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Modeling Exchange Traded Funds Portfolio using Optimization Model

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***Abstract*—In recent years Exchange Traded Funds has emerged as an important investment alternative that combines both the low risk and high liquidity advantages. The construction and active management of ETFs are the central issues for the exploitation of its potential. This paper conducts the empirical studies, using the Markowitz portfolio optimization model, to construct an optimal ETF portfolio in the emerging markets. We found that the portfolio performance improves with the proposed approach against the benchmark market indexes. The performance is sensitive to the optimization criteria chosen and optimization parameters used.**

***Keywords*-Exchange Traded Funds; Markowitz Portfolio Optimization; Standard Deviation**

I. Introduction

Since the financial crisis and the collapse of major investment banks in 2008, investors are increasingly conservative, putting low risk and and high level of transparency their priority during the investment process. Exchange Traded Funds (ETF) is an open-ended investment fund that can be traded like a stock on a stock exchange. ETF is also an index-tracking collective investment fund aiming to track the performance of an underlying index. It is achieved by holding a portfolio of the constituent stocks of that underlying index [1]. Compared to traditional mutual funds known to be associated with high level of cost, low level of liquidity and transparency issue, ETF is often viewed as more cost-effective alternative as they have low cost and administrative expenses due to their passive nature that investment managers simply follow the underlying tracking indices without the need to develop complicated and high cost investing strategies [2], [3].

There are many advantages over investing ETFs. For example, diversification across many shares through a single investment and small size investment; relatively low management cost since it is passively managed; high liquidity as ETFs can be bought and sold instantaneously on major stock exchanges; highly transparent as Since the level of the index and the constituent stocks that make up the index is publicly available information; can help to delay capital gains taxes, to name just a few. Thus in periods of uncertainty and volatile market environments, investors will find ETFs attractive in providing benefits of investing in a wide range of asset classes, with prior knowledge of the compositions and characteristics of the index.

Despite its advantages, the passive nature of its management style has put strains on its further development as it is mostly used to track a particular index and lacks the flexibility investors may demand. These include higher return in addition to other ETF features, shifting from the passive management paradigm to more active management oriented paradigm. More importantly, investors may be interested in investing in several particular sectors, but lack the ETF product to invest.

Recently there has been the emergence of research and practice of actively managed ETF to address these issues. The main idea is to replace the underlying market portfolio index with the specially designed index that suits investors' demand. However, the tracking index usually lacks the authoritative status and is hard to meet versatile needs in the financial market. This approach also risks reducing the conservative nature desired for turbulent period.

Therefore this paper proposes the portfolio optimization algorithm to construct ETF portfolios. This approach would offer more flexibility, such as higher returns and accessibility to more sectoral markets, to satisfy investors requirements while retaining the stable performance and the benefits with passive investment style. To the best of our knowledge, there is very limited researches in the literature exploring the ETF portfolio optimization models, especially concerning the benefits of Asian investors or in particular, Hong Kong listed ETFs with emphasis on local retail investors.

The remainder of the paper is organized as follows: the literature on the ETF and portfolio optimization literature are reviewed in section II. Section III proposes the methodology. Empirical studies are conducted to evaluate the performance improvement for the proposed optimized ETF portfolios in section IV. Section V concludes.

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II. Literature Review

Compared to Open-Ended Funds (OEFs), numerous empirical studies show the superior performance of ETFs. For example, [4] makes a comparison between Open-Ended Funds and ETFs, concluding that ETFs overcome the constraints of Open-Ended Funds (OEFs), while maintaining the benefits of low cost, diversification and tax efficiency. [5] shows that the ETF is a more suitable investment vehicle when investors have more correlated liquidity shocks or when the underlying indexes are narrower or less liquid. [6] also suggests that ETFs are an especially important tool for larger investors and that long-term retail investors can also use them effectively. [7] compare the risk and return performance of ETFs and Closed-End Funds (CEFs) for 14 countries. Results show that ETFs exhibit higher mean returns and higher Sharpe ratios than CEFs. However, when it comes to the evaluation of the performance of ETFs against the benchmark market portfolio, the results are not so optimistic, and generally leaning toward the negative side. For example, [8] and [9] examines the performance of ETFs relative to their respective benchmarks and conventional index funds. Study shows that ETFs have generally underperformed competitive conventional mutual funds and their benchmark indices. [10] estimate tracking errors from 26 ETFs utilizing three different methods and test their relative performance using Jensen's model. The finding of negative Jensens alphas implies that investing in ETFs does not provide a significant benefit compared to their benchmark returns. [5] compare ETFs and target market index portfolios and conclude that while ETFs may offer more diversified benefits than target market, there are no significant performance differences between indirect invest method (ETFs) and direct one. Research by Blitz et al. (2012) shows that European index funds and exchange-traded funds underperform their benchmarks by 50 to 150 basis points per annum. [11] examined the performance of sector ETFs in relation to their S&P industry sectors and prospectus benchmark indexes. They applied regression analysis to analyze diversification and employed Sharpes Single Index Market Model and the Sharpe ratio to analyze performance. They found that ETFs do not provide an investor with a level of sector risk exposure equal to that of the S&P sector. Meanwhile, actively managed ETFs have recently emerged due to the investors demand for more flexibility and higher returns. Review by Rosella and [12] argued that despite its successful debut in the market place, it still faces the concerns both from SEC and the market place on whether it can retain the advantages of traditional ETFs including portfolio transparency and arbitrage opportunity. Empirical evidence in the literature so far has shown it also failed to beat the market index. For example, [12] conducted the empirical studies in the US market, consisting of both recent emerging active and passive ETFs. Experiment results show that both active and passive underperform the tracking index and the market portfolios, where actively managed ETFs performed the worst. [13] argued that portfolio management have been part of the ETF management strategies as two ETFs with the same underlying index perform differently in their empirical studies. The most relevant work identified in the literature is [14]. They investigated the performance improvement of constructed ETF portfolios using optimization algorithm under a Markov regime-switching framework. They compared the performance of the proposed algorithm against the naive equal weighting strategy. However, the focus of their work was on the development of innovative optimization algorithm, and less on the potential of active management portfolio construction using optimization algorithm.

III. Methodology

Data investigated in this research consist of the historical daily Net Asset Values (NAVs) of 14 ETFs from iShares, a major ETF provider listed in Hong Kong stock exchange and their corresponding closing prices of the tracked underlying indexes. The data were obtained from the website of the ETF provider such as Hong Kong Exchanges and Clearing Limited, which provide publicly available data source. As ETFs are listed on different starting day, the starting date for the data analysis chosen to be on or before 20 July 2010, which covers the period of the European debt crisis that would provide an interesting period of analysis, as well as provide consistent historical data for analysis due to data availability. The end date for the data asset is set to be April 2013, when the latest data are made available as the research was conducted. ETFs for both China and emerging markets are investigated. ETF in Chinese market are mostly synthetic as the foreign investors do not have direct access to the strictly controlled Chinese market and are forced to resort to the total return swap to construct ETF portfolio. The performance of ETF is evaluated against the major indexes these ETFs are tracking in their respective markets, as well as the benchmark market indexes. The data span through the latest date when data are made available as the research is conducted. The performance is measured using the common return and risk measures. Return is measured with simple return r calculated as $r_t = \frac{NAV_{t+i} - NAV_t}{NAV_t}$ or $r_t = \frac{Index_{t+i} - Index_t}{Index_t}$ where NAV and $Index$ refer to the price of NAV of ETF and the underlying index at different time t. The risk is measured with standard deviation σ calculated as $\sigma = \frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2$. The risk adjusted return is measured by Sharpe calculated as $\frac{r_i - r_m}{\sigma_i}$, which calculates the return per risk, where $r_i - r_m$. The tracking error is measure as $TE_i = \frac{\sum_{t=1}^{n}(D_{i,t} - \bar{D}_i)^2}{n-1}$, where $D_{i,t}$ is the i_{th} difference between the return of ETF and index at time t, $\bar{D}_i$ is the mean of $D_{i,t}$. The Markowitz mean variance portfolio optimization model is formulated as follows:

$$Min\sigma = \sqrt{\sum_{j=1}^{n}\sum_{i=1}^{n} w_i w_j \rho_{i,j}\sigma_i\sigma_j}$$

$$\begin{cases} w_i < W_i \\ w_i > 0 \\ \sum_{i=1}^{n} w_i r_i > R \\ \sum_{i=1}^{n} w_i = 1 \end{cases}$$

Where $r_i, (i \in R)$ and $\sigma_i, (i \in R)$ refers to the return and the standard devaition of the i_{th} asset in the portfolio. R and σ refer to the expected (required) return and standard deviation for the portfolio.$w_i, (i \in R)$ and W_i refers to the weight and the upper bound for the i_{th} asset respectively. $\rho, (i, j \in R)$ refer to the correlation coefficient between the i_{th} and j_{th} assets.

IV. Empirical Studies

Data set is divided into two parts. The first part serves as the training set to determine the optimal weights for the ETFs in the portfolio. It covers the time range from July 2010 to December 2012. The second part serves as the testing set, evaluating the performance of the optimized portfolio against the benchmark market portfolios. It covers the time range from January 2013 to April 2013. The code and name of ETFs investigated are listed in table I.

Table I
Name list for ETFs

ETF Code	ETF Name
2836	iShares BSE SENSEX India Index ETF
2846	iShares CSI 300 A-Share Index ETF* (* This is a synthetic ETF)
3001	iShares CSI A-Share Consumer Discretionary Index ETF* (* This is a synthetic ETF)
2841	iShares CSI A-Share Consumer Staples Index ETF* (* This is a synthetic ETF)
3050	iShares CSI A-Share Energy Index ETF* (* This is a synthetic ETF)
2829	iShares CSI A-Share Financials Index ETF* (* This is a synthetic ETF)
3006	iShares CSI A-Share Infrastructure Index ETF* (* This is a synthetic ETF)
3039	iShares CSI A-Share Materials Index ETF* (* This is a synthetic ETF)
2823	iShares FTSE A50 China Index ETF* (* This is a synthetic ETF)
3010	iShares MSCI Asia APEX 50 Index ETF
3032	iShares MSCI Asia APEX Mid Cap Index ETF
3004	iShares MSCI Asia APEX Small Cap Index ETF
2801	iShares MSCI China Index ETF
2802	iShares MSCI Emerging Asia Index ETF

Experiment Returns and risk performance for different ETF portfolios are listed in table II.

Results in table II show that ETFs show different levels of returns and risk levels, offering investors different choices. However, the return level is generally low, accompanying the low level of risks born by the investors. We conduct experiments to derive the optimal weights given different expected returns. The resulting efficient frontier are illustrated in figure 1 while detailed results are presented in table III.

Results in both figure 1 and table III show that the optimal portfolio with the optimal risk adjusted return, measured by Sharpe ratio, has been achieved when the portfolio is constructed with ETF code 2841 and ETF code 3006. The optimal weighting for them are 99The comparison between the performance of the optimized portfolio and the

Table II
In-sample Performance of different ETFs

Average return	Variance	Standard deviation	
F2836	-0.00192	1.798782	1.341187
F2846	-0.01077	1.788404	1.337312
F3001	-0.00556	2.146651	1.465146
F2841	0.030562	2.08458	1.443808
F3050	0.007381	3.237232	1.799231
F2829	0.010678	1.885922	1.373289
F3006	-0.02548	1.388637	1.178404
F3039	0.006538	3.205596	1.790418
F2823	-0.00068	1.55433	1.246728
F3010	0.039279	1.640484	1.280814
F3032	0.006663	1.738846	1.318653
F3004	0.013323	1.473497	1.213877
F2801	0.013955	2.148883	1.465907
F2802	0.035299	1.648265	1.283848

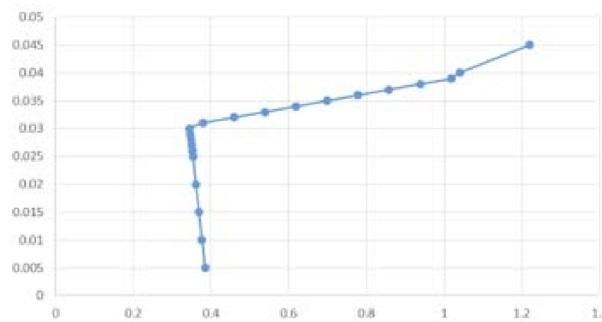

Figure 1. Sharpe ratios for different ETF portfolios

Table III
Sharpe Ratio for different ETF portfolios

Number	Sharpe Ratio	Expected Return	Risk
1	0.012988	0.005	0.384983
2	0.026519	0.01	0.377086
9	0.03692	0.045	1.218858
22	0.038325	0.039	1.017614
8	0.038466	0.04	1.03989
21	0.040518	0.038	0.937849
3	0.04063	0.015	0.369189
20	0.043119	0.037	0.858086
19	0.046253	0.036	0.778323
7	0.050103	0.035	0.698566
18	0.050103	0.035	0.698559
17	0.054945	0.034	0.618796
4	0.055357	0.02	0.361292
16	0.061221	0.033	0.539032
15	0.069676	0.032	0.459269
5	0.070742	0.025	0.353395
10	0.073903	0.026	0.351814
11	0.077091	0.027	0.350234
12	0.080308	0.028	0.348657
14	0.081684	0.031	0.379509
13	0.083555	0.029	0.347077
6	0.086831	0.03	0.345498

benchmark index during the same period are illustrated in figure 2 while details are listed in table IV.

Table IV
PERFORMANCE COMPARISONS OF ETF PORTFOLIOS AND BENCHMARK INDEXES

Portfolio Number	Return for Portfolio	Return for Benchmark Index
1	-1.0882	12.6950
2	1.6737	15.9861
3	4.4357	19.2771
4	7.1976	22.5681
5	9.9595	25.8591
6	12.7215	29.1502
7	16.9985	30.7276
8	20.8233	31.8918
9	23.7247	35.2944
10	10.5119	26.5173
11	11.0643	27.1755
12	11.6167	27.8337
13	12.1691	28.4920
14	13.4232	29.6394
15	14.3170	29.9115
16	15.2108	30.1835
17	16.1046	30.4556
18	16.9985	30.7276
19	17.8923	30.9997
20	18.7861	31.2718
21	19.6799	31.5438
22	20.5737	31.8159

The comparison between the performance of the optimized portfolio and the benchmark index during the same period are illustrated in figure 2.

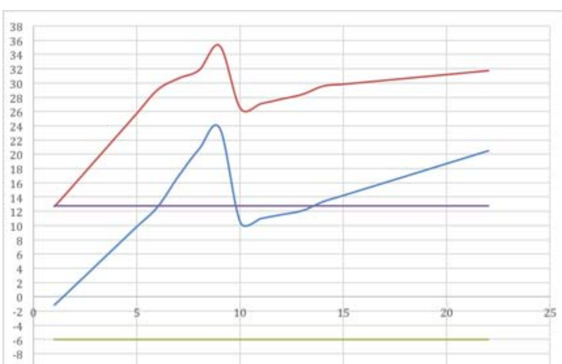

Figure 2. Performance comparisons of ETF portfolios and benchmark indexes

The optimized weights for different ETF portfolios given different expected return is listed as follows.

With the optimized portfolio weights listed in table V, we further conduct experiments to test the performance of the optimized portfolio against the benchmark indexes out-of-sample, holding fix the optimized portfolio weights and using the data from January 2013 to April 2013. Experiment results are listed in table VI.

The comparison between the performance of the optimized portfolio and the benchmark index during the out-of-sample testing period are illustrated in figure 3.

Table V
OPTIMIZED WEIGHTS FOR DIFFERENT ETF PORTFOLIOS

Number	F2836	F2846	F3001	F2841	F3050	F2829	F3006	F3039	F2823	F3010	F3032	F304	F2801	F2802
1	0	0	0	0.54	0	0	0.46	0	0	0	0	0	0	0
2	0	0	0	0.63	0	0	0.37	0	0	0	0	0	0	0
3	0	0	0	0.72	0	0	0.28	0	0	0	0	0	0	0
4	0	0	0	0.81	0	0	0.19	0	0	0	0	0	0	0
5	0	0	0	0.9	0	0	0.1	0	0	0	0	0	0	0
6	0	0	0	0.99	0	0	0.01	0	0	0	0	0	0	0
7	0	0	0	0.49	0	0	0	0	0	0.51	0	0	0	0
8	0	0	0	0	0	0	0	0	0	1	0	0	0	0
9	0	0	0	0	0	0	0	0	0	1	0	0	0	0.16
10	0	0	0	0.92	0	0	0.08	0	0	0	0	0	0	0
11	0	0	0	0.94	0	0	0.06	0	0	0	0	0	0	0
12	0	0	0	0.95	0	0	0.05	0	0	0	0	0	0	0
13	0	0	0	0.97	0	0	0.03	0	0	0	0	0	0	0
14	0	0	0	0.95	0	0	0	0	0	0.05	0	0	0	0
15	0	0	0	0.84	0	0	0	0	0	0.16	0	0	0	0
16	0	0	0	0.72	0	0	0	0	0	0.28	0	0	0	0
17	0	0	0	0.61	0	0	0	0	0	0.39	0	0	0	0
18	0	0	0	0.49	0	0	0	0	0	0.51	0	0	0	0
19	0	0	0	0.38	0	0	0	0	0	0.62	0	0	0	0
20	0	0	0	0.26	0	0	0	0	0	0.74	0	0	0	0
21	0	0	0	0.15	0	0	0	0	0	0.85	0	0	0	0
22	0	0	0	0.03	0	0	0	0	0	0.97	0	0	0	0

Table VI
PERFORMANCE COMPARISONS BETWEEN DIFFERENT ETF PORTFOLIOS AND THE BENCHMARK INDEXES

Portfolio Number	Return for Portfolio	Return for Benchmark Index
1	-0.0449	-0.0319
2	-0.0487	-0.0346
3	-0.0525	-0.0373
4	-0.0563	-0.0400
5	-0.0601	-0.0427
6	-0.0639	-0.0454
7	-0.0466	-0.0406
8	-0.0296	-0.0357
9	-0.0338	-0.0410
10	-0.0608	-0.0433
11	-0.0616	-0.0438
12	-0.0624	-0.0443
13	-0.0631	-0.0449
14	-0.0626	-0.0452
15	-0.0586	-0.0441
16	-0.0546	-0.0429
17	-0.0506	-0.0418
18	-0.0466	-0.0406
19	-0.0426	-0.0395
20	-0.0386	-0.0383
21	-0.0347	-0.0372
22	-0.0307	-0.0360

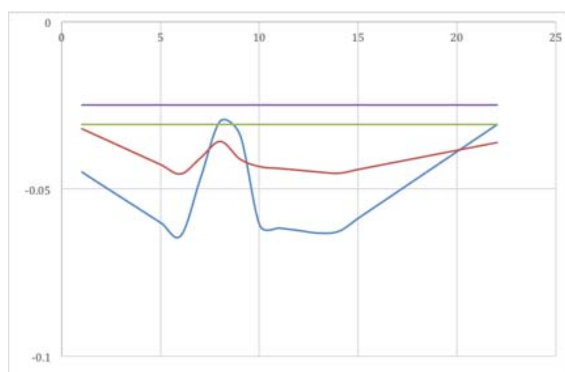

Figure 3. Performance comparisons between different ETF portfolios and the benchmark indexes

Results from figure 3 and table VI show that the optimization algorithm can lead to improved performance in general, competent to the market portfolio. Among them, portfolio 8 has achieved the competent returns, higher than the CSI300.

V. Conclusions

In this paper, we have proposed the Markowitz portfolio optimization model to construct an optimal ETF portfolio. The criteria has been set to maximize risk adjusted return. Empirical studies using ETFs in the emerging markets on the performance of ETF portfolio optimization approach has been conducted, against the benchmark market indexes. Depending on the criteria set, we found that ETF portfolio can be constructed with optimized return characteristics that meet investors' needs, which is the Sharpe ratio in this paper, but could be extended to other criteria such as the sleekness and kurtosis as well. Work in this paper provides the convincing evidence that ETF portfolio construction using optimization algorithm represent the important investment alternative.

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