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Asian Emerging Market Government Bond Portfolio Optimization Using Mean-Variance Analysis in the Presence of Duration Constraint

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ABSTRACT
This study applies Markowitz's mean-variance optimization method (1952) by setting duration constraint for an investment portfolio consisting of Asian emerging market local currency government bond indexes. The historical return data used in this study are obtained from daily bond indexes of Indonesia, Malaysia, Thailand, the Philippines, and Korea provided by ICE Data Indices, LLC (with permission) for the period of 2010-2019. This study shows that the portfolio composition strategy resulting from the optimization provides the highest Sharpe ratio from January to June 2020 (out-of-sample) compared to several other strategies without any duration constraint, such as capitalization-weighted and equally-weighted, as well as other strategies with duration constraint. End-of-month performance monitoring between January 2020 and June 2020 indicates that the Sharpe ratio of the optimal strategy began to increase after market volatility due to COVID-19 pandemic anxieties, which peaked around March 2020. The optimization strategy in this study would be an alternative strategy for conservative investors to perform asset allocation as a long-term investment policy to have exposure to Asian emerging market before adding other asset classes, such as Asian emerging market corporate bonds and stocks.

Keywords: *Asian Emerging Market Local Currency Government Bond, Bond Indexes, Mean-Variance Analysis, Duration Constraint, Sharpe Ratio.*

1. INTRODUCTION

The Asian financial market has increasingly become an alternative for global investors to place their money. The global financial crisis in 2008, with an epicentre in the United States (US), triggered the US central bank (Federal Reserve) to launch a Quantitative Easing (QE) policy. The QE policy led to the flow of fresh money into the global financial market, thus encouraging investors to seek higher-return investments, such as corporate bonds, equities, and financial assets in emerging markets. Consequently, the Federal Reserve's QE policy brought capital flows into the Asian emerging market. Global investors deemed financial assets in the Asian emerging market attractive because they offered relatively high yields, while Asian economies tended to be resilient amidst the 2008 global financial crisis. Asian economies had successfully conducted structural reforms on governmental policy pertaining to the control over fiscal deficit and inflation, as well as on the private sector's behavior related to risk management which resulted in stronger banking and corporation position in facing a crisis [1]. This is in line with the research of Miyajima, Mohanty, & Chan [2] that noted the resilience of emerging economies have the potential to provide diversification benefits.

Besides the high yields offered and Asian economies that are relatively resilient to crisis, the attractiveness of Asian financial markets has increased after global rating agencies upgraded the sovereign ratings of emerging market Asian countries to investment grade. Global investors who have a minimum investment grade threshold for investing have started to include assets in Asian emerging markets into their portfolios, especially after several market index providers, such as Bloomberg Barclays Global Aggregate Index and JPMorgan Government Bond Index-Emerging Markets, include Asian government bonds into the indexes. For example, Indonesian government bonds were included in the

Bloomberg Barclays Global Aggregate Index as of May 2018 after the upgrade in Indonesia's sovereign rating to investment grade (BBB-) by S&P in May 2017 [3]. Nevertheless, the relatively high yields contain risks that should be managed thoughtfully. According to Johansson [4] and Amstad, Packer, & Shek [5], the risks of investing in emerging market government bonds include country risk and currency risk.

For global investors investing in Asian emerging markets, local currency government bonds would be their initial entry into Asian emerging market investments before increasing exposure to other asset classes, such as Asian corporate bonds and stocks, especially for conservative institutional investors, such as pension funds, insurance, sovereign wealth funds (SWFs) and central banks, for a long-term investment period. The conservative stance in determining asset allocation is relevant to the current market condition, during which the Coronavirus (COVID-19) pandemic has been the largest source of market volatility since early 2020. According to Brinson, Hood, & Beebower [6], asset allocation decisions are more dominant in affecting portfolio performance than the decision on market timing and securities selection. Asset allocation decision is part of investment policy determined by investors to obtain an average long-term return, while the decision on market timing and security selection is part of tactical strategies in managing portfolios. Rational investors tend to invest in riskier assets over the long-term horizon [7]. As local currency government bonds in the Asian emerging market carry relatively higher risk than in developed markets, investors generally tend to invest in emerging markets for a long-term period.

Markowitz's modern portfolio theory (1952) applies mean-variance analysis, which until now has been widely referred to in allocating assets. Markowitz's mean-variance is an optimization method which was originally developed for stock portfolio management. However, it presents challenges in managing bond portfolios, considering the systematic dissimilarities between stocks and bonds. The remaining life, scheduled payments of coupon, default risk, and the effect of interest rate movements on bond price and bond return are some factors that differentiate bonds from stocks, leading to the complexity of input parameters' estimation in the mean variance model [8].

In this study, the mean-variance optimization is used for an investment portfolio consisting of bond indexes, with the development of setting duration constraint to reduce the sensitivity of bond price to the movement of interest rate due to the finite maturity of bond. The composition of constituents in a bond index is determined by market capitalization. Bond portfolio managers generally manage portfolios based on certain bond indexes by replicating risk factors from the benchmark indexes [9]. This study seeks to develop Markowitz's mean-variance optimization method by setting a specified duration constraint for an investment portfolio consisting of Asian emerging market local currency government bond indexes.

2. LITERATURE REVIEW

To predict the cumulative return of an asset in the future, Hughson, Stutzer, & Yung [10] suggest that continuous compounding from the expected logarithmic return will provide an improved prediction of an investor's expected return, compared to the compounding expected simple return. According to Hudson & Gregoriou [11], logarithmic return is given by:

$$R_{t+1} = ln\,ln\,(P_{t+1}) - ln\,ln\,(P_t) \;= ln\,\frac{(P_{t+1})}{(P_t)} \qquad (1)$$

where R_{t+1} is the return on asset at time t+1, P_{t+1} is the asset's value at time t+1, and P_t is the asset's value at time t. The expected return of an investment portfolio that has several assets is obtained by:

$$E(R_p) = w_1 E(R_1) + w_2 E(R_2) + \cdots + w_G E(R_G) \qquad (2)$$

where $E(R_p)$ is portfolio expected return, $E(R_{1,2,\ldots,G})$ *is* the expected return for asset-*1, 2, ..., G* in the portfolio, $w_{1,2,\ldots,G}$ is weight for asset-*1, 2, ..., G*, with 100% total weight, and *G* is the amount of assets in the portfolio [12]. Furthermore, the risk of an investment portfolio consisting of several assets is the value of expected return's variance of the portfolio, which is given by:

$$var(R_p) = \sum_{g=1}^{G} \quad w_g^2 var(R_g) + \sum_{g=1\ and}^{G} \quad \sum_{h=1\ h\neq g}^{G} \quad w_g w_h cov(R_g, R_h) \qquad (3)$$

where $var(R_p)$ is the portfolio expected return's variance, w_g is the weight for asset-*g* in portfolio, $var(R_g)$ is the expected return's variance for asset-*g*, w_h is the weight for asset-*h*, and $cov(R_g, R_h)$ is the covariance between the expected return of asset-*g* and asset-*h* [12]. According to Caldeira, Mourab, & Santos [13], mean-variance optimization is resulted from minimizing the variance, as given by:

$$w_t min\, w_t \Sigma_{r_{t|t-1}} \quad w_t - \frac{1}{\delta} w_t' \mu_{r_{t|t-1}} \qquad (4)$$

with a total weight (w_t') of 100% and $w_t \geq 0$. In this study, the portfolio performance is measured using the

Sharpe ratio or reward-to-risk ratio. Sharpe [14] states that the Sharpe ratio illustrates how much additional return will be gained by increasing certain risk. The extra risk is taken by investing in beyond risk-free assets. The Sharpe ratio measurement is given by:

$$S = \frac{[E(R_p) - R_f]}{SD(R_p)} \quad (5)$$

where S is the portfolio's Sharpe ratio, $E(R_p)$ is the risky portfolio's expected return, R_f is the risk-free rate of return, for instance, the US Treasury bills' return, and $SD(R_p)$ is the risky portfolio's expected return standard deviation [15]. One of the most common risks in portfolio management is duration, i.e. the sensitivity of portfolio value to changes in yield.

According to Deguest, Fabozzi, Martellini, & Milhau [16], the application of portfolio duration constraint that follows market capitalization duration is a basis in the perspective of asset-only management, which its goal is to achieve outperformance over a certain benchmark based on risk-adjusted return. In comparison, the application of portfolio duration constraint that follows liabilities' duration is common in asset-liability perspective, whose aim is to adjust the interest rate exposure between assets and liabilities. In this study, bond portfolio optimization applies a mean-variance method which includes duration constraint. According to Caldeira et al. [13], the duration constraint is to be added to the optimization formula in equation (4).

Referring to Deguest et al. [16], an optimal portfolio has the same duration as the portfolio duration with weights that follow market capitalization. They suggest various strategies to determine the weight of assets in a portfolio:

- CW: cap-weighted strategy, i.e. the weighting of assets in a portfolio is equal to the market share of each asset.
- EW: equally-weighted strategy, i.e. each portfolio asset has similar weight, which is 100% divided by the number of assets. This strategy is also known as a naive portfolio. According to DeMiguel, Garlappi, & Uppal [17], a naive portfolio does not always deliver lower portfolio performance compared to an optimal portfolio.
- MC: minimum-concentration strategy, i.e. asset weighting aims to minimize concentration on a particular asset based on a calculation given by:

$$max \frac{1}{\sum_{n=1}^{N} (w_n)^2} \quad (6)$$

- where w_n is the weight for each asset. The duration constraint in MC strategy is the same as the portfolio duration with weights that follow market capitalization. The asset weighting in MC strategy applies hard constraint.
- MV: minimum-variance strategy, i.e. asset weighting is based on portfolio optimization using minimum variance. The duration constraint in MV strategy is the same as the portfolio duration with weights that follow market capitalization. The asset weighting in MV strategy applies either hard constraint or norm constraint.
- SR: maximum Sharpe ratio strategy, i.e. asset weighting is based on portfolio optimization using maximum Sharpe ratio. The duration constraint in SR strategy is the same as the portfolio duration with weights that follow market capitalization. The asset weighting in SR strategy applies either hard constraint or norm constraint.

Deguest et al. [16] suggest that weight constraint based on hard constraint should have a minimum weighting of $\frac{1}{\delta N}$ and a maximum weighting of $\frac{\delta}{N}$ for each asset, where N is the number of assets in the portfolio and $\delta = 1, \ldots, N$. Meanwhile, weight constraint based on norm constraint satisfies $\frac{1}{N \times \sum_{n=1}^{N} (w_n)^2} \geq K$, where K is the level of deconcentration.

3. RESEARCH METHODOLOGY

The research model applied in this study is mean-variance optimization model [18] to obtain an optimal portfolio which comprises Asian emerging market local currency government bond indexes (unhedged to USD) of Indonesia, Malaysia, Thailand, the Philippines, and Korea. The country selection considers that there is no obligation to obtain a license or quota/limit by the authorities in investing in those countries' domestic financial markets. Those local currency indexes have been converted to USD, so that they are comparable to each other. The indexes' historical data are obtained from ICE Data Indices, LLC (with permission) for the period of 2010-2019. Based on 2010-2019 historical data, portfolio construction is carried out by enforcing short-selling restrictions. This is derived from the fact that doing short-selling in the emerging market is difficult because of the lack of liquidity compared to the US Treasury's bonds market [19]. According to Wang [20], the level of inefficiency in a portfolio that imposes short-selling restrictions is much lower than that of a portfolio that is freed to do short-selling. This study will perform comparisons of risk and return profile results from various asset allocation strategies

Table 1. Asset Allocation Strategies

Strategies without Duration Constraint	**Strategies with Duration Constraint [16]**
• cap-weighted strategy • equally-weighted strategy • min. variance strategy • max. Sharpe ratio strategy	• min. concentration strategy with hard constraint • min. variance strategy with hard constraint • min. variance strategy with norm constraint • max. Sharpe ratio strategy with hard constraint • max. Sharpe ratio strategy with norm constraint

without duration constraint as well as with duration constraint, as shown in Table 1. Therefore, the main constraint used in those asset allocation strategies is duration constraint that follows the market capitalization duration.

Afterward, the asset allocation suggested from the abovementioned strategies are applied for the indexes' data from January to June 2020 (out-of-sample). The performance of those strategies for the period of January to June 2020 is then analysed using the Sharpe ratio.

4. RESULT

4.1. Optimization Strategies Based on 2010-2019 Data

Based on 2010-2019 historical data, portfolio optimization is performed for strategies without duration constraint as well as with duration constraint. Strategies with duration constraint follow the market capitalization duration, i.e. 8.12. For strategies with duration constraint, hard constraint strategies use δ = 5, and norm constraint strategies use K = 75%. According to the results in Table 2, the maximum Sharpe ratio strategy delivers the highest Sharpe ratio (1.148) among strategies without duration constraint. Meanwhile, maximum Sharpe ratio strategy with norm constraint delivers the highest Sharpe ratio (1.136) among strategies with duration constraint.

4.2. Optimization Strategies Applied for January-June 2020 Data (Out-of-Sample)

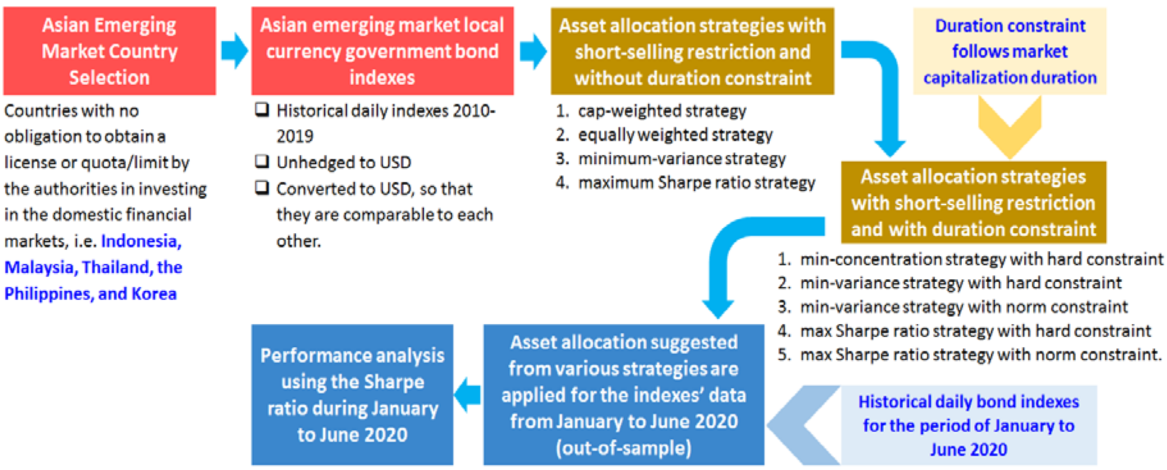

Figure 1 Asset Allocation Strategies

Table 2. Asset Allocation Strategies Based on 2010-2019 Data

Optimization Strategies	**Strategies without Duration Constraint**				**Strategies with Duration Constraint**				
	Capital Weighted	**Equally-Weighted**	**Minimum Variance**	**Max. Sharpe Ratio**	**Minimum Concen-tration**	**Min. Variance with hard constraint**	**Min. Variance with norm constraint**	**Max. Sharpe Ratio with hard constraint**	**Max. Sharpe Ratio with norm constraint**
Based on 2010-2019 Data									
RISK RETURN									
Annualized Return	5.13%	5.31%	5.90%	6.65%	5.48%	5.90%	5.87%	6.39%	6.61%
Annualized Std Dev	6.44%	5.71%	5.12%	5.27%	5.61%	5.12%	5.12%	5.21%	5.28%
SHARPE RATIO	**0.702**	**0.825**	**1.034**	**1.148**	**0.869**	**1.032**	**1.028**	**1.110**	**1.136**
MOD. DURATION	**8.12**	**7.46**	**8.18**	**8.56**	**8.12**	**8.12**	**8.12**	**8.12**	**8.12**

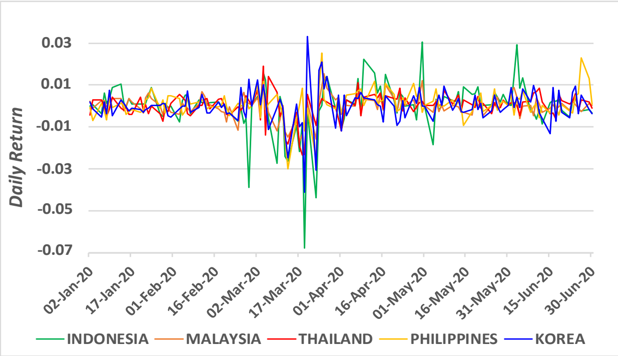

Figure 2 Daily Return on Asian Emerging Market Government Bonds January-June 2020

The asset allocations suggested from various strategies above are applied for the indexes' data from January to June 2020 (out-of-sample). As presented in Figure 2, the daily return on the five Asian emerging market countries' government bonds began to fluctuate around March 2020 on the back of global investors' concerns about the COVID-19 pandemic.

Table 3 shows that maximum Sharpe ratio strategy with norm constraint for out-of-sample data gives the highest Sharpe ratio (1.076) not only among strategies with duration constraint but also among strategies without duration constraint.

Performance monitoring is conducted every end of month for year-to-date (YTD) position from January to June 2020 as reported in Appendix. The change of Sharpe ratio is presented in Figure 3 and Figure 4. Figure 3 shows the Sharpe ratio movement in every YTD end of month for maximum Sharpe ratio strategy with norm constraint compared to the four strategies without duration constraint. Meanwhile, Figure 4 shows the Sharpe ratio movement in every YTD end of month for the maximum Sharpe ratio strategy with norm constraint compared to the other four strategies with duration constraint.

Figure 3 and Figure 4 reveal that maximum Sharpe ratio strategy with norm constraint gives the highest Sharpe ratio performance as of the end of June 2020 (YTD) compared to the other strategies without and with duration constraint. The highest Sharpe ratio indicates that the maximum Sharpe ratio strategy with norm constraint becomes the optimal strategy in this study. The optimal strategy's Sharpe ratio started to rebound after market volatility due to the COVID-19 pandemic anxieties peaked around March 2020.

Table 3. Asset Allocation Strategies Applied for January-June 2020 Data (Out-of-Sample)

Optimization Strategies	**Strategies without Duration Constraint**				**Strategies with Duration Constraint**				
	Capital Weighted	**Equally-Weighted**	**Minimum Variance**	**Max. Sharpe Ratio**	**Minimum Concen-tration**	**Min. Variance with hard constraint**	**Min. Variance with norm constraint**	**Max. Sharpe Ratio with hard constraint**	**Max. Sharpe Ratio with norm constraint**
Applied for January-June 2020 Data (Out-of-Sample)									
RISK RETURN									
Annualized Return	0.28%	4.19%	5.94%	8.04%	2.17%	5.95%	6.15%	9.31%	10.41%
Annualized Std Dev	10.42%	9.56%	8.01%	8.38%	9.24%	8.10%	8.00%	8.31%	8.43%
SHARPE RATIO	**-0.102**	**0.298**	**0.574**	**0.800**	**0.090**	**0.569**	**0.601**	**0.958**	**1.076**
MOD. DURATION	**8.43**	**7.71**	**8.50**	**8.89**	**8.43**	**8.43**	**8.43**	**8.41**	**8.40**

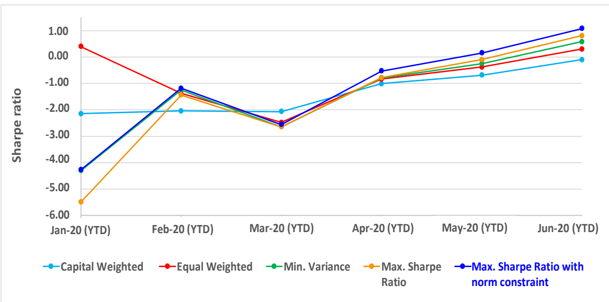

Figure 3 Sharpe ratio comparison between Maximum Sharpe Ratio Strategy with Norm Constraint and Strategies without Duration Constraint

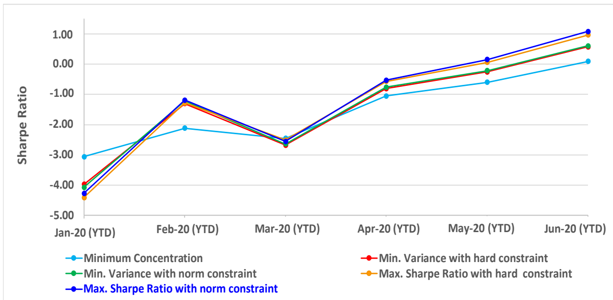

Figure 4 Sharpe ratio comparison between Maximum Sharpe Ratio Strategy with Norm Constraint and Strategies with Duration Constraint

5. DISCUSSION

Based on 2010-2019 historical daily return data, maximum Sharpe ratio strategy delivers the highest Sharpe ratio (1.148) among strategies without duration constraint, while the maximum Sharpe ratio strategy with norm constraint delivers the highest Sharpe ratio (1.136) among strategies with duration constraint. It indicates that duration constraint affects the reduction in the Sharpe ratio. Nevertheless, the aim to add duration constraint in the portfolio is to manage the sensitivity of portfolio value to the movement of market interest rate; hence, the duration constraint of the portfolio follows market capitalization duration.

When the optimal strategy with duration constraint, i.e. the maximum Sharpe ratio strategy with norm constraint, is applied from January to June 2020, the out-of-sample Sharpe ratio at the end of June 2020 (YTD) has the highest value among other strategies with duration constraint as well as strategies without duration constraint. This optimal strategy could become a recommendation for investors in allocating their assets for long-term investment. The performance monitoring during the investment period of January to June 2020 shows that when the investors persist with the suggested optimal strategy, the investors get the highest Sharpe ratio compared to other strategies explained in this study. The performance monitoring also shows that the optimal portfolio's Sharpe ratio began to recover in April 2020.

The implication of the aforementioned findings is that although asset allocation decisions are made for long-term investment, it is important to review the allocation regularly, for instance, monthly or quarterly. The review is conducted to evaluate whether the asset allocation's risk and return profile is still in line with investment objectives, investment policies, and investors' risk-return preferences in the midst of the latest market developments. Market volatility does not have to be responded to by changing the asset allocation as it could be addressed using tactical strategy of portfolio management, which includes market timing and security selection. However, if there are fundamental changes either from internal factors (such as investment objectives, investment policies, and investor's risk-return preference) or from external factors (such as macroeconomic conditions and governments' policies), then it is necessary to consider the adjustment of asset allocation. Regardless, this study has a limitation as it only uses historical daily return as an input to find the portfolio's expected return. On the other hand, fundamental macroeconomic development could trigger an adjustment to the market outlook, which may bring in changes in the expected return.

6. CONCLUSION

Portfolio optimization using mean-variance model [18] with duration constraint for Asian emerging market local currency government bonds gives more value to investors as its Sharpe ratio is higher than other strategies without duration constraint, i.e. capitalization-weighted, equally-weighted, minimum variance, and maximum Sharpe ratio. The performance monitoring shows that the optimal strategy delivered a positive Sharpe ratio at the end of June 2020 (YTD) and recovered in April until June 2020 in the midst of investors' concerns on the impacts of COVID-19 pandemic.

AUTHORS' CONTRIBUTIONS

The optimization strategy in this study would be an alternative strategy for conservative investors to perform asset allocation as a long-term investment policy in having exposure to Asian emerging market before the investors add other asset classes, such as Asian emerging market corporate bonds and stocks, into their portfolio. Any further study can extend the use of the optimization strategy to other asset classes beyond government bonds, such as corporate bonds and stocks in Asian emerging markets. Thus, the study will provide recommendations for not only conservative investors but also investors with higher risk preference. In consideration of the limitation of the study as mentioned in Section 5, any further study could determine the expected return by combining historical data return with forecasting return models that consider the macroeconomic conditions of each country.

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