IS PORTFOLIO REBALANCING GOOD FOR INVESTORS?

by

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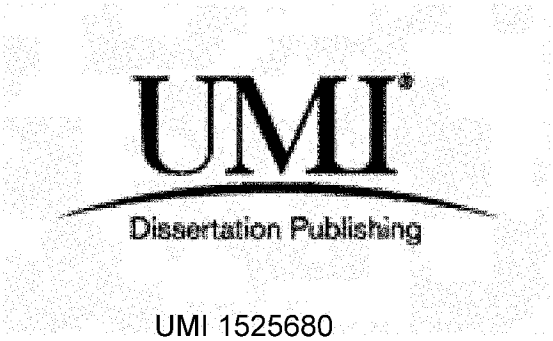

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ABSTRACT

Our study seeks to examine the value of various portfolio rebalancing strategies using historical data for 20-years period for U.S. which includes business cycles – expansion and contractions, our study is based on hypothetical of portfolio asset allocations – 60/40 (stock fund), 50/50 (balanced fund), and 40/60 (bond fund). We combine both periodic rebalancing (daily, monthly, quarterly, semi-annually, annually, 2^{nd}-yearly, 3^{rd}-yearly, 4^{th}-yearly, and 5^{th}-yearly) and threshold rebalancing (0%, 5%, 10%, 15%, 20%, 25%, and 30%) in our study. We investigate for the whole 20-years period contraction and expansion periods. In the 20-years period, our findings show that: a) rebalancing strategies improve return of a portfolio as compared with buy-and-hold strategy, b) the rebalancing strategies results is slightly lower risk than buy-and-hold strategy, c) periodic rebalancing leads to better risk-return outcome than buy-and-hold strategy, and d) portfolio rebalancing based on certain threshold choice perform better buy-and-hold strategy in the long run. Based on the results of the study, we recommend the optimal rebalancing strategy for investors to be threshold rebalancing 25 percent/annually or 30 percent/annually. In addition, our results also indicate that the returns of rebalancing strategies during business cycles perform better than buy-and-hold strategy. However, the difference in portfolio performance of various rebalancing strategies vis-à-vis buy and hold strategy is not substantial to warrant a definitive recommendation of a particular portfolio rebalancing strategy.

Key words: Portfolio rebalancing; Business cycle

JEL classification: C61, C63, G11

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GLOSSARY

BAH – Buy and hold

DAF – Dimensional Fund Advisors

DJIA - Dow Jones Industrial Average

GDP – Gross Domestic Product

MPT – Modern Portfolio Theory

MSCI – Morgan Stanley Capital International

MSCI EAFE – MSCI of Europe, Australasia, and Far East

MSCI EM - Morgan Stanley Capital International Emerging Markets

NASDAQ – National Association of Securities Dealers Automated Quotations

NASDAQ NM – NASDAQ National Market System

NYSE – New York Stock Exchange

NYSE Amex – NYSE American Stock Exchange

NYSE Arca – previously known as ArcaEx, an abbreviation of Archipelago Exchange

REIT – Real Estate Investment Trusts

S&P 500 – Standard & Poor 500

U.S. – United States

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Chapter I

INTRODUCTION

Markowitz (1952) portfolio selection model is the cornerstone of modern portfolio theory. It is based on expected return and variance of financial assets and hence named mean-variance framework. Markowitz model provides rationale of asset allocation. But the dynamic part of the investment decision is the portfolio monitoring strategy including guidelines for rebalancing the portfolio when market conditions change (O'Brien, 2006). Portfolio rebalancing is undertaken not only by institutional investors like insurance/ pension funds, but also by retail investor's indirectly as they hold bulk of institutional investors assets (Ameriks and Zeldes, 2004; Brunnermeier and Nagel, 2008; Calvet *et al.*, 2009). Financial theory suggests a wide range of motives for portfolio rebalancing: one of the widely reported rationales is the fact that investor is passively exposed to greater market risk when realized return on financial assets result in mechanical variations in portfolio allocation. This risk is managed by actively rebalancing his/her portfolio when asset returns change over time. The periodical resetting of weights of asset classes – stocks and bonds – in the portfolio is one of the controversial aspects of portfolio management.

Rebalancing of portfolio often involves taking profit from outperforming assets (so as to avoid overweighting) and buying underperforming assets. But critics argue that frequent rebalancing will result in selling profitable investments too soon and thereby miss on big prospective gains (Jackson, 2006; Daryanani, 2008; Lim, 2013). It is also argued that

portfolio rebalancing results in higher transactions costs and low return to the investors (Best and Hlouskova, 2003; Bertsimas and Pachamanova, 2008).

Portfolio rebalancing is often counter intuitive: it is normal for investors to buy assets that are going up which they assume will go up in future. Such behavioral bias prevents investors from rebalancing their portfolios (commonly referred to as 'status quo bias'). Investors who never rebalance tend to be 'risk –averse'. Some of the other behavioral biases include (a) stock market avoidance – tendency to avoid risky assets like stocks, (b) insufficient diversification (mainly attributed to home bias and using rules of thumb for allocation decisions), (c) insufficient trading (attributed to overconfidence of investors). The behavioral bias and emotions driven investing has negative consequences on the long-term wealth of investors. Portfolio rebalancing helps investors achieve their investment goals and avoid the common investment mistakes (O'Brien, 2006). In that sense, we are looking at the issue of rebalancing of an existing portfolio, where one can hold an asset in both the current and rebalanced portfolio weights.

The literature talks about two major benefits when the investors rebalance their portfolio. The first benefit is *risk control* which maintains the asset allocation as its original target. The second benefit is the *potential return* which can be achieved by buy-low/sell-high opportunities (Buetow *et al.*, 2002; Tokat, 2007; Daryanani, 2008; Calvet *et al.*, 2009). Following are some of the methods of rebalancing portfolio discussed in the literature (Stine and Lewis, 1992; Tsai, 2001; Buetow *et al.*, 2002; Plaxco and Arnott, 2002; Donohue and Yip, 2003; Barney, 2005; Riepe, 2007; Daryanani, 2008; Horan, 2012): (a) *calendar*

rebalancing (portfolios are reset to their target allocations on a fixed schedule such as biweekly, monthly, semi-annually, annually, etc.), (b) *range rebalancing to band* (if any asset class drifts outside the rebalance bands, it will be brought back to the nearest edge of the bands), (c) *range rebalancing to portfolio benchmark* (if any asset class drifts outside the rebalance bands, it will be brought back to the target allocation), (d) *range rebalancing to tolerance band* (if any asset class drifts outside the rebalance band, then it will be brought back within the tolerance band), (e) *volatility-based rebalancing strategy* (when volatility rises above a certain predetermined threshold, higher-volatility asset classes are sold and lower-volatility asset classes are purchased), (f) *tactical rebalancing strategy* (the investors have freedom to make the decision when they think it is a good time to rebalance and the target allocation of assets could be adjusted all the time); and (g) *non-rebalancing strategy* (the portfolios will drift along with the market)[1]. In addition, rebalancing strategies can be combined. All these strategies will be discussed in more details in chapter II.

Portfolio rebalancing involves cost – transaction costs have to be paid if we change the amount held of any asset[2]. This is called the direct cost of portfolio adjustment and is estimated to cost around 3% in commissions and one per cent in bid-ask spread (for average round-trip trade in excess of $1,000)[3]. It also involves the total time cost of making a rebalancing decision (Tokat, 2007; Daryanani, 2008; Bonaparte *et al.*, 2012). Given the existence of transaction cost, it has been argued that the best way to manage is the passive

[1]See Goodsall and Plaxco (1996); Plaxco and Arnott (2002); Donohue and Yip (2003); Barney (2005); Riepe (2007); Daryanani (2008); Horan (2012).

[2] In the literature, the common form of transaction cost is the V-shaped function, where transaction cost is directly related to the absolute difference between the proportion (or the number of units) associated with the asset in the new current portfolio. The literature also discusses a concave function, where the transaction cost is a concave function of the amount traded. See Best and Hlouskova (2003); Bertsimas and Pachamanova (2008).

[3]See Barber and Odean (2000).

'buy-and-hold'[4] (B&H) strategy as opposed to 'active'[5] portfolio management. Jensen (1967) first demonstrated that mutual funds do not outperform a buy-and-hold strategy on an average. On the other hand, Binay (2005) argues that institutional investors generate excess returns based on their style and stock picking. Similarly, other studies find that professionals significantly outperform less sophisticated investors (Grinblatt and Keloharju, 2000; Barber *et al.*, 2009).

Active management of portfolio is widely pursued by institutional investors and recommended by financial advisers with the aim of minimizing risk of portfolio. The rationale for portfolio rebalancing is based on the argument that an investor who chooses an asset allocation strategy that is optimal for an investor finds at the beginning of the year, find changes in the weighting of each asset class in his/her portfolio by the end of the year due to market movements. The weighting has changed over the course of the year because the market value of each security within investors' portfolio earned a different return, resulting in a weighting change. Portfolio rebalancing is like a tune-up for your car: it allows individuals to keep their risk level in check and minimize risk. Thus, rebalancing is the process of buying and selling portions of your portfolio in order to set the weight of each asset class back to its original state. In addition, if an investor's investment strategy or tolerance for risk has changed, he or she can use rebalancing to readjust the weightings of each security or asset class in the portfolio to fulfill a newly devised asset allocation.

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[4] Under the strategy of 'buy-and-hold', the investor (or portfolio manager) buys a strategic portfolio at the beginning of the investment period and nothing else is done until portfolio is liquidated at the end (See Cesari *et al.*, 2003).

[5] Under 'active' portfolio management, investor (or portfolio manager) chooses a tactical trading strategy of buying and selling assets (risky and risk free assets) so that rebalancing of assets so as to achieve an optimal portfolio for a given investor over his or her investment horizon (See Cesari *et al.*,2003).

Lovell *et al.*, (1989) mentioned that both rebalancing strategies and buy-and-hold strategy have costs. There are so many factors affect the costs of rebalancing such as trading cost, tax cost, operation cost, etc. On the other hand, the costs for buy-and-hold strategy are also various. Holding an overpriced asset or overpriced portfolio is very risky; the investors might get the inferior return in the future. The portfolio will not be updated with the new assets which are in modern market. In addition, the old asset allocation might not fit the investors after certain of time. The investors sometimes have conflicts between rebalancing strategies and un-rebalancing strategy when their asset allocation ratios drift out of their original target. If they rebalance their portfolio to maintain the target proportions of asset allocation, then their portfolio will incur so many costs. However, if they let the portfolio drift overtime, then their portfolio might be in high risk. Each method has both advantages and disadvantages, and we can go further details in the next chapters (Donohue and Yip, 2003; Leland, 2000).

Many researchers have studied the effects of portfolio rebalancing strategies at different time periods[6]. Most of the empirical literature on rebalancing strategies are either on calendar (such as weekly, biweekly, monthly, quarterly, annually, etc.) or volatility (such as rebalancing whenever asset ratios drift more than 5%, 10%, 15%, 20%, etc. from the target ratios). It is increasingly recognized that portfolio rebalancing strategies have different outcomes depending on market conditions. For example: during 2008-09 credit crisis,

[6] See Stine and Lewis (1992); Goodsall and Plaxco (1996); Tsai (2001); Buetow *et al.* (2002); Donohue and Yip (2003); Riepe (2007); Tokat (2007); Daryanani (2008); Lee (2008).

investors found themselves substantially underweight in equities and overweight in fixed income (bond) assets relative to their asset allocation policy.

In recent times, increasing attention is also paid on (mutual) fund performance during business cycles (economic expansion and contraction periods). There is increasing evidence that the ability of fund managers to generate active returns depends on the state of the economy- during economic expansion periods fund managers generate 'above market' returns while during economic contraction periods, they are not able to deliver the same outcome. The events of summer 2007 saw major funds realizing large losses and this event brought an immediacy to this question. The question raised is about the usefulness of portfolio rebalancing and the need to promote 'great rotation' between asset classes like stocks and bonds, rather than a uniform portfolio rebalancing strategy.

The study is organized as follow: Chapter II describes the literature in this field on the subject and sets up the hypotheses for empirical investigation. Chapter III will discuss the database and methodology used in the study. Chapter IV will present the empirical results and explain some of our findings for 20 years. Chapter V will present the empirical results and explain some of our finding for expansion and contraction periods. Chapter VI will summarize the conclusions.

CHAPTER II

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

This chapter briefly reviews the literature on rebalancing strategies and develops hypotheses for empirical investigation. The chapter is organized as follows: Section 1 critically reviews the concept of portfolio rebalancing and rebalancing strategies; Section 2 describes the different methods of rebalancing strategies; Section 3 discusses the factors which influence the rebalancing strategies; Section 4 describes the dynamic trading strategies, and Section 5 develops hypotheses for empirical investigation.

2.1 Portfolio Rebalancing

Markowitz (1952) portfolio selection model is the cornerstone of modern portfolio theory. Markowitz model is based on expected return on the portfolio and variance. The most important of optimization portfolio is the correlation of return of individual stock in the portfolio. When the portfolio returns are highly correlation, then the investors will not diversify the returns, and vice versa (Markowitz, 1952; Fabozzi et al, 2012). The modern Portfolio Theory (MPT) deals with estimation errors associated with Markowitz model. Investors collect diverse assets together to maximize risk adjusted returns because it is not good for investors when they just invest in a few specific stocks. When the investors invest in many kinds of stocks, they will get the benefit of diversification and also reduce the risk of their portfolios (McClure, 2010; Fabozzi et al., 2012).

Based on Markowitz (1952) concept of portfolio allocation, the aim of rebalancing is to maintain the original asset allocation weights so as to avoid overweighting or underweighting of asset weights (from original asset allocation weights). Rebalancing of portfolio often involves taking profit from outperforming assets (so as to avoid overweighting) and allocating the proceeds to buy underperforming assets. But critics argue that frequent rebalancing would result in selling profitable investments too soon and thereby miss on big prospective gains (Stine and Lewis, 1992; Jackson, 2006; Daryanani, 2008; Lim, 2013). It is also argued that portfolio rebalancing results in higher transactions costs and low return to the investors (Best and Hlouskova, 2003; Bertsimas and Pachamanova, 2008). Rebalancing strategies thus involve (a) asset allocation and (b) portfolio diversification.

For example, the investor starts to invest $10,000 portfolio and allocates 60% for asset A ($6,000), 30% for asset B ($3,000), and 10% for asset C ($1,000). Over time, asset A earns a return of 5% ($6,300), asset B earns a return of 1% ($3,030), and asset C earns a return of -13% ($870). The total value of portfolio at this time is $10,200. In order to maintain their allocations, the investor will sell $180 of asset A and use the proceeds to purchase $30 for asset B and $150 for asset C.

Table 2.1: How Rebalancing Work in a Portfolio – Hypothetical Example

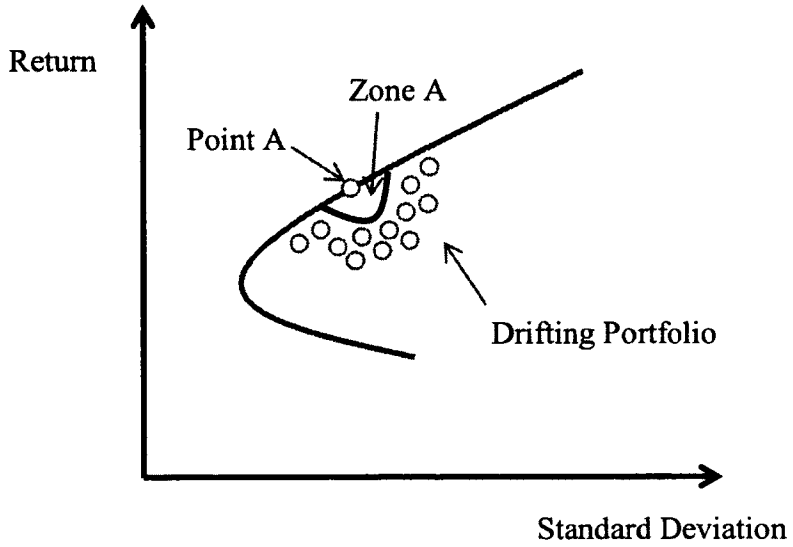
Allocations	Beginning	Drifting	Before Rebalancing	Rebalancing	After Rebalancing
A	$6,000	+5%	$6,300	-$180	$6,120
B	$3,000	+1%	$3,030	+$30	$3,060
C	$1,000	-13%	$870	+$150	$1,020
Total	$10,000		$10,200		$10,200

In the literature on portfolio optimization, there are two definitions of portfolio rebalancing. First is the issue of a creating a portfolio from cash (a portfolio creation problem). In forming an efficient portfolio of financial assets (stocks and bonds), the basic approach followed universally is the model of Markowitz (1952) which is popularly known as the mean-variance framework. Markowtiz (1952) considered the problem as one of trading off reward (as measured by mean portfolio return) against the risk involved (as measured by variance in portfolio return). When portfolio managers set up the asset allocation at the time they start to invest, the investors expect their portfolio has a certain of risks and returns. However, over time some assets classes outperform others and the asset allocation will drift from its original target. Here comes the need for portfolio rebalancing which is the second dynamic dimension to the portfolio optimization problem.

Chart 2.1 will help the investors have a better understanding how the rebalancing strategies work with no-trade region. Suppose at the beginning of the investment, the investor determines the target allocation for asset A is 40% of the investment portfolio. This asset A has a risk/return trade-off corresponding to point A on the efficient frontier. Over time, asset A will drift out of its target allocation. The investor sets up the no-trade region around asset A such as [35%-45%]. If asset A has a small drift which is still in no-trade region (zone A), it will not be rebalanced. However, when asset A drifts out of zone A which is less efficient (high risk, low return, or both), it will be rebalanced back. Some researchers argue to rebalance it back to the nearest band such as 35% or 45% (Leland, 1996 and 2000; Donohue and Yip, 2003), some researchers argue to rebalance it back to the original target allocation

such as 40% (Buetow *et al.*, 2002; Jaconetti, 2010), while others argue to rebalance it back to the zone A (Leland, 1996 and 2000; Donohue and Yip, 2003; Daryanani, 2008; Lee, 2008).

Chart 2.1: No-trade Region with Drifting Portfolio



Source: Daryanani (2008), p.49.

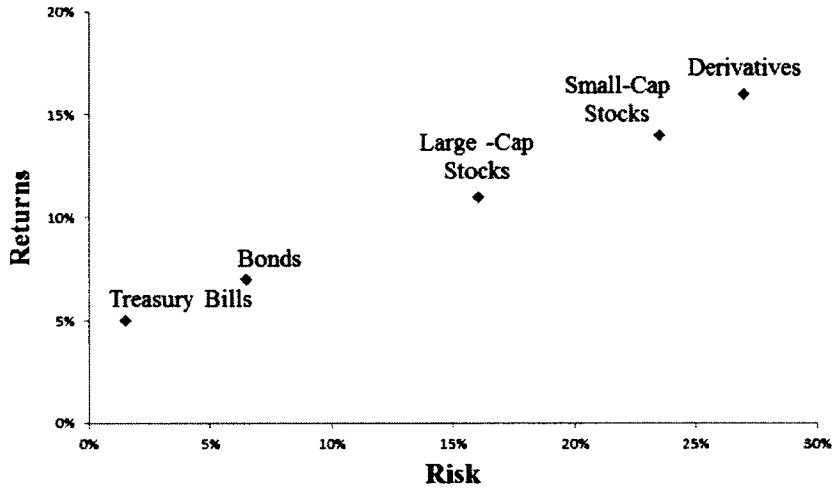
2.1.1 Asset Allocation

There are different kinds of financial asset class vehicles such as stocks, bonds, cash, derivatives, etc. Besides there are diversified asset classes such as mutual funds, index funds, exchange traded funds, etc. which are diversified asset classes themselves (Plaxco and Arnott, 2002; Barney, 2005; Collins and Stampfli, 2005; McWhinney, 2011; Walsh, 2012). These asset classes have varying return-risk profile. Asset allocation determines the proportion of each financial asset class in the portfolio. Stocks are the highest risks and highest returns among three major asset categories. Bonds are less risky and less return than stocks. Cash or cash equivalents are the least risk and least return among three major asset categories. They are also the safest investment such as savings deposits, treasury bills, money market funds, etc. Derivatives: Options and future contracts are derivative securities and are

risk management tools. Investors can use the options and future contracts to limit or manage portfolio risk.

Chart 2.2 displays the relationship between the risk and return of major asset classes (Barney, 2005)

Chart 2.2: Risk-Returns of Asset Classes



The asset allocation decision determines the risk and the return of the portfolio. In addition, different asset categories generate different returns over time and this result in the portfolio drifting from its original asset allocation shares. As a result, the return and the risk of the portfolio change, as they deviate from their original target (Tsai, 2001; Donohue and Yip, 2003; Tokat, 2007). A non-rebalanced portfolio will become heavier in higher return assets and higher risk than the original allocation (Barney, 2005; Tokat, 2007; Lee, 2008).

A well-diversified portfolio should have two properties, and it should be diversified between asset categories and within asset categories. The investors may choose to invest in a wide range sectors/companies, but the stock portion of their investment portfolio should not change. The reason the investors diversify within asset categories because each stock has

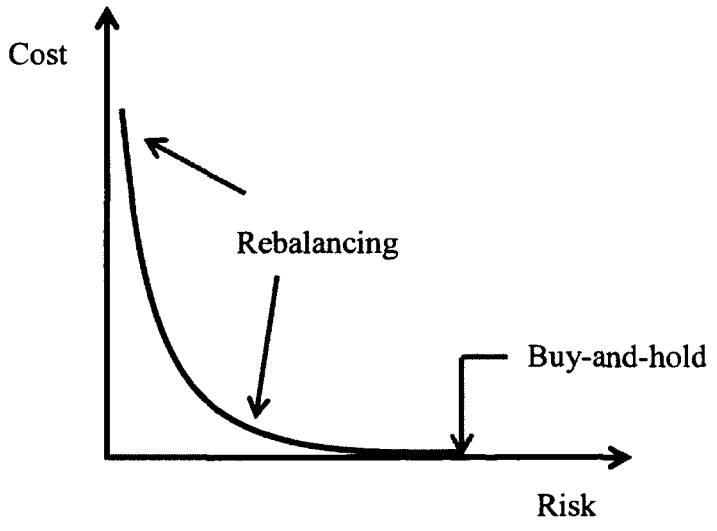
different performance profile under different market condition (Stine and Lewis, 1992; Inderst and Ottaviani, 2012).

It is difficult to predict return and risk. Hence diversification can help the investors not to hold so much proportion in one asset class. However, diversification sometimes can make the portfolio not meet the least risk or the highest returns (Collins and Stampfli, 2005). If asset classes do not move upward together in the long run, then rebalancing makes an investor move funds from outperforming asset categories to underperforming asset categories (Collins and Stampfli, 2005; Jackson, 2006).

2.1.2. Rebalancing

Chart 2.3 displays the trade-off between the cost and the risk of rebalancing as compared with buy-and-hold strategy (Harris, 2000).

Chart 2.3: Trade-off of Portfolio Rebalancing



Source: Harris (2000), p.1.

When the investors start to invest, they set up asset allocations weights for their portfolios. Low volatile assets, such as T. bills or bonds, tend to pay low returns. High volatile assets, such as stocks, tend to pay higher high return over the long term. This is a trade-off because investors accept higher short term volatility for high volatile assets. Over time, high volatile asset will grow faster than low volatile assets. If the investors do not rebalance their portfolio, their portfolios will be heavily in high volatile assets. Their portfolios become less diversified and more risky. If the investors rebalance their portfolio (sell outperform assets and use proceeds to purchase underperform assets), their portfolios will tend to come back the original target asset allocations. Their portfolios become more diversified and less risky. The more times the investors rebalance their portfolio, the more costs and the lower risk the investors will incur (Harris, 2000; Tsai, 2001; Barney, 2005).

Chart 2.4 presents the case for trading and no-trading. There is an argument that there is a no-trade region around the target ratios for the optimal rebalancing strategy. Over times, assets values move up and/or move down unpredictable, and the asset allocation diverge from the target ratio. If the current asset ratios are in the no-trade region, then there is no case for rebalancing portfolio. However, if the current asset ratios are outside the no-trade region, then these assets will be moved back to the predetermined ratios (Leland, 1996 and 2000; Donohue and Yip, 2003).

Chart 2.4: No-Trade Region of Asset Classes

Buy Asset 1 Sell Asset 2	Sell Asset 2	Sell Asset 1 Sell Asset 2
Buy Asset 1	**No-Trade Region** ★ **Target**	Sell Asset 1
Buy Asset 1 Buy Asset 2	Buy Asset 2	Sell Asset 1 Buy Asset 2

Source: Donohue and Yip (2003), p. 54.

The optimal rebalancing strategy is dependent on how frequently the investors monitor the portfolio and the size of the no-trade region. In addition, the size of no-trade region is dependent on the trading costs and the risk aversion. The higher the transaction costs, the larger the size of the no-trade region. The greater the risk aversion, the smaller the size of the no-trade region (Leland, 1996 and 2000; Donohue and Yip, 2003).

According to Walsh (2012), rebalancing can help the portfolio reduce the risk of overexposure and increase diversification. The investors can sell some of the best performing assets and use the proceeds to purchase underperformance assets which the investors are holding or to buy other assets which investors think they are under-valued (Tsai, 2001; Buetow *et al.*, 2002; Jackson, 2006; Daryanani, 2008; Walsh, 2012). In addition, Walsh (2012) also recommended the investors to monitor their portfolio annually because it matches

other market assessments (year-to-date performance) and any life change (marriage, divorce, education, retirement or inheritance).

In the following paragraphs, we discuss some methods for investors to choose when the asset allocation has deviated from its original target (Goodsall and Plaxco, 1996; Plaxco and Arnott, 2002; Donohue and Yip, 2003; Tokat, 2007; Collins and Stampfli, 2005; Horan, 2012):

1. Tactical Rebalancing: This is the oldest method of rebalancing strategies. It adjusts asset allocation tactically based on a number of factors (discussed in section 2.3).
2. Disciplined Rebalancing Strategies: The portfolios are rebalanced based on periodic methods or threshold methods. These methods include some strategies which will be in section 2.2.
3. Insurance Rebalancing Strategy: Portfolio insurance sets a floor which the investors' wealth should fall. This strategy does the opposite way compared with disciplined rebalancing strategies by purchasing outperforming asset and selling underperforming assets (discussed in section 2.4.2).
4. Buy-and-hold Strategy: This method just let all assets classes drift along the index with no touch. The market will rebalance the asset classes.

Table 2.2: Pros and Cons of All Portfolio Strategies

	Advantages	Disadvantages
Tactical Rebalancing	The portfolio will be updated the most recently information of market conditions with expert analysis.	Cost time and money to evaluate a lot of factors for the best optimal rebalancing.
Disciplined Rebalancing Strategies	The investors set up the own rules to control risk and improve return if it is possible.	It is not flexible and it is independent to all other data. The portfolio might have insignificant rebalancing.
Insurance Rebalancing Strategy	The investors protect their wealth in a down trend market, and their wealth will increase fast in an uptrend market.	In a flat market with price reversal, portfolio insurance does poorly.
Buy-and-hold Strategy	The investors do not need to touch the portfolio.	The asset classes may be out of favors of other investor when they are hold for long periods. In addition, the investors may get inferior when the stock prices do not rebound.

The investors do not follow the herds when they use tactical rebalancing or disciplined rebalancing strategies, but these strategies force the investors to behave in a contrarian fashion. In addition, the tactical rebalancing strategy has a similar risk level to disciplined rebalancing strategies, but it has the potential to add useful additional returns (Arnott and Lovell, 1992; Goodsall and Plaxco, 1996; Barney, 2005; Walsh, 2012).

2.1.3. Behavior Finance

Behavior finance provides rationale of how behavioral and cognitive psychologies affect the investors' decisions especially portfolio rebalancing. According to Beach and Rose (2005) and Phung (2009), the investors might have three behavioral finance faults which may

lead them to get inferior returns such as herd-mentality, regret aversion, and mental accounting.

- Herd-mentality: People tend to follow the mass, because they do not want to be alone. They believe that a large group has valuable information and they want to do the same way. They think that a large group could not be wrong. In investing, it means the investors buy what others buy (and also increase the demand) and sell what other sell (increase the supply). Increasing in demand will increase the price, and vice versa. On the other hand, increasing in supply will decrease the price, and vice versa. In addition, these investors do not want to underperform other investors. Professional fund managers do not want to face the reputational risk if they drift too far their peers.
- Regret aversion: This is quite similar with perseverance of belief. Nobody wants to admit mistakes, especially in the investments. It could lead investors to hold a depreciate stock too long. They do not want to sell this stock at a loss because it means the original purchase was a mistake. In addition, they also may not want to buy a depreciate asset even though it is usually a good time to buy it.
- Mental accounting: Mental accounting refers to people who separate their investment rather than as a *comprehensive* portfolio. Mental accounting can mislead investors from the goal of investment. They may save money (with little earnings for saving account) for a vacation or a new home while carrying expensive credit-card debt such as 20% annually. Mental accounting people treat money depends on its source. They tend to spend a lot on "found" money such as

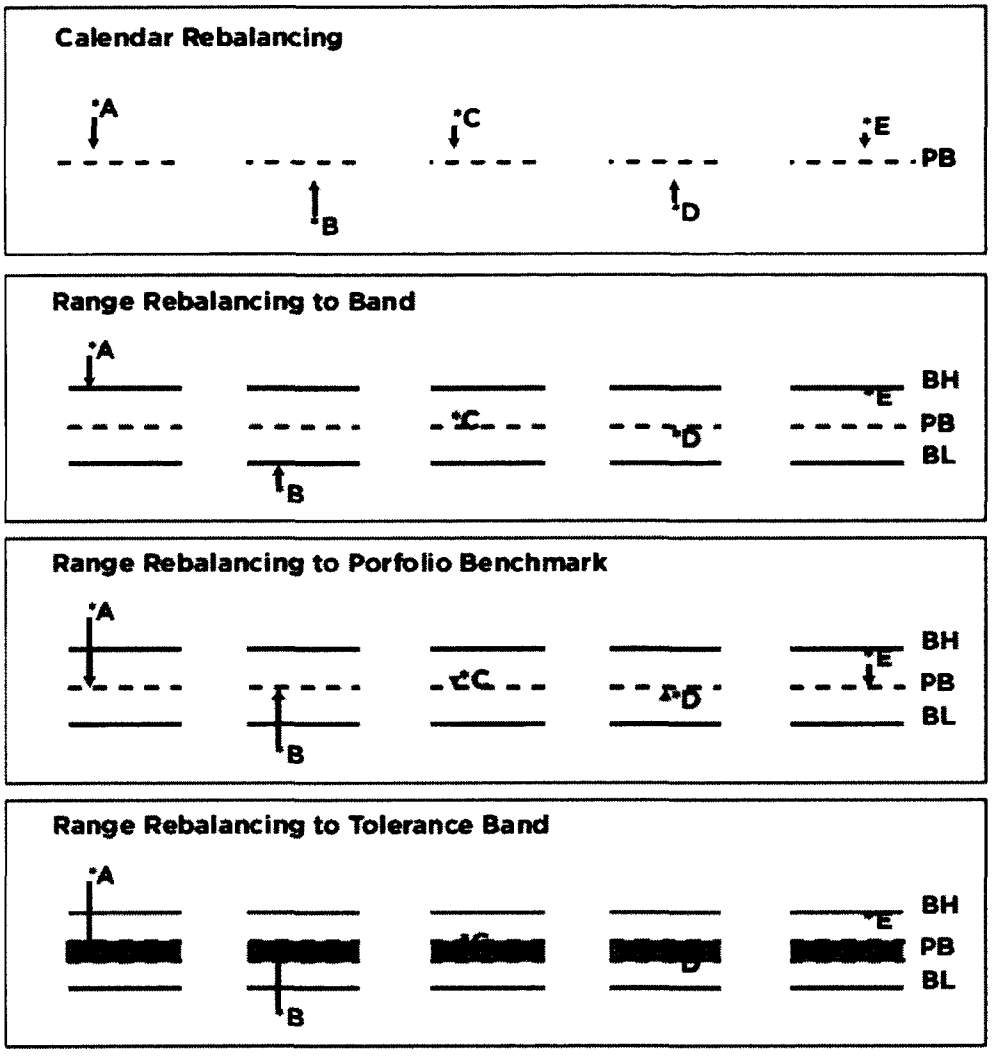
winning lottery ticket, work bonus, or gifts compared with similar amount of money on their regular paychecks.

2.2 Different Methods of Rebalancing Strategies

According to Goodsall *et al.* (1996), the rebalancing strategies not only reduce the risk of the portfolio, but also give more options for the future when it renews the assets (Arnott and Lovell, 1992; Goodsall and Plaxco, 1996; Plaxco and Arnott, 2002; Jackson, 2006; Walsh, 2012).

There are two factors for investors to rebalance their portfolio such as the trigger (time-based triggers or tolerance-based-triggers) and the target (back to strategic target or back to tolerance boundary) (Riepe and Swerbenski, 2007). In chapter I, we referred to most of the empirical literature on rebalancing strategies are either (a) *time calendar* (such as daily, weekly, biweekly, monthly, quarterly, annually, etc.), (b) *threshold strategies* (such as rebalancing whenever asset ratios drift more than 5%, 10%, 15%, 20%, etc. from the target ratios), or (c) *time-threshold strategies*. The following sections describe more details about these strategies (Harris, 2000; Buetow *et al.*, 2002; Plaxco and Arnott, 2002; Donohue and Yip, 2003; Daryanani, 2008; Lee, 2008; Jaconetti *et al.*, 2010; Horan, 2012).

Chart 2.5: Rebalance Approaches



Source: Daryanani (2008), p. 50.

2.2.1 Time Rebalancing Strategy (Calendar Rebalancing).

Portfolios are reset to the predetermined allocation on a regular schedule such as monthly, quarterly, annually, etc. Overweighed assets are sold, and underweighted assets are purchased until the original target is reached. Portfolios are rebalanced based on a predetermined schedule regardless of market direction or expectation for the market.

Arnott and Lovell (1992) studied the risk and reward for calendar rebalancing strategies from 1968 to 1991. They allocated 50/50 stock/bond mix at the beginning of the investment. The authors assumed there was 1% trading cost. The result produced a return of 9.10% and a standard deviation of 11.47% for monthly rebalancing, a return of 9.08% and a standard deviation of 11.44% for quarterly rebalancing, a return of 9.06% and a standard deviation of 11.49% for annually rebalancing. As we can see, there is slightly difference between return and the risk of each strategy. The monthly rebalancing gets the highest return with 9.10% on average, but the quarterly rebalancing gets the lowest standard deviation with 11.44%, while the annually rebalancing get the lowest return of 9.06% and highest standard deviation of 11.49%. The results show that more frequently periodic rebalancing is better than less frequent.

2.2.2 Threshold Rebalancing Strategies.

(a) Range Rebalancing Strategy (Range Rebalancing to Band)

If any asset class is outside the rebalance band, then it will be brought back to the nearest band, not the target allocation. For example, a portfolio has a 20% target for small-cap stocks with 10% rebalance band. If the asset class drifts outside the rebalance range of [18% - 22%], it will be brought back to the nearest band either 18% or 22% allocation.

Arnott and Lovell (1992) studied the risk and reward for calendar rebalancing strategies from 1968 to 1991. They allocated 50/50 stock/bond mix at the beginning of the investment. The authors assumed there was 1% trading cost. The result produced a return of 9.08% and a standard deviation of 11.45% for [48-52%] range rebalancing, a return of 9.08%

and a standard deviation of 11.46% for [49-51%] range rebalancing, a return of 9.07% and a standard deviation of 11.46% for [45-555] range rebalancing. As we can see, there is slightly difference between return and the risk of each strategy. Both ranges [48-52%] and [49-51%] get the same average return of 9.08%, but the range [48-52%] has lowest standard deviation of 11.45%. On the other hand, the range [45-55%] is 9.07% and has the standard deviation of 11.46% which is same with the standard deviation of range [49-51%].

(b) Threshold Rebalancing Strategy (Range Rebalancing to Portfolio Benchmark)

If any asset class is outside the rebalance band, then it will be brought back to the target allocation. We can use the same example of (b), but these small-caps will be sold until they come back to 20% allocation.

Arnott and Lovell (1992) studied the risk and reward for calendar rebalancing strategies from 1968 to 1991. They allocated 50/50 stock/bond mix at the beginning of the investment. The authors assumed there was 1% trading cost. The result produced a return of 9.09% and a standard deviation of 11.45% for +/-5% threshold rebalancing, a return of 9.07% and a standard deviation of 11.46% for +/-2% threshold rebalancing, a return of 9.04% and a standard deviation of 11.47% for +/-1% threshold rebalancing. As we can see, there is slightly difference between return and the risk of each strategy. The +/-5% threshold rebalancing gets the highest return of 9.09% and lowest standard deviation of 11.45%. On the other hand, the +/-1% threshold rebalancing gets the lowest return of 9.04% and highest standard deviation of 11.47%. The results show that more threshold rebalancing is better than less threshold rebalancing.

(c) Range Rebalancing to Tolerance Band

If any asset class drifts outside the rebalance band, then it will be brought back within the tolerance band. We can use the same example of (b) with the 5% tolerance band. If any asset class drifts outside the rebalance range of [18% - 22%], it will be brought back within the tolerance band of [19 % - 21%] allocation.

Daryanani (2008) studied the rebalancing strategies with portfolios of 25% U.S. large (S&P 500 Total Return), 20% U.S. small (Russell 2000 Total Return), 10% real estate investment trusts (Dow Jones REIT Total Return), 5 % commodities (Dow Jones AIG Total Return), and 40% bonds (Bloomberg 7-10 Total Return) from January 1992 to December 2004. The author also used the rebalance bands of 0%, 5%, 10%, 15%, 20%, and 25%. The author looked at daily, weekly, biweekly, monthly, quarterly, semiannually, and annually to see if any asset was out of rebalance band. If it was, then the author rebalanced it to the tolerance band which was assumed to be 50% of the rebalance band. The flat trading cost was assumed $20 per trade regardless the size of the trade. As the result, the optimal strategy on 12-month average return is rebalancing daily with 20% rebalance band while buy-and-hold strategy did not perform well in this period.

(d) Equal Probability Rebalancing Strategy

Each asset has a no-trade region around its target. Triggers are based on a common multiple of the standard deviation of each asset's expected return to determine the size of that

asset's no-trade region. When an asset drifts outside its no-trade region, that asset will be rebalanced back to its target ratio.

Donohue and Yip (2003) studied the portfolio rebalancing strategies from January 1987 to December 1996. They allocated the assets of 35% in U.S. fixed-income, 50% in U.S. equities, and 15% in non-U.S. equities. The portfolio involves three risky assets and one risk-free asset. The trading costs are equal for all risky assets, and subtracted from the allocation to the risky asset. For each risky asset, the range set is the standard deviation of each asset multiple the expected return of each asset. Each asset has expected returns of 5%, 20%, 35%, and 50%. The results produced the expected returns of 50% has the highest annual return and highest standard deviation, while the expected returns of 5% has the lowest annual return and lowest standard deviation. The more the expected returns of the portfolio, the more annual returns the portfolio achieves.

2.2.3 Time-threshold Rebalancing Strategy.

This strategy combines both periodic strategy and threshold strategies. The portfolio is monitored on a scheduled basic and rebalanced only if its asset allocation has drifted by a predetermined minimum rebalancing threshold.

By using the same empirical evidence of Range Rebalancing to Tolerance Band above, the optimal strategy on 12-month average return is rebalancing daily with 20% rebalance band (Daryanani, 2008).

2.2.4 Other Rebalancing Strategies

(a) Tactical Rebalancing Strategy

Portfolios are rebalanced based on some factors which will be discussed in section 2.3. This method gives the investors the freedom to make the decision when they think it is a good time to rebalance and the target allocation of assets could be adjusted all the time.

Goodsall and Plaxco (1996) studied the performance of the portfolios from 1986 to 1995 including these countries: Australia, Austria, Belgium, Canada, Denmark, France, Germany, Hong Kong, Italy, Japan, the Netherlands, Norway, Singapore, Spain, Sweden, Switzerland, the United Kingdom and the United States. Each asset class has 2.5% of range rebalancing. Each trading cost is 20 basis points for equity index future and 10 basis points for bonds future. However, the equity index future is not available or illiquid in Austria, Belgium, Norway, and Singapore; the authors applied 100 basis points for each trading cost. The results produced the highest annualized return of 15.91% and second lowest annualized risk of 14.82% (just greater the annualized risk of quarterly rebalancing). In their research, the tactical rebalancing provide the optimal strategy compared with monthly rebalancing, quarterly rebalancing, annualized rebalancing, and drifting.

(b) Buy-and-hold Strategy:

Under this strategy, the asset allocation of the portfolio drifts randomly along with the market movements and the market will rebalance the asset allocation. According to the efficient market hypothesis, stock prices incorporate all public information. In addition, the random walk behavior of stock prices is unpredictable. Stock prices are likely to go up and to

go down, and no one can abnormal profits by trading, stock picking, or market timing. Active trading is wasteful and a buy-and-hold policy cannot be beaten (Azar and Hourani, 2010).

Arnott and Lovell (1992) studied the risk and reward for calendar rebalancing strategies from 1968 to 1991. They allocated 50/50 stock/bond mix at the beginning of the investment. The authors assumed there was 1% trading cost. The buy-and-hold strategy produced the lowest return of 9.03% and standard deviation approximately of 11.46% compared with time rebalancing, range rebalancing, and threshold rebalancing strategies.

2.2.5 Portfolio Selection with Mean-Variance-Skewness

As discussed above, by rebalancing the portfolios, the investors can choose the strategy which fits their expected return and risk. Investors are interested in the portfolio which gives maximum expected return with given standard deviation. Similarity, they are also interested in the portfolio which gives minimum standard deviation with predetermined expected return. In addition, some researchers state that the skewness of stock return is also relevant to portfolio selection (Lai, 1991; Chunhachinda *et al.*, 1997; Harvey and Siddique, 1999, 2000). The skewness depends on the extreme values on two tails, and these points affect the allocation of weights in the optimum portfolio (Canela and Collazo, 2007). The investors prefer the positive skewness in the rate of returns because positive skewness refers to an elongated tail on a right hand of density function of asset return. When the investors increase the skewness, they decrease the probability of large negative rate of return in the future. Moreover, the investors are likely to give up expected returns in order to increase the skewness. The efficient portfolio selection will become three dimensions: rate of return-

variance- skewness. The optimal investment portfolio becomes the trade-off between maximizing the expected rate of return and positive skewness, and simultaneously minimizing the variance (standard deviation or risk). The presence of skewness causes a major change in the construction of the optimal portfolio (Lai, 1991; Chunhachinda *et al.*, 1997; Prakash *et al.*, 2003; Sun and Yan, 2003; Bhattacharyya *et al.*, 2011). Different investors have different views, and they may allocate differently the assets and choose the skewness under the same investment. An inefficient mean-variance portfolio maybe optimal in the mean-variance-skewness portfolio, and vice versa (Lai, 1991; Bhattacharyya *et al.*, 2011).

2.3 Factors Influence Rebalancing

When the investors use the tactical method for rebalancing their portfolios, they consider many factors. The investors spend time to collect the data and information, analyze them and decide when asset allocations of their portfolios should have been adjusted. It is time consuming for investors. There are some factors which influence the rebalancing strategies such as:

1/ Time Horizon:

The time horizon is the period of time the investors want to invest in in order to acquire the specific financial target. The investors with long time horizon are willing to take more risk on the investment because they can hold their portfolios when the markets go up and down frequently. On the other hand, the investors with short horizon are willing to take less risk on the investments because they do not want to sell their stocks when the markets go

down (Stine *et al.*, 1992; Beginners' Guide to Asset Allocation, 2009). In the short term, cash is least risky. However, inflation-linked bond is safer in the long term (Cavezzali *et al.*, 2012). A portfolio with a short term horizon suggests less frequent rebalancing because there is less time for the portfolio to drift from the target asset allocation. Moreover, the return of this portfolio may not recover the rebalancing costs (Tokat, 2007).

2/ Risk Tolerance:

The investors with high risk tolerance are willing to lose some or all their original investment in order to get better returns. On the other hand, the investors with low risk tolerance are willing to maintain their original investments. However, portfolios that are not rebalanced can lose the risk reduction benefits, and drift toward an unintended large percentage of higher risk assets or inefficient allocations (Buetow *et al.*, 2002; Beginners' Guide to Asset Allocation, 2009). Greater volatility implies a greater need to rebalance, and vice versa (Barney, 2005; Tokat, 2007).

3/ Asset Allocation:

Stocks and bonds are appropriate for long term investment because they are riskier than cash equivalents (savings deposits, certificates of deposit, treasury bills, money market deposit accounts, and money market funds). On the other hand, cash investment may be appropriate for short term investment (Stine and Lewis, 1992; Beginners' Guide to Asset Allocation, 2009).

The portfolio tends to drift toward high expected return assets, increasing the risk of deviation from the target allocation and thus increase the need to rebalance (Stine and Lewis, 1992; Tokat, 2007; Dichtl *et al.*, 2012).

4/ Assets Correlation:

The rebalancing strategies will be less meaningful when the asset classes have positive correlation. The lower the correlations, the more returns on different assets will tend to offset each other, reducing portfolio volatility. When assets are perfectly negatively correlated, the rebalancing adds the most value (Buetow *et al.*, 2002; Barney, 2005; Value of Rebalancing). If asset classes move the same direction, their correlation will be high. The portfolios do not need to rebalance because the asset allocation tends to remain unchanged (Tokat, 2007).

5/ Taxes:

When the outperform assets are sold, then the investors need to pay tax for the capital gains. The taxes costs are based on individual's income, federal or provincial, working area, etc. (Barney, 2005; Daryanani, 2008; Horan, 2012). The more times the investors rebalance the portfolio, the more taxes and the lower compounded returns the investors will incur. However, if the market is broadly flat for the next few years but fluctuates wildly over short terms, then investors probably do not mind the taxes when they rebalance the asset allocation (Jackson, 2006; Tokat, 2007). The most important is when the investors sell assets, the payment of the capital gains taxes based on the sale of assets, not the market value of the

assets. In addition, the capital gains taxes rate does not depend on how long the investors have held the assets (Daryanani, 2008).

6/ Costs:

There are two parts of rebalancing human capital: the cost for looking to check if the asset classes are out of balance and the cost for correcting the out-of-rebalance classes (Barney, 2005; Tokat, 2007; Daryanani, 2008). The investors might ask the wealth manager to monitor their portfolios on a regular basic schedule to see if the asset classes drift out of balance. The wealth manager will charge the investors the fees for management (Stine and Lewis, 1992; Donohue and Yip, 2003; Daryanani, 2008; Horan, 2012).

When the asset classes are out of rebalance over time, the wealth manager will realign them back to the predetermined asset allocation in the portfolio. The wealth manager will charge the investors the fees for trading the assets categories (Stine and Lewis, 1992; Buetow *et al.*, 2002; Barney, 2005; Daryanani, 2008; Swedroe, 2012). When the trading cost is fixed, rebalancing to the target allocation is optimal because it decreases the need for further transactions. On the other hand, when the trading cost based on the size of the trade, rebalancing to the nearest edge of the boundary is optimal because it minimizes the size of the transaction. When the trading cost includes fixed cost and variable costs, the optimal strategy is to rebalance to between the target allocation and the nearest edge of the boundary (Donohue and Yip, 2003; Tokat, 2007).

7/ Market Condition (Stine *et al.*, 1992; Jackson, 2006; Swedroe, 2012):

The returns of different asset classes move up and move down under different market conditions (Beginners' Guide to Asset Allocation, 2009), and the investors might protect the returns as follows:

- If the market is flat in the next few years but it fluctuates in short periods, investors can make some profits by rebalancing.
- If the market goes up (a boom phase), then rebalancing is not necessary because it reduce the compounded return.
- If the market goes down (a bust phase) and the investors rebalance the portfolio, then the portfolio will incur the cost with negative returns.

8/ Exogenous Cash Flow to the Fund:

According to Barney (2005), "some costs can be avoided- or at least reduced- through the management of cash inflows and outflows. New cash, such as regular contributions to a pension fund, can be used to purchase underweighted asset categories to bring the portfolio back toward the target allocations. Cash withdrawals can be used to reduce overweighted asset classes. One study estimated that such cash management techniques can lower rebalancing turnover by more than half- reducing not only transaction costs, but tax liabilities as well. Cash for needed rebalancing moves can also come from the portfolio itself, in the form of dividend and interest income. These payments can be directed into an interest-bearing account, and then invested in underweight asset classes as need. Such cash management techniques can be particularly useful when a portfolio contains asset categories- such as private equity or private placement bonds- that are relatively illiquid, or when it

contains investment vehicles- such as hedge funds- that include lock up agreements or other constraints that can inhibit the ability of investors to reallocate funds"[7].

Over time, the portfolio will generate dividends, interest payments, or capital gains, etc. The investor can re-invest all these income to his/her portfolio in order to cut the rebalancing cost while he or she maintains the asset allocation (Jaconetti *et al.*, 2010). However, all the proceeds from the investing should be added back to the investment with no new money (no money is taking out, and no money is putting in) so that it is easy for investor to keep track the returns.

2.4 Dynamic Trading Strategies

2.4.1 Benchmarking

When the investors do the trades over the world, it is important that they should choose the appropriate indexes. Hamza *et al.* (2006) demonstrate that the equally weighted emerging market index outperforms both cap-weighted index and GDP weighted index over the 1990-2004 period. In addition, the authors also indicate that the equally weighted index benefits from three factors: lower concentration, more frequent rebalancing, and larger allocation for small countries. In addition, equal-weighting allows investors to benefit from the mean reverting nature of emerging market return. The emerging markets were part of the MSCI EM index of their sample over the 1990-2004 period. MSCI country returns are total return (capital gains plus dividend) in U.S. dollars.

[7] See Barney (2005).

Plaxco and Arnott (2002) use domestic U.S. and global asset class for rebalancing. There are 11 countries/regions in the portfolios such as Australia, Canada, EMU, France, Germany, Italy, Japan, the Netherlands, Spain, the U.K and the U.S. In addition, Azar and Hourani (2010) demonstrate that "The first test is on the four averages of the Jensen's alphas. The average of the alphas is positive and statistically significant when the benchmark is either the S&P 500 or the Dow Jones Industrial Average (DJIA). When the benchmark is the Russell 3000, the average of the alphas is statistically insignificant. When the benchmark is the NASDAQ, the average of the alphas is negative and statistically significant. The second hypothesis test is on the four medians of the Jensen's alphas. This test is applied because of the presence of outliers in the four samples of Jensen's alphas. When the benchmark is the S&P 500, the median of the alphas is positive and marginally significant. When the benchmark is the DJIA, the median of the alphas is statistically insignificant. When the benchmark is either the Russell 3000 or the NASDAQ, the two medians of the alphas are negative and statistically significant. There is evidence that the S&P 500 is the most appropriate benchmark".

Investors tend to invest different markets over the world, then they need to choose appropriate global policy benchmark (Plaxco and Arnott, 2002; Hamza *et al.*, 2006; Azar and Hourani, 2010). There are some appropriate indexes for global investors, and they may consider S&P 500 Index, MSCI Emerging Markets Index, MSCI Europe Index, and Barclays Capital Aggregate Bond Index for their portfolios.

2.4.2 Portfolio Insurance

Portfolio insurance (constant proportion strategy) has the opposite strategy with rebalancing strategy by purchasing strong relative performers and selling underperformers (Overway and Bearce; Black and Jones, 1987; Perold and Sharpe, 1995; Collins and Stampfli, 2005). Portfolio insurance has the following form:

$$Dollars\ in\ Stocks = Lesser\ of\ [m(Assets - Floor), Assets]$$

Where:

m= multiplier (The ratio of the initial stock to the initial cushion)

Assets – Floor= Cushion

Portfolio insurance sets a floor which the investors' wealth should not be below. Commonly, this floor is about 20% - 30% of the original portfolio value. The multiplier is applied to determine the initial stocks value. The higher the multiplier, the faster the investors' portfolio will approach the floor in the bear market, or the faster the investors' portfolio will increase their wealth in the bull market. However, in a flat market with price reversals, portfolio insurance will perform relatively poorly because they sell the underperformers to see the market rebound, and buy outperformers to see the market weaken (Black and Jones, 1987; Perold and Sharpe, 1995; Collins and Stampfli, 2005).

Perold and Sharpe (1995) have an example for portfolio insurance such as we assume that there is $100.00 of initial wealth, a floor of $75.00 and a multiplier of two. The initial

cushion will be $25.00, and the initial dollars in stocks should be $50.00. The asset allocation will be 50/50 for stocks/bills.

We suppose that the stock market falls from 100 to 90, and then the investors' stock will fall 10 per cent, from $50.00 to $45.00. Total asset will be $95.00 and the cushion will be $20.00 ($95.00 - $75.00). Based on the insurance form, the dollars in stocks should be $40.00 (2x$20.00). It requires the investors sell $5.00 of stock and invest the proceeds in bills. When stock prices fall further, more stock will be sold. When stock prices go up, stocks will be purchased.

According to Perold and Sharpe (1995), rebalancing is a '*concave*' strategy which 'buy stocks as they fall, sell as they rise'. This strategy does not have much downside protection, and does poorly in upside markets. However, it does very well in flat (but oscillating) markets. On the other hand, portfolio insurance is a '*convex*' strategy which 'sell stocks as they fall, buy as they rise'. This strategy does poorly in flat (but oscillating) markets. However, it tends to have good downside protection and perform well in up markets. Concave and convex strategies can be seen as mirror images of one another on either side of buy-and-hold strategy. Each 'buyer' of a convex strategy is a 'seller' of a concave strategy, and vice versa. Rebalancing strategies exhibit less downside protection, and represent the sale of portfolio insurance (Arnott and Lovell, 1992; Perold and Sharpe, 1995; Dichtl *et al.*, 2012).

In addition, the investors can protect the portfolio insurance by future contracts such as put option. Using the cash market for rebalancing would be expensive; however, future contracts offer a cheaper way to rebalance the portfolio and it will benefit for the portfolio (Black and Jones, 1987; Buetow *et al.*, 2002).

2.4.3 Technical Analysis

Different researchers have different optimal rebalancing strategies. However, many researchers come up with the solution to define a no-trade region for asset allocations. The portfolios only rebalance when the asset allocations drift out of no-trade region. When asset classes drift outside the no-trade region, the investors will either buy or sell these assets to bring them back into the no-trade region (Leland, 1996 and 2000; Donohue and Yip, 2003).

When the investors set up the rebalancing strategies for their portfolios, taxes and transaction costs need to be considered in the investment. The lower the amount of trading, the lower the taxes and the transaction costs reducing the portfolio returns, and vice versa (Tsai, 2001; Horan, 2012).

According to Stine and Lewis (1992), the investors should rebalance their portfolios when the portfolio reaches a predetermined level of risk exposure rather than to make adjustments on a calendar basis. The advantage of this method is it requires fewer rebalances in most cases and the investments tell investors when to rebalance. On the other hand, Tsai (2001) suggests the investors should rebalance their portfolios based on calendar basic. The advantage of this method is it reminds the investors when they should consider rebalancing.

However, many researchers state that it does not matter what methods the investors choose, the most important is that the portfolios are rebalanced. No rebalancing strategy is consistently better across portfolios of differing risk profiles. In either case, rebalancing tends to work best when done on a relatively infrequent basis (Beginners' Guide to Asset Allocation, 2009; Tsai, 2001; Horan, 2012).

According to Jackson (2006), the correction may not be "How often should I rebalance?", but rather "How far should I allow my asset classes to stray from their target allocation before I rebalance?". In addition, Jackson (2006) also suggests that the investors should rebalance the portfolios when any asset class reaches 150% of the target allocation due to tax efficient and more profitable portfolio. However, the investors cut it back to below the target allocation, such as 75% of the target allocation. If the asset class falls to 50% of the initial allocation, then it will be restore to 150% of the original allocation. The reason is if one asset class is increasing much faster than others in the portfolio, it is better for investor to let it ride to 150% of the initial allocation. When the investors are ready to trim back the asset class, it must be overvalued relative to other assets. The investors should sell more of it so that it would be required to return to the "normal" asset allocation. If the asset class decreases significantly, it must be cheap relative to other asset classes, and the investors can buy more of it to overweight its allocation.

2.5 Hypothesis Development

According to Buetow *et al.* (2002) and Daryanani (2008), by monitoring the portfolios on regular basis and rebalancing when they need, the investors do not miss any

buy-low/sell-high opportunity. Moreover, the investors can take advantage of investment options to update their portfolios after analyzing available information. The rebalancing strategies involve selling an asset as it increase in value (relative to other assets in the portfolio), and redistributes this proceeds to buy asset classes that have underperformed that asset. This is expected to improve the return of the portfolio and leads to the first hypothesis:

Hypothesis 1: Rebalancing strategies improve return of portfolio as compared with buy-and-hold strategy.

According to Buetow *et al.* (2002), Barney (2005) and Walsh (2012), rebalancing strategies tends to reduce portfolio volatility. Over time, buy-and-hold strategy has a wider range of exposure (difference between the minimum and the maximum equity) and drifts further from its target than other rebalancing strategies. Buy-and-hold strategy experiences both higher absolute volatility and higher volatility per unit of return than any rebalancing strategies. In other words, buy-and-hold portfolios have higher risk compared with rebalancing strategies. Rebalancing is imperative from a risk control standpoint which systematically addresses the policy benchmark (Stine and Lewis, 1992; Goodsall and Plaxco, 1996; Tsai, 2001; Plaxco and Arnott, 2002; Jaconetti *et al.*, 2010; Dichtl *et al.*, 2012). This leads to the second hypothesis:

Hypothesis 2: The rebalancing strategies results is lower risk than buy-and-hold strategy.

Different authors have different optimal periodic rebalancing strategies based on different time periods. Some authors argues that annual rebalancing strategy produces the

best optimal portfolio (Daryanani, 2008; Jaconetti *et al.*, 2010), while others states that quarterly rebalancing strategy provides the best return-risk adjustment (Arnott and Lovell, 1992; Goodsall and Plaxco, 1996). In his research, Walsh (2012) suggests the investors to monitor their portfolio annually because it matches other market assessments and any life change (marriage, divorce, education, retirement or inheritance). The time horizon based on the risk-aversion of each investor[8]. This leads to the third hypothesis:

- Hypothesis 3: Portfolio rebalancing based on time rebalancing leads to better risk-return outcome than buy-and-hold strategy.

Some researchers mention that the investors should be advised to rebalance the portfolios based on predetermined level of risk rather than the calendar basis. The advantage is it reduces the number of rebalances and it produces narrower range of stock weights (Stine and Lewis, 1992). When the investors are willing to take high risk exposure, they are also expecting to receive an appropriate return. Their portfolios are in danger when the assets drift too far away from their allocations, and these portfolios are in great need to rebalance (Barney, 2005; Tokat, 2007). However, the stock prices usually fluctuate consistently, and there is must be an optimal portfolio with certain of threshold rebalancing[9]. This leads to the fourth hypothesis:

- Hypothesis 4: Portfolio rebalancing based on certain threshold choice perform better buy-and-hold strategy in the long run.

[8] See Appendix 1
[9] See Appendix 2

According to Collins and Stampfli (2005), Tokat (2007), and Dichtl *et al.* (2012), there are so many costs for investors when they rebalance their portfolios. In the trending markets (expansion and contraction periods), the buy-and-hold strategy is likely to outperform to rebalancing strategies. In a strong bull or bear market (when a reversals are small), rebalancing strategies will have more of the marginal purchase and sell decisions which will decrease the portfolios' returns. When the assets trend upward over periods of time, frequent rebalancing could trigger unnecessary capital gain and reduce the compounded return. Buy-and-hold strategy produce superior returns in markets with a prolonged upward (or downward) bias, and rebalancing strategies produce superior returns in stagnant markets (Perold and Sharpe, 1995; Goodsall and Plaxco, 1996; Bernstein and Wilkinson, 1997; Harris, 2000; Jackson, 2006; Tokat, 2007; Daryanani, 2008). However, the buy-and-hold strategy tends to develop significantly higher risk. The more frequently the portfolios are rebalanced, the tighter their risk control relative to the target asset allocation. This leads to the fifth hypotheses:

- **Hypothesis 5: The returns of rebalancing strategies in trending markets underperform than the buy-and-hold strategy.**

CHAPTER III

DATABASE AND METHODOLOGY

This chapter discusses the database and methodology used in the empirical investigation. The chapter is divided into two sections for the study: Section 1 discusses the database and Section 2 discusses the methodology used in the empirical investigation.

3.1 Database

The study is based on historical data of stocks and bonds for 20 years. We created hypothetical portfolios and used daily stock price (of index) to compare the performance of various rebalancing strategies vis-a-vis buy-and-hold strategy. Our portfolios are created by S&P 500 Index and Barclays Capital Aggregate Bond Index – U.S. Long Government/ Credit Bond Index. A brief description of various stock/bond market indices is given below.

Table 3.1: Indices Description

Variables	Indices	Description
Stocks	S&P 500	The S&P 500 Index consists of 500 constituents traded on stock exchanges in the U.S. market. The index constituents are traded on the NYSE (including NYSE Arca and NYSE Amex) and the NASDAQ National Market System (Nasdaq NM). S&P 500 index focuses on the large-cap companies with over 80% coverage of U.S. equities. The index primarily includes companies from financial, healthcare, consumer discretionary, industrials, consumer staples, and energy sectors.
Bonds	Barclays Capital Aggregate Bond Index – U.S. Long Government/ Credit Bond Index	The Barclays Capital Aggregate Bond Index, is used to be called the 'Lehman Aggregate Bond Index', is a broad base index. It is considered to be the best total market bond index, and it is used by more than 90% of investors in the U.S.

Sources: S&P Capital IQ

3.2 Methodology:

3.2.1 Financial Variables

(a)Standard Deviation

$$\delta = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2}$$

Where:

δ = standard deviation of portfolio

n = number of years in the portfolio

x = the observed values of portfolio

$\overline{x}$= the mean value of portfolio

(b) Compound Annual Growth Rate: Geometric Average Rate of Return

➢ Arithmetic Return

$$r_{arith} = \frac{V_f - V_i}{V_i}$$

Where:

r_{arith} = arithmetic return

V_i = The initial value of an investment

V_f = The final value of an investment

➢ Geometric Average Rate of Return (Annualized Return)

$$\overline{r}_{geometric} = \sqrt[n]{\prod_{i=1}^{n}(1 + r_{arith,i})} - 1 = \sqrt[n]{(1+r_1)(1+r_2)(1+r_3)\dots(1+r_n)} - 1$$

Where:

$\overline{r}_{geometric}$= geometric average rate of return

r = arithmetic return

n = number of years

(c) Risk Reward (Sharpe ratio)

$$\text{RVAR} = \frac{\overline{\text{TRp}} - \overline{\text{RF}}}{\delta_p} = \frac{\text{Excess return}}{\text{Risk}}$$

Where:

RVAR = reward to variability ratio

$\overline{TRp}$ = the average total return for portfolio p during some period of time

$\overline{RF}$ = the average risk free rate of return during the period

δ_p = the standard deviation of return for portfolio p during the period

$\overline{TRp} - \overline{RF}$ = the excess return (risk premium) on portfolio p

3.2.2 Hypothetical Examples:

Below are some hypothetical examples which demonstrate how disciplined rebalancing strategies work:

Hypothetical Example 1: Simple Portfolio of Indices

O'Brien (2006) studied four indices case with 40% U.S. bonds (Lehman Intermediate Government/ Credit 1-10 Year), 30% on U.S. large stocks (S&P 500), 15% on U.S. small stocks (Russell 2000), and 15% on international stocks (MSCI EAFE).The data is covered

from 1994 to 2004 which includes variety of market conditions such as rising market, down market, and a recovering up market.

The author compared the performance of periodic annual rebalance with 10% range on asset classes, the performance of quarterly rebalancing back to the original target asset allocation, and the performance of non-rebalancing portfolio. The author found that the return on quarterly rebalancing is highest, and the return on annual rebalancing is lowest. On the other hand, the risk level of non-rebalancing is highest, and the risk level of quarterly rebalancing is lowest. The results is interesting that quarterly rebalancing has highest return and lowest risk level.

Hypothetical Example 2: Diversified Portfolio of Six Mutual Funds.

O'Brien (2006) also studied four indices case with 40% U.S. bonds (Vanguard Total Bond Market Index), 30% on U.S. large stocks, 20% on U.S. small stocks, and 10% on international stocks value (Tweedy Browne Global Value). The 30% on U.S. large stocks is divided into 15% of U.S. large stocks growth (American Funds Growth) and 15% of U.S. large stocks value (DFA U.S. Large Cap Value Index). The 20% on U.S. small stocks is divided into 10% of U.S. small stocks growth (Columbia Acorn Z), and 10% of U.S. small stocks value (DFA U.S. Small Cap Value Index). The data is from 1994 to 2004 which includes variety of market conditions.

The author compared the performance of periodic annual rebalance with 5% threshold on asset classes, the performance of quarterly rebalancing back to the original

target asset allocation, and the performance of non-rebalancing portfolio. The author found that the return on non-rebalancing is highest, and the return on quarterly rebalancing is lowest. On the other hand, the risk level of non-rebalancing is highest, and the risk level of quarterly rebalancing is lowest. The results show that the return of non-rebalancing strategy is highest, and the risk level of quarterly rebalancing is lowest as compared with other two portfolios.

When we compare each pair of annual rebalancing, quarterly rebalancing and non-rebalancing in two hypothetical examples, the six-class portfolio produced higher return and less risk than the four-asset class portfolio. As we can see the results, quarterly rebalancing reduced risk level as compared with annual rebalancing and non-rebalancing.

3.2.3. Methodology:

According to Buetow *et al.* (2002), Tokat (2007), Daryanani (2008), Calvet *et al.* (2009), there are two major benefits when investors rebalance their portfolio such as risk control and potential return. The original percentage of asset allocation will change overtime. We use the initial amount and the investment amount at the end of periods to calculate the 12-month average geometric returns and standard deviation of each strategy.

In this study, we combined both the calendar rebalancing and threshold rebalancing which we discussed in chapter II (section 2.2). There are some variables which we also considered for our portfolios:

(a) Asset allocation:

We created portfolios with 60/40, 50/50, and 40/60 (equity/bond) allocation because these are moderate investments which most investors invest in.

(b) Investment horizon period:

Due to the short maturity of Barclays Capital Aggregate Bond Index, we decided to start creating all portfolios on December 31, 1992 and analyzed all rebalancing strategies until December 31, 2012 which is 20-years horizon. Fortunately, this period includes many market conditions such as rising, flat, volatile, and trending directions. In addition, the Sarbanes Oxley Regulation is also in this period. We believe that this 20-years investment horizon is long enough for us to investigate the performance of the rebalancing strategies and buy-and-hold strategy.

(c) Rebalance bands:

The rebalance band is described as a no-trade region around the target ratios. If the current indexes ratios are in the rebalance bands, then there is no trading. If the current index ratios are not in the rebalance bands, then they will be moved back to the original targets.

We do not move ratios back to the nearest edge of the rebalance bands because there is a reasonable chance we have to rebalance again in the near future. By moving ratios back to their original targets, we are likely to reduce the number of trade made and the trading cost. In this research, we studied the rebalance band of 0%, 5%, 10%, 15%, 20%, 25%, and 30% from original index allocations.

(d) Intervals:

We looked at all portfolios at different interval such as daily, monthly, quarterly, semi-annually, annually, 2nd-yearly, 3rd-yearly, 4th-yearly, and 5th-yearly and rebalanced any index to its original allocation if it drifted outside their rebalance bands.

(e) Rebalancing costs:

The portfolios will incur some costs each time they are rebalanced such as trading costs, tax costs, operational cost, commission costs, time and labor costs. In order to make our calculations simplicity, we used the trading costs only. The indexes were rebalanced back to the target weights when they were out of rebalance band, then the flat trading costs were appropriate for our calculations because it decreases the need for further transactions. According to Daryanani (2008) and Lee (2008), the $20 trading cost is used in their papers. Following their steps, we assumed a flat $20.00 per trade regardless of the size of the trade.

(f) Empirical studies:

We studied the rebalance bands of 0%, 5%, 10%, 15%, 20%, 25% and 30% from original target allocations. In addition, we looked at different interval such as daily, monthly, quarterly, semi-annually, annually, 2nd-yearly, 3rd-yearly, 4th-yearly, and 5th-yearly. At the time we looked the portfolios, we did nothing if all indexes were inside the rebalance bands. However, if any index was outside the rebalance band at the time we looked at the portfolios, we rebalanced it back its original allocation. For the rebalance band of 0%, we rebalanced all indices back to their original targets every time we looked at the portfolios. This is also

called periodic rebalancing strategy. The buy-and-hold strategy was included in our studies as compared the outcome with other disciplined rebalancing strategies.

For example: Suppose there is an index with 20 percent of the portfolio, the rebalance band is 10 percent from the target allocation. At the time we look at the portfolios (such as daily, monthly, quarterly, etc.), we did nothing if this index was inside the [18%; 22%] rebalance band. On the other hand, if this index drifted outside the [18%; 22%] rebalance band at the time we looked at the portfolio, we rebalanced this index back to 20 percent of the portfolio. The rebalancing process requires at least two trades for each time the investors rebalance their portfolios.

Table 3.2: Classification of Implemented Rebalancing Strategies

Rebalancing Strategies	Frequency	Threshold	Reallocation	Classification	No.
Buy-and-hold	No adjustment	No threshold	No reallocation	Buy-and-hold	1
Daily periodic rebalancing	Daily	No threshold	Target weights	Periodic	2
Monthly periodic rebalancing	Monthly	No threshold	Target weights	Periodic	3
Quarterly periodic rebalancing	Quarterly	No threshold	Target weights	Periodic	4
Semi-annually periodic rebalancing	Semi-annually	No threshold	Target weights	Periodic	5
Annually periodic rebalancing	Annually	No threshold	Target weights	Periodic	6
2^{nd}-yearly periodic rebalancing	2^{nd}-yearly	No threshold	Target weights	Periodic	7
3^{rd}-yearly periodic rebalancing	3^{rd}-yearly	No threshold	Target weights	Periodic	8
4^{th}-yearly periodic rebalancing	4^{th}-yearly	No threshold	Target weights	Periodic	9
5^{th}-yearly periodic rebalancing	5^{th}-yearly	No threshold	Target weights	Periodic	10
Daily rebalancing to target weights	Daily	Threshold	Target weights	Threshold	11
Monthly rebalancing to target weights	Monthly	Threshold	Target weights	Threshold	12
Quarterly rebalancing to target weights	Quarterly	Threshold	Target weights	Threshold	13
Semi-annually rebalancing to target weights	Semi-annually	Threshold	Target weights	Threshold	14
Annually rebalancing to target weights	Annually	Threshold	Target weights	Threshold	15
2^{nd}-yearly rebalancing to target weights	2^{nd}-yearly	Threshold	Target weights	Threshold	16
3^{rd}-yearly rebalancing to target weights	3^{rd}-yearly	Threshold	Target weights	Threshold	17
4^{th}-yearly rebalancing to target weights	4^{th}-yearly	Threshold	Target weights	Threshold	18
5^{th}-yearly rebalancing to target weights	5^{th}-yearly	Threshold	Target weights	Threshold	19

Notes: This table presents all rebalancing strategies under investigation. The periodic rebalancing strategies from 2 to 10 are rebalanced to the predetermined target weights at the end of each period. Strategies from 11 to 19 present both periodic and threshold rebalancing to the target weights. The threshold of 0%, ± 5%, ± 10%, ± 15%, ± 20%, ± 25%, ± 30% are applied to our investigation.

CHAPTER IV

PORTFOLIO REBALANCING - EMPIRICAL RESULTS

This chapter discusses the empirical results of the portfolio rebalancing outcome for 20 year period in U.S. based on hypothetical portfolios of (a) 60/40, (b) 50/50 and (c) 40/60 (stocks/bonds). This chapter is organized as follows: Section 1 discusses return performance of portfolio rebalancing in U.S. for 20 year period; Section 2 discusses the risk associated with various portfolio rebalancing strategies; Section 3 discusses the risk-reward performance of various portfolios rebalancing, and Section 4 discusses the risk-adjusted performance of various portfolio rebalancing strategies based on threshold rebalancing.

4.1 Return Performance of Portfolio Rebalancing

(a) Stock Fund - 60% stock/ 40% bonds

By investing the initial investment of 10 million dollars at 60/40 (equity/bond) and providing the trading cost of $20 per trade, the terminal portfolio balance on end December 2012 comes to $48.76 million for 25 percent/daily rebalancing (Table 4.1.a). This comes to cumulative growth (geometric mean) of 8.24% per annum, which is the highest return of our portfolios as compared to other strategies.

As is evident from Table 4.1 (a) and (b), chart 4.1 (a) and (b) that daily, quarterly, and annually rebalancing strategies outperform the 3rd, 4th, 5th-yearly rebalancing and buy-and-hold strategies for all rebalancing bands. The outcomes of semi-annually and 2nd-yearly rebalancing strategies are higher than 3rd, 5th-yearly rebalancing and buy-and-hold strategies'

in all rebalancing bands. On the other hand, 3rd-yearly rebalancing strategy underperforms all other strategies in all rebalancing bands except 5th-yearly rebalancing and buy-and-hold strategies. Similarly, buy-and-hold strategy underperforms all other strategies for all rebalancing bands except 3rd and 5th-yearly rebalancing strategies.

Chart 4.1(a): Terminal Asset Values on Time Rebalancing for Different Portfolio (60/40) Rebalancing Strategies (December 1992 – December 2012)

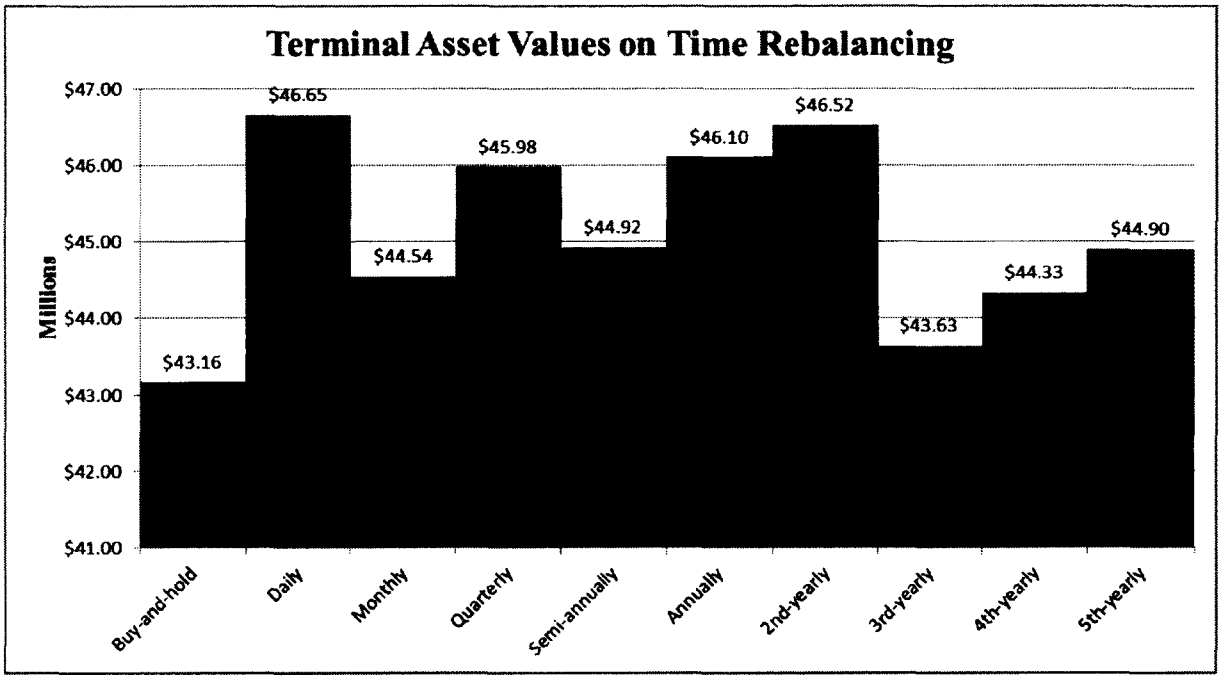
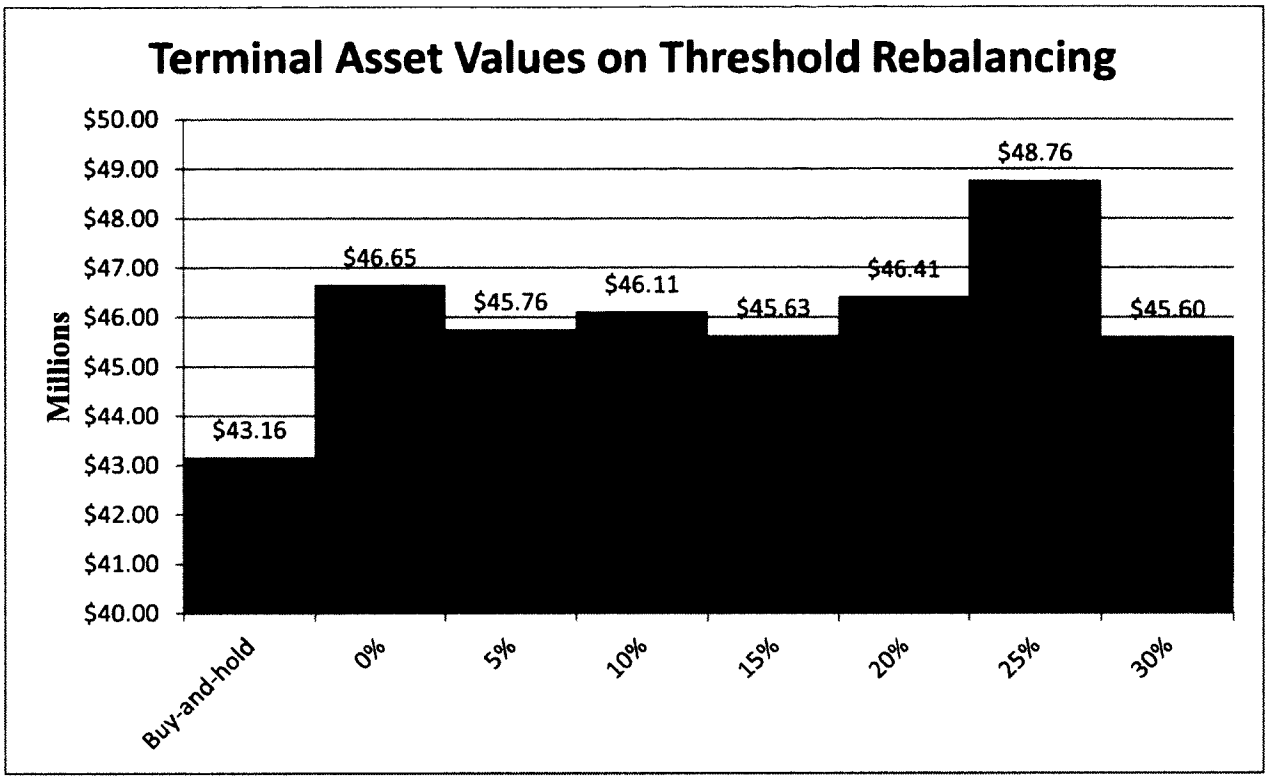


Chart 4.1(b): Terminal Asset Values on Threshold Rebalancing for Different Portfolio (60/40) Rebalancing Strategies (December 1992 – December 2012)



The 0 percent/2nd-yearly rebalancing outperforms all other rebalance bands of 2nd-yearly rebalancing including buy-and-hold strategy. However, the outcomes of 15 percent/quarterly and 15 percent/5th-yearly rebalancing are different. The 15 percent/quarterly outperforms all other strategies of the same interval quarterly including the buy-and-hold strategy. The 15 percent/5th-yearly underperforms all other strategies of the same interval 5th-yearly and buy-and-hold strategy. In the case rebalancing band of 20%, monthly and 3rd-yearly rebalancing strategies outperform all other strategies of the same interval respectively including the buy-and-hold strategy. The outcome of 25 percent/daily outperforms all other strategies of the same interval daily including the buy-and-hold

strategy. On the other hand, the 25 percent/3rd-yearly underperforms all other strategies of the same interval 3rd-yearly including buy-and-hold strategy. The 30 percent/annually rebalancing outperforms all other strategies of the same interval annually including buy-and-hold strategy. Finally, buy-and-hold strategy does not perform well in this period when it underperform daily, monthly, quarterly, semi-annually, annually, 2nd and 4th yearly of all rebalancing bands.

Table 4.1(a): Terminal Wealth (in millions) for Different Portfolio (60/40) Rebalancing Strategies (December 1992 – December 2012)

	Rebalance Bands						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	$43.16	$43.16	$43.16	$43.16	$43.16	$43.16	$43.16
Daily	$46.65	$45.76	$46.11	$45.63	$46.41	$48.76	$45.60
Monthly	$44.54	$44.70	$44.95	$45.75	$47.16	$44.96	$45.98
Quarterly	$45.98	$46.18	$46.86	$47.47	$44.76	$45.55	$46.70
Semi-annually	$44.92	$45.48	$45.50	$44.89	$44.63	$46.61	$46.61
Annually	$46.10	$45.86	$46.07	$45.65	$44.90	$46.13	$48.02
2nd-yearly	$46.52	$45.97	$46.31	$44.90	$44.90	$43.42	$43.42
3rd-yearly	$43.63	$43.29	$43.29	$43.87	$44.48	$42.41	$43.16
4th-yearly	$44.33	$44.33	$44.65	$44.65	$44.65	$43.42	$43.42
5th-yearly	$44.90	$44.90	$44.90	$42.26	$43.16	$43.16	$43.16

Table 4.1(b): Return (Geometric Mean) of Portfolio using Different (60/40) Rebalancing Bands (December 1992 – December 2012)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	7.59	7.59	7.59	7.59	7.59	7.59	7.59
Daily	8.00	7.90	7.94	7.89	7.98	8.24	7.88
Monthly	7.76	7.77	7.80	7.90	8.06	7.81	7.93
Quarterly	7.93	7.95	8.03	8.10	7.78	7.88	8.01
Semi-annually	7.80	7.87	7.87	7.80	7.77	8.00	8.00
Annually	7.94	7.91	7.94	7.89	7.80	7.94	8.16
2nd-yearly	7.99	7.93	7.97	7.80	7.80	7.62	7.62
3rd-yearly	7.64	7.60	7.60	7.67	7.75	7.49	7.59
4th-yearly	7.73	7.73	7.77	7.77	7.77	7.62	7.62
5th-yearly	7.80	7.80	7.80	7.47	7.59	7.59	7.59

We use the initial amount and the investment amount at the end of periods to calculate the 12-month average geometric returns of each strategy. Table 4.1(b) shows that the return of buy-and-hold strategy is just higher than the returns of 25 percent/3rd-yearly and 15 percent/5th-yearly. The highest return is on 25 percent/daily strategy, and our result is similar with the results of Daryanani (2008) and Lee (2008). The highest return of Daryanani (2008) is on 20 percent/daily. The return of 20 percent/daily of Lee (2008) is slightly less than the highest return (20 percent/biweekly) about 0.02% per year on his research.

It is evident from these results that buy-and-hold strategy does not produce highest return as compared with other strategies. Daily rebalancing with a 25% rebalancing band is found to be the strategy which maximizes the return of the portfolio over long period horizon. The second highest return is on 30 percent/ annually. On the other hand, buy-and-hold strategy just outperforms 25 percent/3rd-yearly and 15 percent/5th-yearly rebalancing strategies (December 31, 1992 to December 31, 2012). The rank of return of buy-and-hold

strategy is 58th over 64 strategies. Thereby validating hypothesis 1 is highly supported and it is similar with conclusion which were derived by Daryanani (2008) and Lee (2008).

(b) Balanced Fund - 50% stock/ 50% bonds

By investing the initial investment of 10 million dollars at 50/50 (equity/bond) and providing the trading cost of $20 per trade, the terminal portfolio balance on end December 2012 comes to $51.54 million for both 25 percent/ annually and 30 percent/ annually. They come to cumulative growth (geometric mean) of 8.54% per annum, which are the highest return of our portfolio as compared to other strategies.

As is evident from Table 4.2 (a) and (b), chart 4.2 (a) and (b) that quarterly and annually rebalancing strategies outperform monthly, 3rd, 4th, 5th-yearly and buy-and-hold strategies for all rebalancing bands. The outcomes of semi-annually and 2nd-yearly rebalancing strategies are higher than 3rd, 5th-yearly rebalancing and buy-and-hold strategies' in all rebalancing bands. The rebalancing of 3rd-yearly strategy underperforms all other strategies for all rebalancing bands except 5th-yearly rebalancing and buy-and-hold strategies. Similarly, buy-and-hold strategy just outperforms only 20 percent/3rd-yearly rebalancing strategy.

Chart 4.2(a): Terminal Asset Values on Time Rebalancing for Different Portfolio (50/50) Rebalancing Strategies (December 1992 – December 2012)

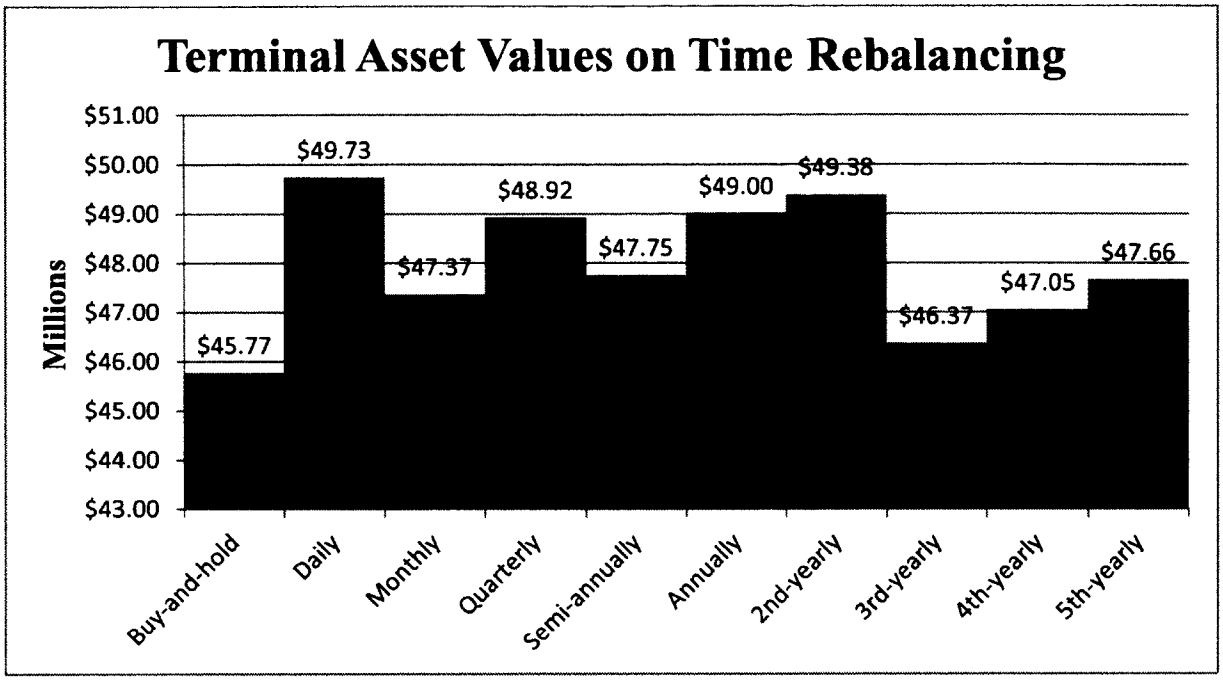
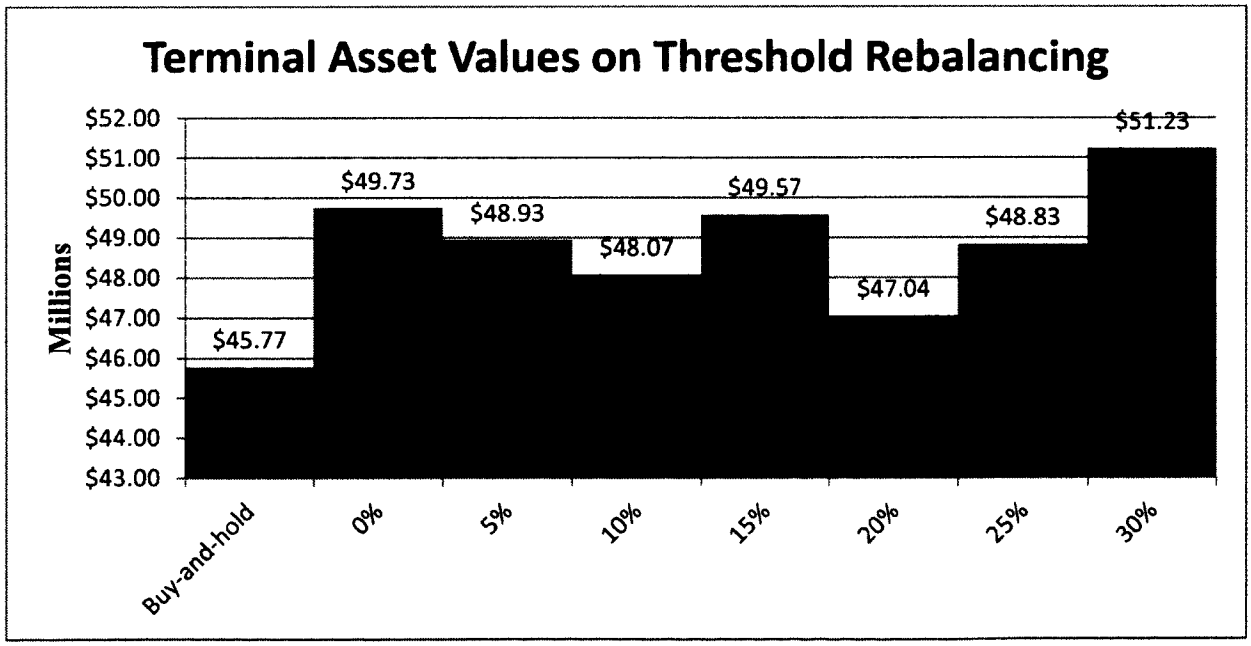


Chart 4.2(b): Terminal Asset Values on Threshold Rebalancing for Different Portfolio (50/50) Rebalancing Strategies (December 1992 – December 2012)



The 10 percent/2nd-yearly rebalancing strategy outperforms all other rebalance bands of 2nd-yearly rebalancing including buy-and-hold strategy. The 15 percent/3rd-yearly rebalancing strategy outperforms all other rebalance bands of 3rd-yearly including buy-and-hold strategy. However, 20 percent/3rd-yearly underperforms all other rebalance bands of 3rd-yearly including the buy-and-hold strategy. On the other hand, 30 percent/daily, monthly, quarterly, semi-annually outperform all other rebalance bands of the same interval respectively including the buy-and-hold strategy. Similarly, buy-and-hold strategy underperforms all other rebalance bands of daily, monthly, quarterly, semi-annually, annually, 2nd-yearly and 4th-yearly rebalancing strategies.

Table 4.2(a): Terminal Wealth (in millions) for Different Portfolio (50/50) Rebalancing Strategies (December 1992 – December 2012)

	Rebalance Bands						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	$45.77	$45.77	$45.77	$45.77	$45.77	$45.77	$45.77
Daily	$49.73	$48.93	$48.07	$49.57	$47.04	$48.83	$51.23
Monthly	$47.37	$47.79	$48.80	$47.59	$47.34	$48.89	$50.86
Quarterly	$48.92	$49.14	$50.15	$49.42	$48.39	$49.57	$51.36
Semi-annually	$47.75	$48.18	$48.58	$47.38	$49.57	$49.57	$50.60
Annually	$49.00	$48.75	$49.77	$47.67	$49.14	$51.54	$51.54
2nd-yearly	$49.38	$48.80	$49.89	$47.67	$46.03	$46.03	$46.03
3rd-yearly	$46.37	$45.99	$45.99	$46.60	$44.98	$45.77	$45.77
4th-yearly	$47.05	$47.05	$47.41	$47.41	$46.03	$46.03	$46.03
5th-yearly	$47.66	$47.66	$47.66	$45.77	$45.77	$45.77	$45.77

Table 4.2(b): Return (Geometric Mean) of Portfolio using Different (50/50) Rebalancing Bands (December 1992 – December 2012)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	7.90	7.90	7.90	7.90	7.90	7.90	7.90
Daily	8.35	8.26	8.17	8.33	8.05	8.25	8.51
Monthly	8.09	8.13	8.25	8.11	8.08	8.26	8.47
Quarterly	8.26	8.29	8.40	8.32	8.20	8.33	8.53
Semi-annually	8.13	8.18	8.22	8.09	8.33	8.33	8.44
Annually	8.27	8.24	8.36	8.12	8.29	8.54	8.54
2nd-yearly	8.31	8.25	8.37	8.12	7.93	7.93	7.93
3rd-yearly	7.97	7.93	7.93	8.00	7.81	7.90	7.90
4th-yearly	8.05	8.05	8.09	8.09	7.93	7.93	7.93
5th-yearly	8.12	8.12	8.12	7.90	7.90	7.90	7.90

We use the initial amount and the investment amount at the end of periods to calculate the 12-month average geometric returns of each strategy. Table 4.2(b) shows that the return of buy-and-hold is just higher than the return of 20 percent/3rd-yearly strategy. The highest return is on both 25 percent and 30 percent for annually.

Again, it is evident from these results that buy-and-hold strategy does not produce highest return as compared with other strategies. Yearly rebalancing with 25 percent or 30 percent rebalancing band is found to be the strategy with maximize the return of the portfolio over long period horizon (December 31 1992 to December 31 2012). Finally, the rank of the geometric return of buy-and-hold strategy is 57th over 64 strategies. Thereby validating hypothesis 1 is highly supported.

(c) Bond Fund - 40% stock/ 60% bonds

By investing the initial investment of 10 million dollars at 40/60 (equity/bond) and providing the trading cost of $20 per trade, the terminal portfolio balance on end December 2012 comes to $54.13 million for 30 percent/annually, and $53.73 million for 25 percent/ annually. They come to cumulative growth (geometric mean) of 8.81% and 8.77% per year, which are the highest and second highest return, respectively, of our portfolios as compared to other strategies.

As is evident from Table 4.3 (a) and (b), Chart 4.3 (a) and (b) that daily and quarterly rebalancing strategies outperform 3rd, 4th, 5th-yearly and buy-and-hold strategies for all rebalancing bands. The returns of semi-annually and 2nd-yearly are higher than the returns of 3rd, 5th-yearly and buy-and-hold strategies for all rebalancing bands. The performance of annually rebalancing strategy outperforms semi-annually, 3rd, 4th, 5th-yearly and buy-and-hold strategies for all rebalance bands. The 3rd-yearly rebalancing strategy underperforms all other strategies with all rebalance bands except the 5th-yearly and buy-and-hold strategy. On the other hand, the buy-and-hold strategy does not outperform any other strategy.

Chart 4.3(a): Terminal Asset Values on Time Rebalancing for Different Portfolio (40/60) Rebalancing Strategies (December 1992 – December 2012)

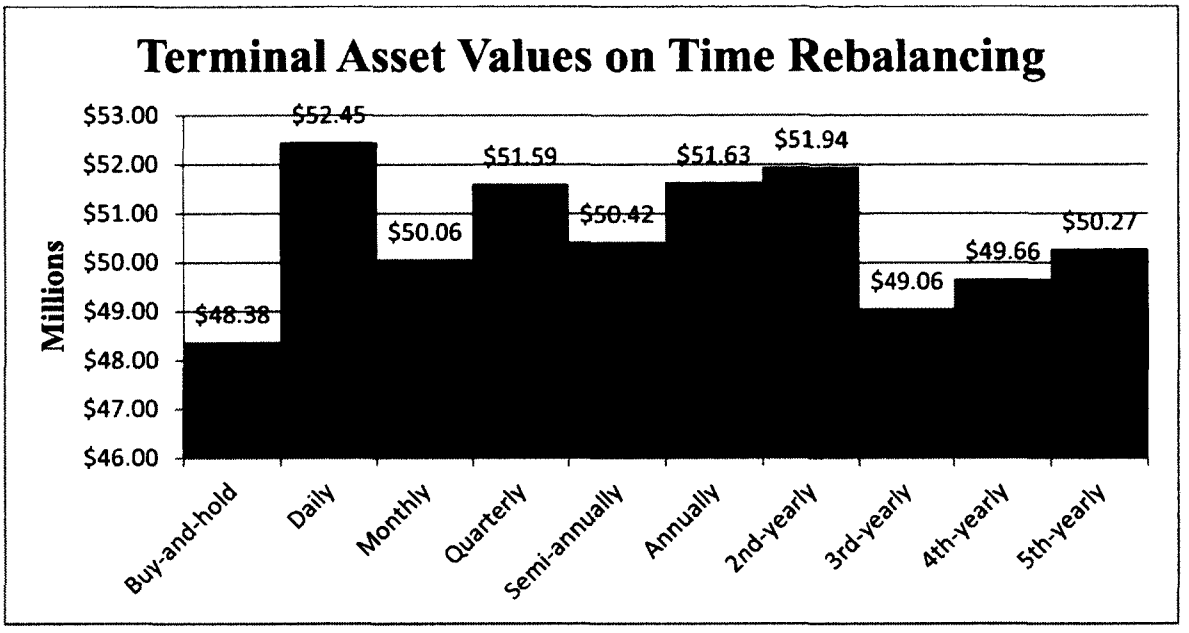
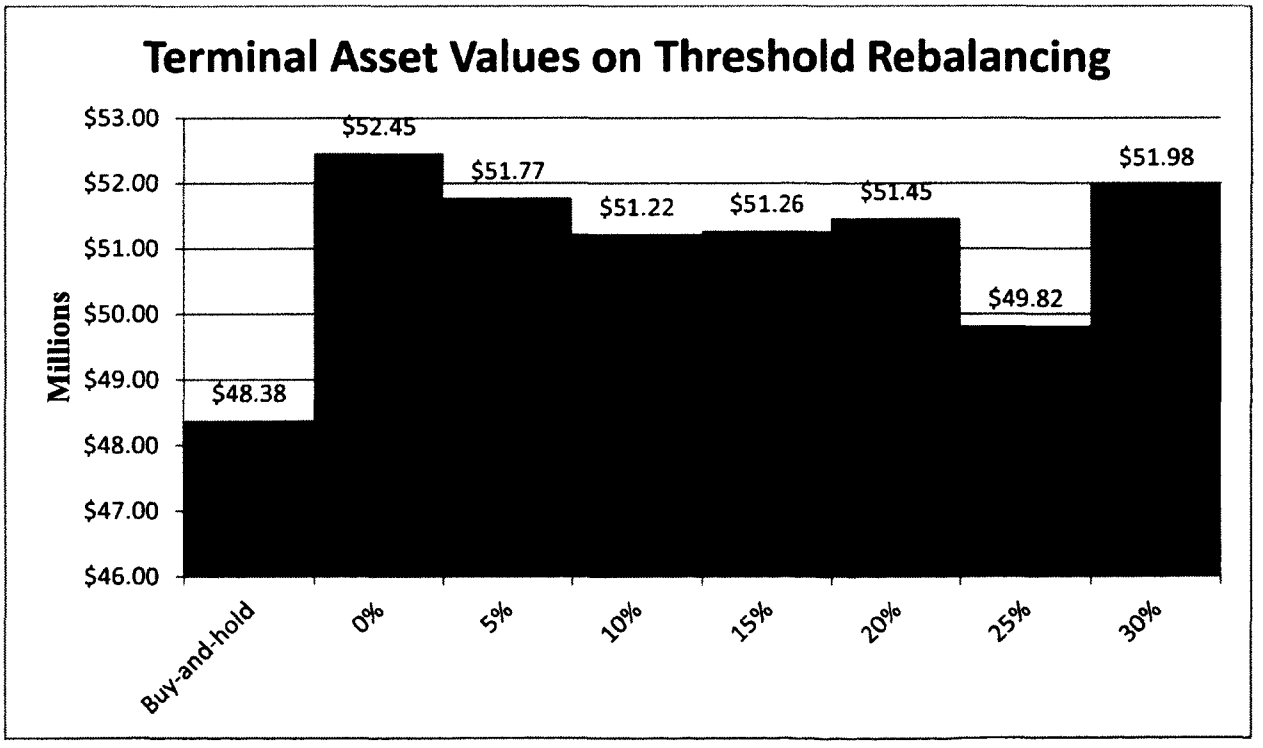


Chart 4.3(b): Terminal Asset Values on Threshold Rebalancing for Different Portfolio (40/60) Rebalancing Strategies (December 1992 – December 2012)



The 0 percent/daily outperforms all other rebalance bands of daily including buy-and-hold strategy. In the case of rebalance band of 15 percent, quarterly and 2nd-yearly rebalancing strategies outperform all other rebalance bands of the same interval respectively including buy-and-hold strategy. The 20 percent/3rd-yearly strategy outperforms all other rebalance bands of the same interval of 3rd-yearly. The case 30 percent/monthly and 30 percent/ annually outperform other rebalance bands of the same interval respectively including the buy-and-hold strategy. However, buy-and-hold strategy does not outperform any of the portfolio rebalancing strategies.

Table 4.3(a): Terminal Wealth (in millions) for Different Portfolio (40/60) Rebalancing Strategies (December 1992 – December 2012)

	Rebalance Bands						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	$48.38	$48.38	$48.38	$48.38	$48.38	$48.38	$48.38
Daily	$52.45	$51.77	$51.22	$51.26	$51.45	$49.82	$51.98
Monthly	$50.06	$50.38	$50.79	$51.17	$50.84	$50.00	$52.40
Quarterly	$51.59	$51.62	$52.51	$53.10	$50.16	$51.03	$52.22
Semi-annually	$50.42	$51.06	$51.04	$50.31	$50.00	$52.22	$52.22
Annually	$51.63	$51.40	$51.66	$52.90	$50.29	$53.73	$54.13
2nd-yearly	$51.94	$51.38	$51.79	$52.02	$50.29	$48.63	$48.63
3rd-yearly	$49.06	$48.67	$48.67	$49.26	$49.88	$48.38	$48.38
4th-yearly	$49.66	$49.66	$50.05	$50.05	$50.05	$48.63	$48.63
5th-yearly	$50.27	$50.27	$50.27	$48.98	$48.38	$48.38	$48.38

Table 4.3(b): Return (Geometric Mean) of Portfolio using Different (40/60) Rebalancing Bands (December 1992 – December 2012)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	8.20	8.20	8.20	8.20	8.20	8.20	8.20
Daily	8.64	8.57	8.51	8.52	8.54	8.36	8.59
Monthly	8.39	8.42	8.47	8.51	8.47	8.38	8.63
Quarterly	8.55	8.55	8.65	8.71	8.40	8.49	8.62
Semi-annually	8.43	8.49	8.49	8.41	8.38	8.62	8.62
Annually	8.55	8.53	8.56	8.69	8.41	8.77	8.81
2nd-yearly	8.59	8.53	8.57	8.59	8.41	8.23	8.23
3rd-yearly	8.28	8.23	8.23	8.30	8.37	8.20	8.20
4th-yearly	8.34	8.34	8.39	8.39	8.39	8.23	8.23
5th-yearly	8.41	8.41	8.41	8.27	8.20	8.20	8.20

We use the initial amount and the investment amount at the end of periods to calculate the 12-month average geometric returns of each strategy. Table 4.3(b) shows that the return of buy-and-hold strategy does not outperform any strategy. The highest return is on 30 percent/annually, and the second highest return is on 25 percent/annually.

It is evident from results that buy-and-hold strategy does not produce highest return as compared with other strategies. The highest return is on 30 percent/annually, and the second highest one is on 25 percent/annually. The rank of the geometric return of buy-and-hold strategy is 59^{th} over 64 strategies. Thereby validating hypothesis 1 is always supported.

But it is a moot question that rebalancing strategy with rebalancing band of 25% and 30% maximize the risk of the portfolio. This is examined in next station.

4.2 Risk

As discussed in chapter III, standard deviation of the return of portfolio is a measure of total risk used in this study.

(a) Stock Fund - 60% stock/ 40% bonds

Table 4.1(c): 12-Month Average Standard Deviation of Portfolio (60/40) using Different Rebalancing Bands (December 1992 – December 2012)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	12.35	12.35	12.35	12.35	12.35	12.35	12.35
Daily	12.38	12.38	12.54	12.47	12.35	12.34	12.11
Monthly	12.53	12.49	12.51	12.38	12.42	12.16	12.06
Quarterly	12.38	12.30	12.27	12.08	12.15	12.08	11.93
Semi-annually	12.32	12.32	12.29	12.10	12.16	12.01	12.01
Annually	12.07	12.13	12.17	12.33	12.39	12.36	11.73
2nd-yearly	11.98	12.08	12.14	12.39	12.39	12.41	12.41
3rd-yearly	12.10	12.14	12.14	11.96	11.97	12.33	12.35
4th-yearly	12.04	12.04	12.14	12.14	12.14	12.41	12.41
5th-yearly	12.12	12.12	12.12	12.78	12.35	12.35	12.35

Table 4.1 (c) summarizes the standard deviation of time & threshold strategies of the portfolios for the whole period from December 31, 1992 to December 31, 2012. Surprisingly, the 15 percent/5th-yearly strategy has the highest standard deviation. For the case of 0% rebalancing band, monthly and quarterly rebalancing strategies have higher risk (standard deviation) than all other strategies of the same interval respectively including the buy-and-hold strategy. However, 2nd-yearly strategy has less risk than all other rebalancing bands with the same interval including the buy-and-hold strategy. In the case of 10% rebalancing band, daily strategy has higher risk than all other rebalancing bands of the same interval including

the buy-and-hold strategy. However, the risk of 3rd-yearly and 5th-yearly strategies of the 15 percent are opposite as compared with other rebalancing bands. The risk of 15 percent/3rd-yearly is lower than the risk of other rebalancing bands including the buy-and-hold strategy. On the other hand, the risk of 15 percent/5th-yearly is higher than the risk of other rebalancing band including the buy-and-hold strategy. In the case of 20 percent rebalancing band, the risk of annually strategy is higher than the risk of other rebalancing bands including the buy-and-hold strategy. In the case of 30 percent rebalancing band, the risk of daily, monthly, quarterly and annually is less than the risk of all other rebalancing bands of the same interval respectively including the buy-and-hold strategy. Finally, the rank of the risk of buy-and-hold strategy is 21th over 64 strategies. The risk of buy-and-hold strategy is not as high as we thought when it is just higher than the risk of semi-annually for all rebalancing bands. The minimum risks belongs to 30 percent/annually (11.73%) and 30 percent/quarterly (11.93%). The hypothesis 2 is slightly supported with our time& threshold strategies when the risk of 20 rebalancing strategies is higher than the risk of buy-and-hold strategy, and the risk of 39 rebalancing strategies is lower than the risk of buy-and-hold strategy. There are 4 rebalancing strategies have the same risk with buy-and-hold strategies.

(b) Balanced Fund - 50% stock/ 50% bonds

Table 4.2(c): 12-Month Average Standard Deviation of Portfolio (50/50) using Different Rebalancing Bands (December 1992 – December 2012)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	11.12	11.12	11.12	11.12	11.12	11.12	11.12
Daily	11.11	11.22	11.32	11.05	11.04	10.82	10.61
Monthly	11.27	11.28	11.24	11.03	10.96	10.84	10.66
Quarterly	11.12	11.05	11.01	10.81	10.82	10.74	10.70
Semi-annually	11.06	11.06	10.93	10.89	10.74	10.74	10.68
Annually	10.81	10.87	10.81	11.13	11.10	10.87	10.87
2nd-yearly	10.74	10.84	10.80	11.13	11.11	11.11	11.11
3rd-yearly	10.88	10.91	10.91	10.77	11.07	11.12	11.12
4th-yearly	10.77	10.77	10.87	10.87	11.11	11.11	11.11
5th-yearly	10.90	10.90	10.90	11.12	11.12	11.12	11.12

Table 4.2 (c) summarizes the standard deviation of time & threshold strategies of the portfolios for the whole period from December 31, 1992 to December 31, 2012. The 10 percent/ daily strategy has the highest 12-month average standard deviation. The risks of semi-annually strategies are less than the risk of buy-and-hold strategy for all rebalance bands. Similarly, the risks of 4^{th}-yearly strategies are less than the risk of 5^{th}-yearly for all rebalance bands including the buy-and-hold strategy. For the case of 0 percent band, the risk of quarterly and the risk of 2^{nd}-yearly are opposite as compared with other rebalance bands. The risk of 0 percent/ quarterly is higher than the risk of other rebalance bands of the same interval including the buy-and-hold strategy. On the other hand, the risk of 0 percent/ 2^{nd}-yearly is lower than the risk of other rebalance bands of the same interval including the buy-and-hold strategy. For the case of 5 percent, the risk of monthly is higher than the risk of other rebalance bands of the same interval including buy-and-hold strategy. For the case of 10 percent, the risk of daily and the risk of annually is opposite as compared with other

rebalancing bands. The risk of 10 percent/ daily is higher than the risk of other rebalancing bands of the same interval including buy-and-hold strategy. On the other hand, the risk of 10 percent/ annually is less than the risk of other rebalancing bands of the same interval including buy-and-hold strategy. For the case of 15 percent, the risk of annually and 2^{nd}-yearly are higher than the risk of other rebalancing bands of the same interval, respectively, including the buy-and-hold strategy. However, the risk of 15 percent/ 3^{rd}-yearly is lower than the risk of other rebalancing bands of the same interval including buy-and-hold strategy. For the case of 30 percent, the risk of daily, monthly, quarterly and semi-annually is lower than the risk of other rebalancing bands, respectively, including buy-and-hold strategy. Finally, the rank of the risk of buy-and-hold strategy is 9^{th} over 64 strategies. Even though the risk of buy-and-hold (50/50) is lower than the risk of buy-and-hold (60/40), but the rank of the risk of buy-and-hold (50/50) increases. The minimum risk belongs to 30 percent/daily (10.61%), 30 percent/monthly (10.66%), 30 percent/semi-annually (10.68%), and 30 percent/ quarterly (10.70%). The hypothesis 2 is supported with time& threshold strategies.

(c) Bond Fund - 40% stock/ 60% bonds

Table 4.3(c): 12-Month Average Standard Deviation of Portfolio (40/60) using Different Rebalancing Bands (December 1992 – December 2012)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	10.12	10.12	10.12	10.12	10.12	10.12	10.12
Daily	10.10	10.13	10.27	10.10	10.23	10.04	9.74
Monthly	10.24	10.23	10.24	10.13	10.05	9.97	9.92
Quarterly	10.12	10.06	10.04	9.91	9.89	9.83	9.76
Semi-annually	10.05	10.04	10.03	9.85	9.89	9.76	9.76
Annually	9.84	9.88	9.91	9.72	10.12	9.52	9.94
2nd-yearly	9.79	9.87	9.93	9.82	10.12	10.03	10.03
3rd-yearly	9.93	9.96	9.96	9.86	9.92	10.12	10.12
4th-yearly	9.78	9.78	9.86	9.86	9.86	10.03	10.03
5th-yearly	9.96	9.96	9.96	10.18	10.12	10.12	10.12

Table 4.3 (c) summarizes the standard deviation of time & threshold strategies for the whole period from December 31, 1992 to December 31, 2012. The 10 percent/ daily strategy has the highest 12-month average standard deviation. The risk of monthly is higher than the risk of quarterly and semi-annually for all rebalancing bands. The risk of semi-annually is lower than the risk of buy-and-hold strategy for all rebalancing bands. The risk of 4^{th}-yearly is lower than the risk of 3^{rd}-yearly, 5^{th}-yearly and buy-and-hold strategies for all rebalancing bands. For the case 0 percent, monthly and quarterly rebalancing strategies have higher risk than all other rebalancing bands of the same interval, respectively, including the buy-and-hold strategy. However, the risk of 2^{nd}-yearly is lower than the risk of other rebalancing bands of the same interval including the buy-and-hold strategy. For the case 10 percent, the risk of daily is higher than the risk of other rebalancing bands of the same interval including the buy-and-hold strategy. For the case 15 percent, the risk of 3^{rd}-yearly and 5^{th}-yearly are

opposite as compared with other rebalancing bands. The risk of 15 percent/3rd-yearly is lower than the risk of other rebalancing bands of the same interval including buy-and-hold strategy. The risk of 15 percent/5th-yearly is higher than the risk of other rebalancing bands of the same interval including the buy-and-hold strategy. For the case 20 percent, the risk of annually and 2nd-yearly is higher than the risk of other rebalancing bands of the same interval, respectively, including the buy-and-hold strategy. For the case 25 percent, the risk of annually is lower than the risk of other rebalancing bands of the same interval including buy-and-hold strategy. For the case 30 percent, the risk of daily, monthly, and quarterly is lower than the risk of other rebalancing bands of the same interval, respectively, including buy-and-hold strategy. Finally, the rank of the risk of buy-and-hold strategy is 12th over 64 strategies. The minimum risk belongs to 25 percent/ annually (9.52%), 15 percent/ annually (9.72%), and 30 percent/ daily (9.74%). The risk of buy-and-hold strategy 40/60 (10.12%) is lower than the risk of buy-and-hold strategy 50/50 (11.12%), and is lower than the risk of buy-and-hold strategy 60/40 (12.35%). As we increase the allocation for the bonds, the risk of our portfolios decreases. Hypothesis 2 is slightly supported with our time & threshold strategies.

4.3 Sharpe Ratio of Time Rebalancing

The Sharpe ratio describes how well the return-risk of the financial asset. The Sharpe ratio is used to evaluate the performance of a portfolio. The greater the portfolio's Sharpe ratio, the better the risk-adjusted performance. Table 4.1(d) reports the Sharpe ratio of periodic rebalancing of asset allocations of 60/40, 50/50, and 40/60 respectively

(equity/bond). For all portfolios, the highest Sharpe ratio was for 2nd-yearly rebalancing strategy.

Table 4.1(d): Risk-Adjusted Performance of the Period on Time Rebalancing (December 1992 – December 2012)

Look Intervals	Sharpe Ratio		
	60/40	50/50	40/60
Buy-and-hold	0.23	0.28	0.34
Daily	0.26	0.32	0.38
Monthly	0.24	0.29	0.35
Quarterly	0.25	0.31	0.37
Semi-annually	0.24	0.30	0.36
Annually	0.26	0.32	0.38
2nd-yearly	0.27	0.33	0.39
3rd-yearly	0.24	0.29	0.35
4th-yearly	0.24	0.30	0.36
5th-yearly	0.25	0.30	0.36

In the next section, we will discuss how buy-and-hold strategy performs risk-return on threshold rebalancing as compared with other strategies.

4.4 Sharpe Ratio for Threshold Rebalancing

Table 4.1(e): Sharpe Ratio of Threshold Rebalancing (December 1992 – December 2012)

Asset Allocation (equity/bond)	Sharpe Ratio							
	Buy-and-hold	0%	5%	10%	15%	20%	25%	30%
60/40	0.23	0.26	0.25	0.25	0.25	0.26	0.28	0.25
50/50	0.28	0.32	0.31	0.30	0.32	0.29	0.32	0.35
40/60	0.34	0.38	0.37	0.36	0.37	0.37	0.35	0.39

Table 4.1(e) reports Sharpe ratio for various threshold rebalancing strategy for various portfolio allocations (60/40, 50/50, and 40/60). The results show that Sharpe ratio was highest for 30 percent rebalancing strategy.

This chapter presents the results of empirical investigation about various time and threshold rebalancing strategies. Based on the Sharpe ratio of portfolio's, 2nd annually rebalancing strategy has the highest return-risk. But the difference between this strategy and buy-and-hold is minimal (0.39). Given monitoring and other costs, the results of 2nd annually rebalancing strategy cannot be considered significantly different from buy-and-hold. Similar results are evident when we extend the analysis to risk and Sharpe ratio (portfolio management measure).

CHAPTER V

BUSINESS CYCLES AND PORTFOLIO REBALANCING

This chapter discusses the performance of portfolio rebalancing outcomes for the trending markets based on 60/40, 50/50, and 40/60 (stocks/bonds) during 20 years from December 31, 1992 to December 31, 2012. This chapter is organized as follows: Section 1 discusses return performance of portfolio on expansion markets; and Section 2 discusses return performance of portfolio contraction market.

When the economic goes down, investors tend to exit the stock market and drive stock prices lower. On the other hand, when the economic goes up, investors tend to enter the stock market and drive stock prices higher. By moving money in or out of the stock market (portfolio rebalancing) because of future profit (or loss), the investors are likely one of the factors which affect the stock market.

5.1 Performance portfolios on expansion markets

Based on the National Bureau of Economic Research, there are three expansion markets during December 1992 – December 2012. We will compare the return of buy-and-hold strategy with other combined rebalancing strategies of interval (daily, monthly, quarterly, semi-annually, annually, 2^{nd}-yearly, 3^{rd}-yearly, 4^{th}-yearly, and 5^{th}-yearly) and rebalancing bands (0 percent, 5 percent, 10 percent, 15 percent, 20 percent, 25 percent, and 30 percent). The comparison will take place with each asset allocation for different expansion periods.

- Expansion 1 (99 months): December 31 1992 – March 31 2001.
- Expansion 2 (73 months): December 01 2001 – December 31 2007.
- Expansion 3 (42 months): July 01 2009 – December 31 2012.

5.1.1. Expansion 1: 99 months (December 31 1992 – March 31 2001)

By investing the initial amount of $10 million dollars with $20 per trading cost, our results show that geometric return of buy-and-hold strategy does not outperform any rebalancing strategies'.

Table 5.1.1(a): 12-Month Average Geometric Return of Portfolio (60/40) on expansion 1 (December 31 1992 – March 31 2001)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	11.55	11.55	11.55	11.55	11.55	11.55	11.55
Daily	11.79	11.78	11.84	11.81	11.71	11.90	12.12
Monthly	11.76	11.77	11.86	11.86	11.74	11.90	12.14
Quarterly	11.84	11.82	11.86	11.91	11.74	11.90	12.14
Semi-annually	11.77	11.90	11.82	11.91	11.71	12.14	12.14
Annually	11.88	11.92	11.98	11.97	11.74	12.41	12.41
2nd-yearly	11.66	11.64	11.74	11.74	11.74	11.55	11.55
3rd-yearly	11.80	11.74	11.74	11.74	11.74	11.55	11.55
4th-yearly	11.64	11.64	11.73	11.73	11.73	11.55	11.55
5th-yearly	11.59	11.59	11.59	11.55	11.55	11.55	11.55

We can see that buy-and-hold strategy has the same geometric return with some strategies on 2^{nd}, 3^{rd}, 4^{th}, and 5^{th}-yearly rebalancing strategies. However, buy-and-hold strategy does not outperform any rebalancing strategies in expansion 1. We will take a look the results at 50/50 (equity/bond) asset allocation below.

Table 5.1.1(b): 12-Month Average Geometric Return of Portfolio (50/50) on expansion 1 (December 31 1992 – March 31 2001)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	11.27	11.27	11.27	11.27	11.27	11.27	11.27
Daily	11.52	11.69	11.73	11.69	11.55	11.80	12.17
Monthly	11.49	11.51	11.59	11.78	11.56	11.90	12.19
Quarterly	11.57	11.57	11.65	11.47	11.65	11.90	12.19
Semi-annually	11.50	11.57	11.65	11.44	11.90	11.90	12.19
Annually	11.62	11.65	11.72	11.48	12.19	12.19	12.19
2nd-yearly	11.39	11.37	11.48	11.48	11.27	11.27	11.27
3rd-yearly	11.54	11.48	11.48	11.48	11.27	11.27	11.27
4th-yearly	11.36	11.36	11.47	11.47	11.27	11.27	11.27
5th-yearly	11.32	11.32	11.32	11.27	11.27	11.27	11.27

When we change asset allocation from (60/40) to (50/50), the geometric return of buy-and-hold strategy slight decreases from 11.55% to 11.27%. However, its geometric return does not outperform any other rebalancing strategies'. Next, we change the asset allocation to (40/60) in order to see the comparison.

Table 5.1.1(c): 12-Month Average Geometric Return of Portfolio (40/60) on expansion 1 (December 31 1992 – March 31 2001)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	10.99	10.99	10.99	10.99	10.99	10.99	10.99
Daily	11.23	11.18	11.27	11.26	11.12	11.26	11.48
Monthly	11.20	11.24	11.33	11.30	11.19	11.28	11.45
Quarterly	11.28	11.22	11.30	11.35	11.19	11.36	11.61
Semi-annually	11.21	11.34	11.26	11.35	11.16	11.61	11.61
Annually	11.32	11.36	11.43	11.43	11.19	11.89	11.89
2nd-yearly	11.10	11.09	11.19	11.19	11.19	10.99	10.99
3rd-yearly	11.25	11.19	11.19	11.19	11.19	10.99	10.99
4th-yearly	11.08	11.08	11.18	11.18	11.18	10.99	10.99
5th-yearly	11.04	11.04	11.04	11.04	10.99	10.99	10.99

When we change asset allocations from (50/50) to (40/60), the geometric return of buy-and-hold strategy decreases from 11.27% to 10.99%. However, its rank does not improve. Buy and-hold strategy does not outperform any other rebalancing strategies. The hypothesis 5 is definitely not supported in expansion 1. We do the same investigation for expansion 2 (December 01 2001 – December 31 2007).

5.1.2. Expansion 2: 73 months (December 01 2001 – December 31 2007)

We have the same initial investment amount $10 million dollars and $20 per trading cost. Our results show that buy-and-hold strategy slight outperforms than few rebalancing strategies. The specific results will be discussed for each asset allocation below.

Table 5.1.2(a): 12-Month Average Geometric Return of Portfolio (60/40) on expansion 2 (December 01 2001 – December 31 2007)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	5.62	5.62	5.62	5.62	5.62	5.62	5.62
Daily	5.98	5.96	5.76	5.98	5.91	6.05	6.34
Monthly	5.90	5.86	5.94	5.77	6.28	6.12	5.62
Quarterly	5.87	5.94	5.98	5.77	6.35	6.18	5.62
Semi-annually	5.82	5.85	5.84	5.75	5.99	5.62	5.62
Annually	5.73	5.75	5.75	5.75	5.62	5.62	5.62
2nd-yearly	5.70	5.70	5.70	5.62	5.62	5.62	5.62
3rd-yearly	5.67	5.67	5.67	5.62	5.62	5.62	5.62
4th-yearly	5.66	5.66	5.66	5.62	5.62	5.62	5.62
5th-yearly	5.62	5.62	5.62	5.62	5.62	5.62	5.62

Terminal asset value of buy-and-hold strategy ($13,948,221.25) is slightly $2,225.11 higher than 0 percent, 5 percent, and 10 percent/5^{th}-yearly rebalancing strategies ($13,945,996.14). On the other hand, buy-and-hold strategy has the same geometric return

with some rebalancing strategies, while other strategies outperforms than buy-and-hold strategy. We will change the asset allocation to (50/50) to investigate the comparison.

Table 5.1.2(b): 12-Month Average Geometric Return of Portfolio (50/50) on expansion 2 (December 01 2001 – December 31 2007)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	5.92	5.92	5.92	5.92	5.92	5.92	5.92
Daily	6.30	6.22	6.29	6.13	6.36	6.68	5.92
Monthly	6.21	6.19	6.19	6.48	6.43	5.92	5.92
Quarterly	6.18	6.29	6.17	6.67	6.49	5.92	5.92
Semi-annually	6.12	6.19	6.14	6.45	5.92	5.92	5.92
Annually	6.03	6.05	6.05	5.92	5.92	5.92	5.92
2nd-yearly	5.99	6.00	6.00	5.92	5.92	5.92	5.92
3rd-yearly	5.96	5.96	5.96	5.92	5.92	5.92	5.92
4th-yearly	5.96	5.96	5.96	5.92	5.92	5.92	5.92
5th-yearly	5.91	5.91	5.92	5.92	5.92	5.92	5.92

Terminal asset value of buy-and-hold strategy ($14,186,428.65) is slightly $2,316.09 higher than 0 percent and 5 percent/ 5^{th}-yearly rebalancing strategies ($14,184,112.56). The result is quite similar with the case (60/40) when some rebalancing strategies outperform buy-and-hold strategy, and some strategies have the same geometric return with buy-and-hold strategy's. The next asset allocation (40/60) will be investigated below.

Table 5.1.2(c): 12-Month Average Geometric Return of Portfolio (40/60) on expansion 2 (December 01 2001 – December 31 2007)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	6.21	6.21	6.21	6.21	6.21	6.21	6.21
Daily	6.57	6.57	6.35	6.48	6.68	6.95	6.21
Monthly	6.49	6.46	6.52	6.35	6.86	6.75	6.21
Quarterly	6.46	6.52	6.57	6.35	6.93	6.75	6.21
Semi-annually	6.40	6.43	6.43	6.33	6.71	6.21	6.21
Annually	6.31	6.33	6.33	6.33	6.21	6.21	6.21
2nd-yearly	6.28	6.29	6.28	6.21	6.21	6.21	6.21
3rd-yearly	6.25	6.25	6.25	6.21	6.21	6.21	6.21
4th-yearly	6.24	6.24	6.24	6.21	6.21	6.21	6.21
5th-yearly	6.20	6.20	6.21	6.21	6.21	6.21	6.21

Terminal asset value of buy-and-hold strategy ($14,424,636.06) is slightly $2,225.14 higher than 0 percent and 5 percent/ 5^{th}-yearly rebalancing strategies ($14,422,410.91). The result is similar with the case (60/40) when some rebalancing strategies outperform buy-and-hold strategy, and some strategies have the same geometric return with buy-and-hold strategy's. As a result, hypothesis 5 is slight not supported by our investigation when most rebalancing strategies outperform than buy-and-hold strategy for expansion 2.

5.1.3. Expansion 3: 42 months (July 01 2009 – December 31 2012)

Having initial investment amount of $10 million dollars and $20 per trading cost for 42 months in expansion period from July 01 2009 to December 31 2012, our results show that buy-and-hold strategy does not outperform any rebalancing strategy. The results is similar as compared with the results in expansion 1.

Table 5.1.3(a): 12-Month Average Geometric Return of Portfolio (60/40) on expansion 3 (July 01 2009 – December 31 2012)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	13.55	13.55	13.55	13.55	13.55	13.55	13.55
Daily	14.45	14.37	14.08	13.55	13.55	13.55	13.55
Monthly	14.10	14.11	13.83	13.55	13.55	13.55	13.55
Quarterly	14.40	14.45	14.39	13.55	13.55	13.55	13.55
Semi-annually	14.10	14.08	13.55	13.55	13.55	13.55	13.55
Annually	13.89	13.81	13.55	13.55	13.55	13.55	13.55
2nd-yearly	13.79	13.79	13.55	13.55	13.55	13.55	13.55
3rd-yearly	13.56	13.55	13.55	13.55	13.55	13.55	13.55

As can be seen, most rebalancing strategies have the same geometric return as compared with buy-and-hold strategy, and no rebalancing strategy underperforms than buy-and-hold strategy. This result is not different as compared with expansion 1. We also check the result when asset allocation is changed to 50/50 (equity/bond).

Table 5.1.3(b): 12-Month Average Geometric Return of Portfolio (50/50) on expansion 3 (July 01 2009 – December 31 2012)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	13.64	13.64	13.64	13.64	13.64	13.64	13.64
Daily	14.57	14.38	14.02	13.64	13.64	13.64	13.64
Monthly	14.20	14.37	13.99	13.64	13.64	13.64	13.64
Quarterly	14.51	14.57	13.64	13.64	13.64	13.64	13.64
Semi-annually	14.21	14.18	13.64	13.64	13.64	13.64	13.64
Annually	13.99	13.90	13.64	13.64	13.64	13.64	13.64
2nd-yearly	13.88	13.88	13.64	13.64	13.64	13.64	13.64
3rd-yearly	13.64	13.64	13.64	13.64	13.64	13.64	13.64

The geometric return of buy-and-hold strategy increases slightly from 13.55% (60/40) to 13.64% (50/50). However, buy-and-hold strategy does not outperform any rebalancing strategy, and most rebalancing strategies have the same geometric return as compared with buy-and-hold strategy. We change the asset allocation to 40/60 (equity/bond) to find different results.

Table 5.1.3(c): 12-Month Average Geometric Return of Portfolio (40/60) on expansion 3 (July 01 2009 – December 31 2012)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	13.72	13.72	13.72	13.72	13.72	13.72	13.72
Daily	14.61	14.57	14.19	13.72	13.72	13.72	13.72
Monthly	14.26	14.27	13.99	13.72	13.72	13.72	13.72
Quarterly	14.55	14.61	14.54	13.72	13.72	13.72	13.72
Semi-annually	14.26	14.24	13.72	13.72	13.72	13.72	13.72
Annually	14.06	13.97	13.72	13.72	13.72	13.72	13.72
2nd-yearly	13.95	13.95	13.72	13.72	13.72	13.72	13.72
3rd-yearly	13.72	13.72	13.72	13.72	13.72	13.72	13.72

When we change asset allocation from (50/50) to (40/60), the geometric return of buy-and-hold strategy increases slightly from 13.64% to 13.72%. However, buy-and-hold strategy does not outperform any rebalancing strategy.

As a result, hypothesis 5 is highly not supported in expansion 1 and expansion 3 when buy-and-hold strategy does not outperform any rebalancing strategy. For expansion 2, hypothesis 5 is slight not supported when few rebalancing strategies slightly outperform than buy-and-hold strategy. We will find the results of hypothesis 5 for the contraction period in the next section.

5.2 Performance portfolios on contraction market

Based on the National Bureau of Economic Research, there are two contraction markets during December 1992 – December 2012.

- Contraction 1 (8 months): April 01 2001 – November 31 2001
- Contraction 2 (18 months): January 01 2008 – June 30 2009

Due to short period of time (less than one year of contraction 1), we just find the result for the contraction 2. We will compare the return of buy-and-hold strategy with other combined rebalancing strategies of intervals (daily, monthly, quarterly, semi-annually, and annually) and rebalancing bands (0 percent, 5 percent, 10 percent, 15 percent, 20 percent, 25 percent, and 30 percent). The comparison will take place with each asset allocation for contraction 2.

Table 5.2.1(a): 12-Month Average Geometric Return of Portfolio (60/40) in contraction 2 (January 01 2008 – June 30 2009)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	-14.22	-14.22	-14.22	-14.22	-14.22	-14.22	-14.22
Daily	-13.87	-14.40	-14.80	-14.57	-14.03	-14.63	-14.10
Monthly	-15.21	-15.03	-14.54	-14.83	-14.52	-14.52	-13.79
Quarterly	-14.66	-14.34	-13.79	-13.79	-13.79	-13.79	-13.79
Semi-annually	-14.42	-14.42	-13.79	-13.79	-13.79	-13.79	-13.79
Annually	-13.79	-13.79	-13.79	-13.79	-13.79	-13.79	-13.79

By investing the initial amount of $10 million dollars and $20 per trading costs for the contraction period from January 01 2008 to June 30 2009, we can see that all strategies get the negative geometric returns. It is surprised that all rebalancing bands of annually

strategy have the same negative geometric return. Half of rebalancing strategies (18 over 36 scenarios) have the same highest geometric return of -13.79%. The geometric return of buy-and-hold strategy is 22th over 36 scenarios. Hypothesis 5 is not supported here because many rebalancing strategies outperforms than buy-and-hold strategy.

Table 5.2.1(b): 12-Month Average Geometric Return of Portfolio (50/50) in contraction 2 (January 01 2008 – June 30 2009)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	-11.37	-11.37	-11.37	-11.37	-11.37	-11.37	-11.37
Daily	-10.93	-11.45	-11.76	-11.42	-11.80	-10.46	-9.94
Monthly	-12.39	-12.22	-12.00	-11.68	-11.68	-10.94	-9.67
Quarterly	-11.82	-11.58	-10.94	-10.94	-10.94	-10.94	-11.37
Semi-annually	-11.58	-11.58	-10.94	-10.94	-10.94	-10.94	-11.37
Annually	-10.94	-10.94	-10.94	-10.94	-10.94	-10.94	-11.37

When we change asset allocation from (60/40) to (50/50), the geometric return of buy-and-hold strategy improves from -14.22% to -11.37%. As a result, its rank increases from 22^{th}/36 to 20^{th}/36 scenarios. Almost half rebalancing strategies outperform buy-and-hold strategy in contraction 2. Hypothesis 5 is not supported here also.

Table 5.2.1(c): 12-Month Average Geometric Return of Portfolio (40/60) in contraction 2 (January 01 2008 – June 30 2009)

	Rebalance Bands (%)						
	0%	5%	10%	15%	20%	25%	30%
Buy-and-hold	-8.58	-8.58	-8.58	-8.58	-8.58	-8.58	-8.58
Daily	-8.09	-8.36	-9.10	-8.89	-7.30	-8.46	-7.71
Monthly	-9.53	-9.37	-8.84	-9.16	-8.87	-8.16	-8.16
Quarterly	-8.99	-8.77	-8.16	-8.16	-8.16	-8.16	-8.16
Semi-annually	-8.77	-8.77	-8.16	-8.16	-8.16	-8.16	-8.16
Annually	-8.16	-8.16	-8.16	-8.16	-8.16	-8.16	-8.16

As can be seen, geometric return of buy-and-hold improves from -11.37% to -8.58%, and its terminal value asset is $8.74 million dollars at the end of contract 2. However, the rank of buy-and-hold strategy decreases from 20^{th} to 25^{th} over 36 scenarios. Other rebalancing strategies still have better geometric return than buy-and-hold strategy. It leads to hypothesis 5 is not supported here.

If the prices go up every period in upward markets, rebalancing strategies keep selling outperformers and investing proceeds in underperformers. The buy-and-hold strategy will have better returns as compared with other rebalancing strategies. On the other hand, if the prices go down every period in downward markets, rebalancing strategies keep buying assets which their prices are falling. The buy-and-hold strategy will also have better return as compared with other rebalancing strategies. In other words, rebalancing strategies generate less return than buy-and-hold strategy in trending markets (Tokat, 2007; Collins, 2005). However, the prices do not always go up or go down in trending markets. They sometimes go down in upward markets, and they also sometimes go up in downward markets. The rebalancing strategies can still captures buy-low/sell-high opportunities in both upward and downward markets to outperform buy-and-hold strategy. As a result, hypothesis 5 is not supported by our empirical results.

From our results, we can see that the return of most rebalancing strategies perform better than buy-and-hold strategy in business cycles. The optimal rebalancing strategy changes for each period. In expansion 1, the optimal rebalancing strategy is either 25 percent/annually or 30 percent/annually. In expansion 2, we recommend 20 percent/quarterly

as the optimal rebalancing strategy. In expansion 3, we recommend either 0 percent/daily or 5 percent/quarterly as the optimal strategy. Our findings is different as compared with Harjoto and Jones (2006) when they conclude that 15 percent threshold rebalancing outperforms than other rebalancing strategies including buy-and-hold strategy during boom and bust markets. Our findings recommend that no strategy usually generates superior returns during the study. The optimal strategy is different for each period because it is impossible to have a "one-size-fits-all" rule for rebalancing strategies.

CHAPTER VI

CONCLUSIONS

The need for portfolio rebalancing and its impacts is a controversial area in investment management. On the one side, protagonists of portfolio rebalancing argue that there is value for portfolio's which are managed actively. Moreover they argue by rebalancing, the investors can ensure that their portfolios are at desired risk and return levels. On the other hand, protagonists of passive investment strategy argue against active management of portfolio's as they argue that purchase portfolio rebalancing leads to higher transaction costs to investors and ultimately investors pay 'larger on large' fees and loose in the long term. In this study, we examine this debate by using data for 20 years with respect to U.S. which is the home of many prominent funds investment.

Periodic rebalancing strategies with short intervals (such as rebalance daily, weekly, or bi-weekly) or threshold rebalancing strategies with narrow bands (such as rebalancing 1%, 2%, or 3%) require many trade numbers, and lead to high transaction costs. On the other hand, periodic rebalancing strategies with long intervals (such as rebalance 3^{rd}-yearly, 4^{th}-yearly, 5^{th}-yearly) or threshold rebalancing strategies with wide bands (such as 20%, 25%, 30%, etc.) require few numbers of trade and may miss buy-low/sell high opportunities, leading to inferior returns (Donohue and Yip, 2003). By investigating various portfolios, we see that our findings are similar with Lovell and Arnott (1989), Tsai (2001), Daryanani (2008), Lee (2008).

First, although the return of buy-and-hold strategy is slightly higher than some of the rebalancing strategies' (such as 20 percent/3rd-yearly, 25 percent/3rd-yearly, 15 percent/5th-yearly) in the 20 year period, generally rebalancing strategies based on annual and 2nd annually based on rebalance bands of 5-15 per cent generally outperform buy-and hold strategies. This validates hypothesis 1.

Second, majority rebalancing strategies have slightly lower risk than buy-and-hold strategy supporting hypothesis 2 that the rebalancing strategies results is lower risk than buy-and-hold strategy. The lowest risk belongs to 25 percent/annually, 30 percent/daily, or 30 percent/annually strategy.

Thirdly, buy-and-hold strategy has the lowest risk-reward as compared with other periodic strategies, and the highest Sharpe ratio belongs to 2nd-yearly strategy of periodic rebalancing. In addition, portfolio rebalancing based on certain threshold choice performs better buy-and-hold strategy in the long run. The highest risk-reward strategy belongs to 30 percent threshold strategy.

Fourthly, the return of buy-and-hold strategy is only greater than the return of 0 percent/5th-yearly, 5 percent/5th-yearly, and 10 percent/5th-yearly in expansion 2. The return of buy-and-hold strategy is not higher than any return of rebalancing strategies in expansion 1 and expansion 3. Therefore, hypothesis 5 "The returns of rebalancing strategies in trending markets underperform than the buy-and-hold strategy" is not supported in the expansion periods. Hypothesis 5 is also not supported in the contraction period.

Based on the returns and the risk of the portfolios during the 20 year period, we recommend the optimal rebalancing strategies for investors are either 25 percent/annually or 30 percent/annually. On the other hand, the rank of portfolio rebalancing's returns in trending markets (expansion and contraction markets) is not uniform. Each expansion and contraction period requires different strategies. In expansion periods, the returns of buy-and-hold strategy outperforms 0 percent/5^{th}-yearly, 5 percent/5^{th}-yearly, and 10 percent/5^{th}-yearly a few times. In contraction period, almost half rebalancing strategies have less return than buy-and-hold strategy. These results call into question the virtues of portfolio rebalancing strategies vis-à-vis buy-and-hold strategy.

There is no strategy which consistently outperforms all other strategies, and there is no consistent winner in all periods. In other words, it is difficult to have a "one-size-fits-all" rule in the investment, especially for rebalancing strategies. The optimal strategy is different for each investor, depending on the risk tolerance (determined by wealth, income, age, tax rate, etc.).

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Appendices

Appendix 1: Summary of Research on Periodic Rebalancing

Authors	Title	Period	Indices	Conclusion
Arnott and Lovell (1992)	Rebalancing: Why? When? How Often?	1968 - 1991	50%/ 50% policy mix	After 1% trading cost, quarterly rebalancing offers the highest treynor ratio (reward/risk tradeoff), while annual rebalancing offers the lowest treynor ratio.
Stine and Lewis (1992)	Guidelines for Rebalancing Passive-Investment Portfolios	3, 5, 10, 15, 20 years	Common stocks, long term government bonds, and U.S. Treasury bills	With 5 horizons investments, the return and standard deviation of annual rebalancing are highest, while the return and standard deviation of quarterly rebalancing are lowest.
Goodsall and Plaxco (1996)	Tactical Rebalancing	1986 - 1995	MSCI indices covers: Australia, Austria, Belgium, Canada, Denmark, France, Germany, Hong Kong, Italy, Japan, the Netherlands, Norway, Singapore, Spain, Sweden, Switzerland, the United Kingdom and the United States.	The quarterly rebalancing produces the highest annualized returns and lowest standard deviation, but annualized rebalancing has lowest annualized return and highest standard deviation.
Eaker and Grant (2002)	The Wealth Effects of Portfolio Rebalancing in Emerging Equity Markets	1976 – 1998	International Finance Corporation (IFC) monthly indices for 9 countries: Argentina, Brazil, Chile, Greece, India, Korea, Malaysia, Thailand, and Zimbabwe.	Semi-annual rebalancing is optimal in this research.
Plaxco and Arnott (2002)	Rebalancing a Global Policy Benchmark	1980 – 2000	60% equity/ 40% bond of countries: Australia, Canada, EMU, France, Germany, Italy, Japan, the Netherlands, Spain, the U.K., and the U.S.	Both quarterly and annual rebalancing strategies have the same annualized returns, while monthly rebalancing has lower annualized return. On the other hand, standard deviation of both monthly and quarterly rebalancing are the same, but standard

				deviation of annual rebalancing is higher. They lead to quarterly rebalancing is the optimal strategy, and annual rebalancing is the worst portfolio.
		1968 – 2000	50% equity/ 50% bond of U.S.	The quarterly rebalancing has highest annualized return and lowest standard deviation. The annualized return and standard deviation of annual rebalancing are higher than the annualized return and standard deviation of monthly rebalancing.
		1980 – 2000	50% equity/ 50% bond of countries: Australia, Canada, EMU, France, Germany, Italy, Japan, Spain, Sweden, U.K., and U.S.	The quarterly rebalancing has highest annualized return and lowest standard deviation. The annualized return and standard deviation of annual rebalancing are higher than the annualized return and standard deviation of monthly rebalancing.
Donohue and Yip (2003)	Optimal Portfolio Rebalancing with Transaction Costs	1987 - 1996	50% U.S. equities 15% non-U.S. equities 35% U.S. fixed income	The annual rebalancing portfolio provides the highest returns, while daily rebalancing produces the lowest returns. Periodic strategies with short periods often trade too frequently, increase transactions costs. The higher the returns, the higher the risk.
Daryanani (2008)	Opportunistic Rebalancing: A New Paradigm for Wealth Managers	1992 – 2004	25% S&P 500 Total Return 20% Russell 2000 Total Return 10% Dow Jones Real Estate Investment Trust	The annual rebalancing portfolio is the optimal, while the daily rebalancing produces the worst returns.

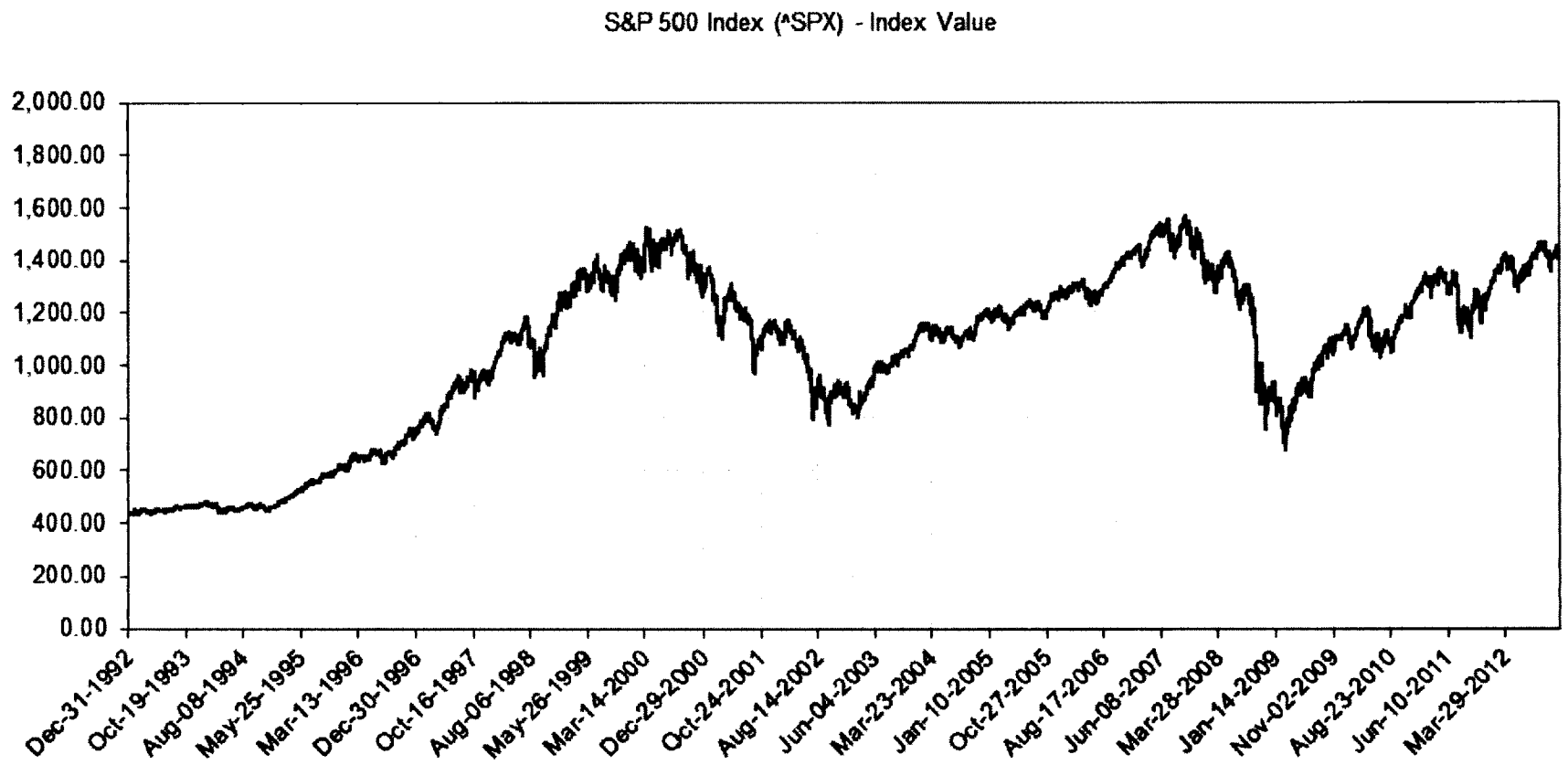
			5% Dow Jones AIG Commodity Total Return 40% bonds (Bloomberg 7-10 Total Return)	
Lee (2008)	Rebalancing and Return	February 1996 – December 2004	25% S&P 500 Index 20% Russell 2000 Index 10% Dow Jones Wilshire U.S. REIT Total Return Index 5% Dow Jones AIG Commodity Index 40% bonds (Bloomberg U.S. Government 7-10 Year Index)	The annual rebalancing portfolio produces the highest average annual geometric return, while the daily rebalancing has the worst returns.
Jaconetti et al. (2010)	Best Practices for Portfolio Rebalancing	1926 - 2009	- 60% stocks S&P 90 (1926 – 1957) S&P 500 (1957 – 2005) MSCI U.S. Broad Market Index (2005 – 2009) -40% bonds S&P High Grade Corporate Index (1926 – 1968) Citigroup High Grade Index (1969 – 1972) Lehman Long-term AA Corporate Index (1973 – 1975) Barclays Capital U.S. Aggregate Bond Index (1976 – 2009)	The quarterly and annually rebalancing strategies provide the highest average annualized return, but annually rebalancing strategy has the lowest standard deviation. It leads to annually rebalancing strategy is the optimal strategy.

Appendix 2: Summary of Research on Threshold Rebalancing

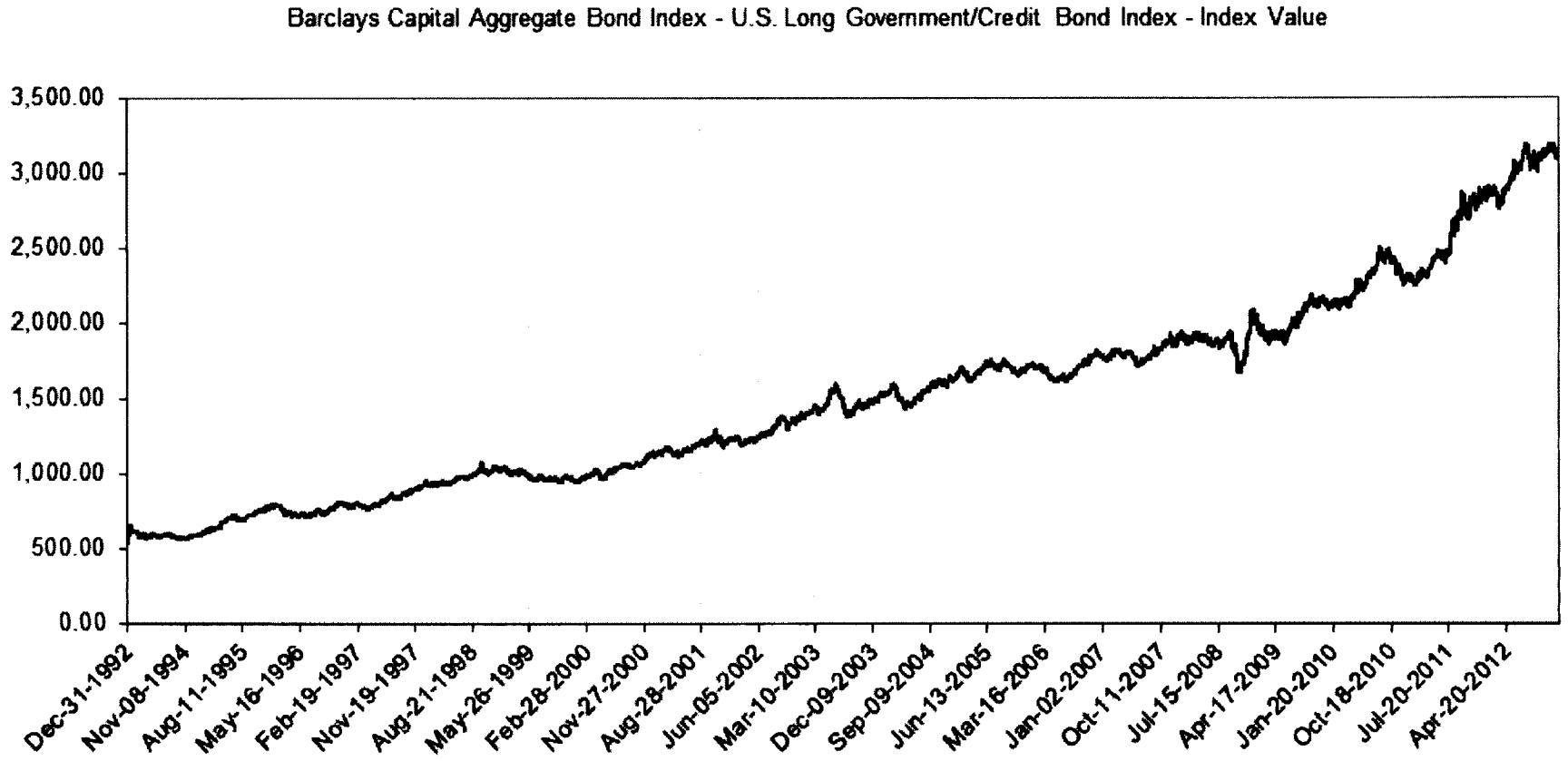
Authors	Title	Period	Indices	Conclusion
Arnott and Lovell (1992)	Rebalancing: Why? When? How Often?	1968 - 1991	50%/ 50% policy mix	After 1% trading cost, 5% threshold provides the optimal strategy with highest average annual return and lowest standard deviation. On the other hand, 1% threshold is the worst portfolio with lowest average return and highest standard deviation.
Stine and Lewis (1992)	Guidelines for Rebalancing Passive-Investment Portfolios	3, 5, 10, 15, 20 years	Common stocks, long term government bonds, and U.S. Treasury bills	The threshold from 7.5% to 10% provides less risk exposure than annual rebalancing, requires less rebalances and lower transaction costs for the portfolio. Rebalancing with 12.5% to 15% threshold is cheaper than rebalancing with 7.5% to 10%, but the portfolio will have more risk.
Harris (2000)	Disciplined Rebalancing: Friend or Foe?	1st quarter 1970 – 1st quarter 2000	35% U.S. large cap (S&P 500) 5% U.S. small cap (Ibbotson small company stocks) 20% non-U.S. equity (MSCI EAFE) 40% U.S. fixed income (LB Aggregate)	Harris estimated the optimal rebalancing method as below: U.S. large cap: +/- 6% U.S. small cap: +/- 1% Non-U.S. equity: +/- 1% U.S. fixed income: +/- 3%
Donohue and Yip (2003)	Optimal Portfolio Rebalancing with Transaction Costs	1987 - 1996	50% U.S. equities 15% non-U.S. equities 35% U.S. fixed income	The 15% threshold rebalancing has the highest annual return, while the 1% threshold rebalancing has the lowest one. Wider threshold can lead significant tracking error, and increase the returns. The higher the returns, the higher the

				standard deviation.
Harjoto and Jones (2006)	Rebalancing Strategy for Stocks and Bonds Asset Allocation	1995 - 2004	60% S&P 500 Index 40% Lehman Bond Aggregate Index	The 15% threshold rebalancing strategy has the highest average return and lowest standard deviation. It makes this strategy has the highest Sharpe ratio.
Jaconetti et al. (2010)	Best Practices for Portfolio Rebalancing	1926 - 2009	- 60% stocks S&P 90 (1926 – 1957) S&P 500 (1957 – 2005) MSCI U.S. Broad Market Index (2005 – 2009) -40% bonds S&P High Grade Corporate Index (1926 – 1968) Citigroup High Grade Index (1969 – 1972) Lehman Long-term AA Corporate Index (1973 – 1975) Barclays Capital U.S. Aggregate Bond Index (1976 – 2009)	The authors tested 4 times, and the 10% threshold provides the best average annualized return of 3 times, and has highest volatility of 4 times.

Appendix 3(a): S&P 500 Index from December 1992 – December 2012



Appendix 3(b): Barclays Capital Aggregate Bond Index from December 1992 to December 2012



Appendix 4: Historical Scenarios during December 1992 – December 2012

From	To	Scenario
01 Sep 1992	13 Aug 1993	**1992 - 1993 European Currency Crisis**
		Upon Germany's reunification, the German mark appreciated rapidly which destabilized the exchange rates between the European countries under the European Monetary System. It led to a series of European currencies devaluation, interest rate increases and exchange rates' range widening in 1992.
31 Jan 1994	13 Dec 1994	**1994 US Rate Hike**
		In combating inflation, the U.S. Federal Reserve raised its interest rate from 3.25% in February to 5.5% in November 1994.
20 Dec 1994	27 Dec 1994	**1994 Mexican Peso Crisis**
		A combination of the Mexican government devaluing the peso, the Mexican presidential election candidate's assassination, its large current account deficit and high debt level, and the U.S.'s interest rate hikes sent the Mexican peso sharply lower.
01 Jul 1995	30 Aug 1995	**1995 US Dollar Rally**
		Under a high Fed fund rate of 6% in 1995, the U.S. dollar rebounded sharply after hitting a trough in June.
08 Jan 1997	16 Feb 1999	**1997 - 1999 Oil Price Decline**
		The combined effects of oversupplying OPEC production and lower oil demand due to the Asian economic crisis sent oil prices into a downward spiral.
01 Jul 1997	09 Jan 1998	**1997 - 1998 Asian Financial Crisis**
		As the Thai baht began to collapse after the Thai government floated the baht, the crisis spread rapidly throughout Asia, resulting in severe equities and currencies selloffs across the Asian markets.
20 Oct 1997	23 Oct 1997	**1997 Hong Kong Economic Turmoil**
		Hong Kong's share prices and property prices collapsed during the Asian financial crisis in mid-1997.
27 Oct 1997	27 Oct 1997	**1997 Mini Crash**
		A mini Asian market crash led by the collapse of the Hong Kong Hang Seng Index occurred in Oct 27, 1997 during the 1997-1998 Asian financial crisis.
17 Nov 1997	17 Nov 1997	**1997 Hokkaido Takushoku Bank Failure**
		As the Japanese real estate bubble collapsed, the heavily indebted Hokkaido Takushoku Bank declared bankrupt in 17 November after its liquidity dried up and failed to obtain more capital for operating its business.
15 Aug 1998	15 Aug 1998	**1998 Hong Kong Interest Rate Raise**
		After the Asian financial crisis, Hong Kong increased its interest rate to 3.12% to catch up with the rising U.S. interest rate and to fend off speculative attack on the Hong Kong Dollar.
17 Aug 1998	21 Sep 1998	**1998 Russian Financial Crisis**
		The financially distressed Russian government due to expanding deficit devalued the ruble and defaulted on its government bonds in August 1998, thus causing huge losses in many financial institutions worldwide.
06 Oct 1998	06 Oct 1998	**1998 Japanese Yen Sell-Off**
		Amid higher credit risk and weaker economic and investment growth in 1998, the sluggish Japanese economy caused the

		yen to depreciate to a historical low.
07 Oct 1998	07 Oct 1998	**1998 LTCM Collapse**
		LTCM, a giant U.S. hedge fund, suffered heavy losses in its portfolio in the aftermath of the Russian debt crisis. It was subsequently bailed out by the U.S. Federal Reserve and 14 financial institutions.
1 Jan 1999	31 Jan 1999	**1999 Brazilian Real Crisis**
		The Brazilian central bank decided to devalue the real by 8% in January 1999 after it failed to defend the weakening real. The real depreciated 66% against the U.S. dollar at the end of January.
12 Jan 1999	29 Jan 1999	**1999 Brazilian Real Crisis (Peak)**
		The Brazilian central bank decided to devalue the real by 8% in January 1999 after it failed to defend the weakening real. The real depreciated 66% against the U.S. dollar at the end of January.
1 Mar 2000	20 Mar 2000	**2000 Emerging Market Decline**
		As financial crisis in emerging markets such as Brazil and Argentina permeated to other emerging countries, it resulted in similar capital outflow and falling equity markets.
03 Mar 2000	26 Jun 2002	**2000 - 2002 Argentine Economic Crisis**
		The political unrest in Argentina jeopardized its economy with its GDP declining. As the peso depreciation intensified during the crisis, the Argentina government eventually defaulted on its debts.
7 Apr 2000	14 Apr 2000	**2000 Tech Bubble**
		As a wave of internet companies experienced a rapid jump in their stock prices and reached their peak, the speculative technology bubble began to burst, which triggered a selloff in those tech companies.
10 Mar 2001	09 Oct 2002	**2001 Dot-com Slowdown**
		Upon the burst of the tech bubble in 2000, more and more internet companies went out of business as the stock market plummeted further.
5 Apr 2001	19 Apr 2001	**2001 Fed Rate Cut**
		A surprising Fed's rate cut from 5% to 4.5% in April 2001 before its regular policymaking meeting buoyed the market.
10 Sep 2001	17 Sep 2001	**2001 Sept 11**
		The U.S. stock market was closed for a week upon a series of coordinated suicide attacks upon the United States on September 11, 2001. It plunged sharply over the week upon reopening.
11 Sep 2001	17 Sep 2001	**2001 September 11 (Week)**
		The U.S. stock market was closed for a week upon a series of coordinated suicide attacks upon the United States on September 11, 2001. It plunged sharply over the week upon reopening.
28 Nov 2001	28 Nov 2001	**2001 Enron Collapse**
		The revelation of Enron Corp's false accounting practices in Oct 2001 dragged its stock prices down as well as downgraded its credit-rating to junk. Enron eventually went bankrupt in Nov 2001.
30 Apr 2002	23 Jul 2002	**2002 Accounting Scandals and WorldCom**
		After the Enron accounting scandal in 2001, more companies were revealed in a series of new accounting scandals that shook investors' confidence in the stock market. WorldCom's bankruptcy in 2002 was the largest as the scandals unfolded.
23 Aug 2002	9 Oct 2002	**2002 Equity Sell-Off**

		As the global economy gradually recovered from the aftermath of Sept 11 in 2001 and the accounting scandals in 2002, the global equity market corrected itself with a sharp fall between August and October of 2002.
10 Oct 2002	27 Nov 2002	**2002 Equity Rally**
		The global equity market rebounded for a month and a half after hitting a low in October 2002.
1 Dec 2002	30 Apr 2003	**2002 - 2003 SARS Outbreak**
		Asian markets tumbled due to the SARS outbreak of 2002 - 2003. The epidemic impacted several Asian markets negatively, prominently Hong Kong and China.
1 Mar 2003	21 Mar 2003	**2003 Iraq War**
		The invasion of allies forces, led by the U.S. into Iraq defeated the Saddam's regime in a surprisingly lighting speed eased oil demand from the allies forces significantly. The little-to-none oil field destruction by the Iraqi Army mitigated markets' anxiety on possible energy shortage, resulting in a sharp fall in oil prices.
20 Mar 2003	20 Mar 2003	**2003 Iraq War (Additional Markets)**
		The invasion of allies forces, led by the U.S. into Iraq defeated the Saddam's regime in a surprisingly lighting speed eased oil demand from the allies forces significantly. The little-to-none oil field destruction by the Iraqi Army mitigated markets' anxiety on possible energy shortage, resulting in a sharp fall in oil prices.
1 May 2003	13 Jun 2003	**2003 Bond Rally**
		Continuously sagging industrial production between late 2002 and early 2003 prompted the U.S. government in discussing fiscal and monetary stimulus to prevent possible deflation which fueled a rally in bond prices.
14 Jun 2003	31 Jul 2003	**2003 Bond Sell-Off**
		The Federal Reserve became more inclined to cutting interest rate than purchasing bonds in June 2003 under the signs of economic recovery which pushed up the yield and exacerbated the bond selloff.
08 Dec 2003	22 Dec 2003	**2003 Parmalat Default**
		Parmalat, a giant Italian-based food company, defaulted on its debt and was downgraded to 'junk' by credit rating agency. Due to the size of Parmalat's bond default and fabricated financial documents, the Italian government rushed to defend its bankruptcy.
10 Mar 2004	24 Mar 2004	**2004 Italian Equity Price Drop**
		Coinciding with the emerging market decline, a drop in Italian GDP with its negative fiscal outlook triggered a selloff in the Italian equity market.
11 Mar 2004	11 Mar 2004	**2004 Madrid Attacks**
		A terrorist bomb attacked a commuter train in Madrid, Spain, three days before Spain's general elections. The explosions killed 191 people and wounded 1,800.
05 May 2004	17 May 2004	**2004 Emerging Market Troubles**
		Emerging market plummeted in fear of rising oil price, U.S. rate hikes and weakening economic outlook.
05 May 2005	06 May 2005	**2005 GM & Ford Downgrade**
		Standard & Poor's downgraded US carmakers General Motors and Ford to 'junk' status to reflect tougher global competition in the market and slower sales of both firms' leading vehicles. The downgrades, affecting debt worth about $290bn (L152bn), are the largest cuts to junk in a single day.
07 Jul 2005	07 Jul 2005	**2005 London Bombings**

		A series of terrorist bombings in London's public transport system during the morning rush hour on 7 July 2005 which triggered panic selloff from fearful investors.
1 May 2006	31 May 2006	**2006 Emerging Market Crash**
		A number of emerging markets including Brazil, India and Argentina plunged rapidly in May 2006.
20 Sep 2006	29 Sep 2006	**2006 Amaranth Hedge Fund Collapse**
		Amaranth Advisors, LLC went bankrupt with losses amounted to $6.6 billion in September 2006, making Amaranth's collapse the largest hedge-fund debacle to have thus far occurred.
18 Jan 2007	27 Jun 2008	**2007 - 2008 Oil Price Rise**
		Oil prices spiked from around $60/barrel from 2007 to a record-high of $145/barrel on July 3, 2008.
1 Aug 2007	01 Mar 2008	**2007 - 2008 Subprime Mortgage Meltdown**
		The burst of the housing bubble in mid-2007 marked the beginning of the years-long subprime mortgage crisis, rooted from the easy credit, low interest rate and loose regulatory environment in early-2000s which made low quality (subprime) mortgaging extremely easy. The contagious meltdown quickly led to plunging asset prices in the financial markets, rising bankruptcies, delinquencies and foreclosures, central banks' monetary rescues and government's' fiscal interventions around the globe.
1 Oct 2007	27 Feb 2009	**2007 - 2009 Subprime Mortgage Meltdown (Oct. to Feb.)**
		The burst of the housing bubble in mid-2007 marked the beginning of the years-long subprime mortgage crisis, rooted from the easy credit, low interest rate and loose regulatory environment in early-2000s which made low quality (subprime) mortgaging extremely easy. The contagious meltdown quickly led to plunging asset prices in the financial markets, rising bankruptcies, delinquencies and foreclosures, central banks' monetary rescues and government's' fiscal interventions around the globe.
01 Aug 2007	31 Aug 2007	**2007 August**
		As home prices continued to fall while mortgage default rate increased during the subprime crisis, Countrywide Financial, among other mortgage lenders, was struggling with its pile of bad mortgage and suffering from its liquidity crunch. Bank of America later announced acquiring Countrywide in August.
01 Sep 2007	30 Sep 2007	**2007 September**
		Liquidity problems and credit crunches emerged in many banks and financial institutions worldwide, which were tied up with the toxic subprime mortgages. In addition to banks posting losses, a bank run in U.K.'s Northern Rock also marked the severity of the subprime mortgage meltdown. The U.S. Federal Reserve cut its interest rate for the first time in this subprime crisis.
01 Oct 2007	31 Oct 2007	**2007 October**
		As the subprime problem went deeper and housing market sank further, a consortium of U.S. banks formed a U.S. government-backed fund to purchase troubled mortgage securities while the U.S. Federal Reserve lowered its interest rate again.
01 Nov 2007	30 Nov 2007	**2007 November**
		The U.S. Federal Reserve took an emergency action by injecting $41 billion into the financial market in early-November to temporarily relief the credit crunch.

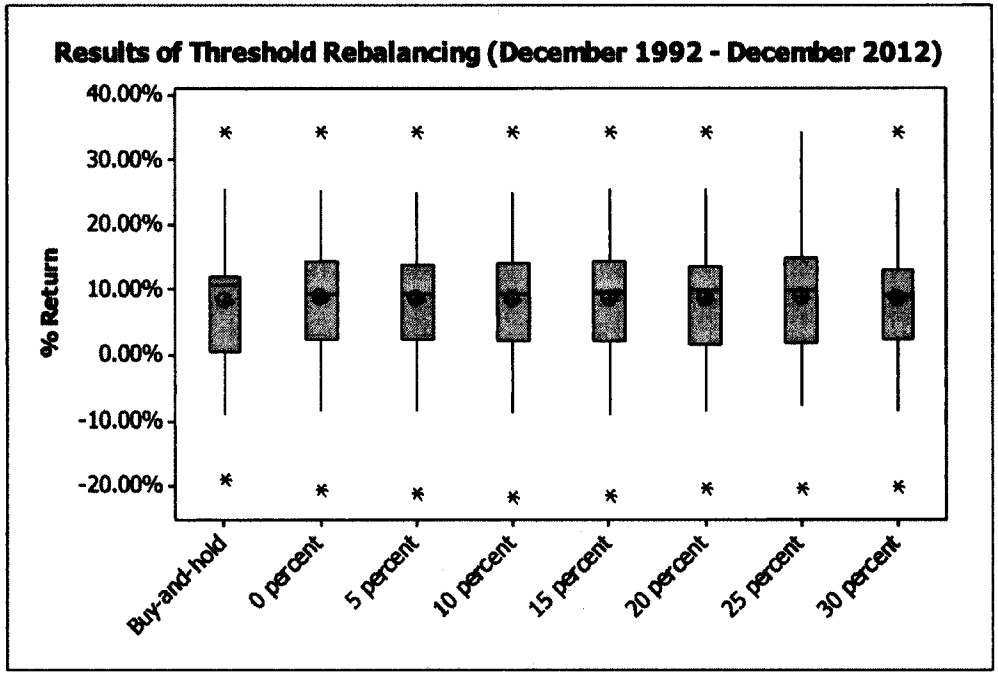
01 Dec 2007	31 Dec 2007	**2007 December**
		As housing problems exacerbated and stock markets declined further, the U.S. Federal Reserve again lowered its interest rate and injected $40 billion into the market while the U.S. government froze some mortgages under its plan to tame the crisis.
1 Jul 2007	31 Dec 2007	**2007 July - January**
		The burst of the housing bubble in mid-2007 marked the beginning of the subprime mortgage crisis. The contagious meltdown quickly led to plunging asset prices in the financial markets, rising bankruptcies, delinquencies and foreclosures, central banks' monetary rescues and governments'' fiscal interventions around the globe.
01 Jan 2008	31 Jan 2008	**2008 January**
		As mortgage delinquencies and foreclosures remained elevated amid the crisis, Bank of America finally acquired Countrywide Financial for $4 billion in January. The U.S. Federal Reserve cut the interest rate twice by a total of 1.25% to stem the battered housing market.
14 Jan 2008	22 Jan 2008	**2008 January (Peak of Crisis)**
		As mortgage delinquencies and foreclosures remained elevated amid the crisis, Bank of America finally acquired Countrywide Financial for $4 billion in January. The U.S. Federal Reserve cut the interest rate twice by a total of 1.25% to stem the battered housing market.
01 Feb 2008	29 Feb 2008	**2008 February**
		The subprime crisis hit the U.K. banking system where the U.K. government nationalized Northern Rock as its capital and credit line dried up.
01 Mar 2008	31 Mar 2008	**2008 March**
		The U.S. Federal Reserve lowered its interest rate by 0.75% to stem the weakening economy and offered J.P. Morgan a $30 billion loan for acquiring Bear Stearns.
13 Mar 2008	17 Mar 2008	**2008 Bear Stearns Collapse**
		In the heated up subprime crisis, the highly leveraged Bear Stearns fell victim when its two subprime hedge funds nearly lost all their values. Finally, the U.S. Federal Reserve bailed out Bear Stearns by loaning $30 billion to J.P. Morgan to buy up its business.
1 Jan 2008	30 Jun 2008	**2008 January - July**
		As the subprime crisis unfolded, financially distressed institutions including Countrywide Financial and Bear Stearns collapsed. The U.S. Federal Reserve cut its interest rate four times to stimulate economic growth as the global financial market faltered extensively.
1 Aug 2008	29 Aug 2008	**2008 August**
		Many financial institutions with assets heavily tied to the mortgage market were struggling amid their declining financial performances. On the other hand, the heightened geopolitical risk caused by the war between Russia and Georgia further depleted the Russian economy.
1 Sep 2008	29 Sep 2008	**2008 September**
		Severe liquidity crisis continued to plague the U.S. financial system when the heavily indebted Lehman Brothers went bankrupt upon the lack of governmental aid. At the same time, Bank of America announced its acquisition of Merrill Lynch. Soon afterwards, the U.S. Federal Reserve bailed out the mortgage-distressed AIG to allay market fear. Washington Mutual

		also filed bankruptcy soon in late September.
5 Sep 2008	20 Nov 2008	**2008 September - November**
		Since Lehman Brothers declared bankruptcy in mid-September, its debt debacle continued to haunt the global financial market as investors became increasingly uncertain when the cascade of bank failures and bankruptcies will stop. In addition to two consecutive rate cuts by the U.S. Federal Reserve in October, the U.S. Treasury also took over Fannie Mae and Freddie Mac in order to stabilize the mortgage and housing market.
1 Oct 2008	31 Oct 2008	**2008 October**
		As the financial crisis escalated further, the U.S. government set up the $700 billion Troubled Asset Relief Program (TARP) to purchase troubled assets from financial institutions while the U.S. Federal Reserve and six other central banks worldwide cut their interest rates together to cushion the market crash.
1 Jul 2008	31 Dec 2008	**2008 July - January**
		The global financial crisis continued to deteriorate in the 2nd half of 2008 with giant bankruptcy cases including Lehman Brothers, Merrill Lynch and AIG. Besides nationalizing Fannie Mae and Freddie Mac by the U.S. government to stablize the mortgage and housing market, the U.S. Federal Reserve also lowered its interest rate three times to a historical low at 0.25% in December.
20 Nov 2008	9 Mar 2009	**2008 November - March**
		With the shockwaves from the subprime crisis permeated to Asia and jeopardized the regional economies, the Chinese government announced its $4 trillion Yuan stimulus program to prevent a hard-landing in its market. Central banks in the U.S., U.K. and Europe also tried to strengthen their economies with further interest rate cuts.
2 Jan 2009	9 Mar 2009	**2009 January - March**
		Facing a deepening financial crisis, central banks such as the European Central Bank and Bank of England further cut their interest rates and stimulates their economies with quantitative easing to bolster economic growth where the stock market bottomed out in March.
1 Jan 2009	30 Jun 2009	**2009 January - July**
		Reeling from the global financial crisis, recession extended into 2009 where stock markets reached their lowest thus undermining investors' confidence in an economic recovery. The European Central Bank cut its interest rate four times to stabilize the euro zone economy. In the U.S., automobile giant, General Motors, filed bankruptcy in June as consumer spending scaled back and credit lines dried up.
1 Jul 2009	31 Dec 2009	**2009 July - January**
		As global economic woes persisted, many countries were saddled with widening budget deficit, rising borrowing cost, slowing growth, higher unemployment and higher inflation which made monetary stimulus difficult. Dubai World sought to delay its huge debt repayment shocked the global market while the financial distress in Greece and Ireland began to emerge in late 2009.
31 Mar 2010	7 May 2010	**2010 Peripheral European Bond Crisis (Mar.31 to May.7)**
		During the European sovereign debt crisis, liquidity access for peripheral European countries such as Greece, Portugal and Ireland were deeply affected by their widening budget deficits, higher borrowing costs and failing banking systems which further exacerbated their sluggish economies.
1 Apr 2010	31 May 2010	**2010 Greek Crisis**

		Immense fears hit global market when investors worried about Greece's ability to repay its mounting large debt obligation when it came due and the question of its debt restructuring first appeared. Greece's sovereign debt downgrade to junk status in late April 2010 further increased its cost of borrowing and deficit.
26 Apr 2010	25 Aug 2010	**2010 Irish Debt Crisis**
		Due to Ireland's property bubble burst, deep fiscal retrenchment and distressed banking system, investors' concerns heightened as a series of Irish banks' bailout further depressed the Irish government's ability in financing its massive budget deficit.
26 Oct 2010	11 Nov 2010	**2010 Peripheral European Bond Crisis (Oct.26 to Nov.11)**
		During the European sovereign debt crisis, liquidity access for peripheral European countries such as Greece, Portugal and Ireland were deeply affected by their widening budget deficits, higher borrowing costs and failing banking systems which further exacerbated their sluggish economies.
25 Jan 2011	27 Jan 2011	**2011 Egyptian Unrest**
		The aggravating violent Egyptian revolution caused by a resistant civil campaign rattled the global equity and commodity markets with fear on uncertain political stability and the potential oil export blockage in the region.
11 Mar 2011	15 Mar 2011	**2011 Japanese Earthquake**
		The magnitude 9.0 earthquake in Japan on March 11, 2011 and its subsequent nuclear crisis devastated the Japanese economy and its equity market.

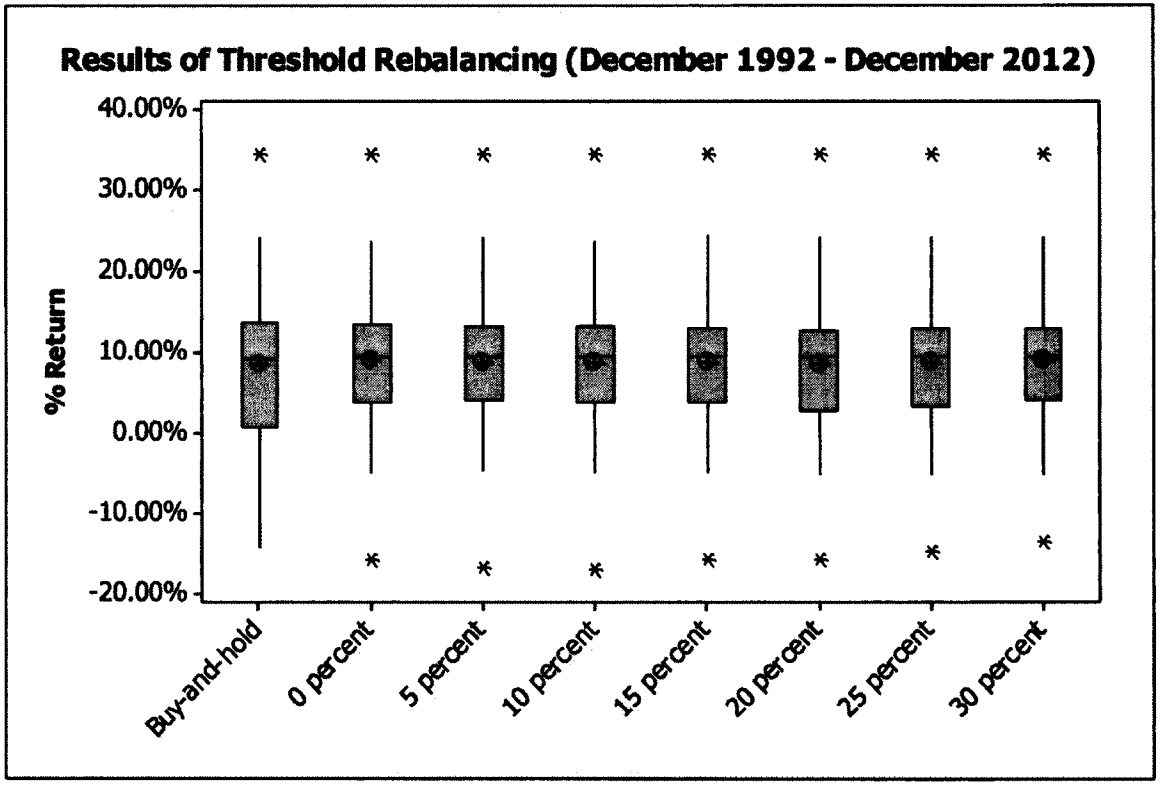
Source: MSCI

Appendix 5(a): Boxplot of Periodic Rebalancing for 50% stocks/ 50% bonds (December 1992 – December 2012)



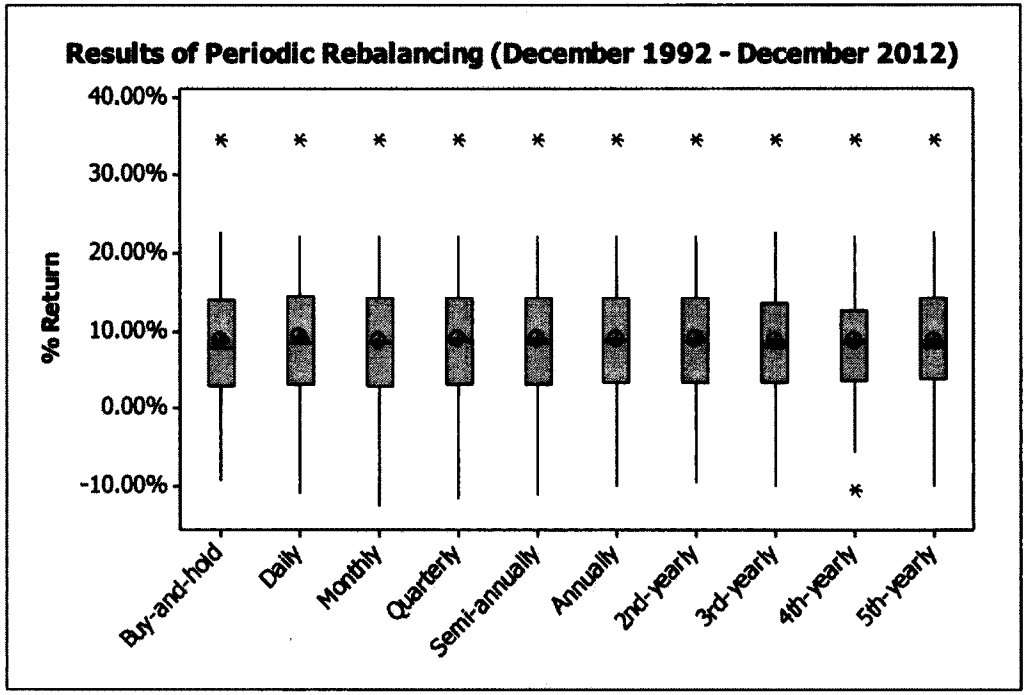
	Outcomes (%)			
	Median	Mean	Interquartile	Outliers?
Buy-and-hold	9.28	8.44	0.76 to 13.87	End 1995= 34.61
Daily	9.55	8.90	3.83 to 13.61	End 1995= 34.62; End 2008= -15.88
Monthly	9.57	8.65	3.59 to 12.95	End 1995= 34.72; End 2008= -17.41
Quarterly	9.65	8.81	3.55 to 12.98	End 1995= 34.66; End 2008= -16.47
Semi-annually	9.59	8.67	3.72 to 13.00	End 1995= 34.61; End 2008= -15.98
Annually	9.63	8.78	3.98 to 13.03	End 1995= 34.60; End 2008= -14.80
2^{nd}-yearly	9.62	8.82	2.59 to 13.03	End 1995= 34.60; End 2008= -14.41
3^{rd}-yearly	9.41	8.49	2.59 to 12.78	End 1995= 34.61; End 2008= -14.80
4^{th}-yearly	9.53	8.56	1.42 to 13.03	End 1995= 34.61
5^{th}-yearly	9.41	8.64	1.98 to 13.65	End 1995= 34.61

Appendix 5(b): Boxplot of Threshold Rebalancing for 50% stocks/ 50% bonds (December 1992 – December 2012)



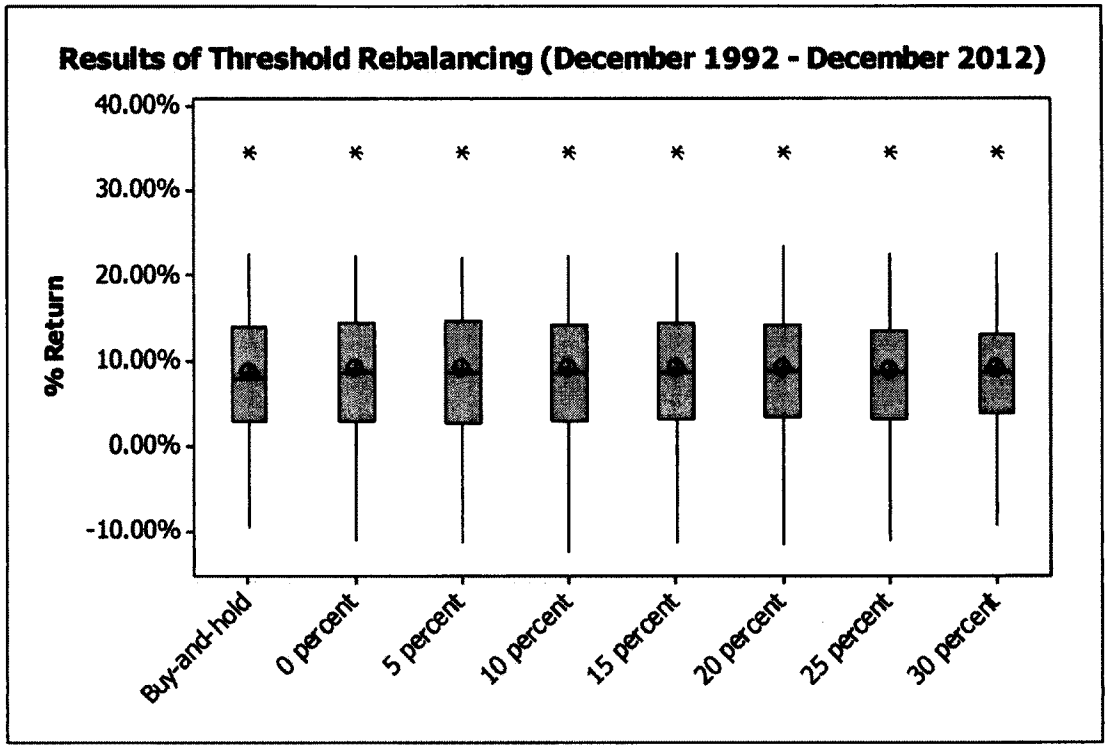
	Outcomes (%)			
	Median	Mean	Interquartile	Outliers?
Buy-and-hold	9.28	8.44	0.76 to 13.87	End 1995= 34.61
0 percent	9.56	8.90	3.83 to 13.61	End 1995= 34.62; End 2008= -15.88
5 percent	9.47	8.82	3.96 to 13.13	End 1995= 34.61; End 2008= -16.90
10 percent	9.59	8.74	3.67 to 13.34	End 1995= 34.61; End 2008= -17.06
15 percent	9.52	8.87	3.82 to 13.10	End 1995= 34.61; End 2008= -15.89
20 percent	9.53	8.59	2.79 to 12.81	End 1995= 34.61; End 2008= -15.75
25 percent	9.53	8.76	3.34 to 12.97	End 1995= 34.61; End 2008= -14.70
30 percent	9.53	9.00	3.97 to 13.10	End 1995= 34.61; End 2008= -13.52

Appendix 6(a): Boxplot of Periodic Rebalancing for 40% stocks/ 60% bonds (December 1992 – December 2012)



	Outcomes (%)			
	Median	Mean	Interquartile	Outliers?
Buy-and-hold	7.82	8.64	2.85 to 14.03	End 1995= 34.71
Daily	8.56	9.08	2.87 to 14.48	End 1995= 34.71
Monthly	8.57	8.84	2.79 to 14.23	End 1995= 34.81
Quarterly	8.65	8.99	2.99 to 14.27	End 1995= 34.76
Semi-annually	8.60	8.86	2.97 to 14.23	End 1995= 34.71
Annually	8.64	8.97	3.23 to 14.26	End 1995= 34.70
2^{nd}-yearly	8.62	9.00	3.23 to 14.26	End 1995= 34.70
3^{rd}-yearly	8.04	8.70	3.23 to 13.66	End 1995= 34.71
4^{th}-yearly	8.54	8.75	3.50 to 12.55	End 1995= 34.71; End 2008= -10.53
5^{th}-yearly	7.93	8.83	3.67 to 14.34	End 1995= 34.71

Appendix 6(b): Boxplot of Threshold Rebalancing for 40% stocks/ 60% bonds (December 1992 – December 2012)



	Outcomes (%)			
	Median	Mean	Interquartile	Outliers?
Buy-and-hold	7.82	8.64	2.85 to 14.03	End 1995= 34.71
0 percent	8.56	9.08	2.87 to 14.48	End 1995= 34.71
5 percent	8.48	9.01	2.78 to 14.59	End 1995= 34.71
10 percent	8.61	8.97	3.00 to 14.30	End 1995= 34.71
15 percent	8.60	8.95	3.19 to 14.52	End 1995= 34.71
20 percent	8.68	8.99	3.44 to 14.25	End 1995= 34.71
25 percent	8.53	8.79	3.06 to 13.52	End 1995= 34.71
30 percent	8.53	8.99	3.83 to 13.12	End 1995= 34.71

Appendix 7(a): Descriptive Statistics of Periodic Rebalancing for 60% stocks/ 40% bonds (December 1992 – December 2012)

	Measure	Buy-and-hold	Daily	Monthly	Quarterly	Semi-annually	Annually	2nd-yearly	3rd-yearly	4th-yearly	5th-yearly
S&P 500	Mean (%)	7.86	8.72	8.74	9.21	9.46	10.30	10.47	8.92	10.09	8.79
	Volatility (%)	18.67	12.17	14.29	16.90	19.10	22.73	26.19	18.16	22.01	22.07
	Kurtosis	0.61	0.80	0.42	0.75	0.22	1.00	1.07	1.21	0.68	1.63
	Skewness	-0.86	-0.20	-0.46	-0.26	0.01	0.32	0.69	-1.00	-0.27	-0.09
	Minimum (%)	-38.49	-19.28	-25.05	-31.41	-32.34	-37.66	-38.49	-39.48	-38.49	-43.21
	Maximum (%)	34.11	34.56	34.29	40.67	47.58	61.48	70.83	34.11	57.96	61.07
	Autocorrelation										
	Lag 1	0.24	0.37	0.22	0.11	-0.02	-0.08	-0.04	0.33	0.13	0.06
	Lag 2	0.13	0.41	0.27	0.17	0.12	0.08	-0.06	0.20	0.11	0.04
	Lag 3	0.10	0.25	0.27	0.25	0.24	0.22	0.19	-0.06	0.01	0.06
Bond	Mean (%)	9.71	8.68	8.26	8.71	8.80	9.29	9.76	8.63	8.62	10.18
	Volatility (%)	10.19	12.75	11.20	12.85	15.54	18.25	16.20	10.22	14.80	13.69
	Kurtosis	1.10	1.12	1.73	0.27	-0.39	-0.73	0.96	1.16	0.08	0.12
	Skewness	0.41	-0.44	0.12	-0.09	0.46	0.04	-0.52	0.58	-0.48	-0.16
	Minimum (%)	-8.39	-22.65	-17.50	-17.27	-17.08	-24.61	-25.73	-8.22	-23.16	-19.66
	Maximum (%)	35.10	34.44	35.10	34.84	41.13	40.99	40.76	35.10	35.10	35.10
	Autocorrelation										
	Lag 1	0.16	0.29	0.41	0.32	0.17	-0.12	0.07	0.16	0.09	0.04
	Lag 2	0.66	0.37	0.50	0.31	0.26	0.31	0.19	0.66	0.26	0.47
	Lag 3	0.42	0.25	0.18	0.18	0.16	0.24	0.24	0.28	0.18	0.42
Portfolio	Mean (%)	8.27	8.70	8.47	8.62	8.49	8.60	8.63	8.30	8.38	8.46
	Volatility (%)	12.35	12.38	12.53	12.38	12.32	12.07	11.98	12.10	12.04	12.12
	Kurtosis	0.60	0.94	1.14	1.06	0.99	0.95	0.90	0.96	1.05	0.89
	Skewness	-0.16	-0.30	-0.35	-0.31	-0.28	-0.21	-0.15	-0.13	-0.18	-0.17
	Minimum (%)	-18.94	-20.64	-22.01	-21.13	-20.67	-19.54	-19.16	-19.54	-20.00	-19.54
	Maximum (%)	34.51	34.51	34.61	34.56	34.51	34.50	34.50	34.51	34.51	34.51
	Autocorrelation										
	Lag 1	0.38	0.34	0.33	0.34	0.34	0.35	0.36	0.37	0.36	0.37
	Lag 2	0.40	0.39	0.37	0.39	0.39	0.41	0.41	0.41	0.41	0.40
	Lag 3	0.17	0.25	0.24	0.25	0.24	0.26	0.25	0.23	0.24	0.21

Appendix 7(b): Descriptive Statistics of Threshold Rebalancing for 60% stocks/ 40% bonds (December 1992 – December 2012)

	Measure	Buy-and-hold	0%	5%	10%	15%	20%	25%	30%
S&P 500	Mean (%)	7.86	8.72	8.66	8.99	8.67	9.03	9.22	8.79
	Volatility (%)	18.67	12.17	12.78	13.73	14.75	14.31	18.65	15.96
	Kurtosis	0.61	0.80	0.41	0.12	0.02	-0.80	-0.08	-0.17
	Skewness	-0.86	-0.21	-0.30	-0.30	-0.37	-0.02	0.30	-0.41
	Minimum (%)	-38.49	-19.28	-20.08	-22.22	-23.29	-15.86	-24.74	-23.37
	Maximum (%)	34.11	34.56	34.11	34.11	34.11	34.11	50.53	34.11
	Autocorrelation								
	Lag 1	0.24	0.37	0.33	0.34	0.24	0.31	0.16	0.20
	Lag 2	0.13	0.41	0.36	0.33	0.24	0.34	0.02	0.27
	Lag 3	0.10	0.25	0.25	0.21	0.22	0.15	0.30	0.28
Bond	Mean (%)	9.71	8.68	8.59	8.43	9.23	9.04	10.65	9.11
	Volatility (%)	10.19	12.75	12.45	13.32	15.30	17.10	20.46	13.65
	Kurtosis	1.10	1.12	1.70	0.41	-0.05	-0.10	1.4	0.24
	Skewness	0.41	-0.44	-0.24	0.07	0.02	0.12	0.95	-0.23
	Minimum (%)	-8.39	-22.65	-22.41	-20.95	-18.98	-26.52	-19.66	-17.45
	Maximum (%)	35.10	34.40	35.10	35.10	37.13	41.55	64.83	35.10
	Autocorrelation								
	Lag 1	0.16	0.29	0.28	0.16	-0.02	-0.08	0.23	0.14
	Lag 2	0.66	0.37	0.43	0.33	0.50	0.30	-0.11	0.40
	Lag 3	0.42	0.25	0.23	0.23	0.18	0.17	-0.03	0.14
Portfolio	Mean (%)	8.27	8.70	8.60	8.66	8.59	8.67	8.93	8.55
	Volatility (%)	12.35	12.38	12.38	12.54	12.47	12.35	12.34	12.11
	Kurtosis	0.60	0.94	1.02	1.04	1.04	0.89	0.89	1.08
	Skewness	-0.16	-0.30	-0.31	-0.35	-0.34	-0.27	-0.29	-0.22
	Minimum (%)	-18.94	-20.64	-21.01	-21.70	-21.35	-20.34	-20.32	-19.99
	Maximum (%)	34.51	34.51	34.51	34.51	34.51	34.51	34.51	34.51
	Autocorrelation								
	Lag 1	0.38	0.34	0.33	0.33	0.32	0.34	0.33	0.35
	Lag 2	0.40	0.39	0.39	0.38	0.39	0.40	0.41	0.42
	Lag 3	0.17	0.25	0.25	0.26	0.25	0.24	0.27	0.26

Appendix 8(a): Descriptive Statistics of Periodic Rebalancing for 50% stocks/ 50% bonds (December 1992 – December 2012)

	Measure	Buy-and-hold	Daily	Monthly	Quarterly	Semi-annually	Annually	2nd-yearly	3rd-yearly	4th-yearly	5th-yearly
S&P 500	Mean (%)	7.86	8.93	8.94	9.53	9.86	10.91	11.13	9.19	10.65	9.02
	Volatility (%)	18.67	10.87	13.34	17.07	19.79	24.54	28.85	18.36	23.40	23.32
	Kurtosis	0.61	0.98	0.26	0.75	0.40	1.53	1.70	1.11	1.04	2.31
	Skewness	-0.86	0.18	-0.28	-0.02	0.31	0.68	1.05	-1.00	0.03	0.23
	Minimum (%)	-38.49	-14.08	-21.38	-29.56	-30.75	-37.46	-38.49	-39.73	-38.49	-44.38
	Maximum (%)	34.11	34.68	34.31	44.65	53.43	70.99	81.95	34.11	66.58	69.74
	Autocorrelation										
	Lag 1	0.24	0.39	0.21	0.08	-0.06	-0.13	-0.07	0.34	0.10	0.03
	Lag 2	0.13	0.51	0.32	0.17	0.11	0.07	-0.09	0.22	0.10	0.02
	Lag 3	0.10	0.31	0.32	0.28	0.25	0.23	0.19	-0.10	-0.01	0.05
Bond	Mean (%)	9.71	8.87	8.51	8.90	8.95	9.36	9.75	8.81	8.81	10.10
	Volatility (%)	10.19	11.41	10.44	11.68	14.11	16.52	14.75	9.60	13.74	12.81
	Kurtosis	1.10	1.17	1.73	0.40	-0.28	-0.72	0.55	1.97	-0.14	-0.14
	Skewness	0.41	-0.12	0.45	0.17	0.56	0.12	-0.32	0.72	-0.31	-0.06
	Minimum (%)	-8.39	-17.66	-13.46	-13.32	-13.79	-20.18	-21.11	-8.22	-18.97	-15.34
	Maximum (%)	35.10	34.56	35.12	34.89	38.16	40.01	37.88	35.10	35.10	35.10
	Autocorrelation										
	Lag 1	0.16	0.31	0.38	0.31	0.17	-0.10	0.08	0.17	0.11	0.06
	Lag 2	0.66	0.46	0.57	0.41	0.35	0.36	0.08	0.70	0.32	0.51
	Lag 3	0.42	0.31	0.25	0.24	0.22	0.27	0.28	0.34	0.22	0.44
Portfolio	Mean (%)	8.44	8.90	8.65	8.81	8.67	8.78	8.82	8.49	8.56	8.64
	Volatility (%)	11.12	11.11	11.27	11.12	11.06	10.81	10.74	10.88	10.77	10.90
	Kurtosis	0.81	1.08	1.30	1.22	1.19	1.21	1.20	1.22	1.40	1.11
	Skewness	0.20	0.03	-0.03	0.02	0.06	0.15	0.20	0.25	0.18	0.20
	Minimum (%)	-14.18	-15.88	-17.41	-16.47	-15.98	-14.80	-14.41	-14.80	-15.29	-14.80
	Maximum (%)	34.61	34.62	34.72	34.66	34.61	34.60	34.60	34.61	34.61	34.61
	Autocorrelation										
	Lag 1	0.39	0.35	0.34	0.36	0.35	0.36	0.37	0.38	0.37	0.38
	Lag 2	0.49	0.49	0.46	0.48	0.48	0.50	0.50	0.50	0.50	0.49
	Lag 3	0.22	0.31	0.29	0.30	0.29	0.32	0.30	0.28	0.29	0.26

Appendix 8(b): Descriptive Statistics of Threshold Rebalancing for 50% stocks/ 50% bonds (December 1992 – December 2012)

	Measure	Buy-and-hold	0%	5%	10%	15%	20%	25%	30%
S&P 500	Mean (%)	7.86	8.93	9.03	8.75	9.36	8.81	9.34	9.86
	Volatility (%)	18.67	10.87	11.87	13.25	13.43	15.35	15.51	15.71
	Kurtosis	0.61	0.98	0.24	0.52	-0.99	0.09	-0.43	-0.62
	Skewness	-0.86	0.18	-0.19	-0.20	0.08	-0.47	-0.32	-0.30
	Minimum (%)	-38.49	-14.08	-16.51	-23.00	-12.09	-23.37	-23.37	-23.37
	Maximum (%)	34.11	34.68	34.11	34.11	34.11	34.11	34.11	34.11
	Autocorrelation								
	Lag 1	0.24	0.39	0.36	0.27	0.15	0.09	0.18	0.14
	Lag 2	0.13	0.51	0.37	0.25	0.48	0.39	0.31	0.31
	Lag 3	0.10	0.31	0.36	0.29	0.30	0.12	0.33	0.37
Bond	Mean (%)	9.71	8.87	8.69	9.06	9.11	9.21	8.95	9.12
	Volatility (%)	10.19	11.41	11.35	12.68	15.17	14.13	12.47	13.80
	Kurtosis	1.10	1.17	1.51	-0.52	0.12	0.27	0.24	0.26
	Skewness	0.41	-0.12	0.22	0.46	-0.01	0.58	-0.19	-0.22
	Minimum (%)	-8.39	-17.66	-17.26	-11.02	-19.56	-11.18	-15.08	-17.70
	Maximum (%)	35.10	34.56	35.10	35.10	36.92	41.43	35.10	35.10
	Autocorrelation								
	Lag 1	0.16	0.31	0.26	0.22	0.09	0.01	0.13	0.14
	Lag 2	0.66	0.46	0.55	0.50	0.31	0.50	0.49	0.39
	Lag 3	0.42	0.31	0.26	0.22	0.15	0.21	0.16	0.14
Portfolio	Mean (%)	8.44	8.90	8.82	8.74	8.87	8.59	8.76	9.00
	Volatility (%)	11.12	11.11	11.22	11.32	11.05	11.04	10.82	10.61
	Kurtosis	0.81	1.09	1.22	1.15	1.20	1.21	1.26	1.28
	Skewness	0.20	0.03	-0.01	-0.01	0.05	0.14	0.18	0.22
	Minimum (%)	-14.18	-15.88	-16.90	-17.06	-15.89	-15.75	-14.70	-13.52
	Maximum (%)	34.61	34.62	34.61	34.61	34.61	34.61	34.61	34.61
	Autocorrelation								
	Lag 1	0.39	0.35	0.35	0.34	0.35	0.35	0.36	0.37
	Lag 2	0.49	0.49	0.48	0.47	0.49	0.49	0.51	0.54
	Lag 3	0.22	0.31	0.31	0.30	0.31	0.30	0.33	0.36

Appendix 9(a): Descriptive Statistics of Periodic Rebalancing for 40% stocks/ 60% bonds (December 1992 – December 2012)

	Measure	Buy-and-hold	Daily	Monthly	Quarterly	Semi-annually	Annually	2nd-yearly	3rd-yearly	4th-yearly	5th-yearly
S&P 500	Mean (%)	7.86	9.13	9.13	9.84	10.26	11.52	11.78	9.46	11.21	9.25
	Volatility (%)	18.67	9.85	12.48	17.47	20.68	26.56	31.69	18.69	24.95	24.68
	Kurtosis	0.61	1.39	0.09	0.72	0.67	2.08	2.31	0.93	1.50	3.11
	Skewness	-0.86	0.61	-0.08	0.22	0.58	0.99	1.34	-0.96	0.32	0.55
	Minimum (%)	-38.49	-8.74	-17.59	-27.67	-29.15	-37.25	-38.49	-39.97	-38.49	-45.56
	Maximum (%)	34.11	34.78	34.32	48.51	59.21	80.49	93.06	34.11	75.21	78.41
	Autocorrelation										
	Lag 1	0.24	0.39	0.20	0.06	-0.10	-0.16	-0.09	0.34	0.08	0.00
	Lag 2	0.13	0.61	0.37	0.16	0.10	0.07	-0.11	0.23	0.09	0.01
	Lag 3	0.10	0.37	0.38	0.29	0.26	0.23	0.18	-0.15	-0.02	0.04
Bond	Mean (%)	9.71	9.05	8.76	9.08	9.10	9.43	9.74	8.99	8.99	10.02
	Volatility (%)	10.19	10.31	9.88	10.72	12.84	14.89	13.42	9.20	12.76	12.01
	Kurtosis	1.10	1.33	1.76	0.61	-0.12	-0.65	0.18	2.63	-0.23	-0.22
	Skewness	0.41	0.27	0.75	0.47	0.66	0.21	-0.10	0.84	-0.13	0.05
	Minimum (%)	-8.40	-12.55	-9.29	-9.27	-10.55	-15.74	-16.48	-8.22	-14.77	-11.01
	Maximum (%)	35.10	34.66	35.13	34.94	35.20	39.03	34.99	35.10	35.10	35.10
	Autocorrelation										
	Lag 1	0.16	0.32	0.34	0.29	0.16	-0.07	0.37	0.18	0.12	0.08
	Lag 2	0.66	0.56	0.63	0.51	0.45	0.43	0.38	0.72	0.39	0.55
	Lag 3	0.42	0.36	0.31	0.31	0.29	0.30	0.32	0.39	0.26	0.45
Portfolio	Mean (%)	8.64	9.08	8.84	8.99	8.86	8.97	9.00	8.70	8.75	8.83
	Volatility (%)	10.12	10.10	10.24	10.12	10.05	9.84	9.79	9.93	9.78	0.10
	Kurtosis	1.25	1.37	1.54	1.48	1.51	1.63	1.66	1.62	1.91	1.50
	Skewness	0.62	0.42	0.36	0.41	0.46	0.54	0.59	0.64	0.60	0.59
	Minimum (%)	-9.47	-11.04	-12.59	-11.68	-11.20	-10.06	-9.69	-10.06	-10.53	-10.06
	Maximum (%)	34.71	34.71	34.81	34.76	34.71	34.70	34.70	34.71	34.71	34.71
	Autocorrelation										
	Lag 1	0.38	0.35	0.34	0.35	0.35	0.36	0.37	0.37	0.36	0.37
	Lag 2	0.58	0.58	0.55	0.57	0.57	0.59	0.59	0.58	0.59	0.58
	Lag 3	0.29	0.36	0.35	0.36	0.35	0.37	0.36	0.34	0.34	0.32

Appendix 9(b): Descriptive Statistics of Threshold Rebalancing for 40% stocks/ 60% bonds (December 1992 – December 2012)

	Measure	Buy-and-hold	0%	5%	10%	15%	20%	25%	30%
S&P 500	Mean (%)	7.86	9.13	9.08	9.42	8.82	9.50	8.96	9.74
	Volatility (%)	18.67	9.85	10.69	11.87	12.23	18.92	14.20	14.09
	Kurtosis	0.61	1.39	0.33	0.00	-0.44	1.27	-0.54	-0.97
	Skewness	-0.86	0.61	0.31	0.12	0.39	0.76	-0.03	0.09
	Minimum (%)	-38.49	-8.74	-9.89	-14.74	-10.14	-23.06	-17.50	-13.04
	Maximum (%)	34.11	34.78	34.11	34.11	34.11	59.38	34.11	34.11
	Autocorrelation								
	Lag 1	0.24	0.39	0.37	0.44	0.38	0.05	0.28	0.49
	Lag 2	0.13	0.61	0.49	0.34	0.23	-0.03	0.25	0.24
	Lag 3	0.10	0.37	0.38	0.35	0.29	0.23	0.18	0.15
Bond	Mean (%)	9.71	9.05	9.01	8.83	9.39	9.58	9.21	8.90
	Volatility (%)	10.19	10.31	10.31	11.10	12.38	13.06	12.53	10.87
	Kurtosis	1.10	1.33	1.64	0.47	-0.26	-0.44	0.22	0.74
	Skewness	0.41	0.27	0.42	0.46	0.25	0.54	0.70	0.32
	Minimum (%)	-8.40	-12.55	-12.52	-10.80	-12.63	-8.39	-8.39	-11.41
	Maximum (%)	35.10	34.66	35.10	35.10	35.10	35.10	35.75	35.10
	Autocorrelation								
	Lag 1	0.16	0.32	0.27	0.14	0.11	0.07	0.09	0.23
	Lag 2	0.66	0.56	0.61	0.56	0.54	0.46	0.46	0.60
	Lag 3	0.42	0.36	0.33	0.32	0.27	0.27	0.47	0.22
Portfolio	Mean (%)	8.64	9.08	9.01	8.97	8.95	8.99	8.79	8.99
	Volatility (%)	10.12	10.10	10.13	10.27	10.10	10.23	10.04	9.74
	Kurtosis	1.25	1.37	1.39	1.40	1.48	1.33	1.58	1.74
	Skewness	0.62	0.41	0.40	0.34	0.43	0.41	0.53	0.64
	Minimum (%)	-9.47	-11.04	-11.47	-12.38	-11.45	-11.62	-11.13	-9.36
	Maximum (%)	34.71	34.71	34.71	34.71	34.71	34.71	34.71	34.71
	Autocorrelation								
	Lag 1	0.38	0.35	0.35	0.34	0.35	0.34	0.35	0.37
	Lag 2	0.58	0.58	0.57	0.56	0.58	0.57	0.57	0.61
	Lag 3	0.29	0.36	0.36	0.36	0.35	0.33	0.35	0.38