Dynamic Option Replication: Applications in
Active Management, Ivy Portfolios, Hedging and Futures

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Abstract

Investors and hedgers can use options, such as puts and calls, to protect themselves against adverse price movement. Most option users purchase options – even at the expense of generally over-priced option premiums. Applying methods such as dynamic option replication can achieve similar results to the purchase of options without the associated high expense of protection. Investment managers can use option replication techniques to protect stock or bond portfolios. Hedgers can use these methods to protect against interest rate, currency, and commodity price risk. Indeed, many approaches used to dynamically replicate options are used in the managed futures industry to capture insurance premiums from hedgers. We study the results of various dynamic option replication schemes and discuss the implications for active and passive management. Results are based on decades’ worth of data in multiple asset classes, including stocks, bonds, commodities and futures.

PAST RESULTS ARE NOT NECESSARILY INDICATIVE OF FUTURE RESULTS.
1. Introduction

Years ago, investment professionals applauded the 60/40 portfolio mix for stocks and bonds. Over time, Harry Markowitz’s idea of the efficient frontier became popular (Markowitz 1952). Analysts realized that a diversified portfolio’s results are driven mainly by the asset allocation policy (Brinson, Hood, and Beebower 1986).

Portfolio managers became interested in the diversification benefits of global stocks and global bonds. Fund companies came out with benchmarks to give access to – and measure performance of – the “world market.” Investment managers seeking additional diversification sought out real estate and real estate investment trusts (REITs). Hedge funds and alternative investment strategies became increasingly popular.

Today, advances in research and technology are morphing asset classes and investment strategies within the investment world. Financial engineers are combining strategies and optimizing diversification into balanced parity schemes (Dalio 2010; Asness 2011).

These so-called “risk parity” strategies have gained traction as a method of exploiting diversification and correlations – to better balance risk and gain excess returns (Callan 2010). Indeed, as the investment world becomes smaller, lines between active and passive management are increasingly blurred (Chin 2011). Some work, such as Faber’s application of quantitative trading techniques to
replicate the so-called “Ivy Portfolio” is not yet widely-accepted – but has gained attention over the years.

2. Methodology: Assets and Data

Historical data is examined to give us a framework of understanding – and to learn from history. Data for multiple asset classes is obtained from a variety of sources. We thank Barclay Hedge (2013), Price Asset Management (2013), Shiller (2013), and CARAT/Adamah Capital (2013) for asset and investment data.

Performance data from 1970-2013 is analyzed for a variety of assets, including stocks, bonds, and the alternative assets: commodities and futures. It is well-established that alternative investment strategies offer good diversification benefits for a portfolio of stocks and bonds (Lintner 1983, Chin 2010). In this paper, we use the following indices for our asset classes:

- Stocks: S&P 500
- Bonds: Government Bonds
- Commodities: RICI (Rogers International Commodity Index);
  S&P/GSCI (Goldman Sachs Commodity Index) prior to 8/98.
- Futures contracts: nearest / most commonly-traded contract.
3. Previous Work and the Ivy Portfolio

Similar to work done by Faber on the Ivy Portfolio, our research related to active management has shown that quantitative approaches can improve risk-adjusted performance. Research shows that a high percentage of Ivy League endowment performance can be captured using quantitative approaches to asset allocation.

An exhaustive analysis of dynamic option replication time-frames is beyond the scope of this paper, but we will review a sampling of methods and results. By simplifying quantitative methods to a binary option approach, we discover that options can be replicated in a dynamic method by using quantitative and technical approaches.

No approach will work well all of the time. Oftentimes, the media will broadcast headlines such as, “Market timers miss market rise,” or “Hedge funds underperform stock indices again.” It is notable that large hedge funds, on average, apply quantitative trading strategies. Large headlines often dictate public opinion on the effectiveness of quantitative systems. However, professional fund managers successfully apply quantitative techniques based on long-term historical data and scientific research.

Research shows that a dynamic option replication approach will improve risk-adjusted performance over the long-term. Some may claim that actual performance is lower than a 100% equity allocation, but risk-adjusted performance is the preferred benchmark. In general, the option portion of the dynamic hedging
is activated – and equity exposure is reduced. *Thus, long-term performance may be reduced slightly, but risk is typically reduced to a greater degree.*

4. Replicating Options with Dynamic Hedging

Before we go into dynamic option replication, let us review the “return distributions” of assets. The underlying asset may be any asset class – but for the sake of an example, we will assume that we are looking at the potential return distribution of equities. Below is the performance of a stock purchased at 100.

**Chart 1: Asset Performance**

<table>
<thead>
<tr>
<th>Return as Function of Price</th>
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</thead>
<tbody>
<tr>
<td>40%</td>
</tr>
<tr>
<td>30%</td>
</tr>
<tr>
<td>20%</td>
</tr>
<tr>
<td>10%</td>
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<td>-20%</td>
</tr>
<tr>
<td>-30%</td>
</tr>
<tr>
<td>-40%</td>
</tr>
<tr>
<td>50 70 90 110 130 150</td>
</tr>
</tbody>
</table>

If protection from downside stock movement is desired, a protective put option can be purchased for the entire downside price protection. The option has
an associated cost, or option premium. The total return distribution will now look like the chart below. The delta, also called a hedge ratio, compares the change in price in a derivative or option, relative to the change in price of the underlying option. In our example, we are applying full price protection, so we have a delta of 1.00. Other factors – such as the option’s strike price, expiration date, volatility, and more – come into play, but that is beyond the scope of this paper.

Chart 2: Asset Performance with Option Protection

(Delta = 1)

Depending on the cost of the option premium and the risk-return characteristics desired by the investor, the level of protection from a decline in the stock price may be adjusted. For example, if the investor is comfortable with
taking on one-half of the downside risk of the stock, the investor can choose to protect one-half of his stock exposure, for a delta of 0.5.

**Chart 3: Asset Performance with Partial Option Protection**

(Delta = .5)

A systematic approach can be developed that applies quantitative methods and a binary tree approach to monitor the underlying asset price, delta, and option performance. By combining concepts of a pure dynamic option replication along with quantitative methods that account for the cost of execution (both slippage and commissions), portfolio protection can be achieved at lower cost than traditional protective put purchases.

On average, a dynamic option replication approach yields the following return distribution for a targeted delta of 1.0. In certain scenarios, a protective
option purchase may yield better results, but for the majority of cases, the dynamic hedging option outperforms a static option purchase.

Chart 4: Asset Performance with Dynamic Option Replication
(Targeted Delta = 1.0)

Instead of paying expensive option premiums, we are able to capture gains by using dynamic option replication. A similar “risk profile” is achieved while maintaining protection for the underlying asset – all at lower cost.

Another benefit is that dynamic hedging generally improves risk / return characteristics of the portfolio or carved-out asset sector. While the return distribution for option purchases will differ slightly, the main goal of price protection is achieved.
5. Skewness and Kurtosis Measures Describe Return Distributions

“Skewness” and “kurtosis” of returns are important measures with today’s financially engineered return distributions, especially when applying quantitative techniques. This is particularly true for our work, where we will compare passive “buy-and-hold” strategies to dynamic hedging methods.

Mathematically, the average return, or mean, can also be called the “first moment.” Standard deviation, a measure of volatility, involves squaring the difference between returns and the mean – and is the “second moment.”

Skewness measures the asymmetry of the return distribution and is the “third moment.” Rational investors prefer positively skewed return distributions. Historically, stock returns are negatively skewed due to large downside surprises such as financial turmoil and market crashes.

Kurtosis, the “fourth moment,” is a measure of “peakedness” or “fat-tails” in a distribution. Kurtosis is also sometimes called the “volatility of volatility.” In general, we prefer positive kurtosis (since we expect positive returns) – especially if the distribution is positively skewed. However, if a distribution has a very negative skew, a very large kurtosis implies large negative surprises.
6. Stocks and Dynamic Hedging

We apply dynamic hedging approaches to the stock market. Our dataset includes major financial crises such as the 1973-74 and 1987 stock market crashes, the internet bubble and the sustained stock market malaise since 2000 – including the 2008 financial stock market stock.

Various sources have cited robust results using long-term approaches on the order of several months to many months. We have studied numerous quantitative and technical approaches and for the purposes of this paper, we apply simple moving averages of ten months and fifteen months. In effect, the moving average is used as an indicator to help monitor the desired hedging delta in a binary fashion.

The table shows that the dynamic hedging method reduces volatility, as measured by standard deviation, from 15.5% to the 12% range. Standard deviation is difficult to understand intuitively, so we also compute a measure of decline, or drawdown. The average annual “largest cumulative decline” (LCD) is reduced by more than a third, from -15.9% to the -9.5% range. This improves the return / risk ratios by roughly 15%-50%, depending on the risk measure.
Table 1: Stocks and Dynamic Hedging (1970 – 2013)

<table>
<thead>
<tr>
<th></th>
<th>Buy &amp; Hold</th>
<th>Stocks with DH10</th>
<th>Stocks with DH15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Annual Return</td>
<td>11.1%</td>
<td>10.0%</td>
<td>10.5%</td>
</tr>
<tr>
<td>Annualized SD</td>
<td>15.5%</td>
<td>11.9%</td>
<td>12.2%</td>
</tr>
<tr>
<td>Ratio (Ret / SD)</td>
<td>0.72</td>
<td>0.84</td>
<td>0.86</td>
</tr>
<tr>
<td>Average Annual LCD</td>
<td>-15.9%</td>
<td>-9.4%</td>
<td>-9.6%</td>
</tr>
<tr>
<td>Ratio (Ret / -LCD)</td>
<td>0.70</td>
<td>1.06</td>
<td>1.09</td>
</tr>
<tr>
<td>Skew</td>
<td>-0.46</td>
<td>-0.62</td>
<td>-0.51</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>1.84</td>
<td>4.60</td>
<td>4.16</td>
</tr>
</tbody>
</table>

What is actually happening when we apply this technique? Below is the pattern of returns, or equity stream, for each strategy.

From the chart, we can see that the dynamic hedging approach does indeed protect the portfolio during large adverse moves in the stock market. Note how the dynamically hedged portfolios have no equity exposure during market crises such as the early 2000s as well as the financial crisis of 2008. The approach also helped to protect the portfolio during the energy crisis of 1973-74 and the stagflation years of the early 1980s.

Our research has shown that this method works across a variety of asset classes including stocks, bonds, international stocks, real estate, commodities and futures. The results are also robust over a fairly wide set of time-frames and quantitative hedging methods. As a sidebar, our research shows that shorter-term time-frames are also effective at replicating options dynamically – and may match some investors’ preferences for downside protection. *Portfolios may be tailored to suit investor preferences based on the robustness of this work.*

7. Implications for Active versus Passive Management

Historical data and research shows that there is no single correct method of investing. Some industry professionals prefer passive management due to lower fees and the underlying returns of traditional asset classes. Others prefer the benefits of active management. These benefits include professional management that assists in limiting downside volatility and drawdowns.
Results show that at times passive management has the advantage over active management and vice versa. Indeed, while Chart 5 shows the benefits of dynamic hedging, we can clearly see that there are also periods of outperformance for a passive buy-and-hold strategy.

In addition, there are many variations of active management styles that outperform others. However, a scientific and robust method helps to overcome limitations due to over-optimization.

While the following phrase may seem counterintuitive, there is a place for active management alongside passive management (Chin 2011). Some analysts prefer to view active management as a risk management tool while others prefer to see active management as additional diversification. In either case, the acceptance of quantitative and active strategies is another development in the investment community: Financial engineering and modern finance are morphing various asset classes and investment strategies into a global portfolio.

8. Commodities and Dynamic Hedging

Our research has shown that dynamic option replication techniques can be applied to just about every asset tested – including bonds, real estate and commodities. This helps to support the thesis that dynamic hedging is a robust method of achieving investment goals and shaping return distributions. In particular, financial engineers are increasingly applying these methods to shape
return distributions to avoid negative surprises and improve the positive skew and kurtosis of investment portfolios.

Below are the results of applying dynamic hedging to commodities. Again, there is a slight reduction in nominal performance, but a larger improvement in risk numbers. Risk-adjusted performance improves 10%-20%.

**Table 2: Commodities and Dynamic Hedging (1970 – 2013)**

<table>
<thead>
<tr>
<th></th>
<th>Buy &amp; Hold</th>
<th>Stocks with DH10</th>
<th>Stocks with DH15</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Annual Return</strong></td>
<td>11.7%</td>
<td>10.5%</td>
<td>10.8%</td>
</tr>
<tr>
<td><strong>Annualized SD</strong></td>
<td>18.1%</td>
<td>15.0%</td>
<td>15.5%</td>
</tr>
<tr>
<td><strong>Ratio (Ret / SD)</strong></td>
<td>0.64</td>
<td><strong>0.70</strong></td>
<td><strong>0.70</strong></td>
</tr>
<tr>
<td><strong>Average Annual LCD</strong></td>
<td>-20.8%</td>
<td>-16.3%</td>
<td>-17.1%</td>
</tr>
<tr>
<td><strong>Ratio (Ret / -LCD)</strong></td>
<td>0.56</td>
<td><strong>0.64</strong></td>
<td><strong>0.63</strong></td>
</tr>
<tr>
<td><strong>Skew</strong></td>
<td>0.18</td>
<td>0.85</td>
<td>0.70</td>
</tr>
<tr>
<td><strong>Kurtosis</strong></td>
<td>3.25</td>
<td>5.63</td>
<td>5.19</td>
</tr>
</tbody>
</table>

The equity stream and pattern of returns again shows that dynamic hedging helps to protect against downside risk during large adverse moves in the underlying asset class.
9. Futures Markets + Dynamic Hedging = Managed Futures

In a similar manner, the application of option replication techniques applied to futures markets captures positive returns – which some say are risk premiums paid by hedgers. The managed futures industry has been in the forefront of applying quantitative and technical methods – doing so since the 1970s. The industry has earned positive returns over the long-term, based on decades’ worth of data.

The chart below shows the result of option replication techniques applied to the most liquid futures markets, including currencies, interest rates, metals, energy,
agriculture, and soft commodities. Proprietary machine-learning techniques are also applied – and the main methodology agrees with that of other futures industry research. The managed futures industry is growing in importance and assets under management for several reasons, including: an underlying return, diversification benefits, and risk management relative to other portfolio components (stocks, bonds, currencies and commodities). *Of particular interest to some are the strongly positive skew and kurtosis measures of managed futures distributions.*

**Chart 7: Managed Futures Index**

**Growth of 1,000**

Summary statistics for the managed futures index:

- Average annual return: 11.7%
- Annualized standard deviation: 8.3%
- Positive skew of 1.12 and positive kurtosis 7.82.
10. Conclusions

The extreme volatility suffered by the financial markets has caused some to declare that buy and hold is dead (Lo 2012). Much work has been done on active versus passive management over the years (Chin 2011) as well as other aspects of asset allocation, including risk parity and leverage aversion (Asness 2011 and Dalio 2010). This research highlights the effectiveness of dynamic option replication and related quantitative approaches to various asset classes.

Dynamic hedging has proven to yield positive results using fairly simple but robust methods. We have performed a wealth of research in this area and various methods will appeal to different investors and their preferences. Of particular interest are the results for “managed futures” – which promise strong diversification benefits along with strongly positive skew and kurtosis traits.

The goal of our research is to improve our understanding of the financial markets and apply the results to improve forward information. As the world moves increasingly to a financially-engineered “global portfolio” of all asset classes and investment strategies, we will see continued growth in alternative assets and quantitative methods.
Risk Disclosure

Investing in commodities, managed futures or other alternative investment products or accounts can involve a high degree of risk. Such investments can be illiquid, speculative, volatile, or employ significant leverage and can have no secondary or a limited secondary market for an investor’s interest.

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References


