CFR Working Paper No. 23-06

How should the Long-term Investor Harvest Variance Risk Premiums?

J. Dörries • O. Korn • G. J. Power

centre for financial research
cologne

How Should the Long-term Investor Harvest Variance Risk Premiums? ¶

Julian Dörries*, Olaf Korn†, Gabriel J. Power‡

JEL Classification: G10, G11, G23

Keywords: Variance Risk Premium; Variance Factor; Trading Strategies; Long-term Investor

¶ We thank Marco Erling, Florian Reibis, Martin Wallmeier, Jörg Zimmermann, as well as participants of the 2021 CFR research seminar and the 2021 Workshop on Structured Retail Products at the University of Hagen for helpful comments and suggestions. Vitus Benson provided excellent research assistance.

* Julian Dörries, Chair of Finance, University of Goettingen, Platz der Göttinger Sieben 3, D-37073 Göttingen, Germany; tel. +49 551 39 27264; email julian.doerries@uni-goettingen.de.

† Olaf Korn, Chair of Finance, University of Goettingen and Centre for Financial Research Cologne (CFR), Platz der Göttinger Sieben 3, D-37073 Göttingen, Germany; tel. +49 551 39 27265; email okorn@uni-goettingen.de.

‡ Gabriel J. Power, Université Laval, Department of Finance, Insurance and Real Estate, Faculté des sciences de l'administration, Pavillon Palasis-Prince, 2325 rue de la Terrasse, Québec, Québec G1V 0A6, Canada; tel. +1 418 656-2131; email gabriel.power@fsa.ulaval.ca.

How Should the Long-term Investor Harvest Variance Risk Premiums?

Abstract

Derivatives strategies that aim to earn variance risk premiums are exposed to sharp price declines during market crises, calling into question their suitability for the long-term investor. Our paper defines, analyzes, and proposes potential solutions to three problems (payoff, leverage and finite maturity) linked to designing suitable variance-based investment strategies. We conduct an empirical study of such strategies for the S&P 500 index options market and find strong effects of certain design elements on risk and return. Overall, our results show that variance strategies can be attractive to the long-term investor if properly designed.

JEL Classification: G10, G11, G23

1 Introduction

The variance risk premium (VRP) is a well-known feature in options markets and exists across asset classes and countries (Zhou 2018). There is strong evidence, in particular, of a negative variance risk premium in options on equity indexes (e.g., Hafner and Wallmeier 2007; Carr and Wu 2009; Kozhan, Neuberger, and Schneider 2013). The literature, however, does not provide much guidance on whether and how the long-term investor could benefit from the VRP. These questions are challenging because the structure of variance risk involves rare, high-impact events. Our paper makes conceptual and empirical contributions to answer these questions. First, we highlight three problems of VRP-earning strategies: (i) The payoff problem: Which payoff profiles are appropriate? Which instruments should be used to create them? (ii) The leverage problem: Which risk level should be chosen? How can the variance risk of different strategies be measured and compared? (iii) The finite maturity problem: Which maturities of derivatives should be chosen? When and how often should positions be rolled over? Second, we propose and analyze VRP-earning strategies with different design elements, to address the three problems. Finally, we assess the different VRP strategies empirically in a study of S&P 500 index options. Our data sample ranges from January 1996 to June 2021, therefore including the two most consequential stock market crashes in recent decades. This data feature is essential to study variance strategies. To implement the strategies, we use realistic assumptions about transaction costs and Chicago Board Options Exchange (Cboe) margin requirements for option positions. As potential solutions to the leverage problem, we suggest and implement two methods to determine risk exposure: First, we use an equal ex-ante factor exposure for all strategies based on the Black-Scholes vega. Second, we use an equal ex-post crash risk that is calibrated to a stock market investment.

Our empirical analysis provides the following main results: (i) Variance strategies differ greatly in terms of return and risk due to different payoff profiles. (ii) Even strategies that are equivalent in a world without market frictions can differ significantly because of different implementation costs. (iii) Variance strategies show positive correlation with the stock market, but this correlation varies across strategies. (iv) Variance strategies consistently earn premiums throughout the whole sample period. This is in stark contrast with strategies based on the Fama-French (2015) factors or the momentum factor, which have not shown a significant upward trend since 2008. (v) The variance factor translates into an attractive factor strategy for long-term investors, both as a stand-alone factor and as a complement to the market investment, despite being correlated with the market. Overall, our study shows that although variance strategies exhibit extreme payoff distributions with high negative skewness and excess kurtosis, they recover quite quickly from large drawdowns and continue to consistently earn premiums. Thus, when properly designed, these strategies are attractive to long-term investors.

2 Related Literature

The objective of this paper is to seek effective ways for the long-term investor to harvest the VRP via options strategies. Formally, the VRP is the deviation between the expected (physical) variance realized over the life of the option and the option-implied (risk-neutral) variance. More loosely speaking, the VRP is the expected return on the "variance factor". Since this variance factor is far from uniformly defined in the literature, approaches to earn its factor premium can differ greatly. What they have in common, however, is that they provide exposure to variance changes. Below, we briefly discuss prior work on trading strategies that earn variance premiums and position our paper in this literature.

A first set of trading strategies hold options in combination with their underlying, usually a broad market index. Since options have non-linear payoffs, they provide exposure to changes in variance. Whaley (2002) describes and analyzes the Cboe BuyWrite Index, which consists of a short position in an out-of-the money (OTM) S&P 500 index call and a long position in the S&P 500 index. Ungar and Moran

(2009) outline a put-write strategy used as the basis for the Cboe S&P 500 PutWrite Index. These strategies outperform the S&P 500 on a risk-adjusted basis.[1] They represent, however, a portfolio approach rather than a pure variance strategy, as they are not delta-hedged but in most cases fully collateralized with a position in the index. Such a design implies a mixture of market exposure and variance exposure, with exposure varying over time (Israelov and Nielsen 2015).

Another strand of literature considers variance exposure as an additional element in a broader portfolio context and examines its role in optimal portfolio choice. Hafner and Wallmeier (2008) consider an investor with constant relative risk aversion (CRRA) utility and investment opportunities in a stock index, a risk-free asset and a variance swap. They show that asset weights of index variance swaps jump when certain thresholds of preference parameters are crossed, a consequence of the high negative skewness and high kurtosis of variance swaps. Egloff, Leippold, and Wu (2010) use a similar setting with CRRA utility investors, a stock index and a risk-free asset. However, they augment the investment opportunity set with two distinct variance swaps with different maturities. They find that short-term variance swaps enter the optimal portfolio with short positions, whereas long-term variance swaps enter with long positions. Overall, considering variance swaps in their portfolio problem leads to significant improvements in performance. Brière, Burgues, and Signori (2010) use a mean-modified Value-at-Risk (VaR) framework to study the efficient frontier of an equity investor who complements her portfolio with volatility positions. They find that taking short positions in variance swaps enhances portfolio returns but adds little diversification benefits. In a similar vein, Fallon, Park, and Yu (2015) augment hypothetical institutional investment portfolios with a variance portfolio and find that adding small amounts of variance risk exposure enhances long-term returns but increases short-term tail risk. In summary, this literature documents certain benefits and difficulties that variance positions create in a port-

[1] Other related strategies, such as PutWrite and BuyWrite strategies with varying strike prices of options or with additional caps and floors, are assessed by Clark and Dickson (2019).

folio context. However, it does not analyze the trade-offs between alternative design elements of the "variance factor" that may be helpful to overcome such difficulties.

Trading the VIX can also earn premiums linked to variance exposure. These strategies generally involve VIX futures (Simon and Campasano 2014) or VIX options (Simon 2017) and aim to roll down the term structure of option-implied volatility (IV), which is typically in contango. Investors can go short in longer-term futures to roll down the VIX futures term structure and, on average, earn the corresponding premium. However, this premium is less a VRP than it is a VIX term premium.[2] This is because VIX strategies earn gains via changes in IV between two points in time, and not by means of the difference between implied and expected realized (physical) volatility, i.e., the VRP that we investigate in our study.[3]

Lastly, the literature has used different instruments to quantify VRPs. Coval and Shumway (2001) use zero-beta straddles as a means to generate variance exposure and Bakshi and Kapadia (2003) employ delta-hedged calls and puts to quantify the VRP. Variance swaps are used, for example, in the studies by Hafner and Wallmeier (2007), Carr and Wu (2009), and Kozhan et al. (2013). Fallon and Park (2016) add a further design element to a variance swap strategy. By adding a cap to a one-month S&P 500 variance swap, they suggest a specific solution to the leverage problem. Our paper goes a step further. Its central contribution is to consider a variety of different derivatives strategies with different design elements and to compare all of them in terms of their suitability for the long-term investor. Furthermore, our study is the first to include the period of the Covid-19 pandemic. Inclusion of this period and its stock market shock is potentially very important to learn about long-term variance strategies.

---

[2] Brière, Burgues, and Signori (2010) also clearly distinguish between strategies that aim to earn the VRP and strategies that profit from changes in IV.

[3] Of course, changes in IV may be correlated with realized volatility. Nevertheless, this type of strategy earns a premium that is conceptually distinct.

3 Strategies, Data, and Study Design

3.1 Three Problems

Designing long-term strategies aimed at harvesting VRPs entails three major problems. The first one is what we call the *payoff problem.* In principle, variance exposure can be generated by selling any convex payoff structure. However, different payoff profiles may be more or less suitable to achieve certain desirable goals. First, a payoff profile should provide sufficient factor exposure that is priced in the market. Second, it should be only weakly correlated with other risk factors, to allow for portfolio diversification benefits. Third, it should limit the occurrence of extreme negative returns in order to avoid large drawdowns. Fourth, it should be implementable with low costs. This last point is crucial for long-term investors, as such costs erode their compounding returns. To be sure, achieving these four goals involves trade-offs, which are at the heart of the payoff problem, i.e., the problem of choosing suitable payoff profiles.

Second is the *leverage problem.* Variance strategies use derivatives to sell convex payoff profiles. Since some derivative strategies require no initial capital (e.g., swap contracts) while others actually generate capital (e.g., delta-hedged puts), a question arises as to the appropriate amount of leverage. The leverage problem can be cast in terms of some similar trade-offs as the payoff problem. On the one hand, strategies should provide sufficient exposure to variance risk. On the other hand, they should limit extreme losses that jeopardize the strategy's long-term success—all in a cost-effective manner. The leverage problem, however, also raises distinct issues. Different strategies may use different instruments despite having similar or even identical payoffs. Therefore, achieving a certain leverage may be more costly or risky for one strategy than for another due to differences in initial capital or margin requirements. In addition, differences in leverage between strategies can lead to sharply different factor exposures, making meaningful comparisons difficult.

Third, there is the *finite maturity problem* involving its own trade-offs. Because derivatives have finite maturities, long-term investors must periodically roll their positions. Investors determine which maturities to choose, when to roll, and how many instruments to use at once. Longer-term contracts may have less factor exposure and higher margin requirements but allow for less frequent trading, reducing transaction costs. Shorter-term contracts may be more liquid, however, resulting in lower transaction costs per trade.

3.2 Variance Strategies

We now present strategies aiming to harvest VRPs and address some of the associated trade-offs. We begin with a short position in an at-the-money (ATM) *straddle* as a first intuitive approach to selling protection against rising variances. The short straddle limits market exposure because it combines a short call (with negative delta) with a short put (with positive delta).[4] It consists of only two ATM instruments, thus limiting transaction costs. The short straddle's stylized payoff profile is shown in part (a) of Figure 1. This payoff is generally consistent with an instrument showing variance exposure. The risk here is that large negative or positive price movements in the underlying could result in large negative returns–even medium price movements already lead to losses.

[Insert Figure 1 about here.]

A first idea to reduce the risk of the straddle is the short *strangle*, which involves shifting option strike prices from ATM to out-of-the-money (OTM), thereby avoiding losses in case of medium price changes in the underlying. It also reduces the magnitude of losses in case of large price moves in the underlying, compared with the straddle. Such a payoff profile is depicted in part (b) of Figure 1. The strangle's disadvantages include, first, that OTM options have less variance exposure than

[4] One could even set the strike price of the options such that the beta of the straddle is exactly zero.

ATM options, and second, the maximum payoff is lower than for a straddle. Finally, large negative returns can still occur since the payoff function has no lower bound.

To counter the risk of extreme losses, one could add a floor to the payoff profile. By adding a long OTM call and a long OTM put, a straddle becomes a *butterfly spread*, as shown in part (c) of Figure 1. The same idea of adding a floor can also be applied to the strangle. The corresponding portfolio is called a *condor strangle* and its payoff profile is depicted in part (d) of Figure 1. Limiting the downside risk, however, also comes with drawbacks. Since two long option positions enter the portfolio together with short positions, the portfolio's overall variance exposure is reduced. Moreover, the additional long positions in calls and puts incur costs—both transaction costs and costs of capital for the option premiums.

A further approach is to sell *delta-hedged call or put* options, i.e., puts or calls hedged with positions in the market index. Delta-hedged options have a similar payoff structure as a straddle. Therefore, they have similar advantages, i.e., limited correlation with the market factor and a portfolio made up of only two instruments, but also similar disadvantages, i.e., potentially large downside risk. However, the long-term performance of delta-hedged options may differ from that of a straddle strategy, since they contain different instruments. Differences in performance may be due to a different potential for leverage or to different transaction costs and margin requirements.

Finally, an investor can gain variance exposure through a *variance swap*, which is the most direct way to earn the VRP. Variance swaps may also limit correlation with the market factor, since they are initially delta-neutral by construction (Kozhan, Neuberger, and Schneider 2013). However, a variance swap can be viewed as a fairly complex option portfolio with potentially high transaction costs and leverage constraints. Moreover, since variance is calculated as the squared difference from the mean, a variance swap could be prone to extreme losses if the realized variance reaches a peak.

Overall, we select seven portfolios: Straddle, strangle, butterfly spread, condor strangle, delta-hedged call, delta-hedged put, and variance swap. All offer convex payoff structures, so selling these portfolios has the potential to earn VRPs. We further target differences in their designs to get insights on trade-offs for variance exposure, downside risk, transaction costs, capital requirements, and margins.

The long-term investor's next question is: What quantities should be held in each portfolio to obtain a suitable risk-return profile? We address this issue in two ways. First, under under the *equal exposure* approach, all strategies are levered until each strategy has the same ex-ante factor exposure. If one strategy requires less capital to achieve this exposure than another, the remaining funds are invested in a risk-free account. Equal exposure strategies help us compare different strategies on an ex-ante risk basis but require an ex-ante measure of factor exposure. As a natural and easily obtainable ex-ante measure of factor exposure, we use the Black and Scholes (1973) (BS) vega. Second, under the *equal crash risk* approach, we lever all strategies in such a way as to deliver the same ex-post crash risk as an investment in the S&P 500 index. Specifically, we choose a leverage that leads to the same maximum monthly loss (in percent) than the market in our sample period. The focus on the most extreme loss allows for a comparison of variance strategies based on an equal vulnerability to large market moves. Moreover, using the market as the reference point provides information on the suitability of variance strategies as potential alternatives to standard market investments.

3.3 Data

We use data on European S&P 500 index options obtained from OptionMetrics IvyDB (U.S.). This database provides historical closing quotes from the Cboe, as well as implied volatilities (IV), interest rates, underlying spot prices, and implied dividend yields. Our sample period starts in January 1996 and ends in June 2021, covering 306 months. We filter our option data set with standard filters from the literature (Goyal and Saretto 2009; Cao and Han 2013). We require best bid and best ask quotes as well as the bid-ask-spread to be non-negative and discard options with special settlement and options that do not have a.m. settlement. Moreover, IV must be greater than zero and we require options to survive standard no-arbitrage conditions. For every month in our sample, we only use data for the first trading day after the third Friday of that respective month. The latter is the standard expiration date of Cboe-traded options. We also require options to mature in the next month. This step retains options with approximately one month to maturity. Our final sample consists of 24,980 call options and 25,450 put options with an average time to maturity of approximately 28 days. For each of these options, we calculate the BS delta and vega, using the IV, underlying spot prices, interest rates, and dividend yields from OptionMetrics.

3.4 Implementation of Strategies

General Specifications We now turn to the concrete design of the trading strategies, which are based on the portfolios we presented in Subsection 3.2. As we use approximately one-month maturity S&P 500 options and hold them until expiration, we have to open new positions every month. Positions are established every Monday after the third Friday of the month. In our implementation, expiring options are exercised at the Friday a.m. SET price. We index each strategy to a level of 100 as of January 1996 and then determine the cumulative wealth level through the end of our data sample in June 2021.

For transaction costs, we use the ask price for option purchases (long positions) and the bid price for option sales (short positions). However, since investors can probably trade at terms better than the quoted spread (Mayhew 2002; De Fontnouvelle, Fishe, and Harris 2003), we use an effective spread of 25% of the quoted spread as our baseline case.[5] Transaction costs are incurred each time an option or the underlying is bought or sold. However, as cash-settled options do not incur additional transaction costs at expiration, we let options expire. We assume that

[5] In practice, many investors also use limit order strategies to reduce transaction costs below the quoted spread.

transactions in the underlying, necessary for delta hedging, are possible at a quoted bid-ask spread of 3 basis points.

In addition, we require margin accounts to collateralize the positions. For option trades, we apply the Cboe margin rules.[6] We use the margin rules for initial margins and assume that there are no maintenance margins or other adjustments required within the trading month.[7] For short positions in the underlying index, we assume that 150% of the short sale proceeds must be deposited, which is equivalent to the Federal Reserve Board's "Regulation T". Finally, the margin requirements for variance swaps are set in accordance with the "margin requirements for non-centrally cleared derivatives" of the Basel Committee on Banking Supervision (BCBS).[8]

For equal exposure strategies, we lever the positions until each strategy has the same factor exposure. In each period, we select the strategy with the lowest vega and lever it until the available capital is fully used up for margin requirements. All other strategies are then scaled down to this exposure and the remaining capital is invested risk-free. As our baseline case, we assume that margin accounts also pay interest. However, we also consider the case that margin accounts are not interest bearing. In this way, strategies with higher margin requirements have higher implementation costs. For equal crash risk strategies, we select the constant vega that leads to the same maximum loss (in percent) of the variance strategy than the maximum loss of the stock market (S&P 500). If a strategy needs additional funds to meet margin requirements for this risk level, we assume that risk-free borrowing is possible but induces extra costs in terms of interest payments.

[6] These rules provide detailed guidelines for individual options and option portfolios. Zhan et al. (2022), for example, also use the Cboe margin rules for their option trading strategies. An overview of the Cboe margin requirements used in our study is provided in the Appendix.

[7] The impact of maintenance margins on the success of the variance strategies is likely to be very small. Even under the most severe market moves in our sample–October 2008 and March 2020–the initial margins were not completely used up for any strategy.

[8] The BCBS requires that 15% of the variance notional be deposited as initial margin. The variance notional is the notional amount by which the difference between the floating leg and the fixed leg is multiplied.

Straddle and Butterfly Spread For the straddle, we choose a call and a put with strike prices closest to the ATM forward point. A straddle has its own Cboe margin rules. The butterfly spread is obtained by adding two options to the straddle. We add a call with a delta of 0.05 and a put with a delta of -0.05. Both options enter the straddle as long positions.[9] Butterfly spread margins are those of a short call spread plus those of a short put spread, as there are no separate rules for butterfly spreads. Both the straddle and the butterfly spread may have some residual index exposure that we delta-hedge with an index position at initiation. At maturity, the option positions are cash-settled and the hedge positions in the index are closed. This is true for all strategies we consider.

Strangle and Condor Strangle These are similar to the straddle and butterfly spread. We choose a call and a put expiring next month with deltas of 0.20 and -0.20, respectively. Selling these two options results in a strangle. For the condor strangle, we again add two options. We add a call with a delta of 0.05 and a put with a delta of -0.05.[10] The Cboe provides its own margin rules for the strangle, while for the condor strangle we combine the margins of a short call spread with those of a short put spread. Again, any remaining delta of the strategies is hedged via index positions.

Delta-Hedged Call and Delta-Hedged Put Here, we select the call and put options expiring next month that are closest to the ATM forward point. We sell these options at the best bid (accounting for the effective spread) and hedge the resulting delta exposure with positions in the underlying.[11] To keep transaction costs low, the delta hedge is set up at initiation and is not readjusted until maturity.

---

[9] The choice of deltas is inspired by the Cboe S&P 500 Iron Butterfly Index, which is a hypothetical option trading strategy calculated by the Cboe that sells butterfly spreads. For more detail, see `https://www.cboe.com/us/indices/dashboard/BFLY/`

[10] This choice is similar to the Cboe S&P 500 Iron Condor Index, which is a hypothetical option-trading strategy from the Cboe selling condor strangles. For more detail, see `https://www.cboe.com/us/indices/dashboard/CNDR/`

[11] The short call requires a long position in the underlying, while the short put requires a short position in the underlying, for which additional margins must be deposited.

Variance Swap For this strategy, we calculate the variance swap rate according to Kozhan, Neuberger, and Schneider (2013). This leads to consistent pricing based on the same options for all strategies in our study. We select all OTM forward call and put options to calculate swap rates. Transaction costs are accounted for by using bid quotes instead of midquotes to calculate variance swap rates. The strategy sells variance swaps at the swap rate and holds this position until maturity. By design, variance swaps are delta-neutral at inception. At maturity, the realized variance over the last month, calculated from daily data, is taken to determine the variance swap's payoff.

4 Empirical Results

4.1 Equal Exposure Strategies

Figure 2 provides the accumulated wealth over time, as created by different strategies. For each strategy, the initial budget in January 1996 is $100. Table 1 shows, by means of summary statistics, how the different strategies perform. Panel A reports the sample moments of monthly returns and Panel B describes downside risk. The first three measures of downside risk (VaR, CVaR, Max Loss) take a monthly perspective and refer to (potential) losses in the following month. This view is sufficient for a monthly investment horizon. A long-term investor, however, cares about the characteristics of the entire path. In particular, the ability of a given strategy to recover from an intermediate downturn is crucial. Therefore, Panel B offers four different drawdown statistics. The maximum drawdown (Max DD) is the maximum percentage loss of a strategy from its current maximum value to a trough. The average drawdown (Average DD) shows how far (on average over all months of the 25-year period) a strategy is from its previous maximum. Drawdown length indicates how many months it takes to reach a new wealth maximum at a given point in time. For this measure, we report the maximum number of months (Max DD Length) and the average (over all months of the 25-year period) number of months (Average DD Length). For completeness, Panel C of Table 1 repeats the final wealth levels at the end of the sample period as seen in Figure 2 and converts them to annual geometric average returns.

[Insert Figure 2 about here.]

[Insert Table 1 about here.]

Figure 2 and Table 1 provide the following key results. First, there is no clear evidence that a strangle helps reduce the risk of a straddle, as strangle returns are even more left-skewed and leptokurtic. In terms of downside risk, the straddle has less negative CVaR, lower maximum loss, average drawdown (DD), maximum DD, and average DD length. VaR and maximum DD length are almost identical. Moreover, the terminal wealth of the strangle strategy is lower than the terminal wealth of the straddle strategy. Second, while the butterfly's and condor's floors help with monthly skewness and kurtosis, they are not effective in reducing downside risk. To the contrary, they show higher downside risk for all risk measures, as compared to the straddle and the strangle, respectively. Moreover, they lead to massive reductions in terminal wealth. Third, the delta-hedged put, delta-hedged call, and straddle have very similar paths and distributional properties. Fourth and last, the variance swap achieves the highest terminal wealth of all the variance strategies. As shown in the figure, this is due to the period since 2012. The variance swap strategy also shows the lowest downside risk for almost all risk measures. Interestingly, the only exception is its maximum loss.

4.2 Why do Strategies Differ? Is it Payoff or Costs?

Variance strategies behave differently, even though they have the same vega exposure by construction. Where do these differences come from? Two possible reasons are different payoff structures and potential differences in transaction costs. Since new derivative positions must be set up regularly due to the finite maturity of options, the latter may be substantial. The similarity of the payoffs should be reflected in high return correlations. Table 2 shows such correlations between the monthly returns of the different strategies. Delta-hedged call, delta-hedged put, and straddle have very high correlations (over 0.99), consistent with theory.[12] Strangle, condor strangle, and butterfly spread are less correlated, consistent with their modified payoff profiles, but still show correlations above 0.9 with the first group. Most striking is the variance swap's lower correlation (below 0.65) with all other strategies, indicating uniqueness.

[Insert Table 2 about here.]

At first glance, it is difficult to say whether it is the payoff profile that makes the variance swap unique. This payoff depends on the realized variance over the price path, while other strategies have payoffs that depend only on the price of the underlying (index level) at the options' maturity date. The initial replicating portfolio of the variance swap, however, can provide some intuition. Its payoff function can be directly compared with the payoff profile of the other strategies. For example, Figure 3 shows the payoff functions of the delta-hedged call and the variance swap replicating portfolio for the setup date 24/10/2016. This picture is also quite typical for other setup dates.[13] The payoff function of the delta-hedged call is a piecewise linear function, with a kink at the forward price. Thus, losses grow linearly with the distance between the index and the forward price. The variance swap's payoff profile, on the other hand, is strongly non-linear. There is a wide range around the forward price where the payoff function is almost flat. This feature also leads to a relatively large gap between the two break-even points (-4.62% and 2.62%), compared to the delta-hedged call (-2.14% and 2.23%). The variance swap makes similar profits over a wide range around the ATM point, consistent with the strategy's relatively smooth path of cumulative wealth. The variance swap's payoff is also strongly asymmetrical: losses remain moderate when the index level

[12] In a world without transaction costs and other market frictions, where put-call parity holds exactly, the payoff profiles of the three strategies are identical for the same vega exposure.

[13] The payoff function depends on the forward price, the available strike prices and the deltas of the options on the setup date. Therefore, the payoff function varies over time.

rises, contributing to a smooth path. Only when the index loses massively does the variance swap realize losses that seem to grow exponentially with the index decline. The latter observation is consistent with the high negative skewness and high maximum loss of the variance swap.

[Insert Figure 3 about here.]

Transaction costs provide another possible reason for differences between strategy outcomes. An intuitive guess is that strategies using a greater variety of option contracts, or OTM and ITM options, are costlier than those using only one or two ATM options. The former properties apply in particular to the butterfly spread and the condor strangle, while the latter one characterizes the delta-hedged call, delta-hedged put, and straddle. This intuitive guess is confirmed by Figure 4. Part (a) shows the strategies' cumulative wealth when we reduce the effective spread from 25% (base case) to zero. Parts (b) to (d) show the strategies' cumulative wealth for effective spreads of 50%, 75%, and 100%, respectively. Moving from a 100% effective spread to zero improves the final wealth (after 25 years) of the condor strangle by 156% and the butterfly spread by 82%. In contrast, the delta-hedged call, put and straddle show an increase in wealth of between 30% and 40%. These numbers also show the importance of transaction costs for the success of variance strategies in general. That said, the condor strangle and the butterfly spread still deliver the lowest terminal wealth even without transaction costs. Thus, different transaction costs are certainly not the only cause of differences in performance between different variance strategies.

[Insert Figure 4 about here.]

Further analysis of implementation costs considers the potential disadvantages of high margin requirements. We assume that margin accounts do not pay any interest. Therefore, requiring high margins is a disadvantage of a variance strategy and it will worsen its performance. Figure 5 shows the cumulative wealth of the different variance strategies when margin accounts do not pay interest. Transaction costs are captured via an effective spread of 25%, as in the base case of Figure 2. The results show that margin costs affect various strategies very differently. For example, the straddle loses only about 10% of its final wealth, as compared to the base case of interest-bearing margin accounts. The effect is much bigger for the variance swap that loses about 30% of its final wealth. Most strikingly, there is a massive effect on the delta-hedged put. The strategy's final wealth of $368.57 in the base case goes down to $164.42 when margin accounts do not pay interest. The reason is the large amount of money held in the margin account for the delta-hedged put strategy. Large margins are required to back up the short sales of the index needed to delta hedge short put options. In contrast, no short selling of the index is required to delta hedge short call options. Thus, even though delta-hedged put, delta-hedged call and straddle have very similar payoff profiles, they can perform very differently when implementation costs are considered. This is the main message from Figure 5.

[Insert Figure 5 about here.]

4.3 "Variance" as an Investment Style

The strategies under study are different ways to earn VRPs. More broadly, they are examples of factor investments because "stock index variance" is just one among many equity-based factors. In this section, we relate variance strategies to other equity-based factor investments. The main purpose is to highlight what kind of risk and return properties investors can expect from variance strategies as compared to other popular investment styles. For the analysis in this section, we focus on only two variance strategies, as the condor strangle and butterfly spread do not provide improvements. The first, the delta-hedged call, represents the group consisting of delta-hedged call, put, straddle, and strangle. The second strategy is the variance swap. To provide a meaningful comparison with other equity-based factor investments, we use the equal crash risk variants of the delta-hedged call and variance swap strategies with base case transaction costs of 25% of the effective spread.

As alternative factor-investment strategies, we consider the S&P 500 index (market), long-short portfolios of the remaining four factors of the Fama and French (2015) five-factor model (Size (SMB), Value (HML), Profitability (RMW), Investment (CMA)), plus Momentum (MOM).[14] Factor returns are constructed such that their return periods coincide with the roll-over periods from our option strategies.[15] We achieve this by computing geometric returns over the specified investment horizon for every individual portfolio and eventually determine the factor returns according to the definitions from Fama and French (2015). Data on the additional factors is from Kenneth French's website.[16]

[Insert Figure 6 about here.]

Figure 6 shows the growth in cumulative wealth for each of the factor investments. One result especially stands out. After the financial crisis, since mid-2009, none of the SMB, HML, RMW, CMA, and MOM strategies has an upward trend.[17] Only the market and the two variance strategies show meaningful upward movements during this period. This distinguishes the variance strategies from the other five strategies that try to earn additional risk premiums besides the market. What is more, in the period prior to the financial crisis, the variance strategies and momentum show the strongest upward trend.

Table 3 presents return and risk statistics for the different factor investments. In our view, the most relevant reference point for variance strategies is the market investment, as it is alone in generating significant premiums after the financial crisis. Looking at the monthly return statistics, market and variance strategies do not differ much in terms of the Sharpe ratio, because the market has both higher mean returns and a higher standard deviation. However, the variance strategies–especially the

[14] Since long-short portfolios do not require an initial investment, the initial capital of $100 is invested in an account earning the risk-free rate.

[15] The original monthly Fama and French (2015) factor returns are based on calendar months.

[16] `https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html`.

[17] When interpreting the performance of these five factor strategies, one has to keep in mind that they provide an overly optimistic view of the corresponding styles. The reason is that no transaction costs of portfolio revisions are taken into account in the performance calculations, as is the case with the variance strategies.

variance swap–show much more negative skewness and much higher excess kurtosis, supporting the idea of "picking up nickels in front of a steamroller".

[Insert Table 3 about here.]

What do these results mean for the long-term investor? Most of the time, the variance strategies generate a cumulative wealth above the wealth level of the market investment. What is more, as shown in Panel B, the delta-hedged call and the variance swap have lower downside risk than the market according to almost all risk measures.[18] The exception is the slightly higher maximum drawdown of the delta-hedged call. While variance strategies do occasionally experience extreme losses, this is not much different from the stock market if the variance strategies are calibrated accordingly. Moreover, variance strategies recover from previous losses relatively quickly, i.e., they generate strong upside movements in a fairly short period of time. This feature is especially clear after the 2008 financial crisis and after the low point of the Covid-19 pandemic.[19] In this sense, variance strategies are able to pick up more than "nickels" in such periods.

Finally, we examine the monthly co-movement of variance strategies with other factor portfolios. This helps us understand under which economic conditions the variance premiums are smaller or larger. Table 4 shows the results of regressing monthly variance strategy returns on either the market returns or the returns of all six factor portfolios. For the market, the relationship is positive and statistically significant. The linear approximation does not fully reveal the true non-linear payoff structure of variance-based instruments, as seen in Figure 3. However, an overall positive co-movement is economically intuitive. It is consistent with large market downturns (within a month) being larger than large market upturns, and the notion of increasing variance in falling equity markets.

[18] Note that the maximum loss of the variance strategies and the market investment is identical by construction.

[19] Until the end of our data series in June 2021, some recovery from the Covid-19 shock since March 2020 is already evident. The variance swap has already recovered 41% of its loss since the market crashed, the delta-hedged call 36%.

[Insert Table 4 about here.]

The only other significant factor is size, which loads positively. Strategies that sell insurance against high market volatility tend to perform poorly when small caps also underperform. This makes economic sense: during volatile times, small caps likely will struggle more than large caps because they are more vulnerable, on average.[20] Taken together, the market and size factors capture 11% (delta-hedged call) or 35% (variance swap) of the variance strategies' return fluctuations.

Then, are variance strategies valuable additions to the long-term investor's opportunity set of stock-related factors? Given the results of Table 4, the answer is ambiguous. The alphas of the delta-hedged call and the variance swap in the full regression model (columns (3) and (4)) are 0.28% and 0.19% per month, respectively. This is economically significant compared with an average market return of 0.93%. However, these alphas are not statistically significant. One reason is the high residual variance caused by only two observations, October 2008 and March 2020. Indeed, these two months have an outsized influence on the resulting estimates of the factor loadings, as the OLS estimator is not robust.[21] We therefore re-estimate the regression models with a more robust method, the least absolute deviation (LAD) estimator, which minimizes the mean absolute residual error.[22]

Table 5 presents the LAD regression results. First, under LAD, factor loadings are much smaller for market and size; indeed the market coefficient becomes insignificant for the delta-hedged call. This finding suggests potentially high diversification benefits if a delta-hedged call strategy complements a market investment, given that such benefits are measured in terms of mean absolute deviations instead of standard

[20] This conjecture is supported by, for example, Duffee (1995) and Ang and Chen (2002).

[21] Specifically, Cook's distances (Cook (1977)) for these two observations reach from 15 to 258 times the average Cook's distance in the respective models, indicating highly influential observations.

[22] See, for example, Hill and Holland (1977). To account for potential heteroskedasticity and autocorrelation in the LAD framework, we determine standard errors with a block bootstrap method. We use a block length of 12, to be consistent with the number of lags applied for the Newey and West (1987) t-statistics of Table 4.

deviations.[23] Second, compared to OLS, LAD regressions attribute a higher proportion of the variance strategies' mean returns to alpha. The estimated alphas of 0.94% and 0.57% per month of the delta-hedged call and variance swap strategies, respectively, are clearly economically and statistically significant.

[Insert Table 5 about here.]

Overall, the results suggest that variance strategies are attractive factor strategies for long-term investors. These strategies can provide valuable alternatives to a market investment, with a similar overall performance but clearly different downside risk characteristics. They can also be useful complements to a market investment by providing diversification benefits and significant alpha.

5 Conclusion

The variance risk premium is a well-documented empirical phenomenon in option markets. This paper analyzes whether and how investors can exploit this premium for long-term capital accumulation. We identify three general problems that arise in designing long-term variance-based investment strategies. We suggest specific design elements to help mitigate these problems and propose corresponding trading strategies. To determine how much variance risk these strategies are exposed to, we consider either (i) an equal ex-ante factor exposure for all strategies based on the BS vega or (ii) an equal ex-post crash risk that is calibrated to a stock market investment. In an empirical study for the S&P 500 index options market, we analyze the performance of different variance strategies. We compare them to each other and to equity-based factor investing strategies. Our analysis shows that variance strategies differ substantially in some key aspects of risk and return, are significantly positively

[23] By moving from a pure market investment to a 50/50 market/delta-hedged call portfolio, the monthly standard deviation is reduced by about 40% and the mean absolute deviation is lowered by about 50%. As the results by Goldstein and Taleb (2007) suggest, even finance professionals consider mean absolute deviation to be a more intuitive dispersion measure than standard deviation.

correlated with the market, and consistently earn premiums over the entire study period. The latter distinguishes variance strategies from other factor strategies, which have not generated premiums since the 2008 financial crisis. Even though variance strategies can be hit hard by rare stock market crashes, they also can recover quickly from these shocks. In sum, our empirical results show that variance strategies can be attractive to the long-term investor—both as an alternative and as a complement to a market investment—if properly designed.

Appendix: Cboe Margin Requirements

This appendix provides a summary of relevant Cboe margin requirements that are used to implement the variance strategies. Further information and sample calculations can be found on the homepage of the Cboe.[24]

Short Call Initial Margin Requirement:

- 100% of option proceeds, plus 15% of aggregate underlying index value (number of contracts × index level × \$100) less out-of-the-money amount, if any
- minimum requirement is option proceeds plus 10% of the aggregate underlying index value
- proceeds received from sale of call(s) may be applied to the initial margin requirement

Short Put Initial Margin Requirement:

- 100% of option proceeds, plus 15% of aggregate underlying index value (number of contracts × index level × \$100) less out-of-the-money amount, if any
- minimum requirement is option proceeds plus 10% of the put's aggregate strike price (number of contracts × strike price × \$100)
- proceeds received from sale of puts(s) may be applied to the initial margin requirement

[24] `https://www.cboe.com/us/options/strategy_based_margin/`.

Short Straddle Initial Margin Requirement:

- short call(s) or short put(s) requirement, whichever is greater, plus the option proceeds of the other side
- proceeds from sale of entire straddle may be applied to initial margin requirement

Short Strangle Initial Margin Requirement:

- short call(s) or short put(s) requirement, whichever is greater, plus the option proceeds of the other side
- proceeds from sale of entire strangle may be applied to initial margin requirement

Short Call Spread Initial Margin Requirement:

- the amount by which the short call aggregate strike price is below the long call aggregate strike price (aggregate strike price = number of contracts $\times$ strike price $\times$ \$100)
- long call(s) must be paid for in full
- proceeds received from sale of short call(s) may be applied to the initial margin requirement

Short Put Spread Initial Margin Requirement:

- the amount by which the long put aggregate strike price is below the short put aggregate strike price (aggregate strike price = number of contracts $\times$ strike price $\times$ \$100)
- long put(s) must be paid for in full
- proceeds received from sale of short put(s) may be applied to the initial margin requirement

References

Ang, A. and J. Chen (2002). Asymmetric correlations of equity portfolios. *Journal of Financial Economics 63*(3), 443–494.

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

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

Brière, M., A. Burgues, and O. Signori (2010). Volatility exposure for strategic asset allocation. *Journal of Portfolio Management 36*(3), 105–116.

Cao, J. and B. Han (2013). Cross section of option returns and idiosyncratic stock volatility. *Journal of Financial Economics 108*(1), 231–249.

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

Clark, S. P. and M. Dickson (2019). Performance expectations of basic options strategies may be different than you think. *Journal of Asset Management 20*(2), 91–102.

Cook, R. D. (1977). Detection of influential observation in linear regression. *Technometrics 19*(1), 15–18.

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

De Fontnouvelle, P., R. P. H. Fishe, and J. H. Harris (2003). The behavior of bid-ask spreads and volume in options markets during the competition for listings in 1999. *Journal of Finance 58*(6), 2437–2463.

Duffee, G. R. (1995). Stock returns and volatility—A firm-level analysis. *Journal of Financial Economics 37*(3), 399–420.

Egloff, D., M. Leippold, and L. Wu (2010). The term structure of variance swap rates and optimal variance swap investments. *Journal of Financial and Quantitative Analysis 45*(5), 1279–1310.

Fallon, W. and J. Park (2016). An asset class characterization of the U.S. equity index volatility risk premium. *Journal of Portfolio Management 43*(1), 72–84.

Fallon, W., J. Park, and D. Yu (2015). Asset allocation implications of the global volatility premium. *Financial Analysts Journal 71*(5), 38–56.

Fama, E. F. and K. R. French (2015). A five-factor asset pricing model. *Journal of Financial Economics 116*(1), 1–22.

Goldstein, D. G. and N. N. Taleb (2007). We don't quite know what we are talking about when we talk about volatility. *Journal of Portfolio Management 33*(4), 84–86.

Goyal, A. and A. Saretto (2009). Cross-section of option returns and volatility. *Journal of Financial Economics 94*(2), 310–326.

Hafner, R. and M. Wallmeier (2007). Volatility as an asset class: European evidence. *European Journal of Finance 13*(7), 621–644.

Hafner, R. and M. Wallmeier (2008). Optimal investments in volatility. *Financial Markets and Portfolio Management 22*(2), 147–167.

Hill, R. W. and P. W. Holland (1977). Two robust alternatives to least-squares regression. *Journal of the American Statistical Association 72*(360a), 828–833.

Israelov, R. and L. N. Nielsen (2015). Covered calls uncovered. *Financial Analysts Journal 71*(6), 44–57.

Kozhan, R., A. Neuberger, and P. Schneider (2013). The skew risk premium in the equity index market. *Review of Financial Studies 26*(9), 2174–2203.

Mayhew, S. (2002). Competition, market structure, and bid-ask spreads in stock option markets. *Journal of Finance 57*(2), 931–958.

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

Simon, D. P. (2017). Trading the VIX futures roll and volatility premiums with VIX options. *Journal of Futures Markets 37*(2), 184–208.

Simon, D. P. and J. Campasano (2014). The VIX futures basis: Evidence and trading strategies. *Journal of Derivatives 21*(3), 54–69.

Ungar, J. and M. T. Moran (2009). The cash-secured PutWrite strategy and performance of related benchmark indexes. *Journal of Alternative Investments 11*(4), 43–56.

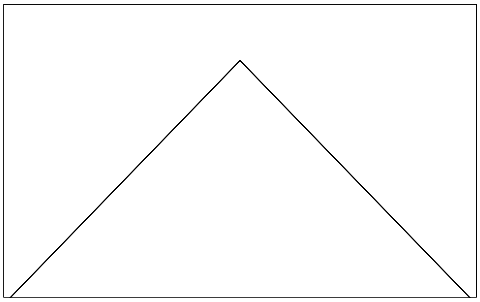
Whaley, R. E. (2002). Return and risk of CBOE Buy Write monthly index. *Journal of Derivatives 10*(2), 35–42.

Zhan, X., B. Han, J. Cao, and Q. Tong (2022). Option return predictability. *Review of Financial Studies 35*(3), 1394–1442.

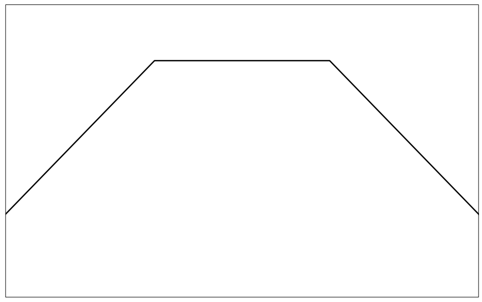
Zhou, H. (2018). Variance risk premia, asset predictability puzzles, and macroeconomic uncertainty. *Annual Review of Financial Economics 10*, 481–497.

Figure 1: Stylized Payoffs: Straddle, Strangle, Butterfly Spread, and Condor Strangle

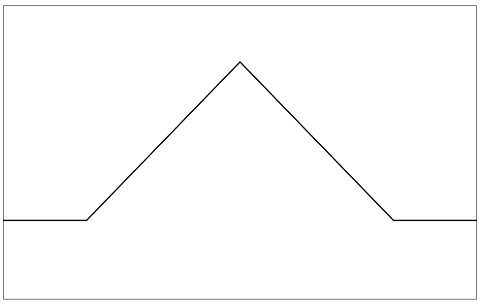
(a) Straddle Short



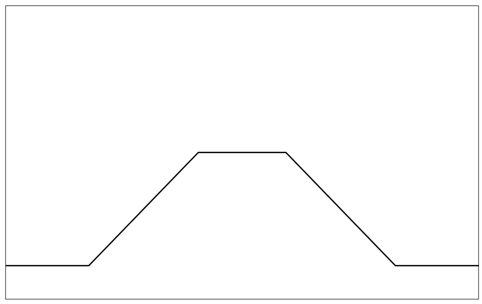
(b) Strangle Short



(c) Butterfly Spread Short

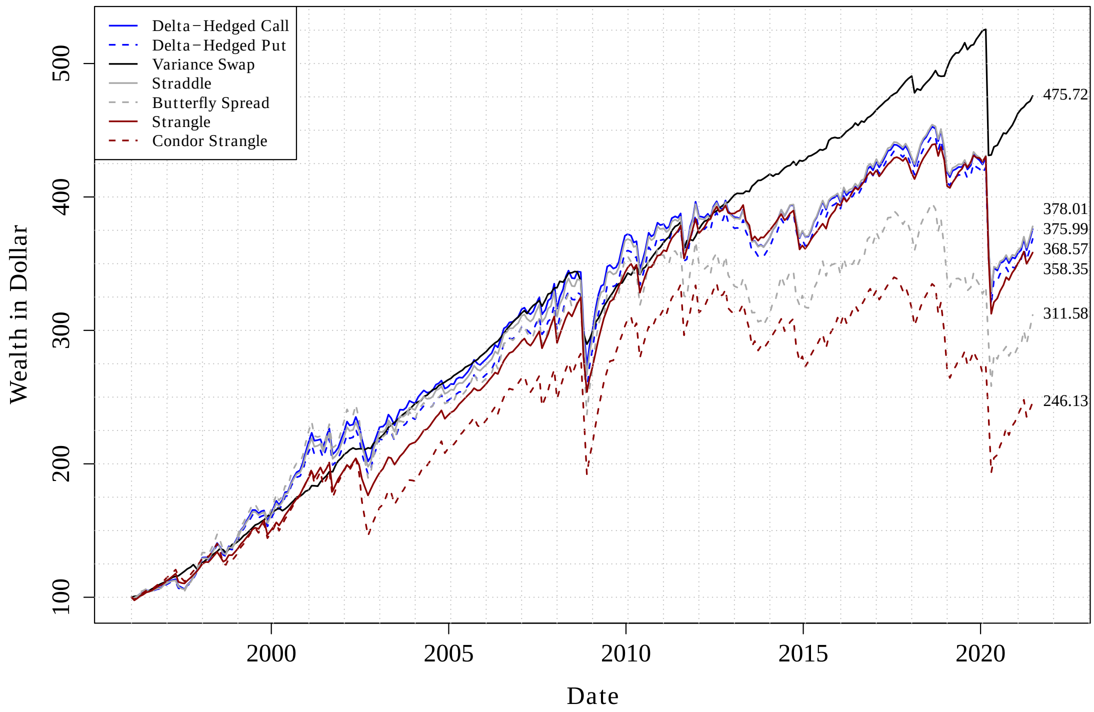


(d) Condor Strangle Short



Note: This figure shows stylized payoffs of a short position in a straddle (part (a)), a short position in a strangle (part (b)), a short position in a butterfly spread (part (c)), and a short position in a condor strangle (part (d)).

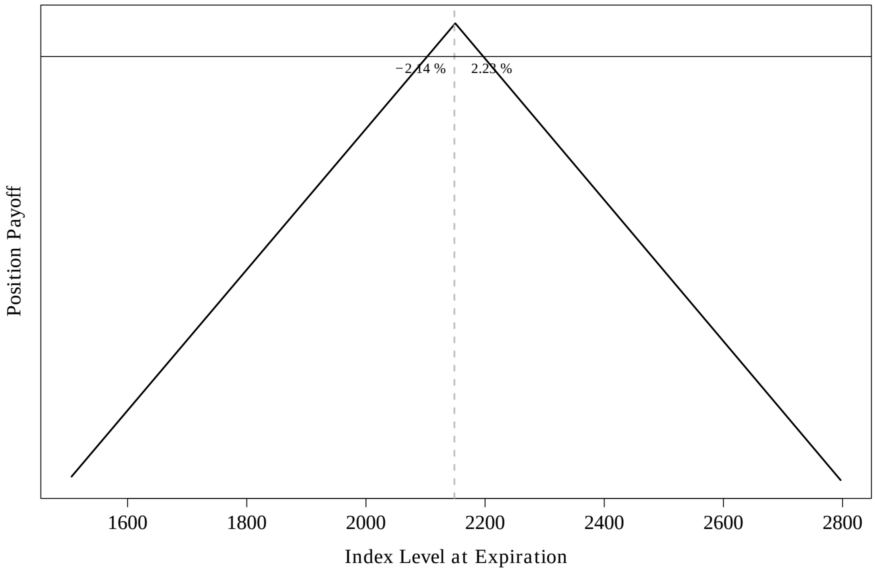
Figure 2: Equal Exposure Strategies: Cumulative Wealth



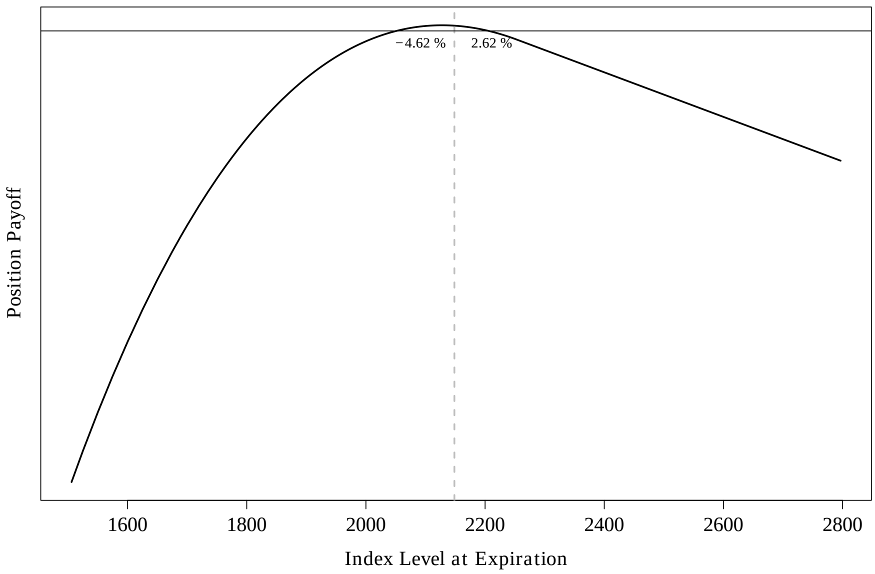
Note: This figure shows the cumulative wealth development of seven equal exposure variance strategies for an initial investment of \$100. The data period covers January 1996 to June 2021.

Figure 3: Payoffs of Delta-Hedged Call and Variance Swap

(a) Delta-Hedged Call



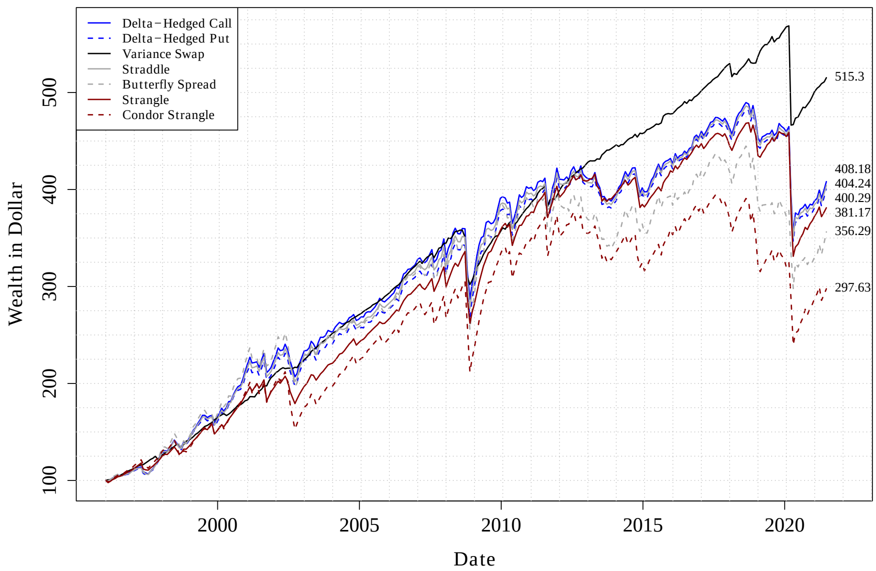
(b) Variance Swap



Note: This figure shows payoff diagrams of a delta-hedged call option (part (a)) and a variance swap (part (b)). The diagram is based on the positions set up on October 24, 2016. The x-axis shows the potential index levels at expiration (November 18, 2016) and the y-axis the corresponding payoffs of the delta-hedged call option and the variance swap, respectively. The horizontal solid line depicts the break-even payoff and the vertical dashed line the index level at initiation (October 24, 2016).

Figure 4: Equal Exposure Strategies: Impact of Transaction Costs

(a) Effective Spread: 0% of Quoted Spread



(b) Effective Spread: 50% of Quoted Spread

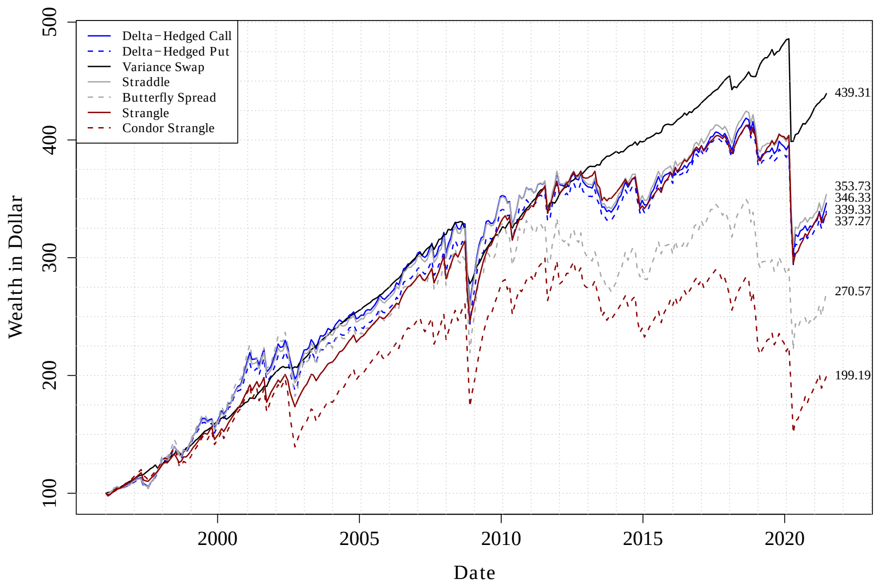
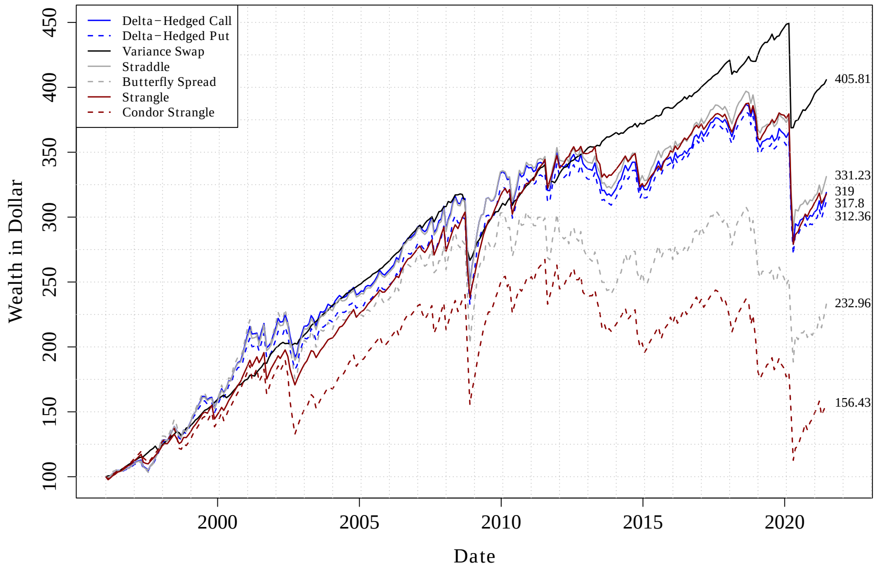
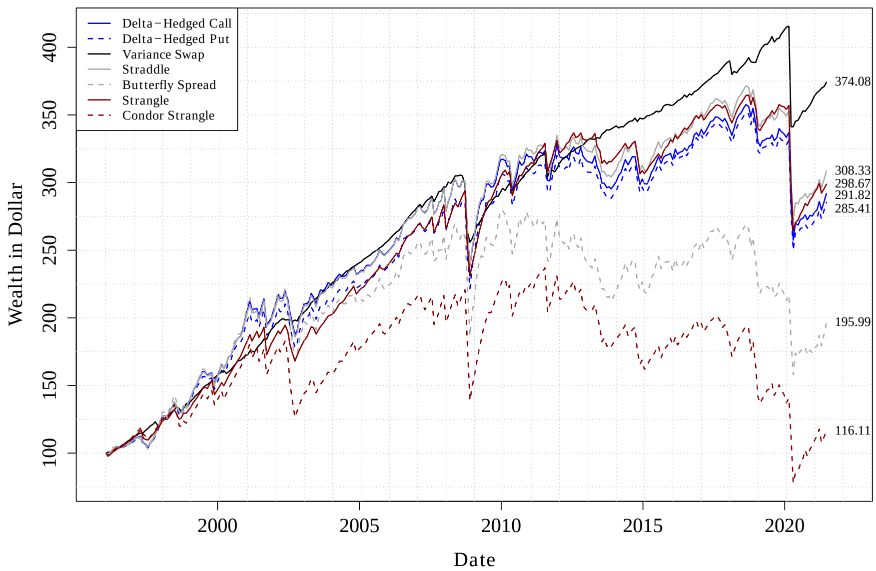


Figure 4: continued

(c) Effective Spread: 75% of Quoted Spread

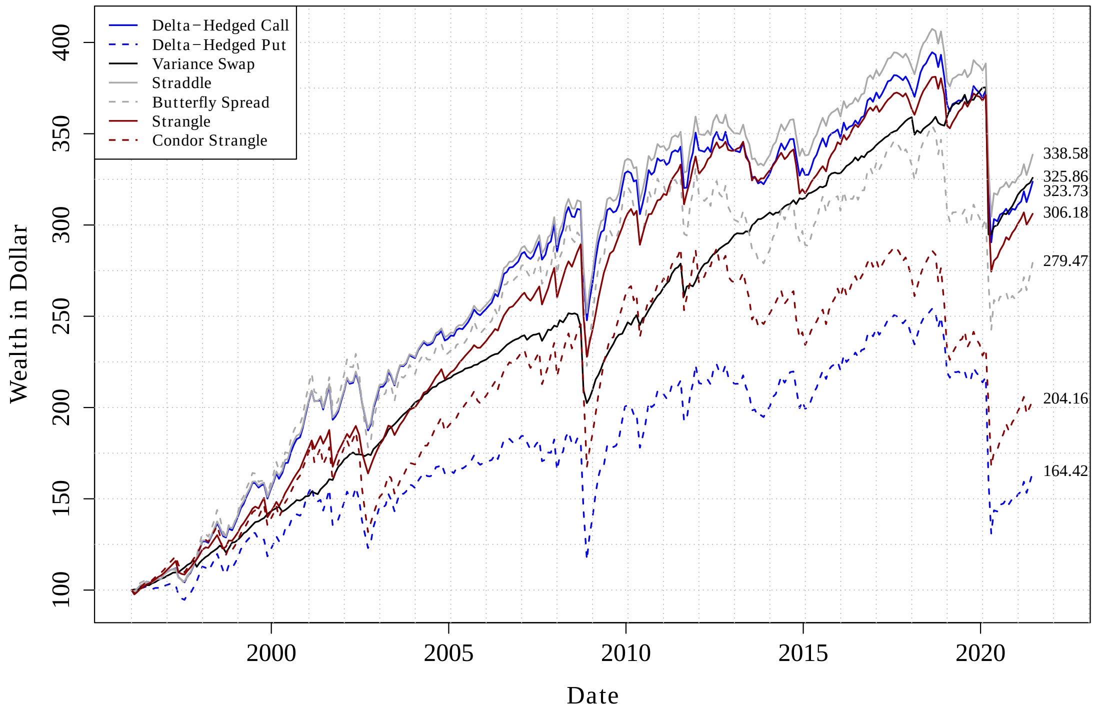


(d) Effective Spread: 100% of Quoted Spread



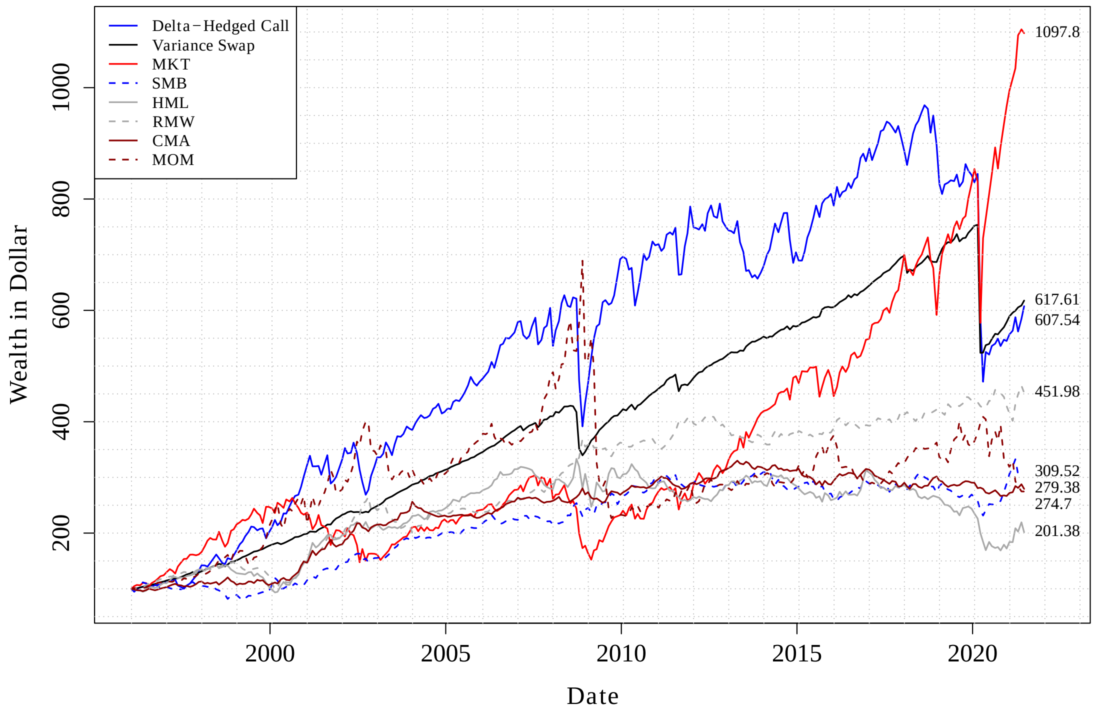
Note: This figure shows the cumulative wealth development of seven equal exposure variance strategies for an initial investment of \$100. The data period covers January 1996 to June 2021. Part (a) shows strategies with an effective options spread of 0% of the quoted bid-ask spread. Parts (b), (c), and (d) show the same strategies with effective option spreads of 50%, 75%, and 100% of the quoted spread, respectively.

Figure 5: Equal Exposure Strategies: Impact of no Interest on Margin Accounts



Note: This figure shows the cumulative wealth development of seven equal exposure variance strategies for an initial investment of \$100. The data period covers January 1996 to June 2021. No interest is paid on the margin accounts.

Figure 6: Alternative Factor Investment Strategies: Cumulative Wealth



Note: This figure provides the cumulative wealth development of two equal crash risk variance strategies (delta-hedged call and variance swap) and six factor investment strategies that correspond to the Fama and French (2015) five-factor model and the momentum factor. The data period covers January 1996 to June 2021. MKT is the market factor, SMB is the size factor, HML is the value factor, RMW is the profitability factor, CMA is the investment factor, and MOM is the momentum factor.

Table 1: Return and Risk of Equal Exposure Strategies

Panel A: Basic Monthly Summary Statistics

	Delta-Hedged Call	Delta-Hedged Put	Variance Swap	Straddle	Butterfly Spread	Strangle	Condor Strangle
Mean	0.0047	0.0046	0.0052	0.0047	0.0042	0.0045	0.0036
Standard Dev.	0.0244	0.0254	0.0149	0.0247	0.0316	0.0241	0.0350
Skewness	−2.0914	−2.0988	−8.4238	−2.0894	−1.1775	−3.5337	−2.4602
Exc. Kurtosis	9.2912	9.5006	92.2391	9.2987	3.8796	17.4102	8.3022
Sharpe Ratio	0.1080	0.1022	0.2161	0.1078	0.0702	0.1027	0.0452

Panel B: Downside Risk Statistics

	Delta-Hedged Call	Delta-Hedged Put	Variance Swap	Straddle	Butterfly Spread	Strangle	Condor Strangle
VaR (95%)	−0.0322	−0.0333	−0.0057	−0.0320	−0.0522	−0.0319	−0.0696
CVaR (95%)	−0.0659	−0.0692	−0.0340	−0.0669	−0.0817	−0.0747	−0.1066
Max Loss	−0.1538	−0.1579	−0.1797	−0.1538	−0.1573	−0.1728	−0.2027
Average DD	−0.0402	−0.0398	−0.0226	−0.0407	−0.0668	−0.0469	−0.0906
Max DD	−0.2756	−0.2848	−0.1797	−0.2758	−0.3467	−0.2893	−0.4310
Average DD Length	6.0256	5.7805	4.4400	5.8974	8.7333	6.3939	9.8800
Max DD Length	36	35	20	35	58	34	59

Panel C: Annualized Geometric Mean Return and Terminal Wealth

	Delta-Hedged Call	Delta-Hedged Put	Variance Swap	Straddle	Butterfly Spread	Strangle	Condor Strangle
Ann. Geom. Return [%]	5.35	5.27	6.33	5.37	4.57	5.15	3.61
Term. Wealth [$]	375.99	368.57	475.72	378.01	311.58	358.35	246.13

Note: This table provides return- and risk-statistics of seven equal exposure variance strategies. Panel A depicts basic summary statistics of monthly returns, while Panel B is dedicated to downside risk statistics. In particular, it considers asymmetric risk metrics for monthly returns such as the 95% value-at-risk (VaR), the 95% conditional value-at-risk (CVaR), and the maximum loss (max loss). Additionally, it shows path-dependent drawdown measures: The average drawdown (Average DD), the maximum drawdown (Max DD), the average drawdown length (Average DD length), and the maximum drawdown length (Max DD Length). Panel C shows the annualized geometric return and the terminal wealth of the strategies.

Table 2: Equal Exposure Strategies' Return Correlation Matrix

	Delta-Hedged Call	Delta-Hedged Put	Variance Swap	Straddle	Butterfly Spread	Strangle
Delta-Hedged Put	0.9956					
Variance Swap	0.5936	0.5934				
Straddle	0.9989	0.9989	0.5932			
Butterfly Spread	0.9682	0.9697	0.4838	0.9701		
Strangle	0.9355	0.9360	0.6357	0.9365	0.8572	
Condor Strangle	0.9103	0.9148	0.4887	0.9134	0.9149	0.9372

Note: This table depicts the correlations between the monthly returns of seven equal exposure variance strategies.

Table 3: Return and Risk of Alternative Factor Investment Strategies

Panel A: Basic Monthly Summary Statistics

	Delta-Hedged Call	Variance Swap	MKT	SMB	HML	RMW	CMA	MOM
Mean	0.0071	0.0063	0.0093	0.0042	0.0029	0.0053	0.0036	0.0049
Standard Dev.	0.0464	0.0226	0.0520	0.0303	0.0361	0.0271	0.0214	0.0540
Skewness	−2.1938	−10.0814	−0.9220	−0.0649	0.3880	0.3611	0.5523	−1.6817
Exc. Kurtosis	10.3173	126.7982	6.8907	2.1928	2.5327	5.7716	1.3767	8.3779
Sharpe Ratio	0.1092	0.1885	0.1395	0.0708	0.0254	0.1218	0.0736	0.0529

Panel B: Downside Risk Statistics

	Delta-Hedged Call	Variance Swap	MKT	SMB	HML	RMW	CMA	MOM
VaR (95%)	−0.0615	−0.0077	−0.0743	−0.0409	−0.0460	−0.0306	−0.0289	−0.0912
CVaR (95%)	−0.1266	−0.0506	−0.1286	−0.0619	−0.0734	−0.0557	−0.0382	−0.1475
Max Loss	−0.3052	−0.3052	−0.3052	−0.1332	−0.1264	−0.1103	−0.0544	−0.3438
Average DD	−0.0748	−0.0331	−0.0769	−0.0677	−0.0712	−0.0617	−0.0606	−0.1037
Max DD	−0.5128	−0.3052	−0.4993	−0.2938	−0.4937	−0.3347	−0.1922	−0.6709
Average DD Length	6.1220	4.6800	7.0303	11.4583	14.0526	12.7500	15.8824	14.3684
Max DD Length	35	21	74	83	154	65	99	152

Panel C: Annualized Geometric Mean Return and Terminal Wealth

	Delta-Hedged Call	Variance Swap	MKT	SMB	HML	RMW	CMA	MOM
Ann. Geom. Return [%]	7.36	7.43	9.89	4.55	2.79	6.11	4.13	4.06
Term. Wealth [$]	607.54	617.61	1097.84	309.52	201.38	451.98	279.38	274.70

Note: This table provides return- and risk-statistics of two equal crash risk variance strategies (delta-hedged call and variance swap) and six other equity-based factor investment strategies. Returns of factor investment strategies are calculated according to the Fama and French (2015) five-factor model, such that the return periods coincide with the return periods from the variance strategies. MKT is the market factor, SMB is the size factor, HML is the value factor, RMW is the profitability factor, CMA is the investment factor, and MOM is the momentum factor. Panel A depicts basic summary statistics of monthly returns, while Panel B is dedicated to downside risk statistics. In particular, it considers asymmetric risk metrics for monthly returns such as the 95% value-at-risk (VaR), the 95% conditional value-at-risk (CVaR), and the maximum loss (max loss). Additionally, it shows path-dependent drawdown measures: The average drawdown (Average DD), the maximum drawdown (Max DD), the average drawdown length (Average DD length), and the maximum drawdown length (Max DD Length). Panel C shows the annualized geometric return and the terminal wealth of the strategies.

Table 4: Equal Crash Risk Strategies vs. Alternative Factor Investment Strategies: OLS Regression

	Delta-Hedged Call	Variance Swap	Delta-Hedged Call	Variance Swap
α	0.0036	0.0026	0.0028	0.0019
	(1.3486)	(1.4452)	(0.9962)	(0.9507)
β_{MKT}	0.1987^{**}	0.2351^{***}	0.1703^{**}	0.2342^{***}
	(2.0678)	(2.8458)	(2.2603)	(2.9545)
β_{SMB}			0.3241^{**}	0.1626^{**}
			(2.2038)	(2.3087)
β_{HML}			0.2037	0.1172
			(1.2937)	(1.1003)
β_{RMW}			0.1043	0.0438
			(0.7702)	(0.5653)
β_{CMA}			-0.0600	-0.0337
			(-0.2583)	(-0.4821)
β_{MOM}			-0.0333	0.0445
			(-0.4532)	(1.0671)
n	305	305	305	305
Adj. R^2	0.0470	0.2920	0.1104	0.3533
F-statistic	15.9994	126.3847	7.2853	28.6757

Note: This table shows the ordinary least squares (OLS) regression results from a regression of the monthly returns of two equal crash risk variance strategies (delta-hedged call, variance swap) on the returns of other factor investment strategies. Specifically, we consider the S&P 500 index (MKT), long-short portfolios of the remaining four factors of the Fama and French (2015) five-factor model (Size (SMB), Value (HML), Profitability (RMW), Investment (CMA)), plus Momentum (MOM). Newey and West (1987) robust t-statistics with 12 lags are reported in parentheses and asterisks indicate significance at the 1% (***), 5% (**), and 10% (*) level, respectively.

Table 5: Equal Crash Risk Strategies vs. Alternative Factor Investment Strategies: LAD Regression

	Delta-Hedged Call	Variance Swap	Delta-Hedged Call	Variance Swap
α	0.0099***	0.0058***	0.0094***	0.0057***
	(3.3485)	(9.9182)	(3.0306)	(8.7025)
β_{MKT}	−0.0337	0.0775***	−0.0669	0.0734***
	(−0.2388)	(4.7284)	(−0.5014)	(3.9366)
β_{SMB}			0.2284*	0.0464**
			(1.9308)	(2.4268)
β_{HML}			0.0377	0.0005
			(0.2945)	(0.0215)
β_{RMW}			0.2239	−0.0026
			(1.3239)	(−0.1062)
β_{CMA}			−0.0685	0.0021
			(−0.2905)	(0.0712)
β_{MOM}			−0.0338	0.0003
			(−0.4754)	(0.0183)
n	305	305	305	305
R^2_{Pseudo}	0.0006	0.1057	0.0206	0.1257

Note: This table shows the least absolute deviation (LAD) regression results from a regression of the monthly returns of two equal crash risk variance strategies (delta-hedged call, variance swap) on the returns of other factor investment strategies. Specifically, we consider the S&P 500 index (MKT), long-short portfolios of the remaining four factors of the Fama and French (2015) five-factor model (Size (SMB), Value (HML), Profitability (RMW), Investment (CMA)), plus Momentum (MOM). Standard errors are determined using a block bootstrap with a block length of 12 and 20,000 bootstrap samples for each individual regression model. Corresponding t-statistics are reported in parentheses and asterisks indicate significance at the 1% (***), 5% (**), and 10% (*) level, respectively.

cfr working papers are available for download from www.cfr-cologne.de.

2023

No.	Author(s)	Title
23-06	J. Dörries, O. Korn, G. J. Power	How Should the Long-term Investor Harvest Variance Risk Premiums?
23-05	V. Agarwal, W. Jiang, Y. Luo, H. Zou	The Real Effect of Sociopolitical Racial Animus: Mutual Fund Manager Performance During the AAPI Hate
23-04	V. Agarwal, B. Barber, S. Cheng, A. Hameed, H. Shanker, A. Yasuda	Do Investors Overvalue Startups? Evidence from the Junior Stakes of Mutual Funds
23-03	A. Höck, T. Bauckloh, M. Dumrose, C. Klein	ESG Criteria and the Credit Risk of Corporate Bond Portfolios
23-02	T. Bauckloh, J. Dobrick, A. Höck, S. Utz, M. Wagner	"In partnership for the goals"? The (dis)agreement of SDG ratings
23-01	F. Simon, S. Weibels, T. Zimmermann	Deep Parametric Portfolio Policies

2022

No.	Author(s)	Title
22-12	V. Agarwal, A. Cochardt, V. Orlov	Birth Order and Fund Manager's Trading Behavior: Role of Sibling Rivalry
22-11	G. Cici, S. Gibson, N. Qin, A. Zhang	The Performance of Corporate Bond Mutual Funds and the Allocation of Underpriced New Issues
22-10	E. Theissen, C. Westheide	One for the Money, Two for the Show? The Number of Designated Market Makers and Liquidity
22-09	R. Campbell, P. Limbach, J. Reusche	Once Bitten, Twice Shy: Failed Deals and Subsequent M&A Cautiousness
22-08	M. Gehde-Trapp, L. Klingler	The Effect of Sentiment on Institutional Investors: A Gender Analysis
22-07	T. Bauckloh, V. Beyer, C. Klein	Does it Pay to Invest in Dirty Industries? – New Insights on the Shunned-Stock Hypothesis
22-06	J. Balthrop and G. Cici	Conflicting Incentives in the Management of 529 Plans
22-05	I. T. Ivanov, T. Zimmermann, N. W. Heinrich	Limits of Disclosure Regulation in the Municipal Bond Market

22-04	M. Ammann, A. Cochardt, S. Straumann, F. Weigert	Back to the Roots: Ancestral Origin and Mutual Fund Manager Portfolio Choice
22-03	A. Betzer, J. Gider, P. Limbach	Do Financial Advisors Matter for M&A Pre-Announcement Returns?
22-02	S. Lesmeister, P. Limbach, P.R. Rau, F. Sonnenburg	Indexing and the Performance-Flow Relation of Actively Managed Mutual Funds
22-01	T. Bauckloh, C. Klein, T. Pioch, F. Schiemann	Under Pressure: The Link between Mandatory Climate Reporting and Firms' Carbon Performance

2021

No.	Author(s)	Title
21-11	V. Agarwal, H. Ren, K. Shen, H. Zhao	Redemption in Kind and Mutual Fund Liquidity Management
21-10	N.C. Brown, W. B. Elliott, R. Wermers, R. M. White	News or noise: Mobile internet technology and stock market activity
21-09	V. Agarwal, B. Barber, S. Cheng, A. Hameed, A. Yasuda	Private Company Valuations by Mutual Funds
21-08	T.G. Bali, H. Beckmeyer, M. Moerke, F. Weigert	Option Return Predictability with Machine Learning and Big Data
21-07	F. Chabi-Yo, M. Huggenberger, F. Weigert	Multivariate Crash Risk
21-06	V. Agarwal, H. Aslan, L. Huang, H. Ren	Political Uncertainty and Household Stock Market Participation
21-05	G. Cici, P. Zhang	On the Valuation Skills of Corporate Bond Mutual Funds
21-04	V. Agarwal, P. Hanouna, R. Moussawi, C.W. Stahel	Do ETFs Increase the Commonality in Liquidity of Underlying Stocks?
21-03	M. Saglam, T. Tuzun, R. Wermers	Do ETFs Increase Liquidity?
21-02	C. Andres, D. Bazhutov, D. Cumming, P. Limbach	Does Speculative News Hurt Productivity? Evidence from Takeover Rumors
21-01	T.G. Bali, F. Weigert	Hedge Funds and the Positive Idiosyncratic Volatility Effect

This document only covers the most recent CFR working papers. A full list can be found at www.cfr-cologne.de.

centre for financial research
cfr/university of cologne
Albertus-Magnus-Platz
D-50923 cologne
fon +49(0)221-470-6995
fax +49(0)221-470-3992
kempf@cfr-cologne.de
www.cfr-cologne.de