S&P Dow Jones Indices

A Division of S&P Global

Research

Indexing Risk Parity Strategies

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INTRODUCTION

Modern Portfolio Theory (MPT), introduced by Harry Markowitz in 1952, sets the framework for building optimal portfolios in which market participants can potentially maximize portfolio returns for a given level of risk. The theory introduces the notion of portfolio diversification by holding non-correlated assets. At the core, one should not view individual asset returns and volatilities in isolation; rather, one should take into account the co-movements, or correlations, of asset returns that comprise a portfolio.

The theory, along with the expectation that long-term asset class Sharpe ratios are similar (Dalio et al. 2015), act as foundational pieces of risk parity. Risk parity strategies propose that portfolio diversification, defined as achieving the highest return per unit of risk, can be maximized when a portfolio's assets contribute equally to total portfolio risk.

Since the launch of the first risk parity fund—Bridgewater's All Weather Fund—in 1996, many asset managers have offered their version of risk parity to clients. The risk parity industry has especially gained traction in the aftermath of the 2008 global financial crisis, growing to an estimated USD 150 billion-175 billion at year-end 2017 according to the IMF (Antoshin et al. 2018).

In the past, such strategies lacked an appropriate benchmark, leaving most investors to benchmark against a traditional 60/40 equity/bond portfolio. The issue with this approach is that a 60/40 portfolio reflects neither the construction nor the risk/return characteristics of risk parity strategies. Generally considered to be diversified in dollar terms, the reality is that nearly all of the portfolio risk arises from the 60% allocation to equities (see Exhibit 6). When a portfolio is equal-risk weighted as opposed to equal weighted, it may lead to superior risk-adjusted return (see Exhibit 11).

With the purpose of providing a transparent, rules-based benchmark for risk parity strategies, we introduced the S&P Risk Parity Index Series. These indices construct risk parity portfolios by using futures to represent multiple asset classes and attempt to reflect the risk/return characteristics of funds offered in the risk parity space. Cognizant of the fact that risk parity funds in the industry can have different volatility targets, the index series consists of three indices with different target volatility (TV) levels: 10%, 12%, and 15%.

Risk parity strategies have long lacked an adequate benchmark.

To fill this absence, S&P Dow Jones Indices has launched the S&P Risk Parity Indices…

…using equity, fixed income, and commodity futures and spreading the risk evenly among them.

In the first part of this paper, we cover the economic rationale for implementing a risk parity approach in a multi-asset portfolio construction. In the second part of the paper, we give an overview of the S&P Risk Parity Indices.

WHY RISK PARITY?

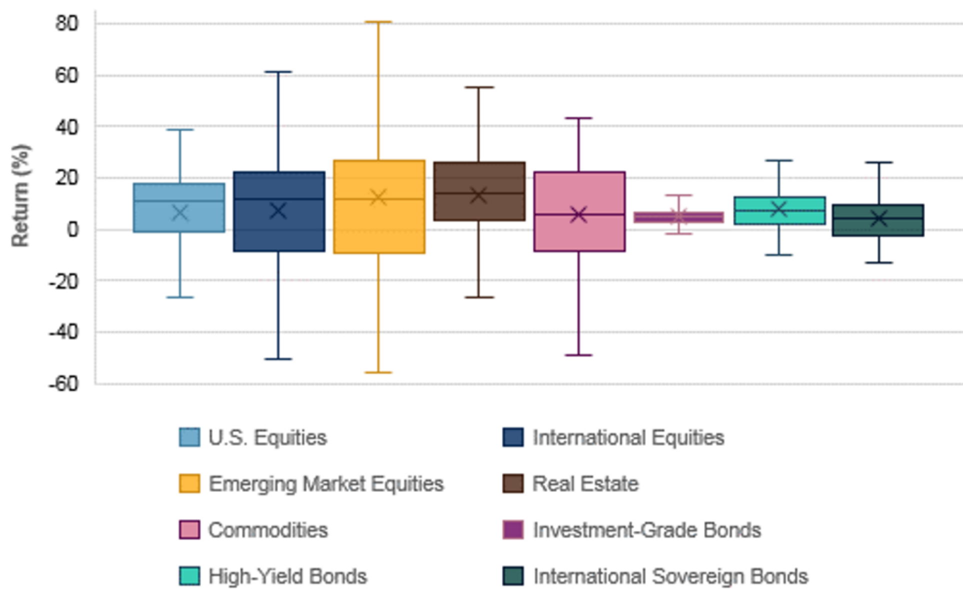
Asset Class Overview

In this section, we demonstrate the potential diversification benefits of a risk parity strategy in terms of risk efficiency (risk-adjusted returns). Using a study period from 2000 to 2017, we first reviewed the historical performance and cross-correlations of major asset classes.[1] We then compared the risk/return characteristics of multi-asset portfolios with various combinations of asset classes.

Lastly, we constructed a rudimentary three-asset risk parity portfolio consisting of stocks, bonds, and commodities. We used this portfolio to illustrate the potential benefits of a risk parity strategy by comparing it with other weighting schemes.

We employ a box and whisker chart[2] in Exhibit 1 to summarize the historical performance of each asset class, based on rolling 12-month total returns of overlapping periods.

Exhibit 1: Asset Class Rolling 12-Month Returns Summary



Source: S&P Dow Jones Indices LLC. Data as of Dec. 29, 2017. Index performance based on monthly total return in USD. See Endnote 2 for an explanation of the chart contents. Past performance is no guarantee of future results. Chart is provided for illustrative purposes and reflects hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

For each asset class, we can observe the average ("x") and median (horizontal line across the shaded area) 12-month returns, as well as the distribution of returns. Emerging market equities and real estate delivered the highest average 12-month returns (12.1% and 13.1%, respectively) for the study period. However, their dispersion of returns, which can indicate the magnitude of return uncertainty, was generally larger than the other asset classes.

We can see the dispersion of returns for each asset class by the height of the inter-quartile range (colored box on vertical line) and the distance between the minimum and maximum returns (the endpoints of the lines extending out from the boxes). While emerging market equities and real estate delivered the highest average returns, they also exhibited higher return uncertainty compared with other asset classes, such as investment-grade bonds.

Exhibit 2 shows the return correlations for each asset pair over the full period. For the 18-year period, there were strong positive correlations between the equity regions, ranging from 0.75 to 0.87. Additionally, equities had moderately positive correlations to real estate, commodities, and high-yield bonds. Meanwhile, equities were negatively correlated with investment-grade bonds. Therefore, adding investment-grade bonds, particularly to an equities portfolio, could lower portfolio volatility and potentially deliver higher returns per unit of risk.

Exhibit 2: Asset Class Correlations

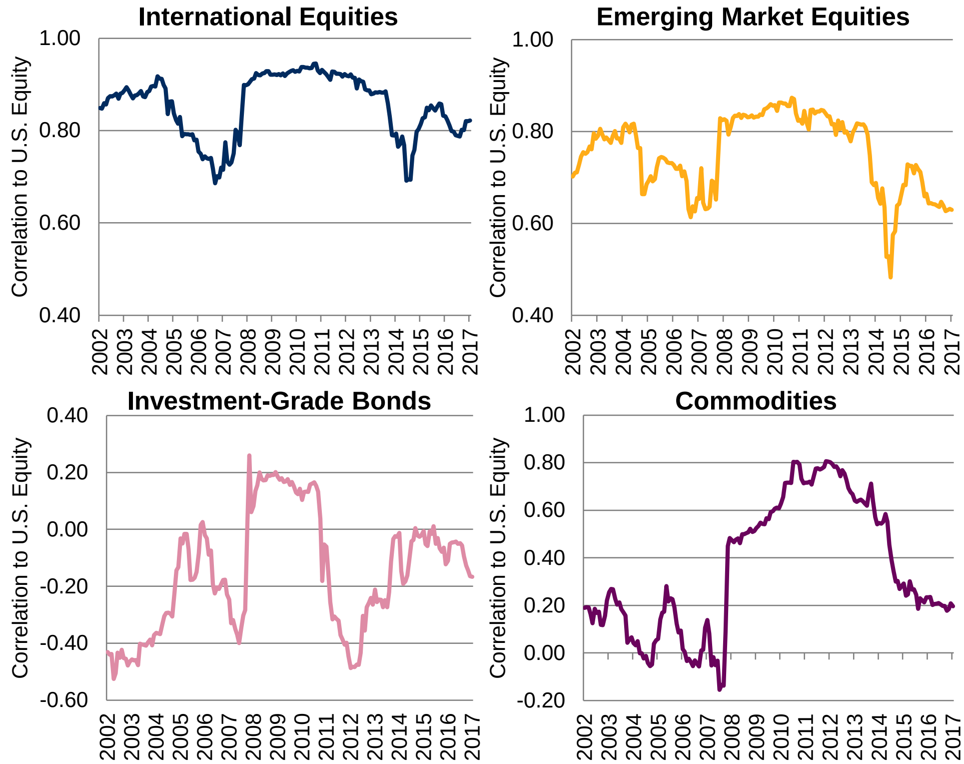
ASSET CLASS	U.S. EQUITIES	INTERNATIONAL EQUITIES	EMERGING MARKET EQUITIES	REAL ESTATE	COMMODITIES	INVESTMENT-GRADE BONDS	HIGH-YIELD BONDS	INTERNATIONAL SOVEREIGN BONDS
U.S. EQUITIES	-	0.87	0.75	0.63	0.39	-0.15	0.63	0.11
INTERNATIONAL EQUITIES	0.87	-	0.87	0.62	0.55	-0.02	0.69	0.31
EMERGING MARKET EQUITIES	0.75	0.87	-	0.53	0.56	-0.01	0.70	0.24
REAL ESTATE	0.63	0.62	0.53	-	0.28	0.10	0.60	0.24
COMMODITIES	0.39	0.55	0.56	0.28	-	0.00	0.43	0.31
INVESTMENT-GRADE BONDS	-0.15	-0.02	-0.01	0.10	0.00	-	0.11	0.53
HIGH-YIELD BONDS	0.63	0.69	0.70	0.60	0.43	0.11	-	0.16
INTERNATIONAL SOVEREIGN BONDS	0.11	0.31	0.24	0.24	0.31	0.53	0.16	-

Source: S&P Dow Jones Indices LLC. Data as of Dec. 29, 2017. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Table is provided for illustrative purposes and reflects hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

While Exhibit 2 shows the correlations over the entire 18-year period, correlations between asset classes can vary greatly in shorter time windows while markets go through different cycles. To examine how correlations changed over time, we computed rolling 36-month correlations for U.S. equities compared with international equities, emerging market equities, investment-grade bonds, and commodities.

Correlations among asset classes varied over time.

Exhibit 3: 36-Month Rolling Correlations of Select Asset Classes to U.S. Equities



Source: S&P Dow Jones Indices LLC. Data as of Dec. 29, 2017. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Charts are provided for illustrative purposes and reflect hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

This demonstrated the importance of the length of the lookback window used when constructing the strategy.

We can see that the correlations between the asset pairs varied over time. For example, the correlation between U.S. equities and investment-grade bonds for the full period was -0.15; however, there were multiple instances where the rolling correlation dropped below -0.40. Additionally, a sharp spike in correlation between U.S. equities and other asset classes took place during the financial crisis in late 2008.

We constructed two-asset portfolios in order to evaluate the use of those correlations as diversification.

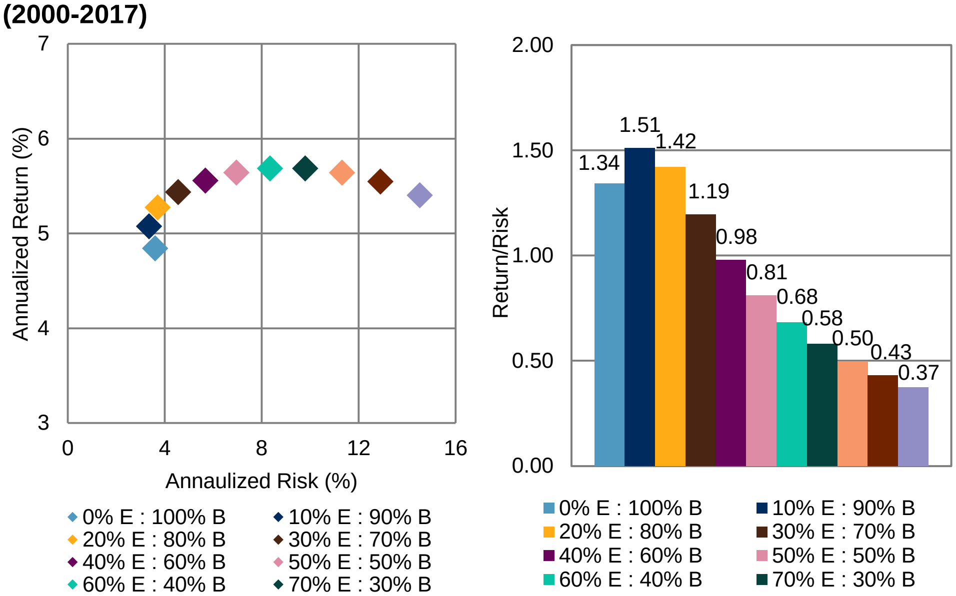
The Impact of Correlations on Portfolio Return and Volatility

Next, we evaluate the effectiveness of incorporating asset class correlations to diversify a multi-asset portfolio. We constructed two-asset portfolios consisting of U.S. equities and investment-grade bonds. In addition to the classic 60/40 equity/bond mix, additional portfolios were created in 10% weight increments, resulting in 11 total portfolios.[3] These portfolios enabled us to view the incremental effect of adding and removing an asset class in a portfolio.

Exhibits 4 and 5 show the performance results of the allocation mixes for two periods; Exhibit 4 is the full 18-year period from 2000 to 2017, and Exhibit 5 is the 10-year period through year-end 2017. The left charts are scatter plots of annualized risk and return, while the right charts are the return-per-unit-of-risk ratio.

The portfolios consisted of U.S. equities and investment-grade bonds.

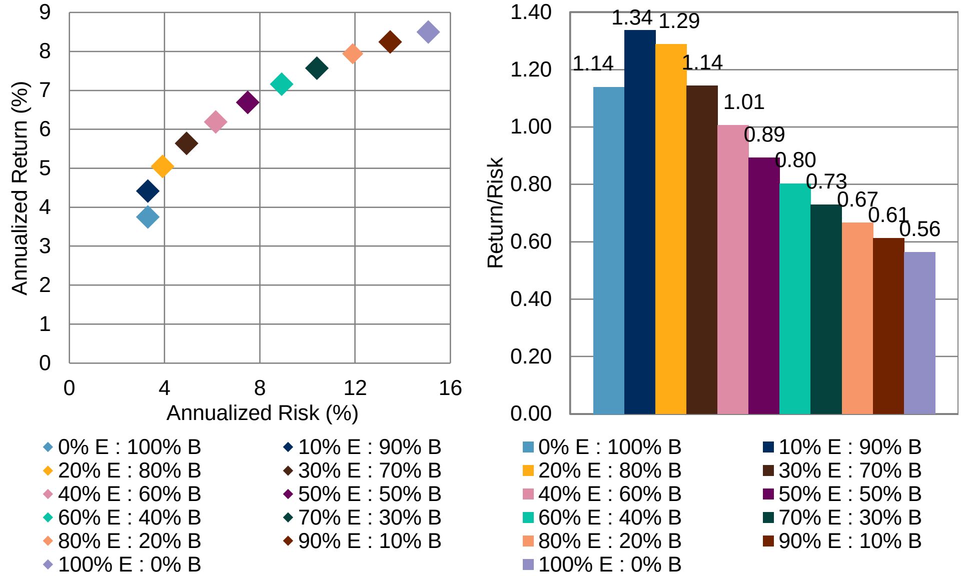
Exhibit 4: Equity-Fixed Income Allocation Portfolios Risk Versus Return (2000-2017)



All portfolios are hypothetical portfolios.
Source: S&P Dow Jones Indices LLC. Data as of Dec. 29, 2017. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Charts are provided for illustrative purposes and reflect hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

There was a non-linear relationship with the changes in portfolio return and risk…

Exhibit 5: Equity-Fixed Income Allocation Portfolios Risk Versus Return (2008-2017)



All portfolios are hypothetical portfolios.
Source: S&P Dow Jones Indices LLC. Data as of Dec. 29, 2017. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Charts are provided for illustrative purposes and reflect hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

We can make several observations from Exhibits 4 and 5. Equities outperformed bonds over the 18-year period, but that excess performance came with significantly higher volatility (left charts). The risk-adjusted return ratios (right charts) show the return per unit of risk for each portfolio—bonds had a significantly higher risk-adjusted ratio of 1.34 versus 0.37 for equities. Thus, on a risk-adjusted return basis, bonds fared better than equities.

…and the best-performing portfolio was often not the one with the highest return-to-risk ratio.

Given the low correlations and higher risk-adjusted return ratio for bonds, combining the two assets led to several allocation mixes with even higher risk-adjusted ratios (e.g., 10/90 equity/bond and 20/80 equity/bond). In fact, the 10/90 equity/bond portfolio had lower volatility relative to bonds along with higher returns—resulting in the highest risk-adjusted return ratio (1.51) out of all the mixes.

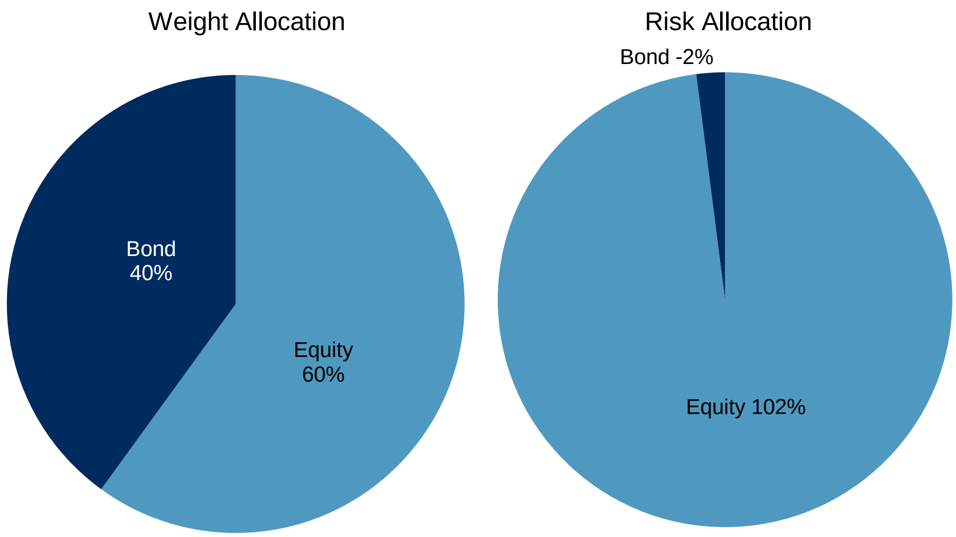
Starting from an initial 100/0 equity/bond portfolio and progressively increasing weight to bonds led to higher absolute returns (until 60/40) and higher risk-adjusted return ratios (until 10/90). These results are a testament to the potential diversification benefit of combining low-correlated assets in a portfolio.

The period studied in Exhibit 5 included the global financial crisis and periods with relatively low interest rates; the resulting return differential between the two asset classes was more significant. In this period, the 100% equity portfolio would have been the best-performing portfolio; however, the 10/90 equity/bond portfolio once again had the highest return/risk ratio (1.34)—almost 2.4 times higher than the 100% equity portfolio.

In the 60/40 equity/bond portfolio, almost all of the total portfolio risk came from equities…

To highlight the drivers of return and volatility for the allocations, we calculated the marginal contribution to total portfolio risk for each asset class.[4] Since equities are typically more volatile than bonds, we could expect that they would contribute more to total risk than the bond component. Exhibit 6 shows the allocations of the two asset classes first by weight and then by risk contribution for the 60/40 portfolio.

Exhibit 6: 60/40 Equity/Bond Portfolio Weight Allocation Versus Risk Allocation



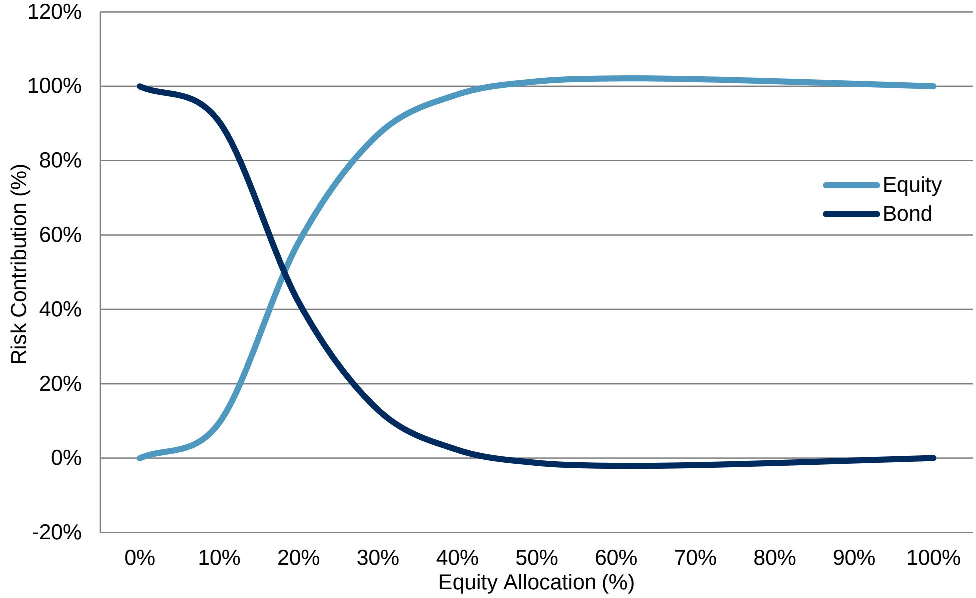
…while in the 10/90 equity/bond portfolio, the average contribution to risk generally mirrored the allocation weights.

The 60/40 equity/bond portfolio is a hypothetical portfolio.
Source: S&P Dow Jones Indices LLC. Data as of Dec. 29, 2017. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Charts are provided for illustrative purposes and reflect hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

The exhibit shows that for the 60/40 equity/bond mix, on average, all of the total portfolio volatility came from equities. In fact, the average contribution for equities was 102%, leading to a -2% average contribution to total risk for bonds. The results demonstrate the volatility contributions of different asset classes, compared with their weights in a portfolio. To see how risk contributions change as weight allocations move from 0%-100% in equities (and 100%-0% in fixed income), Exhibit 7 shows the annual averages.

We then extended the analysis by adding commodities to construct a three-asset portfolio.

Exhibit 7: Equity/Bond Portfolio Weight Allocation Versus Risk Allocation



All portfolios are hypothetical.
Source: S&P Dow Jones Indices LLC. Data as of Dec. 29, 2017. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Chart is provided for illustrative purposes and reflects hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

The equity and commodity asset classes were the primary contributors to total portfolio risk…

There is a clear non-linear relationship between the change in weight and the change in risk contribution. Since equities tend to be more volatile than bonds and the return correlation between the two is low, as the allocation to equities increases, their risk contribution to total portfolio volatility increases at a higher rate. In the end, the point where the two asset classes most closely contribute equally to portfolio volatility is at the 20/80 equity/bond mix.

Exhibits 6 and 7 show that the risk contribution percentages can be materially different from weight allocation percentages for assets in a portfolio. Building upon this conclusion, we next constructed a basic three-asset risk parity strategy and compare it to an equal-weight portfolio.

Equal-Weighting Versus Equal-Risk-Weighting Strategies

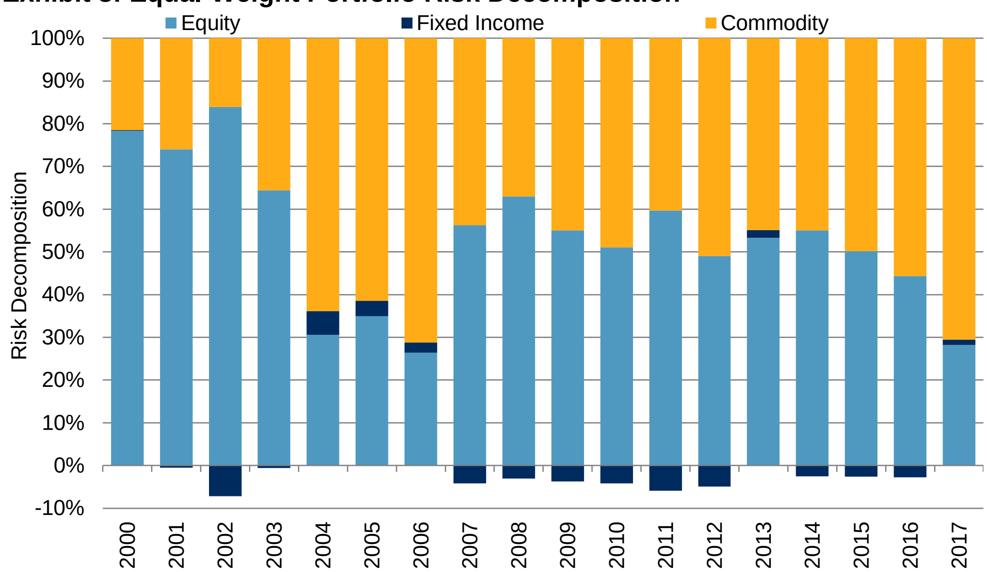
…and in fact, bonds had a negative contribution to the total risk.

In this section, we extended the analysis from the prior section by adding commodities in order to construct a three-asset portfolio. Commodities historically has shown relatively low to moderate correlation to traditional asset classes such as equities and bonds, thereby potentially providing diversification benefits in a multi-asset portfolio. Moreover, commodities generally perform well in periods of high growth and rising inflation. Like equities, commodities historically have had relatively high return volatility. Hence, when combined in a three-asset portfolio with bonds, we could anticipate that equities and commodities would contribute most to total portfolio volatility.

In a market-cap-weighted portfolio, the risk is often significantly out of proportion with the weight of the asset class.

We weighted the portfolio in two ways; the first portfolio was equally weighted and the second portfolio assumed an equal-risk-contribution apporach.[5 6] These constructed portfolios will help us to understand the effectiveness of weighting a portfolio such that each asset contributes equally to portfolio risk, as opposed to equally weighting the assets. We first focused on the risk decomposition of the equal-weight portfolio. To do so, we computed the contribution to risk for the portfolio on an annual basis (see Exhibit 8).

Exhibit 8: Equal-Weight Portfolio Risk Decomposition



The equal-weight portfolio is a hypothetical portfolio.
Source: S&P Dow Jones Indices LLC. Data as of Dec. 29, 2017. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Chart is provided for illustrative purposes and reflects hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

In this case, commodities contributed 71% of risk, which making up 33% of the portfolio…

For 2017, commodities contributed most to portfolio volatility, at 71%, significantly higher than its one-third weight allocation. Equities contributed the second most, with 28%, while fixed income contributed just 1%. For the whole period, we observed that equities and commodities were the dominant contributors to total portfolio risk.

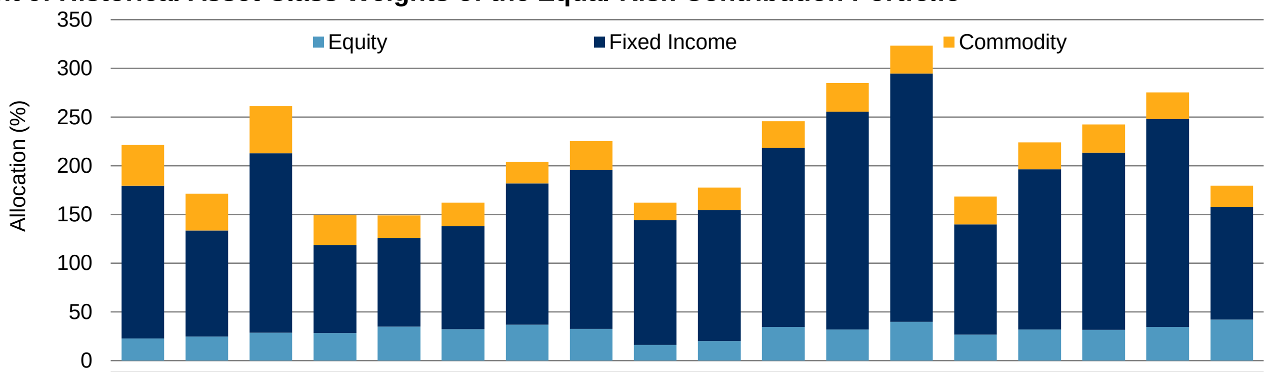
…while bonds, also with a weight of 33%, contributed just 1%.

On average, equities contributed 53% and commodities 48%—therefore, bonds negatively contributed (-1%) to the total risk. However, contributions varied from year to year; equities contributed as much as 84% to portfolio volatility in 2002, fixed income contributed 6% in 2004, and commodities contributed 71% in 2006 and 2017.

Next, we constructed an equal-risk-contribution portfolio with the same three assets. The portfolio was rebalanced annually, with the objective of arriving at an asset class mix wherein: 1) each asset class would contribute one-third of the total portfolio risk and 2) the target volatility level would be set as the volatility of the equal-weight portfolio from the previous year.[6]

Exhibit 9 shows the resulting weights of each asset class on an annual basis. The asset class weights of the equal-risk-contribution portfolio are quite different from the weights of the same asset classes in an equal-weight portfolio. In fact, the weight for fixed income often exceeds 100%, which is necessary to get the risk contribution up to the riskier asset classes' contributions. As individual asset class volatility and cross-correlations vary through time, the total nominal weight of the portfolio at the end of each year ranged from 149% to 324%.

Exhibit 9: Historical Asset Class Weights of the Equal-Risk-Contribution Portfolio

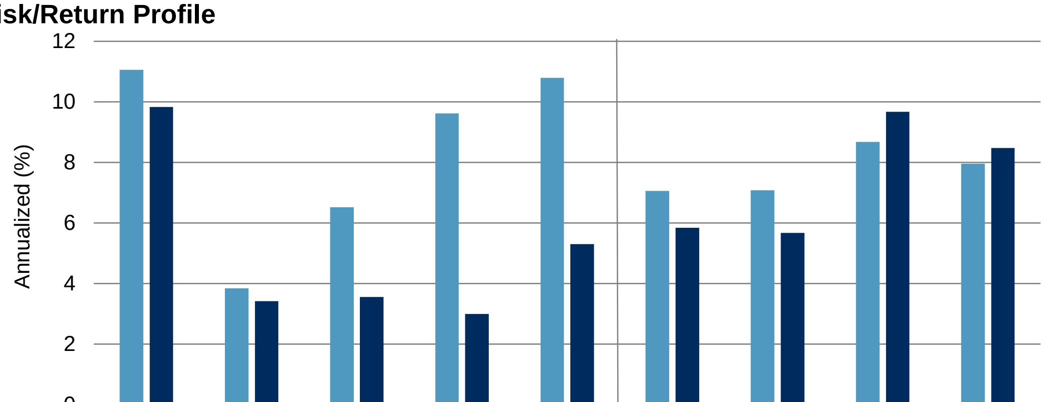


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Commodity	42	38	48	31	23	24	22	30	18	23	27	29	29	29	28	29	27	22
Fixed Income	157	109	184	91	91	106	145	163	128	135	184	224	255	113	164	182	214	116
Equity	23	25	29	28	35	32	37	32	16	20	35	32	40	27	32	32	35	42

The equal-risk-contribution portfolio is a hypothetical portfolio.
Source: S&P Dow Jones Indices LLC. Data as of Dec. 29, 2017. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Chart is provided for illustrative purposes and reflects hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

Shifting to the impact that the two weighting schemes had on portfolio returns, Exhibit 10 shows the historical annualized return and volatility figures (see Appendix A for asset class returns and volatilities).

Exhibit 10: Historical Risk/Return Profile



	Annualized Return (%)					Annualized Volatility (%)			
	1 Year	3 Year	5 Year	10 Year	17 Year	3 Year	5 Year	10 Year	17 Year
Equal-Risk-Contribution Portfolio	11.06	3.85	6.52	9.62	10.79	7.05	7.08	8.68	7.95
Equal-Weight Portfolio	9.83	3.41	3.55	3.00	5.30	5.84	5.67	9.67	8.48

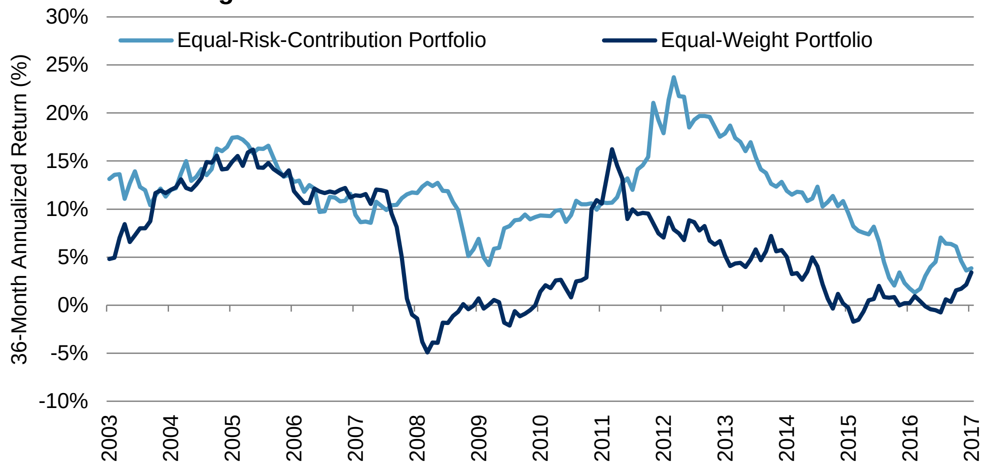
The equal-risk-contribution and equal-weight portfolios are hypothetical portfolios.
Source: S&P Dow Jones Indices LLC. Data as of Dec. 29, 2017. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Chart is provided for illustrative purposes and reflects hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

Since the target volatility for the equal-risk-contribution portfolio is that of the equal-weight portfolio, the realized historical portfolio volatilities were similar. However, the return for the equal-risk-contribution portfolio was higher than its equal-weight counterpart across all periods measured.

Comparing an equal-risk-contribution portfolio to an equal-weight portfolio shows us that they can have large differences in their performance…

The long-term horizons (10 and 17 years), covering periods of bear markets in equities and commodities, show relatively high return spreads, and therefore showed substantially higher risk-adjusted returns. To further isolate performance in different periods, we also computed the rolling three-year annualized returns (see Exhibit 11).

Exhibit 11: Rolling Three-Year Annualized Returns



The equal-risk-contribution and equal-weight portfolios are hypothetical portfolios.
Source: S&P Dow Jones Indices LLC. Data as of Dec. 29, 2017. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Chart is provided for illustrative purposes and reflects hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

In certain periods, the two portfolios performed similarly, while in others the equal-risk portfolio noticeably outpaced the equal-weight portfolio. The equal-risk portfolio outperformed the equal-weight portfolio 84% of the time and by an average of 5.51%.

…and in fact, the former outperformed the latter 84% of the time.

Up to this point, we have shown that an equal-risk-contribution approach to constructing a multi-asset portfolio can potentially lead to higher absolute or risk-adjusted returns than an equal-weight approach. Building upon the findings in the section, we introduce the S&P Risk Parity Indices in the following sections of the paper.

INTRODUCING THE S&P RISK PARITY INDICES

Risk parity aims to have equal contribution to portfolio volatility by the underlying asset classes…

Since 1996, many investment companies have begun to offer risk parity funds to their clients, especially in the aftermath of the global financial crisis. Such strategies have lacked an appropriate benchmark, leaving many to fall back on a traditional 60/40 equity/bond portfolio benchmark. One of the issues with this approach is that a 60/40 portfolio has a different construction and risk/return characteristics than risk parity strategies.

As we discussed previously, the traditional 60/40 approach leads to a disproportionate allocation of risk to equities (see Exhibit 6). A risk parity strategy, on the other hand, attempts to have a balanced risk contribution from all asset classes. Some benchmarks, such as the HFR Risk Parity Indices, bypass the portfolio construction of a risk parity strategy and instead use weighted average returns of active risk parity managers. Unfortunately, this approach lacks transparency in holdings and return attribution and may be subject to survivorship bias.

With that in mind, we introduced the S&P Risk Parity Indices in an effort to provide transparent, rules-based benchmarks for risk parity strategies. The series constructs risk parity portfolios by using liquid futures that represent various asset classes and seeks to reflect the risk/return characteristics of strategies offered in this space. The index series comprises three indices with volatility targets of 10%, 12%, and 15%.

Constructing a Risk Parity Portfolio

As we noted in earlier sections, risk parity, or equal risk contribution by definition, aims to have equal portfolio volatility contribution by the underlying asset classes. There are multiple ways to construct a risk parity portfolio, depending on how one measures and defines risk.

In a standard Markowitz mean-variance framework, risk is defined as the standard deviation of an asset's returns. Alternatively, one could use value at -risk (VaR) as a measure of risk. The advantage of using VaR over standard deviation is that it incorporates skewness and kurtosis.

However, in practice, standard deviation, or volatility, of returns is the default adopted by investors to measure risk. Since we measure risk by volatility, the contribution of each asset class to the total risk of the portfolio is easily determined. For a multi-asset portfolio, the marginal contribution of the i^{th} asset to total portfolio risk is illustrated in Equations 1a and 1b.

$$\mathrm{MC_i} = \mathrm{w_i} * \sigma_\mathrm{p} * \beta_\mathrm{i} \quad (1a)$$

Where β_i is defined as:

$$\beta_\mathrm{i} = \frac{\mathrm{Cov}(\sigma_\mathrm{i},\sigma_\mathrm{p})}{{\sigma_\mathrm{p}}^2} \quad (1b)$$

A top-down approach to building a risk parity portfolio often uses an optimizer to adjust asset class weights until the marginal contributions to portfolio risk are all equal. However, the computational complexity of the covariance matrix estimation is proportional to the square of the number of underlying securities. The result is that the process could be data intensive and time consuming. Besides, many market participants tend to steer away from the "black box" nature of optimizers and prefer transparency in the allocation process.

The approach taken by the S&P Risk Parity Indices uses a fixed volatility target and aims for the same amount of volatility from each asset class…

Arguably, the simplest approach to build an equal-risk portfolio is to set each asset's weight to be proportional to the inverse of its standard deviation (see Equation 2). The result is that on a relative basis, lower volatile assets will have a higher weight than higher volatile assets.

$$w_i = \frac{1/\sigma_i}{\sum(\frac{1}{\sigma_k})} \quad (2)$$

In the actual implementation of risk parity, the cross-correlation of assets is typically considered in addition to individual asset class volatility. Other measures of risk can be used in certain cases, but this simple approach is often a starting point for more advanced techniques.

…which ensures that less capital is allocated to more volatile asset classes…

In *Understanding Risk Parity* (Hurst et al. 2010), AQR proposes another simple risk parity strategy, which targets a similar amount of volatility from each asset class each month. This approach begins by estimating an expected volatility for each asset class. The position weight for each asset class, calculated at the beginning of each month, is the TV level divided by the forecasted volatility for that asset class (see Equation 3).

$$w_i = \frac{\text{Target Volatility}}{\sigma_i} \quad (3)$$

Actual portfolio construction would then incorporate asset class correlations, volatility forecasting, and volatility targeting, as well as tactical over- and underweights.

Indexing Risk Parity Strategies

The approach taken by the S&P Risk Parity Indices is similar to AQR's proposal in that it uses a fixed volatility target and aims for the same amount of volatility from each asset class. This ensures that: 1) less capital is allocated to more volatile asset classes, and 2) portfolio holdings shift as volatility changes.

…and portfolio holdings shift as volatility changes.

We also believe that a fixed volatility target can lead to more consistent risk/return statistics for the overall portfolio. To avoid the complexities involved with volatility forecasting, we instead use the long-term realized volatility of the asset classes. The lookback window for realized volatility is a minimum of five years at the beginning of the historical back-test and increases up to 15 years as time passes and the strategy accumulates more data.

CONSTITUENTS

We use long-term realized volatility to measure risk, rather than forecasted volatility, to avoid the dependency of volatility forecasting models.

The benchmark includes 26 liquid futures that cover developed market equities, fixed income, and commodities. Futures contracts is the implementation vehicle of choice for several reasons. First, they provide liquid, low cost, and transparent access to commodities. Second, they provide efficient coverage to equities—the three equity index futures in the risk parity indices cover 775 individual securities. Third, the structure of futures contracts limits the total foreign currency exposure inherent in investing in international markets; the exposure is limited to the profit or loss of the position, as opposed to the entire notional value of the contract. Finally, funding rates are implicit in futures contract pricing. Therefore, we know that all investors will get the same outcome. This is particularly important given that a risk parity strategy usually uses leverage. To be considered liquid, futures contracts must have a minimum annual total dollar value traded of USD 5 billion. Please refer to Appendix A for the complete list of futures contracts and their roll schedules.

Exhibit 12: Constituents

EQUITY		FIXED INCOME		COMMODITIES	
CONTRACT	**CODE**	**CONTRACT**	**CODE**	**CONTRACT**	**CODE**
S&P 500®	SP	U.S. T-Notes (5-year)	FV	Crude Oil	CL
Euro Stoxx 50	FESX	U.S. T-Notes (10-year)	TY	Natural Gas	NG
Nikkei 225 Futures	NKJ	U.S. T-Bonds (30-year)	US	Brent Crude	B
		Euro-Bobl	FGBM	Gasoline	RB
		Euro-Bund	FGBL	Heating Oil #2	HO
		Long Gilt	LG	Gas Oil	G
		JBG (10-year)	JGB	Gold (100 oz.)	GC
				Silver	SI
				Copper	HG
				Corn	C
				Wheat	W
				Soybeans	S
				Live Cattle	LC
				Sugar #11	SB
				Coffee "C"	KC
				Cotton #2	CT

Source: S&P Dow Jones Indices LLC. Data as of July 2018. Table is provided for illustrative purposes.

To balance true risk over at least one full market cycle and avoid incorporating historical volatility in the distant past…

…the preference is to use a 15-year lookback window.

RISK MEASUREMENT

In the S&P Risk Parity approach, we use long-term realized volatility to measure risk. Realized volatility rather than forecasted volatility is used to avoid the dependency of volatility forecasting models. A short lookback window may react more quickly to market movement, but it may not reflect the true risk over time. To balance true risk over at least one full market cycle and avoid incorporating historical volatility in the distant past, the preference is to use a 15-year lookback window.

Due to data limitations, the lookback window in the historical back-test has a minimum of a five-year history for each asset class at the start and then is increased until the maximum of 15 years is reached.

We use a bottom-up approach to determine the weight of each futures contract…

WEIGHTING MECHANISM

The approach targets a similar amount of volatility from each asset class. In order to do this, the calculated position weight for each asset class is simply the predefined TV level of the index divided by the asset class realized volatility.

…and then we group these securities into three asset classes: equity, fixed income, and commodities.

Within each asset class, futures are combined using the same approach to ensure equal risk contribution from futures to the asset class they belong to. This process occurs once again at the portfolio level. Due to correlations among asset classes, we can expect that the simulated volatility of the risk parity portfolio would be lower than the TV. To correct for this, we apply a multiplier to the position weights to achieve the TV. This approach avoids estimating the variance-covariance matrix, while still capturing historical correlation effects. We repeat this process at the end of each month and rebalance to new weights on the second trading day of the following month.

S&P RISK PARITY INDEX CONSTRUCTION

In this section, we illustrate the index construction process of the S&P Risk Parity Index – 10% Target Volatility (TV). The futures' and asset classes' realized volatility used in the illustration are hypothetical. While 10% is the TV set in this example, the process is the same for the other volatility targets of 12% and 15%.

We combine all the asset classes and compute the realized volatility of the portfolio, which is usually lower than the target volatility due to the correlations among asset classes.

As shown in Exhibit 14, there are three major steps to constructing the index.

1) We use a bottom-up approach to determine the weight of each futures contract. We begin by calculating the long-term realized volatility for each futures contract. The contract position weight calculated at the beginning of each month is the TV divided by the realized volatility for that futures contract (see Equation 3).
2) We then group these securities into three asset classes: equity, fixed income, and commodities. For each asset class, all the futures contracts leveraged or deleveraged to the TV are combined with an equal weight. That means the weights calculated in the previous step are divided by the number of futures in the asset class.

We then compute the realized volatility of the asset class. Due to correlation among securities, the asset-class-level realized volatility is usually lower than the TV (see Equation 4). We then derive a multiplier, M_i, for the i^{th} asset class, which is the ratio of the TV to the volatility of the asset class (see Equation 4). The weights of all the securities in the i^{th} asset class are then multiplied by M_i so that the asset class's overall risk equals the TV. By doing so, we ensure that all asset classes aim for the same level of volatility.

3) We combine all the asset classes and compute the realized volatility of the portfolio, which is usually lower than the TV due to the correlation among asset classes. We again calculate a portfolio-level multiplier in the same manner as we did on the asset class level, which is then applied to the weights of all the futures contracts.

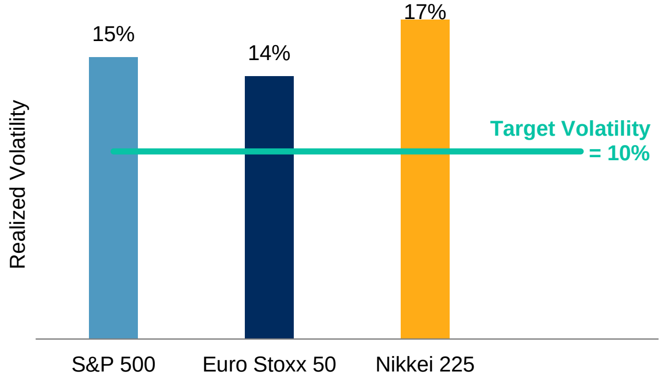
   Note that this final step is not required for the purpose of equal risk allocation among assets; this step keeps the portfolio's long-term risk in line with its target. The portfolio multiplier represents the dynamic leverage applied to the overall portfolio based on cross-asset correlation.

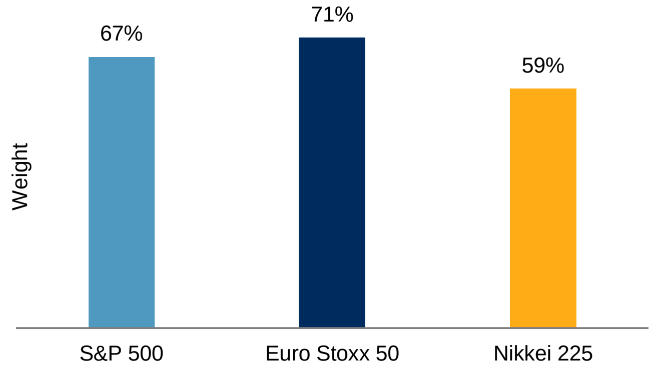
$$M_i = \frac{\text{Target Volatility}}{\sigma_i} \quad (4)$$

Positions of each constituent are calculated at the end of each month, using data from the end of the previous business day, and they become effective on the second trading day of the next month.

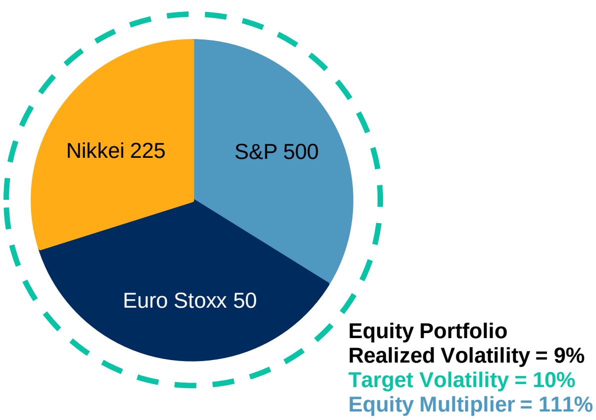
Exhibit 13: Hypothetical Weighting of the S&P Risk Parity – 10% TV

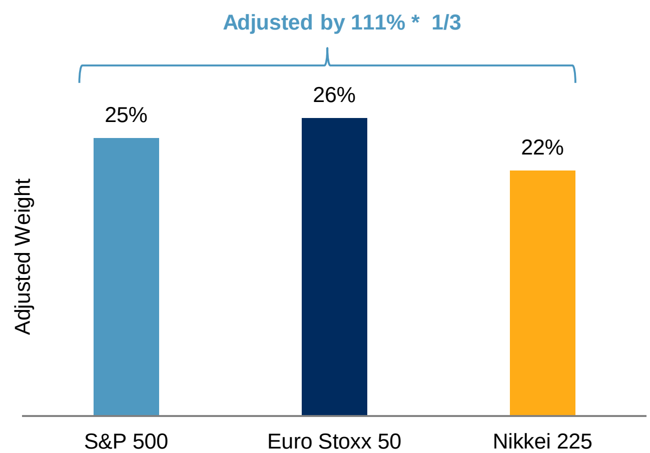
Step 1: Determine the Futures Weights at TV



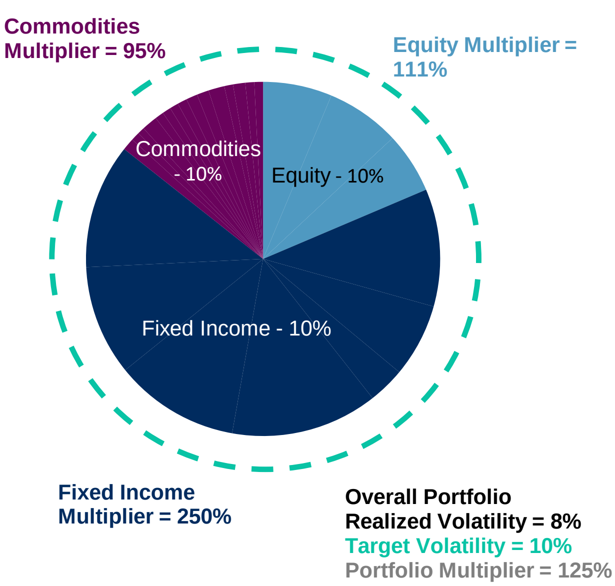


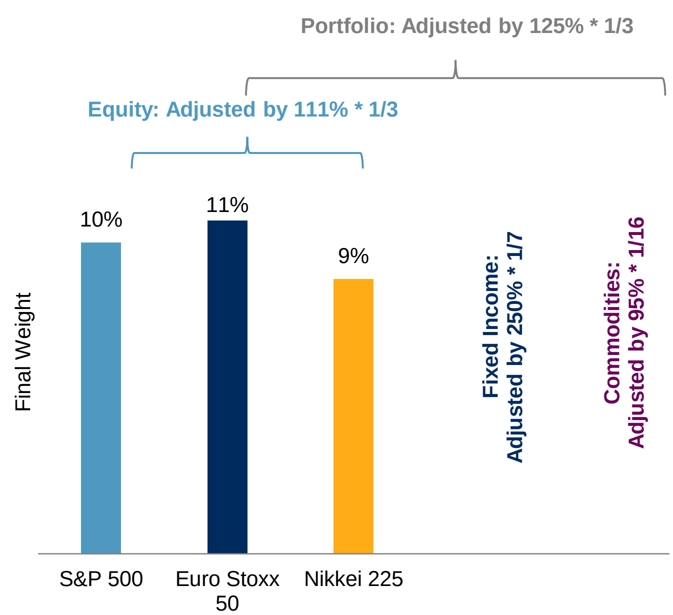
Step 2: Construct Risk Parity Equity Portfolio at TV





Step 3: Construct Risk Parity Overall Portfolio at TV





Source: S&P Dow Jones Indices LLC. Charts are provided for illustrative purposes.

Historical Performance

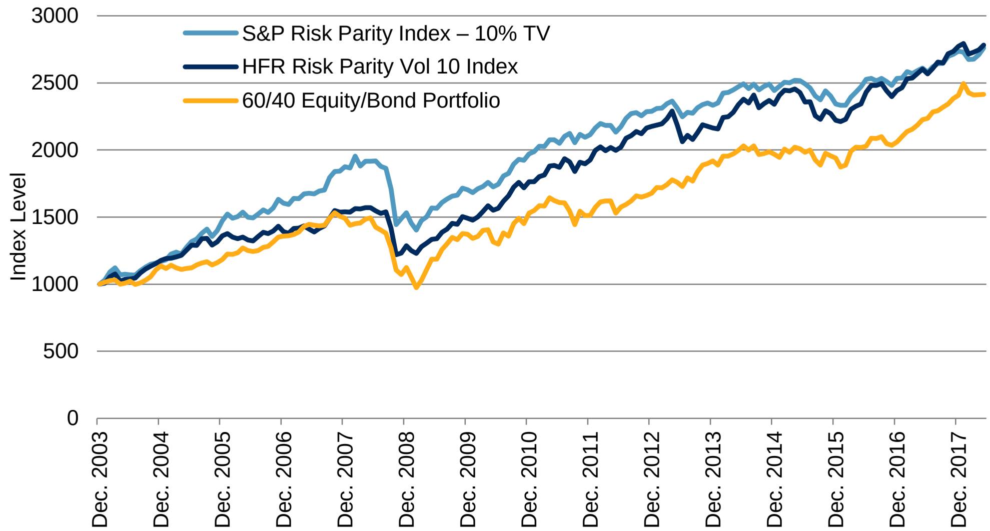
In this section, we use the S&P Risk Parity Index – 10% TV as an example to illustrate historical performance and risk/return characteristics. Exhibits 14 and 15 show the cumulative returns of the index and other key performance statistics.

We use the S&P Risk Parity Index – 10% Target Volatility as an example to illustrate historical performance and risk/return characteristics.

We compared it with a traditional 60/40 equity/bond portfolio and the HFR Risk Parity Vol 10 Index as a proxy of active risk parity funds in the market.[7] For reference, the HFR Risk Parity Indices represent the weighted average performance of the universe of active fund managers employing an equal-risk-contribution approach in their portfolio construction. These indices also have three volatility targets (10%, 12%, and 15%).

The historical performance shows that the index tracked the risk parity active fund managers much closer than the 60/40 portfolio…

Exhibit 14: Cumulative Returns



The 60/40 equity/bond portfolio is a hypothetical portfolio.
Source: S&P Dow Jones Indices LLC, HFR Index, LLC. Data from Dec. 31, 2003, to May 31, 2018. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Chart is provided for illustrative purposes and reflects hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

…with higher correlation and lower tracking error.

Exhibit 15: Performance Statistics

METRIC	S&P RISK PARITY INDEX – 10% TV	60/40 EQUITY/BOND PORTFOLIO	HFR RISK PARITY VOL 10 INDEX
Annual Return (%)	7.30	6.31	7.36
Annual Volatility (%)	8.34	9.90	8.34
Sharpe Ratio	0.73	0.52	0.74
Maximum Peak-to-Trough Drawdown (%)	-28.17	-36.42	-22.43
Annualized Tracking Error (%)	3.99	6.54	-
Correlation	0.89	0.76	-

The 60/40 equity/bond portfolio is a hypothetical portfolio.
Source: S&P Dow Jones Indices LLC, HFR Index, LLC. Data from Dec. 31, 2003, to May 31, 2018. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Table is provided for illustrative purposes and reflects hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

For the 14-year period, equities, fixed income, and commodities each showed roughly the same marginal contribution to portfolio risk…

The historical performance shows that the S&P Risk Parity Index – 10% TV tracked the risk parity active fund managers much closer than the 60/40 portfolio, with higher correlation (0.89 versus 0.76) and lower tracking error (3.99% versus 6.54%). The overall annualized return, realized volatility, and Sharpe ratio of the S&P Risk Parity Index – 10% TV were similar to the average numbers of active risk parity fund managers in the market. Performance statistics of the other indices in the S&P Risk Parity Index Series can be found in Appendix C.

Attribution and Allocation

Risk parity, by definition, aims for balanced risk contribution from all asset classes. Hence, a proper benchmark of risk parity strategies should demonstrate roughly equal risk contribution from all asset classes. In this section, we continue to use the S&P Risk Parity Index – 10% TV as an example to illustrate risk attribution, return contribution, and capital allocation.

RISK ATTRIBUTION

…with some fluctuations over time.

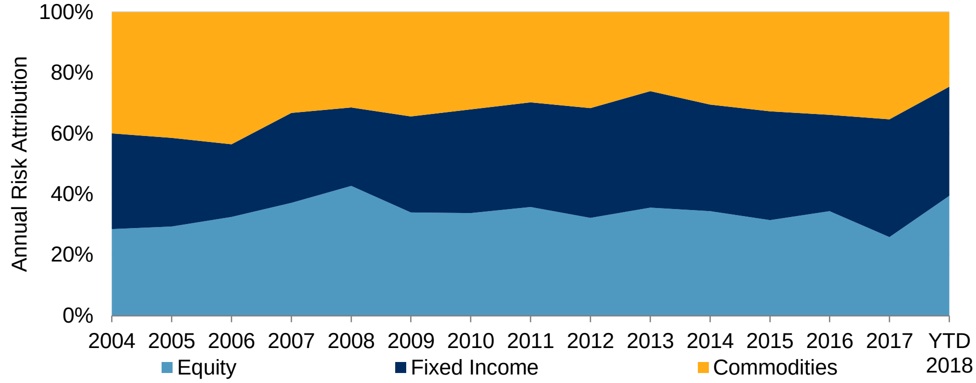
Exhibit 18 shows the back-tested historical risk attribution at the asset class level. Over the past 14 years, equities, fixed income, and commodities each displayed roughly the same marginal contribution to portfolio risk, despite some fluctuations over time. We noticed that risk attribution from different asset classes varied in different market environments.

This was not surprising since we used realized historical volatilities as the risk measure. For example, in 2008, when the economy headed into a recession, equity risk attribution reached an all-time high of 42.79%. After incorporating the volatility of 2008 into the historical lookback period for the realized volatility calculation, equity risk attribution decreased to 33.99% in 2009, close to the one-third risk attribution expected in a risk parity portfolio.

Within each asset class, individual futures contracts have roughly contributed the same amount of risk (see Appendix C for details).

Historical capital allocation verifies that an equal-risk allocation is materially different from an equal-weight allocation.

Exhibit 16: Annual Risk Attribution by Asset Class of the S&P Risk Parity Index – 10% TV



ANNUAL RISK ATTRIBUTION (%)	EQUITY	FIXED INCOME	COMMODITIES
Mean	33.85	32.84	33.31
Median	33.99	34.10	32.60
Maximum	42.79	38.80	43.47
Minimum	25.92	24.01	24.51

Source: S&P Dow Jones Indices LLC. Data from Dec. 31, 2003, to May 31, 2018. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Chart and table are provided for illustrative purposes and reflect hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

Fixed income had the largest capital allocation, to ensure its equal-risk contribution to the portfolio (approximately 60%)…

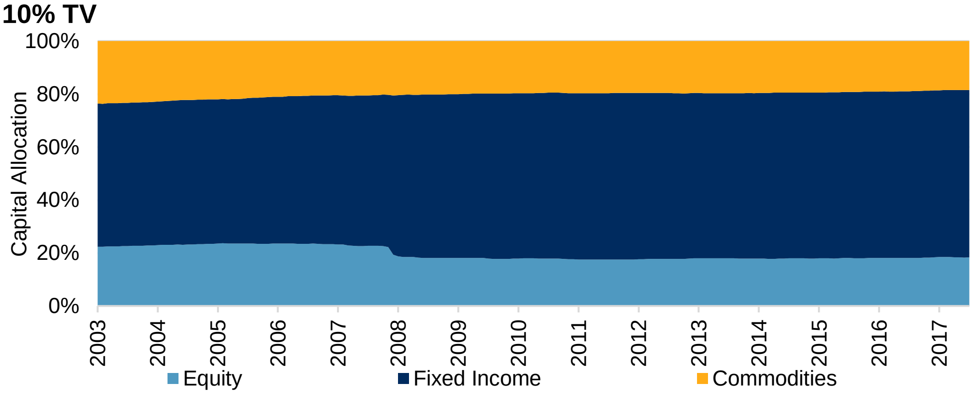
CAPITAL ALLOCATION

Historical capital allocation verifies that an equal-risk allocation is materially different from an equal-weight allocation (see Exhibit 17). Fixed income, the least volatile asset class, had the largest capital allocation to ensure its equal-risk contribution to the portfolio.

In the 14-year back-tested period, approximately 60% of the capital was allocated to fixed income (mean = 60.0%, median = 62.3%). The remaining 40% of capital was split roughly evenly between equities (mean = 19.8%, median = 18.2%) and commodities (mean = 20.2%, median = 19.7%). The allocations among the three asset classes were stable over time.

…while the remaining 40% was split roughly evenly between equities and commodities.

Exhibit 17: Capital Allocation by Asset Class of the S&P Risk Parity Index – 10% TV



Source: S&P Dow Jones Indices LLC. Data as of May 31, 2018. Chart is provided for illustrative purposes.

RETURN CONTRIBUTION

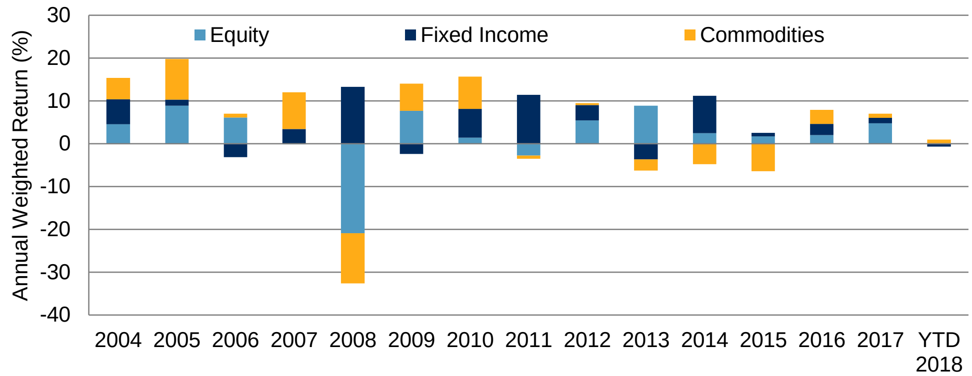
The equal-risk allocation did not lead to equal return contribution.

The historical performance of each asset class shows that the equal-risk allocation did not lead to equal return contribution (see Exhibit 18). Fixed income contributed the highest return to the overall portfolio over the full period studied, as this low volatility asset class has been overweighted in risk parity strategies.

The return decomposition of the S&P Risk Parity Index – 10% TV showed that the return contribution of the three asset classes varied significantly from year to year, due to changes in the performance of individual asset classes and the correlation among them, affecting the overall portfolio performance. In 2008, equity and commodities experienced market drawdown and only fixed income had a positive return. As a result, the overall portfolio posted a loss.

Fixed income contributed the highest return to the overall portfolio over the full period studied…

Exhibit 18: Annual Weighted Return by Asset Class of the S&P Risk Parity Index – 10% TV



ANNUAL RETURN (%)	EQUITY	FIXED INCOME	COMMODITIES
Mean	2.01	3.28	1.15
Median	2.47	2.62	0.93
Maximum	8.91	13.29	9.47
Minimum	-20.94	-3.64	-11.70
Full Period (January 2004 to May 2018)	1.97	3.39	1.10

…as this low volatility asset class has been overweighted in risk parity strategies.

Source: S&P Dow Jones Indices LLC. Data as of May 31, 2018. Past performance is no guarantee of future results. Chart and table are provided for illustrative purposes and reflect hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

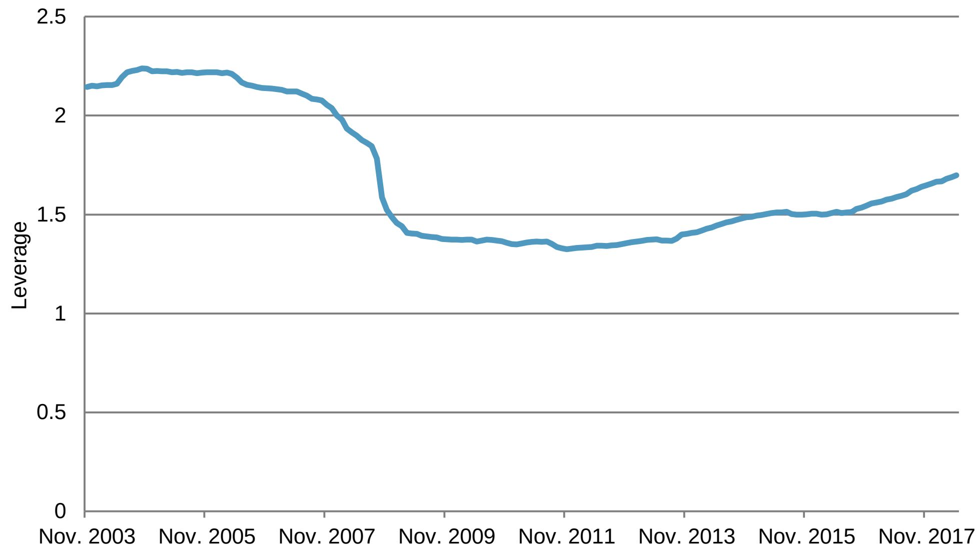
Leverage

Another key feature of risk parity strategies is the application of leverage. According to the capital asset pricing model, long-term asset class returns are generally proportional to the risk taken. Since risk parity portfolios tend to have a higher allocation to asset classes with lower volatility, such as fixed income, fund managers usually use leverage to make the risk contribution the same among the asset classes. The combination of equal-risk contribution and leverage helps the risk parity portfolio to meet the challenges of achieving market returns while reducing the risk of a multi-asset portfolio.

Employing the S&P Risk Parity Index – 10% TV as an example, leverage historically ranged between 1.32 and 2.24 (see Exhibit 19). On average, the portfolio had a leverage of 1.68. As leverage is dependent on the TV percentage, it typically increased in low volatility environments and dropped in high volatility environments. It is expected that leverage would climb higher as the TV increases.

Risk parity strategies aim to build balanced risk portfolios that deliver market-level returns at lower risk…

Exhibit 19: Leverage of the S&P Risk Parity Index – 10% TV



Source: S&P Dow Jones Indices LLC. Data as of May 31, 2018. Chart is provided for illustrative purposes.

…and we have seen that the realized marginal contribution of each asset class to total portfolio risk shows that the index series reflects the objective of equal-risk contribution.

CONCLUSION

Risk parity strategies aim to build balanced risk exposure portfolios that deliver higher risk-adjusted returns than the broad-based market and a traditional 60/40 portfolio. Although the concept is widely accepted, variations in implementation have led to the lack of an appropriate benchmark in the market. Some existing indices use a weighted average of active risk parity fund performance, but these lack transparency and are also subject to survivorship bias.

The S&P Risk Parity Indices aim to serve as a transparent, rules-based passive implementation of risk parity strategies. Data shows that the indices track active risk parity funds much closer than a traditional 60/40 equity/bond portfolio. Additionally, the realized marginal contribution of each asset class to total portfolio risk shows that the index series achieves its objective of equal risk contribution from the underlying asset classes.

ENDNOTES

1. The S&P 500 represented U.S. equities; the S&P Developed Ex.-U.S. BMI represented international equities; the S&P Emerging BMI represented emerging market equities; the Dow Jones U.S. Real Estate Index represented real estate; the Dow Jones Commodity Index represented commodities; the S&P U.S. Treasury Bond Index represented investment-grade bonds from Dec. 31, 1999, to April 30, 2002, and after that, the category was represented by the S&P U.S. Aggregate Bond Index; the S&P U.S. High Yield Corporate Bond Index represented high-yield Bonds, and the S&P Global Developed Sovereign Ex-US Bond Index represented international sovereign bonds.
2. The box and whisker chart summarizes the distribution of the returns of a time series, highlighting the mean and outlier range. What follows is a description of the chart content. The shaded box is the inter-quartile range, which includes all returns between quartile 1 and quartile 3. Inside the box, the "x" represents the mean and the line across the box represents the median. The endpoints of the whisker lines, which extend out below and above the shaded area, are the local minimum and local maximum. The local range signifies that the chart excludes outliers. A data point is considered an outlier if it is greater (less) than quartile 3 (1) plus (minus) 150% times the inter-quartile range distance. The inter-quartile range distance is the distance from quartile 1 to quartile 3.
3. We rebalanced the allocation mixes to their target weights annually at the end of each year.
4. The contribution to portfolio risk for each asset class was determined at the end of each year based on that year's daily returns. Computationally, the marginal contribution of asset i to the portfolio risk is:

$$MC_i = w_i * \sigma_p * \beta_i$$

   Where β_i is defined by:

$$\beta_i = \frac{Cov(\sigma_i, \sigma_p)}{{\sigma_p}^2}$$

5. The portfolio is equally weighted and rebalanced annually at the end of the year.
6. To construct the equal-risk-contribution portfolio, at the beginning of each calendar year, we used the past one year of daily returns and the resulting covariance matrix to compute the marginal contribution to risk for each asset class. We employed an optimizer to determine the final set of weights such that each asset class contributed approximately one-third of the total portfolio volatility, subject to several constraints. We set the target portfolio volatility to be equal to the realized portfolio volatility of the equal-weight portfolio from the prior year, subject to a maximum of 10%. The portfolio is constrained to be long only (no negative weights or shorting). Lastly, using the three-month U.S. Treasury Bill as the borrow cost, leverage was allowed for fixed income. Hence, the total nominal portfolio weight could exceed 100%.
7. The 60/40 equity/bond portfolio was hypothetically constructed by combining the S&P Developed BMI with 60% weight and the S&P Global Developed Aggregate Ex-Collateralized Bond Index with 40% weight, rebalanced monthly.

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APPENDIX A: ASSET CLASS AND THREE-ASSET PORTFOLIO PERFORMANCE

Exhibit A1: Asset Class Performance

PERIOD	EQUITY	FIXED INCOME	COMMODITY
ANNUALIZED RETURN (%)			
1-Year	21.83	3.30	4.36
3-Year	11.41	2.07	-4.07
5-Year	15.79	1.91	-7.94
10-Year	8.50	3.75	-5.09
15-Year	9.92	3.92	3.44
18-Year	6.52	5.84	5.14
ANNUALIZED VOLATILITY (%)			
3-Year	10.07	2.54	13.28
5-Year	9.49	2.55	12.39
10-Year	15.08	3.29	18.02
15-Year	13.26	3.48	16.89
18-Year	14.52	3.61	16.17
RETURN/RISK			
3-Year	1.13	0.81	-0.31
5-Year	1.66	0.75	-0.64
10-Year	0.56	1.14	-0.28
15-Year	0.75	1.13	0.20
18-Year	0.45	1.62	0.32

Source: S&P Dow Jones Indices LLC. Data as of Dec. 29, 2017. Index performance based on monthly total return in USD. The portfolio resets to equal-weights annually at year-end. Past performance is no guarantee of future results. Table is provided for illustrative purposes and reflects hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

APPENDIX B: FUTURES CONTRACTS AND ROLL SCHEDULES

Exhibit B1: Futures Contracts

CATEGORY	CONSTITUENT	EXCHANGE	SECTOR	CURRENCY
COMMODITIES				
Energy	Natural Gas	NYMEX	E	USD
	Heating Oil #2	NYMEX	E	USD
	Gas Oil	ICE	E	USD
	Crude Oil	NYMEX	E	USD
	Brent Crude	ICE	E	USD
	Gasoline	NYMEX	E	USD
Softs & Livestock	Sugar #11	NYBOT	C	USD
	Live Cattle	CME	C	USD
	Coffee "C"	NYBOT	C	USD
	Cotton #2	NYBOT	C	USD
Grains	Soybeans	CBOT	C	USD
	Corn	CBOT	C	USD
	Wheat	CBOT	C	USD
Metals	Copper	NYMEX	C	USD
	Gold (100 oz.)	COMEX	C	USD
	Silver	COMEX	C	USD
FIXED INCOME				
U.S.	T-Notes (10-year)	CBOT	FI	USD
	T-Notes (5-year)	CBOT	FI	USD
	T-Bonds (30-year)	CBOT	FI	USD
Europe	Long Gilt	ICE	FI	GBP
	Euro-Bund	EUREX	FI	EUR
	Euro-Bobl	EUREX	FI	EUR
Asia	JGB (10-year)	TSE	FI	JPY
EQUITY				
U.S.	S&P 500	CME	SI	USD
Europe	Euro Stoxx 50	EUREX	SI	EUR
Asia	Nikkei 225 Futures	OSE	SI	JPY

Source: S&P Dow Jones Indices LLC. Data as of July 2018. Table is provided for illustrative purposes.

Exhibit B2: Schedule of Contract Months

FUTURES CONTRACT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Coffee "C"	H	K	K	N	N	U	U	Z	Z	Z	H	H
Sugar #11	H	K	K	N	N	V	V	V	H	H	H	H
Cotton #2	H	K	K	N	N	Z	Z	Z	Z	Z	H	H
Corn	H	K	K	N	N	U	U	Z	Z	Z	H	H
Soybeans	H	K	K	N	N	X	X	X	X	F	F	H
Live Cattle	J	J	M	M	Q	Q	V	V	Z	Z	G	G
Wheat	H	K	K	N	N	U	U	Z	Z	Z	H	H
Copper	H	K	K	N	N	U	U	Z	Z	Z	H	H
Gold (100 oz.)	J	J	M	M	Q	Q	Z	Z	Z	Z	G	G
Silver	H	K	K	N	N	U	U	Z	Z	Z	H	H
Crude Oil	H	J	K	M	N	Q	U	V	X	Z	F	G
Heating Oil #2	H	J	K	M	N	Q	U	V	X	Z	F	G
Gasoline	H	J	K	M	N	Q	U	V	X	Z	F	G
Natural Gas	H	J	K	M	N	Q	U	V	X	Z	F	G
Gas Oil	H	J	K	M	N	Q	U	V	X	Z	F	G
Brent Crude	J	K	M	N	Q	U	V	X	Z	F	G	H
U.S. T-Notes (10-year)	H	M	M	M	U	U	U	Z	Z	Z	H	H
U.S. T-Bonds (30-year)	H	M	M	M	U	U	U	Z	Z	Z	H	H
U.S. T-Notes (5-year)	H	M	M	M	U	U	U	Z	Z	Z	H	H
Long Gilt	H	M	M	M	U	U	U	Z	Z	Z	H	H
Euro-Bund	H	M	M	M	U	U	U	Z	Z	Z	H	H
Euro-Bobl	H	M	M	M	U	U	U	Z	Z	Z	H	H
JGB (10-year)	H	M	M	M	U	U	U	Z	Z	Z	H	H
S&P 500	H	H	M	M	M	U	U	U	Z	Z	Z	H
Euro Stoxx 50	H	H	M	M	M	U	U	U	Z	Z	Z	H
Nikkei 225 Futures	H	M	M	M	U	U	U	Z	Z	Z	H	H

Source: S&P Dow Jones Indices LLC. Data as of July 2018. Table is provided for illustrative purposes.

Exhibit B3: Contract Month Letter Codes

LETTER	CONTRACT EXPIRATION
F	January
G	February
H	March
J	April
K	May
M	June
N	July
Q	August
U	September
V	October
X	November
Z	December

Source: S&P Dow Jones Indices LLC. Table is provided for illustrative purposes.

APPENDIX C: HISTORICAL PERFORMANCE

Exhibit C1 compares the historical performance of the S&P Risk Parity Indices to the traditional 60/40 equity/bond portfolio over the period from January 2003 to May 2018. There are three key observations. First, the S&P Risk Parity Indices with different volatility targets delivered similar Sharpe and return over maximum drawdown ratios during the period. This was expected, since they are essentially the same portfolio in terms of relative weighting, but with different levels of leverage. Second, the indices had a 37% higher Sharpe ratio and a 45% higher return over maximum drawdown ratio compared with the 60/40 equity/bond portfolio. The material increase in risk-adjusted returns could be driven by the portfolio construction methodology and improved risk diversification. Third, the indices did relatively better in most of the major market shocks (equity or bond) since 2003, including the global financial crisis from 2007-2009, the Europe/Greece debt crisis in 2010, and the downgrade of U.S. debt in 2011.

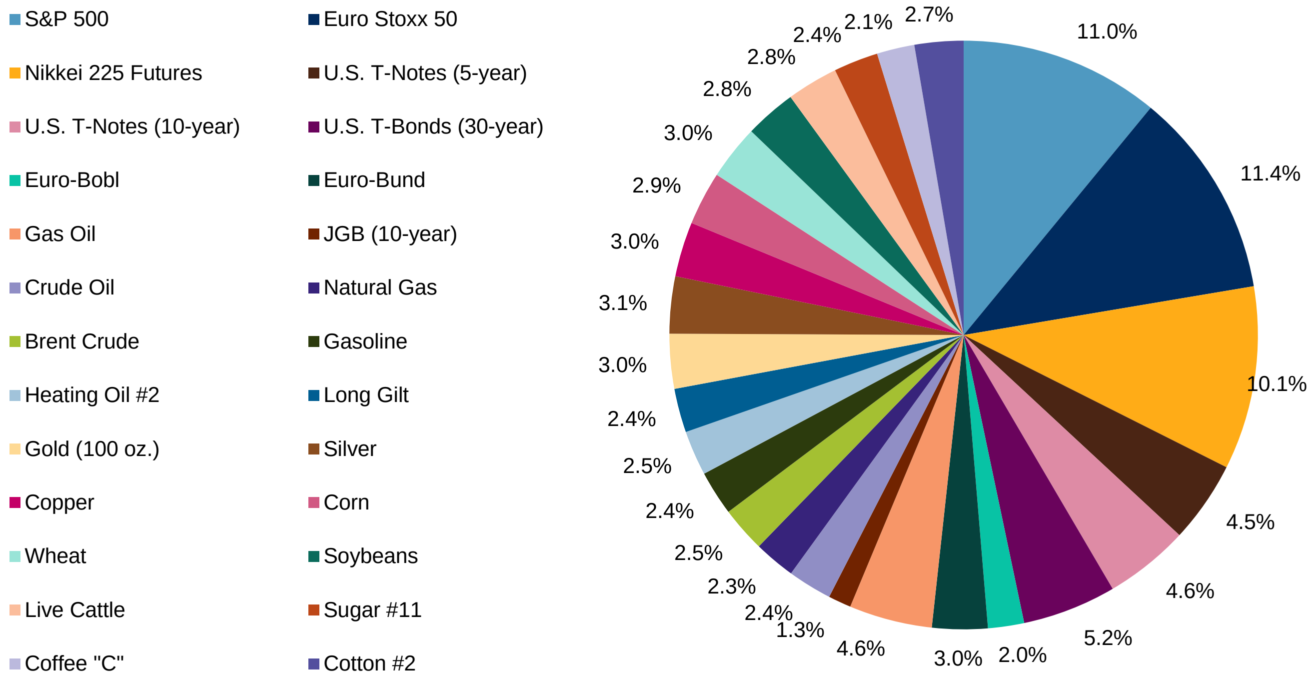
Exhibit C1: Historical Performance of the S&P Risk Parity Indices Versus a 60/40 Equity/Bond Portfolio

METRIC	S&P RISK PARITY INDEX – 10% TV	S&P RISK PARITY INDEX – 12% TV	S&P RISK PARITY INDEX – 15% TV	60/40 EQUITY/BOND PORTFOLIO
Annual Return (%)	7.30	8.52	10.37	6.31
Annual Volatility (%)	8.34	10.03	12.59	9.90
Sharpe Ratio	0.731	0.730	0.729	0.516
Maximum Peak-to-Trough Drawdown (%)	-28.17	-33.19	-40.26	-36.42
Return Over Maximum Drawdown	0.259	0.257	0.258	0.173
CUMULATIVE RETURNS (%) – SELECT PERIODS				
Global Financial Crisis (October 2007-February 2009)	-23.6	-28.3	-34.9	-36.4
Europe/Greece Debt Crisis (March-June 2010)	-24.1	-28.5	-34.8	-26.1
Downgrade of U.S. Debt (August-November 2011)	0.9	1.1	1.3	-7.2
China's Black Monday (May-September 2015)	-1.4	-1.7	-2.2	-2.2
Inflation Fears (January 2018-March 2018)	-6.4	-7.7	-9.6	-7.0

Source: S&P Dow Jones Indices LLC, HFR Index, LLC. Data as of May 31, 2018. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Table is provided for illustrative purposes and reflects hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

APPENDIX D: RISK AND RETURN ATTRIBUTION PER SECURITY

Exhibit D1a: Individual Instrument Risk Attribution



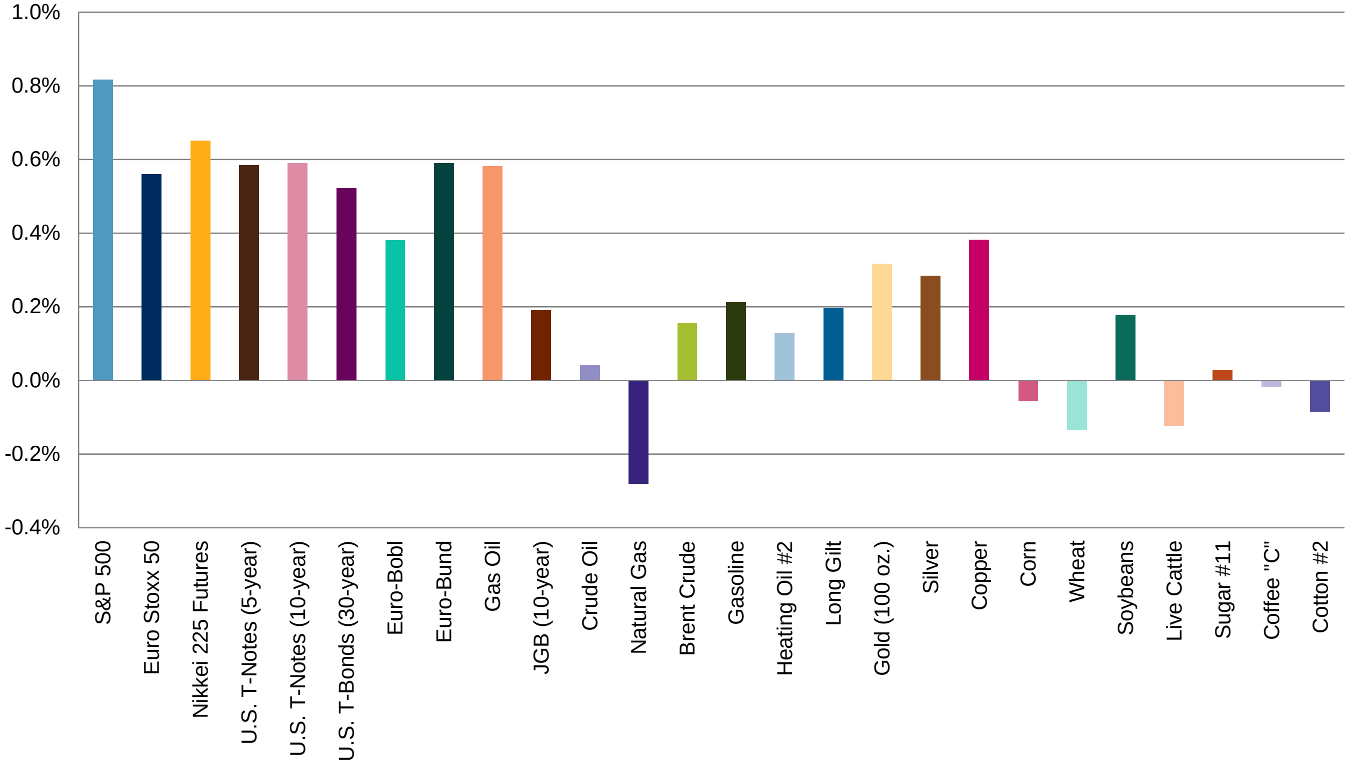
Source: S&P Dow Jones Indices LLC. Data as of May 31, 2018. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Chart is provided for illustrative purposes.

Exhibit D1b: Individual Instrument Risk Attribution

EQUITY	RISK ATTRIBUTION (%)	FIXED INCOME	RISK ATTRIBUTION (%)	COMMODITIES	RISK ATTRIBUTION (%)
S&P 500	3.1	U.S. T-Notes (5-year)	1.3	Natural Gas	0.6
Euro Stoxx 50	3.2	U.S. T-Notes (10-year)	1.3	Heating Oil #2	0.7
Nikkei 225 Futures	2.0	U.S. T-Bonds (30-year)	1.5	Gas Oil	0.7
Total	**7.1**	Long Gilt	1.3	Crude Oil	0.7
		Euro-Bund	0.6	Brent Crude	0.7
		Euro-Bobl	0.9	Gasoline	0.7
		JGB (10-year)	0.4	Sugar #11	0.7
		Total	**5.9**	Live Cattle	0.8
				Coffee “C”	0.6
				Cotton #2	0.8
				Soybeans	0.8
				Corn	0.8
				Wheat	0.8
				Copper	0.9
				Gold (100 oz.)	0.8
				Silver	0.9
				Total	**6.6**

Source: S&P Dow Jones Indices LLC. Data as of May 31, 2018. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Table is provided for illustrative purposes.

Exhibit D2a: Individual Instrument Annualized Return Attribution



Source: S&P Dow Jones Indices LLC. Data as of May 31, 2018. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Chart is provided for illustrative purposes.

Exhibit D2b: Individual Instrument Annualized Return Attribution

EQUITY	RETURN ATTRIBUTION (%)	FIXED INCOME	RETURN ATTRIBUTION (%)	COMMODITIES	RETURN ATTRIBUTION (%)
S&P 500	1.0	U.S. T-Notes (5-year)	0.7	Natural Gas	-0.3
Euro Stoxx 50	0.7	U.S. T-Notes (10-year)	0.7	Heating Oil #2	0.2
Nikkei 225 Futures	0.8	U.S. T-Bonds (30-year)	0.6	Gas Oil	0.3
Total	**2.4**	Long Gilt	0.7	Crude Oil	0.0
		Euro-Bund	0.5	Brent Crude	0.2
		Euro-Bobl	0.7	Gasoline	0.2
		JGB (10-year)	0.2	Sugar #11	0.0
		Total	**4.0**	Live Cattle	-0.2
				Coffee "C"	0.0
				Cotton #2	-0.1
				Soybeans	0.2
				Corn	-0.1
				Wheat	-0.2
				Copper	0.5
				Gold (100 oz.)	0.4
				Silver	0.3
				Total	**1.2**

Source: S&P Dow Jones Indices LLC. Data as of May 31, 2018. Index performance based on monthly total return in USD. Past performance is no guarantee of future results. Table is provided for illustrative purposes.

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Past performance of the Index is not an indication of future results. Prospective application of the methodology used to construct the Index may not result in performance commensurate with the back-test returns shown. The back-test period does not necessarily correspond to the entire available history of the Index. Please refer to the methodology paper for the Index, available at www.spdji.com for more details about the index, including the manner in which it is rebalanced, the timing of such rebalancing, criteria for additions and deletions, as well as all index calculations.

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