Best practices for portfolio rebalancing

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- The primary goal of a rebalancing strategy is to minimise risk relative to a target asset allocation, rather than to maximise returns. Over time, asset classes produce different returns that can change the portfolio's asset allocation. To recapture the portfolio's original risk-and-return characteristics, the portfolio should therefore be rebalanced.

- In theory, investors select a rebalancing strategy that weighs their willingness to assume risk against expected returns net of the cost of rebalancing. Vanguard research has found that there is no optimal frequency or threshold for rebalancing, since risk-adjusted returns do not differ meaningfully from one rebalancing strategy to another.

- As a result, we conclude that for most broadly diversified equity and bond fund portfolios (assuming reasonable expectations regarding return patterns, average returns, and risk), annual or semi-annual monitoring, with rebalancing at 5% thresholds, is likely to produce a reasonable balance between risk control and cost minimisation for most investors. Annual rebalancing is likely to be preferred when taxes or substantial time/costs are involved.

Return data for Figures 2, 3, 5, 6, and 8 of this paper are based on the following equity and bond benchmarks, as applicable: Equities are represented by the Standard & Poor's 90 from 1926 through 3 March 1957; the S&P 500 Index from 4 March 1957, through 1969; the MSCI World Index from 1970 through 1987; the MSCI All Country (AC) World Index from 1988 through 31 May 1994; and the MSCI AC World IMI Index from 1 June 1994, through 2014. Bonds are represented by the S&P High Grade Corporate Index from 1926 through 1968; the Citigroup High Grade Index from 1969 through 1972; the Lehman Long-Term AA Corporate Index from 1973 through 1975; the Barclays U.S. Aggregate Bond Index from 1976 through 1989; and the Barclays Global Aggregate Bond Index (USD hedged) from 1990 through 2014. Except as noted, the portfolios are weighted 50% equities/50% bonds.

Notes on asset-return distributions and risk

The asset-return distributions shown here represent Vanguard's view on the potential range of risk premiums that may occur over the next ten years; such long-term projections are not intended to be extrapolated into a short-term view. These potential outcomes for long-term investment returns are generated by the Vanguard Capital Markets Model™ (VCMM — see the description in Appendix I) and reflect the collective perspective of our Investment Strategy Group. The expected risk premiums — and the uncertainty surrounding those expectations — are among a number of qualitative and quantitative inputs used in Vanguard's investment methodology and portfolio-construction process.

All investing is subject to risk, including the possible loss of the money you invest. Diversification does not ensure a profit or protect against a loss in a declining market. There is no guarantee that any particular asset allocation or mix of funds will meet your investment objectives or provide you with a given level of income.

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Vanguard believes that the asset allocation decision — which takes into account each investor's risk tolerance, time horizon, and financial goals — is the most important decision in the portfolio-construction process. This is because asset allocation is the major determinant of risk and return for a given portfolio.[1] Over time, however, as a portfolio's investments produce different returns, the portfolio will likely drift from its target asset allocation, acquiring risk-and-return characteristics that may be inconsistent with an investor's goals and preferences. By periodically rebalancing, investors can diminish the tendency for "portfolio drift", and thus potentially reduce their exposure to risk relative to their target asset allocation.

As part of the portfolio-construction process, it's important for investors to develop a rebalancing strategy that formally addresses "how often, how far, and how much": that is, how frequently the portfolio should be monitored; how far an asset allocation can be allowed to deviate from its target before it is rebalanced; and whether periodic rebalancing should restore a portfolio to its target or to a close approximation of the target. Although each of these decisions has an impact on a portfolio's risk-and-return characteristics, the differences in risk-adjusted returns among the strategies are not very significant. Thus, the how often, how far, and how much are mostly questions of investor preference. The only clear advantage for any of these strategies, so far as maintaining a portfolio's risk-and-return characteristics, and without factoring in rebalancing costs, is that a rebalanced portfolio more closely aligns with the characteristics of the target asset allocation than a portfolio that is never rebalanced.

Costs of rebalancing

Throughout this paper, the term *costs of rebalancing* refers to:

- **Taxes (if applicable):** If rebalancing within taxable registrations, capital gains taxes may be due upon the sale if the asset sold has appreciated in value.

- **Transaction costs to execute and process the trades:** For individual securities and exchange-traded funds (ETFs), the costs are likely to include brokerage commissions and bid-ask spreads.[2] For mutual funds, costs may include purchase or redemption fees.

- **Time and labour costs to compute the rebalancing amount:** These costs are incurred either by the investor directly or by a professional investment manager. The costs may include administrative costs and management fees, if a professional manager is hired.

Keep in mind that in addition to these costs, there may be trading restrictions that could limit the frequency of transacting on the accounts. Finally, since there is little difference in the results between the frequencies analysed, these costs should be considered when selecting a rebalancing strategy.

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1 See Brinson, Hood, and Beebower (1986); Brinson, Singer, and Beebower (1991); Ibbotson and Kaplan (2000); Davis, Kinniry, and Sheay (2007), and Wallick et al. (2012).

2 The bid-ask spread is the difference between the highest price a buyer is willing to pay for an asset and the lowest price a seller is willing to accept for it.

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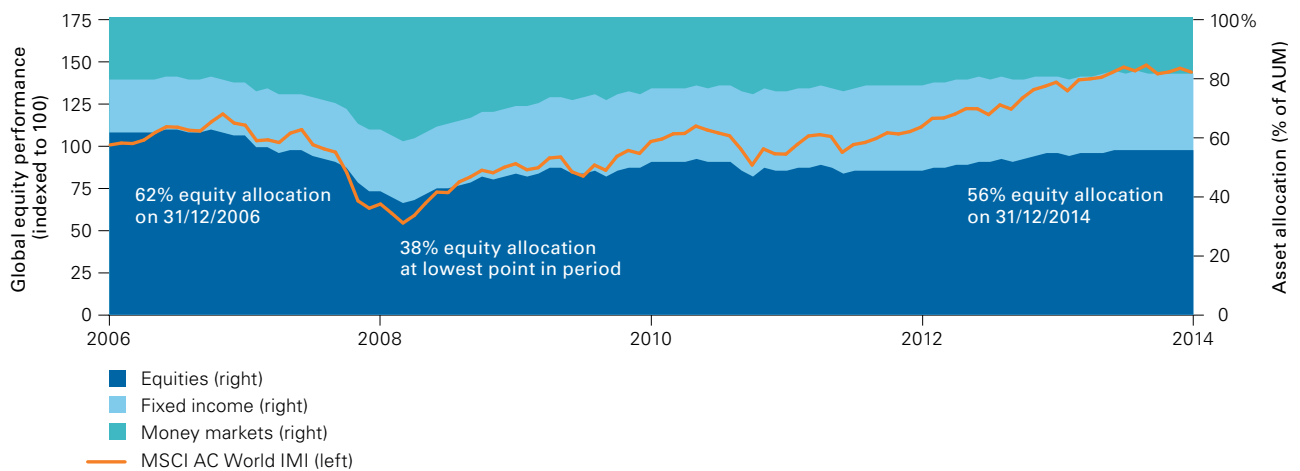## For many investors, rebalancing can be difficult

Rebalancing can be an emotional decision for many investors. After a prolonged period of the equity bull market, with global equities up nearly 200% since 9 March 2009 (according to Morningstar, Inc., as at 31 December 2014), rebalancing may seem counterintuitive: It involves selling the outperforming assets (equities) and reallocating to the lagging ones (bonds). This may seem especially trying to some investors, given the current low interest rates on bonds and their low expected returns in the near future. The situation is typical in periods of prolonged one-directional markets, and was also the case when Vanguard first published the original research for this paper in 2010, shortly after the global equity markets lost nearly –60%. In fact, when looking at total assets under management in the mutual fund industry globally from 2006 through 2014, there is some evidence that investors may not readily embrace rebalancing. **Figure 1** shows that the number of assets under management during those years for equity, fixed income, and money market funds tended to drift based on market

performance (for example, the equity allocation declined from 62% to 38% and then increased again to 56%, in line with the equity market's performance during the period). This suggests that investors in aggregate may not rebalance, since rebalancing would have shown a relatively more stable asset mix for the entire period.

Benefit of rebalancing

Many investors spend substantial time defining their investment goals and selecting an asset allocation to help them achieve those goals, while also being mindful of their tolerance for risk. To be successful, however, they must be able to stick with their plan in all kinds of markets. Due to the equity risk premium, over long time horizons, the equity portion of the portfolio will likely grow faster than the bond portion, exposing a larger portion of the portfolio to potential equity market corrections. These corrections can lead investors to abandon their investment plan, possibly jeopardising their chances of meeting their financial goals. By rebalancing the portfolio and bringing the risk level back

Figure 1. Global assets under management in open-end mutual funds and ETFs: 2006 through 2014

Notes: Global equity performance represented by MSCI AC World IMI, year-end 2006 through year-end 2014. AUM = assets under management.
Sources: Vanguard, based on data from Morningstar, Inc.
Past performance is no guarantee of future returns.

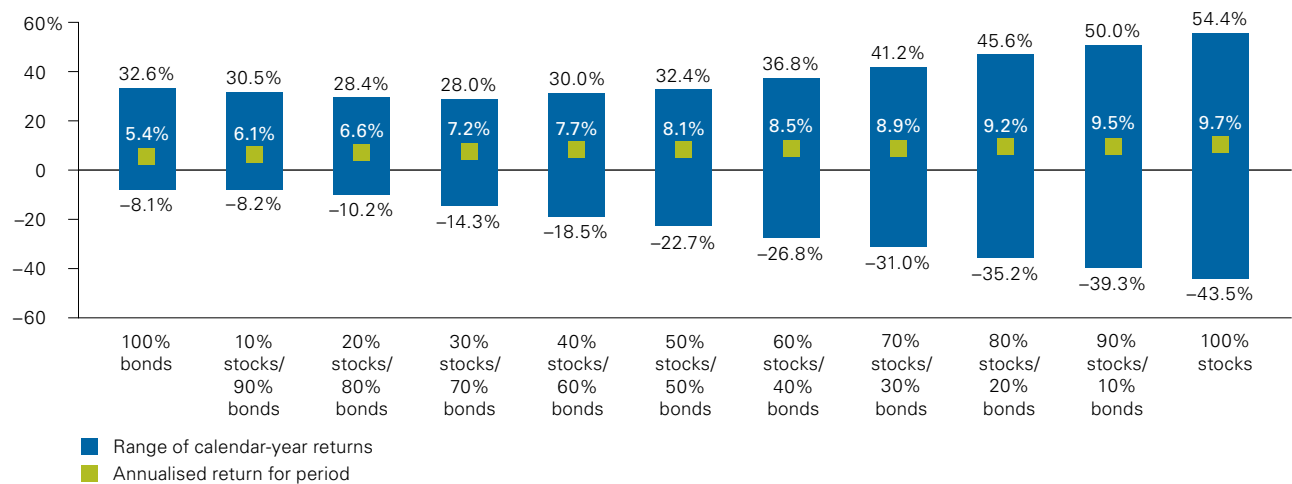**For Professional Investors as defined under the MiFID Directive only.**

to an acceptable level, investors are more likely to stick to their plan, endure market downturns, and be in a better position to meet their long-term financial goals within their investment time horizon.

Given the equity risk premium, it's important to keep in mind that the primary benefit of portfolio rebalancing is to maintain the risk profile of an investment portfolio over time, rather than maximise returns. In fact, if a given investor's portfolio can potentially hold either equities or bonds, and the sole objective is to maximise return regardless of risk, then that investor should select a 100% equity portfolio.[3] Equities have historically outperformed bonds over long time horizons; the trade-off is increased volatility. **Figure 2** shows the historical return distributions for various balanced portfolios, moving from 100% bonds on the left-hand side of the figure to an all-equity portfolio on the right, in 10% increments. As expected, Figure 2 bears out that portfolios with larger allocations to equities have a much wider *variability* of annual returns

(both positive and negative) as well as higher *average* annualised returns to compensate for the additional risk. Because investors select an asset allocation based on the level of risk they are willing to bear, those who choose to include bonds must also accept the fact that they will likely receive a lower return on their portfolio over the long term, compared with an all-equity portfolio.

Similar to the selection of a portfolio's target asset allocation, a rebalancing strategy involves a trade-off between risk and return. As we discussed, the more risk an investor is willing to assume, the higher the expected return over the long term (the equity risk premium). If a portfolio is never rebalanced, it tends to gradually drift from its target asset allocation as the weight of higher-return, higher-risk assets increases. Compared with the target allocation, the portfolio's expected return increases, as does its vulnerability to deviations from the return of the target asset allocation.

Figure 2. Distribution of calendar-year returns: 1926 through 2014

Sources: Vanguard calculations, based on data from FactSet.
Past performance is no guarantee of future returns.

To illustrate this, we compared two hypothetical portfolios, each with a target asset allocation of 50% global equities/50% global bonds for the period 1926 through 2014; the first portfolio was rebalanced annually, and the second portfolio was never rebalanced (see Figure 3). As the figure shows, and consistent with the risk-premium theory, the never-rebalanced portfolio's equity allocation gradually drifted upward, to a maximum of 97%, and was 81% on average for the period. As the never-rebalanced portfolio's equity exposure increased, the portfolio displayed higher risk (a standard deviation of 13.2%, versus 9.9% for the rebalanced portfolio) and a higher average annualised return (8.9% versus 8.1%, respectively).

Figure 3. Comparing a hypothetical 50% global equities/ 50% global bonds annually rebalanced portfolio versus a 50%/50% never-rebalanced portfolio: 1926 through 2014

	Annually rebalanced	Never-rebalanced
Maximum equity weighting	60%	97%
Minimum equity weighting	35%	27%
Average equity weighting	51%	81%
Final equity weighting	49%	97%
Average annualised return	8.1%	8.9%
Annualised volatility	9.9%	13.2%

Notes: This illustration is hypothetical and does not represent the returns of any particular investment. We assumed a portfolio of 50% global equities/50% global bonds. All returns in nominal US dollars. For benchmark data, see box on page 2. There were no new contributions or withdrawals. Dividend payments were reinvested in equities; interest payments were reinvested in bonds. There were no costs. All statistics were annualised.

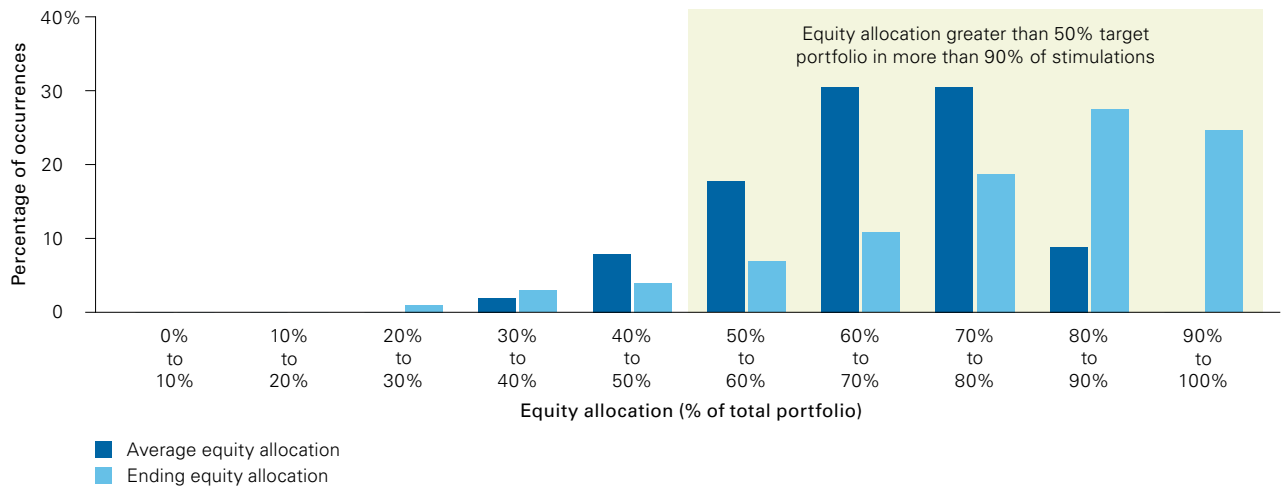Sources: Vanguard calculations, based on data from FactSet. Equity weightings rounded to nearest whole number.

Given that the equity risk premium is expected to continue in the future, we also performed the analysis on a forward-looking basis, using the Vanguard Capital Markets Model (VCMM) to simulate 10,000 potential scenarios for global balanced portfolios (see Figure 4).[4] As expected, in most of our simulations (more than 70%), a nonrebalanced 50% equities/50% bonds portfolio resulted in 30-year returns that were greater than those of an annually rebalanced 50%/50% portfolio. The median return of the drift portfolio was 7.6%, compared to the median rebalanced portfolio return of 7.1%. However, nearly 70% of the higher return simulations came with additional volatility. For comparison, the median volatility of the drift portfolios was 11.9%, compared to the median rebalanced portfolio volatility of 9.2%. The higher returns and volatility were driven by the growing equity allocations through time.

Figure 4 shows the distribution of the average equity allocation for our 10,000 simulations, as well as their ending portfolio weights. Although the average and ending equity allocations varied greatly, the majority of each was above 50%. In fact, in more than 90% of our scenarios, both the average and ending equity allocations were above the starting 50% target, and in 25% of cases they ended above the 90% allocation.

When faced with the decision to rebalance, investors may not realise that by not rebalancing they could be exposing their portfolio to a much higher level of risk than they had intended or were willing to assume in their target portfolio. This is particularly important, because not only does the equity exposure increase relative to investors' targets, but as they approach their investment goal, or time horizon, their risk tolerance may be decreasing, magnifying their relative risk exposure even further.

4 For further details, readers are also referred to Vanguard research titled *Vanguard Global Capital Markets Model* (Davis et al., 2014).

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Figure 4. Distribution of average and ending equity allocations for a nonrebalanced 50%/50% portfolio over 30 years (Vanguard projections)

Important note: The projections or other information generated by the VCMM regarding the likelihood of various investment outcomes are hypothetical in nature, do not reflect actual investment results, and are not guarantees of future results. Distribution of return outcomes from the VCMM is derived from 10,000 simulations for each modelled asset class. Simulations as at 31 December 2014. Results from the model may vary with each use and over time. For more information, see Appendix I.
Source: Vanguard Capital Markets Model.

Selecting a rebalancing strategy

A rebalancing strategy measures risk and return relative to the performance of a target asset allocation (Leland, 1999; Pliska and Suzuki, 2004). The decisions that can ultimately determine whether a portfolio's actual performance is in line with the portfolio's target asset allocation include how frequently the portfolio is monitored; the degree of deviation from the target asset allocation that triggers a rebalancing event; and whether a portfolio is rebanced to its target or to a close approximation of the target.

First we address ways an investor can determine when to trigger a rebalancing event. Although various triggers can be used, we focus primarily on three: "time-only", "threshold-only", and "time-and-threshold". The decision as to which rebalancing strategy to implement largely depends on the investor's risk tolerance, the

correlation of the portfolio's assets, and the costs involved in rebalancing. We analysed the historical results of each of these strategies for the period 1926 through 2014. In each case, we assumed a portfolio consisting of 50% global equities/50% global bonds that was rebalanced according to the strategy under consideration.[5]

Strategy #1: 'Time-only'

When using the "time-only" strategy, the portfolio is rebalanced at a predetermined time interval — daily, monthly, quarterly, annually, and so on. As the strategy's name implies, the only variable taken into consideration is time, regardless of how much or how little the portfolio's asset allocation has drifted from its target.

The data in **Figure 5** compare hypothetical results for the time-only rebalancing strategy using several different frequencies: monthly, quarterly, annually, and never.[6] The figure assumes that each portfolio is rebalanced at the predetermined interval, regardless of the magnitude of deviation from the target asset allocation. As the figure shows, changing the rebalancing frequency from monthly to quarterly to annually did not meaningfully change the portfolio average equity allocations, average annualised returns, or volatilities. However, a significant difference does exist between the results of portfolios that were rebalanced and the never-rebalanced portfolio. The never-rebalanced portfolio drifted to an average equity allocation of about 81%, which significantly increased the volatility to 13.2%, compared to that of about 10% for the monthly, quarterly, and annually rebalanced portfolios. Deciding which frequency to choose comes down to costs. The number of rebalancing events was significantly higher with more frequent rebalancing — 1,068 for a monthly rebalanced portfolio, versus 88 for one rebalanced annually; the former would obviously result in higher trading costs.

Figure 5. Comparing hypothetical portfolio rebalancing results for 'time-only' strategy: Various frequencies, 1926 through 2014

Monitoring frequency	Monthly	Quarterly	Annually	Never
Threshold	0%	0%	0%	NA
Average equity allocation	50.1%	50.2%	50.6%	80.6%
Costs of rebalancing				
Annual turnover	2.6%	2.2%	1.7%	0.0%
Number of rebalancing events	1,068	355	88	0
Absolute framework				
Average annualised return	8.0%	8.2%	8.1%	8.9%
Annualised volatility	10.1%	10.1%	9.9%	13.2%

Notes: This illustration is hypothetical and does not represent the returns of any particular investment. We assumed a portfolio of 50% global equities/50% global bonds. All returns in nominal US dollars. For benchmark data, see box on page 2. There were no new contributions or withdrawals. Dividend payments were reinvested in equities; interest payments were reinvested in bonds. There were no costs. All statistics were annualised.

Sources: Vanguard calculations, based on data from FactSet.

Strategy #2: 'Threshold-only'

We next compare the "threshold-only" strategy, which ignores the time aspect of rebalancing. Investors following this strategy rebalance the portfolio only when the portfolio's asset allocation has drifted from the target asset allocation by a predetermined minimum rebalancing threshold such as 1%, 5%, or 10%, regardless of the frequency. The rebalancing events could be as frequent as daily or as infrequent as every five years, depending on the portfolio's performance relative to its target asset allocation.

To analyse the impact of threshold-only rebalancing strategies, we conducted a historical analysis for rebalancing thresholds of 1%, 5%, and 10%, assuming *daily* monitoring, which is required with this strategy to determine each rebalancing event. If the hypothetical portfolio's allocation drifted beyond the threshold on any given day, it would be rebalanced back to the target allocation. Due to the limited availability of daily data (and therefore lack of comparability to the other figures in the body of this paper), the details of the analysis are included in Appendix II (see **Figure A-1**).

Again with this strategy, the magnitude of the differences in the average equity allocation, average annual return, and annualised volatility may not warrant the additional costs associated with a 0% threshold (8,826 rebalancing events) versus a 10% threshold (6 rebalancing events). The primary drawback to the threshold-only strategy is that it requires daily monitoring, which investors can either perform themselves or pay an adviser to do for them (ultimately lowering the portfolio's total return because of the additional cost). The preferred strategy depends primarily on investor preference.

Strategy #3: 'Time-and-threshold'

The final strategy analysed, "time-and-threshold", calls for rebalancing the portfolio on a scheduled basis (e.g. monthly, quarterly, or annually), but only if the portfolio's asset allocation has drifted from its target asset allocation by a predetermined minimum rebalancing threshold such as 1%, 5%, or 10%. If, as at the scheduled rebalancing date, the portfolio's deviation from the target asset allocation is less than the predetermined threshold, the portfolio will not be

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6 Although daily rebalancing is certainly an option, we excluded this option from our analysis in Figure 5 because of the limited availability of daily return data.

rebalanced. Likewise, if the portfolio's asset allocation drifts by the minimum threshold or more at any *intermediate* time interval, the portfolio will not be rebalanced at that time.

To analyse the impact of time-and-threshold rebalancing strategies, we conducted a historical analysis over the period 1926 through 2014 on the performance of several hypothetical portfolios. As **Figure 6** demonstrates, there were no meaningful differences in the average equity allocations, returns, or volatilities among the various combinations of both time and threshold for the rebalanced portfolios, similar to our findings for the other rebalancing strategies. Average equity allocations for all rebalanced strategies were in a tight range of 50.1% to 52.4%, with returns and volatility differences that were relatively insignificant. Once again, costs played a larger part than other factors in the time-and-threshold decision. A rebalancing strategy that included monthly monitoring and a 1% threshold was more costly to implement (423 rebalancing events) than one that included annual monitoring and 10% rebalancing thresholds (19 rebalancing events). (Again, we note that the never-

rebalanced portfolio drifted to an average equity allocation of nearly 81%, significantly increasing its volatility to 13.2%, compared with a volatility of about 10% for the rebalanced portfolios.)

Although this simulation implies that portfolios that are rebalanced more frequently track the target asset allocation more closely, it also suggests that the cost of rebalancing may place upper limits on the optimal number of rebalancing events. Transaction costs and taxes (when applicable) detract from the portfolio's return, potentially undermining the risk-control benefits of some rebalancing strategies. In our simulation, the number of rebalancing events and the annual turnover were proxies for costs, with actual costs depending on a portfolio's unique transaction costs and taxes.

After taking into consideration reasonable expectations for return patterns, average returns, and risk, we concluded that for most broadly diversified equity and bond portfolios, annual or semi-annual monitoring, with rebalancing at 5% thresholds, produced a reasonable balance between risk control and cost minimisation.

Figure 6. Comparing portfolio rebalancing results for 'time-and-threshold' strategy: Various frequencies and thresholds, 1926 through 2014

Monitoring frequency	Monthly				Quarterly			Annually			Never
Threshold	0%	1%	5%	10%	1%	5%	10%	1%	5%	10%	NA
Average equity allocation	50.1%	50.1%	51.2%	52.2%	50.2%	50.9%	51.0%	50.6%	51.2%	52.4%	80.6%
Costs of rebalancing											
Annual turnover	2.6%	2.3%	1.6%	1.3%	2.1%	1.5%	1.2%	1.7%	1.6%	1.5%	0.0%
Number of rebalancing events	1,068	423	64	24	227	50	22	79	36	19	0
Absolute framework											
Average annualised return	8.0%	8.0%	8.1%	8.3%	8.2%	8.3%	8.3%	8.1%	8.2%	8.3%	8.9%
Annualised volatility	10.1%	10.1%	10.1%	10.2%	10.1%	10.2%	10.1%	9.9%	9.8%	10.0%	13.2%

Notes: This illustration is hypothetical and does not represent the returns of any particular investment. We assumed a portfolio of 50% global equities/50% global bonds. All returns in nominal US dollars. For benchmark data, see box on page 2. There were no new contributions or withdrawals. Dividend payments were reinvested in equities; interest payments were reinvested in bonds. There were no costs. All statistics were annualised.
Sources: Vanguard calculations, based on data from FactSet.

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There are two important qualifications to this conclusion. First, this analysis assumed that some approximation of the equity and bond markets' historical return patterns, average returns, volatility, and low-return correlation can be expected to persist in the future. Second, we assumed that a portfolio holds a broadly diversified group of liquid assets with readily available market prices.[7]

Implementing a rebalancing strategy

In translating this conceptual rebalancing framework (summarised in **Figure 7**) into practical strategies, it's important to recognise two real-world limitations to the framework's assumptions. First, conventional wisdom among financial practitioners suggests that investor preferences may be less precise than theory assumes. Investors' target asset allocations are typically flexible within 5% to 10% ranges, indicating that they are mostly indifferent to small risk-or-return deviations. Second, some costs of rebalancing — time, labour, and market impact — are difficult to quantify. Such costs are often included indirectly in advisory fees or reflected as

trading restrictions, making it difficult to explicitly consider rebalancing costs. Several practical strategies discussed next aim to capture the risk-control benefits illustrated by our theoretical framework while minimising the costs of rebalancing.

Rebalance with portfolio cash flows. Rebalancing a portfolio with dividends, interest payments, realised capital gains, or new contributions can help investors both exercise risk control and trim the costs of rebalancing. Typically, investors can accomplish this by sweeping their taxable portfolio cash flows into a money market or bank account and then redirecting these flows to the most underweighted asset class as part of their scheduled rebalancing event.[8]

Figure 8 illustrates how dividend and interest payments can be used to reduce potential rebalancing costs for several hypothetical portfolios. The "Redirecting income" column shows a 50% equity/50% bond portfolio that was rebalanced by investing the portfolio's dividend and interest payments in the underweighted asset class from 1926 through

Figure 7. Summary of various rebalancing strategies

Rebalancing strategy	Trigger	Key considerations
1. Time-only	Based on set time schedule, such as daily, monthly, quarterly, annually, etc.	Only variable taken into consideration is time.
		Disregards how much, or how little, the portfolio's asset allocation has drifted from its target.
2. Threshold-only	Target asset allocation deviates by a predetermined minimum percentage, such as 1%, 5%, 10%, etc.	Only variable taken into consideration is asset allocation.
		Disregards the frequency of rebalancing events.
		Requires daily monitoring to determine if rebalancing is needed.
3. Time-and-threshold	Based on set time schedule, but only rebalances if the target asset allocation deviates by a predetermined amount, such as 1%, 5%, 10%, etc.	Both frequency and drift from target allocation are considered. If portfolio drifts by the minimum threshold or more at any intermediate time frequency, the portfolio will not be rebalanced at that time.

Source: Vanguard.

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7 A concentrated or aggressive, actively managed portfolio of equities and bonds may also behave differently from our illustrated examples. Such portfolios tend to be more volatile than broadly diversified equity and bond portfolios, requiring more frequent rebalancing to maintain similar risk control relative to the target asset allocation.

8 The sweep process just described can improve the after-tax return of the portfolio at the margin; however, investors should weigh the time and effort required against the potential increased returns.

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2014. An investor who had simply redirected his or her portfolio's income would have achieved most of the risk-control benefits of more labour and transaction-intensive rebalancing strategies at a much lower cost.

For example, a portfolio that was monitored monthly and rebalanced at 5% thresholds had 64 rebalancing events and annual portfolio turnover of 1.6% (see Figure 8). The portfolio that was rebalanced by simply redirecting income had no rebalancing events and portfolio turnover of 0%. For taxable investors, using income to rebalance means no securities (or funds) need to be sold, and therefore no capital-gains or income taxes are paid, resulting in a strategy that is very tax-efficient. The differences in risk among the various rebalancing strategies were very modest.

One caution: The high levels of dividends and interest rates during this 89-year period may not be available in the future. An effective approach independent of the level of dividends and bond yields is to use portfolio contributions and withdrawals to rebalance the portfolio.

However, the potential tax consequences of these transactions may require more customised rebalancing strategies.

Rebalance to target asset allocation or some intermediate asset allocation. Finally, the decision to rebalance either to the target asset allocation or to some intermediate allocation (an allocation short of the target allocation) depends primarily on the type of rebalancing costs. When trading costs are mainly fixed and independent of the size of the trade — the cost of time, for example — rebalancing to the target allocation is optimal because it reduces the need for further transactions. On the other hand, when trading costs are mainly proportional to the size of the trade — as in commissions or taxes, for example — rebalancing to the closest rebalancing boundary is preferred, minimising the size of the transaction. If both types of costs exist, the preferred strategy is to rebalance to some intermediate point.

Figure 8. Impact of rebalancing with portfolio cash flows: 1926 through 2014

Monitoring frequency	Monthly	Monthly	Quarterly	Annually	Never	Redirecting income
Threshold	0%	5%	5%	5%	NA	NA
Average equity allocation	50.1%	51.2%	50.9%	51.2%	80.6%	53.3%
Costs of rebalancing						
Annual turnover	2.6%	1.6%	1.5%	1.6%	0.0%	0.0%
Number of rebalancing events	1,068	64	50	36	0	0
Absolute framework						
Average annualised return	8.0%	8.1%	8.3%	8.2%	8.9%	8.1%
Annualised volatility	10.1%	10.1%	10.2%	9.8%	13.2%	9.7%

Notes: This illustration is hypothetical and does not represent the returns of any particular investment. We assumed a portfolio of 50% global equities/50% global bonds. All returns are in nominal US dollars. For benchmark data, see box on page 2. There were no new contributions or withdrawals. Except in the "Redirecting income" column, dividend payments were reinvested in equities; interest payments were reinvested in bonds. The "Redirecting income" column shows a 50% equity/50% bond portfolio that was rebalanced by investing the portfolio's dividend and interest payments in the underweighted asset class from 1926 through 2014. There were no costs. All statistics were annualised.

Sources: Vanguard calculations, based on data from FactSet.

Conclusion

Just as there is no universally optimal asset allocation, there is no universally optimal rebalancing strategy. The only clear advantage so far as maintaining a portfolio's risk-and-return characteristics is that a rebalanced portfolio more closely aligns with the characteristics of the target asset allocation than with a never-rebalanced portfolio. As our analysis has shown, the risk-adjusted returns are not meaningfully different whether a portfolio is rebalanced monthly, quarterly, or annually; however, the number of rebalancing events and resulting costs increase significantly. As a result, we conclude that a rebalancing strategy based on reasonable monitoring frequencies (such as annual or semi-annual) and reasonable allocation thresholds (variations of 5% or so) is likely to provide sufficient risk control relative to the target asset allocation for most portfolios with broadly diversified equity and bond holdings, without creating too many rebalancing events over the long term.

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Appendix I. About the Vanguard Capital Markets Model

IMPORTANT: The projections or other information generated by the Vanguard Capital Markets Model regarding the likelihood of various investment outcomes are hypothetical in nature, do not reflect actual investment results, and are not guarantees of future results. VCMM results will vary with each use and over time.

The VCMM projections are based on a statistical analysis of historical data. Future returns may behave differently from the historical patterns captured in the VCMM. More important, the VCMM may be underestimating extreme negative scenarios unobserved in the historical period on which the model estimation is based.

The Vanguard Capital Markets Model is a proprietary financial simulation tool developed and maintained by Vanguard's Investment Strategy Group. The model forecasts distributions of future returns for a wide array of broad asset classes. Those asset classes include US and non-US equity markets, several maturities of the US Treasury and corporate fixed income markets, non-US fixed income markets, US money markets, commodities, and certain alternative investment strategies. The theoretical and empirical foundation for the Vanguard Capital Markets Model is that the returns of various asset classes reflect the compensation investors require for bearing different types of systematic risk (beta). At the core of the model are estimates of the dynamic statistical relationship between risk factors and asset returns, obtained from statistical analysis based on available monthly financial and economic data from as early as 1960. Using a system of estimated equations, the model then applies a Monte Carlo simulation method to project the estimated interrelationships among risk factors and asset classes as well as uncertainty and randomness over time. The model generates a large set of simulated outcomes for each asset class over several time horizons. Forecasts are obtained by computing measures of central tendency in these simulations. Results produced by the tool will vary with each use and over time.

The primary value of the VCMM is in its application to analysing potential client portfolios. VCMM asset-class forecasts — comprising distributions of expected returns, volatilities, and correlations — are key to the evaluation of potential downside risks, various risk–return trade-offs, and diversification benefits of various asset classes. Although central tendencies are generated in any return distribution, Vanguard stresses that focusing on the full range of potential outcomes for the assets considered, such as the data presented in this paper, is the most effective way to use VCMM output.

The VCMM seeks to represent the uncertainty in the forecast by generating a wide range of potential outcomes. It is important to recognise that the VCMM does not impose "normality" on the return distributions, but rather is influenced by the so-called fat tails and skewness in the empirical distribution of modelled asset-class returns. Within the range of outcomes, individual experiences can be quite different, underscoring the varied nature of potential future paths. Indeed, this is a key reason why we approach asset-return outlooks in a distributional framework.

Index simulations

The long-term returns of our hypothetical portfolios are based on data for the appropriate market indices through December 2014. We chose these benchmarks to provide the most complete history possible, and we apportioned the global allocations to align with Vanguard's guidance in constructing diversified portfolios. Asset classes and their representative forecast indices are as follows:

- **US equities:** MSCI US Broad Market Index.
- **Global ex-US equities:** MSCI All Country World ex USA Index.
- **US REITs:** FTSE/NAREIT US Real Estate Index.
- **Commodity futures:** Bloomberg Commodity Index in USD.
- **US cash:** U.S. 3-Month Treasury–constant maturity.
- **US Treasury index:** Barclays U.S. Treasury Bond Index.
- **US credit bonds:** Barclays U.S. Credit Bond Index.
- **US high-yield corporates:** Barclays U.S. High Yield Corporate Bond Index.
- **US bonds:** Barclays U.S. Aggregate Bond Index.
- **Global ex-US bonds:** Barclays Global Aggregate ex-USD Bond Index.
- **US TIPS:** Barclays U.S. Treasury Inflation Protected Securities Index.
- **US short-term Treasury index:** Barclays U.S. 1–5 Year Treasury Bond Index.
- **US long-term Treasury index:** Barclays U.S. Long Treasury Bond Index.

Appendix II. 'Threshold-only' rebalancing analysis

To analyse the impact of "threshold-only" rebalancing strategies, we conducted a historical analysis for minimum rebalancing thresholds of 0%, 1%, 5%, and 10%, assuming daily monitoring of a hypothetical 50% equity/50% bond portfolio. If the portfolio's allocation drifted beyond the rebalancing threshold on any given day, it would be rebalanced back to the target allocation.

As shown in **Figure A-1**, the portfolio that is rebalanced daily with no threshold over the period 1980 through 2014 had an average equity allocation of 50.0% (and an average annualised return of +9.5%), whereas the portfolio that was monitored on a daily basis with a 10% threshold had an average equity allocation of 52.8% (and an average return of +9.6%).

Once again, the magnitude of the differences in the average equity allocation, the average annualised return, and the volatility may not warrant the additional costs associated with a 0% threshold (8,826 rebalancing events) versus a 10% threshold (6 rebalancing events). The chosen strategy depends primarily on investor preference.

Appendix **Figures A-2, A-3,** and **A-4** have been included for comparison purposes and are based on data from 1980 through 2014.

Limited availability of daily return data

It is important to note that the average *annualised* returns for the 50% equity/50% bond portfolio in Figure A-1, which incorporates *daily* returns, are higher than those of tables in the body of this paper, owing to the fact that the returns here are based on the period 1980 through 2014, whereas all the other returns in the paper (except where noted) are based on data from 1926 through 2014. *The shorter time period was necessitated due to the limited availability of reliable daily data.* Accompanying this appendix are comparable tables for monthly, quarterly, and annual rebalancing statistics for the period 1980 through 2014. These tables have been added for comparison purposes. We believe that incorporating the longer time series provides more valuable insight and have only included the 1980 through 2014 results because of the limited availability of daily returns.

Figure A-1. Comparing daily portfolio rebalancing results for 'threshold-only' strategy: Various thresholds, 1980 through 2014

Monitoring frequency	Daily	Daily	Daily	Daily	Never
Threshold	0%	1%	5%	10%	NA
Average equity allocation	50.0%	50.1%	50.5%	52.8%	63.6%
Costs of rebalancing					
Annual turnover	8.3%	5.5%	2.4%	1.6%	0.0%
Number of rebalancing events	8,826	414	23	6	0
Absolute framework					
Average annualised return	9.5%	9.6%	9.6%	9.6%	9.5%
Annualised volatility	7.7%	7.7%	7.7%	7.9%	10.5%

Notes: This illustration is hypothetical and does not represent the returns of any particular investment. We assumed a portfolio of 50% global equities/50% global bonds. All returns in nominal US dollars. Equities represented by Russell 3000 Index, 1980 through 1985; FTSE World Index, 1986 through 1993; FTSE All-World Index, 1994 through
11 September 2003; FTSE Global All Cap Index thereafter through 2014. Bonds represented by Thomson Reuters U.S. All Lives Government Total Market Index, 1980 through 1988; Barclays U.S. Aggregate Bond Index, 1989 through 31 May 2000; and Barclays Global Aggregate Bond Index (USD hedged) thereafter through 2014. There were no new contributions or withdrawals. Dividend payments were reinvested in equities; interest payments were reinvested in bonds. There were no costs. All statistics were annualised.
Sources: Vanguard calculations, based on data from FactSet.

Figure A-2. Comparing monthly portfolio rebalancing results for 'time-and-threshold' strategy:
Various thresholds, 1980 through 2014

Monitoring frequency	Monthly	Monthly	Monthly	Monthly	Never
Threshold	0%	1%	5%	10%	NA
Average equity allocation	50.1%	50.1%	50.6%	52.8%	63.6%
Costs of rebalancing					
Annual turnover	4.5%	3.8%	2.5%	1.7%	0.0%
Number of rebalancing events	420	159	21	6	0
Absolute framework					
Average annualised return	9.6%	9.6%	9.7%	9.6%	9.5%
Annualised volatility	8.6%	8.6%	8.6%	8.9%	10.5%

Figure A-3. Comparing quarterly portfolio rebalancing results for 'time-and-threshold' strategy:
Various thresholds, 1980 through 2014

Monitoring frequency	Quarterly	Quarterly	Quarterly	Quarterly	Never
Threshold	0%	1%	5%	10%	NA
Average equity allocation	50.2%	50.2%	51.0%	51.3%	63.6%
Costs of rebalancing					
Annual turnover	3.5%	3.3%	2.2%	1.9%	0.0%
Number of rebalancing events	139	82	16	6	0
Absolute framework					
Average annualised return	9.6%	9.6%	9.7%	9.8%	9.5%
Annualised volatility	8.6%	8.6%	8.7%	8.7%	10.5%

Figure A-4. Comparing annual portfolio rebalancing results for 'time-and-threshold' strategy:
Various thresholds, 1980 through 2014

Monitoring frequency	Annually	Annually	Annually	Annually	Never
Threshold	0%	1%	5%	10%	NA
Average equity allocation	50.4%	50.5%	50.6%	52.3%	63.6%
Costs of rebalancing					
Annual turnover	2.6%	2.5%	2.2%	0.8%	0.0%
Number of rebalancing events	34	31	12	3	0
Absolute framework					
Average annualised return	9.7%	9.7%	9.7%	9.6%	9.5%
Annualised volatility	8.6%	8.6%	8.7%	8.9%	10.5%

Notes for appendix Figures A-2, A-3, and A-4: These illustrations are hypothetical and do not represent the returns of any particular investment. We assumed a portfolio of 50% global equities/ 50% global bonds. All returns in nominal US dollars. Equities represented by Russell 3000 Index, 1980 through 1985; FTSE World Index, 1986 through 1993; FTSE All-World Index, 1994 through 11 September 2003; FTSE Global All Cap Index thereafter through 2014. Bonds represented by Thomson Reuters U.S. All Lives Government Total Market Index, 1980 through 1988; Barclays U.S. Aggregate Bond Index, 1989 through 31 May 2000; and Barclays Global Aggregate Bond Index (USD hedged) thereafter through 2014. There were no new contributions or withdrawals. Dividend payments were reinvested in equities; interest payments were reinvested in bonds. There were no costs. All statistics were annualised.

Sources for appendix Figures A-2, A-3, and A-4: Vanguard calculations, based on data from FactSet.

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