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Supply chain networks with corporate financial risks and trade credits under economic uncertainty

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ABSTRACT

The focus of this paper is to provide an analytical framework which can be used to investigate how financial risks affect the values of interconnected supply chain firms from a network perspective, and how financial risks affect the supply chain firms' profitability as well as the cash and credit transactions. In particular, we develop a variational inequality equilibrium model in conjunction with capital asset pricing model (CAPM) and the net present value (NPV) to determine the optimal supply chain prices, profits, and implicit equity values of supply chain firms under financial risks and economic uncertainty. We illustrate the analytical framework with computational studies which yield interesting managerial implications to the following questions: (1) How do financial risks and economic uncertainty affect the values of interconnected supply chain firms from a network perspective? (2) How do financial risks and economic uncertainty affect the supply chain firms' profitability as well as the cash and credit transactions? (3) How does the effect of financial risks change under different competition scenarios?

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1. Introduction

Supply chains have become complex global networks where suppliers, manufacturers, distributors, and retailers are highly interconnected through material/product flows, information flows, and financial flows (Coyle et al., 2008). Such complex network systems are vulnerable to various risks, among which financial risk has become increasingly prominent and critical since the global financial and economic meltdown in 2007. For example, Circuit City, once the second largest U.S. electronics retailer, filed bankruptcy and liquidated all its retail stores in 2009 after its suppliers had been concerned about its financial situation and refused to extend trade credits (Church and Clothier, 2009). For another example, approximately 670,000 suppliers closed across China in 2009 due to insufficient demands, delayed payments, and tight credit markets (Fenton, 2009). A recent global survey conducted by McKinsey Quarterly reported that the financial volatility is among the top three risk factors that concern the supply chain managers (McKinsey & Company, 2008). It is now a business imperative for the managers to reconsider their strategies and reevaluate the values of their supply chain partners as well as their own businesses under financial and economic uncertainty.

Note that the nature of the problem requires one to consider the financial risks of the highly interconnected supply chain firms from a network perspective. The main contribution of this paper is to use a novel approach that merges the theory in corporate finance and network equilibrium analysis to provide a modeling framework where inter-firm financial relationships are reflected in network connections. The model proposed in this paper allows one to investigate how financial risks affect the values of inter-connected firms in supply chain networks, and how financial risks affect the supply chain firms' profitability as well as the cash and credit transactions.

The interface between supply chain management and finance is an emerging research area that has drawn increasing attentions from researchers. Applequist et al. (2000) proposed a new method to evaluate the risk and uncertainty of chemical manufacturing supply chains where the authors utilized the capital asset pricing model (CAPM) to construct the benchmark risk premium for facility investment decisions. In our paper CAPM will also be used to construct the risk premiums for the cash flows from supply chain partners. We also use the net present value (NPV) method to estimate the value of the cash flows under risks. Net present value (NPV) is a standard method in corporation finance to compute the benefit of a project over time and under risk. The NPV method has been widely adopted in supply chain management to analyze various problems. For example, Sun and

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Queyranne (2002) developed a multiproduct, multistage production and inventory model where the net present value of the total cost was optimized. Yang et al. (2005) proposed a mixed inventory model with variable lead times based on the NPV method. For more applications of the NPV method in supply chain management, see Wee and Law (2001), Chung et al. (1998) and Moon and Yun (1993).

A number of studies have focused on the utilization of trade credit in supply chains. Ho et al. (2008) presented an integrated supplier–buyer inventory model where they assumed that the market demand is sensitive to the retail price and the supplier uses a trade credit policy. The authors investigated the optimal pricing, shipment and inventory policy for the problem. Huang and Hsu (2008) investigated the retailer's inventory policy under two levels of trade credit. The authors allowed the retailer and the supplier to transact through either partial or full trade credit. For more studies regarding trade credit in supply chains, see Thangam and Uthayakumar (2010) and Jaber and Osman (2006). These papers primarily focused on the optimal trade credit policy of one or two supply chain firms. Our paper, on the other hand, investigates how cash and trade credit transactions in supply chain networks are influenced by financial risks and economic uncertainty. Cruz et al. (2006) focused on the risk management and financial engineering of integrated global supply chain networks and social networks. The authors modeled the dynamic co-evolution of the product transactions, the product prices, and the relationship levels on the supernetwork until an equilibrium pattern is achieved. Liu and Nagurney (2007) established supernetwork equivalence between transportation networks and financial networks under the mean-variance framework.

Our research differs from the above mentioned studies in that we take an innovative approach which merges the theory in corporate finance into network equilibrium modeling to incorporate financial risks into business connections among firms in supply chain networks. To our knowledge, this is the first network model that analyzes the equilibrium among heterogeneous firms in supply chain networks with a focus on the financial values and risks of supply chain relationships under economic uncertainty. In particular, we utilize our model to investigate the following questions:

1. How do financial risks and economic uncertainty affect the values of interconnected supply chain firms from a network perspective?
2. How do financial risks and economic uncertainty affect the supply chain firms' profitability as well as the cash and credit transactions?
3. How does the effect of financial risks change under different competition scenarios?

Our results show that in equilibrium, a supplier's marginal profit received from a manufacturer with lower sensitivity to economic uncertainty is lower than that from a manufacturer with higher sensitivity; and a supplier's marginal profit received from a manufacturer with higher growth potential is lower than that from a manufacturer with lower growth potential. Such results suggest that suppliers be willing to sacrifice some profits to gain more businesses from manufacturers with lower financial risks or with higher growth potential. We also find that firms with lower financial risk and lower sensitivity to economic uncertainty are more valuable from their suppliers' perspective since these firms are more likely to generate steady revenue streams for the suppliers during economic downturns. The firms with lower financial risks may get better discount in term of purchasing prices which will help them lower costs and gain higher demand in the competition. As a result, such firms may have higher profits

than the firms with higher financial risks. In addition, as the economic uncertainty increases, the values of suppliers' implicit equity stakes in the buyer firms will decline. However, the gap between the values of firms with lower and higher financial risks will become wider which will make the firms with lower financial risks more competitive and more profitable. Moreover, our results show that as the economic growth or inflation rate increases, the values of suppliers' implicit equity stakes in the buyer firms will decline. The higher rate of growth or inflation will reduce the gap between the values of firms with different levels of financial risks, which will make the competitive advantage of the firms with lower financial risks become smaller. Finally, we find that competition will enlarge the gap between the manufacturers' implicit equity values perceived by the suppliers, which will further increase the profit of the manufacturer with lower financial risk, and will further decrease the profit of the manufacturer with higher financial risk.

This paper is organized as follows: In Section 2, we develop the supply chain network model with corporate financial risks and trade credits. We model heterogenous decision-makers in supply chain networks, and construct the equilibrium conditions, along with the variational inequality formulation. We also provide some interesting analytical results. In Section 3, we provide the model's qualitative properties, and propose a computational procedure. In Section 4, we present a series of computational examples to study the impacts of financial risk and economic uncertainty on the values, profits, and decisions of supply chain firms from a network perspective. Section 5 highlights the managerial insights and concludes the paper.

2. The supply chain network model

As we discussed in Introduction the firms in supply chains are highly interconnected through material/product flows and financial flows. The main motivation of our paper is provide a modeling framework that allows one to analyze the values of their supply chain partners as well as their own businesses from a network perspective under financial and economic uncertainty.

2.1. The idea of the model

The key issue of our research is how to model business relationships among firms in the supply chain network so that the financial risks are properly reflected in these relationships. In order to build up a supply chain network model where such inter-firm financial relationships are correctly incorporated in the network connections we take an innovative approach that merges the corporate finance theory into network equilibrium modeling. First, based on the theory in corporate finance we model the business connection between a supplier and a manufacturer in the supply chain network as an implicit equity stake of the manufacturer owned by the supplier. Second, we then use the variational inequality theory to model the equilibrium of the entire supply chain network consisting of multiple suppliers, manufacturers, and demand markets. The remainder of this section briefly explains the idea of the implicit equity stake in corporate finance as well as the variational inequality theory used in this paper.

The implicit equity stake: Ng et al. (1999) pointed out that "a supplier in a repeated relationship with a buyer has an implicit equity stake (non-salvageable investment) in the buyer." (see also, Smith, 1987 and Petersen and Rajan, 1997). In particular, a supplier's net cash flow gained from a buyer is an analogy of the stock dividend paid by the buyer firm in each period. If the buyer's business is booming the buyer will purchase more from