DOWNSIDE DEVIATION QUADRATIC PROGRAMMING AND HEURISTIC APPROACHES FOR SHARIAH STOCK PORTFOLIO OPTIMIZATION

NOOR SAIF MUHAMMAD MUSSAFI

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DEDICATION

This thesis is dedicated to Allah the Almighty. It is also dedicated to Allahuyarham, my late father, who initially motivated me, particularly when he was struggling with his illness, to start this tremendous step and taught me to be a pious, honest, independent, optimistic, and determined person. Lastly to my mother, who taught me that even the largest task can be achieved if it is done one step at a time and for her unceasing prayers and encouragement throughout my studies.

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ABSTRACT

Portfolio investment is a passive investment since the investor is not actively involved in the management of the stock corporation. It is the concept of pooling all of one's assets and managing them in such a way that one earns the highest rate of return with the least risk. One of the most challenging aspects of stock portfolio investment is risk minimization, which can be achieved by addressing portfolio selection and optimization. This study presents a hybrid approach to portfolio selection involving double-layer filtering. Spesifically, a modified mean-variance optimization (MVO) model called the downside deviation quadratic programming (DDQP) is developed. The new model is applied to a secondary dataset consisting of weekly historical prices of all companies listed on the Jakarta Islamic Index (JII) from June 2016 to May 2019, as well as some ancillary financial data. The data was split into four categories for comparative purposes: (1) sectoral, (2) fundamental, (3) technical, and (4) hybrid. All schemes were evaluated using a diversification ratio to create a well-diversified portfolio. The portfolio were then optimized using MVO and DDQP to achieve optimal risk and stock weighting. Two heuristic methods were used to ensure that the results are robust and consistent, namely simulated annealing (SA) and pattern search (PS). The results show that a hybrid analysis of sales growth (SG) and beta β (risk of an individual stock as compared to composite index) produces a well-diversified portfolio based on actual data. The DDQP is built as an enhancement to MVO, primarily by substituting the standard deviation for the downside deviation in the objective function. Both SA and PS were integrated into portfolio optimization environments. In terms of portfolio optimization, both exact methods of MVO and DDQP can be used to determine the portfolio's optimal risk and the weight of the shariah stock portfolio. For instance, using the DDQP model, portfolio 6 achieves the lowest risk of 1.18% by investing in TLKM, UNVR, ASII, ICBP, and UNTR with corresponding weights of 26.30%, 20.24%, 23.27%, 29.88%, and 0.31% respectively. The DDQP generated more robust and consistent results in producing lower risk (with an average efficiency rate of 76.99%) than MVO by altering the composition of various portfolios into 12 scenarios. Portfolio 19 was tested as a hybrid study of SG-beta and a well-diversified portfolio by considering six indicators and running the experiment 20 times with different starting points to approach the DDQP optimal solution. The numerical results show that the risk of the portfolio generated by DDQP is similar across all 20 trials. These results also show a linear trend, indicating that the DDQP's performance is consistent and robust across different initial points. It can be concluded that the SA and PS heuristic methods were successful in reaching the DDQP's optimal risk threshold. Overall, the PS method was found to be a better approximation of the exact DDQP result than the SA method.

ABSTRAK

Pelaburan portfolio adalah pelaburan pasif kerana pelabur tidak terlibat secara aktif dalam pengurusan perbadanan saham. Ia adalah konsep mengumpulkan semua aset seseorang dan mengurusnya dengan cara yang membolehkan seseorang memperoleh kadar pulangan tertinggi dengan risiko yang paling sedikit. Salah satu aspek pelaburan portfolio saham yang paling mencabar ialah pengurangan risiko, yang boleh dicapai dengan menangani pemilihan dan pengoptimuman portfolio. Kajian ini membentangkan pendekatan hibrid kepada pemilihan portfolio yang melibatkan penapisan dua lapisan. Khususnya, satu model pengoptimuman min-varians (MVO) yang diubahsuai, dipanggil pengaturcaraan kuadratik sisihan ke bawah (DDQP) telah dibangunkan. Model baru ini telah digunakan kepada satu data sekunder yang mengandungi harga sejarah mingguan semua syarikat yang disenaraikan pada Jakarta Islamic Index (JII) dari Jun 2016 hingga Mei 2019, serta beberapa data kewangan sampingan. Data ini telah dibahagikan kepada empat kategori untuk tujuan perbandingan: (1) sektoral, (2) asas, (3) teknikal, dan (4) hibrid. Semua skim telah dinilai menggunakan nisbah kepelbagaian untuk mencipta portfolio terpelbagai dengan baik. Portfolio kemudiannya dioptimumkan menggunakan MVO dan DDQP untuk mencapai risiko optimum dan wajaran saham. Dua kaedah heuristik telah digunakan untuk memastikan keputusan adalah mantap dan konsisten iaitu penyepuhlindapan tersimulasi (SA) dan carian pola (PS). Keputusan menunjukkan bahawa analisis hibrid pertumbuhan jualan (SG) dan beta β (risiko saham individu berbanding indeks komposit) menghasilkan portfolio terpelbagai dengan baik berdasarkan data sebenar. DDQP ini telah dibina sebagai peningkatan kepada MVO, terutamanya dengan menggantikan sisihan piawai untuk sisihan ke bawah dalam fungsi objektif. Kedua-dua SA dan PS telah disepadukan ke dalam persekitaran pengoptimuman portfolio. Dari segi pengoptimuman portfolio, kedua-dua kaedah tepat MVO dan DDQP boleh digunakan untuk menentukan risiko optimum portfolio dan pemberat portfolio saham syariah. Sebagai contoh, dengan menggunakan model DDQP, portfolio 6 mencapai risiko terendah sebanyak 1.18% dengan melabur dalam TLKM, UNVR, ASII, ICBP dan UNTR dengan wajaran sepadan 26.30%, 20.24%, 23.27%, 29.88% dan 0.31% masing-masing. DDQP telah menjana keputusan yang lebih teguh dan konsisten dalam menghasilkan risiko yang lebih rendah (dengan kadar kecekapan purata 76.99%) daripada MVO dengan mengubah komposisi pelbagai portfolio kepada 12 senario. Portfolio 19 telah diuji sebagai kajian hibrid SG-beta dan portfolio terpelbagai dengan baik dengan mempertimbangkan enam penunjuk dan menjalankan eksperimen 20 kali dengan titik permulaan yang berbeza untuk mendekati penyelesaian optimum DDQP. Keputusan berangka menunjukkan bahawa risiko portfolio yang dijana oleh DDQP adalah serupa merentas kesemua 20 percubaan. Keputusan ini juga menunjukkan satu arah aliran linear, menandakan bahawa prestasi DDQP adalah konsisten dan teguh merentas titik awal yang berbeza. Dapat disimpulkan bahawa kaedah heuristik SA dan PS berjaya mencapai ambang risiko optimum DDQP. Secara keseluruhannya, kaedah PS didapati merupakan penghampiran yang lebih baik bagi hasil DDQP tepat daripada kaedah SA.

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LIST OF ABBREVIATIONS

ADF	-	Augmented Dickey-Fuller
ADRO	-	Adaro Energy Tbk.
DD	-	Downside Deviation
DDQP	-	Downside Deviation Quadratic Programming
DES	-	Daftar Efek Syariah
DiR	-	Diversification Ratio
DR	-	Debt Ratio
GA	-	Genetic Algorithm
IDX	-	Indonesia Stock Exchange
IP	-	Initial Point
IR	-	Individual Return
JII	-	Jakarta Islamic Index
MC	-	Market Capitalisation
MPT	-	Modern Portfolio Theory
MV	-	Mean-Variance
MVO	-	Mean-Variance Optimization
OJK	-	Otoritas Jasa Keuangan
PER	-	Price Earnings Ratio
PMPT	-	Post-Modern Portfolio Theory
PS	-	Pattern Search
QP	-	Quadratic Programming
ROE	-	Return on Equity
SA	-	Simulated Annealing
SD	-	Standard Deviation
SG	-	Sales Growth
SR	-	Sortino Ratio
TR	-	Treynor Ratio
VaR	-	Value at Risk

LIST OF SYMBOLS

r_i	-	Rate of return of stock i
$\overline{r_i}$	-	Mean return of stock i
r_f	-	Risk-free rate
μ_i	-	Expected return of stock i
σ	-	Standard deviation
σ_p	-	Standard deviation of portfolio
$\hat{\sigma}_d$	-	Downside deviation
σ^2	-	Variance
$\hat{\Sigma}^2$	-	Semivariance
Σ	-	Variance-covariance matrix
β	-	Beta of portfolio
w_i	-	Weight of stock i
λ_i	-	Lagrange multipliers i

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

One of the most important tasks for investors is to choose the best investment opportunities to maximize their investment return. Choosing investment options is crucial, exciting and multifaceted, particularly for large business such as insurance, banks, real estate, investing institutions, and other areas that pursue high return possibilities at a rational risk. There are many types of investments available, including bonds, stocks portfolio, options, and gold. None of these investment types can be said to be the best, so rather than sticking to one, a wise person will diversify by looking for combinations to spread the risk of loss. A diversified portfolio has flatter risk characteristics, i.e., less variance, which is related to the term *diversification*. When one has a well-diversified portfolio, the volatility of the portfolio is reduced because the portfolio securities are assumed to be normally distributed, which means that the prices of all securities do not change in the same direction at the same time.

Risk and return are two important aspects of an investment that are opposed. According to economic rules, those seeking lower risk should expect lower returns and vice versa. There are at least three types of investors based on their response to risk, namely risk-averse, risk-taker, and risk-neutral. A risk-averse, also known as a conservative way, dislikes or avoids risk whereas a risk-taker investor (see Brigham and Houston (2019)) is willing to take more risk in exchange for a higher return. A risk-neutral investor is someone who is neither risk-averse nor risk-taker. Note that despite taking on more risk, the risk-taker investors still think rationally, requiring a minimum acceptable return on investment.

The goal of the aforementioned issue is to minimize risk while maximizing return. It is related to portfolio optimization, which is defined as the process of

selecting the weights of many assets to include in a portfolio to create a portfolio that outperforms all others based on certain criteria. In practice, the criterion would be combined in terms of either the expected rate of return or risk measures.

Portfolio optimization is also known as mean-variance optimization (MVO). The term of mean refers to the investment's expected return while variance is a risk measure associated with a portfolio. Markowitz (1952) was the first to propose the concept of mean-variance (MV), also known as modern portfolio theory (MPT). It is based on an advanced investment decision strategy that enables an investor to classify, estimate, and control the type and amount of expected risk and return. The main purpose of MPT is to optimally allocate investments among various assets. Scholars continue to debate Markowitz's (1952) interpretation of MPT, particularly in terms of standard deviation, which is not reflected in investor behaviour.

The post-modern portfolio theory (PMPT) was developed in the 1980s to enhance the MPT to better fit market realities. The PMPT modifies financial theory and practice to accommodate investor expectations, although the MPT has remained a major benchmark in portfolio theory (Todoni, 2015). In more detail, PMPT enables portfolio management models to be more realistic, with a greater potential to represent economic reality. Unlike MPT, PMPT proposed an alternative set of risk measures, including those that penalise only the negative part (adverse), referred to as the downside risk.

One of the problems in portfolio theory is building a set of portfolios. Fundamental and technical analyses are the most common types of analysis used by investors when putting together a portfolio for long-term stock exchange investment. Fundamental analysis is a procedure for estimating the intrinsic value of securities by examining all aspects of business activity or market as shown in a company's financial report (Drakopoulou, 2016). Technical analysis is the procedure for identifying and evaluating securities using statistics. Financial analysts exploit data from periodic market movement, such as historical stock prices, returns, and volume of transactions to create a pattern chart of stock price and trends in securities movement. Technical analysis is briefly a tool which used in forecasting the future movement of a particular

stock by analysing their past trading activity. Technical analysis is a tool that is used to forecast the future movement of a stock by analysing its previous trading activity. It's worth noting that combining these two approaches could yield a more comprehensive result.

The assets allocation can be considered after a portfolio is established. Quadratic programming (QP), in which the target function is represented by a second-order function, is a method of building a portfolio composition that yields a minimum risk for a prescribed level of return or a maximum return for a certain level of risk. QP will yield an exact solution. In practice, many large-scale optimization problems cannot easily be solved to gain optimal level because finding an optimum takes a long time. As a result, heuristic method are required to provide accurate and quick approximations to the exact or optimal solution (Gilli & Schumann, 2012; Laarhoven, 1989). One of the heuristic methods, simulated annealing (SA), refers to the analogy between simulation of solid annealing and the problem of solving large combinatorial optimization problems. Additionally, pattern search (PS), which refers to direct search without the use of gradients, is also a heuristic method (Ackora-Prah, Gyamerah, Andam, & Gyamfi, 2014). The downside deviation quadratic programming (DDQP), SA and PS, respectively, are three models developed in this study based on exact and heuristic approaches.

The fundamental rule in this study deviates from the notion of PMPT and focuses on creating a set of stock portfolio and minimizing risk for risk-averse investors. DDQP, SA and PS are used to minimize the risk associated with portfolio and stock weighting. The objective function of DDQP is an improvement to the standard QP. SA has some flaws, particularly when it comes to restricted functions. In this study, the SA algorithm is represented in such a way that it fits both the standard optimization problem and the DDQP.

1.2 Problem Statement

Shariah stock differs from conventional stock in terms of trade regulations and halal products. Otherwise, both shariah and conventional stocks have the same market index characteristics and contribute to the same macroeconomic elements. In some countries, the shariah stock trend has shown positive growth over the last few years. However, there is still a scarcity of research on this ethical investment.

The main goals in stock investment are to minimize risk and/or maximize return. Some researchers have proposed technical analysis to solve this problem, while others have suggested fundamental analysis. In practice, the variables affecting the appearance of stock are determined not only by stock price fluctuations but also by the company's intrinsic value, which is influenced to some extent by the macroeconomy. As a result, thorough observation should be able to provide more precise results. Unfortunately, the combination of technical and fundamental analyses to solve stock investment problems is not well-established in the literature.

The MV problem can be solved with QP, which minimize the risk of a given return. The standard deviation utilized in the MV problem does not correspond to the intuitive notion of risk held by the majority of investors, as it is defined as the distribution of returns above and below the expected average. Investors, in practice, are only concerned with negative variances. Moreover, heuristic methods, such as SA and PS, are required to approximate the results for large-scale optimization problems. Previous research did not adequately combine these three methods.

Therefore, both technical and fundamental analyses are combined in this study to build the optimal set of portfolios. This requires the modelling of QP, SA algorithms and PS algorithm, as well as determining the minimum risk and weight of stock investment. The objective function of QP can still be improved by eliminating the non-negative rate of return. These mechanisms are critical in this investigational research.

1.3 Research Questions

(i) How to design and build a portfolio from certain shariah stocks using hybrid analysis (fundamental and technical analyses)?

(ii) How to improve the QP solution by constructing the DDQP model for solving portfolio optimization?

(iii) How to minimize risk and determine the weight of a shariah stock portfolio investment?

(iv) How to construct the heuristic method of the SA and PS algorithm for solving portfolio optimization to verify the results of the exact method of DDQP?

1.4 Research Objectives

(i) To design and build a portfolio from certain shariah stocks using hybrid analysis (fundamental and technical analyses).

(ii) To improve the QP solution by constructing the DDQP model for solving portfolio optimization.

(iii) To minimize risk and determine the weight of portfolio investment based on shariah stock in the real-world problem.

(iv) To construct the heuristic method of the SA and PS algorithm for solving portfolio optimization to verify the results of the exact method of DDQP.

1.5 Scopes of the Study

The scopes of the study are divided into three parts, (1) sample dataset, (2) portfolio selection and portfolio optimization methods, and (3) comparative study on portfolio optimization approaches.

1.5.1 Scopes of the Data

The dataset contains three years weekly closing data price of all shariah stock index corporates associated with Jakarta Islamic Index (JII) from 1st June 2016 to 31st May 2019. Supporting data, such as corporate profile, financial statement of corporations, stock index releases and risk-free rate were also considered. All data was obtained from Yahoo Finance, Investing.com, the official website of the Indonesia Stock Exchange (IDX), the official website of Bank Indonesia as an Indonesian central bank, the official website of Financial Services Authority of Indonesia (OJK), and the website of all stocks by companies listed in JII.

1.5.2 Scopes of the Methods

This study focuses on four methods for portfolio selection, namely sectoral analysis, fundamental analysis, technical analysis and hybrid analysis. The selected portfolio was built into an optimization model, which was then optimized using the QP method. The DDQP method was also proposed as an improved version of the QP method.

1.5.3 Scopes of Comparative Study on Portfolio Optimization Approaches

This study compares the results of exact and heuristic portfolio optimization approaches. The risk level of the DDQP method, which is an exact approach, was benchmarked against the risk level of SA and PS as heuristic approaches. The percent error was used to assess the accuracy of the comparison between the exact and approximate values. The robustness and consistency of the results generated by DDQP were evaluated.

1.6 Significance and Contributions of Study

A hybrid or combination of fundamental and technical analyses is proposed in this study to build a portfolio. The DDQP model, SA algorithm and PS algorithm were developed to obtain a portfolio with optimal risk and stock weighting. The findings of this study contribute to the advancement of theoretical and practical financial investment, including:

(a) offering an alternative approach to portfolio construction by combining fundamental and technical analyses,
(b) establishing an improved QP model that accommodates the downside part of standard deviation so-called the DDQP,
(c) establishing SA and PS algorithm for portfolio optimization,
(d) establishing an optimal risk value and stock weighting that reduces portfolio risk.

Some practical contributions are:

(a) advising financial or government decision-makers on short-term or long-term investment programmes,
(b) providing an alternative way for investors to make decisions about stock portfolios, particularly in terms of the proportion of funds available for investment.

1.7 Organization of Research

This study is divided into six chapters. The first chapter serves as an introduction. This section provides the background of the study, problem statement, research questions, research objectives, research scope, and significance and contributions of the study.

Chapter 2 reviews some of the existing literature on forming and solving a portfolio and optimization methods particularly the exact and heuristic methods. It also discusses some fundamental theories that lead to optimization method, shariah stock portfolio, fundamental and technical analyses on portfolio selection, and risk analysis.

Chapter 3 provides the study direction and an overview of the research methodology. The flowchart of the study framework and the method of data collection are presented first. Also covered are the procedures for building a portfolio, as well as the design of DDQP, SA and PS for portfolio, implementation and result comparison. Lastly, the method used for verifying the proposed model is described.

Chapter 4 discusses the portfolio selection phases. It begins with data collection, followed by a unit root test and relevant descriptive statistics. The selection focuses on five essential schemes, including hybrid analysis and diversification testing.

Chapter 5 describes the optimization method in handling the selected portfolio for both the exact and heuristic approaches. The DDQP model is proposed as an alternative portfolio optimization that improves MVO. As benchmarks, two popular heuristic models, SA and PS, are used. The risk minimization and stock weighting on actual shariah stock index data based on the constructed model are also presented. The results of the DDQP model are compared to MVO. The goodness, robustness, and consistency of the DDQP model will then be tested against two heuristic algorithms, SA and PS. Finally, Chapter 6 summarises the findings and recommendations of this study.

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LIST OF PUBLICATIONS

Indexed journal

1. Mussafi, N. S. M., & Ismail, Z. (2021). Optimum Risk-Adjusted Islamic Stock Portfolio Using the Quadratic Programming Model: An Empirical Study in Indonesia. *The Journal of Asian Finance, Economics and Business*, *8*(5). DOI: 10.13106/jafeb.2021.vol8.no5.0839. The journal was published by Korea Distribution Science Association in May 2021. **(Indexed by WOS)**

2. Mussafi, N. S. M., & Ismail, Z. (2021). A Review on Shariah Stock Portfolio Optimization. *DLSU Business & Economics Review*. 31(1), 142-157. The journal was published by De La Salle Publishing House in July 2021. **(Indexed by SCOPUS)**

Indexed conference proceeding

1. Mussafi, N. S. M., & Ismail, Z. (2020). Quadratic Programming for Optimizing the Diversified Shariah Stock Portfolio. *The 2nd International Seminar on Science and Technology (ISSTEC 2019)* (pp. 139-147) DOI: 10.2991/assehr.k.201010.021. Atlantis Press. This article was presented at the 2nd International Seminar on Science and Technology (ISSTEC) on Nov 25, 2019, with manuscript ID: 093/ISSTEC/2019. It was organized by Universitas Islam Indonesia in Yogyakarta. **(Indexed by WOS)**