PORTFOLIO OPTIMIZATION IN INDIAN STOCK MARKET: A STUDY USING FINANCIAL ANALYTICS

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"The greatest enemy of knowledge is not ignorance, it is the illusion of knowledge."

-Stephen Hawking

Dedicated to my parents
Shri. R. Jothimani and Smt. T. Eswari

Certificate

The thesis entitled **"Portfolio Optimization in Indian Stock Market: A Study Using Financial Analytics"**, being submitted by **Ms. Dhanya Jothimani** to the Indian Institute of Technology Delhi, for the award of the degree of **"Doctor of Philosophy"** is a record of *bona fide* research work carried out by her. She has worked under our supervision in conformity with rules and regulations of the Indian Institute of Technology Delhi. The research reports and results presented in the thesis have not been submitted in part or full for the award of any degree or diploma in any other University or Institute.

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Abstract

Portfolio optimization is an investment decision-making process to hold a set of assets based on various criteria such as risk and return. Availability of several financial instruments makes it complex. Portfolio optimization can be carried out in three stages, namely, asset selection, asset weighting and asset management. Previous researches have invariably focussed on either first two stages of portfolio optimization or on each stage separately. This study aims to provide a comprehensive end-to-end framework for portfolio optimization focussing on all three stages. Further, it also addresses the issues related to improving the covariance matrix and improving the forecasting accuracy of stock price. The scope of the work is limited to analysis of non-financial stocks, listed on National Stock Exchange.

First phase of the study proposes an analytical framework for portfolio optimization. The historical performance of the firms is evaluated using data envelopment analysis, thus, aiding in selection of potential stocks for portfolio formation.

Hierarchical risk parity model based on Gerber statistics (HRP-GS) is proposed for determining the weights to be assigned for each asset in the portfolio. The performance of the proposed model is compared with three models, namely, global minimum variance model based on historical correlation, global minimum variance model based on Gerber statistics, and hierarchical risk parity model based on historical correlation. The HRP-GS model is proposed to address instability issues in covariance matrix and improving the estimates of covariance matrix.

Six ensemble forecasting models (Empirical Mode Decomposition (EMD)-Artificial neural network (ANN), EMD-Support Vector Regression (SVR), Ensemble EMD (EEMD)-ANN, EEMD-SVR, Complete Ensemble Empirical Mode Decomposition with Adaptive Noise (CEEMDAN)-ANN and CEEMDAN-SVR) are developed for predicting prices of stocks constituting the portfolio. Trading rules are designed to guide the investors to buy/sell/hold stocks according to varying market conditions. The experimental analysis carried out on the data from Indian stock market data shows the strength of the proposed framework.

In second phase of the study, a survey is carried out to understand the investment practices adopted by portfolio managers in Indian stock market. Survey results suggest that implementation of Financial theories in Indian stock market is very minimal.

सार

पोर्टफोलियो ऑप्टिमाइजेशन विभिन्न मानदंडों जैसे रिस्क और रिटर्न के आधार पर परिसंपत्तियों (assets) का एक समूह रखने के लिए एक निवेश निर्णय प्रक्रिया है। कई वित्तीय साधनों की उपलब्धता इसको जटिल बना देता है। पोर्टफोलियो ऑप्टिमाइजेशन तीन चरणों में किया जा सकता है: एसेट सिलेक्शन, एसेट वेटिंग (weighting) और एसेट मैनेजमेंट। पिछले शोध कार्य में हमेशा पोर्टफोलियो ऑप्टिमाइजेशन के पहले दो चरणों या प्रत्येक चरण पर अलग-अलग रूप से ध्यान केंद्रित किया गया हैं। इस अध्ययन का उद्देश्य सभी तीन चरणों पर पोर्टफोलियो ऑप्टिमाइजेशन के लिए व्यापक एंड -टू-एंड फ्रेमवर्क प्रदान करना है। इसके अलावा, यह कोवेरियन्स (covariance) मैट्रिक्स को बेहतर बनाने और स्टॉक की कीमत की भविष्यवाणी की सटीकता में सुधार करने से संबंधित मुद्दों को भी संबोधित करता है। नेशनल स्टॉक एक्सचेंज में सूचीबद्ध नॉन-फाइनेंसियल शेयरों के विश्लेषण के लिए काम का दायरा सीमित है।

अध्ययन का पहला चरण पोर्टफोलियो ऑप्टिमाइजेशन के लिए एक विश्लेषणात्मक रूपरेखा का प्रस्ताव करता है। इस प्रकार, पोर्टफोलियो के गठन के लिए संभावित शेयरों के चयन में सहायता के लिए डाटा इनवेलपमेंट एनालिसिस (data envelopment analysis) का उपयोग करके फर्मों (firms) के ऐतिहासिक प्रदर्शन का मूल्यांकन किया जाता है।

पोर्टफोलियो में प्रत्येक परिसंपत्ति के लिए आवंटित किए जाने वाले वजन (weight) का निर्धारण करने के लिए गेरबेर स्टेटिस्टिक्स (Gerber Statistics) (एचआरपी-जीएस – HRP-GS) पर आधारित हिरार्चिकाल रिस्क पैरिटी (Hierarchical Risk Parity) मॉडल प्रस्तावित किया गया है। प्रस्तावित मॉडल के प्रदर्शन की तुलना तीन मॉडलों के साथ की गयी है, अर्थात्, ग्लोबल मिनिमम वेरियंस मॉडल बेस्ड ऑन हिस्टोरिकल कॉरेलशन (Global Minimum Variance based on historical correlation), ग्लोबल मिनिमम वेरियंस मॉडल बेस्ड ऑन गेरबेर स्टेटिस्टिक्स (Global minimum variance based on Gerber Statistics), और हिरार्चिकाल रिस्क पैरिटी मॉडल बेस्ड ऑन हिस्टोरिकल करेलशन (Hierarchical Risk Parity model based on historical correlation) । एचआरपी-जीएस मॉडल को मैट्रिक्स के अस्थिरता मुद्दों को संबोधित करने और कोवेरियन्स मैट्रिक्स के अनुमानों में सुधार करने का प्रस्ताव है।

छह एन्सेम्बल पूर्वानुमान मॉडलों का उपयोग किया है जो इस प्रकार है: एम्पिरिकल मोड डिकम्पोज़िशन () - आर्टिफीसियल न्यूरल नेटवर्क (ईएमडी-एएनएन-EMD-ANN), ईएमडी- सपोर्ट वेक्टर रिग्रेसन (ईएमडी - एसवीआर-EMD-SVR), एन्स्बलबल ईएमडी - एएनएन (EEMD-ANN), ईईएमडी-एसवीआर (EEMD-SVR), कम्पलीट एन्सेम्बल मोड डोम्पोसिशन विथ अडाप्टिव नॉइज़ (सीईएमडीएएन) –एनएनएन (CEEMDAN-ANN) और सीईएमडीएएन-एसवीआर (CEEMDAN-SVR)। यह सारे मॉडल पोर्टफोलियो का गठन करने वाले शेयरों की कीमतों की भविष्यवाणी के लिए विकसित किए गए हैं। व्यापारिक नियमों

(trading rules) को डिज़ाइन किया गया है ताकि बाज़ारों की अलग-अलग स्थितियों के अनुसार शेयरों को खरीदने / बेचने / रखने के लिए निवेशकों को निर्देशित किया जा सके। भारतीय शेयर बाजार के आंकड़ों के डेटा पर किया गया प्रयोगात्मक विश्लेषण प्रस्तावित ढांचे की ताकत को दर्शाता है।

अध्ययन के दूसरे चरण में भारतीय शेयर बाजार में पोर्टफोलियो प्रबंधकों द्वारा अपनाई गई निवेश प्रक्रिया को समझने के लिए एक सर्वेक्षण किया गया है। सर्वेक्षण के परिणाम बताते हैं कि भारतीय शेयर बाजार में वित्तीय सिद्धांतों का कार्यान्वयन बहुत कम है ।

Contents

List of Figures

List of Tables

Abbreviations

ABC	**A**rtificial **B**ee **C**olony
AHP	**A**nalytic **H**ierarchy **P**rocess
ANN	**A**rtificial **N**eural **N**etwork
ANP	**A**nalytic **N**etwork **P**rocess
ARCH	**A**uto**R**egressive **C**onditional **H**eteroskedasticity
ARMA	**A**uto**R**egressive **M**oving **A**verage
ARIMA	**A**uto**R**egressive **I**ntegrated **M**oving **A**verage
BCC	**B**anker **C**harnes **C**ooper
BSE	**B**ombay **S**tock **E**xchange
CCR	**C**harnes **C**ooper **R**hodes
CEEMDAN	**C**omplete **E**nsemble **E**mpirical **M**ode **D**ecomposition with **A**daptive **N**oise
CRS	**C**onstant **R**eturns to **S**cale
DA	**D**irectional **A**ccuracy
DE	**D**ifferential **E**volution
DEA	**D**ata **E**nvelopment **A**nalysis
DJIA	**D**ow **J**ones **I**ndustrial **A**verage
DMU	**D**ecision **M**aking **U**nits
DWT	**D**iscrete **W**avelet **T**ransform
EOB	**E**lectronic **O**rder **B**ook
EMD	**E**mpirical **M**ode **D**ecomposition
EEMD	**E**nsemble **E**mpirical **M**ode **D**ecomposition
FA	**F**irefly **A**lgorithm
GA	**G**enetic **A**lgorithm

GARCH	**G**eneralised **A**uto**R**egressive **C**onditional **H**eteroskedasticity
GMV	**G**lobal **M**inimum **V**ariance
GP	**G**enetic **P**rogramming
GS	**G**erber **S**tatistics
HRP	**H**ierarchical **R**isk **P**arity
IMF	**I**ntrinsic **M**ode **F**unction
MAD	**M**ean **A**bsolute **D**eviation
MAE	**M**ean **A**bsolute **E**rror
MCDA	**M**ulti **C**riteria **D**ecision **A**nalysis
MSE	**M**ean **S**quare **E**rror
NSE	**N**aional **S**tock **E**xchange
NMSE	**N**ormalised **M**ean **S**quare **E**rror
NYSE	**N**ew **Y**ork **S**tock **E**xchange
PSO	**P**article **S**warm **O**ptimization
OWA	**O**rdered **W**eighted **A**veraging
RMSE	**R**oot **M**ean **S**quare **E**rror
ROA	**R**eturn **O**n **A**sset
ROE	**R**eturn **O**n **E**quity
ROI	**R**eturn **O**n **I**nvestment
RSE	**R**egional **S**tock **E**xchange
SA	**S**imulated **A**nnealing
SEBI	**S**ecurities and **E**xchange **B**oard of **I**ndia
SVM	**S**upport **V**ector **M**achine
SVR	**S**upport **V**ector **R**egression
TS	**T**abu **S**earch
VRS	**V**ariable **R**eturns to **S**cale
WSRT	**W**ilcoxon **S**igned **R**ank **T**est