# Portfolio revision and optimal diversification strategy choices

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## Abstract

**Purpose** – Since equity markets have a dynamic nature, the purpose of this paper is to investigate the performance of a revision procedure for domestic and international portfolios, and provides an empirical selection strategy for optimal diversification from an American investor's point of view. This paper considers the impact of estimation errors on the optimization processes in financial portfolios.
**Design/methodology/approach** – This paper introduces the concept of portfolio resampling using Monte Carlo method. Statistical inferences methodology is applied to construct the sample acceptance regions and confidence regions for the resampled portfolios needing revision. Tracking error variance minimization (TEVM) problem is used to define the tracking error efficient frontiers (TEEF) referring to Roll (1992). This paper employs a computation method of the periodical after revision return performance level of the dynamic diversification strategies considering the transaction cost.
**Findings** – The main finding is that the global portfolio diversification benefits exist for the domestic investors, in both the mean-variance and tracking error analysis. Through TEEF, the dynamic analysis indicates that domestic dynamic diversification outperforms international major and emerging diversification strategies. Portfolio revision appears to be of no systematic benefit. Depending on the revision of the weights of the assets in the portfolio and the transaction costs, the revision policy can negatively affect the performance of an investment strategy. Considering the transaction costs of portfolios revision, the results of the return performance computation suggest the dominance of the global and the international emerging markets diversification over all other strategies. Finally, an assessment between the return and the cost of the portfolios revision strategy is necessary.
**Originality/value** – The innovation of this paper is to introduce a new concept of the dynamic portfolio management by considering the transaction costs. This paper investigates the performance of a revision procedure for domestic and international portfolios and provides an empirical selection strategy for optimal diversification. The originality of the idea consists on the application of a new statistical inferences methodology to define portfolios needing revision and the use of the TEVM algorithm to define the tracking error dynamic efficient frontiers.

**Keywords** Transaction costs, Estimation error, International and domestic diversification optimal choices, Portfolios revision, Tracking error efficient frontiers
**Paper type** Research paper

## 1. Introduction

Dynamic portfolio choice has become a popular subject of research that interests portfolio managers and academics since it gives much more insights than static portfolio choices especially in high volatility stock markets. Although the static portfolio management strategy continues to dominate most academic and practical applications,

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portfolio revision has become a powerful risk-control strategy (Tsai, 2001; Tokat and Nelson, 2007; Faulkenberry, 2010). Almost every portfolio manager has to decide whether to make revisions, in order to maximize portfolio return given a certain risk level. This paper contributes to the literature by providing some insights about the portfolio revision strategy into how managers can address their risk by formalizing guidelines about how frequently the portfolio should be monitored, how far an asset allocation can deviate from its target before it's revised, and whether periodic revision should be performed. In a different way to the common literature works, we investigate the dynamic portfolio management based on periodical revisions using the tracking error efficient frontiers (TEEF) and we evaluate the after revision return performance of the dynamic diversified portfolios considering the transaction costs.

In this paper, we analyze an optimal dynamic portfolio for an American investor who is concerned about the performance of a portfolio relative to a given benchmark (Browne, 2000; Basak and Makarov, 2014). To recapture the portfolio's original risk and return characteristics, the portfolio must be revised to its original asset allocation. In addition we address the tracking error problem which focusses on minimizing the deviations from a benchmark portfolio (Roll, 1992; Rudolf *et al.*, 1999; Jorion, 2003). The research design is innovative and contributes to the growing literature. First, we use statistical inference procedures to decide whether portfolio needs revision referring to the Sample Acceptance and the Statistical Equivalence Regions. Second, we introduce the tracking error variance minimization (TEVM) algorithm to plot the TEEF for all diversification strategies used to define an optimal dynamic choice.

In this study, we also consider the impact of estimation errors on the optimization of financial portfolios using the resampled efficiency theory (Scherer, 2004; Michaud and Michaud, 2008). Many studies show that classical mean-variance optimization algorithm suffers from error maximization (Michaud, 1998) since expected returns and covariances are assumed to be known with certainty. Naturally, this is not the case in practice and the inputs have to be estimated with estimation errors. The contribution of this paper is to define an optimal diversification strategy choices based on improved-adjusted-resampled frontiers. We propose a methodology combining the resampling method, through Monte Carlo (MC) simulation, and the tracking error minimization algorithm to resolve the controversy problem choices between domestic and international diversification. In fact, the preference of international investors for domestic stocks remains a subject of controversy, since many studies indicate that greater profits can be made by international diversification. Home bias toward holding domestic financial assets continues to be an important phenomenon of global financial markets up to the present moment. Although portfolio theory prescribes that optimal portfolios should be well diversified internationally, in practice investors prefer to invest in domestic assets. Many studies document the benefits of international diversification (Solnik, 1995; Li *et al.*, 2003; Meyer and Rose, 2003; Driessen and Laeven, 2007; Chiou, 2009). Nevertheless, in spite of the international diversification benefits, most investors hold nearly all of their wealth in domestic assets (French and Poterba, 1991; Tesar and Werner, 1995; Antoniou *et al.*, 2010). Since the optimal choice between domestic and international diversification is considered as a problem for an American investor, our contribution is to evaluate the performance of a portfolio revision procedure and to build a framework for resolving the problem of the optimal dynamic diversification strategy.

Using a data set consisting of American and Asian geographical blocks of financial market indices combining 19 emerging (E) and major (M) markets and 27 American stocks from August 3, 1997 to August 31, 2011, our main finding is that global diversification seems to be more beneficial for all tracking error levels. The results also show that domestic diversification outperforms international major, and emerging dynamic diversification strategies. Referring to the adjustment of the weights of the assets in a portfolio toward target weights, given that trades seem to be costly, the results show that a revision strategy can affect negatively the performance of the local and the international dynamic diversification strategies. Considering the transaction costs of portfolio revisions, the results of the return performance computation suggest the dominance of the global and the international emerging markets diversification over all other diversification strategies. Finally, an assessment between the profit and the cost of the revision strategy seem to be necessary in order to define an adequate decision rule.

The remainder of this paper is organized as follows. Section 2 advances the literature review relating to the motivations and the importance of our study. Section 3 presents the data description and the research hypotheses. Section 4 discusses the dynamic investment choices using portfolio revision strategy. The last section summarizes and concludes.

## 2. Literature review

In practice, financial markets are naturally dynamic. Since the optimal weights vector generated by asset allocation process is instable, the periodic portfolio revision seems to be required. Financial portfolio revision is a very practical problem in the investment management field. Over time, as the different investments in a portfolio produce different returns, the portfolio drifts from its target asset allocation, and may acquire risk and return characteristics which are inconsistent with an investor's goals and preferences. Browne (2000) consider a dynamic portfolio management problem relative to a given benchmark portfolio. This allows a new direct quantitative analysis of the risk/return tradeoff, with risk defined directly in terms of probability of shortfall relative to the benchmark, and return defined in terms of the expected time to reach investment goals relative to the benchmark. Pawley and Zly (2005) suggest that it is counter-intuitive to continuously revise to the established asset allocations due to the dynamic nature of asset classes. It was therefore imperative that the established asset allocations be periodically tested to ascertain that they remained optimal. Michaud and Michaud (2008) show that portfolio optimization information' is often insignificant. In particular, they note that the MV optimization is insensitive to the investment information insignificance that leads to very low changing in portfolio weights resulting in frequent portfolio rebalancing that may have no investment value.

The optimal revision of portfolio given the transaction costs is considered as a complex problem. It is studied in several papers. Dybvig (2005) uses a mean-variance analysis of portfolio revision given the transaction costs to illustrate a number of important economic features in a context that is simple to understand and solve completely. The results reveal that the single-period case is suggestive of good strategies in more realistic cases, and is a useful benchmark for comparisons. Lynch and Tan (2010) contribute to the dynamic portfolio choice and the transaction cost literatures. They characterize the investor's optimal portfolio choice with proportional and fixed transaction costs, and with return predictability similar to that observed for the US stock market. The authors numerically find the revision rule to be a no-trade region for the portfolio weights with revision to the boundary. Holden and Holden (2013) discuss the optimal revision of portfolios with the transaction costs. They investigate both proportional and fixed transaction costs and show the existence of a no-trade region that is a fixed threshold for each investment with risk.

Portfolio managers are frequently judged by their ex-post excess returns relative to a prescribed benchmark. They adopt an optimal strategy that maximizes an expected excess return adjusted by the tracking error relative to the benchmark and they wisely expect their investment portfolios to maintain a performance level that is close to a desired benchmark. Unfortunately, asset returns are exceedingly noisy, many managers focus on the volatility of the tracking error. Roll (1992) shows that beating the benchmark on average is tantamount to having a positive expected tracking error. Reducing the volatility of the tracking error is tantamount to minimizing the variance of the difference between managed portfolio returns and benchmark returns. He reveals that investment manager is obliged to follow a new optimization process; minimize the variance of the tracking error conditional on a given level of the expected performance relative to a specific benchmark. Jorion (2003) explores the risk and the return relationship of dynamic portfolios subject to a constraint on the tracking error variance (TEV). The empirical results show that TEV-constrained portfolios can substantially improve the performance of the dynamic portfolio. In general, the plan sponsors should concentrate on controlling total portfolio risk. El-Hassan and Kofman (2003) investigate a dynamic portfolio allocation strategy that exploits the predictability in the conditional variance-covariance matrix of asset returns. To illustrate the empirical procedure, Jorion's (2003) tracking error frontier methodology is used for representative portfolio of Australian stocks. The authors find that the frequent revision is an absolute necessity to keep some control over total risk (and *ex ante* tracking error risk) when dynamically managing portfolios.

Ammann *et al.* (2006) show that it is important for investors to know what trading strategies an asset manager pursues to generate excess returns. They propose an alternative approach for analyzing trading strategies used in dynamic investing. The authors apply the TEV as a measure of activity to identify the investment strategies of all asset managers. Using distance measure function (tracking error), De Waal and Bradfield (2003) try to identify whether an existing portfolio is different enough from an efficient frontier portfolio (accounting for resampling efficiency) to require restructuring. The authors apply the statistical equivalence test to establish an area that can be interpreted as a no-trade zone. Fang *et al.* (2006) propose a linear programming model for the portfolio revision with the transaction costs based on fuzzy decision theory. The computation results show that the portfolio revising model with a non-linear function can generate a favorite portfolio revision strategy according to the investor's degree of satisfaction.

While theoretically important for modern finance, mean-variance optimization's sensitivity to uncertainty in risk-return estimates typically results in an unstable asset management framework, ambiguous portfolio optimality, and poor out-of-sample performance. The resampled efficiency technique introduces the MC resampling and the bootstrapping methods into MV optimization to more realistically reflect the uncertainty in investment information taking into account the estimation errors. Jobson and Korkie (1980, 1981), Best and Grauer (1991), and Chopra and Ziemba (1993) investigate the impact of the estimation errors on the optimal allocation weights in a portfolio allocation. They find that the composition of the optimal portfolios is very sensitive to the changes in expected returns, variances, and covariances.

Moreover, the authors introduce the concept of the portfolio resampling using the MC method to analyse the effect of the sample size on the estimation errors. Michaud (1998) notes that MV optimizers are estimation errors maximizers. To deal with the estimation errors, the author introduces the resampled efficiency to generate new inputs parameters' leading to construct the resampled efficiency frontier. Markowitz and Usmen (2003) compare the Michaud resampling with the MV optimizer model using improved inputs by taking into account the uncertainty problem in the input parameters optimization. Their experiment reveals that Michaud's resampled efficiency frontier produces portfolios with more diversified collections of stocks and better returns for a given level of risk. Scherer (2002, 2004) reviews the portfolio resampling methodology. The results reveal that optimizers are far too powerful for the quality of the inputs. In fact, resampling remains an interesting heuristic to deal with the important problem of the error maximization. Abu Mansor *et al.* (2006) apply the resampled efficiency methodology introduced by Michaud (1998) to compare the optimal portfolio based on the MV and the resampled efficiency. They find that the resampled efficiency performed well with data having the least estimation errors for equity portfolio. To reduce the impact of the estimation errors on the optimal portfolio composition, Becker *et al.* (2014) compare the resampled efficiency of the performance of the traditional MV optimization with the Michaud's estimate. Bai *et al.* (2009a, b, 2011) reveal that the traditional return estimate is always larger than its theoretical value with a fixed rate depending on the ratio of the dimension to sample size. They further propose a new method for reducing this error by incorporating the bootstrap approach into the theory of a large dimensional random matrix. The bootstrap-modified estimator analytically corrects the overestimation and is proportionally consistent with the theoretical return parameter.

## 3. Data description and research hypotheses

### *3.1 Data description*

The data analyzed in this paper are daily continuously compounded returns, for stocks and market indices in the period from August 3, 1997 to August 31, 2011. Daily closing prices of 27 American stocks obtained from CRSP[1] are used to form various domestic diversified portfolios. To form international (both major and emerging) diversified portfolios, we use data obtained from Datastream including two financial blocks[2]: emerging (E) and major (M) markets, and two geographical blocks: North and Latin American countries and Asian countries. The first financial block consists of markets from United-States$^{M}$, Canada$^{M}$, Argentina$^{E}$, Brazil$^{E}$, Mexico$^{E}$, Venezuela$^{E}$ whereas the second block consists of markets from China$^{E}$, Hong-Kong$^{M}$, India$^{M}$, Indonesia$^{E}$, Japan$^{M}$, South Korea$^{M}$, Malaysia$^{M}$, Pakistan$^{E}$, Philippines$^{E}$, Sri Lanka$^{E}$, Singapore$^{M}$, Taiwan$^{E}$, and Thailand$^{E}$, respectively. To avoid the exchange rate bias, all indices are expressed in US dollar (see, e.g. Geert *et al.*, 2005).

The revision procedure of the resampled efficient diversified portfolios consists of specifying investment horizon length. We divided the period of the study into 12 sub-periods counting ten months. We compute the return performance level of each dynamic diversification strategy at the end of each sub-period.

### *3.2 Research hypotheses*

In this paper, we try to resolve the problem of the optimal dynamic diversification strategy choices by using the statistical inferences procedure and evaluate the performance of the portfolio revision strategy. Besides, to remove the estimation errors on portfolio optimization processes, the adjusted resampled procedure will be introduced in the portfolio optimization to construct the efficient diversification strategies.

Dynamic portfolio management is based on domestic (DODREP), global international (INDREP), international major markets (IMDREP), and international emerging markets (IEDREP) improved-adjusted resampled efficient diversified portfolios. For the four investment strategies, we are going, firstly to test the mean-variance dominance between the portfolios in the following pairs: (DODREP, INDREP), (DODREP, IMDREP), (DODREP, IEDREP), (INDREP, IMDREP), (INDREP, IEDREP), and (IMDREP, IEDREP) referring to the shape of the resampled-adjusted efficient frontiers. We specify the following hypotheses:

$H_{0j}^{1}$. DODREP dominates INDREP (IMDREP, IEDREP).

$H_{0j}^{2}$. INDREP dominates (IMDREP, IEDREP) DODREP.

Second, we want to measure the dominance degree between all the dynamic tracking error diversification strategies and evaluate the periodic return performance level of the revised portfolios from a US investor's point of view by considering the transaction costs. Two hypotheses will be defined:

$H_{0}^{RD}$. Dynamic resampled domestic diversification seems to be more performing than dynamic resampled international diversification (majors and emerging markets diversification) for an American investor. $H_{1}^{RD}$ is the alternative hypothesis.

$H_{0}^{PRD}$. Considering the transaction cost, periodic revision of the resampled efficient domestic/international diversified portfolios is beneficial for an American investor. $H_{1}^{PRD}$ is the alternative hypothesis.

## 4. Dynamic investment choices using portfolio revision strategy

### *4.1 Statistical inferences methodology and research design*

This paper tries to investigate the performance and the choice of the dynamic investment strategies. Empirical study is based on the computation of the returns for all sample assets. Using the resampled efficiency procedure, DODREP, INDREP, IMDREP, and IEDREP portfolios and their corresponding resampled efficient frontiers will be constructed.

*4.1.1 Resampled and mean-variance efficiency.* In this study, we introduce the estimation errors in the portfolio optimization algorithm by using the resampling procedure. We formulate efficient portfolios for the four investment strategies by adopting a MC measure called portfolio resampling. To generate the random return variables of the all sample assets, we use the following Brownian process:

$$R_{it} = \mu_i + \sigma\varepsilon_{it} \quad \text{for } i = 1, 2, \ldots, N \text{ and } t = 1, 2, \ldots, T; \qquad (1)$$

where $R_{it}$ is the return of asset $i$ at time $t$, $\mu_i$ the mean returns vector of the original data, $\sigma$ the computed standard deviation, and $\varepsilon_{it}$ the normally distributed random noise.

Referring to Fabozzi *et al.* (2007), to construct the resampled efficient frontiers, the procedure can be summarized as follows:

Step 1: Estimate the mean vector, $\mu_N$, and covariance matrix, $\Sigma_N$, from the historical data;

Step 2: Draw $N$ random samples $R$ times from the multivariate distribution $N(\mu_N,\Sigma_N)$ and use these data to estimate a new mean returns vector $\hat{\mu}_N$ and a new covariance matrix $\hat{\Sigma}_N$;

Step 3: Calculate an efficient frontier from the input parameters from Step 2 over the interval from portfolio with minimum risk to portfolio with maximum risk. The interval is partitioned into $M$ equally spaced intervals and record the weights vector $w_{Mi} = w_{1,i}, \ldots, w_{M,i}$ of $N$ assets for each of $M$ portfolios for each simulation i;

Step 4: Repeat Steps 2 and 3 $R$ times. We obtain $R$ resampled efficient frontier giving $R\ w_{Mi}'$s;

Step 5: Calculate the resampled portfolio weights vector $w_M^{RES}$ as the mean of $w_{Mi}$ weights vector:

$$w_M^{RES} = \frac{1}{R}\sum_{i=1}^{R} w_{Mi}, \tag{2}$$

and evaluate the resampled frontier with the mean vector and covariance matrix from Step 1.

We note that the number of draws $R$ ($R = 1{,}000$ times in our study) corresponds to the uncertainty in the inputs used. As the number of draws increases, the dispersion decreases and so do for the estimation errors, the difference between the original estimated input parameters and the sampled input parameters (Scherer, 2004). The number of portfolios M can be chosen freely according to how well the efficient frontiers are being depicted.

Resampled efficient frontiers of the four diversification strategies are displayed in Figure 1.

Figure 1 examines the impact of the estimation errors on the efficient portfolios optimization and consequently on the investment strategy decision choices. The results reveal that the simulated efficient frontiers are not consistent with the efficient frontier intuition and may not monotonically increase in expected return with increasing risk. Moreover, the curve of the resampling frontiers is remarkably short comparing with the MV efficient frontiers.

Since addressing estimation errors is an important issue, to make comparison easier, we apply a resampled adjusted method to construct new frontiers named improved-adjusted-resampled frontiers. This method uses the expected return levels of each portfolio located on the MV efficient frontier rather than the return levels of the resampled portfolios generated from simulation using the quadratic optimization procedure.

We first adopt the MV optimization to generate the resampled-adjusted efficient diversified portfolios used to plot the resampled-adjusted efficient frontiers for the four diversification strategies; global international, domestic, emerging, and major markets. Figures 2-5 report the weights of the assets in all the resampled-adjusted efficient diversified portfolios (including INDREP, DODREP, IEDREP, and IMDREP).

Figures 2-5 exhibit the weights of the assets in each MV resampled-adjusted efficient portfolio formulated from adopting the different diversification strategies.

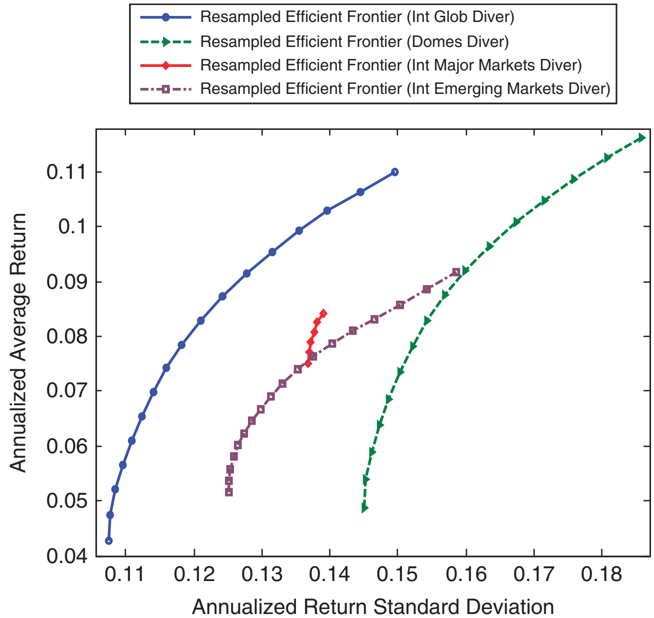


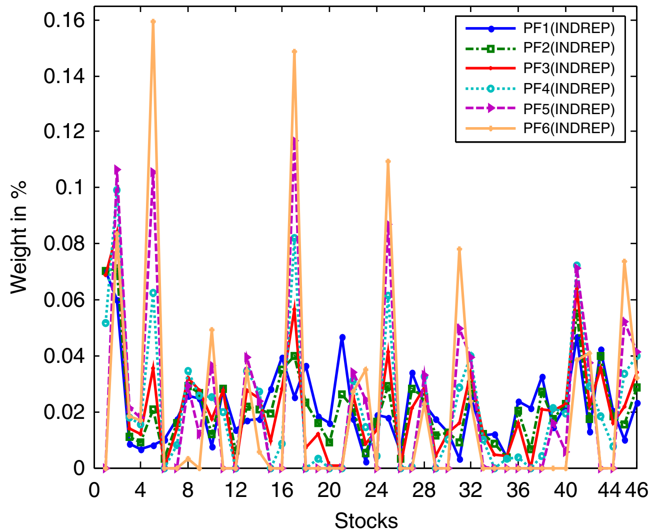

**Figure 1.**
Resampled efficient frontiers of the various diversification strategies

From the plots, we find that the higher the risk/return level, the lowest the number of assets in the portfolios. This property holds for all the cases of all strategies. In fact, the minimum variance portfolios (PF1 in all figures) regroup all the assets considered (46, 28, 11, and 8 assets). In contrast, the maximum variance portfolios (PF6, PF14, PF8, and PF5 in Figures 2-5, respectively) seem to be the least diversified and consist of 19, 10, 8, and 4 assets (stocks and indices) only. Compared to the MV efficient diversified portfolios, results show that the resampled-adjusted efficient diversified portfolios are more diversified revealing the lowest weights of the corresponding assets.

Figure 6 illustrates the improved-adjusted-resampled frontiers of the four diversification strategies.

Given that the regions of dominance are ambiguous, the results show that the dominance between the efficient diversification strategies is not obvious since the efficient frontiers intersect. With the exception of the global diversification, it is not easy to determine which of the other three strategies will dominate each other. Figure 6 reveals that, for a risk level lower than 17.15 percent, global diversification strategy dominates all other strategies in the resampling approach. The $H^2_{0j}$ hypothesis is accepted. Nevertheless, for the rest of the risk levels, it is not easy to determine any superiority relationship among the different diversification strategies. US investors, who seek advice on investing internationally or domestically, could not be able to make a decision to choose any diversification strategy based on the improved-resampled-adjusted-efficient frontiers. Consequently, the optimal choice could not be defined.

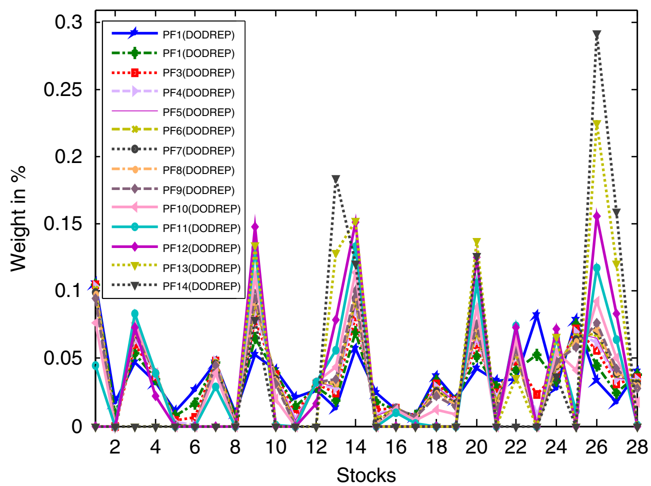
*4.1.2 Sample acceptance regions (SAR).* After choosing a portfolio efficiency measure, whether it is mean-variance or resampled efficiency, as the next step, we want to decide whether portfolio needs revision to be efficient. Since not all portfolios require revision, some are close to the efficient frontier and are statistically indistinguishable




**Notes:** The assets considered to formulate global adjusted resampled efficient diversified portfolios are the index: (1) S&P 500 Composite Index, (2) S&P/TSX Composite Index, (3) Argentina Merval Price Index, (4) Brazil Bovespa Price Index, (5) IPC Bolsa Price Index, (6) Venezuela SE General Index, (7) Shanghai SE Composite, (8) Hang Seng Index, (9) BSE SENSEX/ BSE 100 Price Index, (10) Jakarta Composite Price Index, (11) Nikkei 225 Stock Average/ TOPIX Index, (12) Korea SE Composite (KOSPI), (13) Kuala Lumpur Composite Price Index, (14) Karachi Stock Exchange 100 Index, (15) Philippine Stock Exchange index, (16) Sri Lanka SE Milanka Index, (17) Singapore Straits T. DS, (18) Taiwan SE Weighted Index, (19) Bangkok S.E.T. Index, and the stocks: (20) ABY, (21) AEP, (22) AXP, (23) AAPL, (24) BK, (25) CO, (26) CA, (27) XOM, (28) GE, (29) GM, (30) IBM, (31) ORCL, (32) RD, (33) LUV, (34) MOT, (35) AMR, (36) BAC, (37) F, (38) AIG, (39) BMY, (40) BNI, (41) CHG, (42) C, (43) DTE, (44) FDX, (45) INTC, (46) MCD

**Figure 2.**
Weights of all assets in the resampled-adjusted efficient global diversified portfolios

from efficiency. We use a statistical inferences procedure to transform the statistical equivalence region into a SAR to control the estimation errors. As introduced by Michaud (1998), an intuitive way to approximate the SAR from the statistical equivalence region is to find an area under the efficient frontier (for all dynamic investment strategies defined) that includes, on average, $(1-\alpha)$ of the resampled portfolios. Therefore, we divide the area under the efficient frontier into mutually exclusive column rectangles that include all the simulated portfolios. Define the base of the rectangle as the minimum return point that contains $(1-\alpha)$ of the simulated portfolios in the rectangle. The curve connection the midpoint of the base of the rectangles contains approximately $(1-\alpha)$ of the simulated portfolios under the curve. This curve is an estimate of the lower boundary of a $(1-\alpha)$ SAR. The test for efficiency



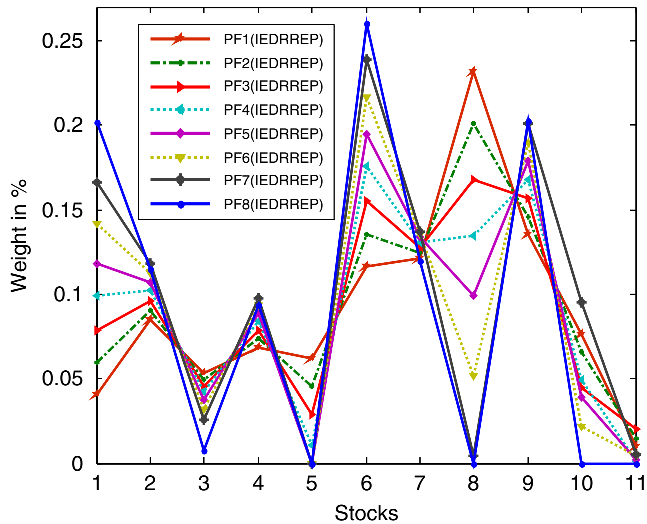

**Notes:** The assets considered to formulate domestic adjusted resampled efficient diversified portfolios are the (1) S&P 500 Composite Index, and the stocks: (2) ABY, (3) AEP, (4) AXP, (5) AAPL, (6) BK, (7) CO, (8) CA, (9) XOM, (10) GE, (11) GM, (12) IBM, (13) ORCL, (14) RD, (15) LUV, (16) MOT, (17) AMR, (18) BAC, (19) F, (20) AIG, (21) BMY, (22) BNI, (23) CHG, (24) C, (25) DTE, (26) FDX, (27) INTC, (28) MCD

**Figure 3.**
Weights of all assets in the resampled-adjusted efficient domestic diversified portfolios

at the $\alpha = 10$ percent confidence level (at the 90 percent acceptance level) proceeds by determining whether the risk and the return of a candidate portfolio is within the SAR.

Figures 7-10 illustrate the SAR, resampled and mean-variance efficient frontiers and resampled portfolios of the different diversification strategies. Results show that a wide range of the resampled portfolios are statistically equivalent to the efficient frontiers. The level of variability is high and reflects the instability and ambiguity of the traditional MV optimization of the investment management. The curves of the SAR are an estimate of the lower boundary of a $(1-\alpha)$ SAR (for; $\alpha = 10$ percent, $\alpha = 20$ percent, and $\alpha = 40$ percent). The test of the resampled efficiency at the 90, 80, and 60 percent acceptance levels proceeds by determining whether the risk and the return of a candidate portfolio is within the SAR. If the portfolio is within the SAR, no revisions may be required; if the candidate portfolio is outside the region, it probably requires revision. If we consider the 60 percent acceptance level, the figures show a great number of the resampled portfolios is below and outside the corresponding acceptance region needing hence a revision. Through the Figures 7-10, more the confidence level increases the lowest number of the resampled portfolios which need revision we have.

*4.1.3 Confidence regions for resampled portfolios*. In reality, the problem often arises is whether a given portfolio is statistically equivalent to an efficient portfolio. Even if the current portfolio is consistent with the resampled efficiency, but not consistent to the target efficient portfolio, it may still need revision. The judgement of the efficiency of a portfolio is then based on how near it is to the target resampled portfolio. We can now test whether two portfolios are statistically different. A distance function is required to define the confidence region which is equivalent to the squared tracking error. If we assume $w_P$ is the weights vector of the testing portfolio, $w_0$ is the weights



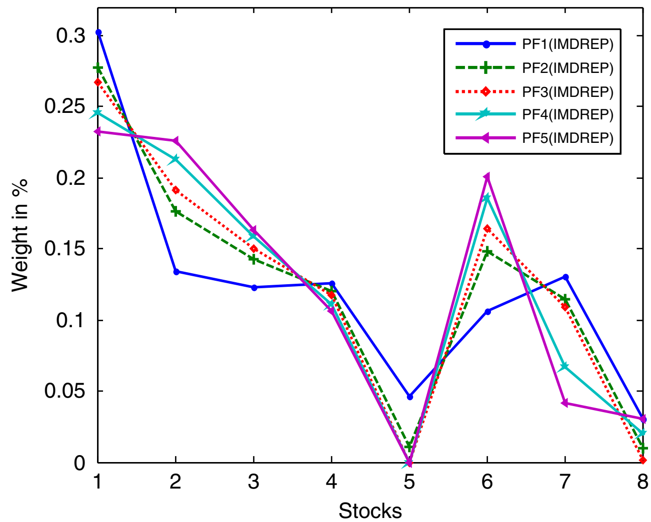

**Notes:** The assets considered to formulate emerging markets adjusted resampled efficient diversified portfolios are the (1) Argentina Merval Price Index, (2) Brazil Bovespa Price Index, (3) IPC Bolsa Price Index, (4) Venezuela SE General Index, (5) Shanghai SE Composite, (6) Jakarta Composite Price Index, (7) Karachi Stock Exchange 100 Index, (8) Philippine Stock Exchange index, (9) Sri Lanka SE Milanka Index, (10) Taiwan SE Weighted Index, (11) Bangkok S.E.T. Index

**Figure 4.**
Weights of all assets in the resampled-adjusted efficient emerging markets diversified portfolios

vector of the target resampled portfolio, $_0$ is the covariance matrix of the historic return, the test statistic of the distance between the portfolio weights $w_p$ and $w_0$ is defined as the relative variance $(w_p - w_0)'\Sigma_0(w_p - w_0)$. In this fact, all portfolios having $(w_p - w_0)'\Sigma_0(w_p - w_0) \geqslant TE_\alpha^2$ are said statistically different. The simulation procedure is used to find the distance function $(w_p - w_0)'\Sigma_0(w_p - w_0)$ and the constant $TE_\alpha^2$ which is the test statistic with $(1-\alpha)$ confidence level. Equally weighted portfolio variance was considered as a target portfolio. The weights vector of the portfolio placed on the resampled efficient frontier and having the same level variance to the weights vector of the target portfolio was established. Three confidence levels are considered; 10, 20, and 40 percent. The following figures visualize the computed tracking error of the each diversification strategy defined above.

Figures 11-14 summarize the tracking error of the four investment strategies through the statistical equivalence test. Results show that tracking error are weak and near to the null value. The distance functions were computed between the target portfolio and all resampled portfolios for all cases. The results show that the tracking error values vary between $0.76 \times 10^{-7}$ and $0.47163 \times 10^{-4}$, $0.65 \times 10^{-7}$ and $0.36045 \times 10^{-4}$, $0.51 \times 10^{-7}$ and $0.21627 \times 10^{-4}$, and $0.2915 \times 10^{-5}$ and $0.19941 \times 10^{-4}$, respectively for the global, domestic, international emerging, and major markets diversification strategies. The critical tracking error values are reported in Table I.

In Table I, we estimate the $TE_\alpha^2$ critical value of each investment strategy assuming three confidence levels; 10, 20, and 40 percent. The results reveal that more the




**Notes:** The assets considered to formulate major markets adjusted resampled efficient diversified portfolios are the (1) S&P 500 Composite Index, (2) S&P/TSX Composite Index, (3) Hang Seng Index, (4) BSE SENSEX/ BSE 100 Price Index, (5) Nikkei 225 Stock Average/TOPIX Index, (6) Korea SE Composite (KOSPI), (7) Kuala Lumpur Composite Price Index, (8) Singapore Straits T. DS Index

**Figure 5.**
Weights of all assets in the resampled-adjusted efficient major markets diversified portfolios

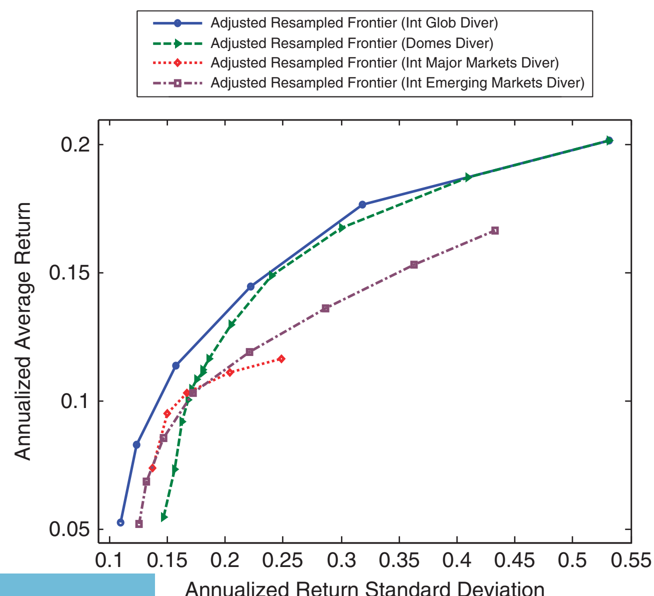



**Figure 6.**
Reasampled-adjusted efficient frontiers of the various diversification strategies

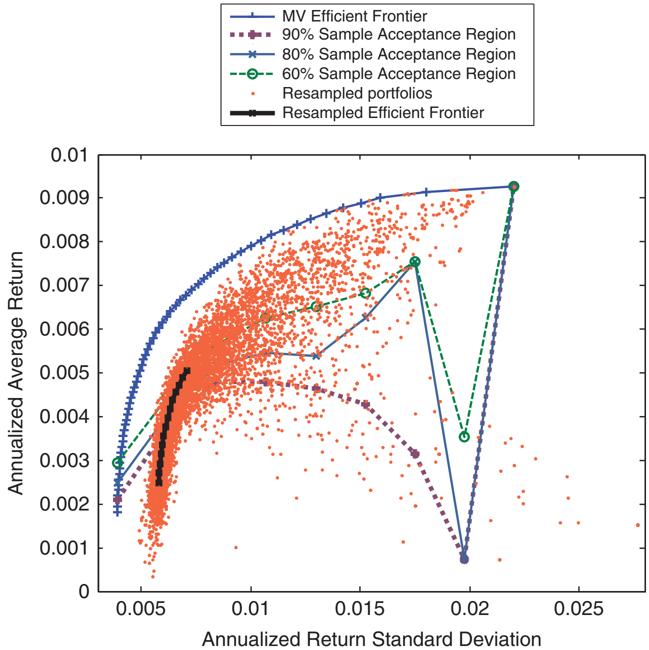



**Figure 7.**
Sample-acceptance-regions, resampled and mean-variance efficient frontiers and resampled portfolios of the global diversification strategy

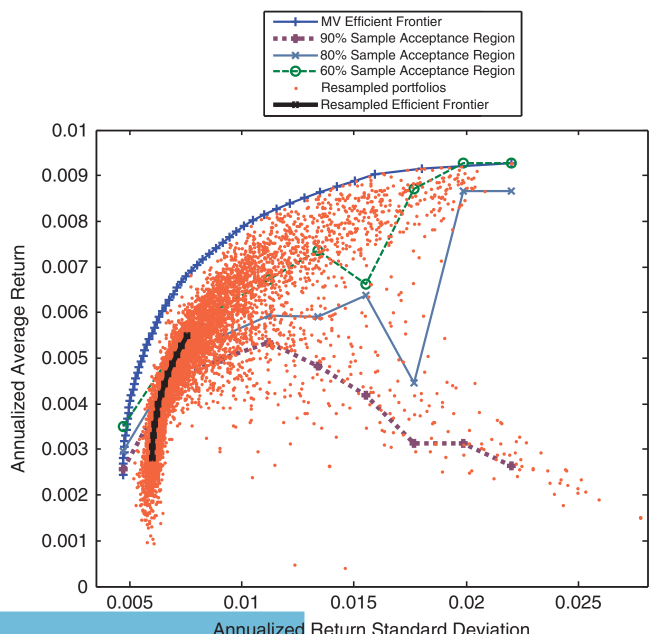



**Figure 8.**
Sample-acceptance-regions, resampled and mean-variance efficient frontiers and resampled portfolios of the domestic diversification strategy

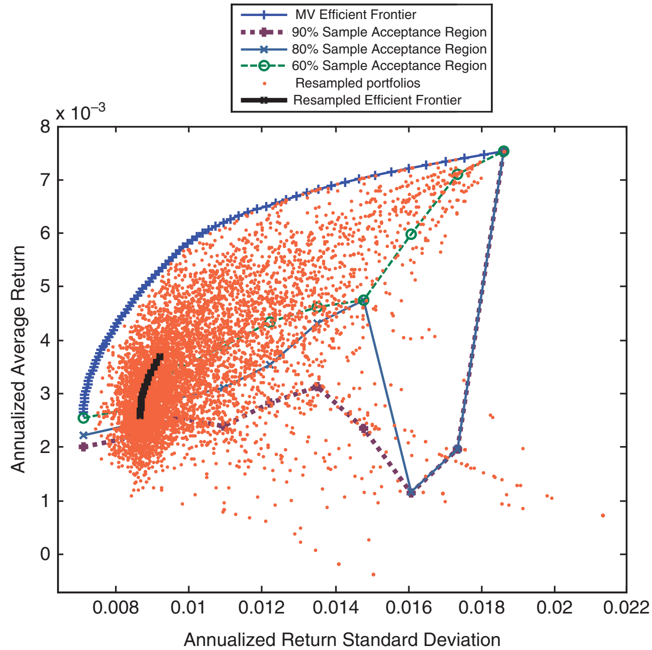



**Figure 9.**
Sample-acceptance-regions, resampled and mean-variance efficient frontiers and resampled portfolios of the international emerging markets diversification strategy

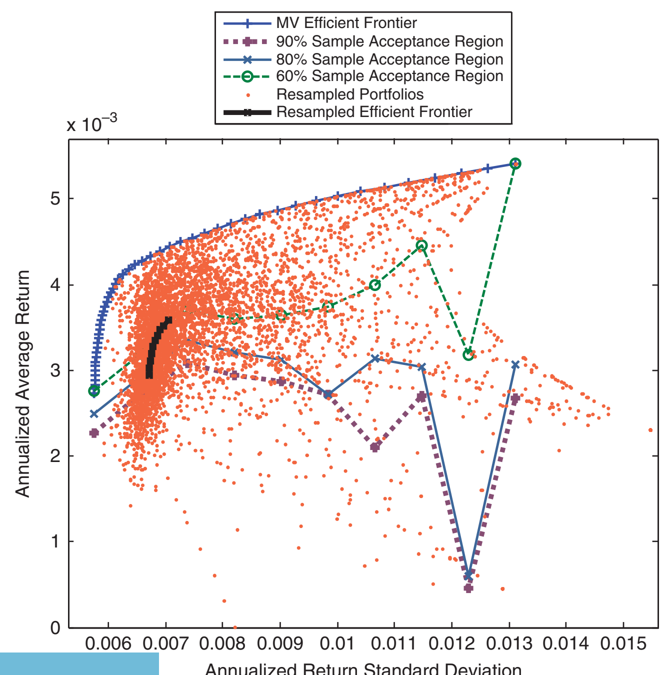



**Figure 10.**
Sample-acceptance-regions, resampled and mean-variance efficient frontiers and resampled portfolios of the international major markets diversification strategy

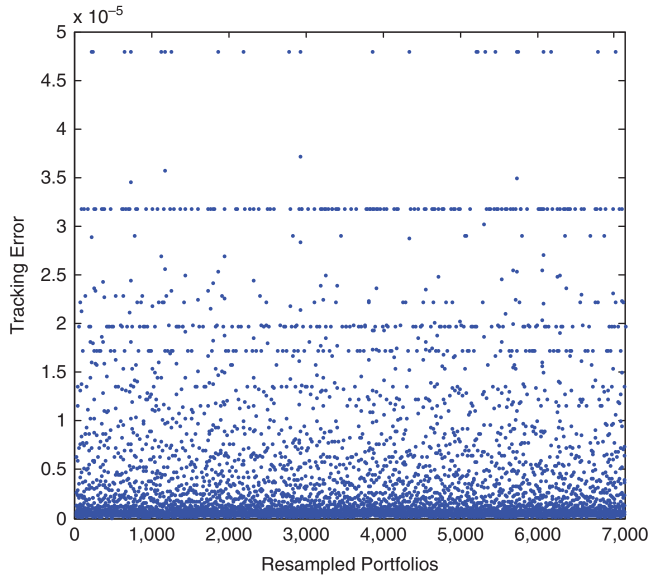



**Figure 11.** Tracking error visualization through statistical equivalence test of the global diversification strategy

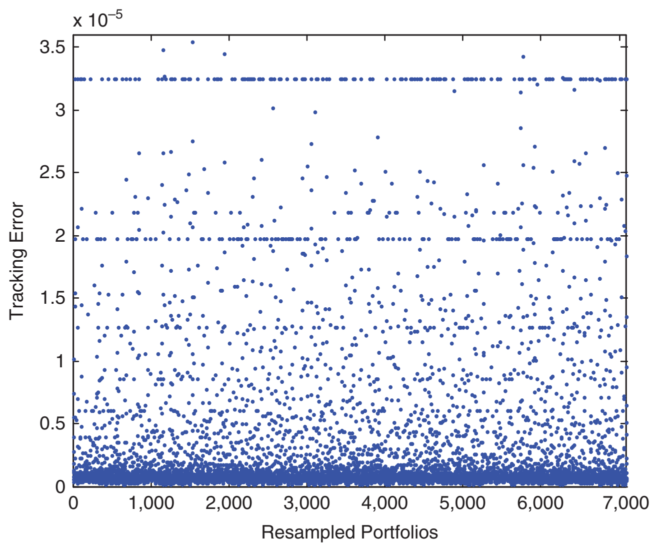



**Figure 12.** Tracking error visualization through statistical equivalence test of the domestic diversification strategy

confidence level increases the higher of the $TE_{\alpha}^{2}$ we have. We compare then the computed tracking error with the $TE_{\alpha}^{2}$ for each case to find the portfolio needing revision basing on the statistical equivalence test between the resampled portfolios and the target portfolio. Table II reports the statistical equivalence/difference portfolio results test.

If we consider 90 percent confidence region, Table II shows that, in 88.25, 95.02, 90.06, and 90 percent of cases of the global, domestic, international emerging and major

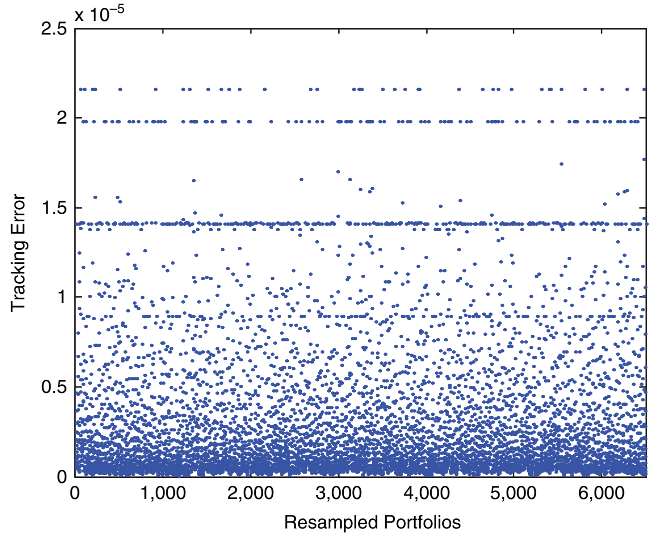



**Figure 13.**
Tracking error visualization through statistical equivalence test of the international emerging markets diversification strategy

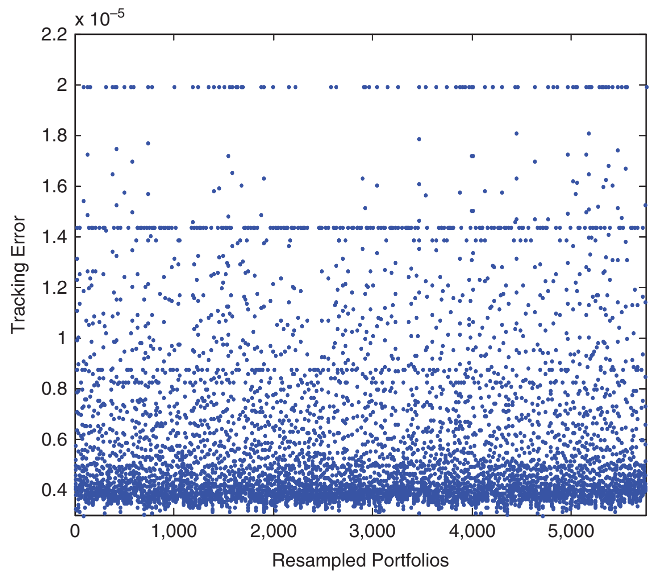



**Figure 14.**
Tracking error visualization through statistical equivalence test of the international major markets diversification strategy

**Table I.**
Critical tracking errors of confidence regions of the statistical equivalence test

| Confidence regions | 90% | 80% | 60% |
|---|---|---|---|
| Critical tracking error (global diversification) | 0.000000299 | 0.000000368 | 0.000000516 |
| Critical tracking error (domestic diversification) | 0.000000310 | 0.000000377 | 0.000000496 |
| Critical tracking error (international emerging markets diversification) | 0.000000318 | 0.000000478 | 0.000001048 |
| Critical tracking error (international major markets diversification) | 0.000003585 | 0.000003742 | 0.000004064 |

markets diversification strategies respectively, the tracking error values are higher than the critical values of the tracking error. In this fact, 11.74, 4.97, 9.93, and 9.99 percent of the resampled portfolios are statistically equivalent to the target portfolio. The revision of the asset weights in these portfolios is not required. The findings reveal that more the confidence level increases the highest number of the resampled portfolios which need revision we have. The results show also that 4,181, 5,680, 3,903, and 3,448 of the resampled portfolios need to be revised if we consider $\alpha = 40$ percent, implying a relatively important transaction costs.

*4.2 TEEF, dynamic investment choices and revision portfolio return performance*

Our empirical purpose consists on the definition of the dynamic investment choices considering the adjustments of all revised portfolios of the four diversification strategies though statistical equivalence tests. We try to construct the efficient portfolios that minimize the tracking error level. The TEVM problem is considered to locate the lowest tracking error given a certain level of the dynamic portfolio return.

*4.2.1 TEVM and TEEF.* Referring to Roll (1992), we assume that the investor pursues the following objective: minimize the variance of the tracking error conditional on a given level of the expected performance relative to a specified benchmark. This is a straightforward optimization problem that can be solved analytically when there are no short-selling constraints. We define the following variables: $N$ is the number of individual assets detained; $q$ an $(N \times 1)$ vector representing the portfolio's proportions invested in asset. In all cases, the portfolio weights sum to unity. We use standard matrix transpose notation, $q'1 = 1$, where 1 is an $(N \times 1)$ vector of 1's; $x$ an $(N \times 1)$ vector representing the difference, stock by stock, between the managed portfolio and the benchmark; where $x'1 = 0$. If we consider $q_p$ is the weights vector of portfolio $p$ dynamically managed, $x$ is defined as:

$$x = q_p - q_{p0}; \tag{3}$$

$R$: An $(N \times 1)$ vector of expected returns on all assets in the universe; $V$: The $(N \times N)$ covariance matrix of individual asset returns; $G$: The manager's target or expected performance relative to the benchmark:

$$G = R_p - R_{p0}. \tag{4}$$

| Resampled portfolios | Diversification strategy | | Confidence regions (%) 90 | 80 | 60 |
|---|---|---|---|---|---|
| 7,193 | Global international | Statistical difference | 88.25 | 79.21 | 58.13 |
| | | Statistical equivalence | 11.74 | 20.78 | 41.86 |
| 7,098 | Domestic | Statistical difference | 95.02 | 90.02 | 80.02 |
| | | Statistical equivalence | 4.97 | 9.97 | 19.97 |
| 6,501 | International emerging markets | Statistical difference | 90.06 | 80 | 60.03 |
| | | Statistical equivalence | 9.93 | 19.99 | 39.96 |
| 5,743 | International major markets | Statistical difference | 90 | 80.09 | 60.03 |
| | | Statistical equivalence | 9.99 | 19.9 | 39.96 |

**Table II.** Statistical equivalence/difference test of the different diversification strategies

The objective is to minimize the volatility of the tracking error conditional on a target expected performance relative to the benchmark. The tracking error's expected value is:

$$G = (q_p - q_{p0})'R = x'R. \tag{5}$$

Tracking error variance is computed as follows:

$$TE = \sqrt{(q_p - q_{p0})'V(q_p - q_{p0})} = \sqrt{x'Vx}. \tag{6}$$

Thus, the formal TEVM optimization problem can be stated as follows:

$$\underset{x}{\text{Min}}\, x'Vx \tag{7}$$

Subject to the constraints:

$x'1 = 0$; $x'R = G$; $q'1 = 1$.

Using the TEVM optimization problem, Figure 15 plots the TEEF of the global international, domestic, emerging, and major markets diversification strategies.

From Figure 15, the shape of the different TEEF suggests the absence of crossing between all frontiers. The results show that the choice between the dynamic investments seems to be easier comparing with the static case. Since the TEEF is placed above all other frontiers, the dynamic global diversification beats all other dynamic diversification strategies. The alternative hypothesis $H_1^{RD}$ is accepted. Furthermore, the empirical findings reveal that the dynamic domestic diversification strategy is more performing that the international major and emerging markets diversification strategies. The $H_0^{RD}$ hypothesis is established. In fact, for a $TE^2$ level

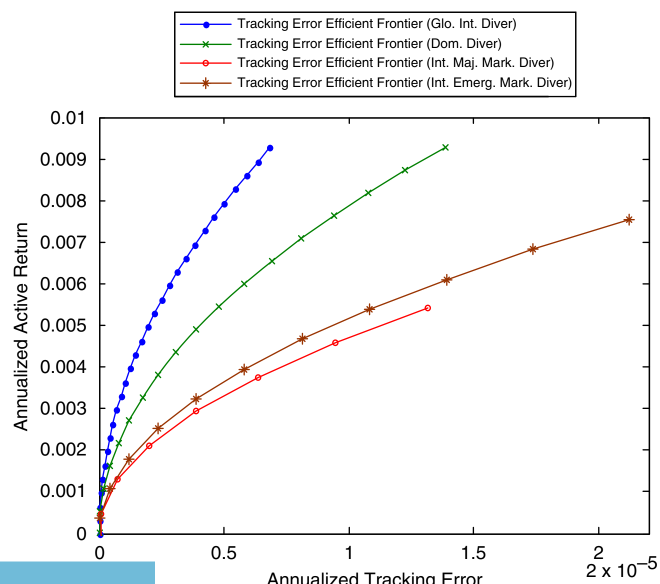



**Figure 15.**
Tracking error efficient frontiers of the all dynamic diversification strategies

lower than 0.00142 percent, diversification in local market is more advantageous than in major or in emerging markets since it produces the higher dynamic return level.

*4.2.2 Portfolios revision and return performance measurement*. Although dynamic strategy is used in practice, it seems to be costly. An efficient revision strategy only trades when the benefits exceed the revision costs. Therefore, it is necessary to compute the revision costs and the return performance level of each investment strategy. We divide our study period into 12 sub-periods counting ten months. For each sub-period, we compute the total absolute value of the weights change of all stocks in each revised portfolio relative to the benchmark portfolio. In each sub-period, we tried to find out the weights vector of the portfolio on the resampled frontier with the same variance as the portfolio to be revised.

Figures 16-19 report the asset weights of the Benchmark portfolios of the global international, domestic, emerging, and major markets dynamic diversification strategies respectively of each revision period. To the exception of some revision periods (the fourth and fifth sub-period; the sixth and eighth sub-period; the first, second, third, and 11th sub-period; and the first, second, and seventh sub-period of the global, domestic, emerging, and major markets diversification strategies, respectively), results a show low asset weights in the benchmark portfolios. The figures results reveal that the majority of the Benchmark portfolios are largely diversified.

The following figures summarize the absolute value sum of weights change of the assets in the various diversified portfolios at the end of each sub-period revision.

From the Figures 20-23, the results suggest that the revision procedures are not automatically achieved in all of the investment sub-periods. Through the 12 study sub-periods, the empirical illustration reveals that the revision is required only in 6, 8, 12, and 7 sub-periods of the international global, domestic, emerging, and major dynamic diversification strategies respectively. Each sub-period is characterized by the

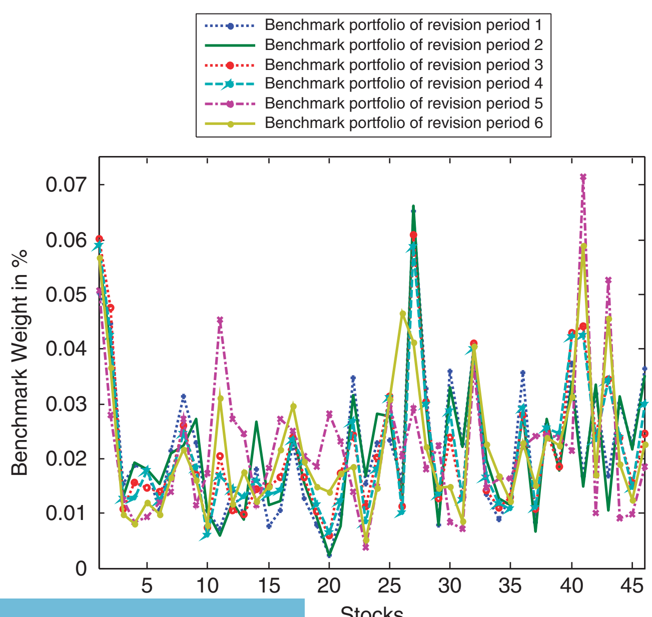



**Figure 16.**
Weights of all assets in the Benchmark portfolio of the dynamic global diversification strategy in each revision period

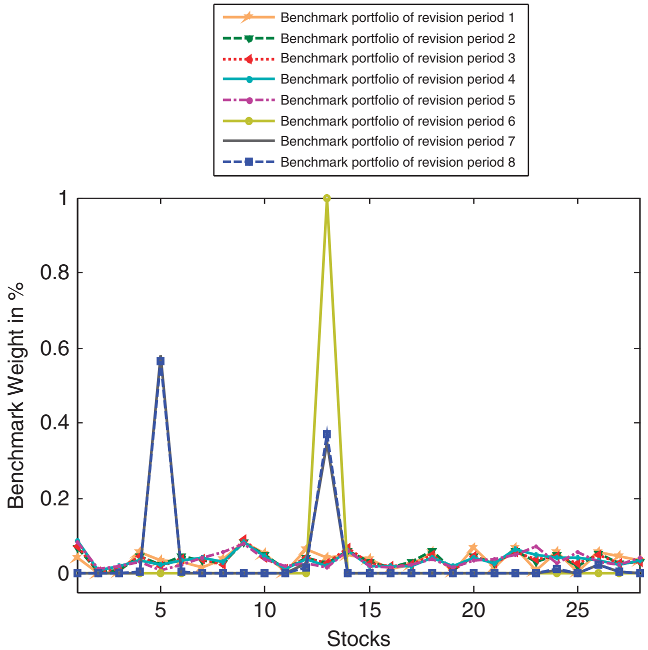



**Figure 17.**
Weights of all assets in the Benchmark portfolio of the dynamic domestic diversification strategy in each revision period

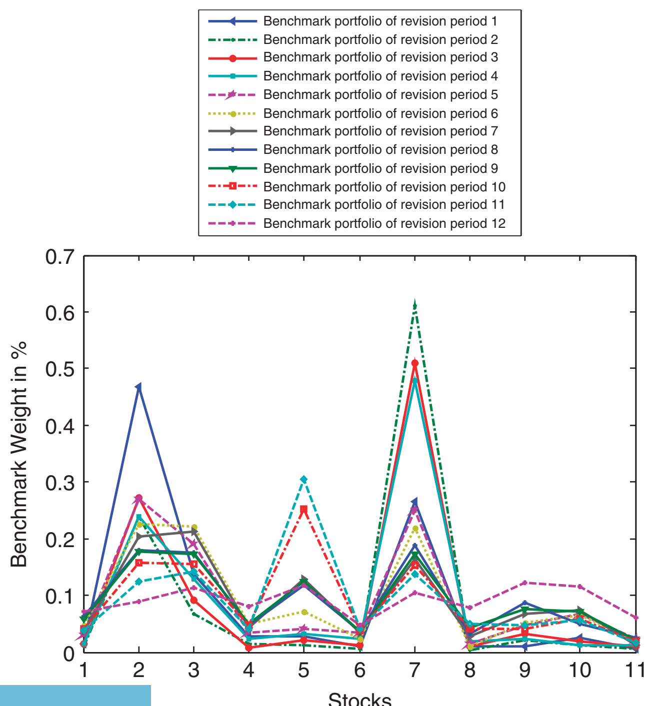



**Figure 18.**
Weights of all assets in the Benchmark portfolio of the dynamic international emerging markets diversification strategy in each revision period

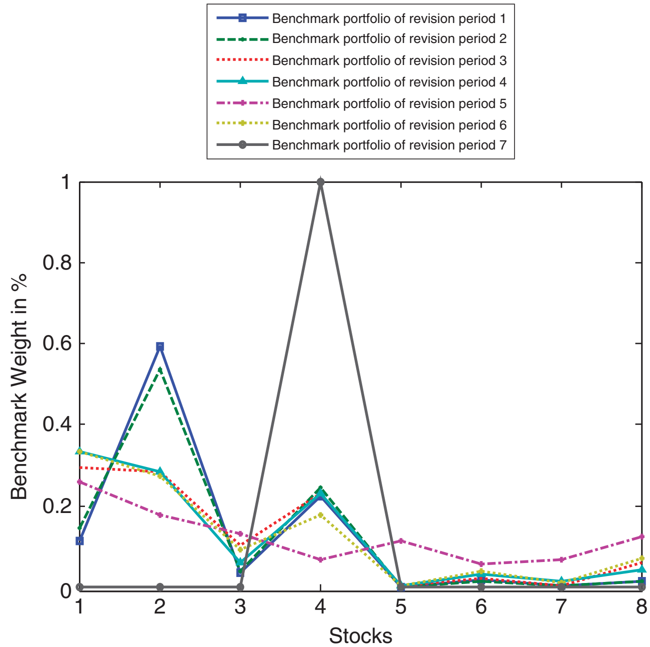



**Figure 19.**
Weights of all assets in the Benchmark portfolio of the dynamic international major markets diversification strategy in each revision period

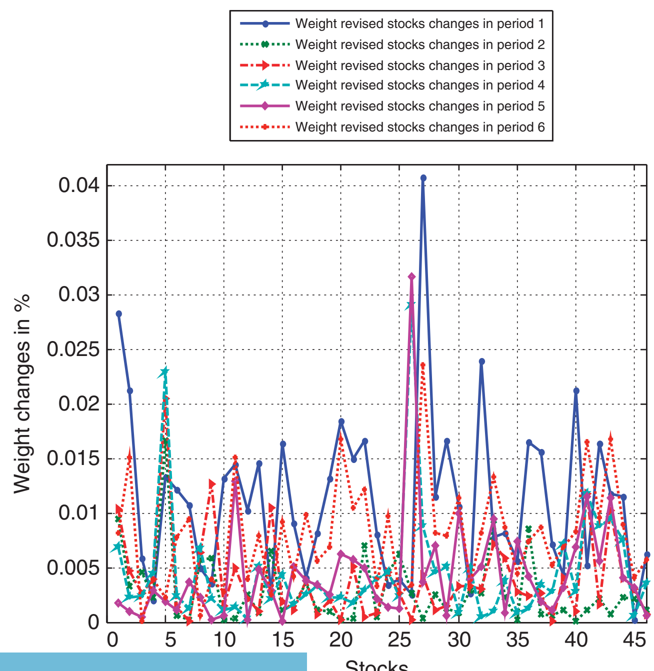



**Figure 20.**
Absolute value of weights change of the assets in the dynamic global diversified portfolios of all specified revision periods

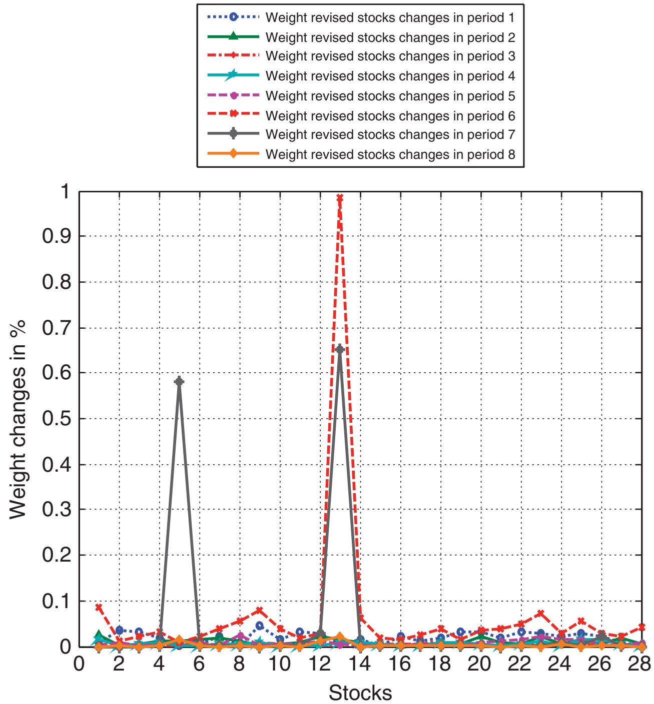



**Figure 21.**
Absolute value of weights change of the assets in the dynamic domestic diversified portfolios of all specified revision periods

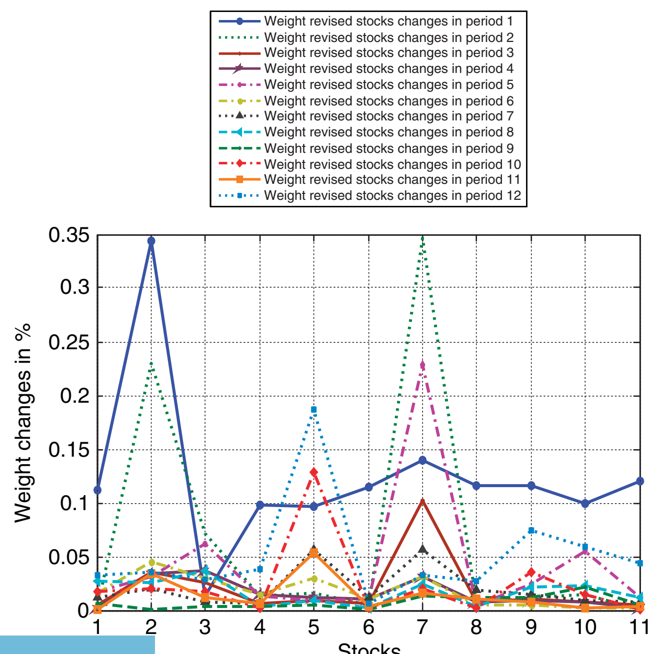



**Figure 22.**
Absolute value of weights change of the assets in the dynamic international emerging markets diversified portfolios of all specified revision periods

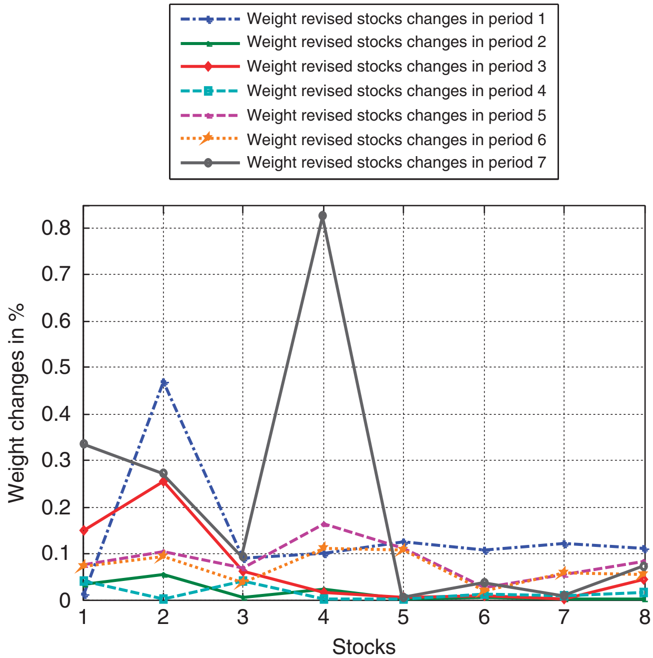



**Figure 23.**
Absolute value of weights change of the assets in the dynamic international major markets diversified portfolios of all specified revision periods

specified absolute value of weights change of the considered assets. All of the peaks illustrated in the figures imply an accentuated absolute value of weights change within each time period. From the Figure 21, the results show that the asset number 13 advances the highest absolute value of weights change equal to 100 percent in the sixth sub-period. It is likely that the accentuated weights change will affect the return performance of the corresponding sub-period investments, as it requires trading costs. Furthermore, Figure 22 reveals that the diversification in the international emerging markets, as considered from an American investor's point of view, needs a continual revision during all investment horizons, which can negatively affect the return performance level if the transaction costs are considered. Compared to the other strategies, Figure 23 shows that the international major markets diversification reveals the highest absolute value of weights change of the corresponding assets.

In the last step of our analysis, we compute periodically the after revision return performance of all dynamic diversification strategies. As there is a fair degree of hindsight bias, we multiply the last sub-period's weights by the next period's $\alpha$ return to calculate the portfolio returns in each period. When there is a revision, we multiply the absolute value of weights change with the transaction costs[3]. We add each period's return by 1 and calculate a cumulative product of all and find out the periodic portfolio returns. Figures 24-27 summarize the periodic return performance levels of the global, domestic, international emerging, and major markets dynamic diversification strategies after revision of the stock weights.

Figures 24-27 show that the periodic return performance of the four dynamic diversification strategies differed, depending on the absolute value of the weights change of the assets examined. The revision procedure was not always beneficial, and may even affect negatively the investment return performance level. Therefore,

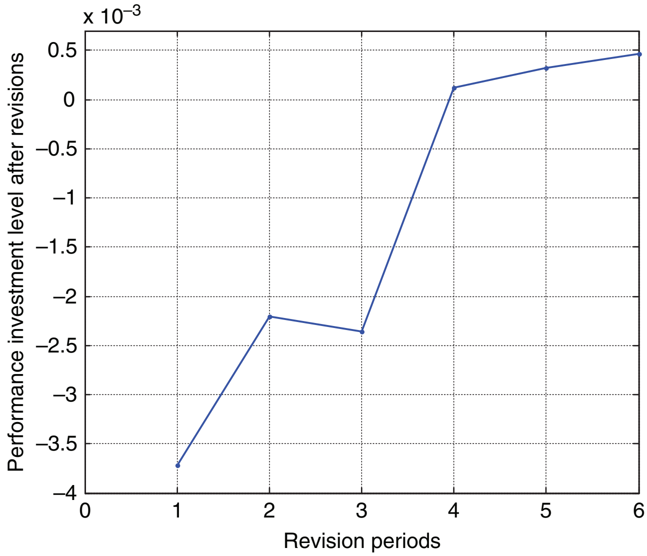



**Figure 24.**
Periodic after revision return performance level of the dynamic global diversification strategy

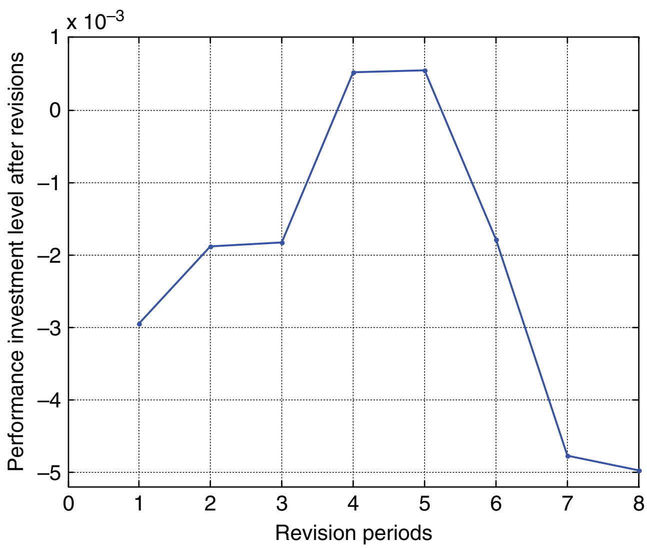



**Figure 25.**
Periodic after revision return performance level of the dynamic domestic diversification strategy

the optimal diversification strategy choices can be modified. The results demonstrate that the portfolio revision beyond the fifth, sixth, and tenth sub-period respectively becomes disadvantageous for the example American investors who prefer domestic, international major, or emerging dynamic diversification strategies. The $H_1^{PRD}$ hypothesis is accepted. Figure 24 suggests that the periodic revision through the three first sub-periods is disadvantageous, and leads to a negative return performance level equal to −0.37, −0.22, and −0.23 percent, respectively. Increased

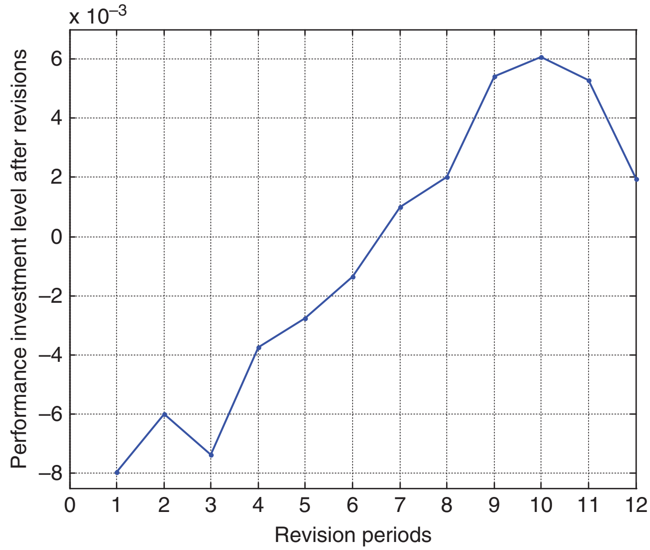



**Figure 26.**
Periodic after revision return performance level of the dynamic international emerging markets diversification strategy

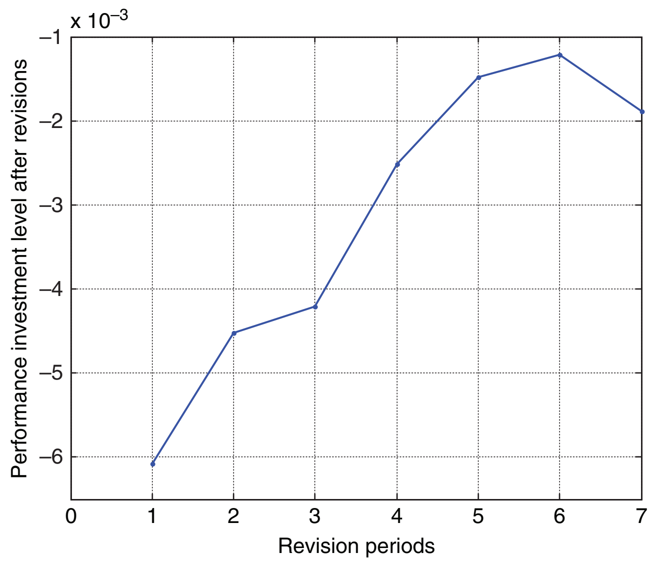



**Figure 27.**
Periodic after revision return performance level of the dynamic international major markets diversification strategy

weights asset transition leads to high revision costs. However, the $H_0^{PRD}$ hypothesis is verified beyond the fourth sub-period as portfolio revision becomes less expensive. In spite of the transaction costs, the dynamic global diversification is advantageous to the US investor in the fourth, fifth, and sixth sub-periods revision. During these corresponding sub-periods, it generates a return performance level equal to 0.12, 0.032, and 0.036 percent, respectively. From Figure 25, in 25 percent of the sub-periods revision, the domestic diversified portfolios revision reveals a negative return performance level equal to −0.29 percent. However, the same strategy shows positive return performance levels in the fifth and sixth sub-periods which are of the order of 0.052 and 0.054, respectively. In 50 percent of the sub-periods revision, Figure 26 suggests that the $H_0^{PRD}$ hypothesis is confirmed. In fact, the revision of the international emerging markets diversified portfolios seems to be advantageous in the seventh, eighth, ninth, tenth, 11th, and 12th sub-periods. Nevertheless, Figure 27 reveals that the revision of the international major markets diversified portfolios is considered not beneficial for an American investor since the cost exceed the return resulting from the revision of the asset weights in the portfolio. In conclusion, when the transaction costs of portfolio revision are considered in the return performance level computation, the empirical findings reveal the dominance of the dynamic international emerging markets and the dynamic global diversification over the domestic and the major markets diversification strategies.

## 5. Conclusion

In this paper, we evaluate the performance of a portfolio revision procedure and we examine the problem of domestic and international dynamic investment choices from an American investor's point of view, while considering the impact of estimation errors on the optimization processes in financial portfolios. We investigate the dynamic diversification strategy choices by the TEEF and we evaluate the return performance of the periodical portfolios revision. Based on daily quotations of American, Latin American, Asian financial block index markets, and American stocks for the period from August 3, 1997 to August 31, 2011, the empirical results suggest that a static and dynamic global diversification strategy enhances the feasibility of the optimal strategies in spite of the benefits of a domestic diversification strategy. TEEF plot reveals that a domestic diversification strategy beats international major and emerging markets dynamic diversification strategies. When the transaction costs are considered, the data suggest that a periodical revision of the weights of the assets in the portfolio appears to be of no systematic advantage. In spite of the benefits, portfolio revision procedures can negatively affect the performance level of the local and the international investments. Considering the transaction costs of portfolios revision, the results of the return performance computation suggest the dominance of the dynamic global and the international emerging markets diversification strategies over all other strategies. An assessment between the return and the cost of the portfolios revision strategy is necessary.

### Notes

1. Abitibi-Consolidated Inc. (ABY), American Electric Power Co Inc. (AEP), American Express Co. (AXP), Apple Computer Inc. (AAPL), Bank of New York (BK), Coca-Cola Co. (CO), Computer Associates International Inc. (CA), Exxon Mobil Corp. (XOM), General Electric Co. (GE), General Motors Corp. (GM), International Business Machines Corp. (IBM), Oracle Corp. (ORCL), Royal Dutch Petroleum Company (RD), Southwest Airlines Inc. (LUV), Motorola Inc. (MOT), AMR Corp. (AMR), Bank of America Corp. (BAC), Ford Motor Co. (F), American International Group Inc. (AIG), Bristol-Myers Squibb Co. (BMY), Burlington Northern Santa Fe Corp. (BNI), CH Energy Group Inc. (CHG), Citigroup Inc. (C), DTE Energy Co. (DTE), Fedex Corp. (Federal Express) (FDX), Intel Corp. (INTC), and McDonald's Corp (MCD).
2. Our choice of database is justified by the fact that the majority of empirical studies have found that, in a globalization context, the presence of the US stock market, index, and investor's point of view would guarantee the global look that any investor would have about international diversification opportunities. Besides, the consideration of the most Asian

countries and the North and Latin American countries have a greater potential for diversification compared to the European countries.

3. We consider a fixed transaction cost equal to 0.3 percent. This value is deducted from the corresponding return of our study period.

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