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MARTIN TUCHMAN SCHOOL OF MANAGEMENT

Major Research Projects and Outputs

Dr. Jim Shi

Associate Professor in Supply Chain Management and Finance

My research interest lies in the following areas:

- Blockchain and Supply Chain Management;
- Container Shipping Logistics;
- Agricultural Supply Chain;
- Production and Inventory Management;
- Interface between Supply Chain Management and Finance

My research studies and their related outputs are exhibited as follows.

I. Blockchain and Supply Chain Management

Nowadays, business is eager to adopt new technology as it witnesses more and more successful business applications of new technologies, e.g., Big Data and A.I. in the retail industry, Cloud Computing in the high tech industry, etc. Blockchain technology is now drawing public attention owing to the Bitcoin phenomenon for which Blockchain serves as the backbone technology. It has been suggested by business media that Blockchain might be the next disruptive technology to change the business world. Furthermore, many people are excited about Blockchain adoption in areas other than its home area, Finance. Leading companies, such as IBM and Walmart, are starting to explore Blockchain-based business opportunities in Supply Chain Management. In view of certain innovative features of Blockchain technology, especially its transparency, traceability, security, efficiency, confidentiality, and immutability, Blockchain holds out the promise of impacting supply chain operational and financial efficiencies.

In contrast to the growing industry attention to Blockchain technology, there is only limited academic research thereof, especially in the Supply Chain Management field. Our literature review shows that some research starts to focus on business process design supported by Blockchain technology, based on the assumption that Blockchain is worthwhile adopting. However, such an assumption is controversial without further justification. Our proposed research aims to fill this research lacuna. We propose to conduct a comprehensive analysis of various business scenarios pertaining to cost structure, demand functions, business uncertainty and supply yield rates with the goal of identifying the optimal Blockchain adoption level. In particular, to maximize the expected discounted profit of a firm that adopts Blockchain, we propose to develop a stochastic dynamic programming model of a class of multiple-period supply chains, conduct a comprehensive analysis and investigate the optimal adoption level of Blockchain for specific scenarios. Our proposed work will take into consideration various demand functions, cost structures, uncertainty levels, and random yield rates, the objective being to derive the optimal Blockchain adoption level appropriate for various business models.

Currently, I have been collaborating with IBM research center on this seminal research study. It is our goal to develop some innovative result and data-driven business insights. This project is in the process of bringing research grant to NJIT.

II. *Agribusiness: Small-Scale Farmers in Africa and Coffee Supply Chain*

Many of the world's poor still depend directly or indirectly on agricultural commodities for their livelihood. Most of them are small-scale farmers in the developing countries. Taking coffee as an example, an estimated 25 million small-scale farmers grow about 70% of the world's coffee, and about 125 million people in the world depend directly on coffee for their livelihoods.

Agricultural industries in developing countries share common features and small-scale farmers world-wide face similar challenges. For instance, weather is still one of the most important factors on the output of agricultural products. Due to the inherent uncertainty of weather, the harvest (or supply) is random and can vary significantly over time. However, the world's consumption of agricultural products is relatively stable and inelastic to prices. Consequently, the prices for agricultural products in the world commodity market are often extremely fluctuated.

Because coffee (in various forms) is storable, intuitively, farmer organizations may improve profitability by holding back inventory when price is low and selling it when price increases. Thus, inventory is not just a liability but also a strategic instrument to hedge price risk if one knows when to hold/sell. The same intuition applies to other storable agricultural products, e.g., tea, cotton and coco. In this paper, we attempt to address two basic questions for storable agricultural products under price fluctuations: First, how to effectively manage inventory to hedge price risk? Second, how do diverse cost structures and harvest/price processes affect the results? This research develops strategic solution to agribusiness to mitigate marketing risk that can be leveraged directly by farmers or farmer cooperatives to improve their business and solve the poverty issue of the world from the management perspective. Our theoretical advancement reveals additional insights for inventory management of agricultural products.

Applying the theory to Kenya coffee industry, we show that optimal policies can significantly outperform the prevailing practice of selling-all regardless, by 10% on average. Currently, we are collaborating with *Kenya Cooperative Coffee Exporters* (KCCE) to implement our solutions.

This on-going research has generated the following article that is currently under review of MSOM.

[J1]. J. Shi, Y. Zhao and K. Kiwanuka, "Optimal Selling Policies for Agricultural Products: Hedging Inventory against Price Fluctuations", *Manufacturing & Service Operations Management* (MSOM), under review, 2013.

III. *Container Shipping and Logistics Management*

Agriculture and railroads have been flourishing as a pair. Agricultural products follow coal and chemicals as the third-largest commodity type moved by the railroads, accounting for 8.2% of tonnage and 9.2% of revenue, according to the Association of American Railroads. Export by containers obtains advantages

at lower cost for moving agribusiness products due to the availability of empty import containers that can be repositioned.

Empty containers are commonly seen in the container shipping industry and they are mainly caused by trade or transshipment imbalance, nationally and internationally. Empty container repositioning (ECR) is one of the most important but challenging issues pertaining to the container shipping industry. Not only does it impose a tremendous economic effect on the stakeholders in the container transport chain, but it also brings a significant environmental and sustainability impact on the society since the reduction of empty container movements could reduce fuel consumption, and congestion and emissions. Agricultural transportation may take the potential advantage of empty containers yielded by other commodity shipping. In this sense, leveraging empty containers to ship agricultural products will be a win-win solution to ECR.

Transloading is one of such strategic solutions, as it uses inland transportation conveyances to bring cargo to the maritime containers. Figure 3 depicts a generic transportation network for agricultural logistics.

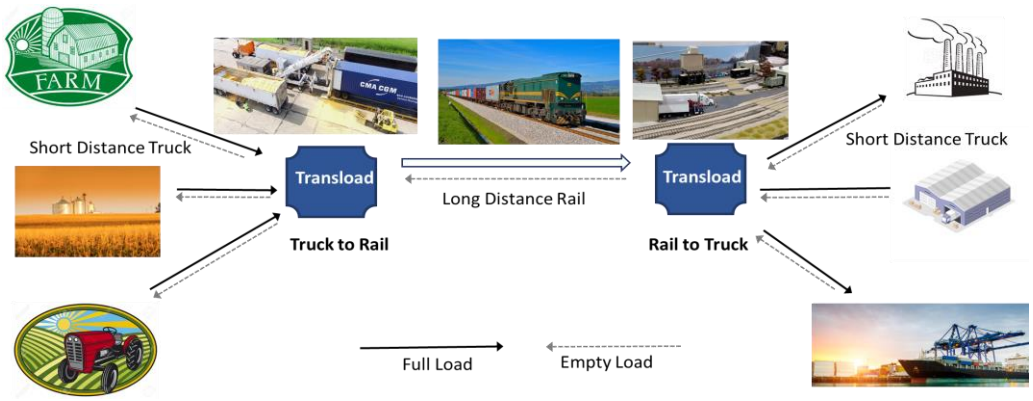

Figure 3. An Example of Transloading Transportation System

This on-going research is funded by USDA under the following agreement:

J. Shi (Primary Investigator), United States Department of Agriculture (USDA), Repositioning Empty Containers for Agricultural Container Logistics; $63,540, 9/19/2016 – 9/18/2018; 20% effort.

It has also generated the following article that is currently under review of POMS and some related media report:

[J2]. L. Gao, M. Gorman, T. Luo and J. Shi, "Container Shipping: Dynamic Order Promising under Heterogenous Leadtime and Random Supply", (POMS), (under review).

[J3]. Media Interview: "Supply Chain Value Destruction" Fair Ocean Working Group, July 2015, NJIT, http://www.fowg.org/supply-chain-value-destruction

IV. Interface between Finance and Operations Management

In the current competitive environment, small-to-medium size enterprises (SMEs), including many startup firms, must make joint decisions concerning interrelated flows of cash and products. Cash is the lifeblood of any business and is often in short supply. Cash flows stem from operations, financing and investing activities. To maximize profits, firms need to manage operations, financing and investing activities, efficiently and comprehensively.

In this study, I have been leading the project collaborating with my colleagues, Dr. M. Katehakis and Dr. B. Melamed at Rutgers. We model a firm that can finance its inventory (ordered or manufactured) with loans in order to meet random demand. The objective is to maximize the expected value of the firm's capital at the end of a finite planning horizon. One of the main contributions is that we have developed an optimal ordering policy which is referred to as the (α, β)-policy. Our study shows that the optimal ordering policy is characterized by a pair of threshold parameters as follows. i) If the net worth is less than the lower threshold, then the firm employs a base stock order up to the lower threshold. ii) If the net worth is between the two thresholds, then the firm orders exactly as many units as it can afford, without borrowing. iii) If the net worth is above the upper threshold, then the firm employs a base stock order up to the upper threshold.

The study yields the following articles, one of which has been recently published at POMS.

[J4]. M.N. Katehakis, B. Melamed and J. Shi*, "Cash-Flow Based Dynamic Inventory Management", *Production and Operations Management Society* (POMS), 2016. (*Corresponding author, authorship in alphabetical order)

[J5]. A. Chang and J. Shi* "Pricing American Option via the Transform-Expand-Sample Forecasting Methods", Journal of Business and Economics, Paper ID: JBE20160824-2, Accepted and forthcoming, 2017.

Stemming from this trend, we are currently extending the study in different directions. For example, we considering accounts receivables which can be presented in the following working paper:

[J6]. J. Shi, M.N. Katehakis and B. Melamed "Inventory and Cash Flow Management with Account Receivable", 2016; Current status: major model has been created.

Target to submit to *Management Science* in 2018, ABDC Ranking: A*

V. Make-to-Stock Systems and Production-Inventory Management

Production-inventory systems are typically implemented by a variety of manufacturing firms. Examples can be found in (1) glass manufacturing, where glass furnaces often produce at constant rates; (2) sugar mills, where raw sugar is produced utilizing a constant production rate; (3) the electronic computer industry, where displays are manufactured at constant production rates; and (4) the pharmaceutical industry, where cell-free proteins and other products are generally produced at constant production rates. Additional examples can be found in the carpet manufacturing industry, where the yarning and

dyeing processes operate at constant rates over long periods of time. These constant rates are selected by the manufacturer at the production planning stage by taking into account the anticipated demands and its cost structures. Production-inventory systems with constant production rates are typically deployed when there are high setup times and high setup costs, where frequent modification (e.g., interruption or rate change) of the production line is financially or operationally prohibitive. Thus, for both financial and operational reasons, it is critical to establish the proper production process early in the planning process.

Supply contracts are designed to minimize inventory costs or to hedge against undesirable events (e.g., shortages) in the face of demand or supply uncertainty. In particular, replenishment terms stipulated by supply contracts need to be optimized with respect to overall costs, profits, service levels, etc.

I started this stream of research as my doctoral dissertation at Rutgers Business School, and then broaden the study extensively in depth from different perspectives of the systems. In particular, we develop an innovative modeling and computational algorithm to find the optimal production rate, that can be leveraged to minimize the system-wide time-average cost, expected discounted cost, etc. In addition, we study the risk measures and service levels pertaining to the system such as the risk of stockout and the fulfill rate.

This topic yields the following articles:

[J7]. J. Shi, "Optimal Production/Inventory System Subject to Stock-Out Risk", Annals of Operations Research, Doi: 10.1007/s10479-016-2339-5, forthcoming, 2017. (Single author).

[J8]. J. Shi, M.N. Katehakis, B. Melamed and Y. Xia, "Optimal Continuous Replenishment for a Production-Inventory System with Compound Poisson Demands and Lost-sales", *Operations Research*, 6 (5): 1048 – 1063, 2014.

[J9]. J. Shi, Doctoral Thesis, "Make-to-Stock Production-Inventory Systems with Compound Poisson Demands, Constant Continuous Replenishment and Lost Sales", Rutgers University, 2010.

Advisors: B. Melamed and M.N. Katehakis

[J10]. M.N. Katehakis, B. Melamed and J. Shi*, "Optimal Time-Average Cost for Inventory Systems with Compound Poisson Demands and Lost-sales", *Annals of Operations Research*, 2015. (*Corresponding author, authorship in alphabetical order)

[J11]. J. Shi, M.N. Katehakis and B. Melamed, "Martingale Methods for Pricing Inventory Penalties under Continuous Replenishment and Compound Renewal Demands", *Annals of Operations Research*, 208(1), 593-612, 2013.

[J12]. J. Shi "Stock-Out Risk Control of the Production/Inventory System with Compound Poisson Demands", *Omega*, Under review, 2016.

VI. *Assemble-To-Order Systems and Component Allocation Rules*

Assemble-To-Order (ATO) systems are an important business model for improving supply chain performance. By eliminating expensive finished product inventory and carrying only component

inventory, ATO systems hold the promise of achieving customization, lower inventory cost and fast response to demand simultaneously. In an ATO system, a product may require a subset of components, and a component can be required by different products. The issues of component commonality and component inventory management (replenishment policy and allocation rule) are critical to the success of an ATO system.

Component commonality is a key enabler of ATO systems. Examples can be found in many industries, such as computers, electronics and automobiles. Because a common component is shared by many products, it allows us to explore the effect of risk pooling in assembly systems. Risk pooling is an important concept in supply chain management: by aggregating demands from different products,

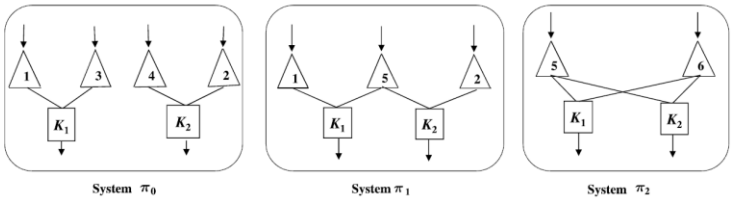

Fig. 1. Two-component ATO systems.

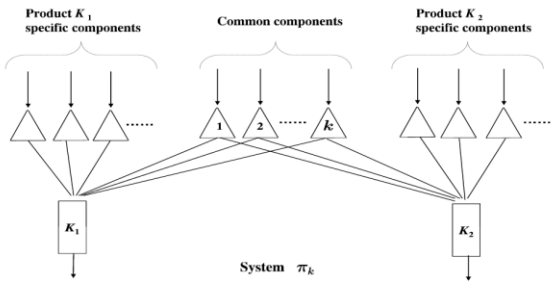

Fig. 2. ATO system with k common components.

In the component commonality literature, researchers have employed a representative two-product ATO system in which each product is assembled from two components as illustrated in Fig. 1. In system π_0, products are assembled from product-specific components only and there is no common component. In system π_1, the products share the common component 5 that replaces components 3 and 4 in System π_0. In system π_2, the two products share both the common components 5 and 6 where component 6 replaces components 1 and 2 in system π_1.

In this study, we examine the value of component commonality in a generalized version of the aforementioned two-component systems with lead times and the non-hold-back (NHB) allocation rules. Using a sample path analysis, we show that under any NHB rule, both the total product backorder and total on-hand component inventory decrease in any event as the degree of commonality increases. However, the system-wide average cost does not always decrease unless a certain cost symmetric condition is imposed.

This study yields the following publication:

[J13]. J. Shi and Y. Zhao "The Value of Component Commonality under Non-Holdback Allocation Rules", *Operations Research Letters*, 42 (6-7), 409 - 413, 2014.

[J14]. J. Shi, X. Yue and Y. Zhao, "Operations Sequencing under Yield Loss", *Naval Research Logistics*, 61(2), 144-154, 2014.

[J15]. J. Shi and Y. Zhao, "Some Structural Results on Acyclic Supply Chains", *Naval Research Logistics*, Vol. 57, No. 6, 605-613, Sep. 2010.

VII. Procurement and Sourcing from Suppliers

Sourcing strategies have been extensively studied and investigated in the literature. One important result commonly raised by those studies is that dual-sourcing or multi-sourcing, in contrast to sole-sourcing, can sometimes be leveraged to optimize the firm's profit and mitigate the associated risk. However, those studies often assume that suppliers' prices and reliability are exogenous. On the other hand, the extant literature on supplier competition often takes the selling price as the major decision variable. To the best of our knowledge, relatively little is known about how suppliers make price and reliability decisions when they compete to serve firms, and how these forms of competition among suppliers influence firms' sourcing decisions.

In fact, suppliers competing on both price and reliability are ubiquitously observed in practice, such as in the natural gas and oil industry, where reliability is a crucial factor for supply in terms of both quality and timing. Supplies often with poor quality or delayed deliveries could greatly affect the safety of the operational process, a major consideration in this industry. As one of the largest energy companies in the world, British Petroleum (BP) defines Enhanced Customer Value as: "*Price + Supply Reliability + Access to BP Expertise*" (http://www.bp.com).

BP enforces safety performance indicators in contracts with business partners to guarantee the safety and quality of supply. These efforts bring it big returns by winning large contracts in the global energy market, one of which is China's first liquefied natural gas (LNG) project. Most research on firms' sourcing strategies assumes that wholesale prices and reliability of suppliers are exogenous. It is of our interest to study suppliers' competition on both wholesale price and reliability and firms' corresponding optimal sourcing strategy under complete information. In particular, we study a problem in which a firm procures a single product from two suppliers, taking into account suppliers' price and reliability differences. This motivates the suppliers to compete on these two factors.

We investigate the equilibria of this supplier game and the firm's corresponding sourcing decisions. Our study shows that suppliers' reliability often plays a more important role than wholesale price in supplier competition and that maintaining high reliability and a high wholesale price is the ideal strategy for suppliers if multiple options exist. The conventional wisdom implies that low supply reliability and high demand uncertainty motivate dual-sourcing. We notice that when the suppliers' shared market/transportation network is often disrupted and demand uncertainty is high, suppliers' competition on both price and reliability may render the sole-sourcing strategy to be optimal in some cases that depend on the format of suppliers' cost functions. Moreover, numerical study shows that when the cost or vulnerability (to market disruptions) of one supplier increases, its profit and that of the firm may not necessarily decrease under supplier competition.

This study has generated the following publication:

[J16]. L. Qi, J. Shi and X. Xu "Supplier Competition under the Dual-sourcing Setting", *Omega*, 55, 91-110, 2015.

VIII. *Marketing Channels and Selling Contract Design*

E-commerce, such as an online channel (a.k.a. a direct channel), provides a good platform to attract potential consumers and thus opens another door to increase manufacturer's revenue. Therefore, more and more manufacturers such as Apple, Hewlett-Packard, Nike, and Sony are marketing their products not only through a brick-and-mortar retailer (referred to as a retail channel), but also through a direct channel, i.e., leveraging dual channels composed of a direct online channel and an indirect retail channel. When a manufacturer produces its products, its yield may be random due to such controllable or uncontrollable reasons as defective units, machine breakdowns, damage or shrinkage occurred during transshipment, and random components allocation from suppliers. In the presence of yield uncertainty, the manufacturer may be inevitably exposed to the risk of supply shortage. Unfortunately, many companies do not have an established, formal and cross-functional process to manage the allocation of insufficient inventory to mitigate the impact on customers and shareholders. How to manage this uncertainty is an imperative and timely issue for the manufacturer to maintain its competitive advantage and secure its profit.

In this research study, we investigate a manufacturer marketing a product through a dual-channel supply chain, comprised of an online channel and a brick-and-mortar retail channel. In particular, we consider the pricing and channel priority strategies of dual-channel supply chain in the presence of supply shortage caused by random yields. To this end, we develop game theoretic models to investigate the price decisions and the channel priority strategy, as well as examine the impacts of channel coordination and the time sequence of decisions, i.e., ex-ante and ex-post production yield, on the channel priority strategy. While encountered with a potential supply shortage, the manufacturer has two channel-allocation priority strategies: direct channel priority and retail channel priority. Our study shows that: (i) coordination of the dual-channel supply chain can alleviate the retailer's complaint of insufficient supply; (ii) counter-intuitively, the retail channel priority is adopted only when the total surplus in the retail channel is low in the decentralized setting; and (iii) the effect of the unit cost of sales of the direct channel on the motivation to use retail channel priority depends on the effect of channel priority on the demand. In addition, we find that the main results of pricing and channel priority strategies remain robust to the time sequence of channel priority decision (yield ex-ante or ex-post).

This study has yields the following publication:

[J17]. T. Xiao and J. Shi, "Strategic Interaction between Contract and Dual Channel Strategies in a Supply Chain with Asymmetric Priority under Supply Shortage", *European Journal of Operational Research* (EJOR), 2016.

As one potential future research, we shall investigate Omni-Channel marketing issues related to supply chain management. Omni-Channel marketing refers to a business delivering a consistent and uninterrupted brand experience across all channels and devices a customer uses to interact with them. Here's an example: Suppose you are browsing the website of a fashion retailer on your cell phone. You find a shirt you like, put it in your online cart, get distracted with something else and don't finish the purchasing process. Fast forward several hours when you're checking Facebook on your iPad. As you browse through your news feed, you see an ad from the same retailer featuring the same shirt that's sitting in your online shopping cart. A couple clicks later, and you discover the shirt you selected earlier in the day is still there in your shopping cart. Just as you are ready to checkout, your iPad's battery dies. You

quickly hop onto your laptop, open the website and voila: You are able to finish the purchase. This is how today's customers expect to buy -- with the convenience of using several synchronized devices and channels. It is of our interest to study consumers' omni-channel behavior and its impact on whole supply chain performance.