ADAPTIVE ASSET ALLOCATION: A PRIMER

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SUMMARY

Modern Portfolio Theory (MPT) is the most widely used method to construct portfolios which maximize expected returns at different levels of risk. Investors often use long-term average asset returns and risks to find optimal portfolios, but these long-term estimates are subject to large errors in the intermediate term. As small errors in estimates can lead to large errors in portfolios formed using MPT, investors add heuristic constraints to produce more intuitive and diversified portfolios than MPT would prescribe. Unfortunately, these heuristic adjustments often drive portfolios far away from optimal values. In this paper, we describe methods of portfolio optimization that rely on shorter term estimates of risk and return, and which change through time in response to observed changes in markets. In stepwise fashion we demonstrate how using shorter-term rolling estimates of risk, diversification, and returns delivers more resilient portfolios which thrive in good times - and bad.

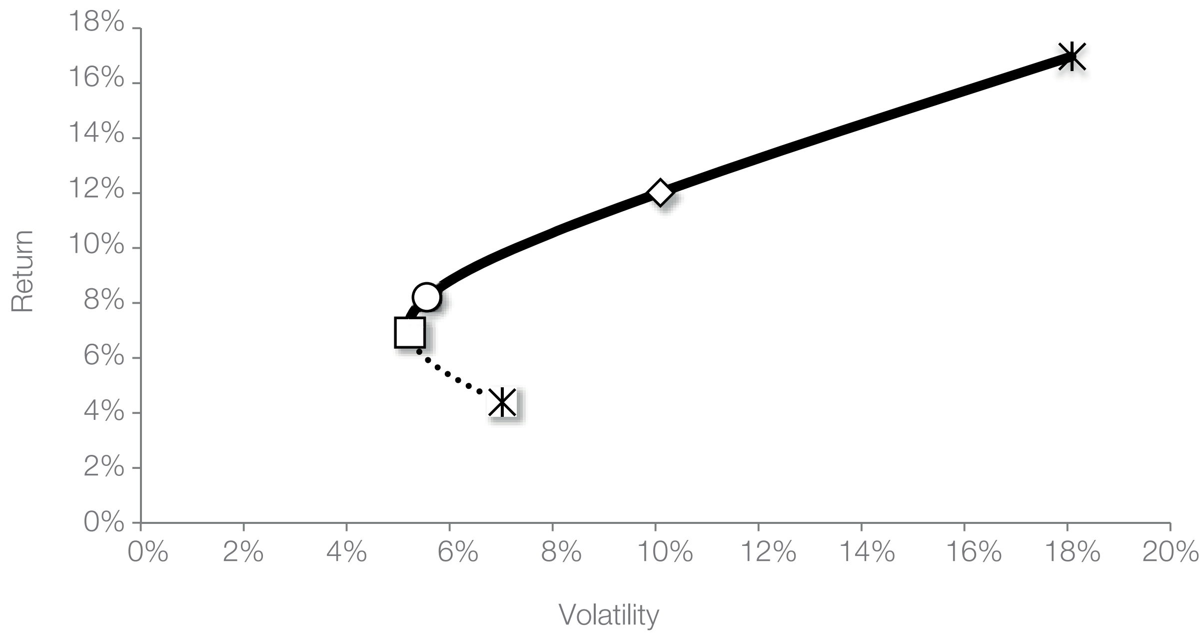
INTRODUCTION

For most of us, the ultimate goal of investing is to achieve a target wealth (or portfolio income) with the lowest possible risk. The vehicle we use to realize this ambition is our investment portfolio. But what mix of investments is most likely to help us realize our ambitions?

Modern Portfolio Theory (MPT) is a Nobel Prize winning mathematical model that relates the expected return and risk of a portfolio to the returns and risks of its individual constituents, after accounting for the effects of diversification. If thoughtfully applied, it can be a valuable tool in the construction of a reasonably efficient portfolio to meet the needs of most investors.

It is useful to think of MPT as a machine. When you feed the machine information about the assets being considered for a portfolio, it produces new information about portfolios constructed from those assets. Specifically, MPT takes in information about the expected return, risk, and correlation for each asset under consideration for investment. In return, it produces information about all of the portfolios that maximize expected returns at each level of portfolio risk. Portfolios which maximize expected return at a level of risk said to be 'efficient' portfolios, and the continuum of all portfolios which maximize return at each level of risk is called the 'efficient frontier'.

Figure 1. Efficient frontier derived via MPT for U.S. stocks and Treasury bonds, 2009-2014



Source: ReSolve Asset Management, 2015. Data from CSI.

Note on the frontier in Figure 1. a square indicating the mix of stocks and bonds that delivered the lowest volatility over the period. This is the so-called 'minimum variance portfolio', resulting from a mix of 22% stocks and 78% bonds. Also observe a circle at the point of highest return per unit of risk, representing the maximum "Sharpe ratio" portfolio, to be explained below. A diamond indicates the return that was available at a 10% target volatility (~12%), which happened to correspond to a mix of 60% stocks and 40% bonds. Lastly, the crossed squares at the ends of the frontier indicate the risk and return from owning either 100% bonds (at the bottom) or 100% stocks (at the top). Of course, this frontier is backward looking so investors should not derive any information about how to construct portfolios for the future from this simple example.

Unfortunately, the MPT machine is only as useful as the information it receives about the assets under consideration. In fact, the nature of the model is such that small errors contained in the information that is fed into the model are amplified within the machine. For this reason, Dr. Richard Michaud, a pioneer in portfolio optimization, describes MPT as, "A molehill of garbage in, a mountain of garbage out."

The fact is, MPT has earned a bad reputation in many investment circles because it is so sensitive to user error. But this is not the fault of MPT – after all, MPT is just math. It's as unassailable as the Pythagorean theorem, which relates the sides of a right triangle, or the math that makes change at the grocery store. Rather, and perhaps unsurprisingly, MPT doesn't work very well if you don't feed it useful information. It's a simple case of GIGO: Garbage In-Garbage Out.

This paper is organized as follows: first, we will explore why traditional inputs to the MPT machine lead investors astray because they do not take into account the dynamic nature of markets. Next, we will build a stepwise framework for thinking about portfolios in an ever-changing investment landscape. Finally, we will demonstrate how portfolios that adapt in real-time to observed market conditions can deliver on the initial promise of MPT: higher returns with less risk.

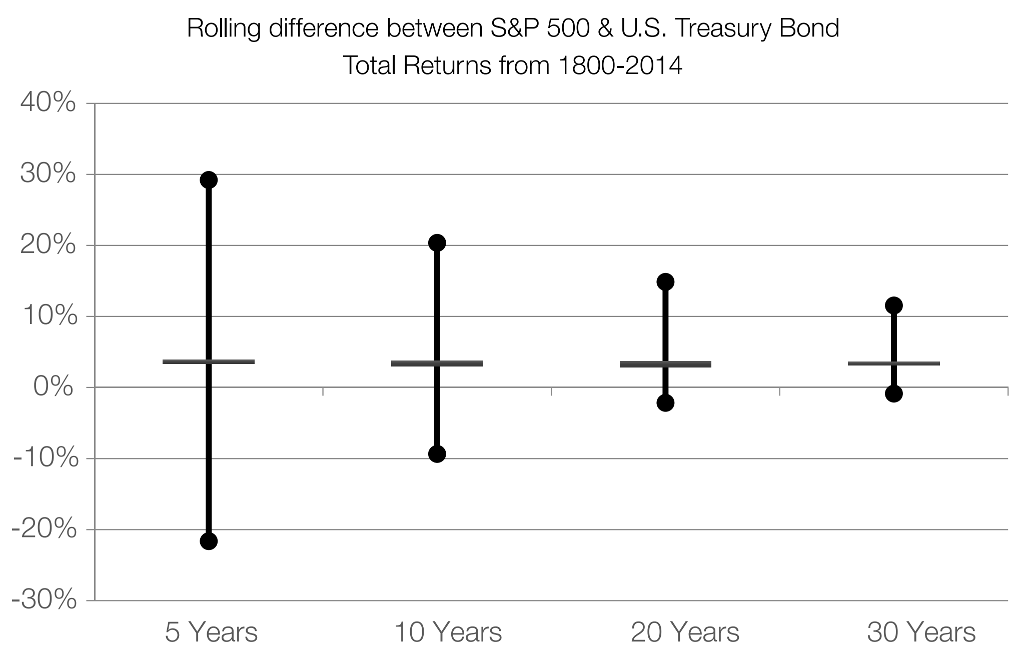
GIGO RETURNS

Many investors are aware that, over the long-term, stocks have outperformed bonds by a significant margin. In fact, over the past two centuries stocks have outperformed benchmark government bonds by almost 4% per year. However, if we look more closely we observe that there is an enormous amount of noise lurking beneath that long-term average.

Figure 2. shows the average and range of excess returns to stocks versus bonds over holding periods ranging from 5 years through 30 years. Note at each horizon that, while the average excess return to stocks is just under 4%, there are examples of bonds outperforming stocks over all horizons. If we observe all rolling 5 year periods, we see that there was a period where stocks outperformed bonds by almost 30% per year; however, there was also a 5 year period where bonds outperformed stocks by over 20% per year. And many investors will be shocked to learn that there have been 30 year periods through history where bonds have outperformed stocks, by almost 1% per year.

Figure 2. Excess returns to stocks over rolling horizons

	5 Years	10 Years	20 Years	30 Years
Average	3.88%	3.73%	3.69%	3.59%
Max	29.21%	20.36%	14.87%	11.55%
Min	-21.62%	-9.35%	-2.16%	-0.85%
Median	3.35%	2.99%	2.84%	3.14%

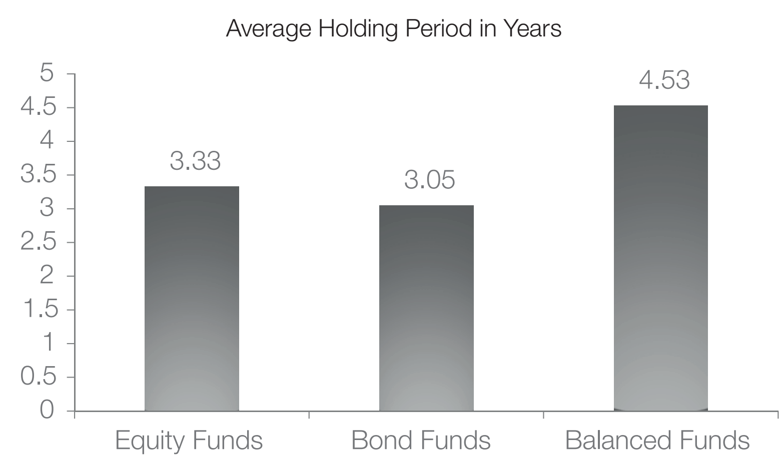


Source: ReSolve Asset Management, 2015. Data from Global Financial Data.

Many investors use the average of long-term returns across history as inputs to MPT. However, these average returns have very large error terms, commensurate with the long tails we observe in Figure 2. This fact is especially concerning given what we observe about investors' typical holding periods for investments.

Figure 3., taken from Dalbar's most recent 'Quantitative Analysis of Investor Behavior', describes the average holding period for retail investors across different asset classes. Investors in stock or bond mandates typically hold onto their funds for just over 3 years, while investors in balanced funds are generally more patient, holding for an average of 4.5 years.

Figure 3. Average holding period



Source: Dalbar (2015)

When we cross-reference the typical 3-5 year holding periods in Figure 3. with the long tails for stock/bond excess returns in Figure 2 at the 5 year horizon, we start to see the problem. Recall that MPT is especially sensitive to errors in the information that we feed into the machine. At a 5 year horizon, the estimate is an excess return of about 4%, but the error around that estimate is about

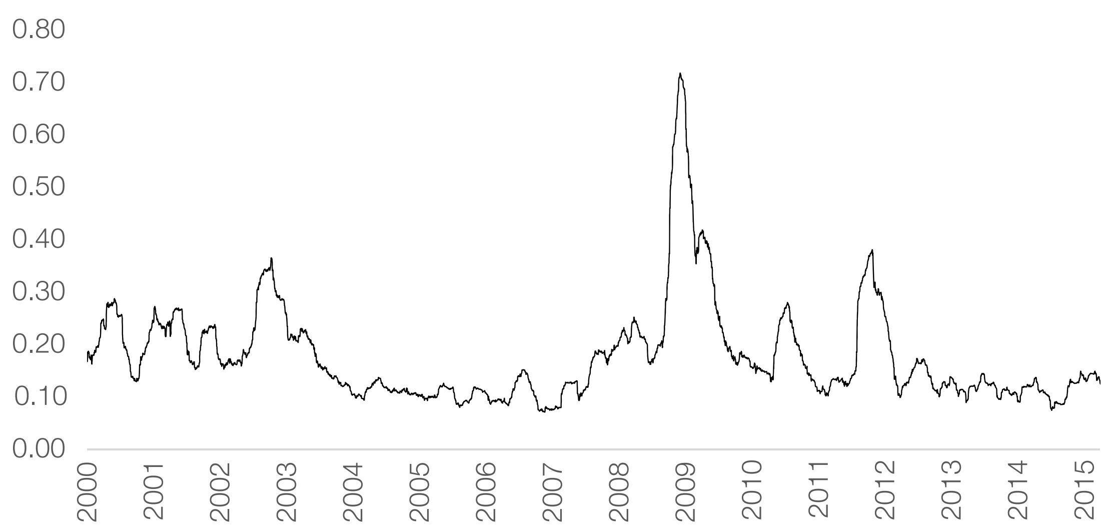
50%. Since the error swamps the estimate at horizons out to about 20 years or more, average historical returns are not very useful for forming portfolios using MPT.

GIGO VOLATILITY

Volatility measures how far the returns in any given period typically stray from their average returns. It is a useful, if imperfect, measure of risk because it can be used to approximate the range of portfolio outcomes over an investment horizon.

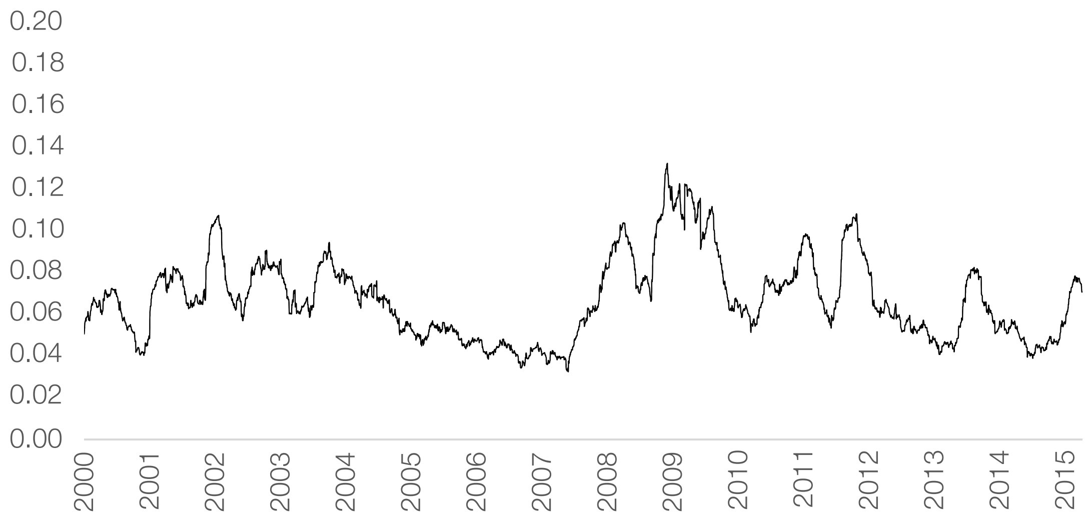
There is a great deal going on under the surface with volatility, too. For example, while stocks deviate on average by about 20% from their long-term mean from year to year, and bonds fluctuate by about 7%, the range of these fluctuations can change profoundly from period to period. Figures 4. and 5. show how substantially volatility can change, observed over rolling 60-day windows since 2000.

Figure 4. US Stock Market 60-Day Rolling Standard Deviation (Annualized)



Source: ReSolve Asset Management, 2015. Data from Global Financial Data.

Figure 5. Intermediate Treasury Bond 60-Day Rolling Standard Deviation (Annualized)



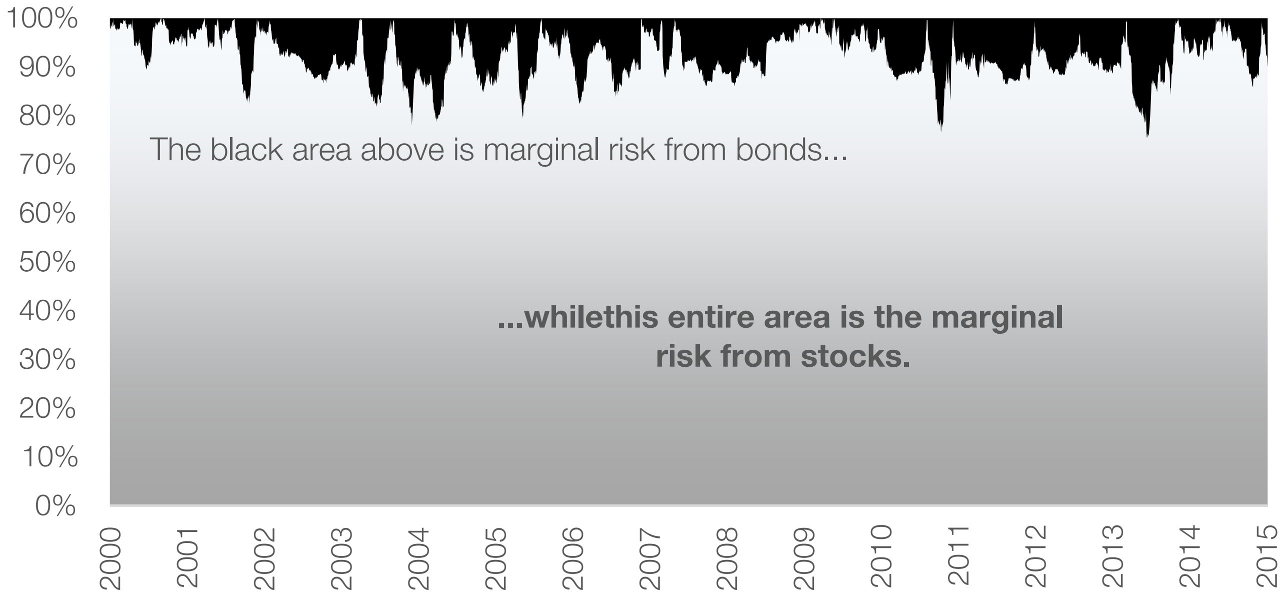
Source: ReSolve Asset Management, 2015. Data from Global Financial Data.

Incredibly, you can see that the volatility of both stocks and bonds can fluctuate by over 500% from one 60-day observation period to the next. This has a dramatic impact on the risk profile of a typical balanced portfolio, and therefore on the experience of a typical balanced investor.

Most investors believe that if a portfolio is divided 60% into stocks and 40% into bonds, that these asset classes contribute the same proportion of risk to the portfolio. However, Figure 6. shows that, for a portfolio consisting of 60% S&P 500 stocks and 40% 10-year Treasury bonds, the stock portion of the portfolio actually contributes over 90% of total portfolio volatility on average, and over 95% of portfolio volatility about 30% of the time. In late 2008 and early 2009 for example, balanced investors at times found themselves over 97% exposed to equity risk.

While the long-term volatility of stocks is likely to be about 3x higher than the long-term volatility of bonds, individual stock and bond volatility, and the volatility of portfolios constructed from stocks and bonds, can vary profoundly through time. These variations represent even more errors for our MPT machine to contend with, and serve to further confound its usefulness in traditional analyses.

Figure 6. Stock vs. bond risk contribution to a 60/40 stock/bond portfolio | 60 day rolling horizon



Source: ReSolve Asset Management, 2015. Data from CSI.

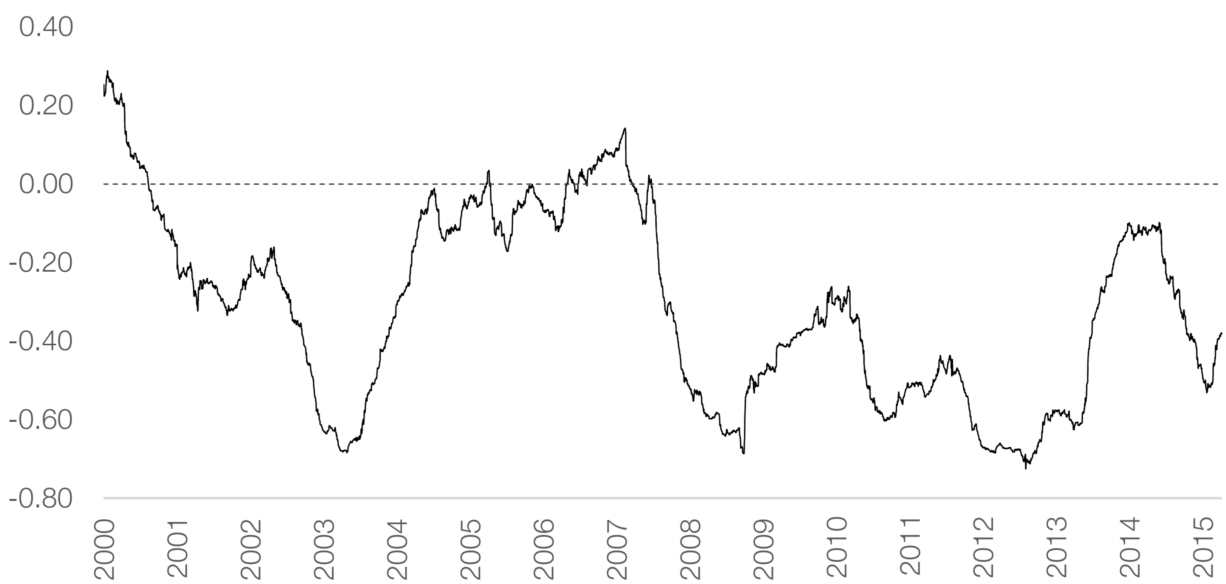
GIGO CORRELATION

By now it probably comes as no surprise that the correlation between asset classes fluctuates substantially over time as well. While the long-term correlation between, for example, U.S. stocks and Treasuries or U.S. stocks and gold, have been low or even negative over the long-term, the actual realized correlation between these assets oscillates between strong and weak over time.

Figure 7. 252-day rolling correlation between US stocks and gold

Source: ReSolve Asset Management, 2015. Data from CSI.

Figure 8. 252-day rolling correlation between US stocks and US Treasury bonds

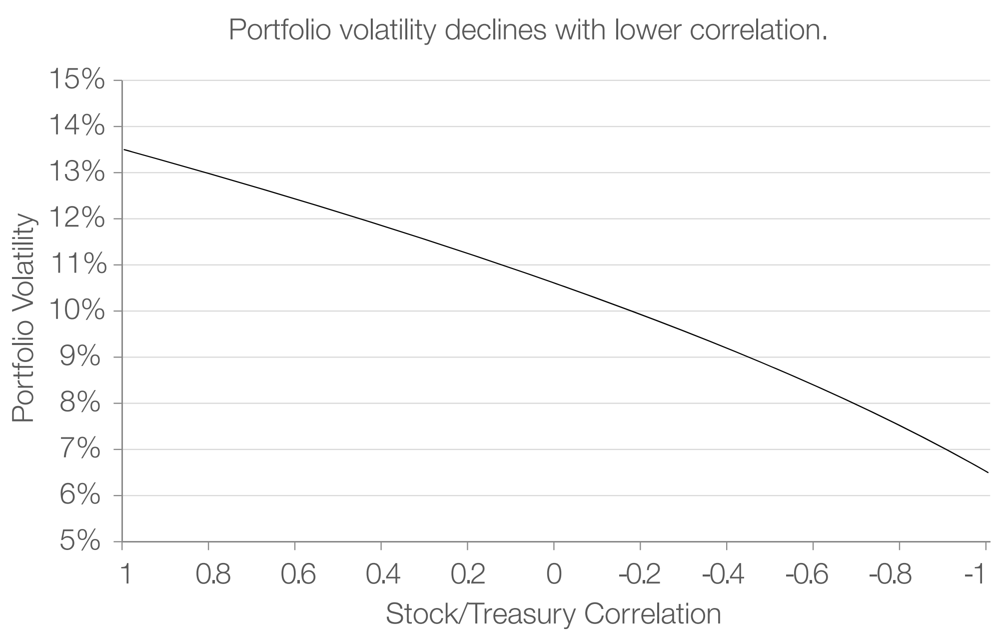


Source: ReSolve Asset Management, 2015. Data from CSI.

From the charts, notice that the long-term average 252-day rolling correlation between stocks and Treasuries over the 15-year period shown is -0.38, and the correlation between stocks and gold is 0.06.

However, the stock/Treasury correlation varies between -0.72 and +0.29 over the period, and the stock/gold correlation varies between -0.22 and +0.43. Given that correlation can only vary between -1 and +1, these ranges are not insignificant. Furthermore, because correlation is directly related to diversification, and a diversified portfolio exhibits lower risk, the correlation between assets in the portfolio can have a large impact on the overall portfolio volatility, as illustrated by Figure 9.

Figure 9. The volatility of a 50/50 stock/bond portfolio as a function of stock/bond correlation.



Source: ReSolve Asset Management, 2015.

Observe how the volatility of the 50/50 stock/bond portfolio declines as the correlation between stocks and bonds moves from 1 (perfectly correlated) to -1 (perfectly anti-correlated). When stocks and Treasuries are perfectly correlated, the portfolio volatility would equal the average of stock volatility (20%) and bond volatility (7%), or 13.5%. On the other hand, were stocks and bonds to exhibit perfect anti-correlation, the portfolio would exhibit less than half of that volatility - just 6.5%.

Importantly, the formula that allows us to calculate portfolio volatility given the asset weights in the portfolio, the asset volatilities, and the correlation between assets, is at the heart of MPT. For those who are interested, here is the formula:

$$vol_P = \sqrt{w_a^2 \times vol_a^2 + w_b^2 \times vol_b^2 + 2 \times w_a \times w_b \times vol_a \times vol_b \times correl_{a,b}}$$

and here is an application using the stock and bond example above, where the volatility of stocks and bonds are 20% and 7% respectively, and their correlation is assumed to be 0.5:

$$vol_P = \sqrt{0.5^2 \times 0.2^2 + 0.5^2 \times 0.07^2 + 2 \times 0.5 \times 0.5 \times 0.2 \times 0.07 \times 0.5}$$

$$vol_P = 12.13\%$$

THE OBJECTIVE OF PORTFOLIO OPTIMIZATION

One of the most important axioms in finance is that the best estimate of tomorrow's value is today's value. This prompts the question: if we can measure the value of these variables today (or over the recent past), and they are better estimates over the near-term than long-term average values, why not construct portfolios based on this current information? That is, why wouldn't we choose for our portfolios to adapt over time based on observed current conditions?

It is worth noting that the overall objective of asset allocation is to deliver the highest returns per unit of risk, where risk is usually defined in terms of volatility. In finance, the ratio of a portfolio's return to its volatility is called the Sharpe ratio, and this is one of the most fundamental units in finance[1].

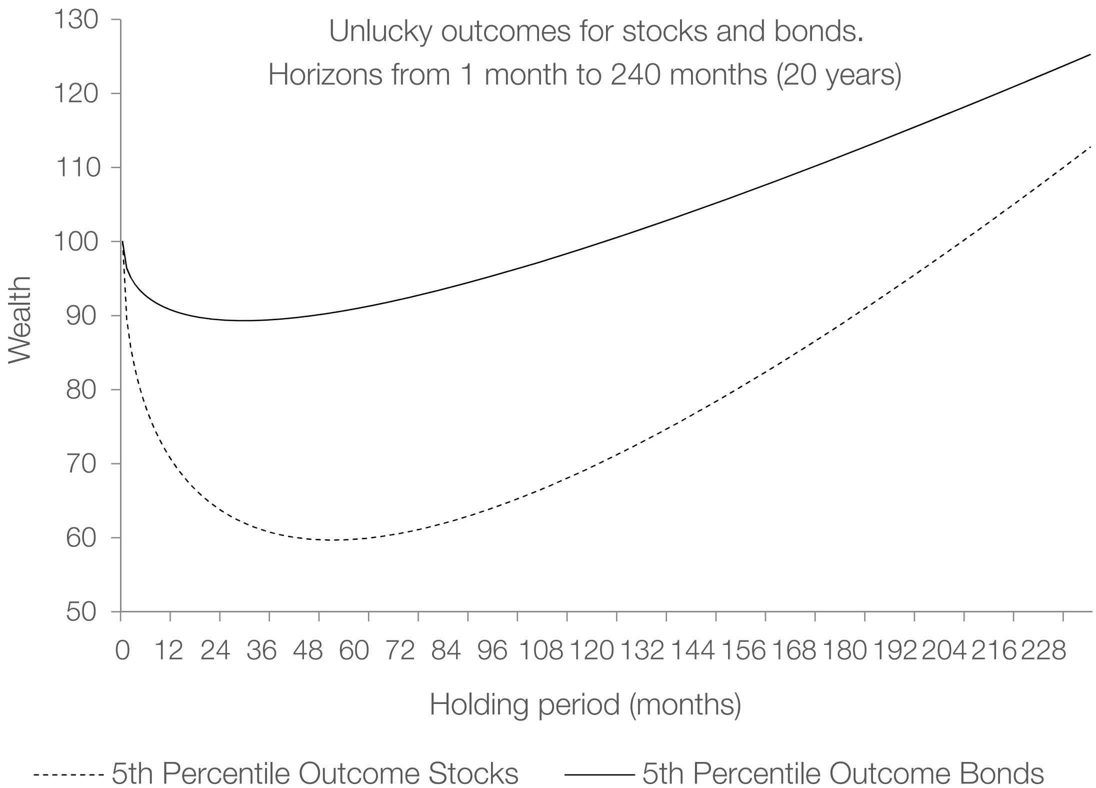
You may wonder why we don't just focus on returns. Well, one reason is that higher risk portfolios are much more difficult to stick with. That's because more volatile portfolios are generally more vulnerable to periods of large losses. For example, we observed that stocks have a higher long-term return than bonds, and higher accompanying volatility. We also know that stocks are vulnerable to periods of extreme losses, in the neighborhood of 50-90% during the most ferocious bear markets. In contrast, bonds have lower returns and lower volatility, and thus we observe much more tolerable losses during bond bear markets.

But at root, higher volatility simply implies that the actual returns that an investor can expect to realize over a finite investment horizon lie in a larger range. This cuts both ways; an optimistic investor might point out that stocks have the potential to 'shoot the lights out' in a way that bonds will never do. While this may be the case, most investors are not investing in hopes of a lottery payoff. Rather, most investors hope to earn good returns, but realize they can't easily endure a highly unlucky outcome, with large losses that last for many months.

Figure 10. shows the trajectories for investments in a stock portfolio and a bond portfolio where the initial investments were made at a particularly unlucky time. Specifically, they are the worst wealth trajectories that might be expected about 5% of the time according to historical precedent. Note how, consistent with what we observed in Figure 2., an unlucky investor in stocks could be outpaced by a bond portfolio in terms of final wealth over as much as 20 years or more (i.e. 240 months).

1 Technically, the Sharpe ratio measures the ratio of excess returns to volatility, where returns are measured in excess of the risk-free rate. However, for simplicity, all Sharpe ratios in this paper are simple ratios of returns / volatility.

Figure 10. Unlucky outcomes for stocks and bonds.



Source: ReSolve Asset Management, 2015. Data from Global Financial Data.

It's critical to understand that volatility is just as important to the investment equation as returns, because volatility describes the range of returns that might be expected over a finite investment horizon. In fact, the volatility side of the coin may be even more important than the return component for typical investors with 3-5 year emotional investment horizons (that's probably you).

We've spent the last few pages making the case that return, volatility and correlation estimates vary widely from their long-term averages over the short and intermediate terms. We've also demonstrated why these wide ranges matter so substantially in the context of a typical investor's experience. Managers who do not monitor and adjust portfolios in response to these changes risk substantial deviation from stated portfolio objectives, and are more likely to deliver a sub-optimal experience for investors.

In the next section, we will explore a variety of methods for constructing portfolios, which adapt to observed changes in expected market returns, risk, and correlation. You will see that by observing and adapting to current market conditions it is possible to construct dynamic portfolios, which have the potential to deliver higher returns with less risk.

INTRODUCING ADAPTIVE ASSET ALLOCATION

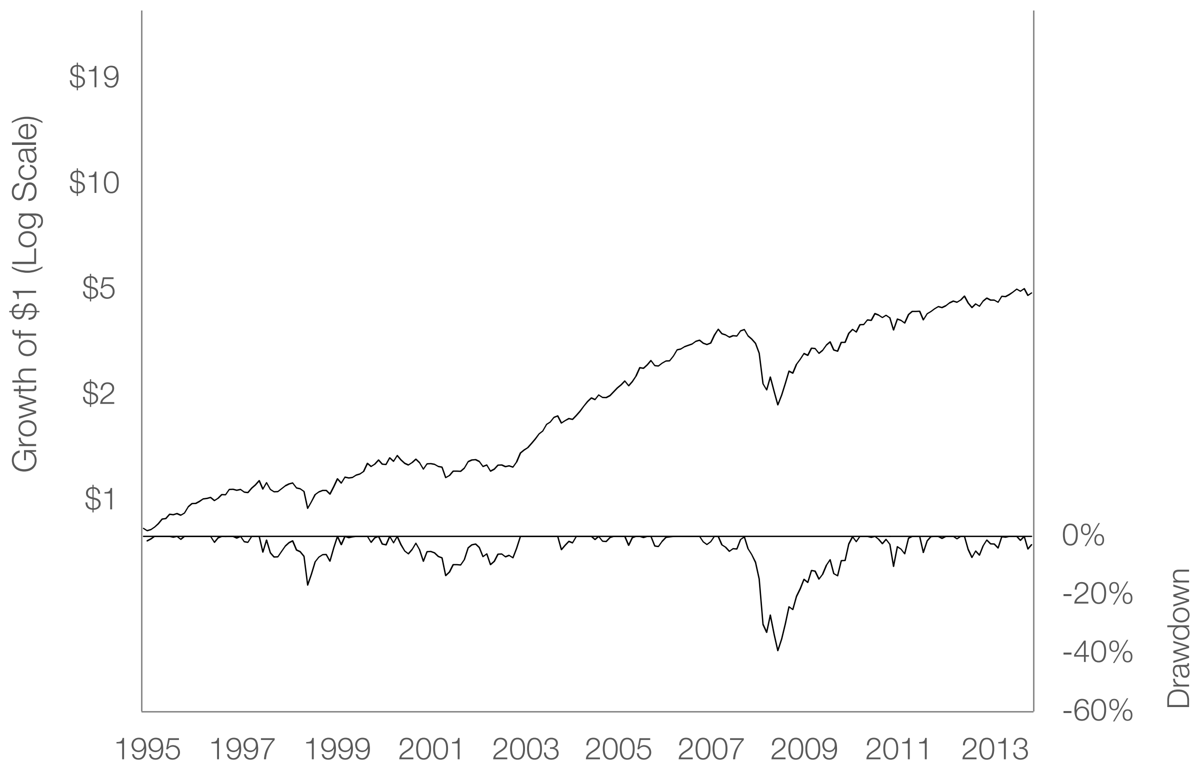
In this section, we will walk through a case study of asset allocation methods to demonstrate the advantage that accrues from using recent observed portfolio parameters to regularly adapt portfolios to changing market conditions.

Our analysis will consider a portfolio consisting of 10 major global asset classes. Where possible, we draw total return data from Exchange Traded Funds. However, prior to ETF inception we use the following sources in order of preference to extend the dataset back to 1995: proxy ETFs in the same asset class; passive no-load mutual funds; underlying indexes; and no-load active mutual funds. The exercise is meant to be illustrative, but we have done our best to use investible assets where possible.

- U.S. stocks
- Japanese stocks
- U.S. REITs
- U.S. 7-10 year Treasuries
- Commodities
- European stocks
- Emerging market stocks
- International REITs
- U.S. 20+ year Treasuries
- Gold

First, consider a naïve investor, with no knowledge of expected relative asset class performance, risk, or correlation information. A rational investor, lacking any information to bias his choices, would logically choose to simply hold each asset in the portfolio in equal weight. Going back to 1995, holding our basket of assets in equal weight, and rebalanced monthly, an investor would have experienced the portfolio growth profile described by Exhibit 1. Note that all risk statistics assume end-of-month values.

Exhibit 1. 10 Assets, Equal Weight Rebalanced Monthly



Source: ReSolve Asset Management, 2015. Data from CSI. Simulated Performance.
Past results are not necessarilly indicative of future results.

Compound Returns	8.1%	Growth of $1	$4.69
Volatility	11.2%	Sharpe Ratio	0.72
Positive Rolling Years	82%	Max Drawdown	-39.2%

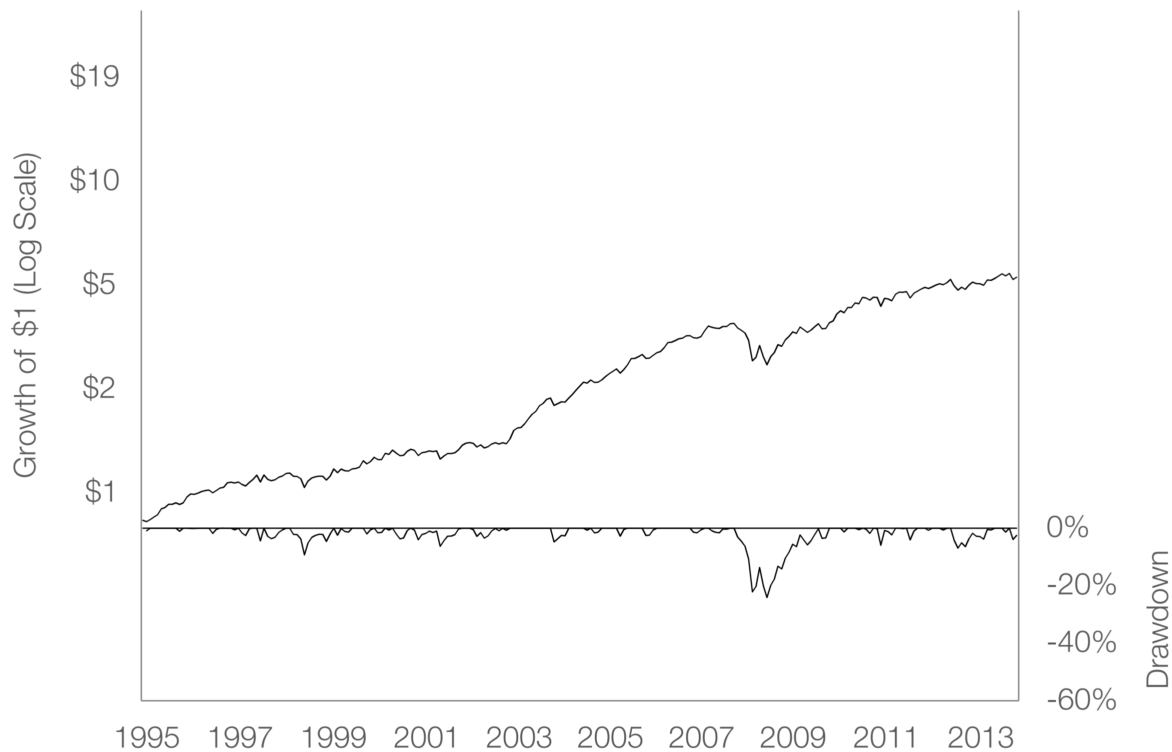
Before we move on, let's review how to interpret the chart and data table from Exhibit 1. The top chart shows the growth of $1 invested in the strategy on January 1st, 1995 through November 2014, where it seems to have grown to about $5. It offers a visual representation of the growth in the portfolio through time, which is summarized in the table below. For example, the compound returns, which took the portfolio from $1 twenty years ago to $4.69 today, equates to 8.1% per year.

The top chart is also informative because you can see the path the portfolio took to get from $1 to $4.69, which included a big dip about 2/3 of the way along in 2008. We take these dips very seriously, so below the growth chart we plot the drawdowns through time as a percentage of the portfolio's drop from its all-time peak. From visual inspection, you can see that the portfolio lost about 40% of its value in the 2008-9 bear market. This is confirmed by glancing at the Max Drawdown data in the table, where we learn that in fact the maximum drawdown was a drop of 39.2% from peak to trough.

Please also note the portfolio volatility and simple Sharpe ratio. The volatility of the portfolio over the entire period averaged 11.2%, which means the Sharpe ratio was 8.1% / 11.2% = 0.72. Lastly, we provide the percentage of all 12-month periods where an investor would have experienced positive absolute returns. In this case, an investor would have seen positive performance over 82% of rolling years.

For our next study, let's assume that an investor believes he has some knowledge only of each asset's risk, but no knowledge of returns or correlations. In the section on GIGO: Volatility, we observed how volatile assets like stocks typically dominate the total risk of a so-called 'balanced' portfolio. Exhibit 1. shows how that concentrated risk can manifest in terms of investor experience – recall that 40% drop in 2008. But what happens if we observe the actual volatility of each asset in the portfolio over the past 60 days, and adjust the allocations at each monthly rebalance period so that each asset contributes the same daily volatility to the portfolio, to a maximum of 100% exposure? Exhibit 2. gives the answer.

Exhibit 2. 10 Assets, Volatility Weighted Rebalanced Monthly



Source: ReSolve Asset Management, 2015. Data from CSI. Simulated Performance.
Past results are not necessarilly indicative of future results.

Compound Returns	8.5%	Growth of $1	$5.06
Volatility	8.6%	Sharpe Ratio	0.99
Positive Rolling Years	89%	Max Drawdown	-24.2%

By simply sizing each asset in the portfolio so that it is expected to contribute the same amount of (nominal) risk, the return delivered per unit of risk (Sharpe ratio) increases from 0.72 to .99 relative to the equal weight portfolio. Of course, this improvement is mostly a function of less overall portfolio risk, as the returns are very similar (8.5% vs. 8.1% for equal weight). Not surprisingly, less volatility also means more consistent returns (89% positive years) and lower maximum drawdowns (-24% vs. -39% for equal weight). And we get all of this benefit simply from preventing the lunatics (stocks) from running the asylum (portfolio).

Exhibit 2. isolated the effect of risk management on portfolio outcomes. In other words, we observed the results from playing a little portfolio defense. Now let's put our offensive team on the field. As such, in Exhibit 3. we form portfolios based on information about expected returns. To generate our return estimates, we will draw on one of the most widely validated properties of markets everywhere: momentum.

The concept of momentum in markets is similar to the concept of momentum in physics: an object in motion will stay in motion (in the same direction) unless acted upon by an outside force. In markets, this means that assets that have gone up the most recently are more likely to continue to go up over the next period. Specifically, the academic research shows that an asset with the greatest relative performance over the past 1 month to 1 year is more likely to exhibit stronger performance over the next few days or weeks.

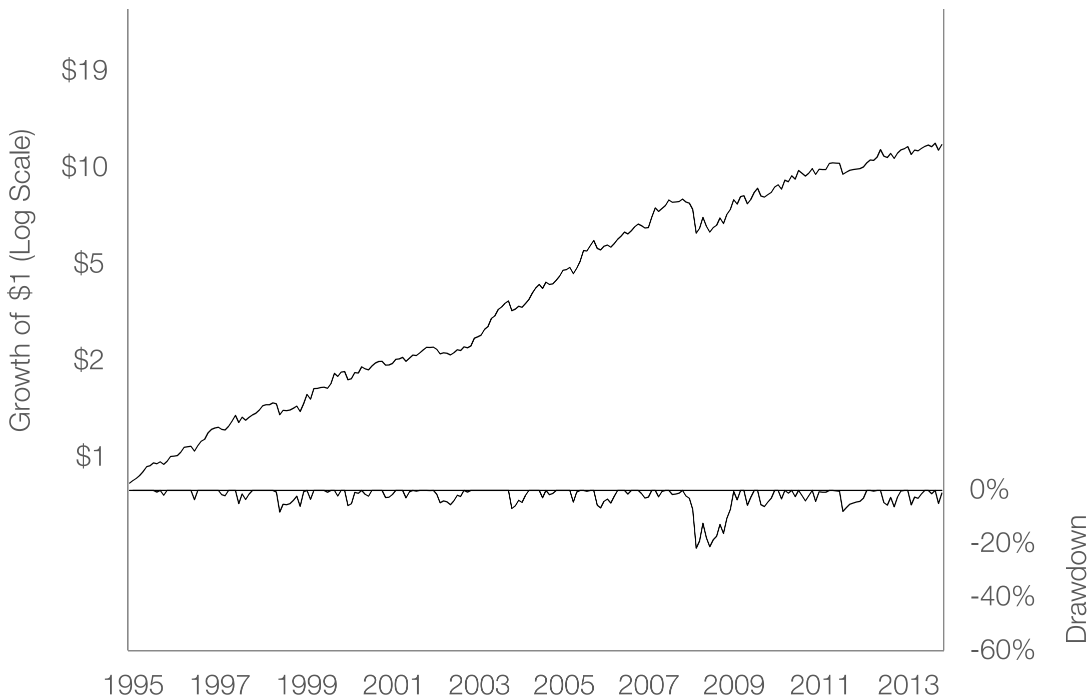
Why should markets behave this way? The academic literature focuses on three compelling reasons, and they relate to: perceptions of risk; human cognitive biases, and; the operation of markets. For example, strategies that harness the momentum factor often act very differently than traditional portfolios. During periods when traditional portfolios are doing really well, being different often means lagging behind. And this underperformance can sometimes last for a couple of years or more. For this reason, many investors find it hard to stick with a momentum strategy for long enough for it to pay off for them.

In addition, the human brain is wired to act against the momentum factor. That's because the human mind experiences the fear of losses about 2.5x more strongly than it experiences the joy of gains. Daniel Kahneman won a Nobel Prize in 2002 for describing this effect. Driven by this imbalance between feelings of fear and joy, investors often feel compelled to sell an asset once it has gone up in order to lock in their gains. On the flip side, they often hold on to losing positions for too long to avoid locking in losses. Counterintuitively, the propensity to act against a strongly trending asset leaves money on the table for others to pick up. Other human tendencies, such as social herding and anchoring biases also contribute to the momentum effect.

Lastly, there are structural reasons why markets exhibit momentum and trends. Perhaps the strongest reason is that market participants do not react instantaneously to new information. Rather, information disperses to investors over time, and different investors act on this information with varying degrees of delay. As a result, markets move to 'catch up' to new information in a way that manifests as momentum.

To take advantage of the momentum effect, each month we will sort assets by their returns over the past six months. Those assets that have delivered better than average returns will be held in the portfolio for the next month. Assets are then re-sorted and portfolios are reformed with the top assets each month through time. Exhibit 3. shows the results of this process, where all top momentum assets are held in equal weight.

Exhibit 3. 10 Assets, Top 5 Equal Weight By 6-Month Momentum, Rebalanced Monthly



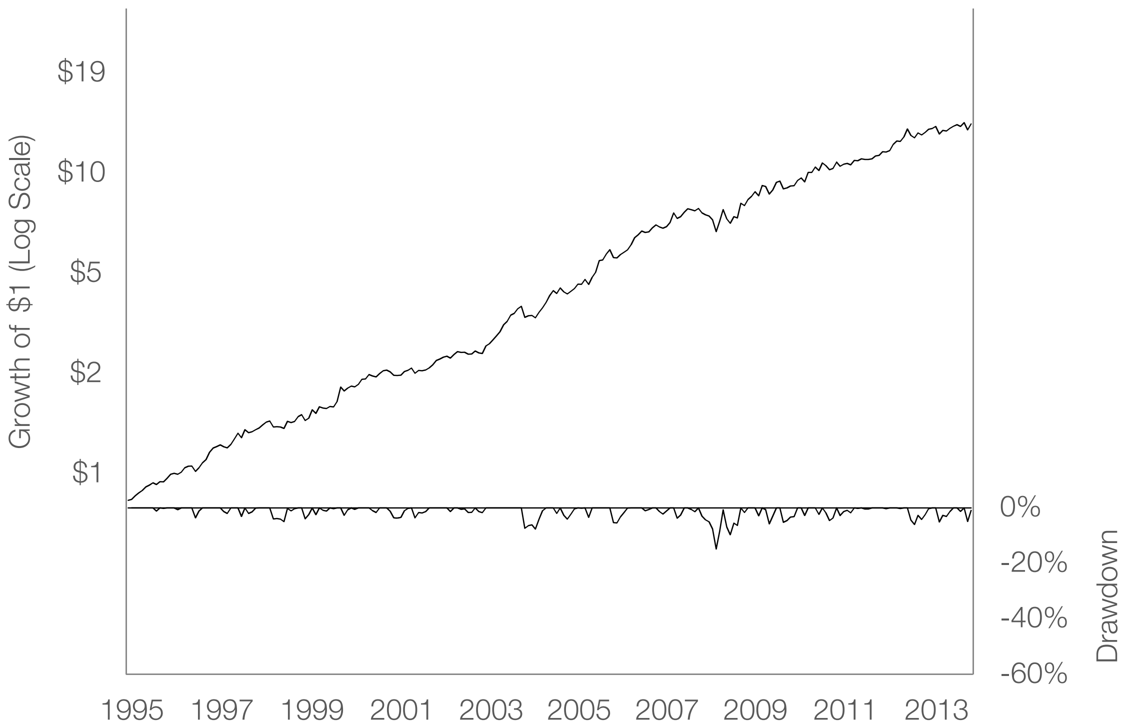
Source: ReSolve Asset Management, 2015. Data from CSI. Simulated Performance.
Past results are not necessarilly indicative of future results.

Compound Returns	13.0%	Growth of $1	$11.35
Volatility	11.0%	Sharpe Ratio	1.17
Positive Rolling Years	93%	Max Drawdown	-21.7%

You can see that by holding the top 5 assets each month based exclusively on their 6-month momentum, we again significantly improve the Sharpe ratio. However, where Exhibit 2. delivered better performance primarily due to lower risk (defense), the momentum method improves outcomes mostly due to higher returns (offense). We move from returns of about 8.5% per year to growth of 13% per year by using momentum to select the most likely top assets in the coming month.

The last two exhibits isolated the effects of either managing risk or harnessing returns in isolation. Our next step is to combine these concepts in one strategy. Exhibit 4. shows the performance of an approach that assembles the top 5 assets by 6-month momentum, and then applies the same volatility sizing overlay as we used in Exhibit 2., so that each of the top 5 assets contributes the same amount of risk to the portfolio over the subsequent month.

Example 4. 10 Assets, Top 5 By 6-Month Momentum, Volatility Weighted, Rebalanced Monthly



Source: ReSolve Asset Management, 2015. Data from CSI. Simulated Performance.
Past results are not necessarilly indicative of future results.

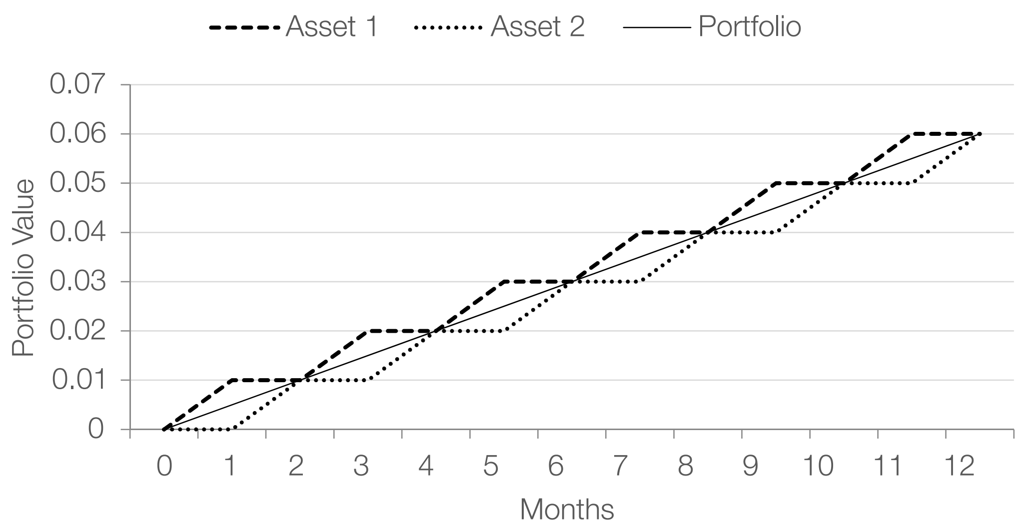
Compound Returns	14.0%	Growth of $1	$13.49
Volatility	9.9%	Sharpe Ratio	1.41
Positive Rolling Years	97%	Max Drawdown	-14.8%

As we would expect, this technique again improves risk-adjusted performance, with the Sharpe ratio jumping from 1.17 for equally weighted momentum to 1.41 with risk weighted momentum. The boost is observed across both returns, which rise to 14% per year from 13%, and risk, which drops from 11% volatility to 9.9%. Again, we see that maximum drawdowns decline commensurate with the reduction in volatility and the slight increase in average returns.

So far, we have observed a step-by-step improvement as we introduced methods to better distribute portfolio risk and harness the momentum factor. Our one missing ingredient is diversification. We have not taken any steps to account for different asset correlations as we construct portfolios.

Remember that diversification has the effect of lowering the risk of a portfolio because some assets in the portfolio are ‘zigging’ while others are ‘zagging’. Importantly, two assets can have a low correlation, and therefore effectively diversify each other, even while both assets are moving in the same average direction. That is, two assets can be rising in price on average, but be negatively correlated. To understand why, consider Figure 11., which shows two securities with positive return trajectories, but that move in opposite directions at each period. As a result, the two securities have perfect negative correlation, while the portfolio of the two securities moves in a straight line, up and to the right. In this way, two risky assets with equal volatility and perfect negative correlation can be combined to form a portfolio with zero volatility and a positive return.

Figure 11. Negatively correlated assets with positive returns.

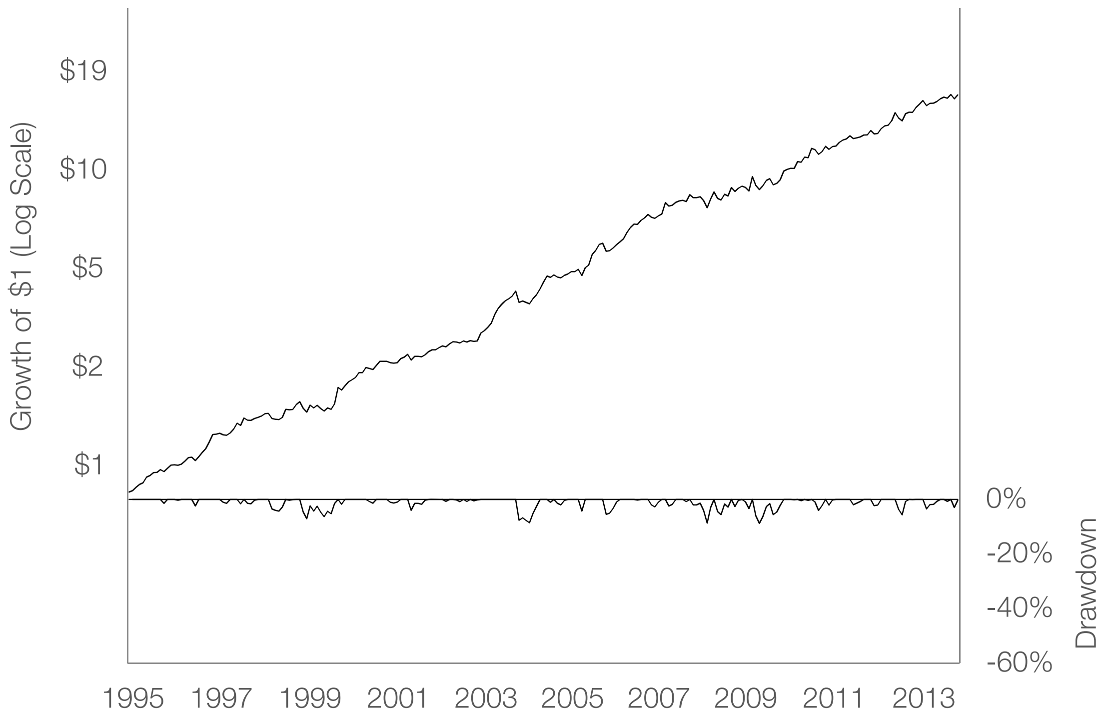


Source: ReSolve Asset Management, 2015.

Of course, in practice there are almost never two assets with perfect negative correlation, but Modern Portfolio Theory provides a framework to assemble assets with low correlation in order to minimize overall portfolio volatility. It turns out there is only one such portfolio for each group of assets, and it is called the minimum variance portfolio. The mathematics and programming used to find the minimum variance portfolio are beyond the scope of this paper, but the process is well established and computationally simple.

In Exhibit 5., we bring all of the concepts discussed so far together in order generate portfolios with strong momentum, and which take advantage of asset class risk and correlations in order to minimize portfolio volatility. Specifically, at the end of each month portfolios are reformed from assets with above average 6-month momentum, and where the assets are held in weights that minimize overall portfolio volatility.

Exhibit 5. 10 Assets, Top 5 By 6-Month Momentum, Minimum Variance, Rebalanced Monthly



Source: ReSolve Asset Management, 2015. Data from CSI. Simulated Performance.
Past results are not necessarilly indicative of future results.

Compound Returns	15.0%	Growth of $1	$16.31
Volatility	9.4%	Sharpe Ratio	1.60
Positive Rolling Years	99%	Max Drawdown	-8.8%

Recall that our naïve equal weight portfolio delivered just 8.1% returns with volatility of 11.2% and a maximum peak-to-trough drawdown of almost 40%. After making thoughtful use of MPT by introducing adaptive momentum, volatility and correlation factors we observe a 7 percentage point boost to returns with lower risk versus our naïve equal weight benchmark. As such, the Sharpe ratio is boosted by over 100%, while the maximum drawdown observed over 20 years was under 10% (with end of month observations).

MANAGING EXPECTATIONS

It's clear that taking advantage of information about markets' current risk, diversification and momentum profiles has the potential to nudge a portfolio toward stronger, steadier returns with less risk. But it's important to understand that returns in the future may not live up to what we have observed in testing. By setting realistic expectations, we are able to make more informed decisions about how and where the approaches described above might fit into a long-term strategic portfolio, and know what to expect for the purpose of sticking with it.

First, we must acknowledge that over the past two decades, markets everywhere have benefitted from tailwinds that we should not count on going forward. One of the most fundamental principles of finance is that risky assets should deliver long-term returns in excess of what one could earn from investing in a risk-free asset, such as a government bond, which future value is guaranteed. The most intuitive example of this concept of 'risk premium' is the equity risk premium, which theorizes that stocks should deliver higher long-term returns than bonds because they are more volatile, lower in the capital structure, and more susceptible to economic events.

From the perspective of risk premium, a portfolio's return can be decomposed into the return one can garner from a risk-free asset, plus the extra return one earns from taking risk, consistent with the following equation:

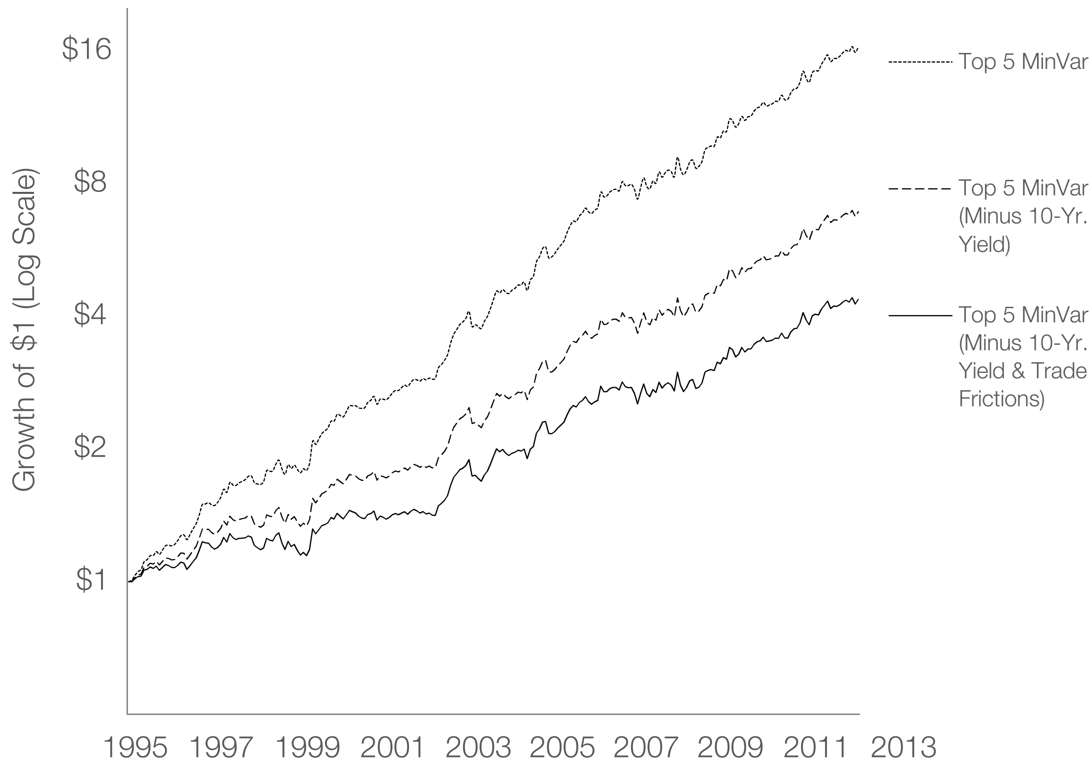
$$\textit{total return}_p = \textit{riskfree return} + \textit{risk premium}$$

We can apply this equation to measure the risk premium to our strategy (Exhibit 5.) in excess of a long-term risk-free investment, such as a 10-year government Treasury bond. To do so, we simply subtract the available yield on the bond in each month through history from the realized return on the asset in the same month. We observe that the risk premium above 10-year Treasury yields for our strategy is about 10% per year, which makes sense since yields on 10-year Treasuries have averaged about 5% over our test horizon, and 15% -5% = 10%.

The yield on the risk free asset is not the only consideration. We should also adjust historical performance to account for transaction costs, trade slippage, and fees. There is no standard formula to account for these factors, but we endeavor to be conservative. First note that for testing we used live ETF total returns for all assets once they were launched. In periods prior to the launch of ETFs we used passive mutual fund proxies, which include management fees and trading costs already. In a few cases where funds were not available prior to the launch of ETFs, (such as commodities and gold) we simply used the total returns to the underlying indexes, which assumed no fees or transaction costs. As such, on average the assets we included in our study already included some realized trading costs and frictions, and some fees.

To be conservative, we will build in even more frictions and costs than are already embedded in returns, as described above. For example, we have accounted for the fact that costs and frictions to access many asset classes were probably higher in earlier periods than they are in modern periods. Specifically, we assume trade frictions of 2.5% in 1995, which scale down linearly to 0.5% in the most recent period. We also assumed a 1% management fee over the entire test period. As such, total costs scaled from 3.5% in 1995 down to 1.5% today. Exhibit 6. shows the return to the strategy in Exhibit 5. after discounting 10-year Treasury yields, and also the cumulative return above both yields and costs.

Exhibit 6: 10 Assets, Top 5 By 6-Month Momentum, Minimum Variance, Rebalanced Monthly Adjusted for 10-Year Treasury Yields and Costs



Source: ReSolve Asset Management, 2015. Data from CSI. Simulated Performance.
Past results are not necessarilly indicative of future results.

	Top 5 Minvar	Top 5 MinVar (Minus 10-Yr. Yield)	Top 5 MinVar (Minus 10-Yr. Yield & Frictions)
Annualized Return	15.1%	10.2%	7.7%
Volatility	9.4%	9.4%	9.4%
Sharpe Ratio	1.61	1.09	0.82
Max Drawdown	-8.8%	-10.2%	-11.3%
Positive Rolling Years	99%	93%	84%

You can see that, after accounting for risk-free yields and aggressive costs the 15% annualized nominal returns we observed in Exhibit 5. scales down to a much more reasonable 8% per year above 10-year Treasury yields. We still observe a strong risk-adjusted return profile – better than what we might expect from a traditional stock, bond, or balanced portfolio – but the profile is much more sensible. Also, keep in mind that the adjusted returns are over and above the yield on the 10-year Treasury bond. Since the current yield on the bond is 2.2%, we might expect nominal returns closer to 10% going forward, which is consistent with the average long-term return on stocks. Not bad at all considering the risk profile.

THE NEXT GENERATION OF PORTFOLIO MANAGEMENT

While there are better algorithms to integrate momentum, volatility and correlation, the examples above show a clear evolution of techniques that demonstrate how to integrate the three primary variables used for portfolio construction under a true Adaptive Asset Allocation framework.

Portfolios assembled using classic Strategic Asset Allocation are vulnerable to the 'flaw of averages' where long-term average values hide enormous variability over time. In contrast, Adaptive Asset Allocation is a process of constantly rotating into assets with the strongest momentum, and minimizing portfolio risk through diversification. As a result, AAA has historically been robust to market shocks, which wreak havoc on the more inflexible approach SAA represents.

The portfolio management industry is undergoing a revolution analogous to the shift that occurred after Markowitz introduced Modern Portfolio Theory over half a century ago. Managers who embrace the new methods will increasingly dominate traditional managers; those who fail to adapt face a grim future, and possibly extinction.

Disclaimer