References with abstracts for QWIM project: Financial Derivatives in quantitative wealth and investment management

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Abstract

This document includes the list of references (incuding abstracts) for this QWIM project

Contents

1 Motivation for the project

Financial derivatives (and options market data in partciular) provide additional information in investment and wealth management areas such as:

- portfolio construction and management
- hedging portfolio risk
- forecasting of asset returns

For example, Forward-looking information on the statistical properties of an asset can be extracted directly from options market data. Although the extraction of a forward-looking risk-neutral distribution is well-established in the literature, obtaining forward-looking real-world distribution is much more challenging (both from a theoretical and from a numerical perspective).

2 Relevant references

2.1 Main references

List of references:

Alankar et al. ("An Introduction to Tail Risk Parity: Balancing Risk to Achieve Downside Protection," 2013)
Alexiou and Rompolis ("Option-implied moments and the cross-section of stock returns," 2022)
Audrino et al. ("An empirical implementation of the Ross recovery theorem as a prediction device," 2021)
Barkhagen et al. ("Recovering the real-world density and liquidity premia from option data," 2016)
Bhansali ("Right Tail Hedging: Managing Risk When Markets Melt Up," 2018)
Bhansali and Holdom ("Good States, Bad States: What Do Options Tell Us About Schizophrenic Behavior of Mr. Market and What Can We Do About It?" 2021)
Bianchi and Tassinari ("Forward-looking portfolio selection with multivariate non-Gaussian models," 2020)
Carr et al. ("Using Machine Learning to Predict Realized Variance," 2020)
Chordia et al. ("Risk-Neutral Skewness, Informed Trading, and the Cross Section of Stock Returns," 2021)
Das and Ross ("The Role of Options in Goals-Based Wealth Management," 2021)
Flint and Mare ("Estimating Option-Implied Distributions in Illiquid Markets and Implementing the Ross Recovery Theorem," 2016)
Flint et al. ("The Information Hidden in Derivatives Markets," 2016)
Flint et al. ("In Search of the Perfect Hedge Underlying," 2016)
Barro et al. ("Volatility versus downside risk: performance protection in dynamic portfolio strategies," 2019)
Gagnon et al. ("Forecasting market index volatility using Ross-recovered distributions," 2021)
Haghani et al. ("Do Options Belong in the Portfolios of Individual Investors?" 2022)
Horvath ("Arbitrage-Based Recovery," 2021)
Israelov and Tummala ("An Alternative Option to Portfolio Rebalancing," 2018)
Jackwerth and Menner ("Does the Ross recovery theorem work empirically?" 2020)
Kiriu and Hibiki ("Estimating forward looking distribution with the Ross recovery theorem," 2019)
Kyriacou et al. ("Optimal portfolio allocation using option-implied information," 2021)
McQuinn et al. ("Portfolio Protection? It's a Long (Term) Story ...," 2021)
Miller et al. ("Income Enhancement with Options," 2022)
Neuhierl et al. ("Stock Option Predictability for the Cross-Section," 2021)
Appel and Mare ("The Ross recovery theorem with a regularised multivariate Markov chain," 2019)
Van Harlow and Brown ("Improving the Outlook for a Successful Retirement: A Case for Using Downside Hedging," 2016)

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2.2.1 Portfolio construction and management using financial derivatives

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Cabej et al. ("Better portfolios with options," 2014)
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Christoffersen and Pan ("Equity Portfolio Management Using Option Price Information," 2014)
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Cohn ("Using options as a risk management tool, protecting assets, and increasing investment income," 2005)
Das and Ross ("The Role of Options in Goals-Based Wealth Management," 2021)
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Dorries et al. ("How Should the Long-term Investor Harvest Variance Risk Premiums?" 2021)
Escobar-Anel et al. ("Derivatives-based portfolio decisions. An expected utility insight," 2022)
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Haghani et al. ("Do Options Belong in the Portfolios of Individual Investors?" 2022)
Israelov and Tummala ("An Alternative Option to Portfolio Rebalancing," 2018)

Israelov and Tummala ("Being Right Is Not Enough: Buying Options to Bet on Higher Realized Volatility," 2020)
Kackar and Rogal ("Application of Credit Derivatives In Portfolio Management," 2022)
Kempf et al. ("Portfolio Optimization Using Forward-Looking Information," 2015)
Koekebakker and Zakamulin ("Warren Buffett versus Zvi Bodie: Should You Buy Or Sell Put Options?" 2021)
Kyriacou et al. ("Optimal portfolio allocation using option-implied information," 2021)
Leung and Ward ("Dynamic index tracking and risk exposure control using derivatives," 2018)
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Van Harlow and Brown ("Improving the Outlook for a Successful Retirement: A Case for Using Downside Hedging," 2016)
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2.2.2 Hedging portfolio risk through financial derivatives

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Bhansali (*Tail risk hedging: Creating Robust Portfolios for Volatile Markets*, 2014)
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El-Ansary ("Alpha insurance: A computational framework to measure hedging demands for active investors," 2008)
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2.2.3 Option-implied information

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2.2.4 Extracting forward-looking information from options market data

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2.2.5 Real world versus risk neutral densities and probabilities

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2.2.6 Testing and comparison procedures for investment portfolios

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Harvey et al. ("An Evaluation of Alternative Multiple Testing Methods for Finance Applications," 2020)
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Hsu et al. ("Asset allocation strategies, data snooping, and the 1 / N rule," 2018)
Huang and Yu ("A new procedure for resampled portfolio with shrinkaged covariance matrix," 2020)
Hwang et al. ("Naive versus optimal diversification: Tail risk and performance," 2018)
Ielpo et al. (*Engineering Investment Process: Making Value Creation Repeatable*, 2017)
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Vovk and Wang ("E-values: Calibration, combination, and applications," 2021)
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Zhang et al. ("Information Coefficient as a Performance Measure of Stock Selection Models," 2020)
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This paper reports an investigation into methods of portfolio performance measurement. The work is motivated first by equivocal empirical evidence reported by several authors about the correlation of performance measures with the Sharpe ratio. Secondly it is motivated by recent work which specifies that performance measures will be monotone functions of the Sharpe ratio if portfolio returns follow the same location-scale distribution. The paper demonstrates that the class of location-scale distributions is broader than previously reported. It presents conditions under which monotonicity with respect to the Sharpe ratio will fail. The paper shows that for large sample sizes the correlation between pairs of performance measures that are functions of the Sharpe ratio is unity. The correct null hypothesis for tests of correlation is therefore rho=1. Two multivariate tests of this null hypothesis are presented. The new tests are used to carry out of a comprehensive study of performance measurement for a set over ninety UK investment trusts.

Alankar, A., DePalma, M., and Scholes, M. (2013). "An Introduction to Tail Risk Parity: Balancing Risk to Achieve Downside Protection." In: *SSRN e-Print*.

Tail Risk Parity (TRP) adapts the risk balancing techniques of Risk Parity in an attempt to protect the portfolio at times of economic crisis and reduce the cost of the protection in the absence of a crisis. In measuring expected tail loss we use a proprietary implied expected tail loss (ETL) measure distilled from options market information.

Whereas Risk Parity focuses on volatility, Tail Risk Parity defines risk as expected tail loss, something that hurts investors more than volatility. Risk Parity is a subset of Tail Risk Parity when asset returns are normally distributed and or volatility adequately captures tail loss risk. Hence, when the risk of tail events is negligible, Tail Risk Parity allocations will resemble Risk Parity allocations.

Tail Risk Parity seeks to reduce tail losses significantly while retaining more upside than Risk Parity or other mean variance optimization techniques. It is very difficult to construct portfolios under symmetric risk measures (such as volatility as used in Risk Parity) that do not penalize both large losses and, unfortunately, large gains. Tail Risk Parity aims to protect investments against large losses when investors can least afford them, when systemic crises unfold and correlations spike unexpectedly. This is exactly when the marginal utility of an extra dollar is highest.

Our research suggests that a Tail Risk Parity approach hedges the risk of large losses more cheaply than using the options market (historically we estimate savings of about 50.

We believe that Tail Risk Parity offers an attractive solution for investors seeking balanced investment portfolios that can cost effectively reduce exposures to tail losses.

Albanese, C., Li, D., Lobachevskiy, E., and Meissner, G. (2013). "A Comparative Analysis of Correlation Approaches in Finance." In: *The Journal of Derivatives* 21(2), pp. 42–66.

Although volatility is the key parameter for plain vanilla option pricing, many kinds of credit derivatives and exotic options involve multiple risk factors, so correlations must also be modeled. Different types of derivatives entail different types of correlation, from the basic Pearson correlation used in ordinary futures hedging and equity portfolio calculations, to copula methods that allow a wide range of tail dependence properties, to the ubiquitous Gaussian copula of credit risk modeling. Models of stochastically time-varying correlations have been developed, and for the correlation structure within a credit portfolio that may contain thousands of individual loans, top-down methods like Vasicek's large homogeneous portfolio approximation may be required. This article provides a comprehensive review of the many correlation concepts and models that are increasingly necessary for modern derivatives researchers.

Alexiou, L., Goyal, A., Kostakis, A., and Rompolis, L. (2021). "Pricing Event Risk: Evidence from Concave Implied Volatility Curves." In: *SSRN e-Print*.

We document that implied volatility (IV) curves extracted from short-term equity options frequently become concave prior to the earnings announcement day (EAD) reflecting a bimodal risk-neutral distribution for the underlying stock price. Firms with concave IV curves exhibit significantly higher absolute stock returns on EAD and higher realized volatility after the announcement, as compared to firms with non-concave IV curves. Hence, concavity in the IV curve constitutes an ex-ante option-based signal for event risk in the underlying stock.

Returns on delta-neutral straddles around EADs are significantly lower in the presence of concave IV curves, showing that investors pay a high premium to hedge against this event risk.

Alexiou, L. and Rompolis, L. S. (2022). "Option-implied moments and the cross-section of stock returns." In: *Journal of Futures Markets* 42(4), pp. 669–691.
We construct a joint score measure using option-implied volatility, skewness, and kurtosis gauging investors' expectations about favorable future return distribution properties. The high-low decile portfolio formed on this measure earns a statistically significant 0.75% value-weighted average monthly return. Risk-adjusted returns are significant and robust when controlling for various characteristics. The positive abnormal return of the spread portfolio can be explained by its exposure to aggregate volatility risk when investors' sentiment is low. When sentiment is high, it is also driven by information flow from the options to the stock market for stocks perceived to be as relatively mispriced.

An, b.-J., Ang, A., Bali, T. G., and Cakici, N. (2014). "The Joint Cross Section of Stocks and Options." In: *The Journal of Finance* 69(5), pp. 2279–2337.
Stocks with large increases in call (put) implied volatilities over the previous month tend to have high (low) future returns. Sorting stocks ranked into decile portfolios by past call implied volatilities produces spreads in average returns of approximately 1 percent per month, and the return differences persist up to six months. The cross section of stock returns also predicts option implied volatilities, with stocks with high past returns tending to have call and put option contracts that exhibit increases in implied volatility over the next month, but with decreasing realized volatility. These predictability patterns are consistent with rational models of informed trading.

Andersen, T. G., Todorov, V., and Ubukata, M. (2021). "Tail risk and return predictability for the Japanese equity market." In: *Journal of Econometrics* 222(1(Part B)), pp. 344–363.
This paper studies the predictability of the Japanese equity market, focusing on the forecasting power of nonparametric volatility and tail risk measures obtained from options data on the S&P 500 and Nikkei 225 market indices. The Japanese market is notoriously difficult to forecast using standard predictive indicators. We confirm that country-specific regressions for Japan - contrary to existing evidence for other national equity indices - produce insignificant predictability patterns. However, we also find that the U.S. option-implied tail risk measure provides significant forecast power both for the dollar-yen exchange rate and the Japanese excess returns, especially when measured in U.S. dollars. Thus, the dollar-denominated Japanese returns are, in fact, predictable through the identical mechanism as for other equity market indices, suggesting a high degree of global integration for the Japanese financial market.

El-Ansary, A. (2008). "Alpha insurance: A computational framework to measure hedging demands for active investors." In: *Journal of Asset Management* 9(5), pp. 310–320.
The purpose of the paper is to develop the concept of portfolio insurance against active managers' stock selection risks. The insurance premium is estimated through the use of exotic options and the impact on investors' utility is analysed within a multi-moment efficient frontier framework. For illustration, the suggested methodology is applied to the Swiss Market Index and employed to estimate the hedging demands faced by investors when portfolio choice problem is considered in a multi-period framework.

Appel, V. van and Mare, E. (2019a). "The recovery theorem with application to risk management." In: *SSRN e-Print*.
The forward looking nature of option prices provides an appealing way to extract risk measures. In this paper, we extracted forecast densities from option prices that can be used in risk forecasting. More specifically, we extracted the real-world return density forecast, implied from option prices, using the recovery theorem. In addition, we backtested and compared the predictive power of the real-world return density forecast with the risk-neutral return density forecast, implied from option prices, and a simple historical simulation approach. In an empirical study, using the South African Top 40 index, we found that the extracted real-world density forecasts, using the recovery theorem, yielded satisfying value at risk measures.

Appel, V. van and Mare, E. (2019b). "The Ross recovery theorem with a regularised multivariate Markov chain." In: *ORiON* 34(2), pp. 133–155.
Recently, Ross derived a theorem, namely the "Recovery theorem", that allows for the recovery of the pricing kernel and real-world asset distribution, under particular assumptions, from a forward-looking risk neutral distribution. However, recovering the real-world distribution involves solving two ill-posed problems. In this paper, the accuracy of a regularised multivariate mixture distribution to recover the real-world distribution is introduced and tested. In addition it is shown that this method improves the estimation accuracy of the real-

world distribution. Furthermore, an empirical study, using weekly South African Top40 option trade data, is carried out to show that the recovered distribution is in line with economic theory.

Arnott, R. D., Harvey, C. R., and Markowitz, H. (2019). "A backtesting protocol in the era of machine learning." In: *The Journal of Financial Data Science* 1(1), pp. 64–74.
Machine learning offers a set of powerful tools that holds considerable promise for investment management. As with most quantitative applications in finance, the danger of misapplying these techniques can lead to disappointment. One crucial limitation involves data availability. Many of machine learning early successes originated in the physical and biological sciences, in which truly vast amounts of data are available. Machine learning applications often require far more data than are available in finance, which is of particular concern in longer-horizon investing. Hence, choosing the right applications before applying the tools is important. In addition, capital markets reflect the actions of people, which may be influenced by others actions and by the findings of past research. In many ways, the challenges that affect machine learning are merely a continuation of the long-standing issues researchers have always faced in quantitative finance. While investors need to be cautious, more cautious than in past applications of quantitative methods new tools offer many potential applications in finance. In this article, the authors develop a research protocol that pertains both to the application of machine learning techniques and to quantitative finance in general.

Audrino, F., Huitema, R., and Ludwig, M. (2021). "An empirical implementation of the Ross recovery theorem as a prediction device." In: *Journal of Financial Econometrics* 19(2), pp. 291–312.
Building on the method of Ludwig (2015) to construct robust state price density surfaces from snapshots of option prices, we develop a nonparametric estimation strategy based on the recovery theorem of Ross (2015). Using options on the S&P 500, we then investigate whether or not recovery yields predictive information beyond what can be gleaned from risk-neutral densities. Over the 13 year period from 2000 to 2012, we find that market timing strategies based on recovered moments outperform those based on risk-neutral moments.

Back, K., Crotty, K., and Kazempour, S. M. (2020). "Risk Premium Bounds: Slackness Tests and Return Predictions." In: *SSRN e-Print*.
Martin (2017) and subsequent authors derive lower bounds for risk premia on the market portfolio and for individual stocks using option prices. If the bounds are tight and the options market is informationally efficient, then the bounds must be the best possible predictors of returns. We test the bounds conditionally and find that they are valid in all market conditions but are not tight in all market conditions. Slackness is significant and predictable. Adding predicted slackness to a bound produces a return predictor that is superior to using the bound alone.

Backwell, A. (2015). "State Prices and Implementation of the Recovery Theorem." In: *Journal of Risk and Financial Management* 8(1), pp. 2–16.
It is generally held that derivative prices do not contain useful predictive information, that is, information relating to the distribution of future financial variables under the real-world measure. This is because the market's implicit forecast of the future becomes entangled with market risk preferences during derivative price formation. A result derived by Ross [1], however, recovers the real-world distribution of an equity index, requiring only current prices and mild restrictions on risk preferences. In addition to being of great interest to the theorist, the potential practical value of the result is considerable. This paper addresses implementation of the Ross Recovery Theorem. The theorem is formalised, extended, proved and discussed. Obstacles to application are identified and a workable implementation methodology is developed.

Bahaludin, H. and Abdullah, M. H. (2020). "The role of an option-implied distribution in improving an asset allocation model." In: *Malaysian Journal of Fundamental and Applied Sciences* 16(1), pp. 64–69.
The objective of this paper is to extend the information embedded in option-implied distribution to asset allocation model. This paper examines whether a parameter estimated from an option-implied distribution can improve a minimum-variance portfolio which consists of many risky assets. The option-implied distribution under a risk-neutral assumption is called risk-neutral density (RND) whereas a risk-world density (RWD) is calculated by incorporating a risk-premium. The computation of option-implied distributions is based on the Dow Jones Industrial Average (DJIA) index options and its constituents. The data covers the period from January 2009 until December 2015. Portfolio performance is evaluated based on portfolio volatility and Sharpe ratio. The performance of a portfolio based on an option-implied distribution is compared to a naive diversification portfolio. The empirical evidence shows that for a portfolio based on an option-implied distribution, the volatility of the portfolio is reduced and the Sharpe ratio is increased.

Bailey, D. H., Borwein, J. M., and Lopez de Prado, M. (2017). "Stock Portfolio Design and Backtest Overfitting." In: *Journal of Investment Management* 15(1), pp. 75–87.
In mathematical finance, backtest overfitting connotes the usage of historical market data to develop an investment strategy, where too many variations of the strategy are tried, relative to the amount of data available. Backtest overfitting is now thought to be a primary reason why investment models and strategies that look good on paper often disappoint in practice. Models and strategies suffering from overfitting typically target the specific idiosyncrasies of a limited dataset, rather than any general behavior, and, as a result, often perform erratically when presented with new data. In this study, we address overfitting in the context of designing a mutual fund or investment portfolio as a weighted collection of stocks. Very often a newly minted equity-based fund of this type has been designed by an exhaustive computer-based search of some sort to obtain an optimal weighting that exhibits excellent performance based, say, on the past 10 or 20 years' historical market data, and the fund often highlights this backtest performance.

Bakshi, G. S., Crosby, J., and Gao, X. (2021). "Ambiguity and Blowups." In: *SSRN e-Print*.
We develop an axiomatically consistent way of ranking and scoring actively managed funds and investment strategies. Our performance measure accounts for the feature that investors may exhibit caution, via the mechanism of ambiguity aversion, when evaluating investment strategies. Linking developed theory to data, we feature evidence on a real-world question: Do investors gain by selling the tails of return distributions? Using data on options on (i) the S&P 500 equity index, and (ii) Treasury bond futures, our answer to this question is in the negative. We complement our evidence from options on STOXX 50, FTSE, and Nikkei equity indexes.

Bali, T. G. and Murray, S. (2013). "Does Risk-Neutral Skewness Predict the Cross-Section of Equity Option Portfolio Returns?" In: *Journal of Financial and Quantitative Analysis* 48(04), pp. 1145–1171.
We investigate the pricing of risk-neutral skewness in the stock options market by creating skewness assets comprised of two option positions (one long and one short) and a position in the underlying stock. The assets are created such that exposure to changes in the underlying stock price (delta), and exposure to changes in implied volatility (vega) are removed, isolating the effect of skewness. We find a strong negative relation between risk-neutral skewness and the skewness asset returns, consistent with a positive skewness preference. The returns are not explained by well-known market, size, book-to-market, momentum, short-term reversal, volatility, or option market factors.

Barker, R. C., Dickinson, A. S., and Lipton, A. (2016). "Simulation in the Real World." In: *SSRN e-Print*.
In this paper, we propose two practicable approaches for consistently modelling the realworld and risk-neutral measures within cross-asset Monte-Carlo frameworks. We go on to explore the necessity of supporting the real-world measure and consider its calibration with the aid of an explicit example of a 3-factor Hull-White model exhibiting the volatility hump and roll-down effect. This example parallels the 1-factor lattice model considered in Hull, Sokol and White, however, allows risk-premia which are stable through time and illustrates the necessity of having a sufficiently rich correlation structure in order to produce realistic dynamic risk-premia.

Barkhagen, M., Blomvall, J. o., and Platen, E. (2016). "Recovering the real-world density and liquidity premia from option data." In: *Quantitative Finance* 16(7), pp. 1147–1164.
In this paper, we develop a methodology for simultaneous recovery of the real-world probability density and liquidity premia from observed SandP 500 index option prices. Assuming the existence of a numeraire portfolio for the US equity market, fair prices of derivatives under the benchmark approach can be obtained directly under the real-world measure. Under this modelling framework, there exists a direct link between observed call option prices on the index and the real-world density for the underlying index. We use a novel method for the estimation of option-implied volatility surfaces of high quality, which enables the subsequent analysis. We show that the real-world density that we recover is consistent with the observed realized dynamics of the underlying index. This admits the identification of liquidity premia embedded in option price data. We identify and estimate two separate liquidity premia embedded in SandP 500 index options that are consistent with previous findings in the literature.

Barro, D., Canestrelli, E., and Consigli, G. (2019). "Volatility versus downside risk: performance protection in dynamic portfolio strategies." In: *Computational Management Science* 16(3), pp. 433–479.
Volatility-based and volatility targeting approaches have become popular among equity fund managers after the introduction in 1993 of the VIX, the implied volatility index on the S&P500 at the Chicago Board of Exchange (CBOE), followed, in 2004, by futures and option contracts on the VIX: since then we have assisted to an increasing interest in risk control strategies based on market signals. In January 2000 also the FTSE implied volatility index (FTSEIVI) was introduced at the London Stock Exchange. As a result, specifically in

the US, portfolio strategies based on combinations of market indices and derivatives have been proposed by Stock Exchanges and investment banks: one such example is the S&P500 protective put index (PPUT). Early in 2016, relevant to the definition of optimal bond-equity strategies, CBOE launched an Index called TYVIX/VIX featuring an investment rotation strategy based jointly on signals coming from the VIX and the 10-year Treasury Yield implied volatility (TYVIX). All these are rule-based portfolio strategies in which no optimization methods are involved. While rather effective in reducing the downside risk, those index-based portfolio approaches do not allow an optimal risk-reward trade-off and may not be sufficient to control financial risk originated by extreme market drops. To overcome these limits we propose an optimization-based approach to portfolio management jointly focusing on volatility and tail risk controls and able to accommodate effectively the return payoffs associated with option strategies, whose cost as market volatility increases may become excessive. The model is based on a mean absolute deviation formulation and tested in the US equity market over the 2000-2016 period and with a focus on three periods of high volatility, in 2000, 2001 and 2008. The results confirm that optimal volatility controls produce better risk-adjusted returns if compared with rule-based approaches. Moreover the portfolio return distribution is dynamically shaped depending on the adopted risk management approach.

Basu, A. K. and Drew, M. E. (2014). "The value of tail risk hedging in defined contribution plans: what does history tell us." In: *Journal of Pension Economics and Finance* 14(03), pp. 240–265.
Hedging against tail events in equity markets has been forcefully advocated in the aftermath of recent global financial crisis. Whether this is beneficial to long horizon investors like employees enrolled in defined contribution (DC) plans, however, has been subject to criticism. We conduct historical simulation since 1928 to examine the effectiveness of active and passive tail risk hedging using out of money put options for hypothetical equity portfolios of DC plan participants with 20 years to retirement. Our findings show that the cost of tail hedging exceeds the benefits for a majority of the plan participants during the sample period. However, for a significant number of simulations, hedging result in superior outcomes relative to an unhedged position. Active tail hedging is more effective when employees confront several panic-driven periods characterized by short and sharp market swings in the equity markets over the investment horizon. Passive hedging, on the other hand, proves beneficial when they encounter an extremely rare event like the Great Depression as equity markets go into deep and prolonged decline.

Bessler, W., Opfer, H., and Wolff, D. (2017). "Multi-asset portfolio optimization and out-of-sample performance: an evaluation of Black Litterman, mean-variance, and naive diversification approaches." In: *The European Journal of Finance* 23(1), pp. 1–30.
The Black Litterman model aims to enhance asset allocation decisions by overcoming the problems of mean-variance portfolio optimization. We propose a sample-based version of the Black Litterman model and implement it on a multi-asset portfolio consisting of global stocks, bonds, and commodity indices, covering the period from January 1993 to December 2011. We test its out-of-sample performance relative to other asset allocation models and find that Black Litterman optimized portfolios significantly outperform na ive-diversified portfolios (1/N rule and strategic weights), and consistently perform better than mean-variance, Bayes Stein, and minimum-variance strategies in terms of out-of-sample Sharpe ratios, even after controlling for different levels of risk aversion, investment constraints, and transaction costs. The BL model generates portfolios with lower risk, less extreme asset allocations, and higher diversification across asset classes. Sensitivity analyses indicate that these advantages are due to more stable mixed return estimates that incorporate the reliability of return predictions, smaller estimation errors, and lower turnover.

Bessler, W. and Wolff, D. (2017). "Portfolio Optimization with Industry Return Prediction Models." In: *SSRN e-Print*.
We postulate that utilizing return prediction models with fundamental, macroeconomic, and technical indicators instead of using historical averages should result in superior asset allocation decisions. We investigate the predictive power of individual variables for forecasting industry returns in-sample and out-of-sample and then analyze multivariate predictive regression models including OLS, a regularization technique, principal components, a target-relevant latent factor approach, and forecast combinations. The gains from using industry return predictions are evaluated in an out-of-sample Black-Litterman portfolio optimization framework. We provide empirical evidence that portfolio optimization utilizing industry return prediction models significantly outperform portfolios using historical averages and those being passively managed.

Bevilacqua, M. and Tunaru, R. (2021). "The SKEW index: Extracting what has been left." In: *Journal of Financial Stability* 53, p. 100816.

This study disentangles a measure of implied skewness that is related to downward movements in the U.S. equity index from the corresponding implied skewness that is associated with upward movements. A positive SKEW index is constructed from S&P 500 call options, whereas a negative SKEW index is constructed from the S&P 500 put options. We show that the positive SKEW is linked to market sentiment, whereas the negative SKEW is related to existing tail risk measures. The negative SKEW is proposed as a more objective prudent tail risk measure, and it is found to be able to predict recessions, market downturns, and uncertainty indicators up to one year in advance. The predictive power of the negative SKEW is also confirmed when we control for other tail risk measures and also out-of-sample.

Bhansali, V. (2014). *Tail risk hedging: Creating Robust Portfolios for Volatile Markets*. McGraw-Hill. 272 pp.
Tail Risk Hedging is built on the author's practical experience applying macroeconomic forecasting and quantitative modeling techniques across asset markets. Using empirical data and charts, he explains the consequences of diversification failure in tail events and how to manage portfolios when this happens. He provides an easy-to-use, yet rigorous framework for protecting investment portfolios against tail risk and using tail hedging to play offense. Tail Risk Hedging explores how to: Generate profits from volatility and illiquidity during tail-risk events in equity and credit markets; Buy attractively priced tail hedges that add value to a portfolio and quantify basis risk; Interpret the psychology of investors in option pricing and portfolio construction; Customize explicit hedges for retirement investments; Hedge risk factors such as duration risk and inflation risk; Managing tail risk is today's most significant development in risk management, and this thorough guide helps you access every aspect of it. With the time-tested and mathematically rigorous strategies described here, including pieces of computer code, you get access to insights to help mitigate portfolio losses in significant downturns, create explosive liquidity while unhedged participants are forced to sell, and create more aggressive yet tail-risk-focused portfolios. The book also gives you a unique, higher level view of how tail risk is related to investing in alternatives, and of derivatives such as zerocost collars and variance swaps. Volatility and tail risks are here to stay, and so should your clients' wealth when you use Tail Risk Hedging for managing portfolios.

Bhansali, V. (2008). "Tail Risk Management." In: *The Journal of Portfolio Management* 34(4), pp. 68–75.
In the current deleveraging episode, the severity and simultaneous realization of low-probability events across a number of strategies has brought portfolio tail-risk hedging to the center of investors' attention. In this article, the author discusses the basic principles and implementation considerations behind portfolio tail-risk management, emphasizing the importance of viewing tail risk as the consequence of a systemic shock during which normally uncorrelated markets become correlated due to a reduction in liquidity. This approach suggests that tail risk should be measured by performing macro scenario analysis and that hedges should be picked based on their cost and joint performance in periods of stress relative to the portfolio being hedged. Since liquidity reduction is a typical consequence of systemic shocks, the author also discusses specific operational issues that come to the fore in such events.

Bhansali, V. (2015). "Tail-Risk Management for Retirement Investments." In: *The Journal of Retirement* 2(3), pp. 78–86.
One of the insights of behavioral finance is the tendency for small investors to overreact to market swings. Even a well-structured portfolio may be vulnerable to panic selling in a downturn.
The article explains how a policy of tail-risk hedging could deter such behavior by putting a floor on drops in the portfolio. Instead of maintaining an overly conservative stance and an unnecessarily low share of equities, investors could hedge their portfolios by relying on options, which have become a much more feasible tool for the small investor in recent years.
The article discusses the relationship between the time to retirement and the need to hedge. Investors nearing retirement have to adopt a more defensive position or hedge explicitly, but younger investors can be more aggressive and buy options with lower strike prices.

Bhansali, V. (2018). "Right Tail Hedging: Managing Risk When Markets Melt Up." In: *The Journal of Portfolio Management*.
Popular academic and practitioner lore claims that buying options, whether puts or calls, is a negative expected return investment and hence should not be undertaken by rational, risk-neutral investors. However, real-world considerations such as the possibility of large jumps and imitative behavior of traders in both bull and bear markets can reverse this conclusion. In particular, the potential for positive economic shocks such as those observed since the 2016 U.S. election may make call options-based strategies superior to buy and hold strategies. In this article, the author extends his work published in The Journal of Portfolio Management in 2007 on left tail or downside tail risk hedging to address upside hedging, which has become increasingly relevant in an

environment of low yields, elevated asset prices, low credit spreads, indexation, and multidecadal lows in call option prices.

Bhansali, V., Chang, L., Holdom, J., and Rappaport, M. (2020). "Monetization Matters: Active Tail Risk Management and the Great Virus Crisis." In: *The Journal of Portfolio Management* 47(1), pp. 16–28.
The authors discuss monetization strategies for both left- and right-tail risk hedging to illustrate the potential benefits of active management of hedges. In particular, by including actual data from the sharp COVID-19 pandemic-related market correction and subsequent rebound of 2020, the authors quantify how monetization strategies have the ability to improve the performance of portfolio hedges. This extends previous work on active tail risk hedging published in this journal. The authors conclude that active management of tail hedging can result in significant increases in the efficacy of tail hedging.

Bhansali, V. and Holdom, J. (2021). "Good States, Bad States: What Do Options Tell Us About Schizophrenic Behavior of Mr. Market and What Can We Do About It?" In: *Journal of Investment Strategies* 19(4), pp. 79–91.
Option prices theoretically encapsulate participants' expectations about good state (bullish) and bad state (bearish) market outcomes. By using a mixture of distributions and reasonable assumptions, the authors extract time series of expected returns, volatilities and mixture probabilities of these outcomes surrounding the current US elections. The bimodality of asset return distributions suggests important modifications for asset allocation and risk management.

Bianchi, M. L. and Tassinari, G. L. (2020). "Forward-looking portfolio selection with multivariate non-Gaussian models." In: *Quantitative Finance* 20(10), pp. 1645–1661.
In this study, we suggest a portfolio selection framework based on time series of stock log-returns, option-implied information, and multivariate non-Gaussian processes. We empirically assess a multivariate extension of the normal tempered stable (NTS) model and of the generalized hyperbolic (GH) one by implementing an estimation method that simultaneously calibrates the multivariate time series of log-returns and, for each margin, the univariate observed one-month implied volatility smile. To extract option-implied information, the connection between the historical measure P and the risk-neutral measure Q, needed to price options, is provided by the multivariate Esscher transform. The method is applied to fit a 50-dimensional series of stock returns, to evaluate widely known portfolio risk measures and to perform a forward-looking portfolio selection analysis. The proposed models are able to produce asymmetries, heavy tails, both linear and non-linear dependence and, to calibrate them, there is no need for liquid multivariate derivative quotes.

Bjerring, T., Ross, O., and Weissensteiner, A. (2017). "Feature selection for portfolio optimization." In: *Annals of Operations Research* 256, pp. 21–40.
Most portfolio selection rules based on the sample mean and covariance matrix perform poorly out-of-sample. Moreover, there is a growing body of evidence that such optimization rules are not able to beat simple rules of thumb, such as 1/N. Parameter uncertainty has been identified as one major reason for these findings. A strand of literature addresses this problem by improving the parameter estimation and/or by relying on more robust portfolio selection methods. Independent of the chosen portfolio selection rule, we propose using feature selection first in order to reduce the asset menu. While most of the diversification benefits are preserved, the parameter estimation problem is alleviated. We conduct out-of-sample back-tests to show that in most cases different well-established portfolio selection rules applied on the reduced asset universe are able to improve alpha relative to different prominent factor models.

Bondarenko, O. and Bernard, C. (2021). "Option-Implied Dependence and Correlation Risk Premium." In: *SSRN e-Print*.
We propose a novel model-free approach to obtain the joint risk-neutral distribution among several assets that is consistent with market prices of options on these assets and their weighted index. In an empirical application, we use options on the S&P 500 index and its nine industry sectors. The results of our analysis reveal that the option-implied dependence for the nine sectors is highly nonnormal, asymmetric, and time-varying. We then study two conditional correlations: when the market moves down or up. The risk premium for the down correlation is strongly negative, while the opposite is true for the up correlation. These findings are consistent with the economic intuition that investors dislike the loss of diversification when markets fall, but they actually prefer high correlation when markets rally.

Bormetti, G., Cocco, F., and Rossi, P. (2021). "Deep learning profit and loss." In: *Risk (Cutting Edge)*.
Building the future profit and loss distribution of a portfolio holding highly nonlinear and path-dependent derivatives, among other assets, is a challenging task. Giacomo Bormetti, Flavio Cocco and Pietro Rossi provide a simple machinery where an increasing number of assets may be accounted for in a simple and semi-automatic

fashion. They resort to a variation of the least squares Monte Carlo algorithm in which the continuation value of the portfolio is interpolated with a feed-forward neural network. They account for the profit and loss distribution of a whole portfolio even when the dependence structure between different assets is very strong, eg, for contingent claims written on the same underlying.

Bruni, R., Cesarone, F., Scozzari, A., and Tardella, F. (2016). "Real-world datasets for portfolio selection and solutions of some stochastic dominance portfolio models." In: *Data in Brief* 8, pp. 858–862.
A large number of portfolio selection models have appeared in the literature since the pioneering work of Markowitz. However, even when computational and empirical results are described, they are often hard to replicate and compare due to the unavailability of the datasets used in the experiments. We provide here several datasets for portfolio selection generated using real-world price values from several major stock markets. The datasets contain weekly return values, adjusted for dividends and for stock splits, which are cleaned from errors as much as possible. The datasets are available in different formats, and can be used as benchmarks for testing the performances of portfolio selection models and for comparing the efficiency of the algorithms used to solve them. We also provide, for these datasets, the portfolios obtained by several selection strategies based on Stochastic Dominance models (see "On Exact and Approximate Stochastic Dominance Strategies for Portfolio Selection" (Bruni et al. [2])). We believe that testing portfolio models on publicly available datasets greatly simplifies the comparison of the different portfolio selection strategies.

Bruni, R., Cesarone, F., Scozzari, A., and Tardella, F. (2017). "On exact and approximate stochastic dominance strategies for portfolio selection." In: *European Journal of Operational Research* 259(1), pp. 322–329.
New type of approximate stochastic dominance designed for portfolio selection. Equivalent to minimizing the expected shortfall of the portfolio below the benchmark. An easily solvable LP model for the practical implementation of our approach. Extensive empirical comparison of stochastic dominance models for portfolio selection. One recent and promising strategy for Enhanced Indexation is the selection of portfolios that stochastically dominate the benchmark. We propose here a new type of approximate stochastic dominance rule which implies other existing approximate stochastic dominance rules. We then use it to find the portfolio that approximately stochastically dominates a given benchmark with the best possible approximation. Our model is initially formulated as a Linear Program with exponentially many constraints, and then reformulated in a more compact manner so that it can be very efficiently solved in practice. This reformulation also reveals an interesting financial interpretation. We compare our approach with several exact and approximate stochastic dominance models for portfolio selection. An extensive empirical analysis on real and publicly available datasets shows very good out-of-sample performances of our model.

Bryzgalova, S., Huang, J., and Julliard, C. (2021). "Bayesian solutions for the factor zoo: we just ran two quadrillion models." In: *SSRN e-Print*.
We propose a novel, and simple, Bayesian estimation and model selection procedure for cross-sectional asset pricing. Our approach, that allows for both tradable and non-tradable factors, and is applicable to high dimensional cases, has several desirable properties. First, weak and spurious factors lead to diffuse, and centered at zero, posteriors for their market price of risk, making such factors easily detectable. Second, posterior inference is robust to the presence of such factors. Third, we show that flat priors for risk premia lead to improper marginal likelihoods, rendering model selection invalid. Therefore, we provide a novel prior, that is diffuse for strong factors but shrinks away useless ones, under which posterior probabilities are well behaved, and can be used for factor and (non necessarily nested) model selection, as well as model averaging, in large scale problems. We apply our method to a very large set of factors proposed in the literature, and analyse 2.25 quadrillion possible models, gaining novel insights on the empirical drivers of asset returns.

Cabej, G., Gilli, M., and Schumann, E. (2014). "Better portfolios with options." In: *IEEE Conference on Computational Intelligence for Financial Engineering and Economics (CIFEr)*. London, UK: IEEE, pp. 107–113.
In the period following the last financial crisis, equity markets have performed poorly. In consequence, equity long-only strategies have generally disappointed over this period. This has motivated the investigation on whether better performance can be achieved by including equity options in the portfolios. We show that simple systematic option strategies improve portfolio performance. Results are supported by thorough backtesting and simulations.

Cao, J., Goyal, A., Zhan, X., and Zhang, W. E. (2021). "Unlocking ESG Premium from Options." In: *SSRN e-Print*.
We find that option expensiveness, as measured by implied volatility, is higher for low-ESG stocks, showing that investors pay a premium in the option market to hedge ESG-related uncertainty. Using delta-hedged option returns, we estimate this ESG premium to be about 0.3% per month. All three components of ESG contribute to option pricing. The effect of ESG performance heightens after the announcement of Paris Agreement, after

speeches of Greta Thunberg, and in the aftermath of Me-Too movement. We find that investors pay ESG premium to hedge volatility, jump, and other higher moment risks. The influence of ESG on option premia is stronger for firms that are closer to end-consumers, facing severer product competition, with higher investors' ESG awareness, and without corporate hedging activity.

Carbonneau, A. (2020). "Deep Hedging of Long-Term Financial Derivatives." In: *arXiv e-Print*.

This study presents a deep reinforcement learning approach for global hedging of long-term financial derivatives. A similar setup as in Coleman et al. (2007) is considered with the risk management of lookback options embedded in guarantees of variable annuities with ratchet features. The deep hedging algorithm of Buehler et al. (2019a) is applied to optimize neural networks representing global hedging policies with both quadratic and non-quadratic penalties. To the best of the author's knowledge, this is the first paper that presents an extensive benchmarking of global policies for long-term contingent claims with the use of various hedging instruments (e.g. underlying and standard options) and with the presence of jump risk for equity. Monte Carlo experiments demonstrate the vast superiority of non-quadratic global hedging as it results simultaneously in downside risk metrics two to three times smaller than best benchmarks and in significant hedging gains. Analyses show that the neural networks are able to effectively adapt their hedging decisions to different penalties and stylized facts of risky asset dynamics only by experiencing simulations of the financial market exhibiting these features. Numerical results also indicate that non-quadratic global policies are significantly more geared towards being long equity risk which entails earning the equity risk premium.

Carr, P., Wu, L., and Zhang, Z. (2020). "Using Machine Learning to Predict Realized Variance." In: *Journal Of Investment Management* 18(2).

Volatility index is a portfolio of options and represents market expectation of the underlying security's future realized volatility/variance. Traditionally the index weighting is based on a variance swap pricing formula. In this paper we propose a new method for building volatility index by formulating a variance prediction problem using machine learning.We test algorithms including Ridge regression, Feed forward Neural Networks and Random Forest on S&P 500 Index option data. By conducting a time series validation we show that the new weighting method can achieve higher predictability to future return variance and require fewer options. It is also shown that the weighting method combining the traditional and the machine learning approaches performs the best.

Cesarone, F., Moretti, J., and Tardella, F. (2018). "Why Small Portfolios Are Preferable and How to Choose Them." In: *SSRN e-Print*.

One of the fundamental principles in portfolio selection models is minimization of risk through diversification of the investment. However, this principle does not necessarily translate into a request for investing in all the assets of the investment universe. Indeed, following a line of research started by Evans and Archer almost 50 years ago, we provide here further evidence that small portfolios are sufficient to achieve almost optimal in-sample risk reduction with respect to variance and to some other popular risk measures, and very good out-of-sample performances. While leading to similar results, our approach is significantly different from the classical one pioneered by Evans and Archer. Indeed, we describe models for choosing the portfolio of a prescribed size with the smallest possible risk, as opposed to the random portfolio choice investigated in most of the previous works. We find that the smallest risk portfolios generally require no more than 15 assets. Furthermore, it is almost always possible to find portfolios that are just 1% more risky than the smallest risk portfolios and contain no more than 10 assets. The preference for small optimal portfolios is also justified by recent theoretical results on the estimation errors for the parameters required by portfolio selection models. Our empirical analysis is based on some new and on some publicly available benchmark data sets often used in the literature.

Cesarone, F., Mottura, C., Ricci, J. M., and Tardella, F. (2019). "On the stability of portfolio selection models." In: *SSRN e-Print*.

One of the main issues in portfolio selection models consists in assessing the effect of the estimation errors of the parameters required by the models on the quality of the selected portfolios. Several studies have been devoted to this topic for the minimum variance and for several other minimum risk models. However, no sensitivity analysis seems to have been reported for the recent popular Risk Parity diversification approach, nor for other portfolio selection models requiring maximum gain-risk ratios.Based on artificial and real-world data, we provide here empirical evidence showing that the Risk Parity model is always the most stable one in all the cases analyzed. Furthermore, the minimum risk models are typically more stable than the maximum gain-risk models, with the minimum variance model often being the preferable one.

Chabi-Yo, F. (2019). "What Is the Conditional Autocorrelation on the Stock Market?" In: *SSRN e-Print*.

We derive lower and upper bounds on the conditional market autocorrelation index at various investment horizons without using the precise form of the utility function. The bounds are derived in terms of option prices and can be computed at daily frequency for any given horizon. The bounds incorporate all the information contained in the entire distribution of returns. We use options on the S&P 500 index to quantify the bounds and document that asset prices imply a negative upper bound on the market conditional autocorrelation index. The upper bound on the market conditional autocorrelation index is highly volatile, skewed, and exhibits fat tails. It varies from -28% to -3% and takes extremely negative values during crisis or recession periods while being close to zero during normal times. On average, the upper bound on the market conditional autocorrelation index is -14%. We also document that periods of extremely negative market conditional autocorrelation index coincide with periods of a high Sharpe ratio, and we show that leading asset pricing models cannot reproduce both the negative market conditional autocorrelation index and the negative average market conditional autocorrelation index implied by asset prices.

Chan, J. R., Huckle, T., Jacquier, A., and Muguruza, A. (2021). "Portfolio optimisation with options." In: *arXiv e-Print*.

We develop a new analysis for portfolio optimisation with options, tackling the three fundamental issues with this problem: asymmetric options' distributions, high dimensionality and dependence structure. To do so, we propose a new dependency matrix, built upon conditional probabilities between options' payoffs, and show how it can be computed in closed form given a copula structure of the underlying asset prices. The empirical evidence we provide highlights that this approach is efficient, fast and easily scalable to large portfolios of (mixed) options.

Chaudhuri, S. E. and Lo, A. W. (2019). "Dynamic Alpha: A Spectral Decomposition of Investment Performance Across Time Horizons." In: *Management Science* 65(9), pp. 4440–4450.

The value added by an active investor is traditionally measured using alpha, tracking error, and the information ratio. However, these measures do not characterize the dynamic component of investor activity, nor do they consider the time horizons over which weights are changed. In this paper, we propose a technique to measure the value of active investment that captures both the static and dynamic contributions of an investment process. This dynamic alpha is based on the decomposition of a portfolio's expected return into its frequency components using spectral analysis. The result is a static component that measures the portion of a portfolio's expected return resulting from passive investments and security selection and a dynamic component that captures the manager's timing ability across a range of time horizons. Our framework can be universally applied to any portfolio and is a useful method for comparing the forecast power of different investment processes. Several analytical and empirical examples are provided to illustrate the practical relevance of this decomposition.

Chen, D., Guo, B., and Zhou, G. (2020). "Firm Fundamentals and the Cross Section of Implied Volatility Shapes." In: *SSRN e-Print*.

We investigate whether firm fundamentals can explain the shape of option implied volatility (IV) curve. Extending Geske's (1997) compound option model, we link firm fundamentals to the prices of equity and equity options, and show how the shape of IV curve can vary across firms with leverage, dividend policy, cost of capital, and so on. Using options of S&P 500 constituent companies, we show further empirically that firm fundamentals are important determinants of the IV curve even after controlling for historical volatility, risk-neutral skewness, kurtosis and systematic risk ratio. Fundamentals not only provide statistically and economically explanatory power on the IV curve, but also help reconcile with some stylized facts and puzzles.

Chordia, T., Lin, T.-C., and Xiang, V. (2021). "Risk-Neutral Skewness, Informed Trading, and the Cross Section of Stock Returns." In: *Journal of Financial and Quantitative Analysis* 56(5), pp. 1713–1737.

In this article, we use volatility surface data from options contracts to document a strong, robust, and positive cross-sectional relation between risk-neutral skewness (RNS) and subsequent stock returns. The differential return between high- and low-RNS stocks amounts to 0.17% per week. Preannouncement RNS is positively related to earnings announcement returns, and the positive RNS-return relation is more pronounced for other nonscheduled news releases. This suggests that it is informed trading that drives the positive relation between RNS and subsequent stock returns. We also find that RNS contains incremental information beyond trading signals captured by option-implied volatility and volume.

Chow, V., Gu, J., and Wang, Z. (2021). "Implied Equity Premium and Market Beta." In: *SSRN e-Print*.

We extend the ex-ante mean-variance (SVIX) models of Martin (2017) and Martin-Wagner (2019) to a mean-variance-asymmetry (AVIX) framework for incorporating higher-moment and co-moment risk in asset pricing. AVIX is a risk-neutral measure of the left-tail asymmetries in return that corrects the SVIX approach's downside bias. The options implied market beta of equity is a weighted sum of the beta of SVIX and that of AVIX.

Empirically, the implied betas possess significant predictability of risk/return relationship and the hedging ability against bear/crashing markets. We develop an investible portfolio MKT that mimics realized outcomes on the implied market index adjusted for volatility-asymmetry.

Christoffersen, P. and Pan, X. N. (2014). "Equity Portfolio Management Using Option Price Information." In: *SSRN e-Print*.
We survey the recent academic literature that uses option-implied information to construct equity portfolios. Studies show that equity managers can earn a positive alpha by using information in individual equity options, by using stocks' exposure to information in market index options, and by using stocks' exposure to crude oil option information. Option-implied information can also help construct better mean-variance portfolios and better estimates of market beta.

Clark, S. P. and Dickson, M. (2019). "Performance expectations of basic options strategies may be different than you think." In: *Journal of Asset Management*.
There is much empirical evidence for the existence of a negative volatility risk premium. We consider how the volatility risk premium affects the returns of portfolios implementing seven popular option strategies. We find that option selling generates substantial excess return as well as risk mitigation by providing short exposure to the volatility risk premium. Net option buying is able to protect against extreme losses; however, these losses are very infrequent and short lived. Even during these periods, the long net exposure to the volatility risk premium erodes protection as the depth and duration of the losses persist.

Cohn, M. D. (2005). "Using options as a risk management tool, protecting assets, and increasing investment income." In: *The Journal of Wealth Management* 8(2), pp. 36–41.
This article starts with a summary of options theory to set the basis for the balance of a discussion which relates to the uses to which one can put these options to work as an important risk management tool. The author then proceeds to describe three different strategies that can be designed to enhance the income earned on a portfolio, manage downside risk, or deal with concentration risk. He finally describes a strategy that might allow the investor to manage both downside and concentration risk, in an original manner.

Cremers, M., Fleckenstein, M., and Gandhi, P. (2021). "Treasury yield implied volatility and real activity." In: *Journal of Financial Economics* 140(2), pp. 412–435.
We show that at-the-money implied volatility of options on futures of five-year Treasury notes (Treasury "yield implied volatility") predicts both the growth rate and volatility of gross domestic product, as well as of other macroeconomic variables, like industrial production, consumption, and employment. This predictability is robust to controlling for the term spread, credit spread, stock returns, stock market implied volatility, and several other variables that prior literature showed to predict macroeconomic activity. Our results indicate that Treasury yield implied volatility is a useful forward-looking state variable to characterize risks and opportunities in the macro economy.

Crisostomo, R. and Couso, L. (2018). "Financial density forecasts: A comprehensive comparison of risk-neutral and historical schemes." In: *Journal of Forecasting* 37(5), pp. 589–603.
We investigate the forecasting ability of the most commonly used benchmarks in financial economics. We approach the usual caveats of probabilistic forecasts studies samples, limited models, and nonholistic validations performing a comprehensive comparison of 15 predictive schemes during a time period of over 21 years. All densities are evaluated in terms of their statistical consistency, local accuracy and forecasting errors. Using a new composite indicator, the integrated forecast score, we show that risk neutral densities outperform historical based predictions in terms of information content. We find that the variance gamma model generates the highest out of sample likelihood of observed prices and the lowest predictive errors, whereas the GARCH based GJR FHS delivers the most consistent forecasts across the entire density range. In contrast, lognormal densities, the Heston model, or the nonparametric Breeden-Litzenberger formula yield biased predictions and are rejected in statistical tests.

Das, S. R. and Ross, G. (2021). "The Role of Options in Goals-Based Wealth Management." In: *SSRN e-Print*.
We develop a facile methodology using dynamic programming for goals-based wealth management over long horizons where rebalancing uses the standard securities and also derivative securities. A kernel density estimation approach is developed to accommodate any number of derivative assets, solving a high dimensional problem with fast computation. The approach easily accommodates skewed and fat-tailed distributions. Portfolio performance is much better with the use of options, especially for investors with aggressive goals.

Davari-Ardakani, H., Aminnayeri, M., and Seifi, A. (2016). "Multistage portfolio optimization with stocks and options." In: *International Transactions in Operational Research* 23(3), pp. 593–622.

We develop a multistage portfolio optimization model that utilizes options for mitigating market risk in a dynamic setting. Due to the key role of scenarios in the quality of investment decisions, a new scenario generation method is proposed that characterizes the dynamic behavior of asset returns. This methodology takes the dependence structure of different asset returns into account, and also considers serial correlations of each of the asset returns. Moreover, it preserves marginal distributions of asset returns. Also, it precludes arbitrage opportunities. To investigate the role of options, we implement the scenario generation method on a set of stocks selected from the New York Stock Exchange. Results show the high performance of the proposed scenario generation method. Afterwards, the generated set of scenarios is used as the uncertainty set for the multistage portfolio optimization model. Static and dynamic assessments are used for measuring the performance of options in mitigating market risks and generating additional returns. Finally, backtesting simulations are used for assessing different trading strategies of options.

Dew-Becker, I., Giglio, S., and Kelly, B. (2021). "Hedging macroeconomic and financial uncertainty and volatility." In: *Journal of Financial Economics* 142(1), pp. 23–45.
We study the pricing of shocks to uncertainty and volatility using a wide-ranging set of options contracts covering a variety of different markets. If uncertainty shocks are viewed as bad by investors, they should carry negative risk premiums. Empirically, however, uncertainty risk premiums are positive in most markets. Instead, it is the realization of large shocks to fundamentals that has historically carried a negative premium. In other words, we find that the return premium for gamma is negative, while that for vega is positive. These results imply that it is jumps, for which exposure is measured by gamma, not forward-looking uncertainty shocks, measured by vega, that drive investors' marginal utility. In further support of the jump interpretation, the return patterns are more extreme for deeper out-of-the-money options.

Diaz, M. and Kwon, R. H. (2019). "Portfolio optimization with covered calls." In: *Journal of Asset Management* 20, pp. 38–53.
Covered calls are traditionally formed as an overlay on an existing portfolio. Our analysis suggests that covered calls formed in two steps by first optimizing underlying equity positions and then selecting call overwriting weights are not risk-return optimal in general. We introduce an optimization framework which simultaneously selects underlying asset positions and call options to sell to form risk-return optimal covered call portfolios. Call option market prices form a critical part of the expected return and risk expressions. Variance of the return, semivariance of the return, and conditional value-at-risk are used as risk measures. The model was first tested by forming covered call portfolios composed of three indices and then by forming portfolios using 92 U.S. equities. We find that selling call options not only reduces risk, but when selected optimally can also benefit the expected return.

Dillschneider, Y. (2021). "Generalized Transform Analysis for Asset Pricing and Parameter Estimation." In: *SSRN e-Print*.
In this paper, we extend the existing generalized transform analysis in a way that allows us to propose a novel GMM approach for estimating asset pricing models. Our methodology is capable of incorporating a broad class of assets within both reduced-form and structural models, while avoiding the drawbacks of competing approaches. To formulate moment conditions, we derive expressions for moments involving transform-based asset prices. Our theory yields analytically tractable expressions for exact moments and an additionally computationally efficient strategy to obtain approximate moments, whose convergence we establish under standard conditions. Exact and approximate moments induce exact and approximate GMM estimators, respectively, for which we discuss asymptotic properties. Finally, we exemplify our methodology with a worked-out estimation problem involving equity options.

Dillschneider, Y. and Maurer, R. (2017). "Functional Ross Recovery: An Operator Approach." In: *SSRN e-Print*.
Recently, Ross (2015) showed that the real-world probability distribution of a discrete Markovian state variable can be recovered from observed option prices. The so-called recovery theorem follows from Perron-Frobenius matrix theory when the pricing kernel is transition independent. In this paper, we generalize the recovery theorem to unbounded continuous state spaces using Perron-Frobenius operator theory. Building on our theoretical results, we devise a nonparametric estimation approach to empirically recover the pricing kernel and real-world probability density in closed form. Using SandP 500 index options, we find that recovered pricing kernels are persistently U-shaped, documenting the well-known pricing kernel puzzle.

Dillschneider, Y. and Maurer, R. (2019). "Functional Ross recovery: Theoretical results and empirical tests." In: *Journal of Economic Dynamics and Control* 108, p. 103750.

Recently, Ross (2015) showed that the real-world probability distribution of a discrete Markovian state variable can be recovered from observed option prices. The so-called recovery theorem follows from Perron-Frobenius matrix theory when the pricing kernel is transition independent. In this paper, we generalize the recovery theorem to continuous state spaces using Perron-Frobenius operator theory. Building on our theoretical results, we devise a nonparametric approach to empirically estimate the recovered pricing kernel and probability density in closed form. Using S&P 500 index options, we analyze recovered pricing kernels empirically and find evidence that Ross recovery is misspecified.

Diris, B., Palm, F., and Schotman, P. (2015). "Long-Term Strategic Asset Allocation: An Out-of-Sample Evaluation." In: *Management Science* 61(9), pp. 2185–2202.
We evaluate the out-of-sample performance of a long-term investor who follows an optimized dynamic trading strategy. Although the dynamic strategy is able to benefit from predictability out-of-sample, a short-term investor using a single-period market timing strategy would have realized an almost identical performance. The value of intertemporal hedge demands in strategic asset allocation appears negligible. The result is caused by the estimation error in predicting the predictors. A myopic investor only needs to predict one-period-ahead expected returns, but hedge demands also require accurate predictions of the predictor variables. To reduce the problem of errors in optimized portfolio weights, we consider Bayesian procedures. Myopic and dynamic portfolios are similarly affected by such modifications, and differences in performance become even smaller.

Dorries, J., Korn, O., and Power, G. (2021). "How Should the Long-term Investor Harvest Variance Risk Premiums?" In: *SSRN e-Print*.
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.

Escobar-Anel, M., Davison, M., and Zhu, Y. (2022). "Derivatives-based portfolio decisions. An expected utility insight." In: *arXiv e-Print*.
This paper challenges the use of stocks in portfolio construction, instead we demonstrate that Asian derivatives, straddles, or baskets could be more convenient substitutes. Our results are obtained under the assumptions of the Black–Scholes–Merton setting, uncovering a hidden benefit of derivatives that complements their well-known gains for hedging, risk management, and to increase utility in market incompleteness. The new insights are also transferable to more advanced stochastic settings. The analysis relies on the infinite number of optimal choices of derivatives for a maximized expected utility (EUT) agent; we propose risk exposure minimization as an additional optimization criterion inspired by regulations. Working with two assets, for simplicity, we demonstrate that only two derivatives are needed to maximize utility while minimizing risky exposure. In a comparison among one-asset options, e.g. American, European, Asian, Calls and Puts, we demonstrate that the deepest out-of-the-money Asian products available are the best choices to minimize exposure. We also explore optimal selections among straddles, which are better practical choices than out-of-the-money Calls and Puts due to liquidity and rebalancing needs. The optimality of multi-asset derivatives is also considered, establishing that a basket option could be a better choice than one-asset Asian call/put in many realistic situations.

Fabozzi, F. J. and Lopez de Prado, M. (2018). "Being Honest in Backtest Reporting: A Template for Disclosing Multiple Tests." In: *The Journal of Portfolio Management* 45(1), pp. 141–147.
Selection bias under multiple testing is a serious problem. From a practitioner perspective, failure to disclose the impact of multiple tests of a proposed investment strategy to clients and senior management can lead to the adoption of a false discovery. Clients will lose money, senior management will misallocate resources, and the firm may be exposed to reputational, legal, and regulatory risks. From the perspective of academic journals that publish evidence supporting an investment strategy, the failure to address selection bias under multiple testing threatens to invalidate large portions of the literature in empirical finance. In this article, the authors propose a template that practitioners should use to fairly disclose multiple tests involved in an alleged discovery when pitching strategies to clients and senior management. The same template could be used by contributors to academic journals so that referees, and ultimately readers, can assess the strategy. By disclosing this information, those who are charged with making the final decision about a discovery can evaluate the probability that the purported discovery is false.

Fan, Z., Londono, J. M., and Xiao, X. (2022a). "Equity tail risk and currency risk premiums." In: *Journal of Financial Economics* 143(1), pp. 484–503.
We find that an option-based equity tail risk factor is priced in the cross section of currency returns; more exposed currencies offer a low risk premium because they hedge against equity tail risk. A portfolio that buys currencies with high equity tail beta and shorts those with low beta extracts the global component in the tail factor. The estimated price of risk of this novel global factor is consistently negative in currency carry and momentum portfolios, and in portfolios of other asset classes, suggesting that excess returns of these strategies can be partially understood as compensations for global tail risk.

Fan, Z., Xiao, X., and Zhou, H. (2022b). "Moment Risk Premia and Stock Return Predictability." In: *Journal of Financial and Quantitative Analysis* 5757(11), pp. 67-9367–93.
We study the predictive power of option-implied moment risk premia embedded in the conventional variance risk premium. We find that although the second-moment risk premium predicts market returns in short horizons with positive coefficients, the third-moment (fourth-moment) risk premium predicts market returns in medium horizons with negative (positive) coefficients. Combining the higher-moment risk premia with the second-moment risk premium improves the stock return predictability over multiple horizons, both in sample and out of sample. The finding is economically significant in an asset-allocation exercise and survives a series of robustness checks.

Farahani, A. and Yan, M. (2014). *Constructing a Liability Hedging Portfolio: A Guide to Best Practices for US Pension Plans*. Tech. rep. Cambridge Associates.
To construct an effective liability hedging portfolio, a key first step is to evaluate the variety of ways liabilities can be calculated and discounted and to identify the most relevant liability metric for a plan sponsor's circumstances. Plan sponsors should also define the acceptable level of surplus risk and carefully consider the appropriate duration of the liability hedging assets-shorter duration assets often have a meaningful mismatch to most defined benefit pension liabilities. Plan sponsors should not construct a liability hedge in isolation, as the size and composition of both the growth portfolio and liability hedge will have important implications for each other. Since the end goal is to maximize portfolio return at a controlled level of risk, the liability hedging portfolio should not attempt to perfectly immunize a cash flow stream-an extremely difficult task when considering real world constraints of corporate bond issuance, transaction costs, and liquidity-but rather optimize duration, curve, and credit spread exposures within the broader context of the total plan's risks related to both its assets and liability. We recommend plan sponsors consider the use of more complex fixed income structures to manage their liability hedge programs. Most notably, we believe prudent use of derivatives (and, implicitly, some degree of portfolio leverage) should be considered, as bond futures, interest rate swaps, swaptions, and other techniques provide far more flexibility to optimize the portfolio when compared to a plain vanilla physical bond portfolio. Derivatives may also allow for a more capital-efficient liability hedging allocation, which we believe is paramount when looking at the low level of return provided by fixed income in the current environment. Still, even with these derivatives-based strategies, a "perfect hedge"is not attainable. Plan sponsors should think carefully about the active management implications of constructing the liability hedge, particularly for those plans that target low surplus volatility and maintain heavy allocations to fixed income. In normal environments, a plan with the majority of its liability hedging assets devoted to bond managers (typically with moderate tracking error) will not be able to generate the same level of value add as a plan with a more diversified portfolio invested in higher active risk strategies such as equities, hedge funds, and private investments. Best practices when developing a liability hedging framework include: Understanding and defining the liability, 1) Quantifying acceptable surplus risk, 2) Acknowledging the basis risks in replicating the liability hedging benchmark, 3) Monitoring the interaction of credit and equities, 4) Emphasizing capital efficiency given the lower returns of liability hedging assets, and 5) Considering derivatives as part of the toolkit.

Ferreira, M. M. G. (2021). "Using option-implied information in portfolio selection and risk management." MA thesis. Universidade Catolica Portuguesa.
The objective of this dissertation is two-fold. The first objective is to examine whether one can use implied information (implied volatility and implied correlations) from the options market to improve the out-of-sample performance of an all-stock optimized portfolio. Portfolio performance is measured using three metrics, namely, returns, volatility, and the Sharpe Ratio. The second objective is to examine the risk metrics of the portfolios to analyze whether a portfolio created using option-implied information is better at predicting risk than one using a conventional sample covariance matrix. This is done by calculating the portfolios VaR using a variety of methodologies. Empirically, this dissertation finds that the use of option-implied volatility when estimating the covariance matrix was able to increase the Sharpe Ratio of both constrained and unconstrained portfolios. There

was no improvement to performance when option-implied correlation was added to the optimization process, thus the primary mechanism for improving performance was the ability to predict asset volatility. The risk management aspect of the dissertation provides two interesting findings. It finds that the use of a covariance matrix using option implied information is better at estimating hit rates than the sample covariance matrix. Also, there is evidence that the use of option implied information in the portfolio selection process reduces tail risk.

Flint, E. J. and Mare, E. (2016). "Estimating Option-Implied Distributions in Illiquid Markets and Implementing the Ross Recovery Theorem." In: *SSRN e-Print*.

We describe how forward-looking information on the statistical properties of an asset can be extracted directly from options market data and how this can be used practically in portfolio management. Although the extraction of a forward-looking risk-neutral distribution is well-established in the literature, the issue of estimation in an illiquid market is not. We use the deterministic SVI volatility model to estimate weekly risk-neutral distribution surfaces. The issue of calibration with sparse and noisy data is considered at length and a simple but robust fitting algorithm is proposed. Furthermore, we attempt to extract real-world implied information by implementing the recovery theorem introduced by Ross (2015). Recovery is an ill-posed problem that requires careful consideration. We describe a regularization methodology for extracting real-world implied distributions and implement this method on a history of SVI volatility surfaces. We analyse the first four moments from the implied risk-neutral and real-world implied distributions and use them as signals within a simple tactical asset allocation framework, finding promising results.

Flint, E. J., Seymour, A. J., and Chikurunhe, F. (2016a). "In Search of the Perfect Hedge Underlying." In: *SSRN e-Print*.

This report attempts to answer the question: What underlying portfolio should one use to hedge an active fund? We introduce a framework which allows us to conduct analysis on simulated realistic active portfolios in order to build intuition as to how hedge mismatch error affects the level of protection from a given hedge. We show that for typical market conditions, hedge effectiveness improves dramatically when using a hedge portfolio that more accurately reflects the underlying portfolio. This has clear consequences for using generic index options to hedge highly active portfolios. We also showcase several active return and tracking error decompositions that allow one to precisely quantify and thus manage the sources of risk and rewards within a given portfolio. We then discuss a mixed integer quadratic programming formulation that enables us to search across a large investment universe in order to find the subset of stocks that most closely replicates a given portfolio's performance, whilst simultaneously complying with realistic market constraints. Motivated by these three elements, we introduce several alternative hedging methods for the fund manager to implement a better hedge for their active portfolio. In this report, we focus specifically on the use of long-only and long/short custom basket options as a means of creating an appropriate portfolio hedge.

Flint, E. J., Seymour, A. J., and Chikurunhe, F. (2016b). "The Information Hidden in Derivatives Markets." In: *SSRN e-Print*.

One of the most important aspects in portfolio management is having an accurate understanding of the future possible returns of the underlying assets. Unfortunately, estimating such return distributions is anything but trivial. In this research, we consider the information embedded in the derivatives market. Derivatives are forward-looking instruments by design and thus should contain forward-looking information about their underlying assets.We describe how forward-looking information on the statistical properties of an asset can be extracted directly from options market data and how this can be used practically in portfolio management. While the extraction of a forward-looking risk-neutral distribution is well-established in the literature, obtaining information on future real-world distributions was until recently thought to be impossible. However, recent work by Ross (2015) has shown that it is indeed possible to derive exactly this distribution purely from options market data. We describe a robust implementation of Ross's method on a history of weekly Top40 Index and USDZAR implied volatility surfaces. We outline some graphical ideas on how one can use this information descriptively and prescriptively and furthermore analyse the recovered moments - expected return, volatility, skewness and kurtosis - from the implied distributions. These recovered real-world moments are shown to be in line with economic rationale and also show promising results when used as signals within a simple TAA framework.

Flint, E. J. (2019). "Quantitative topics in portfolio and risk management." PhD thesis. University of Pretoria.

The modern quantitative portfolio manager is the quintessential "jack of all trades". Not only do they need to be an expert in the specific area of portfolio management, they also need to have a thorough understanding of the related areas of valuation, data processing, risk management and performance analysis. What this means

practically is that quantitative portfolio managers are regularly faced with problems spanning the entire P - Q spectrum of quantitative finance. Spurred by this reality, the central research question motivating this thesis is exactly the core motivation behind every decision taken by a quantitative portfolio manager: What is the most efficient, practical method for constructing, managing and evaluating optimal multi-asset portfolios in dynamic, non-normal markets? In this thesis, we attempt to provide insight into this broad central research question by offering new perspectives and practical solutions to a selection of subproblems that a quantitative portfolio manager would have to address in practice. In particular, this thesis is comprised of six essays that each tackle specific problems in the related areas of derivatives, return modelling, systematic trading strategies and portfolio construction.

Fu, X., Arisoy, Y. E., Shackleton, M. B., and Umutlu, M. (2016). "Option-Implied Volatility Measures and Stock Return Predictability." In: *The Journal of Derivatives* 24(1), pp. 58–78.
Do changes in implied volatilities (IVs) or differences among options at different spots on the volatility surface contain predictive information for future returns? The question has been asked repeatedly-and often answered in the affirmative for specific measures-but questions remain. In this article, the authors perform a comparison test on six return predictors that are all computed as differences among implied and realized volatilities and that have been proposed in the literature. The authors consider more measures, more maturities, and longer samples than earlier articles, and they include a variety of appropriate control variables. They find that the difference between at-the-money (ATM) call and put IV (CPIV) and out-of-the-money (OTM) put IV minus ATM call IV are both highly significant at the individual stock level, while a long-short portfolio strategy based on realized minus implied volatility does very well. The alternative volatility combinations are substantially less effective as return predictors.

Fusari, N., Jarrow, R., and Lamichhane, S. (2020). "Testing for Asset Price Bubbles using Options Data." In: *SSRN e-Print*.
We present a new approach to identifying asset price bubbles based on options data. Given their forward-looking nature, options are ideal instruments with which to investigate market expectations about the future evolution of asset prices, which are key to understanding price bubbles. By exploiting the differential pricing between put and call options, we can detect and quantify bubbles in the prices of underlying asset. We apply our methodology to two stock market indexes, the S&P 500 and the Nasdaq-100, and two technology stocks, Amazon and Facebook, over the 2014-2018 sample period. We find that, while indexes exhibit rare and modest bubbles, Amazon and Facebook show more frequent and much larger bubbles. Since our approach can be implemented in real time, it is useful to both policy-makers and investors.

Gagnon, M.-H., Power, G., and Toupin, D. (2020). "The Sum of All Fears: Forecasting International Returns using Option-implied Risk Measures." In: *SSRN e-Print*.
This paper investigates international index return predictability using daily-updated option-implied information in predictive regressions and out-of-sample forecasts. We document the significant predictive power of the variance risk premium (VRP), Generalized Riskiness (GR), and higher-order moments for horizons ranging from 1 to 250 days. These four risk metrics, which capture cumulative market "fears", perform well in the US and internationally. VRP and GR are significant and complementary predictors for several horizons, including under one month (VRP) and longer horizons (GR). Risk-neutral skewness and kurtosis are significant for several countries across multiple horizons. Utility gain calculations confirm the economic significance of these risk-neutral variables internationally.

Gagnon, M.-H., Power, G. J., and Toupin, D. (2021). "Forecasting market index volatility using Ross-recovered distributions." In: *Quantitative Finance*.
The Ross recovery theorem shows that option data can reveal the market's true (physical) expectations. We adapt this approach to international index options data (S&P, FTSE, CAC, SMI, and DAX) to improve volatility forecasting. We separate implied volatility into Ross-recovered expected volatility and a risk preference proxy. We investigate the performance of these variables, constructed domestically or globally, to forecast realized volatility as well as index excess returns. The results show evidence of significantly improved forecasts and yield new insights on the international dynamics of risk expectations and preferences. Across indexes, models using Ross-recovered, value-weighted global measures of risk preferences perform best. The findings suggest that the recovery theorem is empirically useful.

Ge, W. (2017). "Stress-Testing Volatility Risk Premium Harvesting Strategies Based on S&P 500 Index Options." In: *The Journal of Index Investing* 8(1), pp. 37–46.

The volatility risk premium (VRP), commonly accessed by writing equity index options, can help investors enhance portfolio returns. Some investors, however, have an aversion to options selling, especially put options, because they fear significant losses in a financial crisis. This article examines this aversion by analyzing the performance of two VRP-harvesting strategies based on writing out-of-the-money SandP 500 Index options (the dedicated VRP and the overlay VRP constructs) in market distress and comparing them with the SandP 500 Index. All series are stress-tested with five historical crisis episodes in the last three decades and three additional extreme scenarios modeled after the worst stock market crashes in the past century. The analysis reveals that the VRP strategies can achieve their objective of outperforming the market and mitigating investors' losses during financial distress. The performance of the VRP constructs in a crisis depends on two main factors: the beta of the VRP strategy and the speed of the market crash. This article concludes that investors' aversion to option selling may be unjustified and they may benefit significantly from the VRP at all times, especially in today's market, when expected returns from traditional assets are subdued.

Ge, W. (2018). "Alternatives to alternative assets: assessing S&P 500 index option strategies as hedge fund replacements." In: *The Journal of Alternative Investments* 20(4), pp. 69–80.

Hedge funds should deliver good risk-adjusted returns and provide diversification for investors portfolios. However, the performance of hedge funds has deteriorated in recent years and many investors may not find investment in hedge funds suitable, due to the high costs, illiquidity, and lack of transparency. The focus of this study is to examine whether equity index option-based strategies may deliver the same coveted ideal hedge fund return characteristics, that is, good risk-adjusted returns, mitigated risk measures, and added diversification. A total of seven S&P 500 Index-based generic option-writing strategies, named CP100 to CP0, are analyzed and compared with a comprehensive set of fourteen Credit Suisse hedge fund indexes using volatility or beta as matching metrics. The three series of CP100, CP80, and CP50, can be viewed as a solid suite of liquid alternatives to hedge funds. They match the fourteen Credit Suisse hedge fund indexes on beta levels, but deliver better risk-adjusted returns. Their annual returns and risk measures are better than or on par with the hedge fund indexes, except for the Credit Suisse Global Macro Index, which may be matched by a levered version of the CP100 option strategy. This suite of three option strategies are transparent, liquid, inexpensive, and easy to implement. They can achieve the same goals of hedge funds: attractive risk-adjusted returns, subdued risks, and added diversification. They may play multiple and important roles in institutional investors portfolios.

Ge, W. (2019). "Using the volatility risk premium to mitigate the next financial crisis." In: *The Journal of Wealth Management* 22(3), pp. 85–97.

Ten years have passed since the trough of the Global Financial Crisis, and the US equity market has experienced one of the longest stretches of ascent in history. Some investors have started questioning whether the US stock market is overvalued and if a recession is on the way. It is usually impossible to predict the next financial crisis. An investor best course of action may be to adjust the investment portfolio to be resilient against potential market headwinds. This paper argues for utilizing the Volatility Risk Premium (VRP), specifically option-selling VRP strategies, to mitigate the losses the portfolio may suffer from a future financial crisis. Such a VRP strategy, if implemented with out-of-the-money equity index options, can help investors cushion the losses from an equity market crash and recover more quickly than the broad equity market. Investors can utilize the VRP by itself or combine it with traditional equity to construct the most suitable investment strategies. This paper further examines implementation choices of such strategies and stress test their performance with four representative crises from the past three decades.

Giamouridis, D. and Skiadopoulos, G. S. (2012). "The Informational Content of Financial Options for Quantitative Asset Management: A Review." In: *Handbook of quantitative asset management*. Ed. by B. Scherer and K. Winston. Oxford University Press.

This paper surveys the literature that deals with the informational content of market option prices for the purposes of quantitative asset management. We review studies that have investigated whether market option prices may help a portfolio manager in the stock selection process, portfolio construction, risk measurement and management. The main ideas are highlighted and the advantages and limitations are outlined. The use of market option prices for stock market and style timing is also discussed and some key papers on the informational role of option's volume are presented.

Golez, B. and Goyenko, R. (2022). "Disagreement in the Equity Options Market and Stock Returns." In: *The Review of Financial Studies*. 35th ser. 3, pp. 1433–1479.

We estimate investor disagreement from synthetic long and short stock trades in the equity options market. We show that high disagreement predicts low stock returns after positive earnings surprises and high stock

returns after negative earnings surprises. The negative effect is stronger for high-beta stocks and stocks that are more difficult to sell short. In the cross-section of all stocks and the subset of the 500 largest companies, high disagreement robustly predicts low monthly and weekly stock returns.

Goyenko, R. and Zhang, C. (2021). "The Joint Cross Section of Option and Stock Returns Predictability with Big Data and Machine Learning." In: *SSRN e-Print*.
Using large set of stock and option specific characteristics, and machine learning, we first provide a comprehensive analysis of what drives expected delta hedged and delta-neutral straddle returns of equity options. In contrast to the previous literature, we find that option, rather than stock, characteristics are important predictors of option returns. Second, option, rather than stock, characteristics are also important predictors of stock returns. Moreover, stock characteristics alone fail to predict cross-section of stock returns in recent data. In terms of variables importance for stock return predictability, most of machine learning methods we use outweigh option illiquidity. Consequently, stock long-short portfolio strategies formed conditioning on options illiquidity outperform in out-of-sample those of machine learning portfolios, and the market overall. The results are consistent with substantial increase in options trading activity compared to stocks, and that options markets leading stock markets in recent years.

Greiner, S. P. and Stoyanov, S. V. (2019). "Portfolio scoring by expected risk premium." In: *The Journal of Portfolio Management* 45(4), pp. 83–90.
In this article, the authors discuss a general method for ranking portfolios that places few limitations on the portfolio constituents other than using publicly traded assets. The ranking scores reflect the expected reward investors would require for accepting the risks of the portfolio in the context of an asset pricing framework. The scores are computed through a factor model that acknowledges the factor return correlations. The authors illustrate the approach with a large universe of exchange-traded funds assuming a linear model with Fama-French-Carhart factors wherein factor premiums (i.e., expected returns) are proportional to factor volatilities. The empirical analysis implies that the most significant factors from the Fama-French-Carhart factor set driving the premiums are the market and the momentum factors.

Guidolin, M., Hansen, E., and Lozano-Banda, M. (2018). "Portfolio performance of linear SDF models: an out-of-sample assessment." In: *Quantitative Finance* 18(8), pp. 1425–1436.
We evaluate linear stochastic discount factor models using an ex-post portfolio metric: the realized out-of-sample Sharpe ratio of mean-variance portfolios backed by alternative linear factor models. Using a sample of monthly US portfolio returns spanning the period 1968-2016, we find evidence that multifactor linear models have better empirical properties than the CAPM, not only when the cross-section of expected returns is evaluated in-sample, but also when they are used to inform one-month ahead portfolio selection. When we compare portfolios associated to multifactor models with mean-variance decisions implied by the single-factor CAPM, we document statistically significant differences in Sharpe ratios of up to 10 percent. Linear multifactor models that provide the best in-sample fit also yield the highest realized Sharpe ratios.

Guo, D. (2019). "A Statistical Response to Challenges in Vast Portfolio Selection." PhD thesis. University of Waterloo.
The thesis is written in response to emerging issues brought about by an increasing number of assets allocated in a portfolio and seeks answers to puzzling empirical findings in the portfolio management area. Over the years, researchers and practitioners working in the portfolio optimization area have been concerned with estimation errors in the first two moments of asset returns. The thesis comprises several related chapters on our statistical inquiry into this subject. Chapter 1 of the thesis contains an introduction to what will be reported in the remaining chapters. A few well-known covariance matrix estimation methods in the literature involve adjustment of sample eigenvalues. Chapter 2 of the thesis examines the effects of sample eigenvalue adjustment on the out-of-sample performance of a portfolio constructed from the sample covariance matrix.

Guo, D., Boyle, P. P., Weng, C., and Wirjanto, T. S. (2019). "When Does The 1/N Rule Work?" In: *SSRN e-Print*.
We propose a "1/N favorability index" to measure how favorable a market is to holding a 1/N portfolio. This index reflects the extent of difficulty for an optimized portfolio to outperform the 1/N portfolio in a specific market. A single-factor model predicts that bull markets are accompanied by a high 1/N favorability index and vice versa. We validate the model implication that the 1/N portfolio is more difficult to beat in bull markets using stock return datasets from a number of countries as well as the classic datasets used by DeMiguel et al. (2009). Our results imply that the reported good performance of the 1/N portfolio in the US equity market can be partially attributed to the long-run bullish trend in the market which gives rise to the high favorability of the market to the 1/N portfolio.

Haghani, V., Ragulin, V., and White, J. (2022). "Do Options Belong in the Portfolios of Individual Investors?" In: *The Journal of Derivatives* 29(3), pp. 13–38.
The use of options by individual investors has grown dramatically in recent years. The authors evaluate several popular options strategies, including portfolio insurance, life cycle investing, buy-write, and single-stock call-buying, from the perspective of an individual investor. The authors suggest that Expected Utility is the most appropriate metric for such evaluation, as it accounts for both return and risk, and naturally handles non-linear payoffs. They assess the different options strategies under a range of assumptions of asset price behavior, investor risk appetite, and option market pricing relative to fair value. They find that for a representative investor the benefit of adding options to the portfolio is at best quite small, and most of this improvement also can be achieved through periodic portfolio rebalancing. However, the benefits of options can be greater for several special investor categories and in certain market environments. The authors also identify several popular uses of options that are likely to be quite harmful to investor welfare.

Haley, M. R. (2017). "K-fold cross validation performance comparisons of six naive portfolio selection rules: how naive can you be and still have successful out-of-sample portfolio performance?" In: *Annals of Finance* 13, pp. 341–353.
Recent research reports that optimal portfolio selection models often perform worse than equal-weight naive diversification in out-of-sample testing. This paper extends this line of inquiry by comparing the out-of-sample performance of the equal-weight naive strategy to the out-of-sample performance of five alternative naive strategies, each of which derives from a simple heuristic that does not require any optimization. Out-of-sample portfolio performance is assessed by mean, standard deviation, skewness, and Sharpe ratio; k-fold cross validation is used as the out-of-sample testing mechanism. The results indicate that the proposed naive heuristic rules exhibit strong out-of-sample performance, in most cases superior to the equal-weight naive strategy. These findings are consequential for at least two reasons: first, if these simple heuristic-based rules outperform the equal-weight naive strategy, then by transitivity they can outperform the mean-variance- and shortfall-optimal portfolio rules that have been shown in the literature to be inferior to the equal-weight naive rule, which further emphasizes the out-of-sample fragility of "optimal"methods; and second, among naive diversification strategies, some appear more robust in out-of-sample testing than others, hence the proposed methods may be useful when forming mixed portfolio selection models wherein a naive strategy is combined with an optimal strategy to improve performance.

Harvey, C. R., Hoyle, E., Rattray, S., Sargaison, M., Taylor, D., and Van Hemert, O. (2019). "The best of strategies for the worst of times: can portfolios be crisis proofed?" In: *The Journal of Portfolio Management* 45(5), pp. 7–28.
In the late stages of long bull markets, a popular question arises: What steps can an investor take to mitigate the impact of the inevitable large equity correction? Hedging equity portfolios is notoriously difficult and expensive. In this article, the authors analyze the performance of different tools that investors could deploy. For example, continuously holding short-dated S&P 500 put options is the most reliable defensive method but also the most costly strategy. Holding safe-haven US Treasury bonds produces a positive carry but may be an unreliable crisis-hedge strategy because the post-2000 negative bond-equity correlation is a historical rarity. Long gold and long credit protection portfolios sit between puts and bonds in terms of both cost and reliability. Dynamic strategies that performed well during past drawdowns include futures time-series momentum (which benefits from extended equity sell-offs) and a quality strategy that takes long (short) positions in the highest (lowest) quality company stocks (which benefits from a flight-to-quality effect during crises). The authors examine both large equity drawdowns and recessions. They also provide some out-of-sample evidence of the defensive performance of these strategies relative to an earlier, related article.

Harvey, C. R., Liu, Y., and Saretto, A. (2020). "An Evaluation of Alternative Multiple Testing Methods for Finance Applications." In: *The Review of Asset Pricing Studies* 10(2), pp. 199–248.
In almost every area of empirical finance, researchers confront multiple tests. One high-profile example is the identification of outperforming investment managers, many of whom beat their benchmarks purely by luck. Multiple testing methods are designed to control for luck. Factor selection is another glaring case in which multiple tests are performed, but numerous other applications do not receive as much attention. One important example is a simple regression model testing five variables. In this case, because five variables are tried, a t-statistic of 2.0 is not enough to establish significance. Our paper provides a guide to various multiple testing methods and details a number of applications. We provide simulation evidence on the relative performance of

different methods across a variety of testing environments. The goal of our paper is to provide a menu that researchers can choose from to improve inference in financial economics.

He, Y. (2021). "Optimization-based Tail Risk Hedging." MA thesis. University of Toronto.
This thesis presents a mixed risk-return optimization framework for selecting long put option positions to hedge the tail risk of investments. We formulate tractable optimization models by utilizing hypothetical portfolios that roll put options on a constant basis. Variance and sample Conditional Value-at-Risk (CVaR) are used as risk measures. Firstly, the tail risk hedging for a single asset such as the S 500 ETF is considered. Our proposed models are tested against the out-of-sample historical S 500 index values as well as the values of the index paired with long put options of varying strike prices. The optimized hedged portfolios could provide sufficient protection in market downturns while not losing significant returns in a longer investment horizon without explicitly predicting future market behavior. This is achieved by dynamically adjusting the positions of put options with different protection levels according to the market trends. Allocations to different put options are analyzed under various market trends and investor risk aversion levels. Then our framework is extended to multiple underlying assets and put options associated with them by constructing a hypothetical portfolio consisting of a combination of each put option and the associated underlying asset. The optimized strategies overcome traditional drawbacks associated with protective put strategies, as well as outperform the strategies of investing directly in the underlying assets and holding constant long positions in put options.

Hens, T., Schenk-Hoppe, K. R., and Woesthoff, M.-H. (2020). "Escaping the backtesting illusion." In: *The Journal of Portfolio Management* 46(4), pp. 81–93.
Two tests can help asset managers to develop more robust investment strategies: an impact test and a survival test. Both tests complement the backtest, in which one checks how a proposed investment strategy would have performed in the past. The impact test considers the performance of the strategy when assets under management grow (crowdedness), and it checks the impact that growth in assets under management in competing strategies has on the proposed strategy (cross impact). The survival test considers the effect of the long-term evolution of assets under management in competition for market capital. Using Shiller S&P 500 index and bond market data, we show that time-series momentum (relative strength) performs best in the backtest and the impact test but that an expected relative cash-flow rule (relative dividend yield) has the best long-term survival properties.

Hollstein, F., Prokopczuk, M., Tharann, B., and Simen, C. W. (2010). "Predicting the equity market with option-implied variables." In: *The European Journal of Finance* 25(10), pp. 937–965.
We comprehensively analyze the predictive power of several option-implied variables for monthly S&P 500 excess returns and realized variance. The correlation risk premium (CRP) and the variance risk premium (VRP) emerge as strong predictors of both excess returns and realized variance. This is true both in- and out-of-sample. Our results also reveal that statistical evidence of predictability does not necessarily lead to economic gains. However, a timing strategy based on the CRP leads to utility gains of more than 5.03% per annum. Forecast combinations provide stable forecasts for both excess returns and realized variance, and add economic value.

Horvath, F. (2021). "Arbitrage-Based Recovery." In: *SSRN e-Print*.
We develop a novel recovery theorem based on no-arbitrage principles. Our Arbitrage-Based Recovery Theorem does not require assuming time homogeneity of either the physical probabilities, the Arrow-Debreu prices, or the stochastic discount factor; and it requires the observation of Arrow-Debreu prices only for one single maturity. We perform several different density tests and mean prediction tests using 25 years of S&P 500 options data, and we find evidence that our method can correctly recover the probability distribution of the S&P 500 index level on a monthly horizon.

Hsu, Y.-C., Lin, H.-W., and Vincent, K. (2017). *Do Cross-Sectional Stock Return Predictors Pass the Test without Data-Snooping Bias?* Tech. rep. Institute of Economics Academia Sinica.
This study examines the possible data-snooping bias as a competing explanation for the anomalies in the cross-section of stock returns. We posit that the exhaustive standalone searches for profitable strategies could lead to recommending spuriously predictive variables. In order to explore the severity of this problem, we use a multiple testing method to evaluate the profitability of portfolios constructed by these predictors. Our empirical analyses suggest that over half of the findings based on individual testing method are no longer statistically significant after we adjust for data-snooping bias. Excluding the micro-cap stocks before portfolios construction and applying the notion of economic significance in this study further weaken the evidence for predictability.

Hsu, P.-H., Han, Q., Wu, W., and Cao, Z. (2018). "Asset allocation strategies, data snooping, and the 1 / N rule." In: *Journal of Banking & Finance* 97, pp. 257–269.

Using a series of advanced tests from White's (2000) Check to correct for data-snooping bias, we assess the out-of-sample performance of various portfolio strategies relative to the naive 1/N rule. When we analyze 16 basic portfolio strategies, 126 learning strategies, and nearly 2,000 extended strategies, we find that some strategies outperform the 1/N rule in conventional tests that do not account for data-snooping bias. However, after we use the new tests that control for such bias, we find that none or very few of these strategies outperform the 1/N rule. Thus, our finding underscores the necessity to control for data-snooping bias when making asset allocation decisions.

Huang, M. and Yu, S. (2020). "A new procedure for resampled portfolio with shrinkaged covariance matrix." In: *Journal of Applied Statistics* 47(44), pp. 642–652.
Dealing with estimation error is an important issue when we implement the mean-variance paradigm for portfolio construction. To tackle the problem, two approaches are proposed in literature, the portfolio resampling technique introduced by Michuad and the well-known shrinkaged covariance matrix method. There are certain evidences on the advantages of shrinkaged covariance over portfolio resampling, however, it is unclear whether a combination of the two approaches could produce a better performance compared with using shrinkaged covariance alone. In this paper, we propose a new algorithm to integrated linear or nonlinear shrinkage estimation with resampled portfolio to achieve a further improvement. Our method are demonstrated via extensive simulation and application in active portfolio management process.

Huggenberger, M., Zhang, C., and Zhou, T. (2018). "Forward-Looking Tail Risk Measures." In: *SSRN e-Print*.
We present an analytical framework for the forward-looking measurement of extreme market risk. In contrast to standard techniques relying on past return data, we propose to extract Value-at-Risk and Expected Shortfall under the physical measure from current option prices. Our empirical evidence suggests that the resulting estimates accurately capture the tail risk of the S&P 500 and that they quickly react to changing market conditions. Compared to dynamic tail risk forecasts driven by past returns, our forward-looking estimates are relatively higher during good times and lower during adverse economic conditions, which could reduce the amplification effects of conventional dynamic risk management policies.

Hull, J. C., Sokol, A., and White, A. (2014). "Modeling the Short Rate: The Real and Risk-Neutral Worlds." In: *SSRN e-Print*.
In this paper, we propose a way to construct a single forward-looking model for interest rates, which represents their evolution under both the Q-measure and P-measure (a joint measure model). As is well known, the market prices of contingent claims are independent of investor risk preferences. This means that risk preferences, and therefore real world processes, cannot be obtained from market prices alone. Using a new concept, the local price of risk, we present a simple way in which historical data can be used in conjunction with market prices to create a joint measure model for the short rate and estimate the real world drift in interest rates. The local price of risk can be used for a wide range of interest rate models.

Hwang, I., Xu, S., and In, F. (2018). "Naive versus optimal diversification: Tail risk and performance." In: *European Journal of Operational Research* 265(1), pp. 372–388.
It is well documented in portfolio optimization that naive diversification outperforms optimal mean-variance diversification because the latter is subject to severe estimation error. Our study provides an alternative explanation for the outperformance of naive diversification by examining the tail risk of naive diversification relative to optimal mean-variance diversification. We utilize a rolling-sample approach and compare the out-of-sample performance and tail risk of various optimal strategies to that of the naive diversification strategy. Using portfolios consisting of individual stocks, we show that for portfolios containing relatively small number of stocks, naive diversification outperforms optimal mean-variance diversification and is less exposed to tail risk. However, for relatively large number of stocks in the portfolio, naive diversification maintains its superior performance but increases tail risk and results in more concave portfolio returns. These results imply that the outperformance of naive diversification acts as compensation for the increase in tail risk and concavity.

Ielpo, F., Merhy, C., and Simon, G. (2017). *Engineering Investment Process: Making Value Creation Repeatable*. Elsevier. 430 pp.
The book explores the quantitative steps of a financial investment process. The authors study how these steps are articulated in order to make any value creation, whatever the asset class, consistent and robust. The discussion includes factors, portfolio allocation, statistical and economic backtesting, but also the influence of negative rates, dynamical trading, state-space models, stylized facts, liquidity issues, or data biases. Besides the quantitative concepts detailed here, the reader will find useful references to other works to develop an in-depth understanding of an investment process.

Israelov, R. (2019). "Pathetic protection: the elusive benefits of protective puts." In: *The Journal of Alternative Investments*.
Conventional wisdom is that put options are effective drawdown protection tools. Unfortunately, in the typical use case, put options are quite ineffective at reducing drawdowns versus the simple alternative of statically reducing exposure to the underlying asset. This article investigates drawdown characteristics of protected portfolios via simulation and a study of the CBOE SandP 500 5% Put Protection Index. Unless option purchases and their maturities are timed just right around equity drawdowns, they may offer little downside protection. In fact, they could make things worse by increasing rather than decreasing drawdowns and volatility per unit of expected return.

Israelov, R. and Nielsen, L. N. (2015). "Still not cheap: portfolio protection in calm markets." In: *SSRN e-Print*.
Recent equity volatility is near all-time lows. Option prices are also low. Many analysts suggest this represents a good opportunity to purchase put options for portfolio insurance. It is well-known that portfolio insurance is expensive on average, but what about in calm markets? History suggests it still is. We investigate the relationship between option richness and volatility across ten global equity indices. Option prices may be low, but their expected values tend to be even lower.

Israelov, R. and Tummala, H. (2018). "An Alternative Option to Portfolio Rebalancing." In: *The Journal of Derivatives* 25(3), pp. 7–32.
Portfolio managers, whether running a passive or an active strategy, typically select target weights on the various asset classes and securities they hold. The prime example is choosing the mix between stocks and bonds. But as market prices evolve, actual weights drift away from the targets. This leads to tracking error and transaction costs in order to rebalance positions to the desired levels. Rebalancing entails selling assets that have gone up in value and increasing exposure to those whose prices have dropped. As Israelov and Tummala point out, this is how a short position in a call option behaves, and they show how to design a hedging strategy based on writing calls that offsets much of the basis risk in trying to run a portfolio with fixed asset weights. An empirical illustration shows that their proposed overlay strategy would have performed well historically in reducing unintended timing risk in a 60/40 stock/bond portfolio. An additional benefit of the plan is that by selling options, it harvests the volatility risk premium embedded in their prices, which enhances returns at the same time risk is being reduced.

Israelov, R. and Tummala, H. (2020). "Being Right Is Not Enough: Buying Options to Bet on Higher Realized Volatility." In: *The Journal of Alternative Investments* 23(2), pp. 16–34.
Speculators who wish to bet on higher future volatility often purchase options to "go long volatility." Should investors who buy options expect to profit when realized volatility increases? If so, under what conditions? To answer these questions, we conducted an analysis of the relationship between long volatility performance (buying options) and contemporaneous changes in volatility. We found that buying one-month S&P 500 options was only consistently profitable in the highest decile of changes in one-month volatility. Buying options consistently lost money in the lowest seven deciles of changes in volatility. We then studied the trade entry and exit timing required to retain the profits from long option positions during significant volatility increases. We found similar results between the S&P 500 options market and global equity option markets.

Al-Jaaf, A. (2022). "Dividend predictability and higher moment risk premia." In: *Journal of Asset Management* 28, pp. 83–99.
I use model-free methods to estimate the term structures of the variance risk premium (VRP) and the skewness risk premium (SRP) derived from dividend futures and options. I find that VRP is on average negative, whereas SRP is on average positive. They have unique characteristics and can hardly be explained by equity risk factors and equity moment risk premia. I present evidence that both dividend moment risk premia contain significant forecasting power for dividend futures returns in- and out-of-sample. Dividend futures returns are predicted by the VRP (SRP) in almost all setups with a negative (positive) sign.

Jackwerth, J. C. and Menner, M. (2020). "Does the Ross recovery theorem work empirically?" In: *Journal of Financial Economics* 137(3), pp. 723–739.
Starting with the fundamental relation that state prices are the product of physical probabilities and the stochastic discount factor, Ross (2015) shows that, given strong assumptions, knowing state prices suffices to back out physical probabilities and the stochastic discount factor at the same time. We find that such recovered physical distributions based on the S&P 500 index are incompatible with future returns and fail to predict future returns and realized variances. These negative results are even stronger when we add economically reasonable constraints. Simple benchmark methods based on a power utility agent or the historical return distribution cannot be rejected.

Jaeger, M., Krugel, S., Marinelli, D., Papenbrock, J., and Schwendner, P. (2020). "Understanding machine learning for diversified portfolio construction by explainable AI." In: *SSRN e-Print*.
In this paper, we construct a pipeline to investigate heuristic diversification strategies in asset allocation. We use machine learning concepts ("explainable AI") to compare the robustness of different strategies and back out implicit rules for decision making.In a first step, we augment the asset universe (the empirical dataset) with a range of scenarios generated with a block bootstrap from the empirical dataset.Second, we backtest the candidate strategies over a long period of time, checking their performance variability. Third, we use XGBoost as a regression model to connect the difference between the measured performances between two strategies to a pool of statistical features of the portfolio universe tailored to the investigated strategy. Finally, we employ the concept of Shapley values to extract the relationships that the model could identify between the portfolio characteristics and the statistical properties of the asset universe. We test this pipeline for studying risk-parity strategies with a volatility target, and in particular, comparing the machine learning-driven Hierarchical Risk Parity (HRP) to the classical Equal Risk Contribution (ERC) strategy.In the augmented dataset built from a multi-asset investment universe of commodities, equities and fixed income futures, we find that HRP better matches the volatility target, and shows better risk-adjusted performances. Finally, we train XGBoost to learn the difference between the realized Calmar ratios of HRP and ERC and extract explanations.The explanations provide fruitful ex-post indications of the connection between the statistical properties of the universe and the strategy performance in the training set. For example, the model confirms that features addressing the hierarchical properties of the universe are connected to the relative performance of HRP respect to ERC.

Jensen, C. S. (2021). "The Ex Ante Physical Distributions of Individual Stock Returns." In: *SSRN e-Print*.
I present a method for deriving the entire physical return distributions of individual stocks directly from option prices. The method is theoretically nested in an equilibrium model, obeys the law-of one-price, and can be implemented in real-time in a forward-looking manner. The method performs well out-of-sample in predicting ex-post distributions of individual stock returns. The physical stock distributions and the co-moments with the market are important for risk-management decisions, portfolio allocation, and can help understand the cross-section of returns. A tradeable long-short portfolio that buys (sells) low (high) co-skewness stocks yields a monthly five-factor alpha of 0.61% (t-stat 3.25). The equity risk factors: value, profitability, investments, momentum, and betting-against-beta can all be used to hedge co-skewness risk.

Jeon, Y., Kan, R., and Li, G. (2019). "Stock Return Autocorrelations and the Cross Section of Option Returns." In: *SSRN e-Print*.
We present a new finding between the cross-section of average returns of equity option and the return autocorrelations of underlying stocks. Extended Black-Scholes model incorporating the presence of stock return autocorrelation suggests that expected returns of both call and put options are increasing in return autocorrelation coefficient of the underlying stock. Consistent with this insight, we find strong empirical support in the cross-section of average returns of equity options. Average returns of calls and puts as well as average returns of straddles all show monotonically increasing relationship with the degree of underlying stock's return autocorrelation coefficient. Additional equity option portfolio analysis shows that the information on stock return autocorrelation helps investors to significantly improve the out-of-sample performance of their portfolios.

Jiao, Y., Liu, Q., and Guo, S. (2021). "Pricing kernel monotonicity and term structure: Evidence from China." In: *Journal of Banking & Finance* 123, p. 106037.
Using all the data of options on the China 50 ETF, we study the pricing kernel monotonicity by adapting the recently proposed conditional density integration approach of Linn-Shive-Shumway (LSS). Methodologically, we improve LSS on several useful aspects and make its procedures applicable universally. Empirically, we provide new supporting evidence for the monotonicity of pricing kernel from a Chinese portfolio. Equally important, we are the first to obtain monotonic pricing kernels over the whole range of returns. Finally, we initialize the study of the term structure of pricing kernel and report the results with one-, two-, four- and eight-week terms. Pricing kernels show little variation for less than one-month terms, but exhibit a higher curvature for eight weeks, implying higher aggregate risk for longer-term positive returns.

Jones, M. W. (2014). "Seeking diversification through efficient portfolio construction using cash-based and derivative instruments." In: *British Actuarial Journal* 19, pp. 468–498.
Diversification across asset classes has declined markedly in the last decade and concerns abound about the ability (or lack) of the financial system to weather another 2008-like event. There is a growing volume of academic literature seeking to derive measurement variables for detecting systemic risk. There is clearly a role for the actuarial profession within this discussion and we hope that this paper can engender further discussions

and papers on this specific issue. Just as diversification across conventional asset classes has decreased there has been greater attention paid to the broader array of potential investment strategies that can be accessed via derivatives. The paper explores the prudent management of derivatives in pension funds and general asset portfolios to improve portfolio efficiency both in terms of implementing investment strategies and in broadening the range of investment opportunities for building an efficient investment portfolio from a risk-based perspective.

Kackar, S. and Rogal, K. (2022). "Application of Credit Derivatives In Portfolio Management." In: *The Journal of Derivatives* 29(3), pp. 81–96.

The use of credit derivatives has grown considerably over the past decade, with participation from a diverse set of institutional investors. Specifically, investors increasingly are using credit default swaps (CDS), credit default swap indices (CDX), and options on CDX to manage their portfolios. In this article, the authors demonstrate how investors apply credit derivatives in the context of portfolio management. The authors show how CDS can be used to create synthetic corporate bonds and how investors structure basis trading opportunities by taking advantage of mispricing between CDS and corporate bonds. Further, the authors illustrate how investors apply options on CDX for the purpose of hedging the tail risks of a fixed income portfolio, and include a discussion on various methods to reduce the cost of such tail-risk-hedging strategies.

Kazak, E. and Pohlmeier, W. (2019). "Testing out-of-sample portfolio performance." In: *International Journal of Forecasting* 35(2), pp. 540–554.

This paper studies the quality of portfolio performance tests based on out-of-sample returns. By disentangling the components of the out-of-sample performance, we show that the observed differences are driven largely by the differences in estimation risk. Our Monte Carlo study reveals that the puzzling empirical findings of inferior performances of theoretically superior strategies result mainly from the low power of these tests. Thus, our results provide an explanation as to why the null hypothesis of equal performance of the simple equally-weighted portfolio compared to many theoretically-superior alternative strategies cannot be rejected in many out-of-sample horse races. Our findings turn out to be robust with respect to different designs and the implementation strategies of the tests. For the applied researcher, we provide some guidance as to how to cope with the problem of low power. In particular, we make use of a novel pretest-based portfolio strategy to show how the information regarding performance tests can be used optimally.

Kazak, E. and Pohlmeier, W. (2020). *Portfolio Pretesting with Machine Learning*. Tech. rep. University of Lancaster.

This paper exploits the idea of pretesting to choose between competing portfolio strategies. We propose an estimator for a portfolio weight vector, which optimally trades off between Type I and Type II errors when choosing the best investment strategy. Furthermore we accommodate the idea of bagging in the portfolio testing problems, which helps to avoid sharp thresholding and reduces the amount of portfolio turnover. Our approach borrows from both shrinkage and forecast combination literature. The portfolio weights of our strategy are weighted averages of the portfolio weights from a set of stand-alone strategies. More specifically, the weights are generated from a pseudo out-of-sample portfolio pretesting, such that they reflect the probability that a given strategy will be overall best performing. Contrary to previous approaches, the shrinkage intensity is continuously updated to incorporate the most recent information in the rolling window forecasting set-up. We show that the bagged pretest estimator performs exceptionally well, especially when combined with adaptive smoothing. The resulting strategy allows for a flexible and smooth switch between the underlying strategies and is shown to outperform the corresponding stand-alone strategies.

Kempf, A., Korn, O., and Sassning, S. (2015). "Portfolio Optimization Using Forward-Looking Information." In: *Review of Finance* 19(1), pp. 467–490.

We develop a new family of estimators of the covariance matrix that relies solely on forward-looking information. It uses only current prices of plain-vanilla options. In an out-of-sample study, we show that a minimum variance strategy based on these fully-implied estimators outperforms several benchmark strategies, including various strategies based on historical estimates, index investing, and 1/N investing. The outperformance originates in crisis periods when information flow and information asymmetry are high. Although the historical benchmark strategies improve when more recent data are used, they never outperform fully-implied strategies. Thus, our results suggest that investors are better off relying on forward-looking information.

Kiriu, T. and Hibiki, N. (2019). "Estimating forward looking distribution with the Ross recovery theorem." In: *Journal of the Operations Research Society of Japan* 62(2), pp. 83–107.

Ross (2015) introduced a remarkable theorem, named the Theorem. It enables us to estimate the real world distribution from the risk neutral distribution derived from option prices under a particular assumption about a representative investor's risk preferences. The real world distribution estimated with the Recovery Theorem

is suitable for many financial problems such as market risk management and portfolio optimization due to its forward looking nature. However, it is not easy to derive the appropriate estimators because of an ill-posed problem in the estimation process. We propose a new method to derive the accurate solution by formulating the regularization term involving prior information. Previous studies propose methods to estimate the real world distribution, but they do not investigate the estimation accuracy. We show the effectiveness of the proposed method through the numerical analysis with hypothetical data.

Koekebakker, S. and Zakamulin, V. (2021). "Warren Buffett versus Zvi Bodie: Should You Buy Or Sell Put Options?" In: *The Journal of Wealth Management* 24(2), pp. 65–81.
Academics and investment professionals often disagree when it comes to investment advice. Legendary investor Warren Buffett is a proponent of time diversification and firmly believes that stocks are less risky in the long run. Therefore, he often sells long-term put options instead of buying them for portfolio protection. By contrast, famous professor Zvi Bodie argues that time diversification is a fallacy and, therefore, his advice to fund managers is to buy long-term portfolio insurance. In this paper, we consider the optimal portfolio choice problem for a loss-averse investor. First, we demonstrate that our loss-averse investor subscribes to the principle of time diversification. In particular, our investor allocates more to stocks as the investment horizon lengthens. Second, we allow our investor to trade in stocks and put options. We find that when the investment horizon is short, our investor is better off with portfolio insurance. Conversely, when the investment horizon is long, our investor sells put options. That is, our loss-averse investor prefers Buffett's investment advice over Bodie's.

Kuntz, L.-C. (2018). "Portfolio Strategies with Classical and Alternative Benchmarks." PhD thesis. Georg August University of Gottingen.
This dissertation addresses different key elements in portfolio management. It intends to improve and analyze influences on portfolio strategies and their performance. Likewise, it aims at the systematization and extension of benchmark specifications as well as their effect on portfolio strategies. Each chapter focuses on a different aspect of developing and implementing portfolio strategies. The dissertation seeks to contribute to the advancement of portfolio strategies by making the performance generating process and influences on it more comprehensible and transparent. In doing so, it attempts to strengthen the awareness of the impact of the exact design of portfolio strategies and benchmarks on the resulting portfolio and its performance. The key findings of this dissertation can be summarized as follows: The benchmark specification, especially in terms of the investible universe and the inherent risk conception, has substantial influence on the explicit design and performance of portfolio strategies. In general, the specification of the benchmark and design of portfolio strategies should be carefully considered and the implementation should be well thought out. Alternative risk conceptions, such as regret risk, can be applied to portfolio selection and lead to clearly different portfolio compositions. Moreover, timing strategies can be improved by choosing a careful investment approach on the basis of distributional regressions. All empirical work 3 of this thesis has in common that it pursues different ideas to set up portfolio strategies while explicitly addressing the benchmark specification used for the implementation and evaluation of said strategies.

Kyriacou, M., Olmo, J., and Strittmatter, M. (2021). "Optimal portfolio allocation using option-implied information." In: *Journal of Futures Markets* 41(2), pp. 266–285.
This paper explores option-implied information measures for optimal portfolio allocation. We introduce two state variables constructed from option prices. The first state variable is the risk-premium on the risky asset and the second variable is the market price of risk. We also explore a lognormal distribution, a mixture of lognormal distributions, and a binomial tree for constructing the implied risk-neutral density function. Using a combination of statistical and economic measures applied to a portfolio given by the 1-month US Treasury bill and the S&P 500 Index we show the good performance of option-implied information measures for optimal portfolio allocation.

Le, T. H., Kourtis, A., and Markellos, R. N. (2021). "Modeling Skewness in Portfolio Choice." In: *SSRN e-Print*.
Despite half a century of research, we still do not know the best way to model skewness of financial returns. We address this question by comparing the predictive ability and associated portfolio performance of several prominent skewness models in a sample of ten international equity market indices. Models that employ information from the option markets provide the best outcomes overall. We develop an option-based model that accounts for the skewness risk premium. The new model produces the most informative forecasts of future skewness, the lowest prediction errors and the best portfolioperformance in most of our tests.

Leung, T. and Ward, B. (2018). "Dynamic index tracking and risk exposure control using derivatives." In: *Applied Mathematical Finance* 25(2), pp. 180–212.

We develop a methodology for index tracking and risk exposure control using financial derivatives. Under a continuous-time diffusion framework for price evolution, we present a pathwise approach to construct dynamic portfolios of derivatives in order to gain exposure to an index and/or market factors that may be not directly tradable. Among our results, we establish a general tracking condition that relates the portfolio drift to the desired exposure coefficients under any given model. We also derive a slippage process that reveals how the portfolio return deviates from the targeted return. In our multi-factor setting, the portfolio realized slippage depends not only on the realized variance of the index but also the realized covariance among the index and factors. We implement our trading strategies under a number of models, and compare the tracking strategies and performances when using different derivatives, such as futures and options.

Liao, W. J. and Sung, H.-C. (2021). "Implied risk aversion and pricing kernel in the FTSE 100 index." In: *The North American Journal of Economics and Finance* (100826).
This paper studies the estimation of the pricing kernel and explains the pricing kernel puzzle found in the FTSE 100 index. We use prices of options and futures on the FTSE 100 index to derive the risk neutral density (RND). The option-implied RND is inverted by using two nonparametric methods: the implied-volatility surface interpolation method and the positive convolution approximation (PCA) method. The actual density distribution is estimated from the historical data of the FTSE 100 index by using the threshold GARCH (TGARCH) model. The results show that the RNDs derived from the two methods above are relatively negatively skewed and fat-tailed, compared to the actual probability density, that is consistent with the phenomenon of "volatility smile." The derived risk aversion is found to be locally increasing at the center, but decreasing at both tails asymmetrically. This is the so-called pricing kernel puzzle. The simulation results based on a representative agent model with two state variables show that the pricing kernel is locally increasing with the wealth at the level of 1 and is consistent with the empirical pricing kernel in shape and magnitude.

Lohre, H., Rother, C., and Schafer, K. A. (2020). "Hierarchical Risk Parity: Accounting for Tail Dependencies in Multi-asset Multi-factor Allocations." In: *Machine Learning for Asset Management: New Developments and Financial Applications*. Ed. by E. Jurczenko. Wiley, pp. 329–368.
This chapter examines the use and merits of hierarchical clustering techniques in the context of multi-asset multi-factor investing. In particular, it contrasts these techniques with several competing risk-based allocation paradigms, such as 1/N, minimum-variance, standard risk parity and diversified risk parity. The chapter introduces hierarchical risk parity (HRP) strategies based on the Pearson correlation coefficient and also introduces hierarchical clustering based on the lower tail dependence coefficient. The chapter provides an overview of traditional risk-based allocation strategies and outlines a framework to measure and manage portfolio diversification. It examines the performance of the introduced HRP strategies relative to the traditional alternatives. The chapter discusses Meucci's approach to managing diversification, which serves to construct a diversified risk parity strategy based on economic factors.

Lopez de Prado, M. (2019). "A Data Science Solution to the Multiple-Testing Crisis in Financial Research." In: *The Journal of Financial Data Science* 1(1), pp. 99–110.
Most discoveries in empirical finance are false, as a consequence of selection bias under multiple testing. Although many researchers are aware of this problem, the solutions proposed in the literature tend to be complex and hard to implement. In this article, the author reduces the problem of selection bias in the context of investment strategy development to two sub-problems: determining the number of essentially independent trials and determining the variance across those trials. The author explains what data researchers need to report to allow others to evaluate the effect that multiple testing has had on reported performance. He applies his method to a real case of strategy development and estimates the probability that a discovered strategy is false.

Lopez de Prado, M. and Lewis, M. J. (2019). "Detection of false investment strategies using unsupervised learning methods." In: *Quantitative Finance* 19(9), pp. 1555–1565.
In this paper we address the problem of selection bias under multiple testing in the context of investment strategies. We introduce an unsupervised learning algorithm that determines the number of effectively uncorrelated trials carried out in the context of a discovery. This estimate is critical for computing the familywise false positive probability, and for filtering out false investment strategies.

Magalhaes, P. T. (2021). "Stock return predictability and variance risk premia : a frequency domain analysis." MA thesis. Universidade Catolica Portuguesa.
The main objective of this thesis is to analyze the out-of-sample equity return forecasting power of the variance risk premia and its frequency components. The variance risk premia (VRP) is represented by the difference between the risk neutral (implied variance) and physical (realized variance) expectations of the variance. In the

literature, a considerable number of variables present strong in- and out of- sample performances, being one of them the variance risk premia. Likewise, by decomposing some variables into their frequencies, their out-of-sample performances increases. Therefore, in order to study the behavior of this variable, we decompose the time series of the variance risk premia into frequencies. The main result of this thesis is that the original time series and its medium frequency component demonstrate a remarkable out-of-sample performance when predicting the equity excess of return. We also show that, although the time series presents a better statistical performance (i.e., a higher out-of-sample R2), in economic terms its medium frequency component delivers higher gains.

Malavasi, M., Lozza, S. O., and Truck, S. (2021). "Second order of stochastic dominance efficiency vs mean variance efficiency." In: *European Journal of Operational Research* 290(3), pp. 1192–1206.
In this paper, we compare two of the main paradigms of portfolio theory: mean variance analysis and expected utility. In particular, we show empirically that mean variance efficient portfolios are typically sub-optimal for non satiable and risk averse investors. We illustrate that the second order stochastic dominance (SSD) efficient set is the solution of a multi-objective optimization problem. We further show that the market portfolio is not necessarily a solution to this optimization problem. We also conduct an empirical analysis, examining the ex ante and ex post performance of SSD and mean variance efficient portfolios, using a bootstrap approach. In an ex ante analysis, we compare empirical moments, the level of diversification and set distances of mean variance and SSD efficient sets. We also show that the global minimum variance (GMV) portfolio and the part of the mean variance efficient frontier (MVEF) composed of highly diversified portfolios is second order stochastically dominated. This result also provides a possible alternative explanation for the diversification puzzle. Conducting an ex post analysis, we construct second order stochastic dominating strategies that outperform the GMV portfolio in terms of wealth and various other performance measures, producing a positive ex post opportunity cost.

Marks, J. M. and Simon, D. P. (2017). "Sector option implied volatility dynamics and predictability." In: *Journal of Derivatives* 25(2), pp. 22–42.
As research is revealing more detail about the behavior of implied volatilities, the empirical evidence points to important differences between systematic volatility, that is correlated with the market index and is shared broadly across stocks, and idiosyncratic volatility that is largely independent of the rest of the market. It is the former that appears to command a significant variance risk premium in market prices. Marks and Simon examine an intermediate case: options on sector exchange traded funds. The underlying asset for an ETF is a portfolio of stocks within a single market sector. That is, the underlying is an index not a single stock, so volatility risk is somewhat systematic, but to the extent there is an important industry component to variance, it might behave more like single-stock idiosyncratic risk than like market risk. The results show a rich array of volatility effects, both in terms of different risk premia on different types of volatility, but also in terms of the speed of adjustmen...

Martin, I. (2021). "On the Autocorrelation of the Stock Market." In: *Journal of Financial Econometrics* 19(1), pp. 39–52.
I introduce an index of market return autocorrelation based on the prices of index options and of forward-start index options and implement it at a six-month horizon. The results suggest that the autocorrelation of the S&P 500 index was close to zero before the subprime crisis but was negative in its aftermath, attaining values around -20% to -30%. I speculate that this may reflect market perceptions about the likely reaction, via quantitative easing, of policymakers to future market moves.

Massacci, F., Williams, J. M., and Zhang, Y. (2016). "Empirical Recovery: Hansen-Scheinkman Factorization and Ross Recovery from High Frequency Option Prices." In: *SSRN e-Print*.
Recent research has shown that the Perron-Frobenius eigenfunction of a Markov risk neutral state price transition matrix has an interesting economic interpretation. Yet, the application to actual market prices presents significant challenge. For instance, even at the intraday frequency market data, has lots of gaps and can contain unpredictable levels of noise. As a consequence, the identification of the risk neutral state transition matrix often results in a matrix that violates the basic properties of the Markov chain presumed to be driving the evolution of asset prices. We provide a fast non-linear programming approach to the Recovery Theorem such that the attained minimum formally satisfies the desired mathematical and economical constraints (e.g. the de facto discount factor being smaller than unity and unimodality of the transition matrix). We demonstrate the empirical effectiveness of the methodology on SandP 500 index options and appeal to recent theoretical results to extend this approach to individual stocks.

McQuinn, N., Thapar, A., and Villalon, D. (2021). "Portfolio Protection? It's a Long (Term) Story ..." In: *The Journal of Portfolio Management* 47(3), pp. 35–50.
Investors have a natural urge to protect their portfolios from sudden crashes. The authors argue that investors should instead focus on bad outcomes that unfold over longerperiods because those tend to be more detrimental to the long-term goal of wealth accumulation. The authors show that options-based hedging can be effective over shorter periods but tends to weaken over time. Worse still, returns tend to be very punitive during prolonged bull markets. In contrast, risk-mitigating and diversifying strategies such as defensive equities, risk parity, alternative risk premiums, and trend-following have more consistently added value in the longer-lasting market drawdowns that matter most to investors-and, unlike puts, can profit in up as well as down markets. This latter point suggests a crucial advantage for these strategies: that unlike options-based hedging, it is never too late to consider diversifying into them.

Meucci, A. (2011). "'P' Versus 'Q': Differences and Commonalities between the Two Areas of Quantitative Finance." In: *GARP Risk Professional*.
There exist two separate branches of finance that require advanced quantitative techniques: the "Q" area of derivatives pricing, whose task is to "extrapolate the present"; and the "P" area of quantitative risk and portfolio management, whose task is to "model the future." We briefly trace the history of these two branches of quantitative finance, highlighting their different goals and challenges. Then we provide an overview of their areas of intersection: the notion of risk premium; the stochastic processes used, often under different names and assumptions in the Q and in the P world; the numerical methods utilized to simulate those processes; hedging; and statistical arbitrage.

Milevsky, M. A. (2020). "Modeling the Risk of Sequence-of-Returns." In: *Retirement Income Recipes in R*. Springer International Publishing, pp. 85–109.
This chapter is focused on a phenomenon known by professionals in the retirement income business, as the sequence-of-returns effect. Broadly speaking – and using terminology introduced in the previous chapter – this relates to the disproportionate sensitivity of portfolio longevity to realized investment returns in the early stages of retirement withdrawals. More specifically this chapter proposes some formal metrics that measure the extent and magnitude of the risk using statistical correlation and regression methodologies. The chapter concludes by analyzing some derivative-based strategies, using put and call options, that can be used to mitigate the risk of sequence-of-returns.

Miller, M., Jacobsen, B., and Vree, M. de (2022). "Income Enhancement with Options." In: *The Journal of Derivatives* 29(3).
Investors have always tried to use various trading strategies to juice their returns. Writing options has often been thought of as a low risk way to get some additional income (premiums) while not disturbing the underlying asset allocation. Sometimes, however, investors are caught off guard when their option strategy does more harm than good. In this educational piece we describe one of the most common option writing strategies, covered call writing, and the practicalities of how to manage these strategies so they hopefully don't backfire. The key is to recognize that the returns from covered call strategies are related to the volatility risk premium (also known as the variance risk premium) as well as the equity risk premium.

Mooney, T., Rapaka, R., and Vera, T. (2020). "Dynamic Regime Strategy for Stress Testing and Optimizing Institutional Investor Portfolios." In: *SSRN e-Print*.
Our work aims to develop a stand-alone trading system to construct portfolios that show the benefits of value and momentum style integration and presents the effectiveness of alternative integration methods for long-only absolute return funds, which seeks absolute returns that are not highly correlated to traditional assets such as stocks and bonds. Our approach uses the CRoss Industry Standard Process for Data Mining (CRISP-DM) model to guide the necessary steps, processes, and workflows for executing our project.

Nardi, F. (2015). "Option Implied Moments (Mean-Variance?) of the Ex-Ante Return Distribution." In: *SSRN e-Print*.
I present a method to recover option implied subjective moments of the S&P 500 index under the assumption of no arbitrage and logarithmic utility. Using index options prices and return data, I test the logarithmic utility assumption and obtain risk aversion estimates not statistically different from one at investment horizons of three to nine months. Under logarithmic utility, I show that the recovered subjective variance has forecasting power controlling for past realized variance. Interestingly, the risk neutral variance is larger than the subjective variance over the entire sample, an empirical fact that quantifies the implied variance premium for a log utility investor.

Lastly, I also find that the forward looking Sharpe ratio has forecasting power; this finding can be adopted as a risk adjusted market timing indicator to improve the return performance of passive indexing.

Neuhierl, A., Tang, X., Varneskov, R. T., and Zhou, G. (2021). "Stock Option Predictability for the Cross-Section." In: *SSRN e-Print*.
We provide the first comprehensive analysis of options-implied information for predicting the cross-section of stock returns by jointly examining extensive sets of firm and option characteristics. Using portfolio sorts and high-dimensional methods, we show that only few option characteristics have significant predictive power after controlling for firm characteristics, earning, e.g., a Fama-French three-factor alpha in excess of 20% per annum. A structural analysis reveals that the strongest option characteristics are associated with information about asset mispricing, overvaluation and tail return realizations. Our findings are consistent with models of informed trading and limits to arbitrage.

Nouvellon, E. and Pirotte, H. (2021). "Can an equity structure dominate the risk-return profile of corporate bonds?" In: *Journal of Asset Management* 22(4), pp. 277–290.
In a very low interest rate and tight credit spread environment, institutional investors look for alternatives to enhance their fixed income portfolios whilst maintaining their risk profile. Some have devised hedge funds as a solution to improve return at comparable risk levels. More recently, some authors show that appropriate optional strategies could offer better risk-return profiles than hedge funds. This paper proposes a synthetic equity derivative structure that mimics the cash flow behaviour of a corporate bond portfolio. Both alternatives are empirically compared, balancing their yield with their level of risk, and integrating the probability of default. In the case of the high-rating class, our results show that the derivative structure offers a better "spread-default" profile than that of corporate bonds. This may have interesting implications for insurers and pension funds that seek to invest a substantial fraction of their portfolio in high-grade fixed income assets and is consistent with the focus of liability-driven investors on yearly cash flow requirements.

Ntantanis, H. and Pohlman, L. (2020). "Market implied GDP." In: *Journal of Asset Management* 21, pp. 636–646.
GDP is the most important and widely studied macroeconomic variable. It indicates the state of an economy and is used as a measure of the economic strength of a country. Due to its comprehensive nature, calculating GDP takes a great deal of work and is often revised over time. This has led to the common practice of forecasting GDP using econometric models. This paper introduces a new method for estimating GDP using a unique data set of options whose values are determined by the levels of GDP and the GDP growth rate. The option is market priced which makes it distinct since it is available daily, subject to no revisions and aggregates the market's opinion about GDP. These option implied values for GDP and GDP growth rate are similar to the concept of implied volatilities. We show that this option improves the GDP growth rate forecasts by 21% compared to conventional econometric models.

Park, H. (2016). "Ross recovery with recurrent and transient processes." In: *Quantitative Finance* 16(5), pp. 667–676.

Platanakis, E., Sutcliffe, C. M., and Ye, X. (2021). "Horses for Courses: Mean-Variance for Asset Allocation and 1/N for Stock Selection." In: *European Journal of Operational Research* 288(1), pp. 302–317.
For various organizational reasons, large investors typically split their portfolio decision into two stages - asset allocation and stock selection. We hypothesise that mean-variance models are superior to equal weighting for asset allocation, while the reverse applies for stock selection, as estimation errors are less of a problem for mean-variance models when used for asset allocation than for stock selection. We confirm this hypothesis in separate analyses of US and international equities using four different types of mean-variance model (Bayes-Stein, Black-Litterman, Bayesian diffuse prior and Markowitz), a range of parameter settings, and a simulation analysis calibrated to US data.

Qin, L. and Linetsky, V. (2016). "Positive Eigenfunctions of Markovian Pricing Operators: Hansen-Scheinkman Factorization, Ross Recovery, and Long-Term Pricing." In: *Operations Research* 64(1), pp. 99–117.
This paper develops a spectral theory of Markovian asset pricing models where the underlying economic uncertainty follows a continuous-time Markov process X with a general state space (Borel right process, or BRP) and the stochastic discount factor (SDF) is a positive semimartingale multiplicative functional of X. A key result is the uniqueness theorem for a positive eigenfunction of the pricing operator such that X is recurrent under a new probability measure associated with this eigenfunction (recurrent eigenfunction). As economic applications, we prove uniqueness of the Hansen and Scheinkman factorization of the Markovian SDF corresponding to the recurrent eigenfunction; extend the Recovery Theorem from discrete time, finite state irreducible Markov chains to recurrent BRPs; and obtain the long-maturity asymptotics of the pricing operator. When an asset pricing

model is specified by given risk-neutral probabilities together with a short rate function of the Markovian state, we give sufficient conditions for the existence of a recurrent eigenfunction and provide explicit examples in a number of important financial models, including affine and quadratic diffusion models and an affine model with jumps. These examples show that the recurrence assumption, in addition to fixing uniqueness, rules out unstable economic dynamics, such as the short rate asymptotically going to infinity or to a zero lower bound trap without possibility of escaping.

Quaedvlieg, R. and Schotman, P. (2022). "Hedging Long-Term Liabilities." In: *Journal of Financial Econometrics*.
Pension funds and life insurers face interest rate risk arising from the duration mismatch of their assets and liabilities. With the aim of hedging long-term liabilities, we estimate variations of a Nelson-Siegel model using swap returns with maturities up to 50 years. We consider versions with three and five factors, as well as constant and time-varying factor loadings. We find that we need either five factors or time-varying factor loadings in the three-factor model to accommodate the long end of the yield curve. The resulting factor hedge portfolios perform poorly due to strong multicollinearity of the factor loadings in the long end, and are easily beaten by a robust, near Mean-Squared-Error- optimal, hedging strategy that concentrates its weight on the longest available liquid bond.

Radovanov, B. and Marcikic, A. (2014). "Testing The Performance Of The Investment Portfolio Using Block Bootstrap Method." In: *Economic Themes* 52(2).
The aim of this paper is to create a stable model of investment portfolio optimization through a high degree of diversification and reduction of sudden changes in the allocation with monitoring of the dynamics of the impact factor. In this sense, there is bootstrap application procedure, which, without an excessive number of constraints involved in the optimization process provides solutions based on uncertain information. Thus defined, the optimization method has been patented by Michaud (1999) entitled re-sampled efficiency. Accordingly, this paper offers a comparison of the performance block bootstrap optimization models and traditional Markowitz's model inside and outside of the sample by applying the most frequently traded stocks on the BSE. The results show a better performance out of the sample and the presence of a larger number of shares forming the portfolio through bootstrap methodology. However, only through the traditional optimization process could be attained optimum according to the required limits. Such effects can be observed by comparing the limits of efficiency obtained through these optimization models. However, optimization-based methods bootstrap finds its place in reducing errors of assessment resulting from the limited sample size.

Rebonato, R. (2019). "A financially justifiable and practically implementable approach to coherent stress testing." In: *Quantitative Finance* 19(5), pp. 827–842.
We present an approach to stress testing that is both practically implementable and solidly rooted in well-established financial theory. We present our results in a Bayesian-net context, but the approach can be extended to different settings. We show (i) how the consistency and continuity conditions are satisfied; (ii) how the result of a scenario can be consistently cascaded from a small number of macrofinancial variables to the constituents of a granular portfolio; and (iii) how an approximate but robust estimate of the likelihood of a given scenario can be estimated. This is particularly important for regulatory and capital-adequacy applications.

Ross, S. (2015). "The Recovery Theorem." In: *The Journal of Finance* 70(2), pp. 615–648.
We can only estimate the distribution of stock returns, but from option prices we observe the distribution of state prices. State prices are the product of risk aversion the pricing kernel and the natural probability distribution. The Recovery Theorem enables us to separate these to determine the market's forecast of returns and risk aversion from state prices alone. Among other things, this allows us to recover the pricing kernel, market risk premium, and probability of a catastrophe and to construct model-free tests of the efficient market hypothesis.

Sanford, A. (2022). "Optimized portfolio using a forward-looking expected tail loss." In: *Finance Research Letters* 46(Part B) (102421).
In this paper, I construct an optimal portfolio by minimizing the expected tail loss derived from the forward-looking natural distribution of the Recovery Theorem. This natural distribution can be used as the criterion function in an expected tail loss portfolio optimization problem. I find that the portfolio constructed using the Recovery Theorem outperforms both an equally-weighted portfolio and a portfolio constructed using historical expected tail loss. The portfolio constructed using the Recovery Theorem has the smallest historical tail loss, smallest maximum drawdown, highest Sortino Ratio, and highest Sharpe Ratio.

Schadner, W. (2021). "Feasible Implied Correlation Matrices from Factor Structures." In: *arXiv e-Print*.
Forward-looking correlations are of interest in different financial applications, including factor-based asset pricing, forecasting stock-price movements or pricing index options. With a focus on non-FX markets, this paper

defines necessary conditions for option implied correlation matrices to be mathematically and economically feasible and argues, that existing models are typically not capable of guaranteeing so. To overcome this difficulty, the problem is addressed from the underlying factor structure and introduces two approaches to solve it. Under the quantitative approach, the puzzle is reformulated into a nearest correlation matrix problem which can be used either as a stand-alone estimate or to re-establish positive-semi-definiteness of any other model's estimate. From an economic approach, it is discussed how expected correlations between stocks and risk factors (like CAPM, Fama-French) can be translated into a feasible implied correlation matrix. Empirical experiments are carried out on monthly option data of the S&P 100 and S&P 500 index (1996-2020).

Schneider, P. and Trojani, F. (2015). "(Almost) Model-Free Recovery." In: *SSRN e-Print*.
Based on mild economic assumptions, we recover the time series of conditional physical moments of market index returns from a model-free projection of the pricing kernel on the return space. These moments identify the minimum variance pricing kernel projection and are supported by a corresponding set of physical distributions. The recovered moments predict S&P 500 returns, especially for longer horizons, give rise to refined conditional versions of Hansen-Jagannathan bounds, and can be traded using delta-hedged option portfolios. They also imply conditional pricing kernel projections that are often far from being uniformly monotonic and convex.

Schneider, P. G. (2020). "Sparse economic scenarios." In: *SSRN e-Print*.
We show how distributions can be reduced to low-dimensional scenario trees. Applied to intertemporal distributions, the scenarios and their probabilities become time-varying factors. From S&P 500 options, two or three time-varying scenarios suffice to forecast returns, implied variance or skewness on par, or better, than extant multivariate stochastic volatility jump-diffusion models, while reducing the computational effort to fractions of a second.

Schreindorfer, D. (2020). "Macroeconomic tail risks and asset prices." In: *The Review of Financial Studies* 33(8), pp. 3541–3582.
I document that dividend growth and returns on the aggregate U.S. stock market are more correlated with consumption growth in bad economic times. In a consumption-based asset pricing model with a generalized disappointment-averse investor and small, IID consumption shocks, this feature results in a realistic equity premium despite low risk aversion. The model is consistent with the main facts about stock market risk premiums inferred from equity index options, remains tightly parameterized, and allows for analytical solutions for asset prices. An extension with non-IID dynamics accounts for excess volatility and return predictability, while preserving the model consistency with option moments.

Schumann, E. (2019). "Backtesting." In: *SSRN e-Print*.
We discuss the backtesting of investment and trading strategies. We start with the challenges and pitfalls: overfitting, data preparation, and the effects of randomness. Then, we introduce and describe R software for backtesting. We demonstrate how to use the software for univariate and multivariate strategies (i.e. portfolio strategies) for two equity data sets. Specifically, we discuss the implementation and testing of momentum and portfolio optimization models. Throughout, we stress the analysis of sensitivity and robustness checks. Since such analyses require to run many backtests, we also discuss how backtests can be run in parallel.

Seck, B. and Elliott, R. J. (2021). "Regime Switching Entropic Risk Measures on Crude Oil Pricing." In: *arXiv e-Print*.
This paper introduces a new type of risk measures, namely regime switching entropic risk measures, and study their applicability through simulations. The state of the economy is incorporated into the entropic risk formulation by using a Markov chain. Closed formulae of the risk measure are obtained for futures on crude oil derivatives. The applicability of these new types of risk measures is based on the study of the risk aversion parameter and the convenience yield. The numerical results show a term structure and a mean-reverting behavior of the convenience yield.

Seymour, A., Flint, E. J., and Chikurunhe, F. (2018). "Dynamic portfolio management strategies: A framework for historical analysis." In: *SSRN e-Print*.
The performance of dynamic trading and investment strategies can be difficult to predict. Although not without its problems, analysis of the historical performance of a strategy can provide valuable insight into its general risk and return properties. Furthermore, historical analysis allows one to compare variations of a strategy and examine the impact of various parameter choices and implementation rules. Dynamic strategy applications in three areas are considered, namely derivatives, asset allocation and equity factor portfolios. Firstly, the analysis of a strategy involving single-stock derivatives is examined in which call options on certain constituents of an index portfolio are sold as an alternative method of under-weighting the underlying. Secondly, the historical performance of an

optimization-based asset allocation strategy is considered. The assumed aim of the strategy is to outperform a benchmark of CPI 5 via dynamic trading in a portfolio of domestic equities, bonds, property and cash, as well as international equities and bonds. Finally, the effects of portfolio construction on factor performance are studied via an historical analysis in which portfolios corresponding to a selection of fundamental factors are managed according to a range of weighting schemes, rebalance frequencies and portfolio sizes.

Smales, L. A. (2020). "News sentiment as an explanation for changes in the VIX futures basis." In: *The Journal of Investing*, joi.2020.1.125.

Chicago Board Options Exchange Volatility Index (VIX) futures have become an increasingly important hedging instrument and aid to portfolio diversification. We study changes in the futures basis, which can be interpreted as changes in expectations of future VIX (fear) levels. We find that higher levels of VIX are associated with a narrowing of the futures basis, suggesting that investors view fear as temporary, and a flatter forward curve. News sentiment offers one plausible explanation for changes in the basis. A wider (narrower) basis accompanies the more positive (negative) news associated with a falling (rising) VIX index. The identified relationships are most pronounced for extreme changes in the VIX futures basis and appear to be concentrated in recession.

Spears, T. (2013). "On estimating the risk-neutral and real-world probability measures." MA thesis. Oxford University.

This dissertation is about inferring market beliefs about the real-world probability distribution describing the future financial returns of an underlying asset from option price data. The primary goal of this dissertation is to present a replication of the econometrics and results of Ross Recovery as applied to S&P 500 index option price data from 27 April, 2011.

Stein, H. J. (2014). "Joining Risks and Rewards." In: *SSRN e-Print*.

The dichotomy between risk analytics and pricing is well known amongst financial practitioners and researchers. For risk analysis, such as computing value at risk and credit exposures, expectations of future values must be computed under the real world measure. For pricing, expectations are computed under a risk neutral measure. This means that for calculations such as value at risk (VaR) and credit exposures (EEs, EPEs, etc) on derivative portfolios, risk factors are evolved to the horizon date under the real world measure, at which point the portfolio is repriced under a risk neutral measure. Simulation under the real world measure followed by repricing under a risk neutral measure is computationally intensive, especially when the repricing requires Monte Carlo. Because of the computational effort involved, shortcuts are often taken. One common shortcut is to assume the real world measure is the risk neutral measure, so that calculations can be done under one measure. This particular shortcut is especially problematic as it leads to results varying wildly depending on the numeraire chosen. Here we detail methods of avoiding this problem by combining the real world measure with the risk neutral measure. We present an application to risk analytics which speeds up the calculations by orders of magnitude, changing O(n*n) calculations to O(n) with a far smaller scaling constant. This allows the computation of exposures under the real world measure, obviating the need for the dangerous practice of computing exposures under a risk neutral measure.

Stilger, P. S., Kostakis, A., and Poon, S.-H. (2017). "What Does Risk-Neutral Skewness Tell Us About Future Stock Returns?" In: *Management Science* 63(6), pp. 1814–1834.

This study documents a positive relationship between the option-implied risk-neutral skewness (RNS) of individual stock returns' distribution and future realized stock returns during the period 1996-2012. A strategy that goes long the quintile portfolio with the highest RNS stocks and short the quintile portfolio with the lowest RNS stocks yields a Fama-French-Carhart alpha of 55 basis points per month (t-statistic of 2.47). The significant underperformance of the portfolio with the most negative RNS stocks is driven by those stocks that are also perceived as relatively overpriced according to a series of overvaluation proxies and are too costly or too risky to sell short, thereby hindering the price correction mechanism. Our findings indicate that a highly negative RNS value, when reflecting high hedging demand for options by investors who perceive the underlying stock as relatively overpriced but hard to sell short, is a robust signal of significant future stock underperformance.

Su, W. (2021). "Volatility of S&P500: Estimation and Evaluation." In: *arXiv e-Print*.

In an era when derivatives is getting popular, risk management has gradually become the core content of modern finance. In order to study how to accurately estimate the volatility of the S&P 500 index, after introducing the theoretical background of several methods, this paper uses the historical volatility method, GARCH model method and implied volatility method to estimate the real volatility respectively. At the same time, two ways of adjusting the estimation window, rolling and increasing, are also considered. The unbiased test and goodness of fit test are used to evaluate these methods. The empirical result shows that the implied volatility is the

best estimator of the real volatility. The rolling estimation window is recommended when using the historical volatility. On the contrary, the estimation window is supposed to be increased when using the GARCH model.

Suhonen, A., Lennkh, M., and Perez, F. (2017). "Quantifying Backtest Overfitting in Alternative Beta Strategies." In: *The Journal of Portfolio Management* 43 (2), pp. 90–104.
The authors investigate the biases in the backtested performance of "alternative beta"strategies using a unique sample of 215 trading strategies developed and promoted by global investment banks. Their results lend support to the cautions in the recent literature regarding backtest overfitting and lack of robustness in trading strategy performance during the "live"period (out of sample). The authors report a median 73 percent deterioration in Sharpe ratios between backtested and live performance periods for the strategies, and they establish a link between performance deterioration and strategy complexity, with the realized reduction in live versus backtested Sharpe ratios of the most complex strategies exceeding those of the simplest ones by over 30 percentage points. The robustness of strategy exposure to risk factors varies between asset classes and strategies; it appears reasonable in equity volatility and FX carry strategies but quite weak in the equity value strategy in particular.

Szado, E. (2019). "The portfolio diversification potential of long VIX futures and options strategies." In: *SSRN e-Print*.
It is well established that the VIX Index tends to be negatively correlated with equity markets. This suggests that VIX futures and options may have the potential to provide significant diversification benefits for traditional portfolios. However, since the term structure of VIX futures is generally upward sloping, long VIX futures positions can place a significant drag on portfolio performance.In this paper we consider the performance of strategies that buy VIX futures or VIX call options in a portfolio context in 2008 and 2016, as well as over a 10+ year period from 2006 to 2017. In addition, we consider alternative strategies including long S&P 500 protective put strategies and the dynamic S&P 500 plus VIX call buying strategy of the VXTH index.Meaningful portfolio diversification benefits for risk-averse investors are possible over particular time periods with small allocations to long VIX futures or call options, but there can be substantial portfolio drag if large allocations are made over long time periods during which there are flat to rising stock markets.

Szado, E., Kazemi, H., and Schneeweis, T. (2018). "Option informed stock picking." In: *The Journal of Alternative Investments* 21(1), pp. 48–66.
A wide range of research has suggested that informed trading in options markets may effectively signal subsequent changes in equity prices. In this article, the authors analyze the performance of long/short strategies based on a number of signals from options markets. In addition, they create an easily implemented long-only strategy based on a subset of the signals (volatility risk premium, option/stock volume ratio, implied volatility skew, and realized volatility). In order to minimize transaction costs and liquidity issues, they restrict their analysis to S&P 500 constituents, rebalance the portfolio monthly, and limit the holdings to 50 individual stocks. The analysis of the period from 1996 through mid-2015 shows significant outperformance of a long-only, equal-weighted portfolio of 50 stocks (and found similar results when considering 10-stock portfolios), relative to the S&P 500 and the equal-weighted S&P 500. A return attribution analysis confirms that the outperformance is provided by individual stock selection rather than sector selection.

Taljaard, B. H. and Maré, E. (2021). "Why has the equal weight portfolio underperformed and what can we do about it?" In: *Quantitative Finance* 21(11), pp. 1855–1868.
It is widely noted that market capitalisation weighted portfolios are inefficient and underperform an equal weighted portfolio over the long-term. However, at least since 2016, an equal weighted portfolio of stocks in the S&P500 has significantly underperformed the market capitalisation weighted portfolio. In this paper, we analyse this underperformance using stochastic portfolio theory. We show that the equal weighted portfolio does appear to outperform the market capitalisation weighted portfolio over the long-term but with periods of significant short-term underperformance. In addition, we find that concentration in the market capitalisation weighted portfolio has increased in recent years and has contributed to the recent underperformance together with a significantly lower level of diversification benefits. Furthermore, we highlight an approach to improve the performance of a portfolio by dynamically selecting a market cap or an equal weighting using a rudimentary linear regression model.

Tan, S. (2013). "The role of options in long horizon portfolio choice." In: *The Journal of Derivatives* 20(4), pp. 60–77.
Option pricing theory depends on the idea that an option is a redundant asset. Its payoff can be replicated by a dynamic strategy involving just the stock and riskless bonds. This leaves the odd theoretical question of what value there is for options to exist in the first place. In this article, Tan tackles this issue in a simulation of long-term equilibrium in an economy with investors who earn labor income over their lifetimes and have access

to a stock index portfolio, riskless bonds but limited ability to borrow, and at-the-money calls and puts on the index. Call options provide considerable utility largely because the leverage they permit allows younger workers with future wage income but little current wealth to increase their exposure to the stock market. Put options, by contrast, add little in the context of this economy.

Tayali, S. T. (2020). "A novel backtesting methodology for clustering in mean–variance portfolio optimization." In: *Knowledge-Based Systems* 209, p. 106454.
The decisions of asset selection and allocation lie at the heart of financial portfolio management. For these challenging tasks, the mathematical programming model of the mean-variance optimization problem proposes to use the concept of diversification. The novel methodology in this article is a representation of the accumulated knowledge of this model from the modern portfolio theory. It is a practical application for portfolio managers to help synthesize the available historical data and to infer rational decisions. The state-of-the-art backtesting methodology integrates the unsupervised machine learning method of clustering analysis into the mean-variance portfolio optimization model. The test results from the proposed novel methodology show that clustering with Euclidean distance measures outperform the results of the benchmark and other specified clustering methods for different datasets, backtesting periods, and temporal scales of major stock indices.

Topaloglou, N., Vladimirou, H., and Zenios, S. A. (2011). "Optimizing international portfolios with options and forwards." In: *Journal of Banking and Finance* 35(12), pp. 3188–3201.
We develop a stochastic programming model to address in a unified manner a number of interrelated decisions in international portfolio management: optimal portfolio diversification and mitigation of market and currency risks. The goal is to control the portfolio's total risk exposure and attain an effective balance between risk and expected return. By incorporating options and forward contracts in the portfolio optimization model we are able to numerically assess the performance of alternative tactics for mitigating exposure to the primary risks. We find that control of market risk with options has more significant impact on portfolio performance than currency hedging. We demonstrate through extensive empirical tests that incremental benefits, in terms of reducing risk and generating profits, are gained when both the market and currency risks are jointly controlled through appropriate means.

Traccucci, P., Dumontier, L., Garchery, G., and Jacot, B. (2019). "A Triptych Approach for Reverse Stress Testing of Complex Portfolios." In: *Risk (Cutting Edge)*.
Pascal Traccucci, Luc Dumontier, Guillaume Garchery and Benjamin Jacot present an extended reverse stress test (ERST) triptych approach with three variables: level of plausibility, level of loss and scenario. Any two of these variables can be derived, provided the third is given as input. A new version of the Levenberg-Marquardt optimisation algorithm is introduced to derive the ERST in certain complex cases.

Trainor, W. J., Chhachhi, I., and Brown, C. L. (2019). "Leaping Black Swans." In: *The Journal of Investing*.
This article examines an option based portfolio insurance strategy where a fixed percentage of the portfolio is used to purchase in the money long-term call options with the remainder invested in a standard investment grade bond fund. Our results show a 90/10 portfolio, where 10% is invested in long term call options, has returns commensurate with the S&P 5000 while mitigating losses. These call option based portfolios don require rebalancing during the term of coverage and are flexible enough to suit investors with very different risk tolerances and portfolio sizes. As constructed, these portfolios outperform put option based portfolio insurance strategies and perform as well as a CPPI, with the added advantage of not needing to be actively managed.

Valentine, K. D., Buchanan, E. M., Scofield, J. E., and Beauchamp, M. T. (2019). "Beyond p values: utilizing multiple methods to evaluate evidence." In: *Behaviormetrika* 46(1), pp. 121–144.
Null hypothesis significance testing is cited as a threat to validity and reproducibility. While many individuals suggest that we focus on altering the p value at which we deem an effect significant, we believe this suggestion is short-sighted. Alternative procedures (i.e., Bayesian analyses and observation-oriented modeling: OOM) can be more powerful and meaningful to our discipline. However, these methodologies are less frequently utilized and are rarely discussed in combination with NHST. Herein, we discuss three methodologies (NHST, Bayesian Model comparison, and OOM), then compare the possible interpretations of three analyses (ANOVA, Bayes Factor, and an Ordinal Pattern Analysis) in various data environments using a frequentist simulation study. We found that changing significance thresholds had little effect on conclusions. Furthermore, we suggest that evaluating multiple estimates as evidence of an effect allows for more robust and nuanced interpretations of results and implies the need to redefine evidentiary value and reporting practices. Recent events in psychological science have prompted concerns within the discipline regarding research practices and ultimately, the validity and reproducibility of published reports (Etz and Vandekerckhove 2016; Lindsay 2015, Open Science Collaboration

2015; van Elk et al. 2015). One often discussed matter is over-reliance, abuse, and potential hacking of p values produced by frequentist null hypothesis significance testing (NHST), as well as misinterpretations of NHST results (Gigerenzer 2004; Ioannidis 2005; Simmons et al. 2011). We agree with these concerns and believe that many before us have voiced sound, generally accepted opinions on potential remedies, such as an increased focus on effect sizes (Cumming 2008; Lakens 2013; Maxwell et al. 2015; Nosek et al. 2012). However, other suggestions have been met with less enthusiasm, including an article by Benjamin et al. (2018) advocating that researchers should begin thinking only of p values less than .005 as "statistically significant", thus changing alpha levels to control Type I error rates. Alternatively, Pericchi and Pereira (2016) promote the use of fluctuating alpha levels as a function of sample size to assist with these errors. Trafimow et al. (2018) critiques this suggestion to broadly lower the alpha level to .005 and suggested that findings should be weighted on the basis of evidence accumulation from multiple studies. We argue that alpha should not be the sole focus of our attention, but rather, we should wonder if a p value should be utilized at all, and, if so, what that p value can tell us in relation with other indicators. While NHST and p values may have merit, researchers have a wealth of other statistical tools available to them. We believe that improvements may be made to the sciences as a whole when individuals become aware of these tools and how these methods may be used, either alone or in combination, to strengthen understanding of data and conclusions. These sentiments have been shared by the American Statistical Association who recently held a conference focusing on going beyond NHST, expanding their previous stance on p values (Wasserstein and Lazar 2016). Therefore, the main goal of this project was to show researchers how two alternative paradigms compare to NHST in terms of their methodological design, statistical interpretations, and comparative robustness. Herein, we will discuss the following methodologies: NHST, Bayes factor comparisons, and observation-oriented modeling. To compare their methodological designs, we first provide historical backgrounds, procedural steps, and limitations for each paradigm. We then simulated data using a three timepoint repeated measures design with a Likert-type scale as the outcome variable to be able to compare the statistical interpretations and comparative robustness. By simulating possible data sets and analyzing them with each of the three paradigms, we will be able to discuss the conclusions these three methods reach given the same data and to compare how often these methodologies agree within different data environments (i.e., given varying sample sizes and effect sizes). Beyond simply comparing methodologies, we also sought to identify how changing the alpha criteria within the NHST framework may alter conclusions. Although previous work has already compared Frequentist NHST to Bayesian approaches (Goodman 1999; Rouder et al. 2012; Wetzels et al. 2011), this manuscript adds a novel contribution: observation-oriented modeling. By introducing social scientists to observation-oriented modeling (OOM), a relatively new paradigm that is readily interpretable, we will show both how useful this paradigm can be in these contexts, and how it compares to two well-known methods. We hope that by discussing these methodologies in terms of a simple statistical analysis researchers will be able to easily compare and contrast methodologies.

van Capelleveen, H. F., Kat, H. M., and Kocken, T. P. (2004). "How Derivatives Can Help Solve the Pension Fund Crisis." In: *The Journal of Portfolio Management* 30(4), pp. 244–253.

Properly constructed option strategies can add substantial value to pension fund management, according to a scenario-based asset-liability model that analyzes their effects on the risk-return profile of defined-benefit pension funds. The results are robust with respect to variations in horizon, equity risk premium, and volatility assumptions. The optimal strategy should be determined in an asset-liability context and not ad hoc, as the intuitively most appealing strategies are not necessarily the most effective. Different types of funds may require significantly different option strategies. What works well for one fund may be less effective or even counter-productive for another. Overall, incorporating options appears an efficient way to improve long-term pension fund health and thus the sustainability of defined-benefit pension plans.

Van Harlow, W. and Brown, K. C. (2016). "Improving the Outlook for a Successful Retirement: A Case for Using Downside Hedging." In: *The Journal of Retirement* 3(3), pp. 35–50.

One of the biggest risks to a successful retirement is the exposure of savings to poor investment returns in the early stages of the retirement. Mitigating this "sequence-of-returns"risk is in consequence an important investment question. In this study, we conduct extensive simulation analysis to show that for sustainable withdrawal rates, hedging with costless collars or with put options can eliminate or significantly reduce funding shortfall risk for a retirement portfolio. In addition, we demonstrate with a few examples that, for a given level of shortfall risk, hedging can increase the income generated by retirement savings by almost 40 percent. Thus, downside hedging strategies within retirement portfolios appear to offer attractive benefits to retirees worried about outliving their income resources.

Vial, C. (2013). "Forward-Looking Information in Portfolio Selection." MA thesis. University of St. Gallen.
This thesis analyzes the informational content of option-implied information in a portfolio optimization context. Options are intended to price future contingencies and thus incorporate the market's expectations about future states. Using this implied information inherent in exchange-traded options allows us to extract forward-looking density functions and moments of the underlying securities. For this purpose, we apply different techniques to interpolate the distribution and moments inherent in Dow Jones Industrial Average (DJIA) and S and P 100 constituent options. We analyze the resulting information relative to different portfolio allocation strategies, and examine whether option-implied portfolios outperform their historical counterparts. For the period of analysis from January 1996 to January 2012 we find that options add forecasting power to a portfolio optimization problem. However, although option-implied portfolios outperform those based on historical information, differences are often insignificant. Only one strategy (BICM Adjusted) significantly outperforms the benchmark portfolios at all times. We can attribute this to its consideration of higher-order implied moments. The results for different optimization strategies and estimation periods are robust, and suggest that forward-looking information is inherent in exchange-traded options. In specific situations, this option-implied information proves to be a reasonable alternative to historical moment estimators.

Vincent, K., Hsu, Y.-C., and Lin, H.-W. (2018). "Analyzing the Performance of Multifactor Investment Strategies under a Multiple Testing Framework." In: *The Journal of Portfolio Management* 44(4), pp. 113–126.
Evaluating portfolios based on numerous combinations of factors using the individual backtesting method could suffer from serious data mining bias and lead to spurious significant findings. Accordingly, the authors employ a multiple hypothesis testing method to examine the multifactor portfolio performance. Their empirical results show that even after they adjust for the multiple comparisons bias, stock-picking strategies with certain combined firm characteristics could generate significantly better liquidity risk-adjusted returns. In addition, the outperforming multifactor strategies that the authors report are robust to alternative definitions of factors. However, they observe that the number of significantly profitable multifactor portfolios has decreased substantially in the era of increased liquidity and trading activity in the U.S. stock market.

Vovk, V. and Wang, R. (2020). "True and false discoveries with e-values." In: *arXiv e-Print*.
The topic of this paper is multiple hypothesis testing based on e-values, which are Bayes factors stripped of their Bayesian content. Using e-values instead of p-values, which are standard in this area, leads to simple and efficient procedures that control the number of false discoveries under arbitrary dependence of the base e-values. We prove an optimality result for our main procedure and demonstrate advantages of our methods over standard methods using simulated and real-world datasets.

Vovk, V. and Wang, R. (2021). "E-values: Calibration, combination, and applications." In: *Annals of Statistics* 49(3), pp. 1736–1753.
Multiple testing of a single hypothesis and testing multiple hypotheses are usually done in terms of p-values. In this paper we replace p-values with their natural competitor, e-values, which are closely related to betting, Bayes factors, and likelihood ratios. We demonstrate that e-values are often mathematically more tractable; in particular, in multiple testing of a single hypothesis, e-values can be merged simply by averaging them. This allows us to develop efficient procedures using e-values for testing multiple hypotheses.

Walther, S. (2020). "Probabilities of Future Equity Returns." PhD thesis. Karlsruhe Institute of Technology.
In this thesis, we develop and present a set of tools that may proof helpful for both practitioners and academics. The structure of the thesis follows the logical grouping of these tools. Chapter II covers the precise measurement of the risk-neutral density. We present and examine our forward-looking estimator for the physical density of equity returns in chapter III. Chapter IV then analyses their ratio, the pricing kernel. In more detail, this thesis is structured as follows: In chapter II, which is based on the working paper Walther and Ulrich (2019), we inspect the sensitivity of multiple option-implied measures to the method that is used in constructing the implied volatility surface. Different state-of-the-art and widely used approaches lead to economically surprisingly large dierences in these measures and some methods lead to systematic biases, especially for out-of-the-money Put options. To overcome this problem we propose two new volatility surfaces, one for end-of-day and onefor intraday applications. Our end-of-day method builds upon a one-dimensional kernelregression, while our intraday method employs a Bayesian approach to lter stable and accurate volatility smiles from tick-by-tick option trade observations. We assess the statistical accuracy of our proposed methods relative to existing state-of-the-art parametric, semi- and non-parametric volatility surfaces by means of leave-one-out cross-validation. Based on 14 years of end-of-day and intraday S&P 500 and Euro Stoxx 50 option data, we show that our methods represent option market information more accurately than existing approaches of the literature. Having established accurate measurements for the

risk-neutral distribution, we next turn to the estimation of the physical distribution of equity returns in chapter III, which is based on the working paper Walther et al. (2019). In this chapter, we present a forward looking estimator for the time-varying physical return distribution with minimal prior restrictions of the shape of the distribution and no exogenous assumptions about the economy or preferences. Our estimator, which is based on a neural network, derives its forecasts from the option-implied moments of the most accurate volatility surface from chapter II and predicts the conditional mean and volatility of returns such that profitable trading strategies can be derived. In contrast to backward-looking estimators and alternative forward-looking parametric and non-parametric approaches, its distribution forecasts cannot be rejected in statistical tests and they feature lower prediction errors and higher conditional log likelihood values than the alternatives. By deliberately varying the input variables of our estimator, we uncover nonlinear relationships between physical and risk-neutral moments, which appear necessary to accurately capture changes in the physical distribution of equity returns. Chapter IV then combines our estimators for the risk-neutral and the physical distribution from the previous chapters to obtain daily measures for the pricing kernel at the monthly time horizon. Despite their time-varying nature, our pricing kernels are non-parametric, forward-looking, agnostic about preferences, economic state variables or their dynamics and rely only on minimal technical constraints. Still, our realized pricing kernel estimates are clearly linked to economic state variables like the term spread, the credit spread or liquidity. We decompose the expected variance of the log pricing kernel and nd that jumps contribute a considerable portion to overall pricing kernel risk. Building on statistical tests, we identify a strong U-shape in the pricing kernel as a function of equity returns, which never ceases to exist in our sample. Overall, we nd clear signs of time variation in the pricing kernel, both with respect to its shape and volatility. Finally, we recapitulate the main results of this thesis in chapter V and briey discuss ideas for future research.

Wiecki, T., Campbell, A., Lent, J., and Stauth, J. (2016). "All That Glitters Is Not Gold: Comparing Backtest and Out-of-Sample Performance on a Large Cohort of Trading Algorithms." In: *The Journal of Investing* 25(3), pp. 69–80.

When automated trading strategies are developed and evaluated using backtests on historical pricing data, there exists a tendency to overfit to the past. Using a unique dataset of 888 algorithmic trading strategies developed and backtested on the Quantopian platform, with at least six months of out-of-sample performance, this article studies the prevalence and impact of backtest overfitting. Specifically, the authors find that commonly reported backtest evaluation metrics, such as the Sharpe ratio, offer little value in predicting out-of-sample performance ($R2 < 0.025$). In contrast, higher-order moments, such as volatility and maximum drawdown, as well as portfolio construction features (e.g., hedging), show significant predictive value of relevance to quantitative finance practitioners. Moreover, in line with prior theoretical considerations, the authors find empirical evidence of overfitting-the more backtesting a quant has done for a strategy, the larger the discrepancy between backtest and out-of-sample performance. Finally, they show that by training nonlinear, machine-learning classifiers on a variety of features that describe backtest behavior, out-of-sample performance can be predicted with much greater accuracy ($R2 = 0.17$) on hold-out data than when using linear, univariate features. A portfolio constructed by using predictions on hold-out data performed significantly better out-of-sample than one constructed from algorithms with the highest backtest Sharpe ratios.

Xiao, X. and Zhou, C. (2014). "Option Implied Risk Measures: A Maximum Entropy Approach." In: *SSRN e-Print*.

This paper investigates option implied risk measures (volatility, skewness and kurtosis) by applying the principle of maximum entropy. Compared to parametric models, e.g. Black Scholes model, this method is free of parametric assumptions. Compared to model-free methods such as that in Bakshi and Madan (2003), this method does not require a large number of options with strike prices covering the entire support of the return distribution and can be used to construct confidence interval for option implied moments. Given different underlying risk neutral distributions, we find that the entropy approach outperforms the Black Scholes model and the model-free methods, particularly when the risk neutral distribution possesses heavy tails and non-zero skewness. Using S&P 500 index options, we apply our method to obtain implied volatilities and test its forecasting performance. We show that the implied volatilities obtained from our method subsumes all information in the Black-Schole implied volatility and historical volatility. In addition, it has more predictive power than the model-free implied volatility following Bakshi and Madan (2003), in both in-sample and out-of-sample setup.

Yfanti, S. and Karanasos, M. (2021). "Financial volatility modeling with option-implied information and important macro-factors." In: *Journal of the Operational Research Society*, pp. 1–21.

The research debate on the informational content embedded in option prices mostly approves the incremental predictive power of implied volatility estimates for financial volatility forecasting beyond that contained in

GARCH and realized variance models. Contributing to this ongoing debate, we introduce the novel AIM-HEAVY model, a tetravariate system with asymmetries, option-implied volatility, and economic uncertainty variables beyond daily and intra-daily dispersion measures included in the benchmark HEAVY specification. We associate financial with macroeconomic uncertainties to explore the macro-financial linkages in the high-frequency domain. In this vein, we further focus on economic factors that exacerbate stock market volatility and represent major threats to financial stability. Hence, our findings are directly connected to the current world-wide Coronavirus outbreak. Financial volatilities are already close to their crisis-peaks amid the generalized fear about controversial economic policies to support societies and the financial system, especially in the case of the heavily criticized UK authorities' delayed and limited response.

Yu, L. (2021). "Comparing Classical Portfolio Optimization and Robust Portfolio Optimization on Black Swan Events." MA thesis. University of Waterloo.

Black swan events, such as natural catastrophes and manmade market crashes, historically have a drastic negative influence on investments; and there is a discrepancy on losses caused by these two types of disasters. In general, there is a recovery and it is of interest to understand what type of investment strategies lead to better performance for investors. In this thesis we study classical portfolio optimization, robust portfolio optimization and some historical black swan events. We compare two main strategies: mean variance optimization vs robust portfolio optimization on two types of black swan events: natural vs anthropogenic. The comparison illustrates that robust portfolio optimization is much more conservative, and has a shorter recovery time than classical portfolio optimization. Moreover, the losses in the stock investment resulted from a natural disaster are very minor compared to the losses resulted from an anthropogenic market crash.

Zhang, C., Li, Y., Chen, X., Jin, Y., Tang, P., and Li, J. (2020a). "DoubleEnsemble: A New Ensemble Method Based on Sample Reweighting and Feature Selection for Financial Data Analysis." In: *IEEE International Conference on Data Mining (ICDM)*. IEEE.

Modern machine learning models (such as deep neural networks and boosting decision tree models) have become increasingly popular in financial market prediction, due to their superior capacity to extract complex non-linear patterns. However, since financial datasets have very low signal-to-noise ratio and are non-stationary, complex models are often very prone to overfitting and suffer from instability issues. Moreover, as various machine learning and data mining tools become more widely used in quantitative trading, many trading firms have been producing an increasing number of features (aka factors). Therefore, how to automatically select effective features becomes an imminent problem. To address these issues, we propose DoubleEnsemble, an ensemble framework leveraging learning trajectory based sample reweighting and shuffling based feature selection. Specifically, we identify the key samples based on the training dynamics on each sample and elicit key features based on the ablation impact of each feature via shuffling. Our model is applicable to a wide range of base models, capable of extracting complex patterns, while mitigating the overfitting and instability issues for financial market prediction. We conduct extensive experiments, including price prediction for cryptocurrencies and stock trading, using both DNN and gradient boosting decision tree as base models. Our experiment results demonstrate that DoubleEnsemble achieves a superior performance compared with several baseline methods.

Zhang, F., Guo, R., and Cao, H. (2020b). "Information Coefficient as a Performance Measure of Stock Selection Models." In: *arXiv e-Print*.

Information coefficient (IC) is a widely used metric for measuring investment managers' skills in selecting stocks. However, its adequacy and effectiveness for evaluating stock selection models has not been clearly understood, as IC from a realistic stock selection model can hardly be materially different from zero and is often accompanies with high volatility. In this paper, we investigate the behavior of IC as a performance measure of stick selection models. Through simulation and simple statistical modeling, we examine the IC behavior both statically and dynamically. The examination helps us propose two practical procedures that one may use for IC-based ongoing performance monitoring of stock selection models.

Zhang, Z., Zohren, S., and Roberts, S. (2020c). "Deep Learning for Portfolio Optimization." In: *The Journal of Financial Data Science* 22(4), pp. 8–20.

In this article, the authors adopt deep learning models to directly optimize the portfolio Sharpe ratio. The framework they present circumvents the requirements for forecasting expected returns and allows them to directly optimize portfolio weights by updating model parameters. Instead of selecting individual assets, they trade exchange-traded funds of market indexes to form a portfolio. Indexes of different asset classes show robust correlations, and trading them substantially reduces the spectrum of available assets from which to choose. The authors compare their method with a wide range of algorithms, with results showing that the model obtains the

best performance over the testing period of 2011 to the end of April 2020, including the financial instabilities of the first quarter of 2020. A sensitivity analysis is included to clarify the relevance of input features, and the authors further study the performance of their approach under different cost rates and different risk levels via volatility scaling.

Zhu, S., Zhu, W., Pei, X., and Cui, X. (2020). "Hedging crash risk in optimal portfolio selection." In: *Journal of Banking & Finance* 119, p. 105905.

When almost all underlying assets suddenly lose a certain part of their nominal value in a market crash, the diversification effect of portfolios in a normal market condition no longer works. We integrate the crash risk into portfolio management and investigate performance measures, hedging and optimization of portfolio selection involving derivatives. A suitable convex conic programming framework based on parametric approximation method is proposed to make the problem a tractable one. Simulation analysis and empirical study are performed to test the proposed approach.