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Big Data and AI Strategies

How to systematically design optimal hedging portfolios

- The question of how to optimally incorporate options into an investment portfolio does not fit easily into the existing portfolio optimization framework due to the non-normality of option returns.
- Instead, we apply and extend the methodology proposed by Faias and Santa-Clara (2017), on three case studies:
    - **Hedging AT1 portfolios with SX7E options**
    - **Hedging Leveraged Loan portfolios with HYG options**
    - **Optimal selection of S&P 500 option hedging strategies**
- With proper investability constraints, the methodology is shown to produce intuitive and effective option hedging portfolios.

Global Quantitative and Derivatives Strategy
Peng Cheng, CFA [AC]
(1-212) 622-5036
peng.cheng@jpmorgan.com
Thomas J Murphy, PhD
(1-212) 270-7377
thomas.x.murphy@jpmchase.com
Marko Kolanovic, PhD
(1-212) 272-1438
marko.kolanovic@jpmorgan.com
J.P. Morgan Securities LLC

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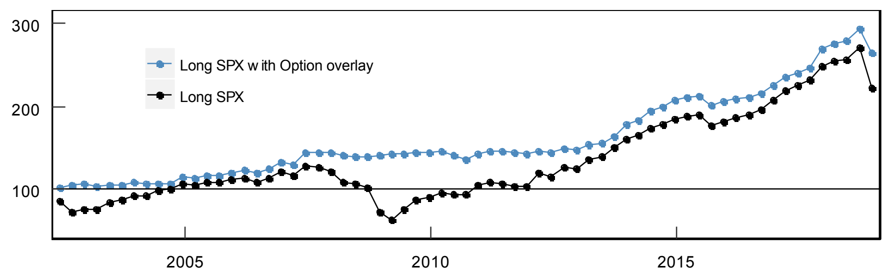
Indexed performance



Source: J.P. Morgan

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Peng Cheng, CFA
(1-212) 622-5036
peng.cheng@jpmorgan.com

How to systematically design optimal hedging portfolios

Although option pricing theory and modern portfolio theory are both highly developed, the question of how to optimally allocate to options in an investor's portfolio is far less understood. The reason is perhaps that portfolio theory focuses on the mean and variance of the asset returns, which cannot easily accommodate the asymmetric nature of option returns.

In this report, we explore systematic ways of creating optimal option hedging strategies on long-only portfolios. To do so, we employ and extend the methodology proposed by Faias and Santa-Clara (2017),[1] which optimizes a myoptic utility function on a portfolio of options, held to maturity.

There are several advantages of the approach: firstly, it accounts for higher moments of the portfolio returns in the optimization process; secondly, it is independent of option pricing model; moreover, from a practical point of view, it requires relatively little historical data for estimation; and last but not least, the methodology does not require the options to have the same underlying asset as the portfolio and therefore can be applied to proxy hedge portfolios on which there is no listed option. The main caveat of the methodology is that the returns are evaluated only at the end of the investment period, and therefore the options are required to be held to maturity.

In the next section, we first describe the methodology, then go on to show three different case studies, each with progressively more complex option structures. Lastly, we run a historical back-test of a sample strategy to demonstrate the effectiveness and suggest potential further extensions.

Methodology

As elaborated by Faias and Santa-Clara (2017), the optimal option portfolio strategy (OOPS) methodology is made up of the following steps:

1. Given an investment horizon (e.g., three months), compute the historical rolling returns of the underlying asset. Scale the time period returns by the ratio of a current volatility measure over the point-in-time volatility measure (e.g., current 3M implied volatilty/historical 3M implied volatility). Doing so normalizes the returns to the current volatility regime.
2. Randomly sample with replacement a large number (e.g., 1,000) of observations from the normalized asset returns.
3. Take the current pricing of the options of interest (e.g., 3M 95% put option etc.), and compute the hypothetical returns of those options, based on the randomly sampled asset returns from the previous step. Option returns are calculated as a percent of the option premium, so long position returns can range between -100% (losing entire option premium) to a large positive number and vice versa for short position returns.
4. With the collection of sample asset and option returns, we solve for the optimal portfolio weights allocated to each instrument.

In the last step, what should be the objective of our optimization? Mean variance optimization is inappropriate, since the higher moments of option returns are not

[1] "Optimal Option Portfolio Strategies: Deepening the Puzzle of Index Option Mispricing," J.A. Faias and P. Santa-Clara, Feb 2017, *Journal of Financial and Quantitative Analysis.*

accounted for. In other words, a mean-variance optimal portfolio may be heavily biased toward selling options and thus defeat the purpose of our analysis. Instead, we maximize the following objective function:

$$\frac{1}{1-\gamma}E[(1+r)^{1-\gamma}]$$

In the expression above, r is the portfolio (asset + options) return and γ (gamma) is a risk aversion parameter that requires our input. The advantage of using this function is that it takes into account all moments of the return distribution. That is, given any γ value, we are able to simultaneously maximize return, minimize variance, maximize (positive) skewness, and so on.

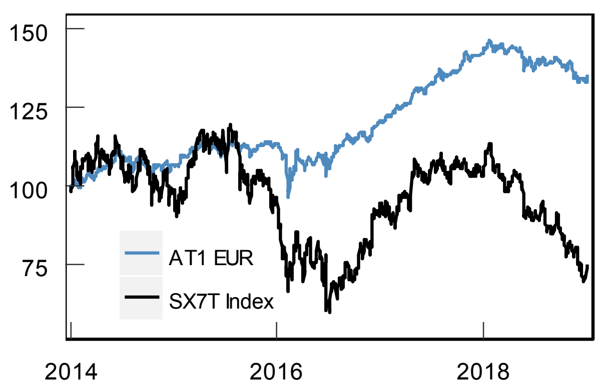
Moreover, note that the steps above do not require the options to have the same underlying as the asset, and therefore the framworks can be extended to any combination of options and assets, as we illustrate below.

Case Study 1: Hedging AT1 portfolio with SX7E puts

In the past, we have written extensively on hedging single AT1 issues with single-name equity options.[2] At the index level, our approach aims to improve the portfolio risk/reward as a whole. Following the recent introduction of total return swaps on iBoxx AT1 indices, investors have a new vehicle for investing in the AT1 asset class.

The AT1 indices are subdivided into EUR and USD issues. In this report, we focus on the **€ Liquid AT1 Index** (**IBXXC2D1).** The historical performance between EUR AT1 index and the SX7E can be seen in Figure 1. The rolling 6M returns between SX7E and the EUR AT1 index exhibit a relatively strong correlation, as seen in Figure 2.

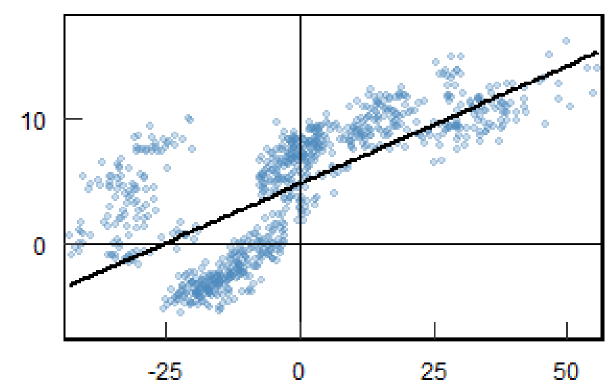
Figure 1: Total return comparison since AT1 EUR index inception (normalized to 100 at inception)



Source: J.P. Morgan

Figure 2: 6M return correlation between SX7E and EUR AT1 index beta = 0.19, R2 = 0.51

EUR AT1 index return (%)



Source: J.P. Morgan

SX7E Return (%)

Our goal in this case study is to allocate optimally between the EUR AT1 index and SX7E 6M 90% put option to improve the risk/reward relative to a long only AT1 portfolio. As discuseed, the OOPS methodology can be easily extended to accommodate proxy hedging scenarios such as this one. The only modification to the

[2] See European Equity Derivatives Outlook, 6 May 2014, and European Equity Derivatives Outlook, 24 June 2014

procedure is to normalize the historical returns of both EUR AT1 index and SX7E index options by the same volatility metric and jointly sample the historical returns. In this case, we choose the 6M ATM implied volatility of SX7E index as the volatility metric since it has a longer history.

In the optimization process, we add the following investability constraints, which are all relatively mild in our view.

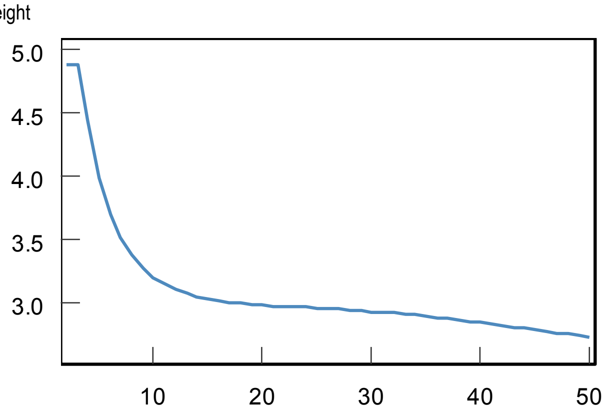
- Sum of all weights add up to 1 (no leverage).
- Spend < 10% of notional as option premium.
- Net notional of put options should be between 0% and 100%—since our intention is to provide protection for the AT1 portfolio, we do not want to be net seller of put options.

Gamma is an input parameter for risk aversion. According to Bliss and Panigirtzoglou (2004),[3] the gamma for S&P 500 options is found to be around 4, and in Faias and Santa-Clara (2017), a gamma of 10 is used. We show in Figure 3 the optimal allocation to SX7E put options over a range of gamma between 2 and 50. As we can see, the allocation stabilizes after gamma > 10. A gamma value of 10 is used for the remainder of this report.

At gamma = 10, we allocate 3% to the SX7E 6M 90% put options and invest 97% of the portfolio in AT1 EUR index. The SX7E 6M 90% put option costs around 4.8% and has a delta of around 0.34. The suggested sizing gives us a SX7E delta exposure of around €22MM. This turns out to be close to the beta between SX7E and AT1 EUR index of around 0.19 (Figure 2). The AT1 EUR index has an annual yield of around 6.7%, and therefore the position is slightly carry positive after spending 3% on 6M SX7E put option.

Figure 3: Comparison of simulated returns at various quantiles

% weight

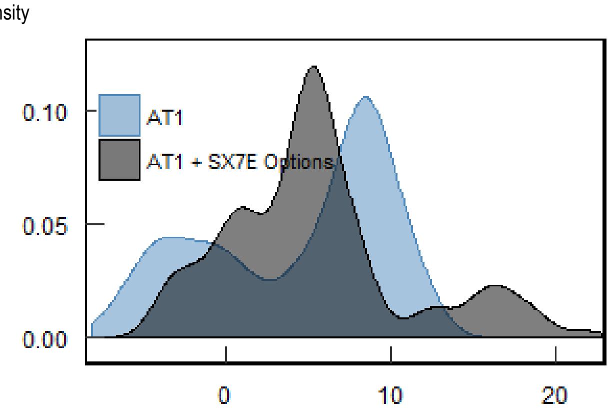


Source: J.P. Morgan

gamma

Figure 4: Simulated return distributions with and w/o option overlay

Density



Source: J.P. Morgan

Simulated 6M returns (%)

Figure 4 shows the distribution of the 1,000 simulations used for our observations. We can see that by adding SX7E put options, the left tail is reduced in exchange for a

[3] "Option Implied Risk Aversion Estimates," R. Bliss and N. Panigirtzoglou, Feb 2004, *Journal of Finance.*

Peng Cheng, CFA
(1-212) 622-5036
peng.cheng@jpmorgan.com

distribution shifted to the left. The risk-adjusted returns of option overlay strategies are superior, as shown in Table 1.

Table 1: Simulated return statistics with and w/o put option overlay (risk aversion parameter = 10)

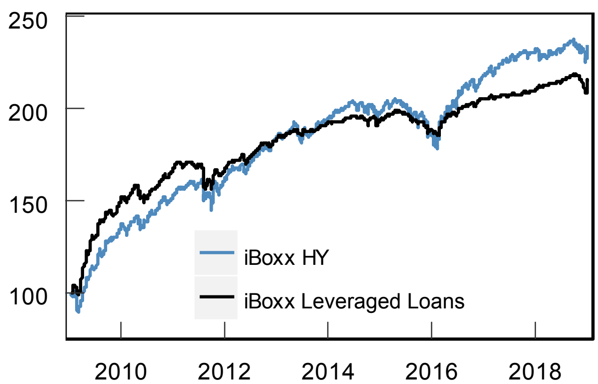
6M Returns	AT1 EUR index	+ SX7E put
Worst drawdown	-8.1%	-5.1%
5% VaR	-5.2%	-2.8%
5% CVaR	-6.2%	-3.6%
Median return	6.7%	5.1%
Average Return	4.4%	5.5%
Standard deviation	5.6%	5.6%
Sharpe ratio (annualized)	1.12	1.39
Sortino ratio (annualized)	3.23	5.77

Source: J.P. Morgan.

Case Study 2: Hedging Leveraged Loans with HYG options

Options are actively traded in the US High Yield corporate bond markets on underlyers such as CDX HY and HYG/JNK ETFs. Leveraged Loan markets, on the other hand, do not have a liquid options market, despite having experienced significant growth in recent years. As Figure 5 and Figure 6 show, iBoxx HY and Leveraged Loan indices exhit moderate correlation. Statistical tests also show that the two assets are cointegrated over the long term. Therefore, a case can be made for using the options on iBoxx HY index (HYG ETF) for hedging Leveraged Loans.

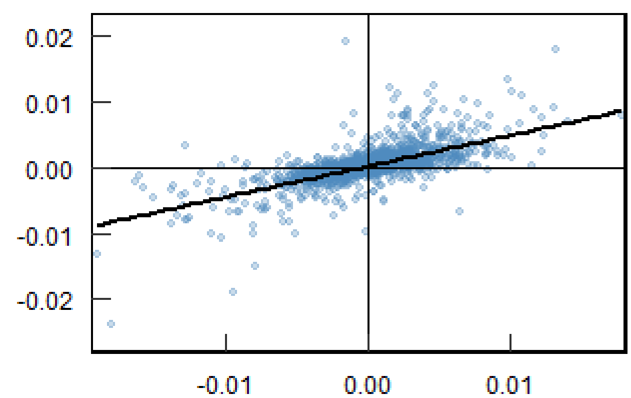
Figure 5: iBoxx HY and Leveraged Loans indices history



Source: J.P. Morgan

Figure 6: 3M return correlation between HYG and iBoxx Leveraged Loans index beta = 0.46, R2 = 0.44

Leveraged loans 3M return



Source: J.P. Morgan

HYG 3M return (%)

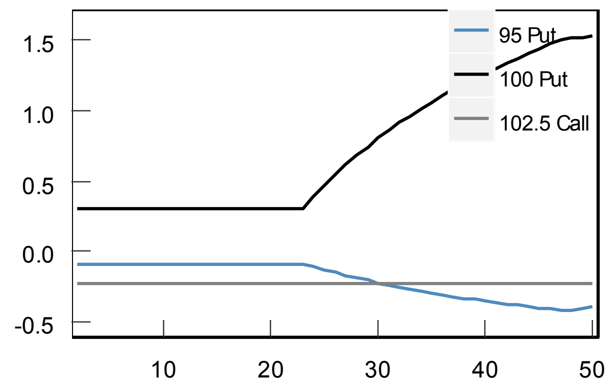
We follow the same procedure as the previous section but increase the complexity by using three HYG options. Specifically, we employ 3M 95% put, 100% put, and 102.5% call options and let the optimization determine the optimal allocation to the three legs. We also alter the maturity to show robustness across different time horizon. The optimization constraints remain the same but adapted to multiple option legs.

- Sum of all weights add up to 1 (no leverage).
- Spend < 10% of asset notional as option premium.
- Net notional of put options should be between 0% and 100%. Net notional of individual options should be between -100% and 100%. Net notional of put

options should be between 0 and 100% (no net short puts). Net notional of call options should be between -100% and +100.

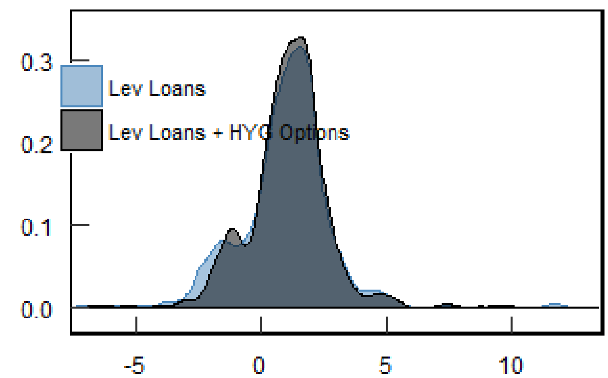
In Figure 7 we observe that the optimal structure is the familiar put spread collar, that is, buying a put spread and selling a call simultaneously. Moreover, the suggested option sizing results in zero premium outlay. Such strategies are commonly observed in practice even though we did not explicitly seek such results in the optimization process.

Figure 7: Comparison of simulated returns at various quantiles



Source: J.P. Morgan

Figure 8: Simulated return distributions with and w/o option overlay



Source: J.P. Morgan

At gamma = 10, we obtain the following option structure. **On $100MM notional Leveraged Loans, buy 3M SX7E ATM/90 put spreads on $13MM equity notional, funded by selling 30M 102.5% calls on $100MM equity notional.** The distribution of simulated returns and summary statistics are shown in Figure 8 and Table 2.

Table 2: Simulated return statistics with and w/o option overlay (risk aversion parameter = 10)

3M Returns	Leveraged Loans	+ HYG options
Worst drawdown	-8.5%	-7.9%
5% VaR	-2.4%	-1.8%
5% CVaR	-3.9%	-3.2%
Median return	1.2%	1.2%
Average Return	0.9%	1.0%
Standard deviation	1.9%	1.7%
Sharpe ratio (annualized)	0.96	1.20
Sortino ratio (annualized)	1.16	1.40

Source: J.P. Morgan.

Case Study 3: Optimal strike selection of S&P 500 hedging option structures

In the previous two case studies, we are able to obtain intuitive option structures using pre-selected strikes. In this section, we employ a larger number of strikes. The purpose is twofold: to test the effectiveness of the OOPS methodology when presented with a large number of variables, and to examine its use for optimal strike selection. The options used are 3M 90%, 95%, and 100% puts and 105% and 110% calls. We exclude 100% call options because they can be replicated by puts and delta positions using put-call parity. For the same reason, we only include out-of-the-money options in our portfolio.

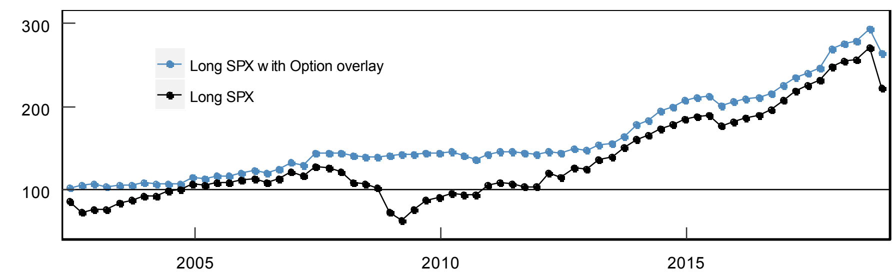
Peng Cheng, CFA
(1-212) 622-5036
peng.cheng@jpmorgan.com

The same constraints are imposed:

- Sum of all weights add up to 1 (no leverage).
- Spend < 10% of asset notional as option premium.
- Premium spent or collected on any individual option is < 10% of notional.
- Net notional of individual options should be between -100% and 100%. Net notional of put options should be between 0 and 100% (no net short puts). Net notional of call options should be between -100% and +100.

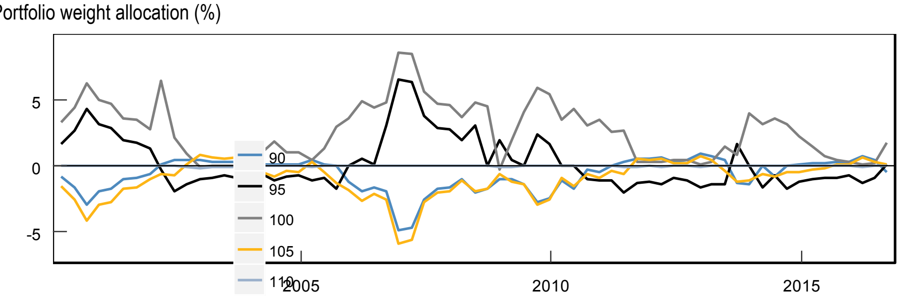
Back-test: To see the out-of-sample effectiveness of the methodology, we run the following back-test. Using a rolling look-back window of two years, we run the optimization on a quarterly basis and compute the one-period-ahead out-of-sample quarterly returns of the portfolio vs. a long-only S&P 500 portfolio. The results show that in our back-text our strategy materially outperformed the long only portfolio both in terms of Sharpe ratio and Sortino ratio. At the same time, it exhibited a smaller drawdown (Figure 9 and Table 3).

Figure 9: Back-test performance with and w/o SPX option overlay (risk aversion parameter = 10)
Indexed performance



Source: J.P. Morgan

Figure 10: Historical allocation of options
Portfolio weight allocation (%)



Source: J.P. Morgan

Peng Cheng, CFA
(1-212) 622-5036
peng.cheng@jpmorgan.com

Table 3: Back-test performance statistics

Historical quarterly returns	Long S&P 500	+ options
Average return	1.50%	1.50%
Standard deviation	7.90%	3.30%
Sharpe ratio (annualized)	0.39	0.92
Sortino ratio (annualized)	0.40	1.37

Source: J.P. Morgan.

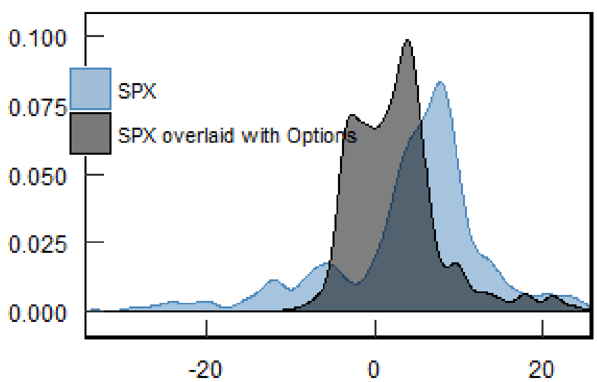
Table 4: Current optimal allocation

Strike	Allocation	Notional
90 Put	-0.9%	-100.0%
95 Put	1.1%	66.0%
100 Put	3.2%	100.0%
105 Call	-0.2%	-15.4%
110 Call	0.1%	43.2%
Delta	96.7%	96.7%

Source: J.P. Morgan.

Current optimal alloation can be seen in Table 4. The distribution of simulated returns and summary statistics, based on the current allocation, is shown in Figure 11 and Table 5.

Figure 11: Simulated return distributions with and w/o option overlay



Source: J.P. Morgan

Table 5: Simulated return statistics with and w/o option overlay (risk aversion parameter = 10)

3M Returns	SPX	+ Options
Worst drawdown	-33.7%	-9.8%
5% VaR	-13.0%	-3.8%
5% CVaR	-21.1%	-5.2%
Median return	5.9%	2.3%
Average Return	4.1%	2.6%
Standard deviation	9.1%	5.4%
Sharpe ratio (annualized)	0.90	0.96
Sortino ratio (annualized)	1.11	3.13

Source: J.P. Morgan.

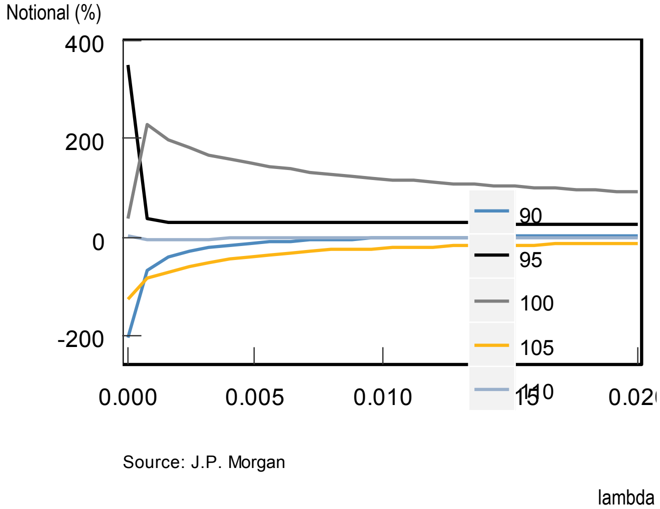
Regularization: From the above analysis, we find that although a few constraints are imposed on option notional, the optimization is still prone to selling deep OTM options to collect a relatively insignificant amount of premium (as seen in Table 4). To address the issue, we propose adding a penalty term to our objective function in place of hard constraints on notional:

L2 norm penalty
$$\frac{1}{1-\gamma}E[(1+r)^{1-\gamma}] - \lambda \sum N_i^2$$

L1 norm penalty
$$\frac{1}{1-\gamma}E[(1+r)^{1-\gamma}] - \lambda \sum |N_i|$$

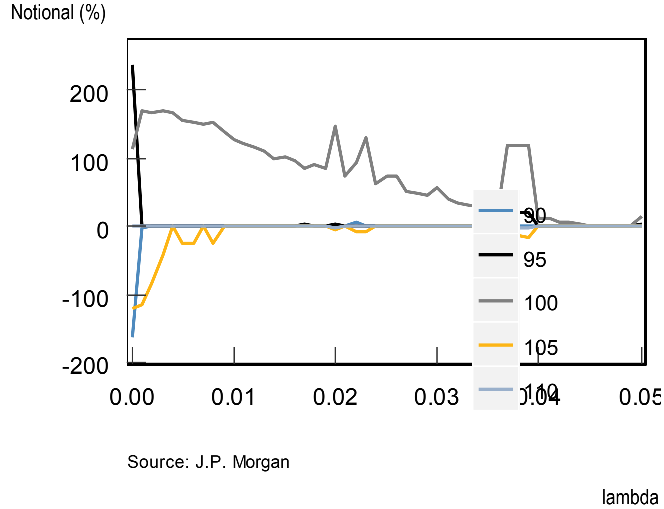
The notional (N_i) of the option is defined as option weights divided by premium. Doing so has the benefit of minimizing overfitting (λ controls the shrinkage), as well as for practical investment purposes (minimize the number of positions in an option structure). One can choose to optimize either the sum of squares (L2 norm) or absolute value (L1 norm) of notional. Minimizing L2 norm produces more stable solutions thanks to its differentiability, while minimizing L1 norm has the advantage of ensuring a sparse solution. To illustrate, we run the optimizations using a range of shrinkage parameter values, as seen in Figure 12 and Figure 13.

Figure 12: Optimal allocation to options across a range of lambda using L2 norm penalty



Source: J.P. Morgan

Figure 13: Optimal allocation to options across a range of lambda using L1 norm penalty



Source: J.P. Morgan

The notional amount of deep OTM options rapidly shrinks with the increase of the shrinkage parameter value. If the goal is to minimize the number of option legs, one might prefer the L1 norm pentaly term, since the notionals approach 0 relatively quickly on most OTM options. The optimal lambda value can be determined by cross-validation.

Conclusion

The question of how to optimally incorporate options into an investment portfolio does not fit easily into the existing portfolio optimization framework due to the non-normality of option returns. In this report we examined three case studies by applying and extending the methodology proposed by Faias and Santa-Clara (2017):

- Hedging AT1 portfolios with SX7E options
- Hedging Leveraged Loan portfolios with HYG options
- Optimal selection of S&P option hedging strategies

With proper investability constraints, we find the methodology to produce intuitive and effective option hedging portfolios.

Risks of Common Option Strategies

Risks to Strategies: Not all option strategies are suitable for investors; certain strategies may expose investors to significant potential losses. We have summarized the risks of selected derivative strategies. For additional risk information, please call your sales representative for a copy of "Characteristics and Risks of Standardized Options." We advise investors to consult their tax advisors and legal counsel about the tax implications of these strategies. Please also refer to option risk disclosure documents.

Put Sale: Investors who sell put options will own the underlying asset if the asset's price falls below the strike price of the put option. Investors, therefore, will be exposed to any decline in the underlying asset's price below the strike potentially to zero, and they will not participate in any price appreciation in the underlying asset if the option expires unexercised.

Call Sale: Investors who sell uncovered call options have exposure on the upside that is theoretically unlimited.

Call Overwrite or Buywrite: Investors who sell call options against a long position in the underlying asset give up any appreciation in the underlying asset's price above the strike price of the call option, and they remain exposed to the downside of the underlying asset in the return for the receipt of the option premium.

Booster : In a sell-off, the maximum realized downside potential of a double-up booster is the net premium paid. In a rally, option losses are potentially unlimited as the investor is net short a call. When overlaid onto a long position in the underlying asset, upside losses are capped (as for a covered call), but downside losses are not.

Collar: Locks in the amount that can be realized at maturity to a range defined by the put and call strike. If the collar is not costless, investors risk losing 100% of the premium paid. Since investors are selling a call option, they give up any price appreciation in the underlying asset above the strike price of the call option.

Call Purchase: Options are a decaying asset, and investors risk losing 100% of the premium paid if the underlying asset's price is below the strike price of the call option.

Put Purchase: Options are a decaying asset, and investors risk losing 100% of the premium paid if the underlying asset's price is above the strike price of the put option.

Straddle or Strangle: The seller of a straddle or strangle is exposed to increases in the underlying asset's price above the call strike and declines in the underlying asset's price below the put strike. Since exposure on the upside is theoretically unlimited, investors who also own the underlying asset would have limited losses should the underlying asset rally. Covered writers are exposed to declines in the underlying asset position as well as any additional exposure should the underlying asset decline below the strike price of the put option. Having sold a covered call option, the investor gives up all appreciation in the underlying asset above the strike price of the call option.

Put Spread: The buyer of a put spread risks losing 100% of the premium paid. The buyer of higher-ratio put spread has unlimited downside below the lower strike (down to zero), dependent on the number of lower-struck puts sold. The maximum gain is limited to the spread between the two put strikes, when the underlying is at the lower strike. Investors who own the underlying asset will have downside protection between the higher-strike put and the lower-strike put. However, should the underlying asset's price fall below the strike price of the lower-strike put, investors regain exposure to the underlying asset, and this exposure is multiplied by the number of puts sold.

Call Spread: The buyer risks losing 100% of the premium paid. The gain is limited to the spread between the two strike prices. The seller of a call spread risks losing an amount equal to the spread between the two call strikes less the net premium received. By selling a covered call spread, the investor remains exposed to the downside of the underlying asset and gives up the spread between the two call strikes should the underlying asset rally.

Butterfly Spread: A butterfly spread consists of two spreads established simultaneously – one a bull spread and the other a bear spread. The resulting position is neutral, that is, the investor will profit if the underlying is stable. Butterfly spreads are established at a net debit. The maximum profit will occur at the middle strike price; the maximum loss is the net debit.

Pricing Is Illustrative Only: Prices quoted in the above trade ideas are our estimate of current market levels, and are not indicative trading levels.

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	Overweight (buy)	Neutral (hold)	Underweight (sell)
J.P. Morgan Global Equity Research Coverage	46%	40%	14%
IB clients*	53%	47%	37%
JPMS Equity Research Coverage	44%	41%	15%
IB clients*	75%	65%	56%

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Peng Cheng, CFA
(1-212) 622-5036
peng.cheng@jpmorgan.com