INTELLIGENT REBALANCING

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Rob Brown, PhD, CFA

Chief Investment Strategist and OCIO Team Leader, Julex Capital Management, LLC

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Robert A. Brown, PhD, CFA

The rebalancing rule applied to a multi asset class portfolio will have a significant impact on both risk and return. All portfolios managed to a fixed-weight policy asset allocation utilizing non-market cap weights require periodic rebalancing since failure to rebalance drives realized asset weights further and further away from policy with the passage of time. The most common approach to rebalancing adopted by the Registered Investment Advisor, Broker/Dealer, and bank trust department segments of the investment industry is fixed-time, e.g., monthly or quarterly. This article demonstrates that frequent fixed-time rebalancing rules are the most harmful to both risk and return, serving to increase risk and to reduce return. Improvements can be made by rebalancing less frequently. Additional enhancements to both risk and return can be obtained by following rebalancing rules that reflect recent market behaviors, i.e., are path-dependent.

COMMONLY ACCEPTED WISDOM

It is generally accepted by the retail investment advisory industry (a $5 trillion business) that rebalancing adds value and that more rebalancing is better than less (abstracting from transactions costs and taxes). This accepted wisdom has two primary sources. First, it is commonly assumed that deviations between a portfolio's realized asset class weights and its policy asset allocation are sub-optimal and cause the portfolio to less efficiently achieve its intended objectives. For this reason, advisers seek more frequent rebalancing (abstracting from transactions costs and taxes) in order to minimize the size of these deviations. Second, advisers have been trained in, and otherwise exposed to, the concept that markets follow a random walk

and that monthly returns are generated by independent and identically distributed distributions (they are iid). Under such idealized conditions, more frequent rebalancing is always superior to less frequent.

However, markets are not random walks and do not follow independent and identically distributed distributions. Instead, they exhibit strong trending and regression-to-the-mean behaviors. These behavioral attributes drive optimal rebalancing:

- Strongly away from more frequent and towards less frequent and
- Away from fixed-time rules and towards path-dependent rebalancing rules.

This article provides an empirical basis for these observations through an examination of alternate rebalancing rules applied to a multi asset class portfolio examined over the long-term and through a diversity of capital market and macroeconomic environments.

INVESTIGATIVE FRAMEWORK

In order to avoid the empirical results from being unduly influenced by any singular capital market or macroeconomic environment, we selected asset classes for which we could obtain high-quality monthly total returns over a long period of time. The period chosen spanned January 31, 1920 through June 30, 2016, and all data was drawn from the GFD Database provided by Global Financial Data. These restrictions forced us to select asset categories that would not generally comprise a real-world policy asset allocation. Nevertheless, we do not believe that this abstraction in any way harms the specific questions this article attempts to address:

- Does the frequency of rebalancing matter?

- Does the rebalancing rule matter?
- What are the tradeoffs?
- What are the opportunities?
- What might an optimal rule look like?

In fact, we believe that the return patterns inherent in the asset categories selected, well represent the time series properties (trending and regression-to-the-mean) inherent in assets more commonly appearing in policy allocations today. Although the reasons that caused, or underlay, the specific returns upon which this article is based are not expected to repeat themselves, we do believe that the level, volatility, and time series properties of the returns themselves are fully representative of the future. The following high-level weighting rules were employed in the construction of our multi asset class policy; so that it includes:

- Stocks, bonds, cash, and commodities
- An approximate 60/40 stock/bond mix
- A 2/3rds domestic and 1/3 international geographic mix
- Domestic bonds that are allocated evenly between treasuries and corporates
- International bonds that are equally-weighted across the available asset categories
- Twenty distinct asset classes

The resulting policy asset allocation is shown in Exhibit 1.

Exhibit 1

Policy Asset Allocation

U.S. Stocks	
Dow Jones Industrial Average	9.70
S&P 500	9.70
Utilities S&P 500	9.70
Transportation S&P 500	9.70

International Stocks	
United Kingdom FTSE All Share	3.88
France CAC All Tradable	3.88
Australia ASX Accumulation Index All Ordinaries	3.88
Sweden OMX Stockholm	3.88
Germany CDAX	3.88

Commodities	
Reuters CRB Total Return Index (w/GFD extension) *	3.00

U.S. Bonds	
10 Year US Treasury	3.81
30 Year US Treasury	3.81
5 Year US Treasury	3.81
90 Day US Treasury Bills	1.50
Moody's AAA Corporate Long Term Maturity	6.47
Dow Jones Corporate	6.47

International Bonds	
France 10 Year Treasury	3.23
Australia 10 Year Treasury	3.23
Sweden 10 Year Treasury	3.23
Italy 10 Year Treasury	3.23

* After April 1, 2015, the S&P GSCI Total Return Commodity Index was used

Each rebalancing rule is examined by applying this policy mix in combination with the 96+ years of monthly returns. In order to avoid starting point bias, 1,000 years of monthly returns were simulated. This was accomplished by linking the time series end point (6/30/2016) with the time series starting point (1/31/1920) and looping through the series repeatedly to generate 1,000 years of returns. This approach preserves all time series properties, both trending and regression to the mean.

FIXED TIME REBALANCING RULES

The first rebalancing rule examined is fixed time, and Exhibit 2 shows the results. The first column identifies the number of months that must pass between each rebalancing.

Exhibit 2

Fixed Time Interval

Rebalance rule parameter	Return per unit of risk	Return	Risk	Correlation	Drawdown	95th percentile	Rebalance frequency	Superiority frequency
1	0.537	5.84	10.9	1.000	-47.3	-4.26	100.00	na
2	0.555	5.87	10.6	0.978	-46.9	-4.25	50.00	78.9
3	0.564	5.89	10.4	0.969	-47.9	-4.22	33.33	71.2
4	0.568	5.88	10.4	0.963	-46.7	-4.21	25.00	67.4
5	0.577	5.91	10.2	0.958	-47.6	-4.17	20.00	65.7
6	0.579	5.90	10.2	0.956	-47.1	-4.20	16.67	64.3
7	0.583	5.93	10.2	0.955	-46.9	-4.17	14.28	63.7
8	0.591	5.95	10.1	0.949	-46.7	-4.13	12.50	62.8
9	0.588	5.96	10.1	0.952	-46.6	-4.17	11.11	62.2
10	0.596	5.98	10.0	0.947	-45.8	-4.13	10.00	61.8
11	0.599	6.00	10.0	0.946	-45.5	-4.11	9.08	61.4
12	0.601	6.00	10.0	0.945	-46.3	-4.11	8.33	60.7
13	0.607	6.01	9.9	0.937	-46.3	-3.99	7.69	61.0
14	0.606	6.04	10.0	0.944	-46.9	-4.09	7.14	60.3
15	0.612	6.07	9.9	0.938	-45.5	-4.07	6.67	59.9
16	0.613	6.03	9.8	0.938	-44.9	-4.06	6.25	59.5
17	0.615	6.11	9.9	0.938	-45.3	-4.09	5.88	59.7
18	0.610	6.05	9.9	0.940	-44.5	-4.10	5.55	59.1
19	0.618	6.06	9.8	0.935	-44.8	-4.09	5.26	59.0

The remaining eight columns are all based on real, inflation-adjusted returns:

- Return per unit of risk is geometric mean return dividend by annualized standard deviation.
- Return is annualized geometric mean.
- Risk is measured by annualized standard deviation of monthly returns.
- Correlation shows the relationship between the specified rebalancing rule and simple fixed time monthly rebalancing.
- Drawdown is the worst outcome (in real terms) during the 1,000 years of simulated returns (measured peak to trough).

- The 95th percentile is a measure of risk, showing the specific isolated monthly return, such that 95% of the months are higher and 5% are lower.
- Rebalance frequency shows the percentage of the months that the portfolio was rebalanced.
- Superiority frequency shows the percentage of the months that the specified rebalancing rule delivered a monthly return greater than that delivered by simple fixed time monthly rebalancing.

As Exhibit 2 demonstrates, the longer the time period between rebalancings, the higher the return and the lower the risk. Moving from monthly rebalancing to rebalancing once every 19 months increased return per unit of risk by 15.1%.

ABSOLUTE DEVIATIONS FROM POLICY

Among pension plans, endowments, foundations, and the ultra-high net worth, it is not uncommon to apply a different rebalancing rule, one that is based on the absolute size of the deviations from policy. Exhibit 3 provides the results for just such a rebalancing rule. With this rule, the sum of the absolute deviations between the current realized weights and the policy weights is calculated, and, if at month-end, this sum exceeds the percentage shown in the first column of Exhibit 3, then the portfolio is rebalanced. The first row of this exhibit corresponds to simple fixed time monthly rebalancing.

Exhibit 3

Sum of Absolute Deviations

Rebalance rule parameter	Return per unit of risk	Return	Risk	Correlation	Drawdown	95th percentile	Rebalance frequency	Superiority frequency
0	0.537	5.84	10.9	1.000	-47.3	-4.26	100.00	na
1	0.537	5.84	10.9	1.000	-47.3	-4.26	97.98	99.2
2	0.539	5.86	10.9	1.000	-47.2	-4.26	70.41	87.9
3	0.540	5.86	10.9	1.000	-47.0	-4.26	48.32	77.8
4	0.542	5.88	10.9	1.000	-46.9	-4.29	33.44	72.3
4.3	0.545	5.92	10.9	1.000	-46.9	-4.26	31.61	71.6
4.7	0.549	5.95	10.8	1.000	-46.8	-4.26	28.34	69.8
5	0.551	5.98	10.8	1.000	-46.7	-4.27	26.43	69.5
7	0.559	6.07	10.9	0.999	-48.0	-4.23	17.03	67.0
7.5	0.573	6.19	10.8	0.997	-47.4	-4.23	14.96	65.8
8	0.575	6.21	10.8	0.997	-47.4	-4.27	13.67	64.6
9	0.589	5.99	10.2	0.955	-47.5	-4.26	11.20	64.8
10	0.589	5.97	10.1	0.955	-46.3	-4.28	9.63	60.5
10.5	0.594	6.02	10.1	0.947	-46.7	-4.13	8.76	60.9
11	0.598	6.08	10.2	0.954	-46.7	-4.25	8.68	61.2
11.5	0.608	6.17	10.1	0.943	-46.7	-4.26	8.33	61.7
13	0.606	6.19	10.2	0.942	-45.6	-4.16	6.24	60.4
14	0.609	6.26	10.3	0.944	-47.4	-4.13	5.88	60.4
14.5	0.612	6.25	10.2	0.944	-46.7	-4.11	5.64	59.0
14.8	0.617	6.30	10.2	0.943	-45.6	-4.15	5.38	60.3
15	0.605	6.15	10.2	0.942	-45.6	-4.25	5.03	57.8
16	0.592	5.99	10.1	0.940	-45.4	-4.2	3.8	54.9
18	0.601	6.08	10.1	0.940	-44.9	-4.2	3.4	55.9
18.5	0.603	6.11	10.1	0.939	-47.0	-4.2	3.3	56.1
19	0.604	6.09	10.1	0.939	-47.0	-4.1	3.1	55.4
20	0.602	6.13	10.2	0.939	-45.5	-4.2	2.9	56.0
20.5	0.606	6.14	10.1	0.939	-45.1	-4.1	2.9	56.5
20.8	0.611	6.25	10.2	0.941	-46.0	-4.0	2.8	57.9
23	0.621	6.31	10.2	0.937	-46.0	-4.1	2.7	57.6

The focus on absolute policy deviations instead of fixed time is a crude attempt to rebalance only when needed as opposed to blindly on some preset schedule. And although there appears to be a slight improvement in risk per unit of return, the benefit is quite small. An alternative to rebalancing based on simple absolute deviations from policy is provided by Exhibit 4. This exhibit

refines the rebalancing rule to apply greater weight to the larger policy deviations. Specifically, the rule uses the sum of the squared absolute deviations from policy.

Exhibit 4

Sum of Squared Absolute Deviations

Rebalance rule parameter	Return per unit of risk	Return	Risk	Correlation	Drawdown	95th percentile	Rebalance frequency	Superiority frequency
0	0.537	5.84	10.9	1.000	-47.3	-4.26	100.00	na
0.9	0.541	5.88	10.9	1.000	-47.1	-4.26	47.14	78.0
1.6	0.548	5.94	10.8	1.000	-46.9	-4.26	33.66	73.2
3	0.548	5.94	10.8	1.000	-47.2	-4.26	22.56	67.1
5	0.557	6.03	10.8	0.999	-47.1	-4.16	15.87	65.3
6.6	0.562	6.07	10.8	0.999	-47.3	-4.23	13.02	65.2
8.2	0.562	6.08	10.8	0.999	-46.7	-4.25	11.78	64.2
11.5	0.568	6.13	10.8	0.998	-46.3	-4.20	9.00	61.0
13.3	0.571	6.20	10.9	0.996	-45.7	-4.3	7.7	60.3
14.3	0.576	6.27	10.9	0.996	-46.0	-4.3	7.5	61.1
15.6	0.580	6.32	10.9	0.996	-45.6	-4.2	6.8	60.4
15.8	0.585	6.37	10.9	0.995	-45.6	-4.2	6.7	60.4
16.8	0.591	6.43	10.9	0.995	-46.0	-4.2	6.7	61.3
17.4	0.603	6.17	10.2	0.953	-46.0	-4.2	6.5	61.8
18.5	0.610	6.27	10.3	0.953	-46.7	-4.2	6.5	61.3
19.4	0.612	6.22	10.2	0.942	-45.8	-4.1	5.6	58.9
21.5	0.610	6.23	10.2	0.944	-45.5	-4.1	5.1	60.9
22	0.602	6.16	10.2	0.944	-45.5	-4.1	4.9	59.3
25.5	0.597	6.02	10.1	0.941	-45.5	-4.0	3.8	57.2
27	0.613	6.24	10.2	0.940	-44.7	-4.1	4.1	58.5
27.5	0.615	6.26	10.2	0.940	-44.7	-4.1	4.1	58.7
29	0.614	6.15	10.0	0.940	-45.5	-4.0	3.4	56.3
29.5	0.615	6.18	10.0	0.940	-45.5	-4.0	3.4	57.3
30.1	0.615	6.17	10.0	0.940	-45.5	-4.0	3.4	57.3
31.9	0.608	6.17	10.1	0.940	-46.5	-4.0	3.3	56.6
34.1	0.610	6.19	10.1	0.939	-45.5	-4.3	3.1	56.3
35.5	0.615	6.24	10.1	0.939	-45.5	-4.1	3.2	57.2
36	0.619	6.27	10.1	0.939	-45.1	-4.1	3.2	57.1
37	0.623	6.30	10.1	0.939	-45.1	-4.1	3.2	56.8

Once again, a minor improvement in risk adjusted return is achieved.

RELATIVE DEVIATIONS FROM POLICY

Often, institutional investors attempt to refine their rebalancing rules by using relative deviations from policy instead of absolute. Essentially, this entails providing wider bands around those particular asset categories with larger policy weights. Exhibit 5 provides the results of just such an approach. Specially, the portfolio is rebalanced at month-end if the sum of the relative absolute percentage (proportionate) deviations from policy exceeds the number appearing in the first column of this exhibit.

Exhibit 5

Sum of Relative Deviations

Rebalance rule parameter	Return per unit of risk	Return	Risk	Correlation	Drawdown	95th percentile	Rebalance frequency	Superiority frequency
1	0.537	5.84	10.9	1.000	-47.3	-4.26	100.00	na
15	0.537	5.84	10.9	1.000	-47.3	-4.26	99.75	99.9
35	0.538	5.85	10.9	1.000	-47.2	-4.26	79.75	91.8
60	0.540	5.86	10.9	1.000	-47.1	-4.26	49.93	78.5
70	0.542	5.88	10.9	1.000	-47.0	-4.28	42.23	76.9
95	0.545	5.91	10.8	1.000	-47.0	-4.26	29.11	70.5
105	0.548	5.95	10.8	1.000	-46.7	-4.27	25.75	68.4
120	0.551	5.98	10.9	0.999	-47.3	-4.27	21.33	66.1
140	0.556	6.02	10.8	0.999	-47.4	-4.24	18.35	68.1
150	0.559	6.05	10.8	0.999	-47.4	-4.25	15.75	65.5
160	0.565	6.12	10.8	0.998	-46.8	-4.27	14.98	65.3
175	0.571	6.18	10.8	0.997	-46.9	-4.25	13.23	65.4
190	0.583	5.95	10.2	0.956	-47.3	-4.28	11.03	63.1
210	0.587	6.33	10.8	0.995	-46.7	-4.23	9.56	62.5
220	0.592	6.03	10.2	0.956	-46.3	-4.16	8.87	61.7
240	0.593	6.43	10.8	0.995	-46.1	-4.21	8.41	62.5
260	0.606	6.18	10.2	0.942	-47.1	-4.17	7.10	60.6
275	0.610	6.22	10.2	0.942	-47.1	-4.11	6.33	60.5
281	0.605	6.09	10.1	0.942	-47.2	-4.1	5.8	61.2
287	0.600	6.03	10.1	0.942	-46.6	-4.1	5.4	58.7
310	0.596	5.97	10.0	0.941	-46.5	-4.0	4.4	56.4
325	0.600	6.11	10.2	0.943	-45.8	-4.2	4.5	56.8
340	0.598	6.01	10.0	0.940	-46.9	-4.1	3.8	55.4
385	0.612	6.18	10.1	0.940	-45.5	-4.2	3.5	57.7
420	0.619	6.24	10.1	0.939	-44.4	-4.2	3.1	55.1
430	0.624	6.29	10.1	0.938	-44.4	-4.1	3.1	55.7
435	0.626	6.32	10.1	0.938	-44.5	-4.1	3.1	56.7
455	0.621	6.36	10.2	0.938	-46.0	-4.1	2.9	56.4
470	0.627	6.42	10.2	0.940	-42.7	-4.1	2.9	56.4

Once again, this more refined approach appears to provide a slight (although quite minor) improvement in return per unit of risk. Many institutions attempted to further refine this approach by giving greater emphasis to the larger relative deviations. Exhibit 6 provides the

results of such an approach by applying a rebalancing rule based on the sum of the squared relative percentage deviations from policy.

Exhibit 6

Sum of Squared Relative Deviations

Rebalance rule parameter	Return per unit of risk	Return	Risk	Correlation	Drawdown	95th percentile	Rebalance frequency	Superiority frequency
1	0.537	5.84	10.9	1.000	-47.3	-4.26	100.00	na
375	0.542	5.88	10.9	1.000	-47.0	-4.28	45.03	78.0
700	0.546	5.92	10.9	1.000	-46.8	-4.26	30.73	70.8
1200	0.548	5.94	10.8	1.000	-47.3	-4.18	22.07	67.8
1600	0.553	6.00	10.8	0.999	-46.8	-4.20	18.48	66.9
2200	0.557	6.02	10.8	0.999	-46.2	-4.27	14.89	63.4
2700	0.558	6.03	10.8	0.999	-46.2	-4.28	12.65	62.5
3500	0.557	6.08	10.9	0.998	-47.4	-4.24	10.48	62.1
4100	0.563	6.13	10.9	0.998	-45.5	-4.23	9.53	61.4
4700	0.563	6.14	10.9	0.998	-47.3	-4.24	9.00	61.4
5600	0.567	6.17	10.9	0.997	-46.6	-4.21	7.88	61.0
6500.0	0.568	6.19	10.9	1.0	-45.8	-4.2	6.9	60.3
7000.0	0.569	6.16	10.8	1.0	-45.0	-4.2	6.6	60.8
7500.0	0.572	6.15	10.7	1.0	-45.3	-4.2	6.0	57.5
8000.0	0.575	6.20	10.8	1.0	-45.0	-4.2	5.8	58.8
8400.0	0.581	6.29	10.8	1.0	-45.6	-4.2	5.4	59.4
9000.0	0.583	6.29	10.8	1.0	-44.5	-4.2	5.1	59.7
10300.0	0.575	5.85	10.2	1.0	-45.1	-4.2	4.1	56.8
10500.0	0.587	5.96	10.2	1.0	-45.1	-4.1	4.1	57.4
11000.0	0.597	6.38	10.7	1.0	-45.5	-4.1	4.3	58.2
11500.0	0.608	6.56	10.8	1.0	-46.0	-4.1	4.2	57.6
11800.0	0.617	6.65	10.8	1.0	-46.0	-4.1	4.3	59.4
11810.0	0.617	6.65	10.8	1.0	-46.0	-4.1	4.3	59.4
12200.0	0.611	6.26	10.2	1.0	-45.1	-4.2	3.8	57.1
12500.0	0.610	6.25	10.2	0.9	-45.1	-4.1	3.7	56.7
13400.0	0.612	6.64	10.8	1.0	-46.0	-4.0	3.7	58.7
14000.0	0.617	6.32	10.2	0.9	-45.3	-4.0	3.4	57.4
14600.0	0.625	6.35	10.2	0.9	-42.8	-4.1	3.3	56.8
15000.0	0.629	6.37	10.1	0.9	-43.2	-4.0	3.2	56.1

As before, the use of squared relative deviations provides a slight improvement in return per unit of risk. It would appear that institutional investor's use of more refined rebalancing rules, reflective of deviations from policy, are directionally correct. Simple monthly rebalancing delivered a return per unit of risk of 0.537. Moving to fixed time rebalancing, once every nineteen months, improved this ratio to 0.618. But by applying squared relative deviations from policy, we improved the ratio to 0.629 (a 17.1% improvement over the base case of simple monthly rebalancing).

PATH-DEPENDENT MARKET BASED RULES

The rules examined so far ignore path dependency and focus instead solely on fixed time or policy mix deviations. This last section examines a series of three alternate path-dependent rebalancing rules (based on recent market behaviors). Exhibit 7 provides the first of these. Specifically, if the annualized standard deviation of the portfolio's last eleven months of nominal returns exceeds the level specified in the first column of Exhibit 7, then the portfolio is rebalanced. As with each of the prior tables, the first row of Exhibit 7 provides the results for rebalancing once every month, the simple fixed time rule.

Exhibit 7

Standard Deviation of Portfolio Returns over last 11 Months

Rebalance rule parameter	Return per unit of risk	Return	Risk	Correlation	Drawdown	95th percentile	Rebalance frequency	Superiority frequency
0	0.537	5.84	10.9	1.000	-47.3	-4.26	99.92	na
5	0.539	5.87	10.9	1.000	-47.3	-4.26	85.61	94.3
7	0.544	5.95	10.9	0.999	-47.3	-4.28	58.93	82.3
8	0.554	6.08	11.0	0.998	-47.3	-4.28	46.18	77.5
9	0.558	6.20	11.1	0.996	-47.3	-4.47	36.29	72.4
10	0.598	6.32	10.6	0.936	-47.3	-4.39	27.85	68.6
10.5	0.593	6.28	10.6	0.935	-47.3	-4.39	24.83	67.2
11	0.588	6.19	10.5	0.935	-47.6	-4.32	21.21	64.1
11.4	0.584	6.20	10.6	0.932	-47.7	-4.40	18.37	63.4
11.6	0.587	6.22	10.6	0.932	-47.5	-4.32	17.33	63.2
11.8	0.610	6.46	10.6	0.932	-47.5	-4.32	16.19	63.1
11.9	0.613	6.47	10.6	0.931	-47.4	-4.26	15.70	61.8
12	0.620	6.50	10.5	0.930	-45.6	-4.26	14.89	61.4
12.05	0.621	6.50	10.5	0.930	-45.6	-4.26	14.31	61.5
12.1	0.621	6.50	10.5	0.930	-45.6	-4.26	14.23	61.5
12.15	0.621	6.50	10.5	0.930	-45.6	-4.26	14.05	61.4

Although this path-dependent rebalancing rule appears to provide no benefit in terms of return per unit of risk, it does offer a different attractive benefit. The far right column (Superiority frequency) shows how often this rebalancing rule outperforms simple monthly rebalancing. Consider the fourth row, i.e., rebalancing if the portfolio's standard deviation exceeds 8.00%. Under this rebalancing rule, return increases from 5.84% to 6.08%, a 4.1% improvement. Risk remains approximately constant. But, most interesting, the percentage of the months that this strategy outperforms simple monthly rebalancing climbs to a high of 77.5%.

A further refinement to this rebalancing rule, while still based on path dependency appears in Exhibit 8. Here, the portfolio is rebalanced at month-end if the portfolio's nominal return over the last ten months was greater than the percentage shown in the first column.

Exhibit 8

Portfolio Return over last 10 Months

Rebalance rule parameter	Return per unit of risk	Return	Risk	Correlation	Drawdown	95th percentile	Rebalance frequency	Superiority frequency
-99	0.537	5.84	10.9	1.000	-47.3	-4.26	99.93	na
0	0.611	5.78	9.5	0.939	-35.8	-3.91	80.33	91.2
5	0.633	5.86	9.3	0.929	-32.5	-3.86	62.43	80.9
6	0.636	5.87	9.2	0.929	-32.5	-3.86	58.29	79.1
7	0.642	5.90	9.2	0.928	-33.4	-3.79	53.36	78.1
8	0.643	5.90	9.2	0.927	-33.5	-3.75	47.94	75.2
9	0.638	5.85	9.2	0.927	-33.5	-3.69	43.91	72.6
10	0.638	5.85	9.2	0.927	-33.5	-3.69	40.38	71.3
11	0.639	5.85	9.2	0.927	-32.7	-3.79	35.97	69.6
12	0.640	5.85	9.2	0.926	-32.7	-3.82	30.99	67.2
13	0.634	5.82	9.2	0.926	-32.7	-3.83	26.93	65.0
13.5	0.637	5.85	9.2	0.926	-32.5	-3.83	25.13	63.6
14	0.632	5.81	9.2	0.926	-32.7	-3.83	23.58	62.9
14.5	0.639	5.77	9.0	0.924	-32.7	-3.83	22.12	62.9
15	0.637	5.78	9.1	0.923	-32.7	-3.83	20.32	61.0
15.5	0.640	5.78	9.0	0.923	-32.7	-3.83	18.77	61.2
15.8	0.639	5.78	9.0	0.923	-32.7	-3.83	17.29	60.4
16	0.640	5.80	9.1	0.923	-32.7	-3.83	16.43	60.4
16.2	0.640	5.81	9.1	0.922	-31.6	-3.88	16.08	59.4
16.5	0.642	5.83	9.1	0.922	-31.6	-3.88	15.13	59.3
17	0.642	5.83	9.1	0.922	-31.6	-3.88	13.48	58.9
17.5	0.640	5.82	9.1	0.922	-31.6	-3.88	12.28	58.0
18	0.645	5.88	9.1	0.920	-31.6	-3.86	10.80	57.6
18.25	0.646	5.88	9.1	0.920	-31.6	-3.86	10.21	57.4
18.5	0.646	5.89	9.1	0.920	-31.6	-3.86	9.87	57.3
18.75	0.645	5.88	9.1	0.920	-31.6	-3.86	9.52	57.3
19	0.654	5.95	9.1	0.916	-31.6	-3.86	9.09	57.7

The results from such a rebalancing rule are somewhat startling and well demonstrate the potential power of a path dependent rebalancing rule. Return increases from 5.84% to 5.95%, a 1.9% increase, and risk falls from 10.9% to 9.1%, a 16.5% decrease. This results in a 21.8% improvement in return per unit of risk.

TACTICAL ASSET ALLOCATION REBALANCING RULE

We conclude with a rebalancing rule more commonly found among tactical asset allocation managers. It is based on a thirteen month moving average. Specifically, the portfolio is rebalanced at month-end if the current value of the portfolio is more than X% above its average nominal value over the most recent thirteen months. The first column of Exhibit 9 shows the value for X%.

Exhibit 9

Portfolio Value Relative to Average Value over last 13 Months

Rebalance rule parameter	Return per unit of risk	Return	Risk	Correlation	Drawdown	95th percentile	Rebalance frequency	Superiority frequency
-99	0.537	5.84	10.9	1.000	-47.3	-4.26	99.90	na
0	0.609	5.72	9.4	0.938	-36.3	-3.94	79.69	90.7
2	0.624	5.78	9.3	0.929	-33.2	-3.86	68.66	84.9
4	0.625	5.76	9.2	0.929	-33.5	-3.86	54.52	78.4
5.5	0.633	5.81	9.2	0.928	-32.7	-3.84	43.32	72.2
6	0.628	5.77	9.2	0.928	-32.7	-3.86	39.27	70.1
6.5	0.638	5.84	9.2	0.925	-32.5	-3.86	34.54	68.0
7	0.647	5.81	9.0	0.922	-32.5	-3.83	31.64	67.0
7.5	0.641	5.79	9.0	0.924	-32.5	-3.82	27.67	65.3
8	0.649	5.85	9.0	0.921	-32.5	-3.82	24.23	64.1
8.5	0.639	5.76	9.0	0.920	-32.5	-3.83	20.07	60.9
9	0.648	5.86	9.0	0.919	-32.5	-3.83	17.15	59.9
9.25	0.644	5.84	9.1	0.918	-32.5	-3.86	16.22	58.9
9.5	0.649	5.89	9.1	0.918	-32.5	-3.86	15.05	58.8
9.75	0.650	5.91	9.1	0.918	-32.5	-3.86	13.93	58.4
10	0.654	5.94	9.1	0.916	-31.6	-3.86	12.79	57.7
10.1	0.654	5.94	9.1	0.916	-31.6	-3.86	12.18	57.7
10.15	0.653	5.93	9.1	0.916	-31.6	-3.86	12.09	57.4
10.2	0.654	5.94	9.1	0.916	-31.6	-3.86	11.84	57.5
10.25	0.655	5.96	9.1	0.916	-31.6	-4.02	11.58	57.4
10.3	0.655	5.96	9.1	0.916	-31.6	-4.02	11.22	57.3
10.35	0.655	5.96	9.1	0.916	-31.6	-4.02	11.22	57.3
10.4	0.655	5.96	9.1	0.916	-31.6	-4.02	11.13	57.3
10.425	0.656	5.97	9.1	0.916	-31.6	-4.02	11.04	57.3
10.45	0.657	5.98	9.1	0.916	-31.6	-4.02	10.96	57.3

This final rule generates a best in class return per unit of risk of 0.657, which is a 22.3% improvement over the 0.537 delivered by simple monthly rebalancing.

SUMMARY - ALTERNATE REBALANCING RULES

Rebalancing rules fall into three main categories: fixed time, deviations from policy, and path dependency. Exhibits 2 through 9 demonstrate three key results:

- First, rebalancing less frequently was generally superior to more frequently. Doing so both enhanced return and reduced risk.
- Second, rules based on deviations from policy have generally offered higher levels of return per unit of risk than have fixed time rules.
- Third, path-dependent rules provided the best return per unit of risk.

However, depending on one's objective, one type of rule might be superior to another. Exhibit 10 provides a telling summary of the results.

Exhibit 10

Superior Rebalancing Rules

Portfolio property	Rule for rebalancing	Return per unit of risk	Return	Risk	Correlation	Drawdown	95th percentile	Rebalance frequency	Superiority frequency
Rebalance once every month	Reblance every month	0.537	5.84	10.9	1.000	-47.3	-4.26	100.00	100.0
Highest return per unit of risk	Portfolio value is above 13 month moving average > 10.45%	0.657	5.98	9.1	0.916	-31.6	-4.02	10.96	57.3
Highest return (without taking on more risk)	Sum squared relative differences from policy > 11,800%	0.617	6.65	10.8	0.991	-46.0	-4.09	4.33	59.4
Lowest risk (without scraficing any return)	Portfolio value is above 13 month moving average > 8%	0.649	5.85	9.0	0.921	-32.5	-3.82	24.23	64.1
Highest frequency of outperforming (but still adding at least 20bps annually and not taking on additional risk)	Standard deviation of 11 months of portfolio returns > 8%	0.554	6.08	11.0	0.998	-47.3	-4.28	46.18	77.5

Depending on the goal, highest return per unit of risk, highest return, lowest risk, or greatest frequency of outperformance (relative to simple monthly rebalancing), a different rebalancing rule might have been selected.

PRACTICAL APPLICATIONS

The results presented in Exhibits 2 through 9 are specific only to the particular multi asset class policy asset mix and timeframe examined herein. They do not identify what the best approach might be for a different policy asset allocation. However, several powerful policy conclusions can be drawn:

- More frequent rebalancing is generally harmful to both risk and return than less frequent rebalancing,
- Fix time period rebalancing based on time intervals as short as monthly or as long as once every twelve months are easily improved upon,
- Fix time period rules are generally myopic and readily improved upon, no matter the frequency between rebalances,
- Deviation from policy rules such as the sum of the squared relative differences from policy may be highly attractive for certain objectives and certain policy allocations,
- Path dependent rules such as deviations from the portfolio's moving average or recent volatility of the portfolio may provide beneficial results above those based on fixed time periods or deviations from policy, and
- The contribution from a well-reasoned approach to rebalancing and a rejection of simple fixed time methods is likely to have a major positive impact on both risk and return.

Clearly, the Registered Investment Adviser, Broker/Dealer, and trust department advisory industry would be well suited by moving away from fixed time interval rebalancing rules. As demonstrated by the empirical results presented above, the potential contributions to both return enhancement and risk mitigation are sizable and readily attainable.