1 Introduction

Dynamic decisions under uncertainty prevail in financial planning and financial engineering problems. In particular, multistage stochastic programming is the most applied methodology to solve them by reason of flexibility to model intrinsic complexity of such problems. Based on Bellman's equations and on the well behaved properties of risk neutral formulation, several models and important algorithms, for instance (PEREIRA; PINTO, 1991) and (ROCKAFELLAR; WETS, 1991), have been developed for different applications such as portfolio selection, asset and liability management, scheduling and energy planning. However, one should choose carefully how to introduce risk aversion into these models. In this thesis we discuss risk measures, utility functions, direct and indirect penalties as examples on how to model a risk aversion. These concepts are developed on four working papers, each one with a different financial application. For each problem, we also develop new methodologies for modeling and solving each of the proposed application.

The first working paper of this thesis deals with risk averse multistage models via risk measures. We show that the intuitive formulation using an widely-adopted risk measure, namely Conditional Value-at-Risk (CVaR), may lead to inconsistencies on decisions over time. Rather than a technicality or an abstract property, time consistency is a major requirement to obtain suitable dynamic solutions and it is the only way to ensure that the first stage decision is optimal and not polluted by spurious future decisions. Regardless of the application, choosing a time inconsistent formulation leads to an improper risk assessment and, consequently, a sequence of potentially reckless decisions. We discuss through a portfolio selection example the severe practical consequences of adopting time inconsistent policies. Then, we propose a risk-averse dynamic stochastic programming model that ensures time consistent policies and develop a clear economic interpretation for its objective function. We also develop a numerical example to illustrate the proposed concepts.

On the second working paper, we first propose a two-stage model that optimizes simultaneously the asset portfolio and leverage level considering a convex piecewise linear borrowing cost function. This function represents the cost of a borrower with a finite number of available lenders, or credit lines, with different borrowing rates and credit limits. As opposed to the usual linear borrowing cost function approximation, our model represents the actual circumstances of a leveraged investment strategy since, one must choose among a finite number lenders and not only one with a fixed rate. For comparison purposes, we consider a two-stage optimization problem that maximizes the expected portfolio return under a risk constraint, using CVaR-based deviation measure. Then, we show using a numerical example that the usual linear approximation leads to suboptimal solutions while our proposed cost function leads to optimality if one considers multiple lenders. Furthermore, we develop a time consistent multistage extension where the borrowing cost function is one clear example where risk aversion is embedded in a indirect penalty. We develop a solution method for the case of stage-wise independent returns and proportional credit limits.

On the third working paper, we develop a multistage linear stochastic programming model for optimal corporate debt management given a predetermined investment schedule. The value of investments, bonds and future revenues are uncertain, affected by financial, macroeconomic and business specific risk factors. Debt portfolios are structured as a mix of securities with differing indexations, denominations, maturities and amortization schedules. Our objective is to find the bond issuance policy that optimizes the mean-risk trade-off between expected terminal cash savings and risk of default at the end of the horizon, considering also penalties for excess leverage at intermediate stages. Uncertainty is represented by an event tree with a hybrid information structure, avoiding exponential complexity with the number of planning stages. Numerical stability tests, sensitivity analysis and an efficient frontier are presented for an illustrative example. Based on the proposed model, a financial planning software tool has been implemented and deployed in Brazilian oil company Petrobras.

Finally, on the forth working paper, we propose a multistage stochastic program to obtain the cash holding policy of a firm facing uncertain investment opportunities. The model endogenously determines the best production, investment, financing and cash holding policies over the planning horizon. This paper includes two contributions for the stochastic programming literature. The first one is to approximate infinite horizon problem using dual equilibrium to mitigate the end effects of a horizon truncation. This method was previously used only for dynamic deterministic problems and we extend it to a dynamic stochastic one. The second contribution is to find a policy rule that approximates the optimal solution of the stochastic programming problem. We used regime switching structure of the stochastic processes to define those rules and compare them to the actual optimal ones. The implications of this model are illustrated for the agricultural firm.