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Probabilistic solutions for a class of deterministic optimal allocation problems

Ka Chun Cheung* Jan Dhaene† Yian Rong‡
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Abstract

We revisit the general problem of minimizing a separable convex function with both a budget constraint and a set of box constraints. This optimization problem arises naturally in many resource allocation problems in engineering, economics, finance and insurance. Existing literature tackles this problem by using the traditional Kuhn-Tucker theory, which leads to either iterative schemes or yields explicit solutions only under some special classes of convex functions owe to the presence of box constraints. This paper presents a novel approach of solving this constrained minimization problem by using the theory of comonotonicity. The key step is to apply an integral representation result to express each convex function as the stop-loss transform of some suitable random variable. By using this approach, we can derive and characterize not only the explicit solution, but also obtain its geometric meaning and some other qualitative properties.

Keywords: Optimal allocation, Constrained optimization, Comonotonicity, Stop-loss transform

MSC: 90B99, 90C30

1 Introduction and problem formulation

Let $(X_1, \ldots, X_n)$ be the portfolio of risks (i.e., random variables representing losses) we are facing. A provision of d dollars is available to be allocated among these n risks. We use the function $f_i(d_i)$ to model the level of riskiness of the risk X_i if d_i dollars is allocated to X_i. When more capital is allocated to risk i, the position is considered to be safer, and hence the corresponding risk level is less. This means that f_i should be a decreasing function. It is also natural to assume that the decrement is diminishing per unit of growth. Accordingly, f_i is both decreasing and convex. As a typical example, we may take $f_i(d_i) := \rho\left((X_i - d_i)_+\right)$, where ρ is some convex and increasing functional. The amount $\rho\left((X_i - d_i)_+\right)$ could be

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