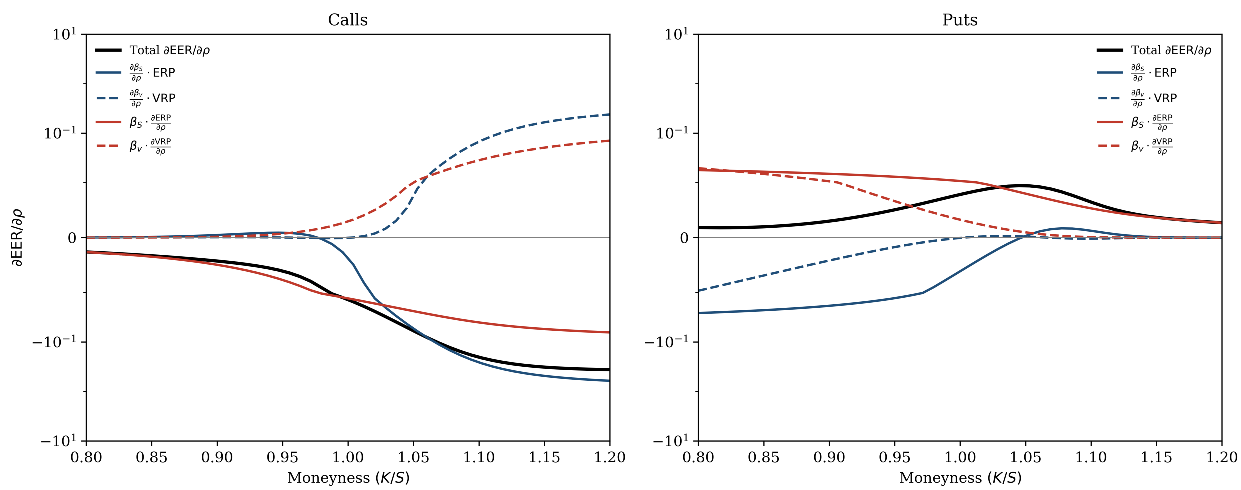


Figure 2: The Leverage Effect and Expected Delta-Hedged Option Returns. This figure plots the sensitivity of expected delta-hedged option returns to the leverage effect, ρ, for options with 30 days to maturity and a one-week holding period, across moneyness $K/S \in [0.80, 1.20]$. The left column reports results for calls and the right column for puts. Figures plot the total sensitivity of the expected excess return, $\partial \text{EER}_{dh}/\partial\rho$ (solid black), together with its two components from Equation (15). Model parameters are set to $\{\kappa, \theta, \sigma, \rho, \gamma, \xi\} = \{2.9862, 0.0372, 0.4500, -0.7458, 2.0527, 1.6599\}$.

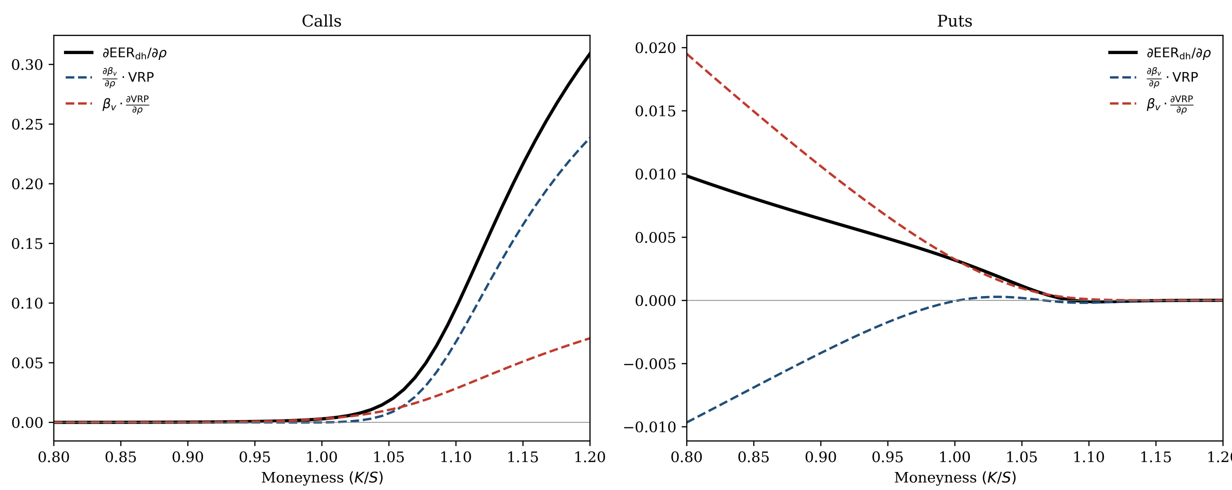


Figure 3: The Leverage Effect and Expected Delevered Option Returns. This figure plots the sensitivity of expected delevered option returns to the leverage effect, ρ, for options with 30 days to maturity and a one-week holding period, across moneyness $K/S \in [0.80, 1.20]$. The left column reports results for calls and the right column for puts. Figures plot the total sensitivity of the expected excess return, $\partial \mathrm{EER}_{dlv}/\partial\rho$ (solid black), together with its four components from Equation (18). Model parameters are set to $\{\kappa, \theta, \sigma, \rho, \gamma, \xi\} = \{2.9862, 0.0372, 0.4500, -0.7458, 2.0527, 1.6599\}$.

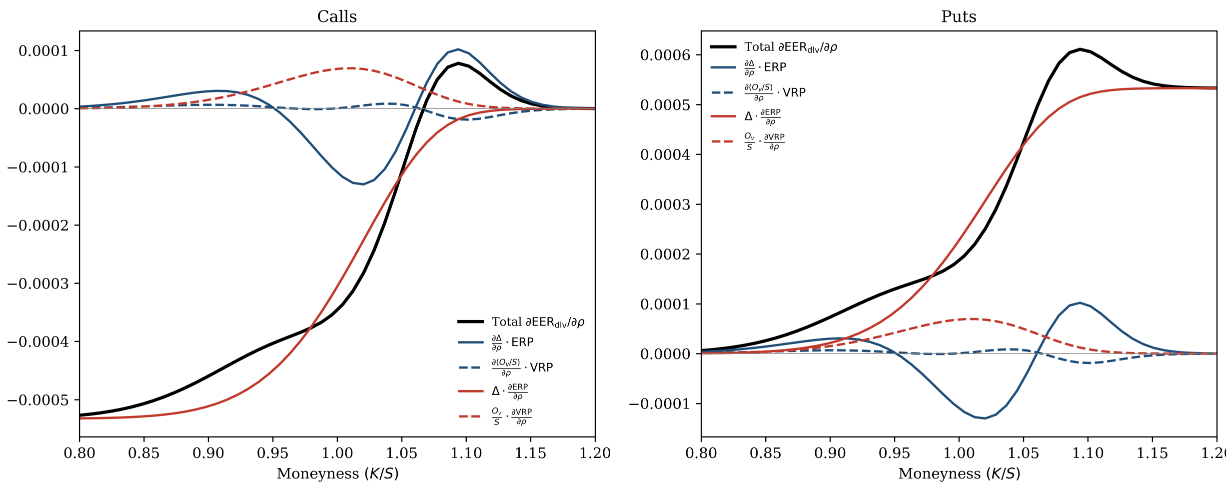


Table 1: Index Options: Summary Statistics. This table reports characteristics of S&P 500 index (SPX) options across five moneyness intervals, computed as time-series averages of weekly cross-sectional averages within each interval. Moneyness is defined as the strike-to-spot ratio K/S. The sample covers January 1996 through December 2023 and is restricted to options with between 15 and 55 calendar days to expiration at the formation date. Positions are formed on Wednesdays and held for one week to the following Wednesday. *Return* is the raw option return (mid price to mid price) over the holding period. *Delta-Hedged Return* is the return on a daily delta-hedged position. *Delevered Return* is the option return multiplied by O/S, where O is option mid price and S is underlying price at formation. *RVOL* and *IV* are the 30-day realized volatility and implied volatility, respectively, both in annualized units. ρ is the 30-day rolling correlation between daily S&P 500 log returns and daily changes in realized variance. *Delta*, *Gamma*, and *Vega* are average option delta, gamma, and vega, respectively. *DTE* is the average number of calendar days to expiration at formation. *Volume* is the average daily trading volume on formation day. Panel A (Panel B) reports results for call (put) options.

	Moneyness (K/S)				
	$[0.95, 0.97]$	$(0.97, 0.99]$	$(0.99, 1.01]$	$(1.01, 1.03]$	$(1.03, 1.05]$
Panel A: Call Options					
Return (%)	1.272	1.289	1.436	1.717	−1.364
Delta-Hedged Return (%)	−0.236	−0.428	−0.677	−1.468	−4.833
Delevered Return (%)	0.063	0.036	0.023	0.009	−0.009
RVOL	0.111	0.111	0.112	0.112	0.111
IV	0.205	0.189	0.175	0.162	0.153
ρ	−0.316	−0.316	−0.316	−0.316	−0.316
Delta	0.786	0.676	0.514	0.325	0.182
Gamma	0.003	0.005	0.006	0.006	0.004
Vega	149.327	182.997	204.700	178.693	125.524
DTE	31.377	30.979	31.667	31.788	32.769
Volume	307.994	591.510	1809.169	1483.844	1263.411
Total Obs.	19849	39048	61874	62583	50429
Panel B: Put Options					
Return (%)	−11.165	−8.602	−6.186	−4.578	−3.484
Delta-Hedged Return (%)	−6.121	−4.038	−2.282	−1.287	−0.795
Delevered Return (%)	−0.101	−0.119	−0.132	−0.142	−0.172
RVOL	0.112	0.112	0.112	0.112	0.116
IV	0.213	0.195	0.180	0.167	0.166
ρ	−0.315	−0.316	−0.316	−0.316	−0.324
Delta	−0.220	−0.325	−0.479	−0.656	−0.791
Gamma	0.003	0.005	0.006	0.006	0.004
Vega	150.146	184.244	205.060	185.160	141.571
DTE	31.792	31.581	31.732	31.603	32.691
Volume	1576.449	1789.227	1968.361	597.873	251.021
Total Obs.	61226	63834	61255	32055	11644

Table 2: Regressions of Index Option Returns on the Leverage Effect. This table reports results for the predictive pooled regressions of weekly SPX option returns on lagged correlation between daily index return and daily variance innovations (ρ). The sample covers S&P 500 index options (SPX) with one-month maturity on average ($15 \leq$ DTE ≤ 55). The first two columns pool all near-the-money contracts with moneyness (K/S) in $[0.95, 1.05]$; the remaining columns partition this range into finer moneyness buckets. For each option contract, we compute weekly return from Wednesday to Wednesday mid prices. ρ is the correlation between daily index returns and daily variance innovations over 30 days. *Controls* equals "✓" if the regression includes the lagged control variables—one-month realized volatility and realized quarticity, days to expiration, moneyness, option delta, gamma, and vega, option volume, option relative spread, option leverage, option's exposure to variance, the VIX level, IV smirk, and the one-week and one-month market returns—and "✗" otherwise. The controls are computed on the formation date. Newey-West t-statistics with five lags are presented in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Calls

	$[0.95, 1.05]$		$(0.99, 1.01]$		$[0.95, 0.99]$		$(1.01, 1.05]$	
	I	II	III	IV	V	VI	VII	VIII
Constant	0.009**	−2.089***	0.014**	−7.538***	−0.011**	−1.901***	0.018**	1.827
	(2.315)	(−6.030)	(2.005)	(−4.992)	(−2.405)	(−2.973)	(2.312)	(1.295)
ρ	−0.112***	−0.126***	−0.099***	−0.103***	−0.094***	−0.101***	−0.127***	−0.158***
	(−13.011)	(−12.310)	(−6.779)	(−6.196)	(−9.348)	(−9.105)	(−7.543)	(−7.606)
Controls	✗	✓	✗	✓	✗	✓	✗	✓
N	233,783	233,783	61,874	61,874	58,897	58,897	113,012	113,012
Adj. R^2	0.168%	0.720%	0.227%	1.313%	0.488%	1.376%	0.132%	0.674%

Panel B: Puts

	$[0.95, 1.05]$		$(0.99, 1.01]$		$[0.95, 0.99]$		$(1.01, 1.05]$	
	I	II	III	IV	V	VI	VII	VIII
Constant	−0.040***	−0.754*	−0.024***	−1.391	−0.047***	0.674	−0.041***	0.088
	(−8.434)	(−1.913)	(−2.656)	(−0.791)	(−5.840)	(0.525)	(−5.238)	(0.077)
ρ	0.099***	0.149***	0.109***	0.148***	0.106***	0.175***	0.066***	0.079***
	(10.265)	(12.548)	(5.745)	(6.508)	(6.532)	(8.769)	(3.817)	(3.784)
Controls	✗	✓	✗	✓	✗	✓	✗	✓
N	230,014	230,014	61,255	61,255	125,060	125,060	43,699	43,699
Adj. R^2	0.099%	1.111%	0.153%	1.315%	0.084%	1.035%	0.103%	1.772%

Table 3: Regressions of Index Option Returns on the Leverage Effect: Moneyness Effects. This table reports results for the predictive pooled regressions of weekly SPX option returns on lagged correlation between daily index return and daily variance innovations. The sample covers S&P 500 index options with different moneyness levels and one-month maturity on average ($15 \leq \text{DTE} \leq 55$). For each option contract, we compute weekly return from Wednesday to Wednesday mid prices. ρ is the correlation between daily index returns and daily variance innovations over 30 days. *Controls* equals "✓" if the regression includes the lagged control variables—one-month realized volatility and realized quarticity, days to expiration, moneyness, option delta, gamma, and vega, option volume, option relative spread, option leverage, option's exposure to variance, the VIX level, IV smirk, and the one-week and one-month market returns—and "✗" otherwise. *ATM* denotes contracts with moneyness between 0.95 and 1.05, inclusive; *OTM* denotes contracts with moneyness between 1.05 (0.80) and 1.20 (0.95) for calls (puts); *All* pools contracts with moneyness between 0.80 and 1.20. Newey-West t-statistics with five lags are presented in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Calls

	ATM		OTM		All	
	I	II	III	IV	V	VI
Constant	0.009**	−2.089***	−0.117***	4.523***	0.008**	−0.621***
	(2.315)	(−6.030)	(−16.273)	(8.348)	(2.187)	(−4.370)
ρ	−0.112***	−0.126***	−0.250***	−0.284***	−0.109***	−0.119***
	(−13.011)	(−12.310)	(−13.645)	(−12.199)	(−14.260)	(−13.474)
OTM dummy					−0.124***	−0.100***
					(−18.444)	(−9.475)
$\rho\times$ OTM dummy					−0.142***	−0.161***
					(−8.586)	(−9.835)
Controls	✗	✓	✗	✓	✗	✓
N	233,783	233,783	70,900	70,900	325,012	325,012
Adj. R^2	0.168%	0.720%	0.658%	4.420%	0.513%	1.262%

Panel B: Puts

	ATM		OTM		All	
	I	II	III	IV	V	VI
Constant	−0.040***	−0.754*	−0.139***	−1.283***	−0.043***	−0.273***
	(−8.434)	(−1.913)	(−23.806)	(−5.883)	(−10.603)	(−3.184)
ρ	0.099***	0.149***	0.020*	0.057***	0.088***	0.114***
	(10.265)	(12.548)	(1.808)	(3.952)	(10.413)	(11.919)
OTM dummy					−0.096***	−0.011
					(−14.481)	(−1.076)
$\rho\times$ OTM dummy					−0.068***	−0.037***
					(−4.868)	(−2.665)
Controls	✗	✓	✗	✓	✗	✓
N	230,014	230,014	234,042	234,042	475,052	475,052
Adj. R^2	0.099%	1.111%	0.002%	0.807%	0.144%	0.857%

Table 4: Regressions of Index Option Returns on the Leverage Effect: Friday-to-Friday Returns. This table reports results for the predictive pooled regressions of weekly SPX option returns on lagged correlation between daily index return and daily variance innovations (ρ). The sample covers S&P 500 index options (SPX) with one-month maturity on average ($15 \leq \text{DTE} \leq 55$). The first two columns pool all near-the-money contracts with moneyness (K/S) in $[0.95, 1.05]$; the remaining columns partition this range into finer moneyness buckets. For each option contract, we compute weekly return from Friday to Friday mid prices. ρ is the correlation between daily index returns and daily variance innovations over 30 days. *Controls* equals "✓" if the regression includes the lagged control variables—one-month realized volatility and realized quarticity, days to expiration, moneyness, option delta, gamma, and vega, option volume, option relative spread, option leverage, option's exposure to variance, the VIX level, IV smirk, and the one-week and one-month market returns—and "✗" otherwise. The controls are computed on the formation date. Newey-West t-statistics with five lags are presented in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	Panel A: Calls									
	$[0.95, 1.05]$		$(0.99, 1.01]$		$[0.95, 0.99]$		$(1.01, 1.05]$		$(1.05, 1.20]$	
	I	II	III	IV	V	VI	VII	VIII	IX	X
Constant	0.031^{***}	-2.435^{***}	0.011	-6.791^{***}	-0.008^{*}	-1.195	0.065^{***}	-2.617	0.048^{***}	-1.624
	(5.917)	(-5.904)	(1.492)	(-4.031)	(-1.645)	(-1.627)	(5.811)	(-1.611)	(3.410)	(-1.633)
ρ	-0.093^{***}	-0.102^{***}	-0.120^{***}	-0.130^{***}	-0.099^{***}	-0.102^{***}	-0.072^{***}	-0.081^{***}	-0.249^{***}	-0.565^{***}
	(-9.163)	(-8.153)	(-7.762)	(-7.437)	(-9.857)	(-9.640)	(-3.446)	(-3.060)	(-7.995)	(-14.431)
Controls	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓
N	222,051	222,051	59,171	59,171	57,419	57,419	105,461	105,461	64,796	64,796
Adj. R^2	0.095%	1.332%	0.303%	1.723%	0.521%	1.615%	0.033%	1.396%	0.234%	13.062%
	Panel B: Puts									
	$[0.95, 1.05]$		$(0.99, 1.01]$		$[0.95, 0.99]$		$(1.01, 1.05]$		$[0.80, 0.95)$	
	I	II	III	IV	V	VI	VII	VIII	IX	X
Constant	-0.008	-0.796^{**}	0.008	-1.846	-0.023^{**}	0.568	0.011	1.162	-0.054^{***}	-0.020
	(-1.440)	(-2.008)	(0.813)	(-1.006)	(-2.510)	(0.433)	(1.235)	(0.914)	(-5.160)	(-0.050)
ρ	0.162^{***}	0.172^{***}	0.173^{***}	0.196^{***}	0.174^{***}	0.198^{***}	0.108^{***}	0.093^{***}	0.209^{***}	0.248^{***}
	(15.998)	(13.144)	(8.984)	(8.377)	(10.470)	(9.257)	(6.224)	(4.266)	(12.764)	(10.815)
Controls	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓
N	218,432	218,432	57,825	57,825	118,942	118,942	41,665	41,665	215,122	215,122
Adj. R^2	0.267%	0.641%	0.400%	0.869%	0.231%	0.622%	0.259%	0.729%	0.146%	0.582%

Table 5: Regressions of Index Option Returns on the Leverage Effect: Excluding Expiration Weeks This table reports results for the predictive pooled regressions of weekly SPX option returns on lagged correlation between daily index return and daily variance innovations (ρ) by excluding expiration weeks, i.e., any holding period includes third Friday of month. The sample covers S&P 500 index options (SPX) with different moneyness levels and one-month maturity on average ($15 \leq \text{DTE} \leq 55$). For each option contract, we compute weekly return from Wednesday to Wednesday mid prices. The first two columns pool all near-the-money contracts with moneyness in $[0.95, 1.05]$; the next six columns partition this range into finer moneyness buckets; and the final two columns cover out-of-the-money contracts with moneyness between 1.05 (0.80) and 1.20 (0.95) for calls (puts). ρ is the correlation between daily index returns and daily variance innovations over 30 days. *Controls* equals "✓" if the regression includes the lagged control variables—one-month realized volatility and realized quarticity, days to expiration, moneyness, option delta, gamma, and vega, option volume, option relative spread, option leverage, option's exposure to variance, the VIX level, IV smirk, and the one-week and one-month market returns—and "✗" otherwise. The controls are computed on the formation date. Newey-West t-statistics with five lags are presented in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Calls

	$[0.95, 1.05]$		$(0.99, 1.01]$		$[0.95, 0.99]$		$(1.01, 1.05]$		$(1.05, 1.20]$	
	I	II	III	IV	V	VI	VII	VIII	IX	X
Constant	-0.006	-1.123^{***}	0.004	-4.520^{***}	-0.025^{***}	-0.306	-0.002	4.387^{***}	-0.153^{***}	5.471^{***}
	(-1.242)	(-3.028)	(0.421)	(-2.773)	(-3.896)	(-0.428)	(-0.179)	(3.162)	(-18.028)	(8.961)
ρ	-0.103^{***}	-0.084^{***}	-0.090^{***}	-0.067^{***}	-0.104^{***}	-0.101^{***}	-0.108^{***}	-0.085^{***}	-0.321^{***}	-0.272^{***}
	(-9.745)	(-6.985)	(-4.818)	(-3.243)	(-7.685)	(-6.965)	(-5.594)	(-3.752)	(-14.784)	(-10.547)
Controls	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓
N	181,738	181,738	48,012	48,012	45,849	45,849	87,877	87,877	55,299	55,299
Adj. R^2	0.158%	0.714%	0.184%	1.263%	0.531%	1.232%	0.113%	0.683%	1.085%	7.482%

Panel B: Puts

	$[0.95, 1.05]$		$(0.99, 1.01]$		$[0.95, 0.99]$		$(1.01, 1.05]$		$[0.80, 0.95)$	
	I	II	III	IV	V	VI	VII	VIII	IX	X
Constant	-0.034^{***}	-2.508^{***}	-0.019	-6.571^{***}	-0.042^{***}	-4.040^{***}	-0.031^{***}	-2.054^{*}	-0.154^{***}	-1.219^{***}
	(-5.421)	(-5.308)	(-1.561)	(-3.308)	(-3.895)	(-2.626)	(-3.259)	(-1.712)	(-19.531)	(-4.319)
ρ	0.077^{***}	0.166^{***}	0.085^{***}	0.157^{***}	0.072^{***}	0.194^{***}	0.078^{***}	0.101^{***}	-0.037^{**}	0.059^{***}
	(5.800)	(10.811)	(3.352)	(5.463)	(3.230)	(7.476)	(3.460)	(3.942)	(-2.148)	(3.025)
Controls	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓
N	179,147	179,147	47,702	47,702	96,928	96,928	34,517	34,517	181,391	181,391
Adj. R^2	0.050%	1.201%	0.079%	1.387%	0.031%	1.090%	0.133%	2.367%	0.006%	0.899%

Table 6: Regressions of Index Option Returns on the Leverage Effect: Maturity Effects. This table reports results for the predictive pooled regressions of weekly SPX option returns on lagged correlation between daily index return and daily variance innovations (ρ) using contracts with longer maturities than one-month on average. The sample covers S&P 500 index options (SPX) with different moneyness levels (near-the-money). For each option contract, we compute weekly return from Wednesday to Wednesday mid prices. ρ is the correlation between daily index returns and daily variance innovations over 30 days. *Controls* equals "✓" if the regression includes the lagged control variables—one-month realized volatility and realized quarticity, days to expiration, moneyness, option delta, gamma, and vega, option volume, option relative spread, option leverage, option's exposure to variance, the VIX level, IV smirk, and the one-week and one-month market returns—and "✗" otherwise. The controls are computed on the formation date. DTE corresponds to days to expiration. Newey-West t-statistics with five lags are presented in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Calls

	$[0.95, 0.99]$		$(0.99, 1.01]$		$(1.01, 1.05]$	
	I	II	III	IV	V	VI
Maturity: $56 \leq$ DTE ≤ 95						
Constant	-0.014^{**}	-1.746^{**}	-0.014^{**}	-3.630^{***}	-0.010	-3.932^{***}
	(-2.423)	(-2.287)	(-1.996)	(-3.105)	(-1.500)	(-4.005)
ρ	-0.066^{***}	-0.078^{***}	-0.083^{***}	-0.082^{***}	-0.094^{***}	-0.073^{***}
	(-5.250)	(-5.675)	(-5.718)	(-4.955)	(-6.414)	(-4.269)
Controls	✗	✓	✗	✓	✗	✓
N	15,667	15,666	17,188	17,186	32,827	32,823
Adj. R^2	0.533%	1.838%	0.506%	1.864%	0.337%	1.308%
Maturity: $96 \leq$ DTE ≤ 135						
Constant	-0.005	-3.629^{***}	-0.000	-4.658^{***}	-0.003	-3.971^{***}
	(-0.682)	(-4.086)	(-0.007)	(-3.631)	(-0.323)	(-3.868)
ρ	-0.049^{***}	-0.034^{*}	-0.061^{***}	-0.031	-0.089^{***}	-0.059^{***}
	(-2.861)	(-1.802)	(-3.308)	(-1.450)	(-5.067)	(-2.770)
Controls	✗	✓	✗	✓	✗	✓
N	5,544	5,536	5,831	5,819	11,270	11,242
Adj. R^2	0.417%	2.533%	0.435%	3.402%	0.595%	2.205%

Panel B: Puts

	$[0.95, 0.99]$		$(0.99, 1.01]$		$(1.01, 1.05]$	
	I	II	III	IV	V	VI
Maturity: $56 \leq$ DTE ≤ 95						
Constant	-0.002	0.651	-0.003	1.346	-0.018^{**}	1.208
	(-0.242)	(0.715)	(-0.309)	(1.066)	(-2.237)	(1.210)
ρ	0.072^{***}	0.095^{***}	0.061^{***}	0.078^{***}	0.049^{***}	0.046^{**}
	(4.701)	(5.263)	(3.313)	(3.646)	(2.625)	(2.147)
Controls	✗	✓	✗	✓	✗	✓
N	34,280	34,279	18,147	18,146	14,813	14,812
Adj. R^2	0.173%	1.026%	0.155%	1.271%	0.133%	1.941%
Maturity: $96 \leq$ DTE ≤ 135						
Constant	-0.018^{**}	3.960^{***}	-0.012	4.539^{***}	-0.028^{***}	2.929^{***}
	(-2.170)	(4.843)	(-1.272)	(3.832)	(-2.961)	(2.955)
ρ	0.041^{**}	0.034^{*}	0.051^{**}	0.026^{*}	0.041^{*}	0.003
	(2.161)	(1.787)	(2.327)	(1.958)	(1.818)	(0.095)
Controls	✗	✓	✗	✓	✗	✓
N	11,797	11,789	6,260	6,248	5,610	5,597
Adj. R^2	0.126%	2.009%	0.210%	2.192%	0.162%	2.677%

Table 7: Regressions of Monthly Index Option Returns on the Leverage Effect. This table reports results for the predictive pooled regressions of monthly SPX option returns on lagged correlation between daily index return and daily variance innovations (ρ). For each option contract, we compute the monthly return from the first Monday following the third Friday of one month to the third Friday of the following month using mid prices. The sample covers S&P 500 index options (SPX) with different moneyness levels and two-month maturity on average ($56 \leq \text{DTE} \leq 95$). The first two columns pool all near-the-money contracts with moneyness in $[0.95, 1.05]$; the next six columns partition this range into finer moneyness buckets; and the final two columns cover out-of-the-money contracts with moneyness between 1.05 (0.80) and 1.20 (0.95) for calls (puts). ρ is the correlation between daily index returns and daily variance innovations over 30 days. *Controls* equals "✓" if the regression includes the lagged control variables—one-month realized volatility and realized quarticity, days to expiration, moneyness, option delta, gamma, and vega, option volume, option relative spread, option leverage, option's exposure to variance, the VIX level, IV smirk, and the one-week and one-month market returns—and "✗" otherwise. The controls are computed on the formation date. Newey-West t-statistics with five lags are presented in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	Panel A: Calls									
	$[0.95, 1.05]$		$(0.99, 1.01]$		$[0.95, 0.99]$		$(1.01, 1.05]$		$(1.05, 1.20]$	
	I	II	III	IV	V	VI	VII	VIII	IX	X
Constant	0.044	-9.553^{***}	0.018	-6.796	0.002	-4.024	0.079	-18.262^{***}	-0.055	-5.094
	(1.572)	(-4.679)	(0.475)	(-1.137)	(0.057)	(-1.063)	(1.535)	(-2.925)	(-1.392)	(-1.365)
ρ	-0.343^{***}	-0.278^{***}	-0.346^{***}	-0.306^{***}	-0.312^{***}	-0.283^{***}	-0.358^{***}	-0.244^{*}	-0.563^{***}	-0.746^{***}
	(-6.194)	(-3.860)	(-4.725)	(-3.392)	(-5.650)	(-4.364)	(-3.525)	(-1.759)	(-5.615)	(-4.728)
Controls	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓
N	16,586	16,575	4,304	4,301	4,075	4,074	8,207	8,200	10,420	10,418
Adj. R^2	1.106%	8.456%	2.029%	9.284%	3.165%	8.194%	0.744%	8.518%	1.136%	13.643%
	Panel B: Puts									
	$[0.95, 1.05]$		$(0.99, 1.01]$		$[0.95, 0.99]$		$(1.01, 1.05]$		$[0.80, 0.95)$	
	I	II	III	IV	V	VI	VII	VIII	IX	X
Constant	-0.056^{**}	0.360	-0.039	1.522	-0.087^{**}	-7.483	-0.012	16.329^{***}	-0.076^{*}	-7.076^{***}
	(-2.083)	(0.189)	(-0.812)	(0.214)	(-2.203)	(-1.407)	(-0.258)	(3.200)	(-1.881)	(-3.304)
ρ	0.220^{***}	0.206^{***}	0.239^{***}	0.236^{**}	0.233^{***}	0.227^{***}	0.162^{**}	0.130^{*}	0.334^{***}	0.500^{***}
	(4.921)	(3.598)	(2.947)	(2.353)	(3.578)	(2.733)	(2.057)	(1.779)	(5.783)	(5.856)
Controls	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓
N	17,226	17,221	4,595	4,593	8,579	8,578	4,052	4,050	22,091	22,085
Adj. R^2	0.339%	4.686%	0.411%	5.841%	0.321%	4.723%	0.218%	4.842%	0.248%	4.380%

Table 8: Regressions of Delta-Hedged Index Option Returns on the Leverage Effect. This table reports results for the predictive pooled regressions of weekly delta-hedged SPX option returns on lagged correlation between daily index return and daily variance innovations (ρ). Delta-hedged returns are constructed by rebalancing the hedge daily over the holding period. The sample covers S&P 500 index options (SPX) with different moneyness levels and one-month maturity on average ($15 \leq \text{DTE} \leq 55$). The first two columns pool all near-the-money contracts with moneyness (K/S) in $[0.95, 1.05]$; the remaining columns partition this range into finer moneyness buckets. For each option contract, we compute the weekly delta-hedged return from Wednesday to Wednesday. ρ is the correlation between daily index returns and daily variance innovations over 30 days. *Controls* equals "✓" if the regression includes the lagged control variables—one-month realized volatility and realized quarticity, days to expiration, moneyness, option delta, gamma, and vega, option volume, option relative spread, option leverage, option's exposure to variance, the VIX level, IV smirk, and the one-week and one-month market returns—and "✗" otherwise. The controls are computed on the formation date. Newey-West t-statistics with five lags are presented in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Calls

	$[0.95, 1.05]$		$(0.99, 1.01]$		$[0.95, 0.99]$		$(1.01, 1.05]$	
	I	II	III	IV	V	VI	VII	VIII
Constant	−0.000	0.437***	0.007***	−0.364	0.002*	0.159	−0.006	3.923***
	(−0.205)	(2.600)	(3.806)	(−0.842)	(1.761)	(1.144)	(−1.539)	(5.308)
ρ	0.030***	0.018***	0.010**	0.018***	−0.000	0.003	0.054***	0.020**
	(7.395)	(3.688)	(2.495)	(3.834)	(−0.079)	(1.152)	(6.611)	(1.986)
Controls	✗	✓	✗	✓	✗	✓	✗	✓
N	233,783	233,783	61,874	61,874	58,897	58,897	113,012	113,012
Adj. R^2	0.049%	1.551%	0.027%	0.774%	−0.002%	0.882%	0.086%	1.934%

Panel B: Puts

	$[0.95, 1.05]$		$(0.99, 1.01]$		$[0.95, 0.99]$		$(1.01, 1.05]$	
	I	II	III	IV	V	VI	VII	VIII
Constant	−0.028***	−0.127	−0.014***	−0.944**	−0.043***	−0.417	−0.007***	0.377
	(−23.587)	(−1.011)	(−8.369)	(−2.495)	(−19.284)	(−0.948)	(−7.724)	(1.644)
ρ	−0.002	0.006*	0.007*	0.017***	−0.008	0.008*	−0.007***	−0.010***
	(−0.890)	(1.840)	(1.833)	(3.858)	(−1.544)	(1.757)	(−2.734)	(−3.445)
Controls	✗	✓	✗	✓	✗	✓	✗	✓
N	230,014	230,014	61,255	61,255	125,060	125,060	43,699	43,699
Adj. R^2	0.000%	1.241%	0.013%	1.846%	0.003%	0.985%	0.044%	7.207%

Table 9: Regressions of Delevered Index Option Returns on the Leverage Effect. This table reports results for the predictive pooled regressions of weekly delevered SPX option returns on lagged correlation between daily index return and daily variance innovations (ρ). Delevered returns are computed by multiplying weekly option returns by O/S at the formation date. The sample covers S&P 500 index options (SPX) with different moneyness levels and one-month maturity on average ($15 \leq \text{DTE} \leq 55$). The first two columns pool all near-the-money contracts with moneyness (K/S) in $[0.95, 1.05]$; the remaining columns partition this range into finer moneyness buckets. For each option contract, we compute the weekly return from Wednesday to Wednesday mid prices. ρ is the correlation between daily index returns and daily variance innovations over 30 days. *Controls* equals "✓" if the regression includes the lagged control variables—one-month realized volatility and realized quarticity, days to expiration, moneyness, option delta, gamma, and vega, option volume, option relative spread, option leverage, option's exposure to variance, the VIX level, IV smirk, and the one-week and one-month market returns—and "✗" otherwise. The controls are computed on the formation date. Newey-West t-statistics with five lags are presented in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Calls

	$[0.95, 1.05]$		$(0.99, 1.01]$		$[0.95, 0.99]$		$(1.01, 1.05]$	
	I	II	III	IV	V	VI	VII	VIII
Constant	−0.000	−0.029***	0.000	−0.100***	−0.000***	−0.068**	0.000**	0.024**
	(−0.669)	(−4.270)	(0.579)	(−3.385)	(−2.694)	(−2.572)	(2.180)	(2.184)
ρ	−0.002***	−0.002***	−0.002***	−0.002***	−0.003***	−0.004***	−0.001***	−0.001***
	(−14.144)	(−14.647)	(−6.800)	(−7.224)	(−9.244)	(−9.339)	(−6.251)	(−6.655)
Controls	✗	✓	✗	✓	✗	✓	✗	✓
N	233,783	233,783	61,874	61,874	58,897	58,897	113,012	113,012
Adj. R^2	0.259%	0.969%	0.274%	1.238%	0.501%	1.458%	0.132%	1.253%

Panel B: Puts

	$[0.95, 1.05]$		$(0.99, 1.01]$		$[0.95, 0.99]$		$(1.01, 1.05]$	
	I	II	III	IV	V	VI	VII	VIII
Constant	−0.001***	0.028***	−0.001***	0.008	−0.001***	0.046**	−0.002***	0.055
	(−11.888)	(3.039)	(−4.234)	(0.217)	(−7.029)	(2.489)	(−6.948)	(1.131)
ρ	0.001***	0.002***	0.001***	0.002***	0.001***	0.001***	0.001**	0.002***
	(5.597)	(8.300)	(3.864)	(5.082)	(3.392)	(5.736)	(2.291)	(2.625)
Controls	✗	✓	✗	✓	✗	✓	✗	✓
N	230,014	230,014	61,255	61,255	125,060	125,060	43,699	43,699
Adj. R^2	0.043%	2.397%	0.089%	2.399%	0.038%	2.498%	0.042%	2.650%

Appendix

A.1 The Impact of Leverage: Implementation Details

We price European call and put options under the Heston (1993) model using the closed-form characteristic-function representation. We set the model parameters to $\{\kappa, \theta, \sigma, \rho, \gamma, \xi\} = \{2.9862, 0.0372, 0.4500, -0.7458, 2.0527, 1.6599\}$. We compute the option price $O(\rho)$ and its Greeks $O_S(\rho)$ and $O_v(\rho)$ at a grid of moneyness levels $K/S \in [0.80, 1.20]$ for options with 30 days to maturity. The equity and variance loadings follow from

$$\beta_S(\rho) = \frac{S\, O_S(\rho)}{O(\rho)}, \quad \beta_v(\rho) = \frac{O_v(\rho)}{O(\rho)}. \tag{20}$$

The risk premiums are linear in ρ, so $\partial\mu(v(t))/\partial\rho$ and $\partial\lambda(v(t))/\partial\rho$ are available in closed form, as derived in Equations (9) and (10). The loadings, in contrast, depend on ρ through the Heston characteristic function and have no closed-form derivative. We compute $\partial\beta_S/\partial\rho$ and $\partial\beta_v/\partial\rho$ using the symmetric difference quotient

$$\frac{\partial f(\rho)}{\partial\rho} \approx \frac{f(\rho+h) - f(\rho-h)}{2h}, \tag{21}$$

where f denotes the loading and h is a small step size. We set $h = 10^{-4}$, which yields stable estimates across the moneyness grid.[9] For each value of $\rho \pm h$, we re-solve for O, O_S, and O_v under the Heston model, recompute the loadings, and apply Equation (21).

The decomposition in Equation (8) delivers an instantaneous sensitivity $\partial\text{EER}/\partial\rho$. To express the magnitudes reported in Section 2.2 as weekly expected excess returns, we set $dt = 7/365$ in Equation (5). The weekly effect of a one-standard-deviation shock to ρ is then

$$\Delta\text{EER}_{\text{weekly}} = \frac{\partial\text{EER}}{\partial\rho} \cdot \sigma_\rho \cdot \frac{7}{365}, \tag{22}$$

where $\sigma_\rho = 0.277$ is the empirical standard deviation of ρ reported. Applying Equation (22) at each moneyness level produces the magnitudes summarized in Section 2.2.

[9] The symmetric difference quotient has truncation error $O(h^2)$, so the choice of h does not materially affect the results. We verified that values of h between 10^{-6} and 10^{-2} produce essentially identical sensitivity estimates.

Figure A.1: Sensitivity of Expected Option Returns: Robustness Across Correlation Levels. This figure plots the total sensitivity of the expected excess return to the return-variance correlation, $\partial\text{EER}/\partial\rho$, across different values of $\rho \in [-0.95, 0.95]$, with the vertical dashed line marking the baseline value $\rho = -0.7458$. The figure plots the total sensitivity, $\partial\text{EER}/\partial\rho$ (solid black), together with its four components from Equation (8). Results are reported for at-the-money options ($K/S = 1$) with 30 days to maturity and a one-week holding period. The left panel reports results for calls and the right panel for puts. The model parameters are set to $\{\kappa, \theta, \sigma, \rho, \gamma, \xi\} = \{2.9862, 0.0372, 0.4500, -0.7458, 2.0527, 1.6599\}$. The figure uses a symmetric log scale.

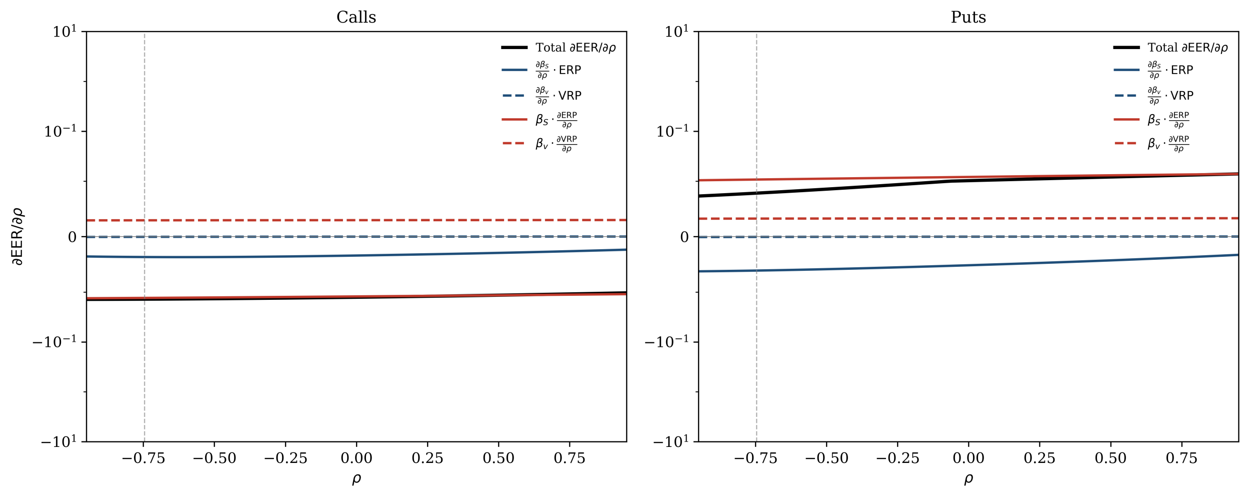
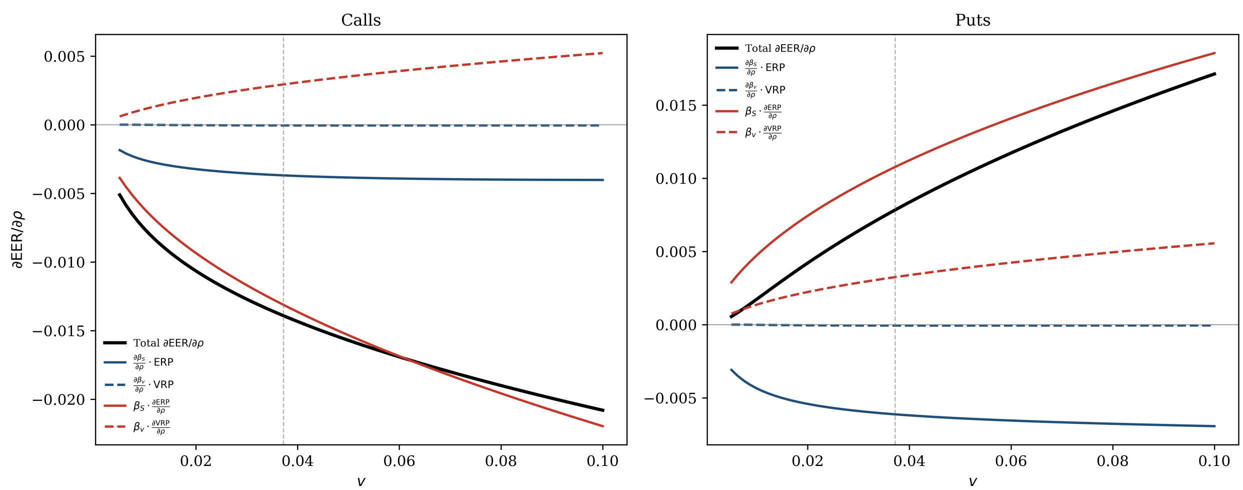


Figure A.2: Sensitivity of Expected Option Returns: Robustness Across Variance and Volatility of Variance Levels. This figure plots the total sensitivity of the expected excess return to the return-variance correlation, $\partial\text{EER}/\partial\rho$, across different values of the variance level v in Panel A and the volatility of variance σ in Panel B, with the vertical dashed lines marking the baseline values $v = 0.0372$ and $\sigma = 0.4500$. The figure plots the total sensitivity, $\partial\text{EER}/\partial\rho$ (solid black), together with its four components from Equation (8). Results are reported for at-the-money options ($K/S = 1$) with 30 days to maturity and a one-week holding period. The left columns report results for calls and the right columns for puts. The remaining model parameters are set to $\{\kappa, \theta, \rho, \gamma, \xi\} = \{2.9862, 0.0372, -0.7458, 2.0527, 1.6599\}$.

Panel A: Varying Variance



Panel B: Varying Volatility of Variance

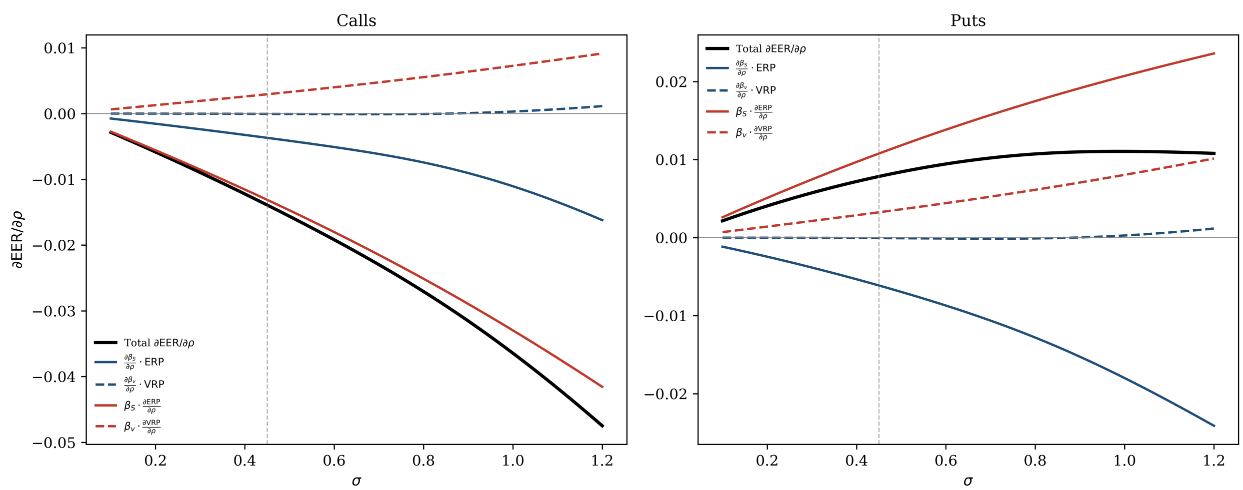
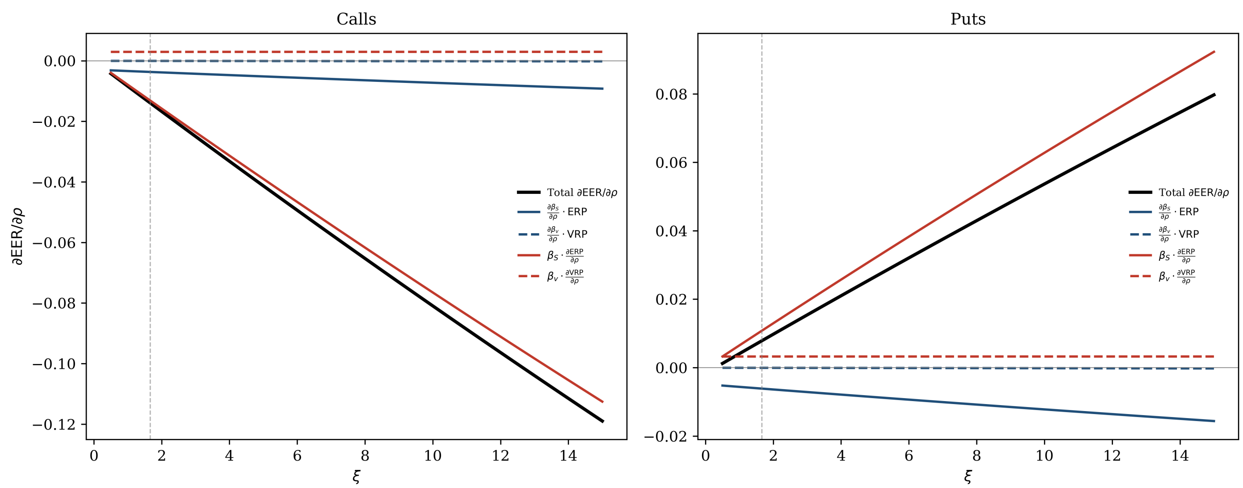


Figure A.3: Sensitivity of Expected Option Returns: Robustness Across Risk Aversion Levels. This figure plots the total sensitivity of the expected excess return to the return-variance correlation, $\partial\text{EER}/\partial\rho$, across different values of the variance risk aversion ξ in Panel A and the equity risk aversion γ in Panel B, with the vertical dashed lines marking the baseline values $\gamma = 2.0527$ and $\xi = 1.6599$. The figure plots the total sensitivity, $\partial\text{EER}/\partial\rho$ (solid black), together with its four components from Equation (8). Results are reported for at-the-money options ($K/S = 1$) with 30 days to maturity and a one-week holding period. The left columns report results for calls and the right columns for puts. The remaining model parameters are set to $\{\kappa, \theta, \sigma, \rho\} = \{2.9862, 0.0372, 0.4500, -0.7458\}$.

Panel A: Varying Variance Risk Aversion



Panel B: Varying Equity Risk Aversion

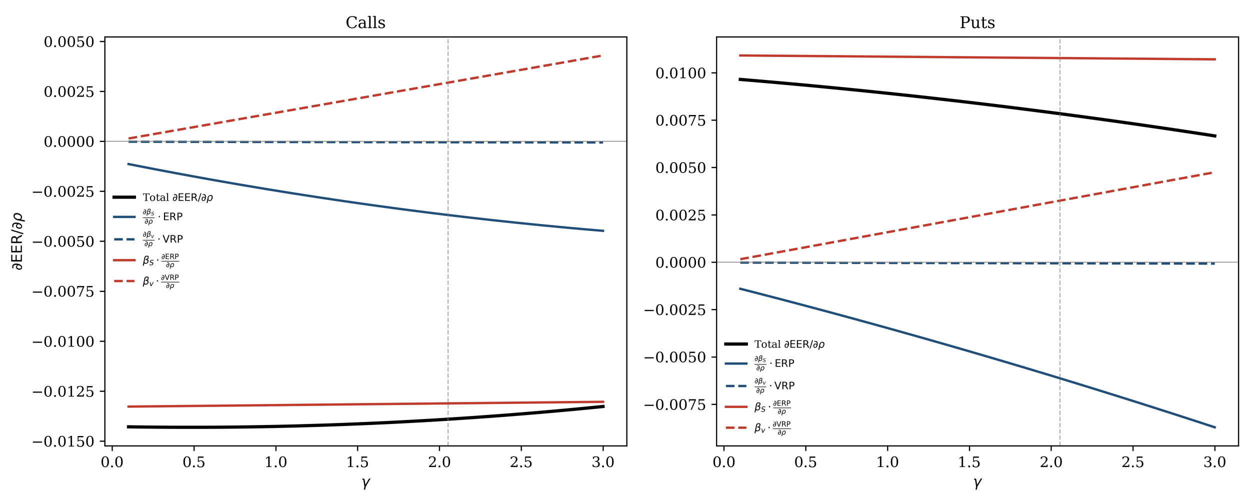


Table A.1: Regressions of Delta-Hedged Index Option Returns on the Leverage Effect: Robustness. This table reports robustness results for the predictive pooled regressions of weekly delta-hedged SPX option returns on lagged correlation between daily index return and daily variance innovations (ρ). All specifications use at-the-money contracts with moneyness (K/S) in $[0.99, 1.01]$ and include the full set of lagged controls. The columns vary the return-measurement window (Friday-to-Friday versus Wednesday-to-Wednesday), whether expiration weeks are excluded (Ex-3F, i.e., dropping any holding period that spans the third Friday of the month), and the maturity range (baseline 15–55 days, 56–95 days, and 96–135 days). ρ is the correlation between daily index returns and daily variance innovations over 30 days. Controls include lagged one-month realized volatility and realized quarticity, days to expiration, moneyness, option delta, gamma, and vega, option volume, option relative spread, option leverage, option's exposure to variance, the VIX level, IV smirk, and the one-week and one-month market returns, all computed on the formation date. Newey-West t-statistics with five lags are presented in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Calls

	Friday-to-Friday				Wednesday-to-Wednesday			
	Baseline	Ex-3F	56–95d	96–135d	Baseline	Ex-3F	56–95d	96–135d
Constant	1.836***	3.218***	0.934***	0.731***	−0.398	−0.111	0.306	0.964***
	(3.901)	(5.353)	(3.553)	(2.666)	(−0.917)	(−0.233)	(1.126)	(3.577)
ρ	0.031***	0.044***	0.018***	0.013***	0.017***	0.013**	0.007*	0.003
	(6.639)	(5.542)	(4.548)	(2.632)	(3.597)	(2.304)	(1.805)	(0.592)
Controls	✓	✓	✓	✓	✓	✓	✓	✓
N	59,171	31,789	18,661	6,392	61,874	48,012	17,188	5,831
Adj. R^2	1.038%	2.841%	1.464%	4.083%	0.750%	0.660%	1.580%	3.767%

Panel B: Puts

	Friday-to-Friday				Wednesday-to-Wednesday			
	Baseline	Ex-3F	56–95d	96–135d	Baseline	Ex-3F	56–95d	96–135d
Constant	−1.337***	−1.983***	−0.605**	0.022	−0.821**	−1.349***	−0.435	0.517**
	(−3.271)	(−3.768)	(−2.338)	(0.097)	(−2.112)	(−3.304)	(−1.520)	(2.058)
ρ	0.037***	0.038***	0.023***	0.018***	0.014***	0.016***	0.006*	−0.000
	(7.128)	(4.665)	(5.159)	(3.608)	(3.184)	(2.951)	(1.713)	(−0.036)
Controls	✓	✓	✓	✓	✓	✓	✓	✓
N	57,825	31,438	19,438	6,981	61,255	47,702	18,147	6,260
Adj. R^2	1.864%	3.395%	2.256%	3.596%	1.786%	1.457%	1.124%	5.095%

Table A.2: Regressions of Delevered Index Option Returns on the Leverage Effect: Robustness. This table reports robustness results for the predictive pooled regressions of weekly delevered SPX option returns on lagged correlation between daily index return and daily variance innovations (ρ), where the delevered returns are computed by multiplying weekly option returns by O/S at the formation date. All specifications use at-the-money contracts with moneyness (K/S) in $[0.99, 1.01]$ and include the full set of lagged controls. The columns vary the return-measurement window (Friday-to-Friday versus Wednesday-to-Wednesday), whether expiration weeks are excluded (Ex-3F, i.e., dropping any holding period that spans the third Friday of the month), and the maturity range (baseline 15–55 days, 56–95 days, and 96–135 days). ρ is the correlation between daily index returns and daily variance innovations over 30 days. Controls include lagged one-month realized volatility and realized quarticity, days to expiration, moneyness, option delta, gamma, and vega, option volume, option relative spread, option leverage, option's exposure to variance, the VIX level, IV smirk, and the one-week and one-month market returns, all computed on the formation date. Newey-West t-statistics with five lags are presented in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Calls

	Friday-to-Friday				Wednesday-to-Wednesday			
	Baseline	Ex-3F	56–95d	96–135d	Baseline	Ex-3F	56–95d	96–135d
Constant	−0.045	0.087*	0.025	−0.064	−0.099***	−0.058*	−0.115***	−0.156***
	(−1.239)	(1.715)	(0.550)	(−1.179)	(−3.332)	(−1.788)	(−2.915)	(−2.757)
ρ	−0.003***	−0.004***	−0.003***	−0.003***	−0.002***	−0.002***	−0.003***	−0.002**
	(−8.583)	(−7.468)	(−5.496)	(−3.036)	(−6.798)	(−4.652)	(−5.670)	(−2.494)
Controls	✓	✓	✓	✓	✓	✓	✓	✓
N	59,171	31,789	18,661	6,392	61,874	48,012	17,188	5,831
Adj. R^2	2.805%	8.214%	3.571%	2.197%	1.206%	1.498%	2.339%	3.288%

Panel B: Puts

	Friday-to-Friday				Wednesday-to-Wednesday			
	Baseline	Ex-3F	56–95d	96–135d	Baseline	Ex-3F	56–95d	96–135d
Constant	0.002	−0.089**	−0.012	0.074	0.019	−0.085**	0.062	0.108**
	(0.066)	(−2.073)	(−0.273)	(1.607)	(0.495)	(−2.202)	(1.349)	(2.223)
ρ	0.003***	0.006***	0.003***	0.002	0.002***	0.003***	0.002***	0.002
	(6.327)	(7.283)	(5.495)	(1.473)	(4.281)	(5.342)	(3.340)	(1.463)
Controls	✓	✓	✓	✓	✓	✓	✓	✓
N	57,825	31,438	19,438	6,981	61,255	47,702	18,147	6,260
Adj. R^2	1.012%	6.539%	1.697%	1.901%	2.262%	4.372%	3.549%	2.891%