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Risk Parity and Efficient Asset Allocation

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RISK PARITY AND EFFICIENT ASSET ALLOCATION

Abstract

A risk parity portfolio is one in which each constituent contributes an equal amount to the total variance of the portfolio[1], eliminating the concentration of risk created by virtually *every* other asset allocation heuristic.[2] In this document we introduce a simple, two-asset version of risk parity and show that a naïve risk parity strategy, implemented using only information available at the time of investment, would have performed on par with the maximum Sharpe ratio portfolio, which is constructed with perfect foresight.[3] Both strategies outperform a typical 60/40[4] portfolio on a risk-adjusted basis. Because risk parity (i) leads to portfolios that are very similar to the maximum Sharpe ratio portfolio and (ii) can be implemented effectively without forecasting future returns, we think it serves as the most reliable proxy for the tangency portfolio.[5] These insights serve as the basis for an *implementable version* of Modern Portfolio Theory wherein risk parity serves as the tangency portfolio. We show how this approach can be used to increase investor returns without increasing risk or, alternatively, to reduce risk while achieving the same level of return.

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[1] Risk Contribution reflects the percentage of the portfolio's risk, as defined by standard deviation, contributed by the underlying assets, equities and bonds. The calculation of risk contribution from equities and bonds is based on modern portfolio theory's calculation of portfolio risk and the contribution of equities and bonds to the portfolio risk are based on the dollar weights, standard deviation, and correlation of equities and bonds. In this paper, Risk Parity refers to a 50% risk contribution from the S&P 500 TR Index and a 50% risk contribution from the Barclays Aggregate Bond Index, formerly the Lehman Aggregate Bond Index until November 2008.

[2] Lee (2011) shows that even heuristics designed to increase diversification, such as 1/n and maximum diversification, lead to concentrations in risk contribution not present in risk parity portfolios.

[3] In our tests, risk parity produced a Sharpe ratio of 0.99, while perfect long-run foresight produced a Sharpe ratio of 0.97.

[4] The 60/40 portfolio consists of a 60% dollar allocation to the S&P 500 TR Index and a 40% dollar allocation to Barclays Aggregate Bond Index, formerly Lehman Aggregate Bond Index until November 2008.

[5] The tangency portfolio achieves higher risk-adjusted returns than any allocation possible given the universe of assets under consideration. Modern portfolio theory shows that it is more efficient to hold combinations of the tangency portfolio and cash (negative cash=borrowing, positive cash=lending) than any other allocation on the efficient frontier.

1. Purpose

This document serves as brief primer on the concept of risk parity. It uses a two-asset example to show how risk parity can be used to combine two asset classes into a diversified portfolio that performs consistently across economic environments, delivering high risk-adjusted returns. We will show that a dynamic risk parity strategy, implemented naively without forecasting future returns of any kind, has provided performance very similar to a portfolio built with perfect long-run foresight.

Put simply, a risk parity portfolio is one in which each constituent contributes an equal amount to the total variance of the portfolio. Although risk parity portfolios have produced high risk-adjusted returns historically, in unlevered form they offer lower absolute levels of expected returns than the typical 60/40 allocation to stocks and bonds. Practitioners of risk parity generally compensate for lower expected returns by implementing risk parity using derivative assets called futures because they can be used to amplify the portfolio's exposure to asset classes that contribute smaller amounts of risk.

In Section 2 we introduce a two-asset example to illustrate the concept of risk parity, and we show how a static risk parity allocation would have performed over the period January 1978 – October 2011. The risk parity portfolio is located on the efficient frontier immediately adjacent to the maximum Sharpe ratio portfolio (MSRP).[6] However, neither of these portfolios is implementable, as their allocations were determined ex-post (or after the fact, with the benefit of knowing the actual history of returns).

In Section 3 we address the more practical problem of strategies one could actually have implemented, which are necessarily based on ex-ante information (information that would have been known ahead of the event, at the time of each rebalancing). We show that an implementable risk parity strategy performs on par with the ex-post MSRP and had similar skewness and kurtosis. This is a profound result because of the critical role MSRP plays in Modern Portfolio Theory (MPT).[7] In practice, we believe the unlevered risk-parity portfolio serves as the best basis for a *feasible capital market line* (FCML) along which investors can select among efficient combinations of risk and return. The FCML portfolio with the same risk as the 60/40 had compounded annual returns of 12.7%, 4.3% more than the 60/40 portfolio.

The next paper in this series will introduce the Salient Risk Parity Index, a broadly-diversified allocation to futures contracts and fixed income swaps across global sovereign interest rates, global fixed income, global equities, and commodities.

[6] Some critics of the risk-parity approach have pointed to the fact that the ex-post (perfect foresight) determination of the risk-parity portfolio in risk/return space resides further out the efficient frontier than the ex-post specification of the maximum Sharpe ratio portfolio (MSRP). In practice, we believe the unlevered risk-parity portfolio represents the best estimation of the MSRP without bias toward any specific economic conditions (e.g. growth, inflation, volatility, investor sentiment, etc.).

[7] Here we are referring specifically to the Mutual Fund Separation Theorem, due to Merton (1972). The Capital Market Line, which will be discussed in detail in section 3, is tangent to the efficient frontier exactly at the maximum Sharpe ratio portfolio. Efficient portfolios will then be combinations of cash (which can be negative, indicating borrowing) and the maximum Sharpe ratio portfolio, and will be located somewhere along the Capital Market Line.

2. Risk Parity: Diversified by Design

A risk parity portfolio is one in which each asset in the portfolio contributes an equal amount of the portfolio's total risk, where risk is measured by variance. Consider a portfolio of two assets: w units of a stock index and $(1-w)$ units of a bond index. Finding the risk parity portfolio is a matter of finding w such that the stock and bond components of the portfolio contribute equally to portfolio variance. In order to make this computation, one needs three ingredients: the volatility of stock returns, σ_s, the volatility of bond returns, σ_b, and the correlation between stock and bond returns, ρ.

The variance contribution of stocks and bonds in a two asset portfolio is given by the equations:

$$\Sigma_{stocks} = w^2\sigma_1^2 + w(1-w)\rho\sigma_1\sigma_2$$

$$\Sigma_{bonds} = w(1-w)\rho\sigma_1\sigma_2 + (1-w)^2\sigma_2^2$$

where:

- Σ_{stocks} is the variance contribution of stocks,
- Σ_{bonds} is the variance contribution of bonds,
- w is the portfolio weight on stocks,
- $(1-w)$ is the portfolio weight on bonds,
- σ_1 is the standard deviation of stock returns,
- σ_2 is the standard deviation of bond returns,
- ρ is the correlation between stock returns and bond returns.

Risk parity is achieved by finding w such that $\Sigma_{stocks} = \Sigma_{bonds}$. This simple quadratic equation turns out to have the solution:

$$w = \frac{\sigma_2}{\sigma_1 + \sigma_2}.$$

In words, risk parity in our two asset class example, is achieved with an allocation to stocks that is exactly equal to the ratio of *bond* volatility to sum of stock and bond volatility. When stock volatility is twice that of bonds, exactly 1/3 of the portfolio will be allocated to stocks. While the correlation between stocks and bonds ρ does not affect the risk parity allocation in the two asset case, it will play a role when allocating to more than two assets.

Continuing the example from above and filling in some details: equities, represented by the S&P 500 Total Return Index compounded returns at an annual rate of 11.2% between 1978 and October 2011 and had annual volatility of 15.6%; bonds, represented by the Barclays Aggregate Bond Index, compounded returns at an annual rate of 8.3% with volatility of 5.7%. The two assets had a correlation of 0.22. Notably, the volatility of stocks in our sample is 2.74 times the volatility of bonds (15.6%/5.7%)[8]. So, despite the fact that stocks generated a superior return of 11.2% over the sample period, we find that the excess return per unit of risk, or Sharpe Ratio, was actually inferior to that of bonds.[9] For every unit of risk employed, a stock investor was rewarded with 0.34 units of excess return. In contrast, a bond investor received 0.45 units of excess return per unit of risk. The following chart illustrates that, after adjusting for risk, a bond investor would have earned a higher return than a stock investor over the sample period.

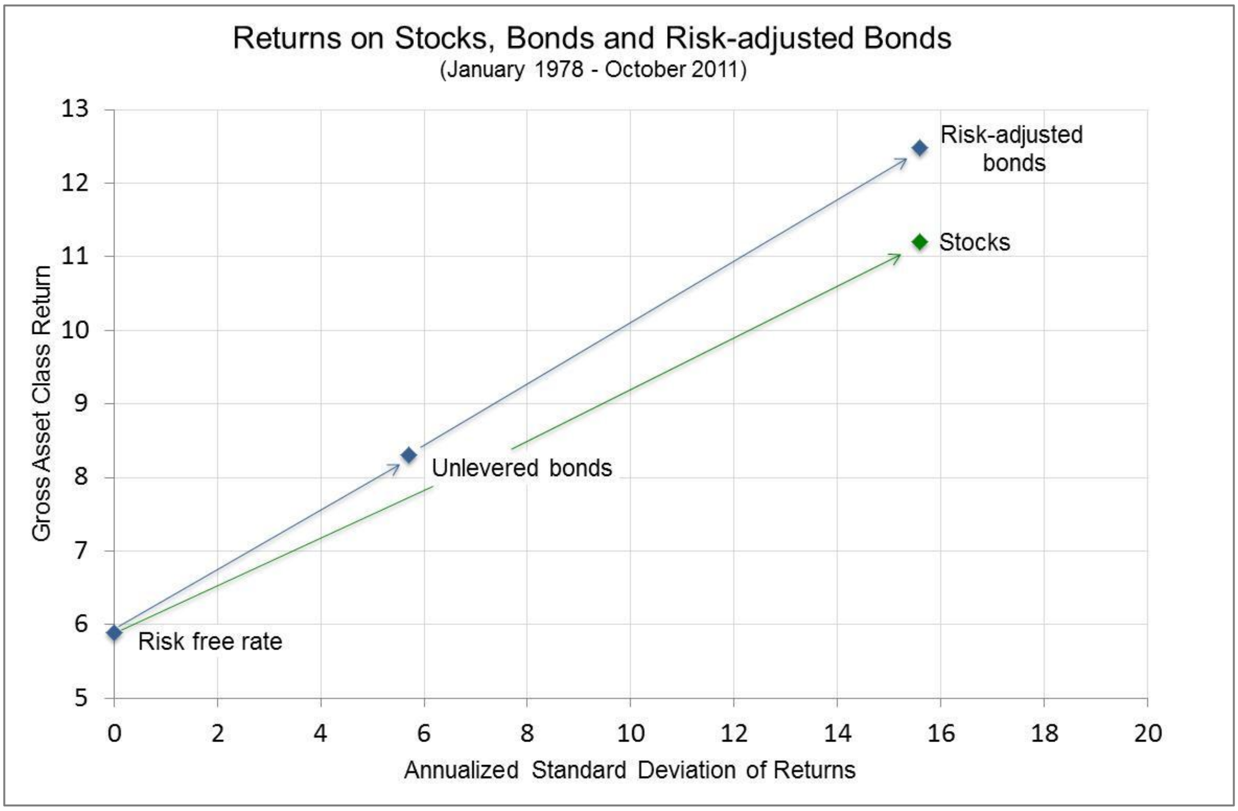

Figure 1: Risk-Adjusted Stock and Bond Returns.
Source: Bloomberg, Salient Capital Advisors, LLC as of 10/31/2011. Note: Past performance is no guarantee of future results.

Figure 1 shows that, at the same level of risk, bonds would have generated a 12.48% return while stocks only generated an 11.2% return. Using this data and the two-asset risk parity calculation detailed above, we find that the risk parity portfolio during the period would have been allocated 27% to stocks and 73% to bonds, producing annual returns of 9.1%, annual volatility of 6.5%, and a Sharpe ratio of 0.51. The efficient frontier for this example period is plotted in Figure 2.

[8] Source: Data from Bloomberg as of 10/31/2011. Note that an investor cannot invest directly in these indices.
[9] The Sharpe ratio is based on the notion of excess returns over the risk free investment or borrowing rate divided by the standard deviation of the asset class or portfolio. In our example we use the Citi 3-month T-bill Total Return Index to represent the risk free rate. By using excess returns over the cash rate rather than the gross asset class returns alone, the Sharpe ratio allows investors to adjust the volatility of the various components of their portfolios by combining them with cash to reduce volatility or borrowing against them to increase volatility. The formula for the Sharpe ratio for asset i is $SR = \frac{E(r_i - r_f)}{std(r_i - r_f)}$.

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Two things are apparent from the figure. First, the risk parity portfolio is very near the maximum Sharpe ratio portfolio on the efficient frontier. Second, even an all-bond portfolio would have compounded returns of over 8%, which is the target return for many institutional funds. However, many of these institutional funds are mandated to seek 8% returns *every* year, not just over the long run. What is not clear from the figure is how often a manager of each strategy would have met such a return target historically.

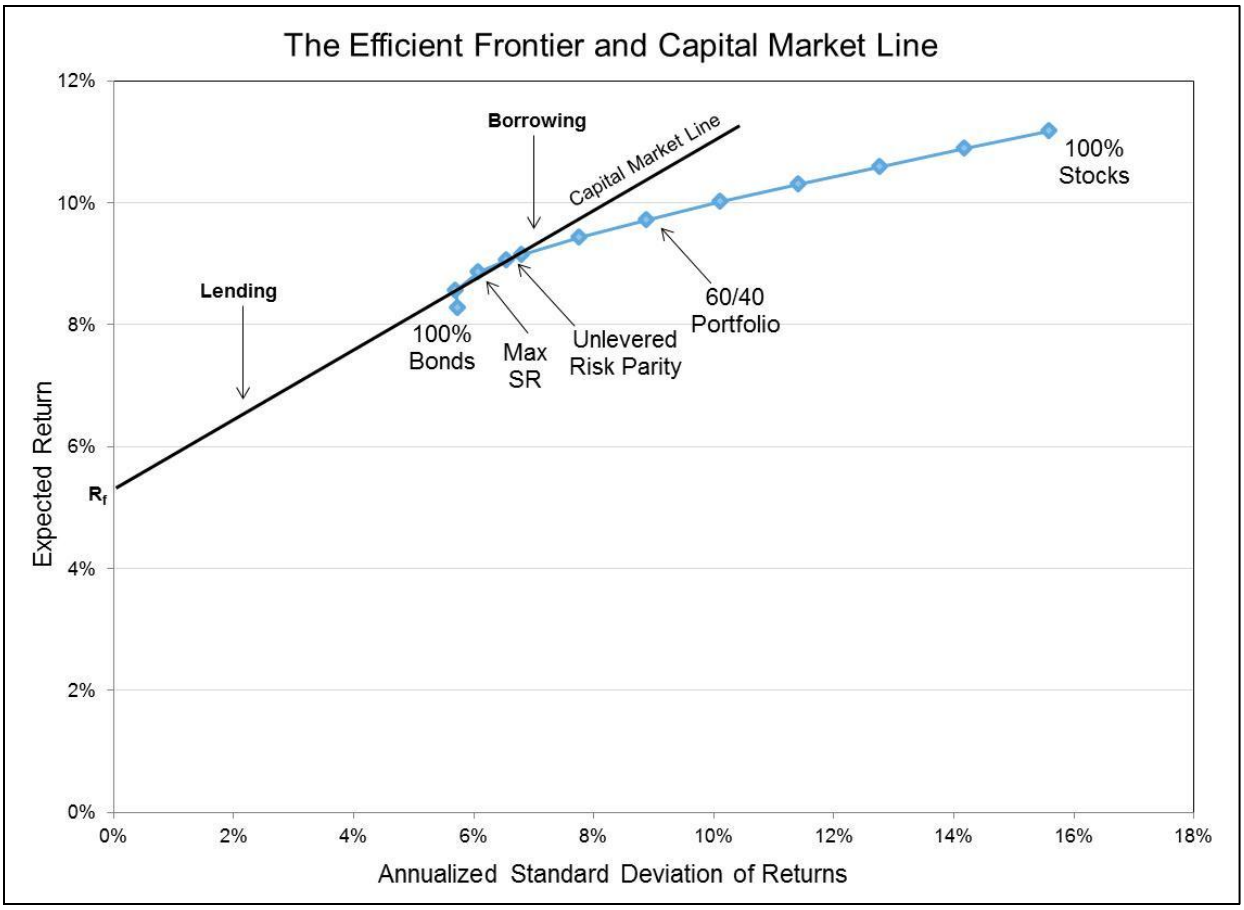


Figure 2: The efficient frontier based on data from January 1978 to October 2011.
Source: Bloomberg, Salient Capital Advisors, LLC as of 10/31/2011. Note: Past performance is no guarantee of future results.

In the 34 full years of data in this example, the unlevered risk parity portfolio would have exceeded the 8% level targeted by many institutional investors exactly 50% of the time (17 times), while a 60/40 portfolio would have achieved the target 62% of the time (21 times). This higher probability of generating returns in excess of some threshold may be why most investors hold portfolios with high equity concentrations, despite the fact that they have lower returns per unit of risk.

Modern Portfolio Theory (MPT), most of which is due to Markowitz (1952), Sharpe (1964), Lintner (1964), and Merton (1972) shows that there is only one efficient portfolio of risky assets: the maximum Sharpe ratio portfolio (MSRP). Referring again to Figure 2, the MSRP is the point at which the Capital Market Line (CML) achieves tangency with the efficient frontier. An investor can achieve any risk/return combination on the CML by either lending or borrowing at the risk free rate and investing in the MSRP. Points along the CML to the right of its tangency with the efficient frontier are achieved by borrowing at the risk free rate and using the proceeds to buy the MSRP. Points along the CML to the left of the MSRP are where an investor holds both the risk-free asset and the MSRP. Because the level of expected return along the CML is always greater than or equal to that available on the efficient frontier at the same level of risk, MPT shows that it is inefficient to hold risky assets in any combination other than the MSRP.

Then why are the vast majority of investors holding equity-dominated portfolios? The most obvious reason is that we don't know what is in the MSRP ex-ante. Attempts to implement MPT to date have involved subjective estimates on forward returns, which can be influenced by behavioral biases such as over- or under-estimating returns on an asset class due to recent performance or over- or under-estimating risk due to investor familiarity with the asset class. The poor quality of these forecasts makes the prospect of levered exposure to such portfolios unappealing. In the next section we show that risk parity offers a potential solution to this problem: the ex-ante risk parity portfolio has served as an excellent proxy for the MSRP over the last several business cycles. We will compare the risk parity portfolio to the MSRP across several metrics and show that they are quite similar. Because of this, we propose using ex-ante risk parity to proxy for the MSRP in the implementation of a *feasible capital market line.* Last, we show the performance of a 10% ex-ante volatility risk parity portfolio. Because risk parity has provided consistent risk-adjusted performance over several decades and across economic environments, this performance is likely indicative of what investors can expect going forward.[10]

3. A Dynamic Risk Parity Strategy

In section 2 we used historical return data to construct maximum Sharpe ratio and risk parity portfolios of stocks and bonds between 1977 and 2011. This illustrated that these portfolios reside near one another on the efficient frontier. However, neither of these allocations was implementable *ex-ante* because an investor in 1977 would not have known the asset weights that would constitute risk parity or the MSRP over the next 34 years. In this section we will consider two implementable strategies and compare them with the 60/40 portfolio and the un-implementable maximum Sharpe ratio portfolio from section two. Limitations in the data necessitate that we work with a shorter data set to test our dynamic strategies; the shorter data begins in January 1989.[11]

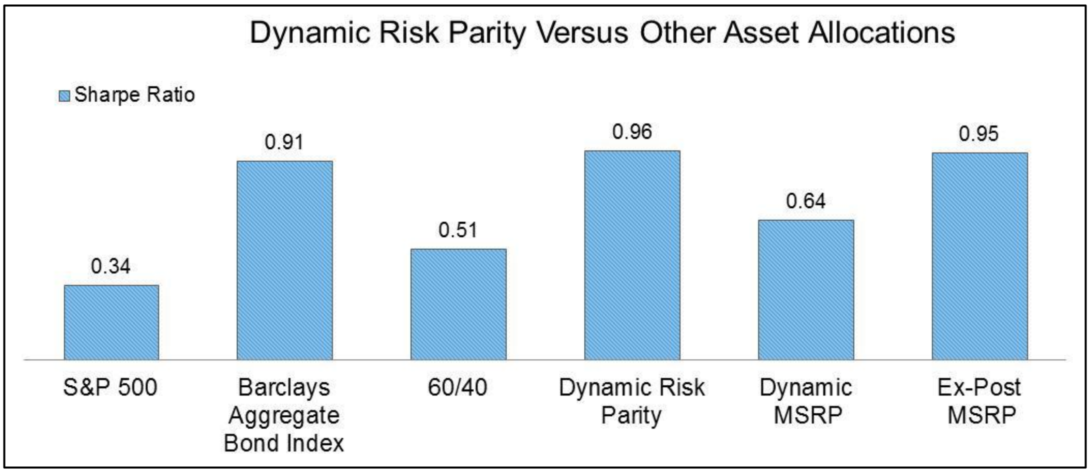
To simulate the historical results of dynamic strategies, each portfolio rebalancing must be based on information that would have been available at the time the portfolio was rebalanced. Our dynamic risk parity strategy will be to model the statistical relationship between stocks and bonds for the two years prior to portfolio formation or rebalancing and use these statistics as the basis for computing risk parity

[10] Chaves, Hsu, Li, and Shakernia (2011) show that risk parity strategies produced more consistent risk-adjusted returns than the other heuristics they examined over the last 30 years. Asness, Frazzini, and Pedersen (2011) show that this holds true within countries and within asset classes, as well as across asset classes over the last hundred years. Note that past performance is no guarantee of future results.

[11] In order to implement the ex-ante strategy we need to model risk, which necessitates the use of daily return data. Such data did not become available for the assets in our example until January 1989.

weights. For example, we use the data from January 1989 - December 1990 to compute the weights for the portfolio held in January 1991. Next, we compute the risk parity weights for February 1991 based on data from February 1989 - January 1991, then roll forward in time again. Repeating this process monthly through October 2011, we generate a historical *pro forma* track record for the two-asset dynamic risk parity strategy (DRP). Inherent in our methodology is the assumption that the covariance of returns in a given month will be similar to its covariance over the past two years.

The second dynamic, implementable strategy we will consider is an ex-ante maximum Sharpe ratio portfolio based on the assumption that the maximum Sharpe ratio portfolio for the coming month will be similar to what we know it was over the past two years. We start the dynamic ex-ante maximum Sharpe ratio strategy (DSR) simulation in January 1991, holding the portfolio that would have generated the highest Sharpe ratio over the previous two years (January 1989 - December 1990). By rolling forward one month at a time and holding the trailing 2-year MSRP, we produce a historical pro forma track record for DSR.



	S&P 500	BABI	60/40	Dynamic RP	Dynamic MSRP	Ex-Post MSRP
Excess Return	5.1%	3.4%	4.7%	4.1%	3.5%	3.5%
Volatility	15.1%	3.7%	9.3%	4.3%	5.5%	3.7%

Figure 3: Comparison of Dynamic Risk Parity to Other Asset Allocations.
Source: Bloomberg, Salient Capital Advisors, LLC as of 10/31/2011. Note: Past performance is no guarantee of future results.

Figure 3 compares the risk-adjusted returns of these two dynamic, implementable strategies, with the 60/40 portfolio and, more importantly, with the un-implementable but theoretically-important ex-post MSRP (XMSR). The take-away from the figure is that the DRP strategy produces risk-adjusted returns on par with—even a little bit better than—the tangency portfolio.

Figure 4 below shows that in addition to producing similar Sharpe ratios (a measure of the first and second moments), the DRP and XMSR portfolios share additional statistical properties. The third and fourth moments, skewness and kurtosis, also look similar for these portfolios. Both portfolios display a decreased left skew and approximately equal kurtosis when compared to the 60/40 portfolio. This implies a more normally distributed return stream.

	60/40	Dynamic RP	Dynamic MSRP	Ex-Post MSRP
Skewness	-0.59	-0.44	-0.65	-0.37
Kurtosis	1.33	1.52	17.62	1.09

Figure 4: Comparison of the Skewness and Kurtosis of Dynamic Risk Parity.
Source: Bloomberg, Salient Capital Advisors, LLC as of 10/31/2011. Note: Past performance is no guarantee of future results.

Superior risk-adjusted returns would be of little interest outside of academia if investors were unable to hold levered exposures to risk parity portfolios because the absolute level of returns they provide would be lower than the 60/40 portfolio. Fortunately, the proliferation of futures markets has made it possible to achieve a desired level of exposure to almost any asset class without expensive borrowing or depending on external sources of financing. Using futures, investors can pursue a risk parity strategy at the level of targeted volatility they prefer. Figure 5 shows the total returns of the 60/40 portfolio along with total returns of dynamic risk parity, dynamic maximum Sharpe ratio, and ex-post maximum Sharpe ratio portfolios, where magnitude of returns on the last three have been levered up to 10% volatility. The dynamic risk parity strategy has performed admirably, even when being compared to the DSR. This is a profound finding, because it suggests that a naïve, risk-parity strategy may provide the right mix of exposures necessary to practice one of the central tenets of modern portfolio theory—investors should seek broad diversification, rather than holding equity-dominated portfolios.

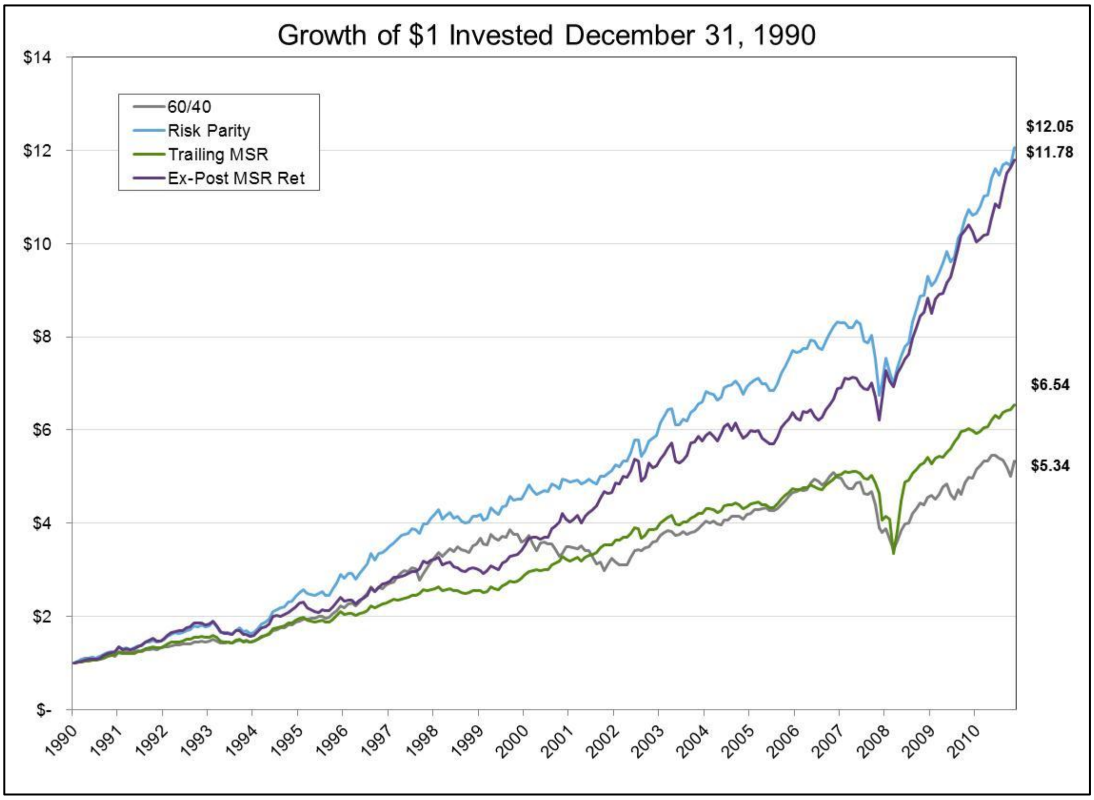


Figure 5: Comparison of Implementable Strategies vs. the Ex-Post Efficient Portfolio

Note that the above 'Growth of $1'chart represents a hypothetical investment in the S&P 500 TR Index and the Barclays Aggregate Bond Index, formerly the Lehman Aggregate Bond Index as of November 2008. Backtested performance is NOT an indicator of future actual results and do the results above do NOT represent returns that any investor actually attained. Backtested results are calculated by the retroactive application of a model constructed on the basis of historical data and based on assumptions integral to the model which may or may not be testable and are subject to losses. Certain assumptions have been made for modeling purposes and are unlikely to be realized. No representations and warranties are made as to the reasonableness of the assumptions. Changes in these assumptions may have a material impact on the backtested returns presented. This information is provided for illustrative purposes only. Backtested performance is developed with the benefit of hindsight and has inherent limitations. Specifically, backtested results do not reflect actual trading or the effect of material economic and market factors on the decision-making process. Since trades have not actually been executed, results may have under- or over-compensated for the impact, if any, of certain market factors, such as lack of liquidity, and may not reflect the impact that certain economic or market factors may have had on the decision-making process. Further, backtesting allows the security selection methodology to be adjusted until past returns are maximized. Actual performance may differ significantly from backtested performance. Backtested results are adjusted to reflect the reinvestment of dividends and other income. The above backtested results do not include the effect of backtested transaction costs, management fees, performance fees or expenses, if applicable. No cash balance or cash flow is included in the calculation.

4. Conclusion

In this document, we introduced the concept of risk parity. In our view, risk parity may serve as an excellent proxy for the theoretical market portfolio because it consistently delivers risk-adjusted returns in the vicinity of the ex-post maximum Sharpe ratio portfolio. The next document in this series will introduce the Salient Risk Parity Index™, a globally-diversified index of equity, fixed income, developed sovereign debt, and commodities allocated according to the principle of risk parity.

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