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New measures and procedures to manage financial risk with applications to the planning of gas commercialization in Asia

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Abstract

This paper presents some new concepts and procedures for financial risk management. To complement the use of value at risk a new concept, upside potential or opportunity value as means to weigh opportunity loss versus risk reduction as well as an area ratio are introduced and discussed. Upper and lower bounds for risk curves corresponding to the optimal stochastic solution are developed, the application of the sampling average algorithm, one scenario at a time, is analyzed, and the relation between two-stage stochastic models that manage risk and the use of chance constraints is discussed. Finally, some anomalies arising from the use of value at risk and regret analysis are pointed out. These concepts are applied to the commercialization of gas and/or gas-derivatives (synthetic gasoline, methanol, and ammonia) in Asia. Results show that, given the set of costs chosen, the production of synthetic gasoline should be the investment of choice and that the use of contracts can increase expected profit. Other suboptimal cases are also revealed and it is shown how financial risk can be managed.

Keywords: Planning; Financial risk; Robust optimization

1. Introduction

A new approach to the management of financial risk was recently presented by Barbaro and Bagajewicz (2003, 2004a, 2004b). The methodology uses a well-known definition of risk based on cumulative probability distributions. A mathematical expression for risk at different aspiration levels was presented and connected to earlier definitions of downside risk (Eppen, Martin, & Schrage, 1989). Some elements of the risk manipulation, similar to the procedure developed by Barbaro and Bagajewicz (2003) have also been recently presented by Gupta and Maranas (2003), although these authors think of risk as a symmetric measure given by variability and believe that the risk definition given by Barbaro and Bagajewicz (2003, 2004a) is an approximation. In particular, Barbaro and Bagajewicz (2003, 2004a) showed that downside risk is the integral of the risk curve. They also proved that downside risk is not monotone with risk, that is, lower downside risk does not necessarily imply lower risk. All these were incorporated into a two-stage stochastic programming framework to manage risk through multiobjective programming. They also showed that a series of candidate Pareto optimal solutions that reduce risk at a cost of reducing expected profit can be obtained and downside risk instead of risk directly, reducing thus the number of binary variables needed (risk uses binary variables, while downside risk does not). Finally they made connections with value at risk (VaR) and suggested the use of a downside expected profit (DEP) as means of making risk-related decisions in a project.

In other related work, Cheng, Subrahmanian, and Westerberg (2003) suggest that risk should be managed directly in its downside risk form for a particular aspiration level together with other project attributes like expected profit and life cycle. They claim that a multiobjective framework, solvable with methodologies rooted in dynamic programming

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methods is the correct procedure to craft a project. This use of risk as a point measure keen to risk-averse decision makers is in apparent contrast with the claim made by Barbaro and Bagajewicz (2003, 2004a) that risk should be looked at through the entire curve. Not looking at the entire curve was in part the reason why symmetric measures, like variance, were used to assess and manage risk in earlier work (Mulvey, Vanderbei, & Zenios, 1995). Recently, the same tendency is seen in the use of value at risk (Guldimann, 2000; Jorion, 2000). Looking at the entire curve is important because, even when one is a risk-averse decision maker, and consequently concerned with the profit distribution at low profit expectations, one can also assess the effect of risk-related decisions in the downside region of the profit distribution on the loss of profit potential at the other end of the spectrum. The difference with the approach proposed by Cheng, Subrahmanian, and Westerberg (2003) is, after all, not so fundamental because one can perfectly add to their approach more than one objective to address risk, much in the way as proposed by Barbaro and Bagajewicz (2003, 2004a) and also use any other risk measure (value at risk, risk, downside expected profit). The only point in which real differences persist are in that Barbaro and Bagajewicz (2003, 2004a) propose to visualize the entire set of curves before making a decision, while the method of Cheng, Subrahmanian, and Westerberg (2003) has to resort to constructing complicated Pareto optimal surfaces, which in higher dimensions are difficult to visualize. The differences, nonetheless, are likely to be secondary and we expect these two approaches to complement each other somehow.

Finally, to overcome the numerical difficulties associated with the use of large number of scenarios, Barbaro and Bagajewicz (2003, 2004a) discussed the use of the sampling average algorithm (SAA) (Verweij, Ahmed, Kleywegt, Nemhauser, & Shapiro, 2001) and compared it with the use of Benders decomposition (Benders, 1962; Geoffrion, 1972). Clearly, large problems including large number of scenarios remain elusive for regular desk computers.

In this paper we address new definitions necessary to properly manage financial risk. These definitions are: upside potential (UP) or opportunity value (OV) and the risk area ratio (RAR). The former is a point measure symmetrically opposite to value at risk, while the second is an integral measure that establishes a relation between the reduction in risk and the loss of profit potential at profit expectations above the expected value. Some intricacies related to the use of these measures are theoretically analyzed and illustrated in the example. We also show briefly that the use of chance constraints is a poor way of managing risk and we discuss and illustrate the shortcomings of the use of regret analysis, by itself or as a constraint of two-stage stochastic models, as proposed by Ierapetritou and Pistikopoulos (1994). Finally we also discuss the use of the sampling algorithm to determine upper and lower risk curves bounding the optimal solutions of the purely stochastic problem. All these concepts are illustrated solving the planning of gas commercialization in Asia.

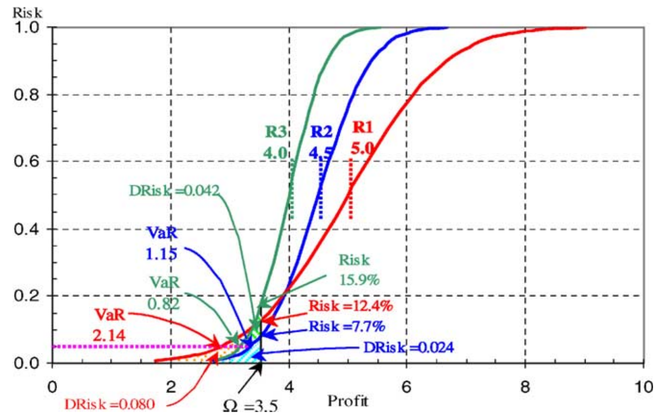

Fig. 1. Comparison of VaR to risk and downside risk.

2. Value at risk and upside potential

A widely used measure of risk in literature is the value at risk (Guldimann, 2000; Jorion, 2000) defined as the expected loss for a certain confidence level usually set at 5% (Linsmeier & Pearson, 2000). A more general definition of VaR is given by the difference between the mean value of the profit and the profit value corresponding to the *p*-quantile (value at *p* risk). VaR has been used as a point measure very similar to the variance. Moreover, it suffers from the same problem, that is, it either assumes a symmetric distribution, or it ignores the effect of reducing VaR on the optimistic scenarios.

VaR measures the deviation of the profit at 5% risk from the ENPV. To compare the performance of VaR to that of risk and downside risk as discussed by Barbaro and Bagajewicz (2003, 2004a), consider the hypothetical risk curves of Fig. 1. VaR, risk and downside risk values for the three solutions are compared in Table 1. Assume that R1 is the stochastic solution that maximizes the ENPV. If the investor is risk-averse and would prefer to have a more robust solution than R1 even if its ENPV is reasonably smaller, then R2 is obviously the best choice. R3 is dominated by R2. In other words, R2 and R3 do not intersect. Table 1 depicts the VaR, risk and downside risk of all three solutions. We also note that R3 would

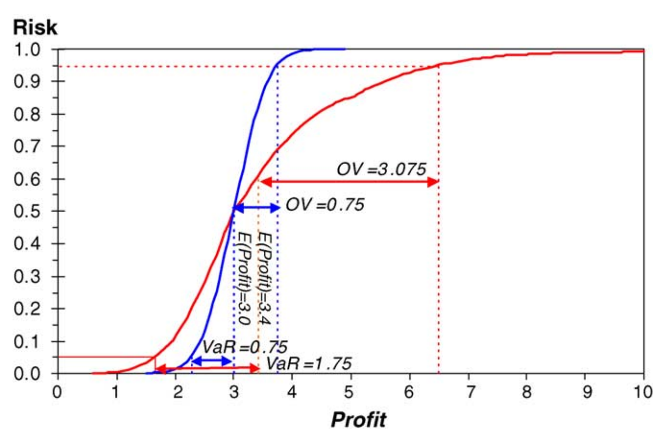

Fig. 2. Upside potential (UP) or opportunity value (OV) vs. VaR.