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Enhanced index tracking with multiple time-scale analysis ☆

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ABSTRACT

This paper considers the process optimal strategies for an enhanced index tracking problem. The investment goals are set to achieve a higher return than the benchmark by setting the portfolio's risk profile identical to the primary index risk factors. Return differences between the index and the tracking portfolio are classified as positive and negative series. Multiple time-scale features of each series are extracted by the method of empirical mode decomposition. Then the positive return deviations are modeled by trend-like low frequency behavior and the negative return deviations are modeled by a trendless high frequency behavior. By adopting an immunity-based multi-objective optimization algorithm, the solutions for the process optimal enhanced index tracking are developed. Five data sets drawn from major world markets are adopted to implement our approach. The computational results show the superiority of our model.

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1. Introduction

Index investment is a type of passive fund management that describes the process of producing a portfolio that is a perfect match to the benchmark index. Since indexed portfolios have lower fees and better diversification than actively managed accounts, this passive strategy has broadly considered by more than just portfolio managers. However, a perfectly indexed portfolio will always underperform the index by the amount of the transactions costs associated with portfolio management, which cannot be found for the index itself. For this reason, the problem of enhanced index tracking has received a lot of attention in the past decade.

Enhanced index tracking, also known as "risk-controlled active", is designed to outperform its benchmark index without incurring much additional risk. Such strategies come in two basic forms: derivative based and stock based. Derivative-based enhanced index tracking intends to provide exposure to the desired equity market through a derivative and the enhanced return through something other than equity investments. The studies about such strategy can be found in Hill and Haviwala (1999), Miller and Mechel (1999). Enhanced index tracking based on stock selection can be executed using either active or passive strategies. By using active strategy, the portfolio is divided into two parts. One is managed by passive strategies to control the risk, whereas the remainders are actively managed to generate alpha by stock selection and market timing. Since the drawbacks incurred by active management (such as more risk and transaction cost) could reduce or eliminate the advantages of index tracking, researchers have focused on passively managed enhanced index tracking. The majority of the related work presented in the literature consists of two steps. The first step is to select stocks of all ones in the index based on some statistical methods, such as stratified and clustered sampling (Dose and Cincotti, 2005; Focardi and Fabozzi, 2004; Frino et al., 2005), or heuristic approaches (Orito et al., 2003). The second step is to allocate the stocks in the tracking portfolio by minimizing some tracking error measures and maximizing the excess return simultaneously. The researches focus on efficient ways for implementing this optimization subject to investment constraints. Some researchers combine these two steps with one optimization problem. See the studies of Canakgoz and Beasley (2009) and Li et al. (2011) for a brief review of all these literatures.

All these studies assume that good results for terminal value of tracking error and excess return can lead to good tracking portfolios. While the terminal value is important indeed, the dynamics of tracking process should also be considered for enhanced index tracking. For example, in the situation of arbitraging on stock index futures which may require minimizing tracking error in any moment, investors may prefer the one with higher short run fluctuations on tracking deviations where they are averse to longer swings. On the other hand, one may

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choose quite a different kind of deviation dynamics for enhanced index tracking. The one with return persistently above the benchmark index would be more favorable. In fact, this issue has been taken into consideration in the studies of pure index tracking. For example, Stock and Watson (1988) suggest that the time dynamics of the stocks composing the index should share the common trend. Based on this statement, Corielli and Marcellino (2006) suggest that the difference between the index and the tracking portfolio should be characterized by a trendless high frequency behavior. They present a factor model in which the factors affecting stock price are ordered from long-term to short-term. The optimal portfolio they construct consists of the stocks that best correlate with each factor. Such procedure results in the tracking portfolio driven by the same persistent factors as the index. Alexander and Dimitriu (2004) propose a model to select optimal tracking portfolio using principal component analysis in the stock returns. By replicating the first principal component, the portfolio accounts for the largest proportion of the variation in the stock returns, and then captures only the common trend of the stocks included in the benchmark index. Some other researchers have also tried to construct portfolios based on a cointegration relationship with the benchmark index (Alexander and Dimitriu, 2005; Dunis and Ho, 2005).

In this paper, we consider the case where investor can choose and control the tracking dynamics of the enhanced tracking portfolio. The model proposed here is still in the framework of passively managed enhanced index tracking, but we add two optimizations for tracking process so that the portfolio could produce good performance in both terminal and the tracking process for enhanced index tracking. More specifically, we use empirical mode decomposition (EMD) to extract the spectral power from the differences between the index and the tracking portfolio. The tracking deviations can be viewed as an equally weighted sum of the spectral power at different frequencies. By removing the restriction of equal weights of time-scale, we allow different weights to be assigned to different time-scale features. The weights reflect the relative importance of each scale in the process of index tracking. For example, in the context of enhanced index tracking, a perfectly enhanced indexed portfolio will constantly outperform the index by a fixed amount. Therefore, the positive return deviations between the portfolio and the index should be characterized by a trend-like low frequency behavior, whereas the negative return deviations should be characterized by a trendless high frequency behavior. For this reason, the weights assigned to the high frequency features of positive deviations and the low frequency features of negative deviations are set to be 0. By maximizing and minimizing the sum of the remainders respectively, the resulting portfolios will favor tracking error and excess return in different frequencies. Although time-scale extractions have been already employed to active portfolio selection, such as covariance matrix filtering and multi-scale variance preference (Bowden and Zhu, 2010), the literature about time-scale based enhanced index tracking is still quite undeveloped. Li et al. (2011) propose an index tracking model by using Wavelets analysis to decompose the stock price series into different time scales. However, they do not actually consider the dynamics of tracking process. Our objective in this paper is to shed some light on the tracking process control involved in enhanced index tracking. The model proposed in this paper can be easily modified and extended to the problem of pure index tracking. We believe that the contribution of this paper is:

(1) To propose a new way to define and analyze the dynamics of the return deviations between the index and the tracking portfolio. By using EMD for the spectral decomposition, our model can filter out time scales at designated frequencies, allowing others to pass through unhindered. Such procedure has the considerable advantage of controlling the tracking process.

(2) To suggest a new model of return enhancement for index tracking. By adding the objectives of maximizing the low frequency of positive return deviations and minimizing the low frequency of negative return deviations to the model, the terminal performance of excess return and tracking error could be improved because of the improved tracking process.

(3) To ensure the common trend capturing in both portfolio construction and portfolio selection. Previous literatures focus either on the step of selecting component stocks, such as factor models, or on the step of portfolio allocation, such as cointegration analysis. Our approach proposes a complete model for common trend index tracking.

The rest of this paper is organized as follows: Section 2 describes the properties of the most widely used tracking objective measures and shows the advantages of our definitions in this paper. Section 3 presents the complete model for enhanced index tracking and Section 4 presents the algorithm applied to solve the model. Section 5 presents computational results followed by a conclusion section.

2. Measures of tracking objective

Tracking error and excess return are the two measures usually employed to measure tracking objectives for enhanced index tracking. Tracking error is the function of tracking risk which measures the distance between the returns of the tracking portfolio and its benchmark index, while excess return measures the extent of portfolio return that is above the return of the index. Other than pure index tracking, enhanced index tracking aims to maximize excess return with minimizing tracking risk at a controllable level. Due to the development of index tracking, measures of tracking objectives have gained tremendous importance because it directly determines the portfolio selection and performance evaluation. Taking tracking error as an example, the most widely used measures of tracking error can be categorized into two forms: one is defined as the variance of return differences between the tracking portfolio and the index (Pope and Yadav, 1994; Rudolf et al., 1999); the other one performs a linear regression of tracking portfolio returns against index returns and adopts the variance of the regression residuals as the measure of tracking error (Treynor and Black, 1973). However, both definitions have a common drawback that tracking error could be zero while the value of index and its tracking portfolio drift apart by a constant. By criticizing that, Beasley et al. (2003) use the tracking mean square error as the measure for the problem of index tracking. Specifically, they define tracking error as:

$$TE = \frac{1}{T}\left[\sum_{t=1}^{T}\left(r_p(t)-R(t)\right)^2\right]^{1/2} \tag{1}$$

where $r_p(t)$ and $R(t)$ are, respectively, the return from the tracking portfolio and from the index.

Corielli and Marcellino (2006) argue that this measure is still not enough to discriminate between “good” and “bad” tracking. Two tracking portfolios might have just the same terminal value of tracking error, yet be exposed quite differently to alternative path dynamics. Consider two tracking portfolios A and B as an example. For A, the positive and negative deviations from the index cross frequently, while portfolio B could spend a long time below the index value and then uniformly above it. Although the tracking processes are different, the terminal value of tracking error for both portfolios could be the same if Eq. (1) is adopted as the measure. It is worth noting that this phenomenon also exists in traditional excess return measures, which is assessed by the average excess return per period achieved by the tracking portfolio or the total return over the entire investment horizon (Beasley et al., 2003).

Bowden and Zhu (2010) refer the sensitivity to particular profiles of value fluctuations through time as path risk. For an active management fund, portfolios are chosen according to the investors' preference for variance horizons. So a portfolio with high return frequency of fluctuations is not good for investors who accept long run variance and vice

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