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Risk Management of Supply and Cash Flows in Supply Chains

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Abstract

This book focuses on several key issues of risk management in supply chains. Initially, the authors studied the supplier selection problem with supply risk. Specifically, the optimal sourcing strategy was identified in a one-retailer two-suppliers supply chain with random yields. The optimal sourcing strategy of a retailer and the optimal pricing strategies of two suppliers were investigated under an environment of supply disruption. Then, the authors studied the dynamic inventory control problems with cash flow constraints, financing decisions, as well as delayed cash payment. Finally, the authors created a model for the bargaining process, of an annual international iron ore price negotiation, to deal with the risk of wholesale price in the game analysis context.

Preface

Risk management has become an essential issue in supply chain management, from the modeling of the decision maker's risk preference, and the studies on uncertain elements such as demand, supply, price, lead time, etc., to the consideration of more practical background including cash flow constraints, inventory financing and delayed cash payment. Theoretically, the book provides a framework to study the interaction of various factors related to risk and their influence on supply chain management.

The core of this book is to analyze risk management of supply and cash flows in supply chains. The book consists of eight chapters. The contents of the book are outlined in the following.

Chapter 1 surveys the applications of risk management to supply chains and reviews the existing literature. The numerous literature in this field is classified into three categories, i.e., risk analysis of supply chain models, disruption management, and financial risk measurement. Throughout this chapter, some representative models are selected and their relationships and distinctions are analyzed.

The sourcing strategy of a retailer who procures from two unreliable suppliers is investigated in Chap. 2. "Unreliable" means that the suppliers may default on their obligations to deliver order quantities at the end of a given production period. The retailer facing stochastic demand needs to determine whether to choose single sourcing from one supplier or dual sourcing from two suppliers, and further how much to order. A two-period model is developed, and for each period, the authors identify the conditions under which the retailer will choose different sourcing strategies. It should be mentioned that more structural results can be found under the setting of deterministic demand.

Chapter 3 investigates not only the sourcing strategy of a retailer but also the pricing strategies of two suppliers under a supply disruption environment. The sourcing strategies of the retailer are characterized in a centralized system and a decentralized system respectively. Based on the assumption of a uniform demand

distribution, the explicit form of the solutions is obtained when the suppliers are competitive. Finally, a coordination mechanism is devised to maximize the profits of both the suppliers.

In Chap. 4, a dynamic inventory control problem of a self-financing retailer is investigated. The retailer can periodically replenish his stock from a supplier and sell it to the market. The replenishment decisions of the retailer are constrained by cash flows, which is updated periodically following the purchasing and the sales in each period. Excess demand in each period is lost when insufficient inventory is available. The retailer's objective is to maximize its expected terminal wealth at the end of the planning horizon. The optimal inventory control policy is characterized. A simple algorithm is designed for computing the optimal policies in each period. Conditions are identified under which the optimal control policies are identical across periods. Finally, comparative static results on the optimal control policy are also presented.

Based on the model introduced in Chaps. 4 and 5 studies the dynamic inventory control problem with the assumption that asset-based financing is allowed for the retailer, when being short of cash flow. Excess demand in each period is lost when insufficient inventory is available. The retailer's objective is to maximize its expected terminal wealth at the end of the planning horizon. The optimal inventory control policy and its dependence on the wealth level are explored. Conditions are identified under which the retailer will choose either to borrow or to deposit in each period. The bankruptcy probability is also studied.

Furthermore in Chap. 6, a framework is proposed for incorporating financial considerations including delayed cash payment and receivable into dynamic inventory models. The financial constraint is updated periodically according to production activities. The dynamic financial constraint and the optimal operational policy are explored. The optimal operational policy's dependence on the financial state is also studied. It demonstrates the importance of firms considering delayed cash payment.

Chapter 7 seeks to provide insights for an annual international iron ore price negotiation by establishing mathematical and economical models and especially extending the Nash bargaining framework. Specifically, a one-supplier two-manufacturer supply chain is studied. The Nash game is first analyzed between the two manufacturers and then the bargaining process between the supplier and each manufacturer is modeled by a sequential Nash bargaining. The results demonstrate the importance of steel manufacturers in increasing the investment on iron ore.

Chapter 8 concludes the book and suggests some topics for future research.

Within the perspectives of risk management in supply chains, analysis on the risk management of supply and cash flows are still in its infancy, and more efforts are needed from academia. Hence the ambition and innovation of this book is to contribute on risk management in supply chains in following ways:

(1) Characterizing the explicit sourcing strategy (i.e., single sourcing or dual sourcing) to deal with supply risk
(2) Introducing the concepts of financial risk measurement by incorporating cash flow constraints, inventory financing and delayed cash payment into inventory management models

(3) Providing insights for the iron ore price negotiation to help the steel manufacturers to handle the risk of price increase

This book is intended for researchers interested in conducting in-depth studies on supply chain risk management. The book is also intended for business practitioners seeking to understand the nature and law governing the working of supply chain risk management and looking for guidance and decision support for the implementation of supply chain risk management. Therefore, the book can be useful not only for researchers but also for practitioners and graduate students in operations management, management science, and business administration.

We would like to thank many friends and colleagues for their help and support rendered to us in preparing this monograph. First, we thank Prof. Fangruo Chen of Columbia University, Prof. Xiuli Chao of The University of Michigan, Prof. Jeannette Song of Duke University, Prof. Gang Yu of The University of Texas at Austin, Prof. T.C. Edwin Cheng of The Hong Kong Polytechnic University and Prof. Kin Kleung Lai of City University of Hong Kong, Prof. Hanqin Zhang, Prof. Ke Liu and Dr Jingan Li of the Academy of Mathematics and Systems Science of the Chinese Academy of Sciences for their helpful discussions, suggestions and valuable comments on our research in this area. We also thank the National Natural Science Foundation of China, the Academy of Mathematics and Systems Science of the Chinese Academy of Sciences, and Beijing University of Chemical Technology for their financial support to our research.

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Chapter 1
Introduction

In recent years, the adopting of some supply chain practice such as outsourcing and lean production helps in smoothing the operations, but it also results in little buffer inventory in a supply chain which may lead to increased vulnerability of the chains.[1] At the same time, the business environment has evolved to be an increasingly complex scenario characterized by high uncertainty and rapid and frequent changes. For example, supply chains are subject to many potential external sources of disruption, e.g., natural disasters, terrorist attacks, and industrial actions, etc. The disruption in one firm can rapidly result in a significant adversary impact on the entire chain. Due to such changes, firm managers not only concern profit maximization but also pay much attention to risk containment or loss minimization for their firms. Motivated by the requirements of real world practice, supply chain risk management attracts more and more attention from academia (Chen et al. 2007; Shi 2004; Tang 2006a; Wu and Wang 2004a,b; Wu et al. 2006a; Zhou et al. 2006).

So far there is no generally agreed definition of supply chain risk management. It is even not clear to distinguish risk and uncertainty in supply chain operations (Tang and Nurmaya Musa 2010; Hua et al. 2010b, 2010c). Based on the review of existing literature, we think a comprehensive definition of supply chain risk management should refer to agents in the supply chain, collaboratively with their partners or on their own, to apply risk management process tools to deal with risks and uncertainties in the supply chain so as to ensure profitability and continuity.

The flows in a supply chain mainly include the forms of material, finance and information. Thus, supply chain risks can also be classified into three types: material flow risks, financial flow risks and information flow risks. For example, organizations increasingly rely on information technology such as enterprise resource planning solutions and internet to improve the supply chain process. Vast assistance

[1] The following discussion in this chapter is largely based on the ideas and results presented in Wu et al. (2011).

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from these IT systems has, however, exposed to another consequence, namely information disruption (Tang and Nurmaya Musa 2010). Tang and Nurmaya Musa (2010) also points out that quantitative methods are missing in information flow risk analysis. This book mainly focus on material flow risks and financial flow risks.

Demand fluctuation and supply disruption are two kinds of primary uncertainties in supply chain material flow and various specific examples of supply chain risks, e.g., uncertainties of purchasing costs, selling prices, and contract parameters, etc., can be ultimately attributed to the variations of supply and demand. Hence, most of the supply chain material flow risks can be classified into two categories known as demand risk and supply risk. Besides, the risks of the cash flow and possibility of bankruptcy need to be incorporated into supply chain management process.

In terms of influence and frequency, risks can also be classified into two types, one is normal risk and the other is abnormal risk. Generally speaking, normal risk mainly includes risks that occur frequently and are easy to track and control. These risks, e.g., demand uncertainty, price fluctuation, and supply variation etc., attract more and more attention to measure and to model from the academia. On the other hand, there is broad category of risk, known as abnormal risk, which arises from great disruptions to normal activities. Such risks are usually caused by unexpected events such as natural disasters, strikes, economic disruptions, and acts of purposeful agents (including terrorists) etc. The famous example is the event so-called "911" in USA. It happened without any premonition and the tangible loss is estimated at more than one hundred billion! Hence, there is special requirement to incorporate abnormal risk into supply chain management. Still abnormal risk management, also known as disruption management, is relatively new and often ignored since it is difficult to quantify, predict and manage.

To the best of our knowledge, most of the existing literature in relation to risk management in supply chains mainly focuses on modeling of the decision maker's aversion to risks, consisting of various risk measurement approaches, such as utility function theory, mean–variance trade-off, and value-at-risk (VaR), etc. In the following chapter, we focus on the literature dealing with the decision maker who wants to take risk into consideration. Thus, it is the ambition of this chapter to bring together the research results from these fields of study in order to contribute to the study of risk management in supply chains. This chapter is not meant to be comprehensive or inclusive, but reviews through representative papers of the various issues studied in the risk management literature on supply chains. This chapter seeks answers to two key questions: What are the underlying supply chain risk management problems? and how have they been addressed in the current literature? We hope that it will be helpful for those who are interested in supply chain risk management.

In the following, Sect. 1.1 attempts to establish a framework of supply chain risk management problems from modeling of decision maker's aversion to risks and supply chain management models. Then some literature on disruption management is reviewed according to the classical risk management paradigm in Sect. 1.2. Finally, Sect. 1.3 proposes some financial and economical instruments which are incorporated into supply chain management models.

1.1 Risk Analysis of Supply Chain Models

Traditional supply chain management mainly focuses on maximizing the expected profit or minimizing the expected cost (Li et al. 2006, 2007, 2008; Gong et al. 2009; He et al. 2010). Seldom of them consider the decision maker's risk preference towards the risk. It is well-known that decision makers are classified into three types based on their preference towards the risk, they are risk-averse, risk-neutral and risk-taking. In supply chain management, risk-averse usually reflects the real risk preference of an agent, either a retailer or a supplier. Hence, the modeling of the decision maker's preference towards the risk mainly focuses on the risk measurement of decision maker's aversion to risks. Almost all methods of risk measurement in supply chain risk management models are originated from economics and finance. From theory of utility function (von Neumann and Morgenstern 1944) and mean–variance methodology (Markowitz 1959) in midterm of the last century, to value-at-risk model and conditional value-at-risk (CVaR) model in recent years, we incorporate all of them into the framework of supply chain management.

In the following, the literature is categorized by risk management tools, and then several representative papers are surveyed with basic models and main results.

1.1.1 Risk Management Tools

1.1.1.1 Utility Maximization

Utility function was first presented by von Neumann and Morgenstern in 1944 with the objective aiming to maximizing the decision maker's expected utility. The literature adopting utility function to study supply chain models includes Bouakiz and Sobel (1992), Eeckhoudt et al. (1995), Agrawal and Seshadri (2000a), Chen et al. (2003), Keren and Pliskin (2006), Wang and Webster (2007, 2009). In the following, several representative papers are reviewed.

Bouakiz and Sobel (1992) studied the inventory replenishment strategy by minimizing the expected utility of the present value of costs over a finite planning horizon and an infinite horizon. Based on an exponential utility function, they had shown that the optimal ordering policy is given by a sequence of critical numbers if the ordering costs are linear and the penalty and holding costs are convex. The infinite-horizon policy is ultimately stationary and approaches the risk-neutral policy as the period gets larger.

Eeckhoudt et al. (1995) studied the effects of risk aversion in the newsvendor model by using expected utility functions. The optimal ordering quantity is given by maximizing the expected utility of a profit function. The decision is based on a subjective utility function of the decision maker. For certain utility functions the solution within this framework is larger or smaller than the solution in the risk neutral case; also the fraction of losses may be reduced. In particular, they presented

a comparatively static effects of changes in the various price and cost parameters in the risk aversion setting. Although many of the comparative effects generally are ambiguous, some fairly simple restrictions on preferences and/or risks increases are shown to lead to qualitatively deterministic results.

Agrawal and Seshadri (2000a) considered how a risk-averse retailer, whose utility function is assumed to be increasing and concave in wealth, chooses the ordering quantity and the selling price in a single-period inventory model. They showed that in comparison to a risk-neutral retailer, a risk-averse retailer would charge a higher price and order less if a change in price affects the scale of demand; whereas, a risk-averse retailer would charge a lower price if a change in price only affects the location of the demand distribution.

Chen et al. (2003) studied a joint optimization problem on both ordering quantity and price. In the paper, a framework is proposed for incorporating risk aversion in multi-period inventory models as well as multi-period models that coordinate inventory and pricing strategies. In each case, the authors characterized the optimal policy for various risk measurements. In particular, they showed that the structure of the optimal policy for a decision maker with exponential utility functions is almost identical to the structure of the optimal risk-neutral inventory (and pricing) policies. These structural results are extended to models in which the decision maker has access to a (partially) complete financial market and can hedge its operational risk through trading financial securities. Computational results demonstrate the importance of this approach not only to risk-averse decision makers but also to risk-neutral decision makers with limited information on the demand distribution.

Wang and Webster (2007) analyzed a supply chain composed of a risk-neutral manufacturer selling a perishable product to a loss-averse retailer. They found that the independence between parameters and market demand breaks down in a buyback contract when the retailer is loss averse. Their results indicate that coordinating contracts based on the assumption of risk neutrality may result in markedly lower supply chain profit when retailers are loss averse. Manufacturers should consider the impact of loss aversion in contract design along with mitigating provisions such as a gain/loss (G/L)-sharing clause, especially when dealing with small retailers for which the assumption of risk neutrality is less likely to hold.

Wang and Webster (2009) used a kind of loss aversion utility function to model a manager's decision-making behavior in the single-period newsvendor problem. They found that if shortage cost is not negligible, then a loss-averse newsvendor may order more than a risk-neutral newsvendor. They also found that the loss-averse newsvendor's optimal ordering quantity may increase in wholesale price and decrease in retail price, which can never occur in the risk-neutral newsvendor model.

Although the utility theory is widely applied in the area of risk management in supply chain risk management, the approach itself can be criticized, since it relies on an independence axiom which may be violated (Kischka and Puppe 1992). Moreover, from a more pragmatic point of view the application of the expected utility is more difficult than expectation since the decision maker has to specify