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Supply Chain Finance and FinTech Innovations

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Contents

Advances in Supply Chain Finance and FinTech Innovations Book Overview

In May 2019, we organized the "Fifth Supply Chain Finance and Risk Management Workshop" at the Olin Business School of Washington University in St. Louis. The Boeing Center for Supply Chain Innovation (BCSCI) at Washington University generously provided the logistics and financial support for this timely workshop. The workshop included relevant and state-of-the-art research presentations, and accompanying thought provoking discussions, by over forty selectively invited top research scholars on topics of supply chain finance, risk management in global supply chains, and financial technologies of impact in working capital management of global firms. Upon our invitation, research scholars participating in the workshop summarized their most recent thoughts and relevant results in a collection of papers appearing in this edited volume.

From a thematic perspective, the papers fall into three themes:

(1) Financing Issues in Supply Chains (Chapters 1–3)

(2) FinTech Innovations for Supply Chains (Chapters 4–5)

(3) Advances in Risk Management of Operational Systems (Chapters 6–10)

We discuss in brief below the papers within each theme, starting first with "Financing Issues in Supply Chains." The first two papers look

into popular working capital management financing practices: trade credits and guarantor practices. In "Trade Credit in Supply Chains: Multiple Creditors and Priority Rules" Yang and Birge discuss advanced trade credit practices in supply chains. Their work focuses on an often-ignored issue: what happens when the debtor cannot meet all of his debt obligations to the supplier issuing the credit. They study trade credit contracts with amended priority rules for the order of repayment when the debtor cannot repay all of his debt. An interesting result of the work is that often assigning low priority to the trade credit in these instances many increase supply chain efficiency. In "Guarantor Financing Selection under Influence of Supply Chain Leadership and Economies of Scale" Lin, Zhou, and Cai study guarantor financing practices for capital constrained retailers. In these practices, the manufacturer or a third party logistics provider (3PL), and sometimes both, act as the guarantor for the retailer who borrows bank credit. The authors analyze a four party game (retailer, bank, manufacturer, and 3PL) to demonstrate the value of guarantor practices and the importance of choosing the Stackelberg leadership in this game. Finally, in "Inventory and Financial Strategies with Capital Constraints and Limited Joint Liability" Cao, Chen, Cheng, Zhong, and Zhou study innovative practices of joint financing of capital constrained firms (let us say, two retailers ordering through a common supplier) by a bank. The paper presents and analyzes a stylized game theory model between the firms under the limited joint liability arrangement offered by the bank, and it derives and interprets the equilibrium strategies.

The two included papers in the theme of "FinTech Innovations for Supply Chains" study business model innovations for supply chain financing supported through new platform technologies (such as blockchain), and simple financial technologies effectively implemented for high impact in supply chain risk management, respectively. In "Financing Inventory through Initial Coin Offerings (ICO)" Gan, Tsoukalas, and Netessine study an innovative approach to fundraising for entrepreneurial organizations with the use of digital tokens implemented on blockchain platforms. The so-called Initial Coin Offerings (ICOs) financing practice is a form of crowdfunding for the product the startup supports, with capital raised through the offering of digital tokens. The paper offers a

simple model to explain the role of ICOs in matching supply and demand for companies involved in production of physical products. It analyzes operational decisions (number of tokens, pricing etc.) and implications for the firm and the investors. The paper concludes by warning that in the current unregulated environment, ICOs lead to risk-shifting incentives, underproduction, and potential loss of firm value. In "Renewable Identification Numbers: A Supply-Chain Risk View" Ghoddusi studies the use of Renewable Identification Numbers (RIN) as a floor-and-trade mechanism to enforce renewable energy standards in the transportation fuels market. RIN is a unique number attached to each gallon of ethanol, and the transportation fuel blender can obtain it when ethanol is added to gasoline. However, RINs can be obtained through trading with other blenders as well. The paper studies the pricing of RIN certificates in such trade markets, and it shows that the RIN price is a spread option on the price of ethanol and gasoline. Furthermore, it offers insights on how the presence of these RIN markets affect the operational and risk management decisions of blending firms.

The remaining five papers fall within the broad categorization of "Advances in Risk Management for Operational Systems" and provide state-of-the art thinking on many risk issues in supply chain operations. In "Managing Production Risk over the Product Life Cycle" Glinsky, Chopra, and Lucker study disruption strategies over the product life cycle, when future demand is influenced by current sales that are affected by current supply disruptions. The work offers insights on how holding risk mitigation inventory and contingent ordering from reliable suppliers perform in these settings. In "Production Planning with Inventory-Based Financing" de Matta and Hsu study the production planning complexities for a capital constrained manufacturer that uses Inventory Based Financing (IBF) scheme to fund its working capital needs. The manufacturer's production plan, and subsequently produced inventory, is constrained by capital availability, but its borrowed credit line amount depends on the level of collateralized inventory from its production process. The paper highlights the financing-motivated role of inventories, with strategic overstocking of inventories in order to secure more loans.

In "Achieving Efficiency in Capacity Procurement" Shao, Anderson, and Chen study an interesting capacity procurement setting, with

capacity obtained via spot purchases (flexible capacity market, but high price uncertainty) and supply options (cost effective, but require commitment via reservation fees for capacity blocks). The paper looks into the capacity procurement decision of a buyer that faces uncertain demand and volatile capacity spot prices in procuring an optimal portfolio of capacity options and capacity purchases from the spot market. Multiple competing suppliers are offering the supply options. Under some assumptions, the work characterizes the optimal bidding behavior of the suppliers and the buyer's optimal procurement arrangements portfolio. In "The Term Structure of Optimal Operations" Guiotto, Roncoroni, and Turcic study capacity planning in the presence of demand and price uncertainty when the timing of when to serve demand, and when to build capacity accounting for lead-times, is also a decision. Their main insights relate to this firm's timing preference driven by the source of uncertainty. For fixed price, the timing is either now or never (think it also as the end of the relevant horizon). However, with stochastic prices, the optimal time to serve demand is between the two extremes.

Finally, Nadarajah and Secomandi contribute an interesting methodological paper on valuing complex real options in dynamic operational settings in "Least Squares Monte Carlo and Approximate Linear Programming with an Energy Options Application." They demonstrate the effectiveness of an approximate dynamic programming technique based on Least Squares Monte Carlo (LSM) approach for real option valuation within operational risk management settings. They demonstrate the effectiveness of the proposed technique in managing the "real options" embedded in the operational flexibility of an ethanol plant (full capacity, mothball, reactivation, or complete termination) in the presence of volatile commodity prices.

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Part I

Financing Issues in Supply Chains

Trade Credit in Supply Chains: Multiple Creditors and Priority Rules

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ABSTRACT

Priority rules determine the order of repayment to different creditors when the debtor cannot repay all of his debt. In this chapter, we study how different priority rules influence trade credit usage and supply chain efficiency under the risk-sharing role of trade credit. We find that with only demand risk, when the wholesale price is exogenous, trade credit with high priority can lead to high chain efficiency, yet trade credit with low priority allows more retailers to obtain trade credit and suppliers to gain higher profits. When the supplier has control of wholesale price, however, the supplier should extend unlimited trade credit, deeming priority rules irrelevant. When other non-demand risks, especially those with longer terms in nature, are present, we show several scenarios when the optimal trade credit policy should change according to different risks, and that in general, trade credit with low priority results in higher chain efficiency.

S. Alex Yang and John R. Birge (2020), "Trade Credit in Supply Chains: Multiple Creditors and Priority Rules", Foundations and Trends® in Technology, Information and Operations Management: Vol. 14, No. 1–2, Special Issue on Advances in Supply Chain Finance and FinTech Innovations. Edited by P. Kouvelis, L. Dong and D. Turcic, pp 5–22. DOI: 10.1561/0200000096-1.

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Guarantor Financing Selection Under Influence of Supply Chain Leadership and Economies of Scale

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ABSTRACT

This paper investigates manufacturer guarantor financing (MG) and third-party logistics (3PL) guarantor financing (LG) in a four-party supply chain game that features a manufacturer, a 3PL, a capital-constrained retailer, and a bank. The manufacturer or 3PL can act as the guarantor for the retailer who borrows bank credit. Two different leadership structures are investigated, namely, Nash game and manufacturer leadership Stackelberg game, where the manufacturer and 3PL make their decisions simultaneously and sequentially, respectively. Our analysis shows that the supply chain under both leadership structures prefers guarantor financing to traditional bank financing when the supply chain is cost-efficient. Nevertheless, both upstream firms prefer the other to be the guarantor in the Nash game, whereas under the manufacturer Stackelberg leadership, the 3PL may prefer itself to be the guarantor. Furthermore, the supply chain under guarantor financing with a longer decision

Tiantian Lin, Weihua Zhou and Gangshu (George) Cai (2020), "Guarantor Financing Selection Under Influence of Supply Chain Leadership and Economies of Scale", Foundations and Trends® in Technology, Information and Operations Management: Vol. 14, No. 1–2, Special Issue on Advances in Supply Chain Finance and FinTech Innovations. Edited by P. Kouvelis, L. Dong and D. Turcic pubyear, pp 23–43. DOI: 10.1561/0200000096-2.

hierarchy (i.e., the Stackelberg game) can be conditionally more efficient than that with a shorter one (i.e., the Nash game). These findings enhance our understanding of the value of guarantor financing in a capital-constrained supply chain and the impact of leadership structure on financing decisions.

Keywords: guarantor financing, bank financing, Stackelberg leadership, Nash game, supply chain finance.

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Inventory and Financial Strategies with Capital Constraints and Limited Joint Liability

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ABSTRACT

We study the financial and operational decisions of two capital-constrained firms via a limited joint liability (LJL) financing scheme offered by a bank. We construct a two-stage game model in which the firms separately determine their individual ordering decisions according to the prior joint liability agreement between the firms and the bank. Applying non-cooperative game theory to analyze the decision-making problems of the two firms, we establish the existence of equilibrium decisions for the two firms. We derive mild conditions

Bin Cao, Xin Chen, T. C. Edwin Cheng, Yuan-Guang Zhong and Yong-Wu Zhou (2020), "Inventory and Financial Strategies with Capital Constraints and Limited Joint Liability", Foundations and Trends® in Technology, Information and Operations Management: Vol. 14, No. 1–2, Special Issue on Advances in Supply Chain Finance and FinTech Innovations. Edited by P. Kouvelis, L. Dong and D. Turcic, pp 44–59. DOI: 10.1561/0200000096-3.

under which the LJL financing scheme is simultaneously preferred by the two firms. We show that the two firms' strategies are complementary and the firms' equilibrium order quantities are always positively influenced by the risk-sharing term. We find that a greater bank loan leverage ratio may not simultaneously improve the two firms' performance. When the credit line and interest rate are endogenized by the bank, we provide insights on the relationship between the optimal interest rate and bank loan leverage ratio through risk hedging.

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Part II

FinTech Innovations for Supply Chains

Financing Inventory Through Initial Coin Offerings (ICOs)

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ABSTRACT

Initial Coin Offerings (ICOs) are an emerging form of fundraising for Blockchain-based startups. We propose a simple model of matching supply with demand with ICOs by companies involved in production of physical products. We examine how ICOs should be designed—including optimal token floating and pricing of utility tokens—in the presence of product risk and demand uncertainty, make predictions on ICO failure, and discuss the implications on firm operational decisions and profits. We show that in the current unregulated environment, ICOs lead to risk-shifting incentives (moral hazard), and hence to underproduction, agency costs, and loss of firm value. These inefficiencies, however, fade as product margin increases and market conditions improve.[1]

[1] This chapter is a summary of Gan *et al.* (2019) of which it may contain some identical content.

Rowena Jingxing Gan, Gerry Tsoukalas and Serguei Netessine (2020), "Financing Inventory Through Initial Coin Offerings (ICOs)", Foundations and Trends® in Technology, Information and Operations Management: Vol. 14, No. 1–2, Special Issue on Advances in Supply Chain Finance and FinTech Innovations. Edited by P. Kouvelis, L. Dong and D. Turcic, pp 60–76. DOI: 10.1561/0200000096-4.

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Renewable Identification Numbers: A Supply-Chain Risk View

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ABSTRACT

Renewable Identification Number (RIN) is a *floor-and-trade* mechanism to enforce renewable energy standards in the U.S. transportation fuels market. Motivated by several real-world cases, this chapter offers a stylized dynamic stochastic optimization framework for the price behavior of RIN certificates. We show that RIN price can be formulated as an American spread option on the price of gasoline and ethanol. A closed-form solution is derived for the case of GBM price processes. The solution suggests that the market prefers accumulating RINs in the early periods and using them towards the end of the compliance period. We also discuss potential connections between the dynamics of the RINs market and firms' operational decisions.

Hamed Ghoddusi (2020), "Renewable Identification Numbers: A Supply-Chain Risk View", Foundations and Trends® in Technology, Information and Operations Management: Vol. 14, No. 1–2, Special Issue on Advances in Supply Chain Finance and FinTech Innovations. Edited by P. Kouvelis, L. Dong and D. Turcic, pp 77–100. DOI: 10.1561/0200000096-5.

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Part III

Advances in Risk Management of Operational Systems

Managing Disruption Risk Over the Product Life Cycle

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ABSTRACT

In this article, we focus on managing disruption risk over the life cycle of a product. We consider two disruption mitigation strategies: holding risk mitigation inventory (RMI) and ordering from a reliable supplier. Our goal is to determine how the two strategies can best be used over the life cycle of a product where future demand is influenced by current sales that may be affected by supply disruptions. Our insights based on numerical analysis indicate that the optimal actions are impacted by the fact that future demand is affected by current sales over the life cycle. This results in optimal behavior that may be quite different from what has been proposed in the literature where demand over time has largely been assumed to be independent of current sales. For example, we show that the order quantity from an unreliable supplier may increase in the probability of disruption.

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Production Planning with Inventory-Based Financing

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ABSTRACT

This paper uses a mixed integer programming model to study a production and inventory planning problem faced by a manufacturer who utilizes Inventory-Based Financing (IBF) to capture additional demands during peak seasons that otherwise will not be met due to a shortage of working capital. By exploiting the problem's inherent structure of three distinct but related manufacturer decisions, i.e., the production, financing and working capital allocation decisions, the paper develops a branch-and-bound procedure to solve the model which is shown to be NP-hard. Through a series of numerical experiments, our study provides a number of interesting managerial insights into how the manufacturer's optimal production and inventory plans could differ with and without IBF. Specifically, we find that (a) the manufacturer would strategically overstock his inventory for the purpose of securing more loans, and this overstocking behavior is more acute in periods immediately prior to the peak demand period; and (b) the manufacturer could take advantage of the difference in peak and non-peak seasons of

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product demands by partially financing the production of one product through pledging the cycle inventory of another product.

Keywords: inventory-based financing; production and inventory planning; supply chain management; new business financing.

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Achieving Efficiency in Capacity Procurement

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ABSTRACT

This chapter studies a capacity procurement problem in which a buyer meets an uncertain demand using a combination of spot purchases and supply options that are offered by a number of competing suppliers. The specific setting we consider involves the suppliers each owning a block of capacity and the buyer restricted to reserving the entire block or none. For this setting, we are interested in understanding the buyer's optimal procurement strategy and the suppliers' competitive bidding behavior in the supply option market. To this end, we first examine the buyer's optimal decision given a set of supply options, and then study the suppliers' optimal bidding strategies in equilibrium. We find that it is optimal for suppliers to set execution price at cost and hence make a profit only through the reservation payment. We also prove that when all the blocks have the same size the buyer's optimal profit as a function of supplier set is submodular. This property allows us to characterize an equilibrium in which the supply chain optimum is achieved, each supplier makes a profit equal to their marginal contribution

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to the supply chain and the buyer takes the remaining profit. When the blocks have different sizes, we develop a recursive procedure to characterize a class of equilibria in which the supply chain efficiency is achieved.

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The Term Structure of Optimal Operations

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ABSTRACT

Inventory and capacity planning models generally take the time of sale as something that is exogenously given. For example, the story associated with the well-known newsvendor model is one of stocking for an upcoming selling season that will happen x units of time from now, where x is exogenous. In this paper, we re-visit the capacity planning decision by assuming that demand follows a stochastic process and study what happens when both the time of sale and capacity are decisions. When the selling price is fixed, our baseline case, we find that the optimal time to sell is either now or never. In contrast, when the selling price is stochastic, the optimal time to serve demand is somewhere *between* now and never. Thus, we link timing preference to two primary sources: uncertainty in demand and uncertainty in the selling price. Our results are useful whenever firms have considerable control over timing, such as in events when firms launch new products or in instances when there is no apparent selling season.

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Least Squares Monte Carlo and Approximate Linear Programming with an Energy Real Option Application

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ABSTRACT

Least squares Monte Carlo (LSM) is an approximate dynamic programming technique commonly used for the valuation of high dimensional financial and real options, but has broader applicability. It is known that the regress-later version of this method is an approximate linear programming (ALP) relaxation that implicitly provides a potential solution to a familiar ALP deficiency. We provide numerical backing for the usefulness of this solution using a numerical study dealing with merchant ethanol production, an energy real option application, based on an ALP heuristic that we propose. When both methodologies are applicable, our research supports the use of regress-later LSM rather than this ALP technique to approximately solve intractable Markov decision processes. Our findings motivate additional research

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to obtain even better methods than the regress-later version of LSM.

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