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Risk propagation through payment distortion in supply chains

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ABSTRACT

The supply chain literature has devoted much attention to studying how the variability of orders propagates upstream. We explore how this insight extends to the variability of payments to suppliers and its impact on how risk is generated and propagates upstream. To do so, we model the financial features of a supply chain based on industry reports and empirical findings from the finance literature. Capturing policies and constraints of the agents in the supply chain in a formal model, we are able to generate and explain the behavior observed in real supply chains. We show that payment variability occurs and propagates, even if orders are constant, in a cash-constrained supply chain. Furthermore, our model reveals that payment variability may even become amplified under severe cash restrictions. We identify the factors that drive the propagation of variability—the industry risk, the firm's operational leverage, the existence of a financial leverage target, and the cost of debt. The model also makes it possible to explore states of nature not often observed in practice, but that may have an effect in managers' behavior, for example, bankruptcies. We numerically illustrate the impact of these drivers on the risk of upper echelons (suppliers and suppliers' suppliers) as well as the interactions between order and payment variability. We close by summarizing our findings and discussing future research opportunities.

1. Introduction

Supply Chain Management (SCM) is concerned with three flows—products, information, and money. To date, SCM literature has explored the benefits of integrated information flows in the supply chain (e.g., Pagell, 2004; Chen, 2003) as well as the competitive advantages of having a fully integrated product stream from supplier to consumer (Frohlich and Westbrook, 2001). This literature, however, has been almost silent on the effects of integration on the financial flows between members of the supply chain and their impact on the state variables that limit these flows. Although material and financial flows are intimately related, cash flows often deviate from order flows and payment variability may occur even in the absence of order variability. In this paper, we explore the impact of financial flows on operational performance. We believe a more careful look into financial flows is necessary as firms are becoming more leveraged,[1] and given the clear patterns of risk propagation and bankruptcies along established supply chains (e.g., Allen and Gale, 2000; Demange, 2016; Egloff et al., 2007). While bankruptcy itself is a rare event, financial distress does affect the risk perception and decision making of agents in a supply chain.

The "financial contagion" identified by the finance literature refers to the increased likelihood of a firm defaulting to its suppliers as a result of its customers' defaults on trade credit, such as customers paying later than agreed (Boissay and Gropp, 2013). The existence of financial contagion via trade credit defaults suggests not only that payments to suppliers are subject to variability, but also that that variability is somehow transmitted upstream. As payment variability represents one type of supply-chain risk, financial contagion is able to spread from a single dyad to an industry, potentially even affecting an entire economy (Bardos and Stili, 2007; Goldin and Mariathasan, 2014). The crisis of 2008 is a good example of widespread contagion because of "massive illiquidity" (Tirole, 2011). Right after the Lehman Brothers episode in September 2008, the credit crisis worsened among financial institutions precisely because of the fear of financial contagion (Jorion and Zhang, 2009).

Two trends make financial contagion through trade credit particularly relevant. First, firms are relying more heavily on trade credit (see Choi and Kim, 2005). During 2001 in France, accounts payable stood at

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[1] For instance, retailers' financial leverage, as measured by total assets over total equity, has increased by roughly 12% in the last 10 years in the US. Source: COMPUSTAT, US retailers (SIC codes available on request) 2005–2014.

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103% of manufacturing firms' financial debt and 219% of their bank borrowing (Bardos and Stili, 2007). For US retailers, accounts payable represent 15% of total assets[2] and have increased by roughly 40% in 10 years with respect to total assets.[3] Second, firms are defaulting on trade credit agreements. According to the National Survey of Small Business Finance, as much as "46% of the firms declared that they had made some payments after the due date during the last year" (Cuñat, 2007, p. 493). Similar reports are found in Boissay and Gropp (2013). If concurrent, customers' trade credit defaults may push the supplier firm to bankruptcy. In fact, bankruptcy is caused by customers' bankruptcy or default on trade credit in 10%–20% of the cases (Blazy and Colombier, 1997).

Our goal is to articulate a set of causal mechanisms that explain payment variability and give preliminary insights into how financial contagion may emerge in supply chains. As such, our work is descriptive, rather than normative. Our approach is to develop a model based on the microstructure of the agents in the supply chain, i.e., their internal policies and structural constraints, and provide an endogenous explanation for the macrobehavior observed in the supply chain (Forrester, 1980; Sterman, 2000). We model a simple supply chain where every echelon pays its only supplier following simple rules developed from the financial empirical literature and we calibrate all model parameters to correspond to what is observed in practice. By following this strategy, we develop a process theory (Mohr, 1982) of the endogenous causal mechanisms that explain payment variability and, at least partially, the observed financial contagion in supply chains. A process theory focuses on the identification of how entities participate in and are affected by events (Monge, 1990), and provides an operational explanation of how and why things happen, as opposed to a statistical correlation approach followed by variance theories (Mohr, 1982). This approach explicitly incorporates the physical and institutional structure of the operational and financial systems, and the decision rules of the agents in those systems (Morrison and Oliva, 2018; Sterman et al., 2015). We believe at this stage, a simple model that articulates these causal explanations constitutes a more substantive contribution to this research stream than a more generalizable model, from which it would be more difficult to derive and isolate insights. The development of a model that articulates these causal relationships lays a theoretical foundation and prepares the way for data collection. It also aids in identifying the key research questions.

Our model, as should be expected from a descriptive process theory, is able to explain previous empirical findings, such as the facts that operational and financial leverage affect the firm's risk profile, and that hedging across multiple buyers reduces the firm's risk. The model not only reproduces the propagation of payment variability in supply chains that has been observed empirically, but also allows us to explore the idea that such variability would be amplified as it propagates. Moreover, the mathematical formalization of the decision rules allows us to analytically identify the conditions for the propagation of payments and to perform numerical sensitivity analyses on model assumptions and parameter values, thus enabling the exploration of operational conditions that would not be easily explored empirically.

The rest of the paper is structured as follows. In §2, we review the relevant financial literature on risk propagation and the operations management literature related to our work. In §3, we describe our model and its empirical grounding, and derive a set of propositions for the creation, propagation and amplification of payment variability. We present our numerical analyses in §4. We close by summarizing our findings and exploring future research lines emerging from this work.

[2] Source: COMPUSTAT, US retailers (SIC codes available on request), 2010–2014.

[3] Source: COMPUSTAT, US retailers (SIC codes available on request), 2005–2014.

2. Literature review

The mechanisms of risk transmission have been studied within the financial literature. The empirical work on trade credit by Stili (2003) and Bardos and Stili (2007) finds that risk transmission presents itself when receivables represent a significant portion of total assets (Bardos and Stili, 2007). Interestingly, they state that payment defaults in supply chains are mainly provoked by retailers and wholesalers (43%), and most likely absorbed by wholesalers (80%). Boissay and Gropp (2013) extend the latter work and focus on the propagation of risk in long chains. They argue that trade credit default chains exist, and that firms that have difficulties accessing new funds pass the liquidity shocks they face to their suppliers. They identify the existence of "deep pockets," firms with robust balance sheets, who stop the chain of defaults by not passing the liquidity shocks to their suppliers. They also find that, even when firms have suffered trade credit defaults, they continue to give trade credit, providing some sort of insurance to their customers.

This does not imply that firms continuously default on their suppliers. On the contrary, according to Cuñat (2007), trade credit is used only when other forms of credit (e.g., debt holders, shareholders) are not available. Cuñat's (2007) model describes the conditions under which suppliers become liquidity providers for their customers, lending them money through trade credit. Choi and Kim (2005) find that the use of trade credit increases during a financial crisis, as this trade credit is used to provide funds from firms with more funds to firms with limited access to funds. In this paper, unlike Lee and Rhee (2011) and Yang and Birge (2011), we take trade credit agreements as given, and consider the effect of credit terms in the supply chain and the possibility of non-compliance.

The financial literature has also developed models on credit contagion. Kiyotaki and Moore (1997) model the propagation of shocks in a network of firms and explain why firms may not insure against accounts receivable shocks. Demange (2016) measures the potential of financial contagion in a network of various countries' financial institutions by defining a "threat index" that captures the impact of a default in one of the countries on the rest of the network. The risk of contagion doesn't only depend on the ability of one node to pay its creditors, but also on the ability of creditors to pay theirs. These financial models, however, are parsimonious and high level, and do not model detailed interactions among firms. For example, they tend to ignore the effect of inventory decisions on credit chains. We argue that these omitted interactions may be a key cause of the amplification of the variability in financial flows, as a large proportion of trade credit defaults occur among wholesalers and retailers (Bardos and Stili, 2007), which hold large levels of inventory (Gaur et al., 2005).

Even though our model includes new interactions and variables that contribute to an operational understanding of the mechanisms of financial contagion, the assumptions in our model are grounded in the financial literature and practice. In fact, we used a combination of direct empirical evidence (e.g., COMPUSTAT, statistics from the US judiciary system and US census data), empirical financial literature—such as Altman (1984); Boissay and Gropp (2013); Choi and Kim (2005); Cuñat (2007); Eberhart et al. (1990); Gilson et al. (1990)—and knowledge from practice (e.g., one of the authors of this paper is a former senior executive in the area of Cash Management and Trade Credit at a multinational bank).

In the operations management literature, most models of risk propagation evaluate local interaction between firms in more detail. For example, Battiston et al. (2007) study bankruptcy propagation in production networks connected by credit ties; Tsai (2008) analyzes the impact of reducing working capital on the risk of a manufacturer; Lai et al. (2009) look at the impact of financial constraints on the transmission of risk from a retailer to her supplier through the contract type, either preorder or consignment; and Xu et al. (2010) propose the use of collaborative formulae between firms to reduce the probability of