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Supply chain network design using trade credit and bank credit: A robust optimization model with real world application

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ABSTRACT

Financing is of paramount importance to supply chains. This paper presents a stochastic robust optimization model for supply chain network design problem, while accounting for financial resources of trade credit and bank credit. The robust model can assist in determining the number and location of facilities as well as financing decisions. The objective is to maximize expected supply chain profit under demand uncertainty. A solution method based on the Lagrangian relaxation technique is developed to solve the model. The application of the proposed approach is investigated using an empirical case study. The obtained numerical results arrive at important managerial insights.

1. Introduction

Supply chain network design (SCND) plays a crucial role in supply chain management. It concerns strategic decisions on the number, location and capacity of facilities required to deliver goods to a predetermined, but possibly evolving, customer base (Jabbarzadeh, Fahimnia, Sheu, & Moghadam, 2016). SCND provides a holistic view of the entire supply chain including various participants (e.g., suppliers, manufacturers, distribution centers (DCs), transporters, financial intermediaries and consumers) and their relationships (Klibi, Martel, & Guitouni, 2010; Diabat, Dehghani, & Jabbarzadeh, 2017). For an efficient and effective SCND, it is of paramount significance that the three major flows in supply chains (i.e., material flow, information flow, and financial flow) are managed properly (Simchi-Levi, Kaminsky, & Simchi-Levi, 2004). While material and information movements have been studied extensively in the context of SCND (Kouvelis, Chambers, & Wang, 2006), financial flows have been rarely addressed in the related literature (Ramezani, Kimiagari, & Karimi, 2014). Given that overlooking financial flows may lead to substantial inefficiencies in supply chain management (Longinidis & Georgiadis, 2013), the main motivation for this study is to present an optimization model and solution method that can be used to account for financial resources in SCND.

The typical financial resources for procurement and facility construction in supply chains include trade credit, bank credit and capital budget (De Blasio, 2005; Love, Preve, & Sarria-Allende, 2007; Maksimovic, 2001; Rajan & Zingales, 1995; Shishebori, Jabalameli, & Jabbarzadeh, 2014). Amongst these resources, bank credit is perhaps the most prevalent option for DCs (Berlin, 2003). Despite the fact that bank credit is commonly used for procurement, it can also be used for financing facility constructions (Jing & Seidmann, 2014). Trade credit is another financing option that can be applied based on two types of policies (Thangam & Uthayakumar, 2009). In the first type, known as 'net-term' or 'open account financing' policy, suppliers allow DCs to delay their payments up to a prespecified "net date". The second policy, known as "cash discount" or 'early payment discount', includes three clauses namely, discount rate, discount period and net date. In this policy, suppliers encourage DCs to repay their debts before "net dates" by awarding them discounts (Lee & Rhee, 2011). In both policies, delays in payments are penalized (Gupta & Dutta, 2011). Finally, capital budget as an internal source of finance is of critical importance in financing DCs. It differs from the former resources in the way that it is not subject to interest charges. However, in most cases the capital budget in hand is not sufficient for procurements and/or facility constructions (Kouvelis & Zhao, 2012). It should be noted that any of these financial resources might not be available from time to time due to financial limitations (Jing & Seidmann, 2014; Marquez, Bianchi, &

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Gupta, 2004).

According to the World Bank report, supply chain finance can improve trading opportunities for companies (Mapper, 2004). According to World Bank report, financial inefficiencies for companies in developing countries are considered as entry barriers for many industries. It is suggested that governments, banks and suppliers give financial supports to small and medium sized companies. Hence, banks can increase economic growth by providing bank credits and suppliers can enhance trading opportunities by financing their downstream counterparts. However, designing the presented network including banks, suppliers and supply chain subsidiaries needs more study.

Lack of capital budget is amongst the constraints in procurement management. Companies take different ways in order to overcome this constraint and manage their procurements. They need to make tactical decisions to supply their requirements (Kouvelis & Zhao, 2012). Bank credit is a well-known finance to tackle financial constraints. However, banks are often reluctant to pay bank credit to small and medium sized companies due to lack of credit history, lack of collateral, and the tenuous nature of their business establishments (Vandenberg, 2003). Limited bank credits encourage the companies to utilize trade credit to supply their requirements (Petersen & Rajan, 1997). Trade credit plays a key role in developing countries (Fisman & Love, 2003). But, the limited capital budget of suppliers enforces businesses to try to attract both bank and trade credits to finance their requirements (Kouvelis & Zhao, 2012). Since the supply chain operations rely on financial decisions (Babich & Sobel, 2004), finance is of paramount importance in supply chains. In other words, supply chain efficiency is closely related to the tactical aspects of supply chain finance.

Financial flows and material flows are the main parts of tactical aspects of supply chain networks. Integrating supply chain configuration and financing decisions can improve the efficiency of supply chain networks (Ramezani et al., 2014). Several well-known companies benefit from this context such as intel, GE, and Deutz (Laínez, Puigjaner, & Reklaitis, 2009). For example, GE enhanced its account payables by%12 which helped them to predict the needed liquidity. Also, Deutz, in Germany, asserts integration of financial and material flows in its inventory system.

To incorporate financial resources into supply chain network design problem, this paper presents an optimization model that determines supply chain configuration decisions (i.e., location and allocation of DCs) and financing strategies (i.e., the quantities of capital budget, trade credit, and bank credit used in each time period) concurrently. The network under investigation consists of suppliers, banks, DCs and customers with random demands. DCs can benefit from various options of trade credit and bank credit with different interest rates which are offered by suppliers and banks. A stochastic robust optimization formulation is developed to address demand uncertainties. To solve the proposed computationally intensive model in large-scale instances, a Lagrangian relaxation algorithm is developed. The presented model and solution method are applied to a real-world case study and the results are thoroughly discussed.

The remainder of this paper is organized as follows. In Section 2, we briefly review the related modeling efforts in the existing literature. Section 3 presents the problem statement and the formulation of the robust model. A Lagrangian relaxation approach is developed in Section 4 to cope with large-sized problems. The application of the proposed robust model and solution approach in a real-life context is examined in Section 5. Finally, Section 6 includes the concluding remarks along with directions for future research.

2. Literature review

The proposed model in this study focuses on robust supply chain network design considering different financial resources. This section briefly overviews the modelling efforts in both areas of 'robust optimization in supply chains' and 'financial flows in supply chains'. This is then followed by discussing the nexus between the two and the associated research gaps.

2.1. Robust optimization in supply chains

SCND is an inherently stochastic optimization problem with a variety of uncertain parameters including demand, supply and price. Therefore, various robust optimization approaches have been applied to SCND problems. A comprehensive review of the early literature on robust SCND is provided in (Klibi et al., 2010). In the rest of this section, a brief review of the recent works focusing on robust SCND is provided.

Ben-tal, Do, Reddy, and Yao (2011) developed a dynamic robust optimization approach to humanitarian relief supply chain design under demand uncertainty. Pishvaee, Rabbani, and Torabi (2011) proposed a robust optimization approach to design a closed-loop supply chain under probabilistic uncertainties in demand, return and transportation costs. In another approach to deal with demand, cost, capacity and job creation uncertainties, Pishvaee, Razmi, and Torabi (2012) applied a robust possibilistic programming technique to design a socially responsible supply chain. Ramezani, Bashiri, and Tavakkoli-moghaddam (2013) adopted a scenario-based robust optimization formulation and a scenario relaxation algorithm to model and solve a closed-loop SCND problem. De Rosa, Gebhard, Hartmann, and Wollenweber (2013) presented a similar scenario-based robust approach to minimize expected regret in a bi-directional sustainable SCND problem under uncertainty. Bozorgi-Amiri, Jabalameli, and Mirzapour Al-e-Hashem (2013) developed a multi-objective robust optimization model of a humanitarian SCND under demand, supply and cost uncertainties. The objectives of this model include coverage maximization and cost minimization. Baghalian, Rezapour, and Farahani (2013) formulated a stochastic robust optimization model to tackle both demand and supply side uncertainties. Tsiakis, Shah, and Pantelides (2001) proposed a stochastic programming model for SCND under demand uncertainty. Jabbarzadeh, Fahimnia, and Seuring (2014) developed a robust optimization approach for supply of blood in disasters under demand uncertainty. Many uncertain factors such as raw material prices, energy costs, product demand, labor costs, finished product prices, exchange rates, etc. can also be modeled using the stochastic programming approach (Klibi et al., 2010; Jabbarzadeh, Fahimnia, & Sabouhi, 2018; Fahimnia & Jabbarzadeh, 2016; Jabbarzadeh, Fahimnia, & Rastegar, 2017; Jabbarzadeh, Haughton, & Pourmehdi, 2018).

Klibi and Martel (2013) categorized uncertainty into three types, namely random, hazardous and deep. Based on these types, a scenario-based robust optimization approach was applied to the SCND problem. In this method, scenarios are extracted using sample average approximation. Hatefi and Jolai (2014) utilized an augmented p-robust approach to design an integrated forward-reverse network, considering facility disruptions and uncertain demands. Huang and Goetschalckx (2014) adopted a mean-standard deviation robust design approach for SCND. In order to deal with the computational complexity of the proposed model, they used a modified branch-and-reduce algorithm. Tian and Yue (2014) developed a novel framework for calculating relative regret limit in a p-robust SCND formulation. Zokaee, Jabbarzadeh, Fahimnia, and Sadjadi (2017) presented a robust optimization approach based on the concept of "price of robustness" to cope with uncertainties in demand, supply capacity and costs components in SCND problems. An analogous interval-based technique was applied by Hasani, Zegordi, and Nikbakhsh (2015) to a global closed-loop SCND