2021

Optimizing Large Financial Portfolios

Huang, Jefferson; Hermis, Judith M.

Monterey, California: Naval Postgraduate School

OPTIMIZING LARGE FINANCIAL PORTFOLIOS

EXECUTIVE SUMMARY

Principal Investigator (PI): Dr. Jefferson Huang, Graduate School of Operational and Information Sciences (GSOIS), Operations Research

Additional Researcher(s): Dr. Judith Hermis, Graduate School of Defense Management (GSDM), Financial Management

Student Participation: No students participated in this research project.

Prepared for:
Topic Sponsor Lead Organization: N8 - Integration of Capabilities & Resources
Topic Sponsor Name(s): CAPT Christopher Gilmore
Topic Sponsor Contact Information: christopher.s.gilmore.mil@us.navy.mil, 703-692-2770

This research is supported by funding from the
Naval Postgraduate School, Naval Research Program (PE 0605853N/2098).

Project Summary
This project addresses the question of how uncertainties in the budgeting process, such as those related to costs, scheduling, and performance, can be tractably accounted for in making funding decisions. We formulate and implement an optimization model based on finding funding allocations that minimize the conditional value-at-risk of the associated portfolio. The implementation is embedded in a dashboard that allows a decision-maker to interactively exercise the parameters associated with return-on-investment risk and budget risk. Major open research directions include how the model inputs related to returns on investment should be estimated, and studying the kinds of behaviors that this and other portfolio optimization models incentivize.

Keywords: *financial modeling, optimization, portfolio optimization, risk, budgeting, uncertainty*

Background
The Office of the Chief of Naval Operations N80E is responsible for providing fiscal analysis to support budget decisions and the defense of the Program Objective Memorandum. There are many sources of uncertainty in this process, including uncertainties in costs, scheduling, and the performance of procured systems. These uncertainties mean that for any given budgeting decision, there is some amount of risk in ending up with less-than-desirable outcomes. On the other hand, certain budgeting decisions carry less risk than others, and among those decisions with a given expected return on investment, those that carry less of a risk of adverse outcomes should be preferred.

As part of ongoing efforts to better account for uncertainty in the budgeting process, this project focused on how to do this in the context of decision problems that can be viewed as allocating investments to several different projects (i.e., portfolio optimization problems). Examples of such problems include deciding which weapons systems to procure, and how much money should be set aside for various appropriation categories. One approach to explicitly accounting for uncertainty and risk in portfolio optimization problems is to minimize the conditional value-at-risk (CVaR) of the portfolio. This approach has received a great deal of attention in the private sector and has attractive computational properties (Rockafellar & Uryasev, 2000). It generalizes more classical portfolio optimization models whose objective is simply to maximize the expected value of the portfolio's return on investment. Such models are often referred to as being risk-neutral, in the sense that they simply optimize the average return without regard to the variability of the return. The CVaR objective includes a tuning parameter that allows the decision-maker to vary their level of risk-aversion, so that portfolios with a higher risk of adverse outcomes are penalized.

Findings and Conclusions
In this project, we formulated and implemented a CVaR optimization model in the context of appropriation-level portfolio optimization, with additional constraints that capture salient features of this problem context. For example, the model allows the benefits of a given investment in a particular fiscal year to be spread out over time and includes constraints on the chance with which the total ownership

cost will be within the total obligation authority in each fiscal year. In addition to an implementation using Pyomo (Hart et al., 2011), we also developed and implemented a dashboard that facilitates the visualization of the portfolios that are recommended by the model and allows for interactive model excursions. Through this dashboard, a decision-maker can quickly see the impact of varying the risk-related model parameters on the recommended portfolios.

Recommendations for Further Research

A major direction for further research deals with how returns on investment should be quantified in the context of defense budgeting. While the model developed in this project can take such values as inputs, it does not explicitly provide guidance on what those values should be. Another important future research direction is in studying the kinds of behavior that the portfolio optimization model incentivizes, and if the incentivized behavior is undesirable, how the model should be modified to incentivize better decisions.

References

Hart, W. E., Watson, J. P., & Woodruff, D. L. (2011). Pyomo: modeling and solving mathematical programs in Python. *Mathematical Programming Computation*, *3*(3), 219-260.

Rockafellar, R. T., & Uryasev, S. (2000). Optimization of conditional value-at-risk. *Journal of Risk*, *2*, 21-42.

Acronyms

CVaR conditional value-at-risk