# Trade credit and supplier competition☆

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A R T I C L E   I N F O

A B S T R A C T

This paper examines how competition among suppliers affects their willingness to provide trade credit financing. Trade credit extended by a supplier to a cash constrained retailer allows the latter to increase cash purchases from its other suppliers, leading to a free rider problem. A supplier that represents a smaller share of the retailer's purchases internalizes a smaller part of the benefit from increased spending by the retailer and, as a result, extends less trade credit relative to its sales. In consequence, retailers with dispersed suppliers obtain less trade credit than those whose suppliers are more concentrated. The free rider problem is especially detrimental to a trade creditor when the free-riding suppliers are its product market competitors, leading to a negative relation between product substitutability among suppliers to a given retailer and trade credit that the former provide to the latter. We test the model using both simulated and real data. The estimated relations are consistent with the model's predictions and are statistically and economically significant.

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## 1. Introduction

Most firms in the United States offer their products and services on trade credit, which is the single largest source of firms' short-term financing (see, e.g., Petersen and Rajan, 1997; Tirole, 2010). This paper examines how equilibrium trade credit provision depends on the strategic interaction among suppliers selling goods to the same customer (retailer). Since offering trade credit is commonly perceived as a source of competitive advantage, one could conjecture that the stronger the competition among suppliers, the greater their incentives to provide trade credit financing. Our theory challenges this intuition by showing that while supplier competition is indeed an important determinant of trade credit provision, suppliers that face more competition when selling to a given customer offer this customer less, not more, trade credit.

Our model features multiple heterogeneous suppliers selling differentiated products to a retailer, which resells these products to end consumers. The suppliers, as well as the retailer, face convex cost of bank financing. As a result, each supplier can increase its sales and, potentially, profit by providing the retailer with some trade credit. We show that in the presence of multiple suppliers, the benefit of providing trade credit is not fully internalized by the trade creditor. The reason is that after obtaining trade credit, the retailer can use the freed-up liquidity to buy more goods

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not only from the trade creditor but also from other suppliers, leading to a free rider problem: each supplier bears the full cost of providing trade credit, whereas the benefit – larger spending by the retailer – is shared among all suppliers.

The extent to which a supplier internalizes the benefit of providing trade credit depends on the supplier's share of the retailer's expenditures. A supplier that is responsible for a larger share of the retailer's purchases internalizes a larger part of the benefit and, as a result, is willing to offer a larger proportion of its goods on credit. The first empirical prediction of our model is, therefore, a positive relation between trade credit provision and the supplier's share of the retailer's spending.

Most existing trade credit theories that consider the effect of supplier competition predict trade credit provision to be negatively related to the supplier's market power (see, e.g., Fisman and Raturi, 2004; Dass et al., 2015; Fabbri and Klapper, 2016). A notable exception is Petersen and Rajan (1997), who argue that a monopolistic supplier, which is more likely to internalize the long-term benefit of helping customers, should be willing to provide more trade credit. This argument is based on the supplier's competitive position vis-à-vis all firms in its industry–whether they sell to the same customers or not. In contrast, we highlight the importance of the supplier's position among all firms selling to the same customers–regardless of their industry affiliations. This contrast becomes most striking if one compares a retailer sourcing from multiple monopolistic suppliers with a retailer sourcing from a single competitive supplier.

The second empirical prediction of our model links the use of trade credit by a retailer to the concentration of suppliers' shares of the retailer's purchases. Because suppliers with larger shares of the retailer's expenditures are willing to sell more on credit, our model predicts a positive relation between a retailer's use of trade credit and its supplier concentration, measured by the Herfindahl index (HHI) of suppliers' shares of the retailer's spending.

Existing studies that we are aware of and that link trade credit financing to supplier concentration – Dass et al., 2015 and Fabbri and Klapper (2016) – examine the effect of suppliers' bargaining power, proxied by supplier industry concentration, on trade credit provision. In contrast, our prediction is about the concentration of suppliers' selling shares at the customer level, irrespective of whether the suppliers belong to the same industry.

The free rider problem arises even if suppliers sell unrelated products, as long as they compete for the retailer's cash. However, this problem becomes especially detrimental to the trade creditor if the free-riding suppliers sell substitutable products and, thus, compete for the same end consumers. This leads to our model's third prediction, which is a negative relation between product substitutability among suppliers to a given retailer and trade credit that these suppliers provide to the retailer.

There are several theories that predict a positive relation between trade credit financing and product differentiation in supplier industry. According to Burkart and Ellingsen (2004), differentiated goods are more difficult to divert for private benefits, which makes the supplier more willing to sell on credit. Cuñat (2007) argues that differentiated goods are associated with higher switching costs, which reduce buyer opportunism and increase the supplier's willingness to offer trade credit. Dass et al. (2015) suggest that trade credit can be used as a commitment device for the supplier to make relationship-specific investments, which are more important in industries that produce differentiated goods.

There is a fundamental difference between these predictions and ours. The theories of Burkart and Ellingsen (2004), Cuñat (2007), and Dass et al. (2015) tie the advantage of trade credit financing to the inherent nature of the transacted good, namely, its differentiation from all other goods in the industry. In contrast, our theory is about product substitutability among suppliers to a particular retailer. Consider, for example, a firm that sources several commodity-like but mutually non-substitutable inputs, each from a different supplier. Given the commodity-like nature of the inputs, all three aforementioned theories would predict little trade credit financing. Given that the inputs are not mutual substitutes, our theory predicts significant trade credit financing.

To examine the economic significance of our predictions, we calibrate the model and examine the relations between trade credit provision on the one hand and the distribution of suppliers' shares and substitutability among their products on the other hand using simulated data, while shutting off all non-strategic factors related to trade credit choices. The results of this exercise suggest that the effects predicted by the model are economically sizable. For example, a one-standard-deviation increase in a supplier's share of the retailer's purchases leads to a 0.25–0.59 standard-deviation increase in the proportion of the supplier's output sold on credit. A one-standard-deviation increase in the Herfindahl index of supplier shares is associated with a 0.26–0.49 standard-deviation increase in the proportion of the retailer's purchases financed by trade credit. A one-standard-deviation increase in suppliers' product substitutability leads to a 0.93–1.26 standard-deviation decrease in the proportion of sales financed by trade credit.

We also provide suggestive empirical evidence of the association between the distribution of supplier shares and substitutability among suppliers' products on the one hand and trade credit provided by suppliers to retailers on the other, using samples of almost 600 retailer-year observations and almost 3000 supplier-year observations, spanning a period of 14 years. Our matching of suppliers with retailers is based on an extended version of Cohen and Frazzini (2008) customer–supplier links. Our estimate of product substitutability among suppliers is based on Hoberg and Phillips (2010, 2016) measure of pairwise similarity of firms' product descriptions. When estimating the predicted relations, we control for various factors that have been shown in the literature to be associated with trade credit provision, most important, for suppliers' industry-level market shares, suppliers' industry concentrations, and product differentiation in suppliers' industries.

Our empirical results are consistent with the model's predictions and suggest that interactions among suppliers to a given retailer explain variation in the use of

trade credit over and above measures of supplier interaction at the industry level, highlighted by Petersen and Rajan (1997), Fisman and Raturi (2004), Cuñat (2007), Dass et al. (2015), and Fabbri and Klapper (2016). Within the sample of suppliers, trade credit provided by a supplier to its retailers is significantly positively associated with the supplier's share of retailers' purchases and is significantly negatively associated with product substitutability among suppliers selling to the same retailers. These relations are economically non-negligible: a one-standard-deviation increase in supplier share is associated with a 0.09 standard-deviation increase in trade credit provided, while a one-standard-deviation increase in product substitutability is associated with a 0.11 standard-deviation decrease in trade credit provided. Furthermore, within the sample of retailers, a one-standard-deviation increase in a retailer's HHI of supplier shares is associated with a 0.08 standard-deviation increase in trade credit received by this retailer, and a one-standard-deviation increase in product substitutability among the retailer's suppliers is associated with a similar reduction in trade credit received by the retailer, both relations being statistically significant. These results are robust to various changes in the set of control variables. They also tend to hold, but become weaker economically, when we replace the sample of retailers with a sample of wholesalers or a sample of corporate customers that are neither retailers nor wholesalers.

The trade credit literature focuses mostly on explaining why firms use trade credit financing in the presence of banks specializing in financial intermediation. Existing theories argue thats suppliers may have an advantage over banks in assessing borrowers' creditworthiness (see, e.g., Smith, 1987; Biais and Gollier, 1997; Chod et al., 2017), monitoring borrowers' revenue (e.g., Jain, 2001), enforcing credit repayment (e.g., Cuñat, 2007), renegotiating debt (e.g., Wilner, 2000), or salvaging repossessed inventory upon borrower's default (e.g., Frank and Maksimovic, 2005). Other explanations of trade credit prevalence are based on moral hazard faced by buyers (e.g., Lee and Stowe, 1993; Long et al., 1993; Kim and Shin, 2012), moral hazard faced by lenders (e.g., Burkart and Ellingsen, 2004; Chod, 2017; Fabbri and Menichini, 2016), price discrimination (e.g., Brennan et al., 1988), transaction costs (e.g., Ferris, 1981; Emery, 1987), and risk sharing and supply chain coordination (e.g., Kouvelis and Zhao, 2012; Yang and Birge, 2017).

Unlike the aforementioned literature, our paper does not attempt to provide a new rationale for the use of supplier financing. Instead, it identifies an important strategic cost associated with providing trade credit, which is due to competitive interaction among suppliers. By examining trade credit provision by multiple competing suppliers, our study complements Brennan et al. (1988), who show how suppliers can use trade credit to achieve market segmentation, and Barrot (2016), who documents how imposition of exogenous constraints on trade creditors affects their competitors. The notion that suppliers' willingness to provide trade credit depends on their ability to internalize its benefit is related to Petersen and Rajan (1995), who argue that banks with greater market power tend to lend more because they are in a better position to internalize the long-

run benefits of providing credit to young and distressed firms. Unlike the argument of Petersen and Rajan (1995), our theory does not assume anything about future interactions between lenders and borrowers. In addition, our theory complements Petersen and Rajan (1995) by examining the effect of product substitutability.

On a broader level, our paper contributes to the literature that links product market competition and debt financing (see, e.g., Brander and Lewis, 1986; Bolton and Scharfstein, 1990). Whereas this literature studies the effect of competition on the amount of debt that firms issue, we examine the effect of competition on the amount of trade credit that firms provide.

## 2. Model

We consider $N$ heterogeneous suppliers, each selling a distinct product to the same retailer. The retailer then resells these products to end consumers. We assume linear consumer demand, i.e., the retail market-clearing price of the product of supplier $i$ (product $i$ henceforth) is given by

$$p_i(\mathbf{x}) = \alpha_i - \frac{1}{t}\left(x_i + \gamma \sum_{j=1, j\neq i}^{N} x_j\right) \text{ for } i = 1,\ldots,N, \qquad (1)$$

where $\alpha_i$ is the demand curve intercept, $x_i$ is the quantity sold of product $i$, $\gamma \in [0, 1)$ measures product substitutability and, therefore, the degree of competitive interaction among suppliers, and $t$ is the length of the time period. We explicitly model the time dimension so that we can later simplify the analysis by focusing on the limiting case of instantaneous time period. Supplier heterogeneity is captured by product-specific demand curve intercepts.

The retailer does not have any cash and relies on two sources of financing: bank credit and trade credit from suppliers. The sequence of events is as follows. First, suppliers simultaneously and independently set wholesale prices and trade credit limits. Second, the retailer chooses quantities to be purchased from the suppliers, which the suppliers produce to order, and the amounts of trade credit and bank financing. Finally, consumer demand is realized and the retailer uses sales proceeds to repay the bank and the suppliers. All firms are value-maximizers and all cash flows are expressed in present value terms. Next, we describe the retailer's and the suppliers' decision problems in greater detail, starting with the retailer.

### 2.1. Retailer

After observing wholesale prices, $\mathbf{w} = (w_1,\ldots,w_N)$, and trade credit limits, $\mathbf{T} = (T_1,\ldots,T_N)$, the retailer chooses quantities to purchase from each of the $N$ suppliers, $\mathbf{x} = (x_1,\ldots,x_N)$. Because the retailer does not have any cash of its own, it needs to finance the inventory cost, $\sum_{i=1}^{N} w_i x_i$, using a combination of trade credit and bank financing.

#### 2.1.1. Bank financing
We assume that the cost of bank credit is convex in the retailer's leverage. Convexity of the cost of debt financing

emerges endogenously from several microeconomic foundations. For example, Froot et al. (1993) and Bernanke et al. (1999) among others, show that convexity of the cost of debt financing arises when creditors can observe the firm's cash flows only at a cost. Other rationales for convex cost of debt financing include agency problems (e.g., Myers, 1977), adverse selection (e.g., Stein, 1998), regulatory capital requirements or managerial risk aversion (e.g., Becker and Josephson, 2016). For parsimony, we adopt convex cost of bank credit by assumption without explicitly modeling its micro foundations. Specifically, we assume that the bank interest rate increases linearly in the retailer's book leverage, defined as bank loan amount over the book value of the retailer's assets, where the latter equals the total cost of purchasing inventory, $\sum_{i=1}^{N} w_i x_i$. Thus, the interest rate, $r_R$, that the bank charges the retailer on a loan of size $y$ over time period $t$ equals

$$r_R = t\theta_R \frac{y}{\sum_{i=1}^{N} w_i x_i},\tag{2}$$

where $\theta_R > 0$ is a parameter that affects the retailer's cost of bank credit.

### 2.1.2. Trade credit

Because the increasing marginal cost of bank financing limits the retailer's demand for suppliers' goods, the suppliers have an incentive to provide trade credit to the retailer. Reflecting the empirical regularity of low variation of trade credit terms within industries, we assume that each supplier offers trade credit at a given industry-specific interest rate, $r_T = t\theta_T$, where $\theta_T$ is the trade credit interest rate per unit of time.[1]

Following Burkart and Ellingsen (2004), we assume that each supplier sets a trade credit limit beyond which it requires cash payment. Because the cost to the retailer of the first dollar of bank credit is zero, the pecking order in the retailer's optimal financing is to (i) first use bank credit; (ii) once the marginal cost of bank credit reaches the trade credit interest rate, start using trade credit along with bank credit; (iii) once the trade credit limit is exhausted, use additional bank financing. Of course, if the trade credit limits set by suppliers are sufficiently high, there is no reason for the retailer to use additional bank financing. As we show in Section 3.4, the retailer's optimal financing mix in this case depends only on the cost of bank financing relative to the industry-specific trade credit interest rate, and not on the strategic interaction among suppliers, which is the object of our study. Therefore, we now focus on the more interesting case in which all trade credit limits are binding.[2] This is the case when the following inequality holds

in equilibrium:

$$r_T < 2t\theta_R \frac{\sum_{i=1}^{N} (w_i x_i - T_i)}{\sum_{i=1}^{N} w_i x_i}.\tag{3}$$

The right-hand side of (3) is the marginal cost of bank financing when the retailer exhausts the trade credit limits, borrowing $\sum_{i=1}^{N} T_i$ from suppliers and $\sum_{i=1}^{N} (w_i x_i - T_i)$ from the bank. Condition (3) guarantees that fully utilizing the trade credit limits minimizes the retailer's overall cost of financing.

The retailer's profit consists of two parts: (i) operating profit, which equals sales revenue net of cost of goods sold, and (ii) financing cost, which is the sum of the cost of trade credit and bank credit, i.e.,

$$\Pi_R = \sum_{i=1}^{N} (p_i(\mathbf{x}) - w_i) x_i$$
$$- \left( r_T \sum_{i=1}^{N} T_i + t\theta_R \frac{\left( \sum_{i=1}^{N} (w_i x_i - T_i) \right)^2}{\sum_{i=1}^{N} w_i x_i} \right),\tag{4}$$

where the retail price $p_i(\mathbf{x})$ is given by (1) for $i = 1, \ldots, N$. The retailer chooses the optimal quantities that maximize this profit, i.e.,

$$\mathbf{x}^*(\mathbf{w}, \mathbf{T}) = \arg \max_{\mathbf{x} \geq \mathbf{0}} \Pi_R(\mathbf{x}, \mathbf{w}, \mathbf{T}).\tag{5}$$

### 2.2. Suppliers

In the first stage, supplier $i$, $i = 1, \ldots, N$, chooses the wholesale price, $w_i$, and the trade credit limit, $T_i$, taking the actions of the other suppliers as given and anticipating the retailer to order the equilibrium quantity, $x_i^*(\mathbf{w}, \mathbf{T})$, given in (5). Subsequently, the supplier produces quantity $x_i$ at a constant marginal cost $c_i$.

To model the cost associated with trade credit provision, we assume that the supplier's production cost, $c_i x_i$, exceeds its cash revenue, $w_i x_i - T_i$, and the supplier needs to obtain financing for the remaining amount, $c_i x_i - w_i x_i + T_i$.[3] We further assume that, similar to the retailer, suppliers face convex cost of financing. In particular, supplier $i$ can borrow from a bank at an interest rate that is linear in the supplier's leverage, defined as the amount borrowed over the book value of assets, where the latter equals the cost of producing inventory, $c_i x_i$. The interest rate faced by supplier $i$ that borrows $c_i x_i - w_i x_i + T_i$ for time period $t$ is, therefore,

$$r_{S_i} = t\theta_S \frac{c_i x_i - w_i x_i + T_i}{c_i x_i},\tag{6}$$

where the financing cost parameter, $\theta_S$, is assumed to be the same across suppliers.

The profit of supplier $i$ consists of three parts: (i) sales revenue minus cost of goods sold, (ii) interest earned on trade credit provided, and (iii) cost of the supplier's own bank financing, i.e.,

$$\Pi_{S_i} = (w_i - c_i) x_i + r_T T_i - t\theta_S \frac{(c_i x_i - w_i x_i + T_i)^2}{c_i x_i}.\tag{7}$$

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[1] In practice, there are two common forms of trade credit contracts. Under "two-part terms," the supplier offers the buyer an early payment discount, which represents implicit trade credit interest. Under "net-terms," the supplier does not offer any such discount. According to Ng et al. (1999), the most common two-part contract is "2/10 net 30," which implies 2% interest rate for a 20-day period. Importantly, Ng et al. (1999) document that trade credit terms tend to be standardized within industries, and the majority of firms in their sample change prices rather than trade credit terms in response to fluctuations in demand.

[2] In Section 3.4 we show that in equilibrium, the retailer is either constrained by *all* trade credit limits, or by *none* of them, and analyze the latter case formally.

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[3] We verify that the condition $c_i x_i > w_i x_i - T_i$ is always satisfied in equilibrium for any $i$.

The equilibrium strategy of supplier $i$ is given by

$$w_i^*, T_i^* = \arg\max_{w_i, T_i \geq 0} \Pi_{S_i}\left(x_i^*\left(w_i, \mathbf{w}_{-i}^*, T_i, \mathbf{T}_{-i}^*\right), w_i, T_i\right), \qquad (8)$$

where $\Pi_{S_i}$ is given in (7), $x_i^*$ is given in (5), and $\mathbf{w}_{-i}^*$ and $\mathbf{T}_{-i}^*$ are equilibrium wholesale prices and trade credit limits set by the other suppliers.

To examine the impact of supplier heterogeneity on trade credit provision, we allow suppliers to be of different sizes, i.e., we allow $\alpha_i \neq \alpha_j$ for $i \neq j$. However, we assume that $\alpha_1/c_1 = \alpha_2/c_2 = \cdots = \alpha_N/c_N \equiv m$, where $m$ captures suppliers' profitability.[4] As we show below, absent any strategic interactions, suppliers that differ in size ($\alpha_i$) but have the same profitability ($\alpha_i/c_i$) provide the same amount of trade credit as a proportion of their sales. This is important because it guarantees that any differences in the relative amount of trade credit that these suppliers provide in equilibrium are due exclusively to the suppliers' strategic interaction, which is the focus of our study.

## 3. Equilibrium and comparative statics

Because the equilibrium conditions in their general form are too complex to provide insights, we focus on the limiting case in which the length of the time period, $t$, approaches zero. In this case, sales quantities, $x_i/t$, trade credit limits, $T_i/t$, interest rates, $r_R/t$, $r_{S_i}/t$, and $r_T/t$, and profits, $\Pi_i/t$, can be all interpreted as instantaneous rates. Therefore, the fundamental trade-off between using bank financing and trade credit is preserved, and the equilibrium proportion of trade credit financing, $T_i^*/w_i^*x_i^*$, remains meaningful. In fact, as we show in Section 3.3, the first best proportion of trade credit financing is independent of $t$. Importantly, because all equilibrium variables are continuous in $t$ for $t > 0$, all comparative statics obtained for this limiting case are also valid for $t$ small enough. In Section 4, we verify numerically that the results are robust and economically significant under parameter values calibrated using annual sales and interest rate estimates.

Before analyzing the effect of strategic interaction among suppliers on the provision of trade credit, we consider a benchmark single-supplier scenario to understand what drives the equilibrium amount of trade credit financing in the absence of strategic considerations.

*Lemma 1. In the case of a single supplier, as $t$ approaches zero, the equilibrium proportion of trade credit financing approaches the following limit:*

$$\lim_{t \to 0} \frac{T^*}{w^*x^*} = \frac{\theta_S(m-1) + \theta_T}{\theta_S(m+1) - 2\theta_R}. \qquad (9)$$

*Proof.* All proofs can be found in Appendix A. □

As one would expect, the supplier provides more trade credit financing, relative to sales, as its cost of bank financing, $\theta_S$, decreases; or as the retailer's cost of bank financing, $\theta_R$, the trade credit interest rate, $\theta_T$, or the supplier's profitability, $m$, increase. Notably, the proportion of trade credit financing in the single-supplier case is independent

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[4] Absent any strategic interactions with other suppliers, supplier $i$'s equilibrium profit margin is $(w_i^* - c_i)/c_i = (m-1)/2$.

of $\alpha$. As discussed earlier, this means that any effects of heterogeneity in $\alpha$'s on equilibrium trade credit provision stem exclusively from strategic interaction among suppliers. Finally, note that in the case of a single supplier and $t \to 0$, condition (3), which ensures that the retailer uses trade credit up to the limit, is equivalent to

$$\theta_T < 4\theta_R\left(1 - \frac{\theta_R}{\theta_S}\right)\frac{1}{m+1}. \qquad (10)$$

We assume inequality (10) to hold throughout our analysis of the limiting case of $t \to 0$.

The supplier sets trade credit limit so that the marginal cost of providing trade credit, i.e., the difference between the supplier's own marginal cost of funds, $2r_{S_i}$, and the trade credit interest rate, $r_T$, equals the marginal benefit of trade credit provision, i.e., the profit from increased sales, $\frac{\partial x_i}{\partial T_i}(w_i - c_i)$. In the next two subsections, we examine how the latter depends on supplier competition.

### 3.1. Free rider effect

In this subsection, we focus on the "free rider effect," whereby each supplier providing trade credit internalizes only a part of the benefit of increasing the retailer's purchasing power. To isolate this effect and, in particular, to differentiate it from the effect of strategic interactions among suppliers in the product market, we begin by examining the case in which suppliers' products are independent, i.e., we assume $\gamma = 0$ throughout this subsection. In the next subsection, we not only show that our findings continue to hold when the suppliers' products are substitutes ($\gamma > 0$), but we also examine how trade credit provision depends on product substitutability.

Let $SH_i^*$ denote supplier $i$'s equilibrium share of the retailer's spending ("supplier share" henceforth), and let $HHI^*$ denote the Herfindahl index of the equilibrium supplier shares, i.e.,

$$SH_i^* \equiv \frac{w_i^*x_i^*}{\sum_{k=1}^{N} w_k^*x_k^*} \quad \text{and} \quad HHI^* \equiv \sum_{i=1}^{N}\left(SH_i^*\right)^2. \qquad (11)$$

The following proposition links the equilibrium amount of trade credit provided by each supplier to the supplier share.

*Proposition 1. As $t$ approaches zero, trade credit provided by supplier $i$ as a proportion of its sales approaches the following limit:*

$$\lim_{t \to 0} \frac{T_i^*}{w_i^*x_i^*} = \frac{\theta_S(m-1) + \theta_T}{\theta_S(m+1) - 2\theta_R HHI^*}\left(1 + \frac{2\theta_R}{\theta_S}\frac{SH_i^* - HHI^*}{m+1}\right), \qquad (12)$$

*and, therefore, suppliers with larger shares provide more trade credit as a proportion of their sales, i.e.,*

$$\frac{T_i^*}{w_i^*x_i^*} > \frac{T_j^*}{w_j^*x_j^*} \iff SH_i^* > SH_j^*. \qquad (13)$$

The intuition is as follows. Suppose supplier $i$ extends an additional dollar of trade credit to the retailer. The retailer optimally uses the freed-up liquidity to simultaneously (i) reduce its bank borrowing, (ii) purchase additional

output from supplier $i$, and (iii) purchase additional output from other suppliers. Thus, a free rider problem arises where the total benefit of increased spending by the retailer is not fully internalized by the trade creditor, but is spread across multiple suppliers. Importantly, a supplier with a larger share of the retailer's purchases internalizes a larger portion of this benefit. Such a supplier is therefore willing to provide more trade credit relative to its sales.

The next proposition characterizes the equilibrium trade credit received by the retailer.

*Proposition 2. As $t$ approaches zero, the proportion of trade credit financing used by the retailer approaches the following limit:*

$$\lim_{t \to 0} \frac{\sum_{k=1}^{N} T_k^*}{\sum_{k=1}^{N} w_k^* x_k^*} = \frac{\theta_S(m-1) + \theta_T}{\theta_S(m+1) - 2\theta_R HHI^*}, \tag{14}$$

*and, therefore, is positively related to supplier concentration measured by the Herfindahl index of supplier shares.*

When the retailer's spending is highly fragmented across suppliers, each supplier internalizes only a small portion of the benefit of providing trade credit. This, in turn, reduces the amount of trade credit that suppliers are willing to provide as a whole. With more concentrated suppliers, larger suppliers are willing to provide more trade credit relative to their sales. Because these larger suppliers also represent a larger share of the retailer's spending, supplier concentration is positively related to the overall proportion of trade credit in the retailer's financing mix.

### 3.2. Product substitutability

In this subsection and throughout the rest of the paper, we allow suppliers' products to be substitutes, i.e., we allow $\gamma \geq 0$. We first confirm that the relation between supplier shares and their provision of trade credit continues to be positive when products are substitutes.

**Proposition 1a.** *At sufficiently small $t$, suppliers with larger shares provide more trade credit as a proportion of their sales, i.e.,*

$$\frac{T_i^*}{w_i^* x_i^*} > \frac{T_j^*}{w_j^* x_j^*} \Longleftrightarrow SH_i^* > SH_j^*. \tag{15}$$

Showing a positive relationship between the retailer's use of trade credit financing and supplier concentration analytically for $\gamma > 0$ is difficult. However, we can do so for the special case of symmetrical suppliers, in which the Herfindahl index of supplier concentration becomes the inverse of the number of suppliers, i.e., $HHI^* = 1/N$.

**Proposition 2a.** *When suppliers are symmetrical and $t$ is sufficiently small, the proportion of trade credit financing, $\frac{T^*}{w^* x^*}$, increases in supplier concentration.*

With fewer symmetrical suppliers, the share of each becomes larger, and so does the equilibrium proportion of trade credit financing. To validate the positive relation between the retailer's use of trade credit and its supplier concentration in the case of asymmetric suppliers, in Section 4 we calibrate the model with typical values of the

Herfindahl index of supplier shares, product substitutability, and bank and trade credit interest rates.

We now examine the relation between the equilibrium provision of trade credit and product substitutability. Because product substitutability is a key determinant of the intensity of competitive interaction among suppliers, one could conjecture that as product substitutability increases, greater competitive pressure would force suppliers to provide more trade credit. Our next proposition challenges this intuition. For the sake of tractability, we assume here that suppliers are symmetrical, but verify, as a part of our calibration exercise in Section 4, that the result is robust to the case of asymmetric suppliers.

*Proposition 3. When suppliers are symmetrical and $t$ is sufficiently small, the proportion of trade credit financing, $\frac{T^*}{w^* x^*}$, decreases in product substitutability among suppliers.*

Recall that trade credit provided by any given supplier enables the cash constrained retailer to increase cash purchases from all other suppliers. As shown above, this free rider problem reduces the equilibrium provision of trade credit even if suppliers sell unrelated products. When suppliers offer substitutable products and, therefore, compete not only for the retailer's cash but also for the same end consumers, the free rider problem becomes even more detrimental to the trade creditor. The reason is that the additional output sold by the competing suppliers reduces the residual consumer demand for the trade creditor's own product and, therefore, the price at which it can be sold. As product substitutability increases, this disadvantage of providing trade credit becomes more significant, and suppliers' willingness to offer trade credit financing decreases.

### 3.3. First-best financing

In the previous two subsections we established that a free rider effect and competitive interaction among suppliers reduce suppliers' willingness to offer trade credit. A natural question is then whether competing suppliers underprovide trade credit relative to the first best. As we show below, the answer is not obvious. To facilitate the exposition, we assume symmetrical suppliers throughout this subsection.

Even before defining the first best, it is useful to formally characterize the effect of supplier competition on trade credit provision by comparing our base-case $N$-supplier scenario with the case in which a single supplier sells all $N$ products. Because one can think of such a supplier as a result of the merger of $N$ independent suppliers, we denote the equilibrium solution in the single-supplier scenario by superscript $M$. For consistency, we use $T^M$ to denote the equilibrium amount of trade credit that the single supplier offers *per product*.

*Lemma 2. At sufficiently small $t$, multiple competing suppliers provide less trade credit relative to their sales than a single supplier of the same products, i.e.,*

$$\frac{T^*}{w^* x^*} < \frac{T^M}{w^M x^M}. \tag{16}$$

As expected, $N$ competing suppliers underprovide trade credit relative to a single $N$-product supplier, which inter-

nalizes the entire benefit of the retailer's increased spending. This of course does not imply that competing suppliers underprovide trade credit relative to the first best, since it is not obvious how the amount of trade credit provided by a single supplier, whose incentives are not aligned with those of the retailer, relates to the first best.

Regardless of the number of suppliers, the equilibrium solution deviates from the first best along two dimensions: quantities produced and trade credit provided. Because coordination of production among suppliers and a retailer is outside the scope of our paper, we focus on the second dimension. In particular, we define the first-best financing as the amount of trade credit per product, $T^{FB}$, that minimizes the total financing cost of the suppliers and the retailer for any given $w$ and $x$, i.e.,

$$T^{FB}(w, x) = \arg\min_{T>0} \left[ t\theta_S \frac{(cx - wx + T)^2}{cx} + t\theta_R \frac{(wx - T)^2}{wx} \right].$$
$$(17)$$

Under first-best financing, the marginal cost of bank credit must be the same for the retailer and for the suppliers, i.e., the retailer and the suppliers must pay the same interest rate to the bank.

The next lemma compares the equilibrium and first-best trade credit provision in the case of a single supplier that sells all $N$ products.

*Lemma 3. At sufficiently small t, there exist thresholds $\bar{m} < \infty$ and $\bar{r}_T < \infty$ such that a single supplier overprovides trade credit relative to the first best, i.e.,*

$$\frac{T^M}{w^M x^M} > \frac{T^{FB}(w^M, x^M)}{w^M x^M},$$
$$(18)$$

*if and only if $m > \bar{m}$ or $r_T > \bar{r}_T$.*

Whether a single supplier overprovides or underprovides trade credit relative to the first best depends on its profitability, $m$, and on the trade credit interest rate, $r_T$. When profitability and/or the trade credit interest rate are high, the supplier's incentive to extend trade credit to increase sales and/or interest revenue is so strong that it leads to overprovision of trade credit beyond the first best.

How the equilibrium amount of trade credit provided by multiple competing suppliers compares with the first best therefore depends on two potentially conflicting forces described in the previous two lemmas: (i) a supplier's incentive to provide trade credit is reduced by the free rider and competitive interaction effects; (ii) absent any strategic considerations, a supplier may have an incentive to overprovide trade credit beyond the first best to boost its sales and/or interest revenue. The next proposition characterizes the interplay of these two forces.

*Proposition 4. At sufficiently small t, there exist thresholds $\bar{N} < \infty$ and $\bar{\gamma} < 1$ such that multiple competing suppliers underprovide trade credit relative to the first best, i.e.,*

$$\frac{T^*}{w^* x^*} < \frac{T^{FB}(w^*, x^*)}{w^* x^*},$$
$$(19)$$

*if and only if $N > \bar{N}$ or $\gamma > \bar{\gamma}$.*

When the number of suppliers is small (i.e., each supplier is responsible for a substantial share of the retailer's

purchases) and their products are not strong substitutes, the equilibrium use of trade credit financing may exceed the first-best level. When, however, the number of suppliers is sufficiently large (i.e., the selling share of each supplier is sufficiently small) or their products are sufficiently strong substitutes, the free rider and competitive interaction effects prevail, and the equilibrium provision of trade credit falls below the first-best level.

### 3.4. Ample trade credit

So far, we have focused on the case in which all suppliers' trade credit limits are binding in equilibrium. In this subsection, we explore the alternative scenario, in which the retailer chooses not to use trade credit up to these limits. To do so, we need to write the retailer's problem in (4) in a more general fashion. Let $U_i$ be the amount of trade credit from supplier $i$ that the retailer uses. The retailer's problem is then

$$\mathbf{U}^*, \mathbf{x}^* = \arg\max_{\mathbf{x}, \mathbf{U} \geq \mathbf{0}} \Pi_R(\mathbf{U}, \mathbf{x}) \text{ subject to } U_i \leq T_i$$

$$\text{for } i = 1, \dots, N, \text{ where} \qquad (20)$$

$$\Pi_R = \sum_{i=1}^{N} (p_i(\mathbf{x}) - w_i) x_i$$
$$- \left( r_T \sum_{i=1}^{N} U_i + t\theta_R \frac{\left( \sum_{i=1}^{N} (w_i x_i - U_i) \right)^2}{\sum_{i=1}^{N} w_i x_i} \right). \qquad (21)$$

Recall that our analysis so far has assumed that the retailer uses up each of the trade credit limits, i.e., $U_i^* = T_i$ for each $i$. Now suppose that the trade credit limit of supplier $j$ is non-binding, i.e., $0 < U_j^* < T_j \leq w_j x_j$. Because $U_j^*$ is an interior solution, it must satisfy the first-order optimality condition, $\frac{\partial \Pi_R}{\partial U_j} = 0$, which can be written as

$$2t\theta_R \frac{\sum_{i=1}^{N} (w_i x_i - U_i)}{\sum_{i=1}^{N} w_i x_i} = r_T. \qquad (22)$$

This condition ensures that the retailer's marginal cost of bank credit equals the trade credit interest rate, $r_T$. Intuitively, if $r_T$ were lower (higher), the retailer would be better off by increasing (reducing) $U_i$ by one dollar, while reducing (increasing) its bank borrowing by the same amount. Note that at any given **w, x**, and **U**, we have $\frac{\partial \Pi_R}{\partial U_1} = \frac{\partial \Pi_R}{\partial U_2} = \dots = \frac{\partial \Pi_R}{\partial U_N}$, i.e., when $U_j^*$ satisfies the interior optimality condition, $\frac{\partial \Pi_R}{\partial U_j} = 0$, so does $U_i^*$ for each $i \neq j$. In other words, when the retailer is not constrained by one of the trade credit limits, it is not constrained by any of them. Intuitively, if the retailer wanted to use more trade credit, it could always obtain more trade credit from supplier $j$. The fact that the retailer does not do so, means that its marginal costs of bank credit and trade credit are the same and, therefore, none of the existing trade credit limits affects the retailer's payoff.

It follows immediately from (22) that the equilibrium proportion of trade credit financing used by the retailer,

$$\frac{\sum_{i=1}^{N} U_i^*}{\sum_{i=1}^{N} w_i^* x_i^*} = 1 - \frac{\theta_T}{2\theta_R}, \qquad (23)$$

depends only on the exogenous parameters determining the retailer's cost of trade and bank credit. In particular, it is independent of supplier share concentration, $HHI^*$, as well as product substitutability, $\gamma$. It further follows from (22) that $\mathbf{U}^*$ is generally not unique: any $\mathbf{U}$ such that $\sum_{i=1}^{N} U_i$ satisfies (22), also satisfies $\frac{\partial \Pi_R}{\partial U_i} = 0$ for all $i$, and is therefore optimal. In other words, unless the retailer uses trade credit from each supplier up to the limit–a scenario we analyzed as the base-case model in Sections 3.1–3.3, its payoff depends only on the total amount of trade credit, $\sum_{i=1}^{N} U_i$, and not on how much of it comes from each supplier. Therefore, absent trade credit rationing, our model does not provide any predictions regarding the amount of trade credit extended by suppliers.

We have considered the cases in which the retailer's marginal cost of bank credit is either *greater than* or *equal to* the trade credit interest rate; see conditions (3) and (22), respectively. To complete the formal analysis, note that there is a third, less interesting scenario, in which the retailer's marginal cost of bank credit is *lower than* the trade credit interest rate and the retailer uses no trade credit at all. In summary, all predictions of our model apply to the first case, in which the retailer's cost of bank financing and, thus, its demand for trade credit are high, and, as a result, suppliers ration trade credit strategically.

## 4. Model calibration

To derive analytical results in the previous section, we had to rely on several restrictive assumptions. First, our analysis assumed that the length of the time period $t$ is short enough. Second, the relation between the Herfindahl index of supplier shares and the amount of trade credit used by the retailer was derived under two alternative assumptions: (i) zero product substitutability, or (ii) symmetrical suppliers. Third, the relation between product substitutability and trade credit provision was developed under the assumption of symmetrical suppliers.

To verify that our results remain valid absent these assumptions, we solve our model numerically for realistic (calibrated) parameter values. Because our calibration is based on annual sales and annual interest payments, we set $t = 1$ year. In addition to serving as a robustness check, the calibration exercise allows us to quantify the economic significance of our results. Finally, using simulated data enables examining the effects of the distribution of supplier shares and product substitutability on trade credit provision in isolation from all other factors associated with firms' real-life trade credit choices–a feat difficult to accomplish using real data.

### 4.1. Data

Our main data source, which we use for both the calibration and empirical tests, is Compustat Annual Industrial Files. To identify customer-supplier links, we use the data of Cohen and Frazzini (2008), extended to 2009. Cohen and Frazzini (2008) establish customer-supplier relations using the Compustat Industry Segment data set, which identifies firms' principal customers. As our focus is on the strategic considerations in firms' trade credit choices, we require a

customer to be listed as such by at least two suppliers. As our theoretical model features customers that are retailers, we impose a restriction that a customer is a retailer, i.e., it belongs to NAICS industries 44–45 (retail trade).

To estimate the degree of substitutability among suppliers' products, we rely on Hoberg and Phillips (2010, 2016) measure of textual similarity between firms' product descriptions in 10K filings for each pair of Compustat firms in years 1996–2013. A similarity of zero means that there are no overlapping words in the two firms' product descriptions, other than designated "common words." A similarity of one means that the two firms' product descriptions are identical bar these common words. Importantly, this measure is purged of vertical relations using the Bureau of Economic Analysis input–output tables.[5] As a result of merging the data of Cohen and Frazzini (2008) with those of Hoberg and Phillips (2010, 2016), our main sample covers years 1996–2009. Our samples of retailers having at least two suppliers and of suppliers listing at least one retailer as their principal customer contain 571 retailer-years and 2781 supplier-years, respectively.

### 4.2. Calibrating interest rates

We begin by calibrating the interest rate parameters, $\theta_R$, $\theta_{Si}$, and $\theta_T$, using Compustat data, with the objective of matching the mean interest rates paid by retailers and suppliers to external financiers and the mean trade credit interest rates to those observed in the data. As follows from (2), the interest rate paid by a retailer to the bank per unit of time equals $\theta_R$ times the retailer's book leverage, defined as the ratio of bank credit, $\sum_{i=1}^{N} (w_i x_i - T_i)$, and the book value (purchase price) of inventories, $\sum_{i=1}^{N} w_i x_i$. We set $t = 1$ year and calibrate $\theta_R$ as the ratio of the retailer's average annual interest rate to its book leverage. We measure a retailer's average annual interest rate as the ratio of interest expense, Compustat item XINT, to the sum of long-term debt, item DLTT, and short-term debt, item DLC. Leverage is measured as the ratio of the sum of items DLTT and DLC to total book assets, item AT. Although it is possible to calibrate $\theta_R$ for each retailer with the available data, we calibrate a single $\theta_R$ to match the sample mean of the ratio of annual interest rate to leverage, which equals 0.324. The reason is that we want to eliminate variation in all factors other than the distribution of supplier shares and product substitutability that could affect the equilibrium amount of trade credit financing, interest rates in particular.

Similarly, it follows from (6) that $\theta_s$ can be calibrated as the ratio of a supplier's average annual interest rate and its book leverage, defined as the ratio of bank financing, $c_i x_i - w_i x_i + T_i$, to the supplier's book value (production cost) of inventories, $c_i x_i$. Thus, we calibrate $\theta_s$ to the sample mean ratio of a supplier's annual interest rate to its book leverage, which is 0.297.

As trade credit terms are unobservable in our data, we rely on estimates from past studies when calibrating trade credit interest rate, $r_T$. In particular,

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[5] We are grateful to Jerry Hoberg and Gordon Phillips for providing us with the complete matrix of firms' pairwise similarities, without imposing the lower bound on the similarities.

Giannetti et al. (2011) report mean annualized trade credit interest rate of 28%, which is what we use in our exercise.[6]

### 4.3. Construction of the simulated data set

For the 571 retailer-level observations, we obtain the following values from the data:

(i) the number of suppliers that list the retailer as their principal customer;
(ii) revenues of each of the suppliers, Compustat item SALE;
(iii) text-based measure of product description similarity among all pairs of the retailer's suppliers, computed by Hoberg and Phillips (2010, 2016), which we denote by $\gamma_{i,i'}$ for the pair of suppliers $i$ and $i'$.

As our data do not have detailed information on sales of each supplier to each retailer, we approximate supplier $i$'s share of retailer $j$'s purchases by the ratio of supplier $i$'s revenue to the total revenue of all suppliers of retailer $j$, $SH_i = \frac{SALE_i}{\sum_{k=1}^{N_j} SALE_k}$, where $N_j$ is the number of firms that list retailer $j$ as their principal customer. We also compute the HHI of supplier shares for retailer $j$ as $HHI_j = \frac{\sum_{i=1}^{N_j} SH_i^2}{(\sum_{i=1}^{N_j} SH_i)^2}$. As our model assumes that the degree of product substitutability is the same for all suppliers to a given retailer, we measure retailer-level degree of product substitutability as the average product description similarity across all supplier pairs of a given retailer, $\overline{\gamma_j} = \frac{\sum_{i=1}^{N_j} \sum_{i'=1, i'\neq i}^{N_j} \gamma_{i,i'}}{N_j(N_j-1)}$.

Next, we choose model parameters so as to match, for each retailer-level observation $j$, the following quantities and their empirical counterparts:

(i) the number of suppliers, $N_j$;
(ii) the mean pairwise substitutability of the suppliers' products, $\overline{\gamma_j}$;
(iii) the equilibrium HHI of supplier shares, $HHI_j^*$;
(iv) the mean profit margin of the suppliers, $\frac{\sum_{i=1}^{N_j}(\frac{w_i^*}{c_i}-1)}{N_j}$; the profit margin in the data is defined as the ratio of operating income after depreciation, Compustat item OIADP, to sales, item SALE; the mean supplier profit margin equals 0.093.

The number of suppliers, $N_j$, and their product substitutability, $\overline{\gamma_j}$, are deep parameters of the model, whereas the Herfindahl index, $HHI_j^*$, and the mean supplier profit margin, $\frac{\sum_{i=1}^{N_j}(\frac{w_i^*}{c_i}-1)}{N_j}$, are determined in equilibrium. To match these quantities, we vary the following model parameters:

(i) intercepts of consumer demand for suppliers' products, $\alpha_i$ for supplier $i$;
(ii) supplier profitability, $m = \alpha_i/c_i$, which is identical for all suppliers of a given retailer in the model as well as in the calibration.

The numerical procedure we use to find these parameters is described in detail in Appendix B. In addition to $N_j$, $\overline{\gamma_j}$, and $HHI_j^*$, we record the equilibrium proportion of sales of each supplier financed by trade credit, $\frac{T_i^*}{w_i^* x_i^*}$ for supplier $i$, and the equilibrium proportion of purchases of retailer $j$ financed by trade credit, $\frac{\sum_{i=1}^{N_j} T_i^*}{\sum_{i=1}^{N_j} w_i^* x_i^*}$. Panels A and B of Table 1 report summary statistics of the simulated samples of suppliers and retailers, respectively.

Each of the two panels of Table 1 reports the mean, standard deviation, and number of observations for the full sample of retailers and for two subsamples: retailers with relatively concentrated suppliers (five or fewer) and retailers with relatively dispersed suppliers (six or more).

As can be seen in Panel A, the mean equilibrium supplier share in the full sample is 0.211 with a standard deviation of 0.326. The mean supplier share is higher in the subsample of retailers with concentrated suppliers, 0.344, and lower in the subsample of retailers with dispersed suppliers, 0.142. The mean measure of product substitutability in the full sample is 0.0081 with a standard deviation of 0.018, and it is similar in the two subsamples.

The mean ratio of suppliers' trade credit to sales is 0.488 with a standard deviation of 0.032. These statistics are very different from their empirical counterparts: the mean ratio of accounts receivable, Compustat item RECT, to sales, item SALE, is 0.159 with a standard deviation of 0.117 (see Table 3 below). These differences are not surprising, as our model abstracts from factors associated with trade credit choices other than strategic interactions among suppliers. Importantly, these differences do not prevent us from analyzing the quantitative effects of the supplier share distribution and product substitutability on equilibrium trade credit provision while shutting off all other factors related to trade credit.

As shown in Panel B, the mean HHI of supplier shares in the full sample is 0.317 and its standard deviation is 0.299, indicating that there is substantial variation in the HHI of supplier shares. The mean HHI is higher within the sample of retailers with more concentrated suppliers and lower within the sample of retailers with more dispersed suppliers. By construction, the distribution of simulated HHI of supplier shares matches perfectly the distribution in the data. The distributions of product substitutability and trade credit ratio are similar to the corresponding distributions in the supplier sample.

### 4.4. Estimation with simulated data

We begin by examining the relation between the proportion of supplier $i$'s sales financed by trade credit, $TC_i^*$, on the one hand, and supplier share, $SH_i^*$, and product substitutability among suppliers selling to retailer $j$, $\overline{\gamma_j}$, on the

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[6] Although the two-part contract that is most common in the United States, "2-10 net 30," corresponds to 43.5% annualized interest rate, a large proportion of trade credit contracts involves no early payment discount, which brings the average interest rate to a much lower value (see, e.g., Giannetti et al., 2011). Our results are robust to using various values of $r_T$ ranging from 10% to 40%.

**Table 1**

Summary statistics: simulated data.

This table presents summary statistics for the simulated sample of 2781 suppliers (Panel A) and 571 retailers (Panel B). Supplier $i$'s trade credit is the equilibrium proportion of its sales done on credit, $\frac{T_i^*}{w_i^* x_i^*}$. Retailer $j$'s trade credit is the equilibrium proportion of its purchases financed by trade credit, $\frac{\sum_{i=1}^{N_j} T_i^*}{\sum_{i=1}^{N_j} w_i^* x_i^*}$, where $N_j$ is the number of retailer $j$'s suppliers. Share of supplier $i$ that sells to retailer $j$ is computed as $SH_i = \frac{SALE_i}{\sum_{k=1}^{N_j} SALE_k}$. Retailer $j$'s Herfindahl index (HHI) of supplier shares is computed as $HHI_j = \frac{\sum_{i=1}^{N_j} SH_i^2}{\left(\sum_{i=1}^{N_j} SH_i\right)^2}$. Mean product substitutability among all suppliers selling to retailer $j$ is computed as $\overline{\gamma_j} = \frac{\sum_{i=1}^{N_j} \sum_{i'\neq i}^{N_j} \gamma_{i,i'}}{N_j(N_j-1)}$, where $\gamma_{i,i'}$ is the textual similarity of product descriptions of suppliers $i$ and $i'$, as described in Section 4.1.

| | Whole sample # supp. = 2,781 # ret. = 571 | | 2 ≤ # suppliers ≤5 # supp. = 947 # ret. = 326 | | # suppliers ≥6 # supp. = 1,834 # ret. = 245 | |
|---|---|---|---|---|---|---|
| | Mean | St. dev. | Mean | St. dev. | Mean | St. dev. |
| *Panel A: Suppliers* | | | | | | |
| Trade credit | 0.4882 | 0.0316 | 0.4984 | 0.0109 | 0.4830 | 0.0321 |
| Supplier share | 0.2109 | 0.3255 | 0.3442 | 0.4105 | 0.1420 | 0.0469 |
| Mean product substitutability | 0.0081 | 0.0180 | 0.0076 | 0.0175 | 0.0083 | 0.0144 |
| *Panel B: Retailers* | | | | | | |
| Trade credit | 0.4922 | 0.0240 | 0.5005 | 0.0080 | 0.4812 | 0.0360 |
| HHI of supplier shares | 0.3174 | 0.2994 | 0.4722 | 0.1455 | 0.1115 | 0.0996 |
| Mean product substitutability | 0.0077 | 0.0239 | 0.0074 | 0.0195 | 0.0080 | 0.0206 |

other. To that end, we estimate the following regression:

$$TC_i^* = \alpha + \beta_1 SH_i^* + \beta_2 \overline{\gamma_j} + \epsilon_i. \tag{24}$$

We estimate (24) for the full sample of retailers, as well as for the subsamples of retailers with relatively concentrated and relatively dispersed suppliers. The results of estimating (24) are presented in Panel A of Table 2.

Our analysis in Section 3 predicts a positive $\beta_1$ and a negative $\beta_2$. This prediction is borne out in the simulated data. The coefficient on $SH_i^*$ is positive, whereas the coefficient on $\overline{\gamma_j}$ is negative in the full sample as well as both subsamples. Both coefficients are highly statistically significant in all instances, as follows from the $t$-statistics reported in parentheses underneath the coefficient estimates. This indicates that the model's qualitative predictions, which we derived under restrictive assumptions in Section 3, continue to hold for typical values of model parameters.

The calibration also allows us to assess the economic significance of the relations predicted by the model. A coefficient's economic significance, reported in curly brackets underneath the $t$-statistic, is computed as the coefficient estimate multiplied by the in-sample standard deviation of the independent variable and divided by the in-sample standard deviation of trade credit provided by suppliers is relatively low because the variation in suppliers' trade credit in the simulated data is solely due to the free rider and strategic effects. Nevertheless, the economic significance of the effects of supplier shares and product substitutability on equilibrium trade credit is quite large.

As shown in Panel A of Table 2, a one-standard-deviation increase in a supplier's share of the retailer's purchases is associated with a 44% (59%, 25%) standard-deviation increase in the supplier's trade credit-to-sales ratio in the full sample (subsample of concentrated suppliers, subsample of dispersed suppliers). A one-standard-deviation increase in product substitutability is associated

**Table 2**

Supplier and retailer trade credit, supplier share, HHI of supplier shares, and product substitutability: simulated data.

Panel A presents regressions of a supplier's equilibrium trade credit on the supplier's share of the retailer's purchases and mean substitutability among suppliers' products. Panel B presents regressions of a retailer's equilibrium trade credit on the HHI of supplier shares and mean substitutability among suppliers' products. See Table 1 for variable definitions. The samples of 2781 suppliers and 571 retailers are simulated to match certain quantities in real data, as described in detail in Section 4.3. Standard errors of coefficients are reported below the coefficient estimates. The numbers in curly brackets indicate the economic significance of the corresponding coefficient, computed as the coefficient estimate multiplied by the in-sample standard deviation of the independent variable and divided by the in-sample standard deviation of the dependent variable.

| | Whole sample | 2 ≤ # suppliers ≤ 5 | # suppliers ≥ 6 |
|---|---|---|---|
| *Panel A: Suppliers* | | | |
| Intercept | 0.4935 | 0.4974 | 0.4913 |
| | (505.62) | (-669.89) | (396.48) |
| Supplier share | 0.0434 | 0.0157 | 0.0832 |
| | (11.73) | (8.89) | (8.65) |
| | {0.447} | {0.591} | {0.245} |
| Mean product substitutability | −1.9050 | −0.5818 | −2.4443 |
| | (−43.45) | (−21.27) | (−61.67) |
| | {−1.085} | {−0.934} | {−1.097} |
| $R$ squared | 76.27% | 62.46% | 93.10% |
| *Panel B: Retailers* | | | |
| Intercept | 0.4894 | 0.4941 | 0.4876 |
| | (394.73) | (493.06) | (279.50) |
| HHI of supplier shares | 0.0389 | 0.0196 | 0.0951 |
| | (12.73) | (9.90) | (7.99) |
| | {0.485} | {0.356} | {0.263} |
| Mean product substitutability | −1.1861 | −0.3831 | −2.1918 |
| | (−27.05) | (−17.91) | (−56.54) |
| | {−1.181} | {−0.934} | {−1.258} |
| $R$ squared | 61.87% | 57.64% | 92.97% |

with 109% (93%, 110%) standard-deviation decrease in the supplier's trade credit-to-sales ratio in the full sample (subsample of concentrated suppliers, subsample of dispersed suppliers).

To estimate the relation between the proportion of retailer $j$'s purchases financed by trade credit, $TC_j^*$, on the one hand, and the Herfindahl index of retailer $j$'s supplier shares, $HHI_j^*$, and product substitutability among retailer $j$'s suppliers, $\overline{\gamma_j}$, on the other hand, we estimate the following regression:

$$TC_j^* = \alpha + \beta_1 HHI_j^* + \beta_2 \overline{\gamma_j} + \epsilon_j. \tag{25}$$

The results of estimating (25) are presented in Panel B of Table 2. Consistent with our theory, the coefficient $\beta_1$ is positive whereas the coefficient $\beta_2$ is negative.

The economic significance of both of these effects is also large. A one-standard-deviation increase in the HHI of supplier shares is associated with a 26–49% standard-deviation increase in the retailer's ratio of trade credit to cost of goods sold. A one-standard-deviation increase in substitutability among suppliers' products is associated with a 93–126% standard-deviation decrease in the retailer's ratio of trade credit to cost of goods sold.

Overall, the results of calibrating the model and estimating the equilibrium relations within simulated data indicate that the analytical relations derived in Section 3 do not hinge on the parametric assumptions that we had to adopt for tractability. Equally important, the effects of the distribution of supplier shares and product substitutability on the equilibrium trade credit provision are economically significant.

## 5. Empirical predictions and discussion

Our model assumes, for ease of exposition, one retailer. Extending the logic to multiple retailers, Propositions 1 and 1a suggest that equilibrium trade credit provided by a supplier to each of its retailers is increasing in the supplier's share of the retailer's purchases. This leads to our first prediction.

**Prediction 1.** *The ratio of trade credit provided by a supplier to its sales is positively related to the supplier's average share of its retailers' purchases.*

We are not aware of any existing theories that yield this prediction. Petersen and Rajan (1997) argue that when a customer's survival depends on obtaining trade credit, a monopolistic supplier, which is more likely to internalize the long-term benefit of helping the customer, should be willing to provide more trade credit. This argument is based on the supplier's competitive position vis-à-vis all firms in its industry–whether they sell to the same customers or not. In contrast, we emphasize the importance of the supplier's position among all firms selling to the same customers–regardless of their industry affiliations. Consider the following example that highlights the distinction. Our model predicts that a retailer buying from multiple monopolistic suppliers obtains less trade credit than a retailer purchasing from a single competitive supplier, whereas Petersen and Rajan (1997) theory predicts the opposite.

The remaining trade credit theories that consider supplier competition predict the relation between trade credit provision and supplier market power to be negative. Fisman and Raturi (2004) argue that a customer of a monopolistic supplier does not have incentives to invest in establishing creditworthiness with this supplier due to potential hold-up, which makes the supplier reluctant to offer trade credit. Dass et al. (2015) predict a negative relation between trade credit provision and supplier bargaining power in the context of relationship-specific investments. Fabbri and Klapper (2016) argue that more powerful suppliers are in a better position to require cash payments. Although the predictions and empirical findings of the three aforementioned papers may seem in contrast with our Prediction 1, they all emphasize a supplier's market power, whereas our focus is on a supplier's share of its customers' purchases.

Our second empirical prediction is based on Propositions 2 and 2a.

**Prediction 2.** *The ratio of trade credit received by a retailer to the cost of its purchases is positively related to the Herfindahl index of supplier shares of the retailer's purchases.*

The existing studies that we are aware of connecting trade credit provision to supplier concentration are Dass et al. (2015) and Fabbri and Klapper (2016). Both these papers argue that more powerful suppliers have a lesser need to provide trade credit, and a supplier's power increases with the concentration of its industry. Once again, this prediction and the evidence in its support are only seemingly in contrast with ours. We focus on the concentration of selling shares of all suppliers that sell to a given retailer, even if they operate in different industries, whereas Dass et al. (2015) and Fabbri and Klapper (2016) focus on the concentration of suppliers that belong to the same industry and may or may not sell to the same customers.

Our next two empirical predictions follow from Proposition 3.

**Prediction 3a.** *The ratio of trade credit provided by a supplier to its sales is negatively related to the average product substitutability among suppliers selling to the same retailers.*

**Prediction 3b.** *The ratio of trade credit received by a retailer to the cost of its purchases is negatively related to the average product substitutability among suppliers selling to that retailer.*

There are several theories that predict a positive relation between product differentiation in supplier industry and trade credit provision. According to Burkart and Ellingsen (2004), differentiated goods are more difficult to divert for private benefits by an opportunistic buyer, which makes suppliers of differentiated goods more willing to sell on credit. Cuñat (2007) argues that differentiated goods tend to be more buyer-specific, leading to higher switching costs for the buyer. As a result, a buyer of differentiated goods is less tempted to strategically default, which increases suppliers' willingness to offer trade credit. Chod et al. (2017) suggest that the generally lower liquidity of differentiated goods makes borrowing in kind more effective in signaling borrower's quality. Consistent with these predictions, the empirical relation between trade credit and product differentiation in supplier industry has been found positive (see, e.g., McMillan and Woodruff, 1999; Cuñat, 2007; Giannetti et al., 2011; Dass et al., 2015).

Although our predictions regarding trade credit provision and product substitutability may appear similar to those of Burkart and Ellingsen (2004), Cuñat (2007),

and Chod et al. (2017), they are fundamentally distinct from all of them. These theories tie the advantage of trade credit financing to the inherent nature of the transacted good, namely, its differentiation from all other goods in the supplier's industry. In contrast, our theory has to do with the relations among suppliers to a particular retailer, i.e., we relate trade credit to product substitutability among suppliers of a given retailer. This distinction is best illustrated by the following example. Suppose that a firm sources several commodity-like but mutually non-substitutable inputs, each from a different supplier. Given the commodity-like nature of the inputs, all of the aforementioned theories would predict little trade credit financing. Given that the inputs are not mutual substitutes, our theory predicts the opposite.

## 6. Empirical tests

### 6.1. Empirical specifications

We examine the model's predictions empirically employing the same data of 571 retailer-years and 2781 supplier-years that we use to calibrate the model. While our model is best suited to describe trade credit provided by suppliers to retailers, i.e., firms that resell suppliers' products to end consumers, we also test the model's predictions using alternative samples of corporate customers: (i) wholesalers, (ii) customers that are neither retailers nor wholesalers, and (iii) all corporate customers. The results for these alternative samples, reported in Table A6 in the Online Appendix, are generally weaker than those for the sample of retailers, but tend to remain statistically significant.

In addition, as we discussed in Section 3.4, our predictions are only relevant for the case in which the retailer's cost of bank credit and, thus, its demand for trade credit are high, resulting in trade credit being strategically rationed by suppliers. Therefore, we also test the model's predictions within a subsample of retailers paying relatively high (above median) interest rates on non-trade-credit debt. Consistent with our theory, we find that the empirical relations between supplier share concentration and supplier product substitutability on the one hand, and retailers' trade credit on the other, are indeed stronger within the high-interest-rate subsample. These robustness results are available in Table A7 in the Online Appendix.

According to Prediction 1, trade credit provided by a supplier is positively related to the supplier's average share of retailers' purchases. Prediction 3a states that a supplier's trade credit is negatively related to the substitutability of its products with those of suppliers selling to the same retailers. We test these predictions by estimating a regression of supplier $i$'s trade credit, $TC_i$, on proxies for the supplier's average share of its retailers' purchases, $\overline{SH_i}$, and for the average product substitutability between the supplier and other suppliers selling to the same retailers, $\overline{\gamma_i}$, while controlling for variables that have been found in past studies to be associated with trade credit, and which we denote by the vector $\mathbf{\Omega}_i$:

$$TC_i = \alpha + \beta_1 \overline{SH_i} + \beta_2 \overline{\gamma_i} + \beta_c' \mathbf{\Omega}_i + \epsilon_i. \tag{26}$$

According to Prediction 2, trade credit obtained by a retailer is positively related to the Herfindahl index of supplier shares of the retailer's purchases. Prediction 3b states that a retailer's trade credit is negatively related to the average product substitutability among its suppliers. We test these predictions by estimating a regression of trade credit obtained by retailer $j$, $TC_j$, on proxies for the retailer's Herfindahl index of supplier shares, $HHI_j$, and for the average substitutability among products of suppliers selling to the retailer, $\overline{\gamma_j}$, while controlling for other variables related to retailers' trade credit, $\mathbf{\Omega}_j$:

$$TC_j = \alpha + \beta_1 HHI_j + \beta_2 \overline{\gamma_j} + \beta_c' \mathbf{\Omega}_j + \epsilon_j. \tag{27}$$

We estimate the regressions in (26) and (27) with OLS using all supplier-year and retailer-year observations, respectively, while including year fixed effects and clustering standard errors by firm.

### 6.2. Variables

#### 6.2.1. Suppliers

*Dependent variable:* Following past studies (see, e.g., Petersen and Rajan, 1997; Giannetti et al., 2011), we define trade credit extended by supplier $i$, $TC_i$, as the ratio of supplier $i$'s accounts receivable, Compustat item RECT, and sales, item SALE. The ratio of trade credit to sales, as all other ratios, are winsorized at the 1*st* and 99*th* percentiles.

*Main independent variables:* In constructing the main independent variables, we need to account for the fact that any given supplier may sell to multiple retailers and face a different set of competitors in each instance. For every retailer in the sample, we identify suppliers that list that retailer as their principal customer. Then, for each supplier in this set, we record all retailers to which the supplier sells and all other suppliers selling to each of these retailers. We then test whether trade credit extended by supplier $i$ is (i) positively related to supplier $i$'s average share of purchases by all retailers to which supplier $i$ sells, and (ii) negatively related to the average substitutability between products of supplier $i$ and products of all other suppliers that sell to the same retailers as supplier $i$.

Note that this approach restricts our analysis to retailer-supplier pairs. In reality, however, suppliers may also sell to corporate customers that are not retailers. Relations with these customers may also influence the amount of trade credit that a supplier extends. Thus, we also examine robustness of our results within stricter samples in which retailers are responsible for at least 25%, 50%, or 100% of suppliers' sales. The results for these alternative samples are presented in Table A3 in the Online Appendix. Since we do not have information regarding sales of each supplier to each customer, we assume that a supplier's sales to each of its customers are proportional to that customer's overall purchases, measured by its cost of goods sold. The results based on these subsamples are similar to those based on the full sample of all suppliers.

*Average supplier share:* Absent information regarding sales of each supplier to each retailer, we proxy for supplier $i$'s share of retailer $j$'s purchases, $SH_{i,j}$, by the total sales of supplier $i$ over the total sales of all $N_j$ suppliers

selling to retailer $j$, i.e., $SH_{i,j} = \frac{SALES_i}{\sum_{k=1}^{N_j} SALES_k}$. To obtain supplier $i$'s average share of retailers' purchases, we average these shares over all $M_i$ retailers to which supplier $i$ sells:

$$\overline{SH_i} = \frac{\sum_{j=1}^{M_i} SH_{i,j}}{M_i}. \qquad (28)$$

Our results are also robust to using retailer-purchases-weighted average supplier share: $\overline{SH_i} = \frac{\sum_{j=1}^{M_i} SH_{i,j} COGS_j}{\sum_{j=1}^{M_i} COGS_j}$, where $COGS_j$ is the cost of goods sold by retailer $j$. The results for alternative specifications of independent variables are available in Table A2 in the Online Appendix.

*Average product substitutability:* As discussed in Section 4, we measure product substitutability between two suppliers by textual similarity of their product descriptions in 10K filings, provided by Jerry Hoberg and Gordon Phillips. We compute average product substitutability between supplier $i$ and other suppliers selling to the same retailers in two steps. First, we compute the average substitutability between products of supplier $i$ and products of the other $N_j - 1$ suppliers selling to retailer $j$ as $\overline{\gamma_{i,j}} = \frac{\sum_{i'=1, i' \neq i}^{N_j} \gamma_{i,i'}}{N_j - 1}$, where $\gamma_{i,i'}$ is the textual similarity between product descriptions of suppliers $i$ and $i'$, both of which sell to retailer $j$. We then compute the mean of the average substitutabilities across all $M_i$ retailers to which supplier $i$ sells:

$$\overline{\gamma_i} = \frac{\sum_{j=1}^{M_i} \overline{\gamma_{i,j}}}{M_i}. \qquad (29)$$

Our results are also robust to using retailer-purchases-weighted mean substitutability, computed as $\overline{\gamma_i} = \frac{\sum_{j=1}^{M_i} \overline{\gamma_{i,j}} COGS_j}{\sum_{j=1}^{M_i} COGS_j}$.

*Control variables:* Trade credit extended by suppliers to their customers may be related to the following factors.

*Suppliers' financing advantage over banks*, which is expected to be greater for suppliers of differentiated goods (see, e.g., Petersen and Rajan, 1997; Johnson et al., 2002; Cũnat, 2007; Giannetti et al., 2011) and suppliers of services (e.g., Giannetti et al., 2011). To control for the nature of transacted goods, we follow Giannetti et al. (2011) and include two indicator variables: a dummy equaling one if a supplier sells differentiated products and a dummy equaling one if it sells services, both based on industry classification of Rauch (1999).

*Suppliers' financial constraints*, which we measure by Hadlock and Pierce (2010) size-age index (see, e.g., Kieschnick et al., 2013; Dass et al., 2015).[7] Suppliers' ac-

cess to external financing also depends on their credit ratings, which we measure using a dummy variable equaling one if the supplier has an investment-grade credit rating, defined as BBB– or above (see, e.g., Campello et al., 2010; Lemmon and Roberts, 2010).[8] In addition, a supplier's ability to extend trade credit may depend on its liquidity and its leverage. We measure liquidity by the ratio of cash and marketable securities, Compustat item `CHE`, to book assets, item `AT`. Leverage is measured as the ratio of the sum of short-term and long-term debt, items `DLC` and `DLTT`, respectively, to the sum of short-term debt, long-term debt, and market value of equity, computed as the product of shares outstanding and the end-of-year price per share, items `CSHO` and `PRCC_C`, respectively.

*Suppliers' incentives to price discriminate*, which are increasing in supplier profitability, proxied by the ratio of operating income after depreciation, item `OIADP`, to sales, item `SALE` (e.g., Petersen and Rajan, 1997).

*Suppliers' growth*, which we measure as the ratio of sales, item `SALE`, to its lagged value minus one (e.g., Petersen and Rajan, 1997).

*Suppliers' relationship-specific investments*, which we proxy by R&D expenditures, item `XRD`, and advertising expenditures, item `XAD`, both normalized by book assets, as in Dass et al. (2015).

*Suppliers' market power*, which reduces the need to use trade credit as an incentive device (see, e.g., Dass et al., 2015; Fabbri and Klapper, 2016). We use two measures of supplier market power: the ratio of a supplier's sales to the total sales in its three-digit SIC industry, and the Herfindahl index of sales in the supplier's three-digit SIC industry.

### 6.2.2. Retailers

*Dependent variable:* Following (Giannetti et al., 2011), we measure trade credit received by retailer $j$, $TC_j$, as the ratio of the retailer's accounts payable, Compustat item `AP`, and the cost of goods sold, item `COGS`.

*Main independent variables:* We test whether trade credit received by retailer $j$ is (i) positively related to the Herfindahl index of supplier shares of retailer $j$'s purchases, and (ii) negatively related to the average substitutability among products of all suppliers selling to retailer $j$.

*Herfindahl index of supplier shares:* Recall our proxy for supplier $i$'s share of retailer $j$'s purchases, $SH_{i,j} = \frac{SALES_i}{\sum_{k=1}^{N_j} SALES_k}$, where $N_j$ is the number of suppliers selling to retailer $j$. The Herfindahl index of supplier shares for retailer $j$ is then computed as:

$$HHI_j = \frac{\sum_{i=1}^{N_j} SH_{i,j}^2}{\left( \sum_{i=1}^{N_j} SH_{i,j} \right)^2}. \qquad (30)$$

*Average product substitutability:* In our model, product substitutability is the same across all pairs of suppliers to

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[7] Given potential non-linearities in the relation between this index and trade credit, we use two dummy variables: a constrained dummy equaling one if the value of the supplier's Hadlock–Pierce index belongs to the top three deciles of the index's distribution in the given year, and an unconstrained dummy equaling one if the value of the index belongs to the bottom three deciles. The coefficients on the main independent variables are similar if the dummies are based on the Hadlock–Pierce index being above or below median as in Acharya et al. (2012), if we use the individual index components (size and age) as in Petersen and Rajan (1997),

or if we use the index itself. We perform similar robustness tests when examining trade credit obtained by retailers and find that the results for retailers are also robust to these changes in variable definitions.

[8] Our results are robust to using a dummy variable equaling one if the supplier has any credit rating instead of an investment-grade rating. A similar statement holds for the retailer regressions.

a given retailer. Since this is not the case in the data, we compute the average product substitutability among the $N_j$ suppliers selling to retailer $j$ as

$$\overline{\gamma_j} = \frac{\sum_{i=1}^{N_j} \sum_{i'=1, i' \neq i}^{N_j} \gamma_{i,i'}}{N_j(N_j - 1)}, \tag{31}$$

where $\gamma_{i,i'}$ is the textual similarity between product descriptions of suppliers $i$ and $i'$, both of which sell to retailer $j$. Our results are robust to using supplier-sales-weighted average product substitutability, defined as $\overline{\gamma_j} = \frac{\sum_{i=1}^{N_j} \sum_{i'=i, i' \neq i}^{N_j} \gamma_{i,i'} (SALES_i + SALES_{i'})}{\sum_{i=1}^{N_j} \sum_{i'=i, i' \neq i}^{N_j} (SALES_i + SALES_{i'})}$. The results for alternative specifications of independent variables are available in Table A5 in the Online Appendix.

*Control variables:* Trade credit received by retailers may be related to the following factors.

*Advantages of trade credit over bank credit*, which are expected to be greater for retailers purchasing a larger share of differentiated inputs and a lower share of service inputs (e.g., Giannetti et al., 2011), and those holding a lower share of finished goods inventories (e.g., Petersen and Rajan, 1997). To control for the nature of transacted goods, we use Rauch (1999) industry-wide estimates of proportions of differentiated and service inputs. To control for the proportion of inventories of finished goods out of total inventories, we compute the ratio of Compustat item INVFG and item INVT.

*Retailers' financial constraints*, which we measure using the Hadlock–Pierce index and credit rating. Because retailers' access to external financing could be related to their tangible assets, which are easier to collateralize, we also control for asset tangibility, defined as the ratio of physical capital stock over book assets, item AT. To measure a firm's stock of physical capital, we adopt a variant of perpetual inventory method.[9] In addition, retailers' access to external financing could be related to their liquidity and leverage, measured similarly to those of suppliers.

*Retailers' growth*, which we measure similarly to that of suppliers.

*Retailers' market power*, which could allow them to obtain more trade credit (e.g., Wilner, 2000), and which we proxy by the retailer's market share in its three-digit SIC industry as well as by the Herfindahl index of the retailer's three-digit SIC industry.

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[9] First, we calculate the three-digit SIC industry-average depreciation rate of physical capital for each year, where a firm's depreciation rate is the ratio of its accounting depreciation, item DP, and its beginning-of-year gross PP&E, item PPEGT. Second, we compute the firm's stock of physical capital in the following way. A firm's capital stock at the end of year 1, which is defined as the first year the firm appears in Compustat, is its gross PP&E depreciated with the industry-wide depreciation rate in year 1. Its capital stock at the end of any year $\tau > 1$ is the sum of the capital stock in year $\tau - 1$ and the capital investment in year $\tau$, computed as the difference between PPEGT in year $\tau$ and that in year $\tau - 1$, and depreciated with the industry-wide depreciation rate in year $\tau$. A similar method is frequently used for computing the stock of intangible capital (see, e.g., Hall et al., 2005; Hirshleifer et al., 2013) and organization capital (e.g., Eisfeldt and Papanikolaou, 2013). We obtain similar results if we use a fixed depreciation rate for all industries and years: 15% as in Hall et al. (2005), 20% as in Hirshleifer et al. (2013), as well as other rates ranging from 10% to 30%.

### 6.3. Summary statistics

Summary statistics are presented in Table 3, which contains two panels. Panel A reports statistics for 2781 supplier-years. Panel B presents statistics for 571 retailer-years.

The mean ratio of trade credit extended by suppliers to their sales is 0.16, whereas the mean ratio of trade credit received by retailers to their cost of goods sold is 0.23. This is consistent with Giannetti et al. (2011), who report that retailers tend to obtain more trade credit than other corporate customers.

The mean supplier share of retailers' purchases is slightly over 20%, consistent with roughly five suppliers per retailer in our sample. The mean Herfindahl index of supplier shares is around 30%, indicating relatively high supplier concentration for most retailers. The average product substitutability among suppliers of a given retailer varies considerably across retailers, with a standard deviation over twice the mean within the supplier sample and three times the mean within the sample of retailers.

Retailers in our sample are quite large–their mean assets are roughly 30 times larger than those of their suppliers, consistent with retailers being typically larger than other corporate customers and with the bias towards large customers in Cohen and Frazzini (2008) data. Retailers also tend to be much older than their suppliers. Retailers are somewhat more profitable than suppliers and grow at a slightly higher pace on average. The mean proportion of tangible assets is twice as large for retailers than for suppliers. Suppliers tend to hold larger liquid assets and tend to be more financially constrained than retailers, whereas the mean leverage is similar across the two groups. Suppliers and retailers have similar market shares in their industries, around 25% on average.

The magnitudes of the correlations between the focal independent variables, reported in Tables A1 and A4 in the Online Appendix, are low: the correlation between the mean supplier share and the mean substitutability of the supplier's products is 9% and that between the HHI of supplier shares and the mean product substitutability among suppliers of a given retailer is −7%.

### 6.4. Empirical results

#### 6.4.1. Suppliers

We first estimate the regression in (26) to test Prediction 1, i.e., a positive relation between a supplier's trade credit and its average share of retailers' purchases, $\overline{SH_i}$, and Prediction 3a, i.e., a negative relation between a supplier's trade credit and substitutability of its products with products of other suppliers that sell to the same retailers, $\overline{\gamma_i}$. The results are presented in Table 4, which has four columns.

In the first column, the set of independent variables includes only $\overline{SH_i}$ and $\overline{\gamma_i}$. In Column 2, we augment the regression with all of the control variables defined in Section 6.2.1. Despite the low correlation between $\overline{SH_i}$ and $\overline{\gamma_i}$, to ensure that inclusion of both does not bias the coefficient estimates, in Columns 3 and 4 we estimate the

**Table 3**

Suppliers and retailers: summary statistics.

This table presents summary statistics for the sample of suppliers in Panel A and for the sample of retailers in Panel B. The sample period is 1996–2009. The sample of suppliers includes 2781 observations of suppliers that sell to at least one retailer (NAICS two-digit industry 44 or 45) that has at least two suppliers. The sample of retailers includes 571 observations of retailers that have at least two suppliers. Customer-supplier links are based on the extended version of Cohen and Frazzini (2008) data set. Trade credit for suppliers is the ratio of accounts receivable, Compustat item `AR`, and book assets, item `AT`. Trade credit for retailers is the ratio of accounts payable, item `AP`, and book assets. Mean supplier share is computed as in (28). HHI of supplier shares is computed as in (30). Mean product substitutability is computed as in (29) for the sample of suppliers, and as in (31) for the sample of retailers. Book assets is item `AT`. Age is the difference between the year of the observation on the one hand and the founding year, incorporation year, or the year the firm first appears in CRSP/Compustat in this order of availability on the other hand. Profit margin is operating profitability, computed as the ratio of item `OIADP` to item `SALE`. Sales growth is year-to-year percentage change in `SALE`. Tangibility is the ratio of capital stock to book assets. Capital stock is estimated using the perpetual inventory model of PP&E, described in Section 6.2.2. Liquidity is the ratio of cash and marketable securities, item `CHE`, to book assets. Leverage is the ratio of the sum of short-term and long-term debt, items `DLC` and `DLTT`, respectively, and the sum of short-term debt, long-term debt, and the market value of equity, given by `CSHO` × `PRCC_C`. R&D is the ratio of R&D expenditures, item `XRD`, and book assets. Advertising is the ratio of advertising expenditures, item `XAD`, and book assets. Hadlock and Pierce (2010) index is computed as $(-0.737 \times Size) + (0.043 \times Size^2) - (0.040 \times Age)$, where size is measured as log book assets, inflation adjusted to 2004 and capped at \$4.5 billion, and age is capped at 37. Constrained (Unconstrained) is a dummy variable that equals one if the firm's Hadlock and Pierce index is in the top (bottom) deciles. Investment-grade rating is a dummy variable that equals one if the firm has a rating above BBB - . Rating present is a dummy variable that equals one if the firm has debt rating available. Standardized goods, differentiated goods, and services are dummy variables that equal one if the supplier belongs to the corresponding industry, according to Rauch (1999) classification. Proportions of standardized inputs, differentiated inputs, and service inputs are continuous variables ranging between zero and one, and defined in Rauch (1999). Proportion of finished inventory is the ratio of inventory of finished goods, item `INVFG`, to total inventory, item `INVT`. Industry share is the ratio of the firm's sales to total sales in the firm's three-digit SIC industry. Industry HHI is the Herfindahl index of sales within the firm's three-digit SIC industry. All ratios are winsorized at the 1% and 99% of their distributions.

| | Panel A: Suppliers | | | Panel B: Retailers | | |
|---|---|---|---|---|---|---|
| | Mean | Median | St. dev. | Mean | Median | St. dev |
| Trade credit | 0.159 | 0.142 | 0.117 | 0.234 | 0.110 | 0.303 |
| Mean supplier share | 0.211 | 0.204 | 0.366 | | | |
| HHI of supplier shares | | | | 0.317 | 0.296 | 0.299 |
| Mean product substitutability | 0.008 | 0.002 | 0.018 | 0.008 | 0.002 | 0.024 |
| Book assets | 3,431 | 267 | 43,201 | 98,636 | 9,041 | 318,826 |
| Age | 32.104 | 19 | 37.326 | 62.357 | 47 | 48.446 |
| Profit margin | 0.058 | 0.072 | 0.192 | 0.093 | 0.066 | 0.090 |
| Sales growth | 0.089 | 0.067 | 0.239 | 0.105 | 0.083 | 0.219 |
| Tangibility | 0.126 | 0.071 | 0.168 | 0.237 | 0.239 | 0.178 |
| Liquidity | 0.118 | 0.048 | 0.160 | 0.089 | 0.054 | 0.091 |
| Leverage | 0.267 | 0.210 | 0.246 | 0.256 | 0.170 | 0.228 |
| R&D | 0.021 | 0 | 0.062 | 0 | 0 | 0.006 |
| Advertising | 0.035 | 0.030 | 0.038 | 0.029 | 0.024 | 0.033 |
| Hadlock-Pierce index | −1.403 | −1.130 | 1.145 | −3.301 | −3.926 | 0.882 |
| Constrained | 0.311 | 0 | 0.463 | 0.007 | 0 | 0.083 |
| Unconstrained | 0.457 | 0 | 0.498 | 0.965 | 1 | 0.184 |
| Investment-grade rating | 0.141 | 0 | 0.348 | 0.559 | 1 | 0.497 |
| Rating present | 0.207 | 0 | 0.405 | 0.709 | 1 | 0.454 |
| Standardized goods | 0.401 | 0 | 0.490 | | | |
| Differentiated goods | 0.313 | 0 | 0.464 | | | |
| Services | 0.176 | 0 | 0.381 | | | |
| Proportion standardized inputs | | | | 0.550 | 0.620 | 0.192 |
| Proportion differentiated inputs | | | | 0.264 | 0.290 | 0.095 |
| Proportion services inputs | | | | 0.077 | 0.090 | 0.030 |
| Proportion finished inventory | 0.436 | 0.504 | 0.361 | 0.059 | 0 | 0.235 |
| Industry share | 0.252 | 0.205 | 0.197 | 0.256 | 0.191 | 0.180 |
| Industry HHI | 0.089 | 0.013 | 0.180 | 0.236 | 0.182 | 0.207 |
| # Obs. | | 2,781 | | | 571 | |

regression while including only one of these two focal independent variables at a time, along with control variables.

Consistent with Prediction 1, the coefficient on $\overline{SH_i}$ is positive and significant at 10% level regardless of the inclusion of the other independent variables. The economic effect of a supplier's average share of its retailers' purchases on trade credit extended by that supplier is not negligible: A one-standard-deviation increase in $\overline{SH_i}$ is associated with an 8% (9%) standard-deviation increase in trade credit in the absence (presence) of control variables. The fact that the economic effect is around five times lower than in the regressions based on simulated data in Section 4, suggests that managers incorporate strategic considerations into their trade credit decisions only par-

tially, and/or trade credit and the supplier's competitive position at the customer level are linked through other channels that are not captured by our model.

Consistent with Prediction 3a, the coefficient on $\overline{\gamma_i}$ is negative and highly statistically significant in all specifications. Economically, a one-standard-deviation increase in $\overline{\gamma_i}$ is associated with a 10–11% standard-deviation reduction in trade credit. Again, the fact that these figures are an order of magnitude lower than those estimated with simulated data suggests that the relation between substitutability among suppliers' products and trade credit that these suppliers extend may have additional facets that are not captured by our model. A comparison of the coefficients on $\overline{SH_i}$ and $\overline{\gamma_i}$ in Columns 3 and 4 with those in Column

**Table 4**

Supplier trade credit, supplier share, and product substitutability.

This table presents the results of estimating the regression of suppliers' trade credit in (26). See Table 3 for the variable definitions. The sample period is 1996–2009. The sample includes 2781 observations of suppliers that sell to at least one retailer that has at least two suppliers. The regressions include year fixed effects and are estimated using OLS. Standard errors are clustered by supplier. *t*-statistics are reported in parentheses.

|  | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Intercept | 0.180 | 0.172 | 0.164 | 0.174 |
|  | (54.33) | (24.76) | (21.81) | (24.50) |
| Mean supplier share | 0.024 | 0.029 | 0.024 |  |
|  | (1.75) | (2.01) | (1.66) |  |
| Mean product substitutability | −0.731 | −0.687 |  | −0.638 |
|  | (−6.19) | (−5.15) |  | (−5.29) |
| Differentiated goods |  | 0.039 | 0.042 | 0.040 |
|  |  | (13.31) | (13.94) | (14.08) |
| Services |  | 0.010 | 0.014 | 0.014 |
|  |  | (2.25) | (2.96) | (2.78) |
| Unconstrained |  | 0.005 | 0.006 | 0.005 |
|  |  | (2.10) | (2.38) | (2.04) |
| Constrained |  | 0.001 | 0.002 | 0.002 |
|  |  | (0.16) | (0.27) | (0.26) |
| Investment-grade rating |  | 0.002 | 0.005 | 0.004 |
|  |  | (0.23) | (0.70) | (0.51) |
| Liquidity |  | 0.014 | 0.009 | 0.014 |
|  |  | (0.71) | (0.47) | (0.69) |
| Leverage |  | −0.061 | −0.063 | −0.060 |
|  |  | (−4.01) | (−4.29) | (−3.88) |
| Profit margin |  | −0.025 | −0.026 | −0.023 |
|  |  | (−0.82) | (−0.85) | (−0.75) |
| Sales growth |  | 0.035 | 0.035 | 0.036 |
|  |  | (3.44) | (3.34) | (3.42) |
| Advertising |  | 0.035 | 0.047 | 0.041 |
|  |  | (1.49) | (2.01) | (1.84) |
| R&D |  | −0.022 | −0.031 | −0.024 |
|  |  | (−0.47) | (−0.64) | (−0.52) |
| Supplier industry share |  | −0.012 | −0.017 | −0.008 |
|  |  | (−1.33) | (−1.70) | (−0.90) |
| Supplier industry HHI |  | −0.079 | −0.072 | −0.080 |
|  |  | (−7.60) | (−7.10) | (−7.59) |
| # Obs. | 2781 | 2781 | 2781 | 2781 |
| *R* squared | 1.84% | 9.83% | 9.74% | 9.52% |

1 suggests that neither of our proxies for the main independent variables substantially alters the relation between trade credit and the proxy for the other main independent variable.

To further ensure that one of the main independent variables is not capturing the measurement error of the other, we also augment the regression in (26) by including quadratic and cubic terms of average product substitutability and average supplier share. The estimates of these augmented regressions, available in Table A8 in the Online Appendix, show that the coefficients on the linear terms and their statistical significance do not change substantially following the inclusion of the higher-order terms. The coefficients on the quadratic terms are either statistically insignificant or have the same sign as the linear term coefficients. The coefficients on the cubic terms are all insignificant. These results suggest that neither of the main independent variables is likely to capture the measurement error of the other.

The coefficients on control variables are generally in line with existing theories and evidence. Suppliers of differentiated goods and services extend more trade credit

than suppliers of standardized goods, consistent with trade credit theories based on borrower opportunism and suppliers' informational advantage. Financially unconstrained suppliers tend to provide more trade credit. Trade credit provision is negatively associated with suppliers' leverage, suggesting that firms closer to their debt capacity are more constrained in offering credit. Growing suppliers provide more trade credit, consistent with their increasing sales being partially fueled by trade credit provision. Advertising is positively associated with trade credit, consistent with the use of trade credit as a commitment device for relationship-specific investments. The concentration of suppliers' industries exhibits a strong negative relation with trade credit, consistent with the supplier market power hypothesis. At the same time, judging from the negative and insignificant coefficients on suppliers' profit margin, we do not find support for the price discrimination hypothesis.

### 6.4.2. Retailers

Next, we estimate the regression in (27) to test Prediction 2, i.e., a positive relation between trade credit received by a retailer and the Herfindahl index of supplier shares of the retailer's purchases, $HHI_j$, and Prediction 3b, i.e., a negative relation between trade credit received by a retailer and the mean product substitutability among the retailer's suppliers, $\overline{\gamma_j}$. The results are presented in Table 5, whose layout is similar to that of Table 4.

The association between the concentration of a retailer's suppliers, $HHI_j$, and the trade credit that the retailer obtains is positive and highly statistically significant. A one-standard-deviation increase in $HHI_j$ is associated with 9–14% standard-deviation increase in the retailer's trade credit. Average product substitutability among a retailer's suppliers is negatively and significantly related to the trade credit obtained by the retailer. The economic significance of the coefficient on $\overline{\gamma_j}$ is consistent with the estimates in Table 4: A one-standard-deviation increase in $\overline{\gamma_j}$ is associated with 8–16% standard-deviation decrease in the retailer's trade credit.

Similar to the case of suppliers, removing one of the two main independent variables from the regression, as well as augmenting the regression by higher-order terms of the main independent variables does not affect the estimates materially. The results of these augmented regressions are available in Table A9 in the Online Appendix. As in the case of suppliers' trade credit regressions, the coefficients on control variables tend to be consistent with past studies and existing theories. Trade credit received by a retailer is negatively related to the proportion of finished goods in the retailer's inventories, consistent with suppliers having a greater advantage over banks in liquidating inventories of raw materials. Trade credit is positively related to the proportion of differentiated inputs, consistent with the moral hazard and information asymmetry theories. Trade credit is negatively related to the proportion of service inputs, for which suppliers' advantage in liquidating repossessed inventory becomes irrelevant. Consistent with the demand for trade credit hypothesis, financially constrained and highly levered retailers use more trade credit, whereas retailers with more tangible assets that

**Table 5**

Retailer trade credit, HHI of supplier shares, and product substitutability.

This table presents the results of estimating the regression of retailers' trade credit in (27). See Table 3 for the variable definitions. The sample period is 1996–2009. The sample includes 571 observations of retailers that have at least two suppliers. The regressions include year fixed effects and are estimated using OLS. Standard errors are clustered by retailer. *t*-statistics are reported in parentheses.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Intercept | 0.202 | 0.651 | 0.635 | 0.552 |
| | (14.22) | (11.82) | (12.46) | (11.88) |
| HHI of supplier shares | 0.139 | 0.091 | 0.104 | |
| | (4.95) | (3.23) | (3.62) | |
| Mean product | −2.057 | −1.034 | | −1.221 |
| substitutability | (−8.05) | (−2.24) | | (−2.61) |
| Proportion finished | | −0.019 | −0.016 | −0.020 |
| inventory | | (−2.02) | (−2.62) | (−2.00) |
| Proportion | | 1.511 | 1.493 | 1.335 |
| differentiated inputs | | (13.64) | (13.54) | (12.83) |
| Proportion service | | −0.992 | −0.991 | −0.913 |
| inputs | | (−9.57) | (−10.40) | (−10.63) |
| Unconstrained | | −0.013 | −0.003 | −0.013 |
| | | (−0.31) | (−0.08) | (−0.31) |
| Constrained | | 0.035 | 0.041 | 0.031 |
| | | (1.74) | (1.85) | (1.64) |
| Investment-grade | | 0.048 | 0.049 | 0.066 |
| rating | | (4.07) | (4.15) | (5.85) |
| Liquidity | | 0.049 | 0.036 | 0.081 |
| | | (0.69) | (0.50) | (1.24) |
| Leverage | | 0.188 | 0.190 | 0.214 |
| | | (5.82) | (6.02) | (6.64) |
| Tangibility | | −0.336 | −0.336 | −0.332 |
| | | (−10.15) | (−10.51) | (−9.83) |
| Sales growth | | 0.062 | 0.060 | 0.060 |
| | | (2.61) | (2.42) | (2.44) |
| Retailer industry share | | 0.061 | 0.054 | 0.038 |
| | | (3.16) | (2.56) | (2.13) |
| Retailer industry HHI | | −0.012 | −0.005 | 0.026 |
| | | (−0.53) | (−0.23) | (1.36) |
| # Obs. | 571 | 571 | 571 | 571 |
| *R* squared | 6.48% | 78.86% | 77.79% | 78.13% |

could be used as collateral for bank credit use less trade credit. Inconsistent with this hypothesis, however, retailers with investment-grade rating, which are likely to have access to other sources of financing, obtain more trade credit. Retailers with growing sales tend to rely more on trade credit. Finally, consistent with the market power hypothesis, retailers with larger market power within their industries receive more trade credit.

Overall, the empirical relations between the distribution of suppliers' selling shares and substitutability among their products on the one hand, and trade credit provided by suppliers to retailers on the other, are consistent with the model's predictions. We interpret these findings as being suggestive of suppliers taking into account strategic interactions with other suppliers that sell to the same customers, when making trade credit decisions.

## 7. Conclusion

In this paper we examine the effect of competition among suppliers on their willingness to provide trade credit. Our theory is based on the observation that when a supplier provides trade credit to a cash constrained retailer, the latter can use the freed-up liquidity to in-

crease cash purchases from other suppliers. This creates a free rider problem, whereby each supplier providing trade credit incurs the full cost of doing so, but internalizes only a part of the benefit.

The portion of this benefit that is internalized by the trade creditor increases with the trade creditor's share of the retailer's purchases. As a result, a supplier responsible for a larger share of a retailer's purchases is willing to finance a larger portion of its sales to this retailer by trade credit. For a similar reason, a retailer with more concentrated supplier shares receives more trade credit. The free rider problem is exacerbated when suppliers sell substitutable products and, therefore, compete not only for retailers' cash but also for end consumers. Therefore, the greater the product substitutability among suppliers selling to a given retailer, the less trade credit they are willing to provide to this retailer.

We calibrate the model and use simulated data, in which all factors related to trade credit extraneous to the model are shut off, to show that the relations predicted by the model are economically significant. We also provide suggestive empirical evidence indicating that the relations between the distribution of supplier shares and substitutability among suppliers' products on the one hand and trade credit on the other, are consistent with our model, statistically significant, and economically sizable.

## Appendix A. Proofs

**Proof of Lemma 1**

The optimal $\mathbf{x}^*(\mathbf{w}, \mathbf{T})$ is given by $\partial \Pi_R(\mathbf{x}, \mathbf{T}, \mathbf{w})/\partial x_j = 0$ for all $j = 1, \ldots, N$, where $\Pi_R$ is given in Eq. (4). Thus, $\mathbf{x}^*(\mathbf{w}, \mathbf{T})$ must satisfy

$$\alpha_j - w_j - \frac{2}{t}\left(x_j + \gamma \sum_{i=1, i \neq j}^{N} x_i\right)$$
$$- t\theta_R w_j \left(1 - \left(\frac{\sum_{i=1}^{N} T_i}{\sum_{i=1}^{N} w_i x_i}\right)^2\right) = 0 \text{ for } j = 1, \ldots, N. \tag{32}$$

With $N = 1$, we can drop the product/supplier index and Eq. (32) becomes

$$\alpha - w - \frac{2x}{t} - t\theta_R w \left(1 - \left(\frac{T}{wx}\right)^2\right) = 0, \tag{33}$$

which directly gives

$$\frac{\partial x}{\partial T} = \frac{t^2 \theta_R \frac{T}{wx^2}}{1 + t^2 \theta_R \frac{T^2}{wx^3}} \tag{34}$$

$$\frac{\partial x}{\partial w} = -\frac{1 + t\theta_R + t\theta_R \frac{T^2}{w^2 x^2}}{\frac{2}{t} + 2t\theta_R \frac{T^2}{wx^3}}. \tag{35}$$

As $t \to 0$, this becomes

$$\frac{1}{t}\frac{\partial x}{\partial T} \to t\theta_R \frac{T}{wx^2}, \tag{36}$$

$$\frac{1}{t}\frac{\partial x}{\partial w} \to -\frac{1}{2}. \tag{37}$$

The supplier's payoff (56) is

$$\Pi_S = (w - c)x + t\theta_T T - t\theta_S \frac{(cx - wx + T)^2}{cx}, \tag{38}$$

and the optimality conditions for $w^*$ and $T^*$ are

$$\frac{d\Pi_S}{dT} = t\theta_T - 2t\theta_S \frac{(cx - wx + T)}{cx}$$
$$+ \frac{\partial x}{\partial T}\left((w - c) - t\theta_S c \frac{(cx - wx)^2 - T^2}{(cx)^2}\right) = 0, \tag{39}$$

$$\frac{d\Pi_S}{dw} = x + 2t\theta_S \frac{(cx - wx + T)x}{cx}$$
$$+ \frac{\partial x}{\partial w}\left((w - c) - t\theta_S c \frac{(cx - wx)^2 - T^2}{(cx)^2}\right) = 0. \tag{40}$$

As $t \to 0$, this becomes

$$\theta_T - 2\theta_S \frac{(cx - wx + T)}{cx} + \frac{1}{t}\frac{\partial x}{\partial T}(w - c) = 0, \tag{41}$$

$$\frac{x}{t} + \frac{1}{t}\frac{\partial x}{\partial w}(w - c) = 0. \tag{42}$$

Finally, as $t \to 0$, Eq. (33) becomes

$$\frac{x}{t} = \frac{\alpha - w}{2}. \tag{43}$$

Combining Eqs. (36)–(43) gives the desired result.

**Proof of Proposition 1**

The retailer's optimality conditions (32) can be written as

$$\alpha_j - w_j - \frac{2}{t}\left((1 - \gamma)x_j + \gamma \sum_{i=1}^{N} x_i\right)$$
$$- t\theta_R w_j \left(1 - \left(\frac{\sum_{i=1}^{N} T_i}{\sum_{i=1}^{N} w_i x_i}\right)^2\right) = 0 \text{ for } j = 1, \ldots, N. \tag{44}$$

Taking the total derivative of (44) with respect to $T_k$ gives

$$-\frac{2}{t}(1 - \gamma)\frac{\partial x_j}{\partial T_k} - \frac{2}{t}\gamma \sum_{i=1}^{N} \frac{\partial x_i}{\partial T_k}$$
$$+ 2t\theta_R w_j \frac{\sum_{i=1}^{N} T_i}{\sum_{i=1}^{N} w_i x_i} \frac{\sum_{i=1}^{N} w_i x_i - \sum_{i=1}^{N} T_i \sum_{i=1}^{N} w_i \frac{\partial x_i}{\partial T_k}}{\left(\sum_{i=1}^{N} w_i x_i\right)^2} = 0 \tag{45}$$

for $j = 1, \ldots, N$. Taking the total derivative of (44) w.r.t. $w_k$ gives

$$1 + \frac{2}{t}\left((1 - \gamma)\frac{\partial x_k}{\partial w_k} + \gamma \sum_{i=1}^{N} \frac{\partial x_i}{\partial w_k}\right) + t\theta_R - t\theta_R \frac{\left(\sum_{i=1}^{N} T_i\right)^2}{\left(\sum_{i=1}^{N} w_i x_i\right)^2}$$
$$+ 2t\theta_R w_k \frac{\left(\sum_{i=1}^{N} T_i\right)^2 \left(x_k + \sum_{i=1}^{N} w_i \frac{\partial x_i}{\partial w_k}\right)}{\left(\sum_{i=1}^{N} w_i x_i\right)^3} = 0, \tag{46}$$

and

$$\frac{2}{t}\left((1 - \gamma)\frac{\partial x_j}{\partial w_k} + \gamma \sum_{i=1}^{N} \frac{\partial x_i}{\partial w_k}\right)$$
$$+ 2t\theta_R w_j \frac{\left(\sum_{i=1}^{N} T_i\right)^2 \left(x_k + \sum_{i=1}^{N} w_i \frac{\partial x_i}{\partial w_k}\right)}{\left(\sum_{i=1}^{N} w_i x_i\right)^3} = 0 \tag{47}$$

for $k = j$ and $k \neq j$, respectively.

As $t \to 0$, conditions (44) simplify into

$$\alpha_j - w_j - \frac{2}{t}\left((1 - \gamma)x_j + \gamma \sum_{i=1}^{N} x_i\right) = 0 \text{ for all } j. \tag{48}$$

As $t \to 0$, conditions (45) simplify into

$$(1 - \gamma)\frac{1}{t}\frac{\partial x_j}{\partial T_k} + \gamma \sum_{i=1}^{N} \frac{1}{t}\frac{\partial x_i}{\partial T_k} - t\theta_R w_j \frac{\sum_{i=1}^{N} T_i}{\left(\sum_{i=1}^{N} w_i x_i\right)^2} = 0$$
$$\text{for all } j \text{ and } k. \tag{49}$$

As $t \to 0$, conditions (46) and (47) simplify into

$$\frac{1}{2} + (1 - \gamma)\frac{1}{t}\frac{\partial x_k}{\partial w_k} + \gamma \sum_{i=1}^{N} \frac{1}{t}\frac{\partial x_i}{\partial w_k} = 0 \text{ for all } k, \text{ and} \tag{50}$$

$$(1 - \gamma)\frac{1}{t}\frac{\partial x_j}{\partial w_k} + \gamma \sum_{i=1}^{N} \frac{1}{t}\frac{\partial x_i}{\partial w_k} = 0 \text{ for all } j \text{ and } k \neq j. \tag{51}$$

Summing Eq. (49) over all $j$'s, we obtain

$$\sum_{i=1}^{N} \frac{1}{t}\frac{\partial x_i}{\partial T_k} = t\theta_R \frac{\sum_{i=1}^{N} T_i \sum_{i=1}^{N} w_i}{(1 - \gamma + \gamma N)\left(\sum_{i=1}^{N} w_i x_i\right)^2}. \tag{52}$$

Combining (49) and (52) gives

$$\frac{1}{t}\frac{\partial x_k}{\partial T_k} = t\frac{\theta_R}{1 - \gamma}\left(w_k - \frac{\gamma \sum_{i=1}^{N} w_i}{(1 - \gamma + \gamma N)}\right)\frac{\sum_{i=1}^{N} T_i}{\left(\sum_{i=1}^{N} w_i x_i\right)^2}$$
$$\text{for all } k. \tag{53}$$

Summing Eqs. (50) and (51) over all $j$'s, we obtain

$$\sum_{i=1}^{N} \frac{1}{t}\frac{\partial x_i}{\partial w_k} = -\frac{1}{2}\frac{1}{1 - \gamma + N\gamma}. \tag{54}$$

Combining (51) and (54) gives

$$\frac{1}{t}\frac{\partial x_k}{\partial w_k} = \frac{1}{2(1 - \gamma)}\left(\frac{\gamma}{1 - \gamma + N\gamma} - 1\right) \text{ for all } k. \tag{55}$$

The objective of supplier $k$ can be written as

$$\Pi_{S_k} = (w_k - c_k)x_k^* + r_T T_k - t\theta_S \frac{\left(c_k x_k^* - w_k x_k^* + T_k\right)^2}{c_k x_k^*}, \tag{56}$$

and the optimality conditions for $w_k^*$ and $T_k^*$ are

$$\frac{d\Pi_{S_k}}{dT_k} = \frac{\partial \Pi_{S_k}}{\partial T_k} + \frac{\partial x_k}{\partial T_k}\frac{\partial \Pi_{S_k}}{\partial x_k} = 0, \text{ and} \tag{57}$$

$$\frac{d\Pi_{S_k}}{dw_k} = \frac{\partial \Pi_{S_k}}{\partial w_k} + \frac{\partial x_k}{\partial w_k}\frac{\partial \Pi_{S_k}}{\partial x_k} = 0. \tag{58}$$

Taking the derivatives, conditions (57) and (58) become

$$\frac{d\Pi_{S_k}}{dT_k} = -2t\theta_S \frac{(c_k x_k - w_k x_k + T_k)}{c_k x_k} + r_T$$
$$+ \frac{\partial x_k}{\partial T_k}\left(w_k - c_k - t\theta_S \frac{(c_k x_k - w_k x_k)^2 - T_k^2}{(c_k x_k)^2}c_k\right) = 0, \text{ and}$$
(59)

$$\frac{d\Pi_{S_k}}{dw_k} = x_k + 2t\theta_S \frac{(c_k x_k - w_k x_k + T_k)x_k}{c_k x_k}$$
$$+ \frac{\partial x_k}{\partial w_k}\left(w_k - c_k - t\theta_S \frac{(c_k x_k - w_k x_k)^2 - T_k^2}{(c_k x_k)^2}c_k\right) = 0. \quad (60)$$

As $t \to 0$, conditions (59) and (60) simplify into

$$-2\theta_S \frac{c_k x_k - w_k x_k + T_k}{c_k x_k} + \theta_T + \frac{1}{t}\frac{\partial x_k}{\partial T_k}(w_k - c_k) = 0, \text{ and}$$
(61)

$$\frac{1}{t}x_k + \frac{1}{t}\frac{\partial x_k}{\partial w_k}(w_k - c_k) = 0, \quad (62)$$

where $\frac{1}{t}\frac{\partial x_k}{\partial T_k}$ and $\frac{1}{t}\frac{\partial x_k}{\partial w_k}$ are given by (53) and (55), respectively. Using Eq. (61), we obtain

$$\frac{T_k}{w_k x_k} \to \frac{2\theta_S(w_k - c_k) + \theta_T c_k + \frac{1}{t}\frac{\partial x_k}{\partial T_k}(w_k - c_k)c_k}{2\theta_S w_k}. \quad (63)$$

Combining (48), (55), and (62) gives us

$$w_k \to \frac{\left(m + 1 - \frac{\gamma}{1-\gamma+N\gamma}\right)c_k - 2\gamma\frac{1}{t}\sum_{i=1}^N x_i}{2 - \frac{\gamma}{1-\gamma+N\gamma}}. \quad (64)$$

Now suppose that $\gamma = 0$. Using Eqs. (53), (63), (48), and (64), as $t \to 0$, we have $\frac{1}{t}x_k \to \frac{m-1}{4}c_k$, $w_k \to \frac{m+1}{2}c_k$, and

$$\frac{T_k}{w_k x_k} \to \left(\frac{m-1}{m+1} + \frac{\theta_T}{\theta_S}\frac{1}{m+1}\right)$$
$$+ \frac{\theta_R}{2\theta_S}\frac{\sum_{i=1}^N T_i}{\left(\sum_{i=1}^N w_i x_i\right)^2}w_k x_k \frac{4}{m+1} \implies \quad (65)$$

$$\frac{1}{t}T_k \to w_k \frac{1}{t}x_k\left(\frac{m-1}{m+1} + \frac{\theta_T}{\theta_S}\frac{1}{m+1}\right)$$
$$+ \frac{\theta_R}{2\theta_S}\frac{\frac{1}{t}\sum_{i=1}^N T_i}{\left(\sum_{i=1}^N w_i x_i\right)^2}(w_k x_k)^2\frac{4}{m+1}. \quad (66)$$

Summing Eq. (66) over $k = 1, \ldots, N$, we get

$$\frac{1}{t}\sum_{k=1}^N T_k \to \left(\frac{m-1}{m+1} + \frac{\theta_T}{\theta_S}\frac{1}{m+1}\right)\frac{1}{t}\sum_{k=1}^N w_k x_k$$
$$+ \frac{2}{m+1}\frac{\theta_R}{\theta_S}HHI\frac{1}{t}\sum_{k=1}^N T_k \implies \quad (67)$$

$$\frac{1}{t}\sum_{k=1}^N T_k \to \frac{\left(\frac{m-1}{m+1} + \frac{\theta_T}{\theta_S}\frac{1}{m+1}\right)}{\left(1 - \frac{2}{m+1}\frac{\theta_R}{\theta_S}HHI\right)}\frac{1}{t}\sum_{k=1}^N w_k x_k. \quad (68)$$

Combining Eqs. (68) and (65) yields the desired result.

**Proof of Proposition 2**

Suppose $\gamma = 0$. It follows from Eqs. (48) and (64) that as $t \to 0$, we have $\frac{1}{t}x_k \to \frac{m-1}{4}c_k$ and $w_k \to \frac{m+1}{2}c_k$ for all $k = 1, \ldots, N$. It also follows from Eqs. (53) and (63) that

$$\frac{1}{t}T_k \to \frac{1}{t}(w_k - c_k)x_k + \frac{1}{t}\frac{\theta_T}{2\theta_S}c_k x_k$$
$$+ \frac{\theta_R}{2\theta_S}w_k\frac{\sum_{i=1}^N T_i}{\left(\sum_{i=1}^N w_i x_i\right)^2}(w_k - c_k)c_k x_k. \quad (69)$$

Summing Eq. (69) over all $k$'s gives

$$\frac{1}{t}\sum_{k=1}^N T_k \to \frac{1}{t}\sum_{k=1}^N(w_k - c_k)x_k + \frac{1}{t}\frac{\theta_T}{2\theta_S}\sum_{k=1}^N c_k x_k$$
$$+ \frac{\theta_R}{2\theta_S}\frac{\sum_{i=1}^N T_i}{\left(\sum_{i=1}^N w_i x_i\right)^2}\sum_{k=1}^N w_k(w_k - c_k)c_k x_k. \quad (70)$$

Therefore,

$$\frac{\sum_{k=1}^N T_k}{\sum_{k=1}^N w_k x_k} \to \frac{\theta_S\frac{\sum_{k=1}^N(w_k-c_k)x_k}{\sum_{k=1}^N w_k x_k} + \frac{\theta_T}{2}\frac{\sum_{k=1}^N c_k x_k}{\sum_{k=1}^N w_k x_k}}{\theta_S - t\frac{\theta_R}{2}\frac{\sum_{k=1}^N w_k(w_k-c_k)c_k x_k}{\left(\sum_{k=1}^N w_k x_k\right)^2}}. \quad (71)$$

Substituting for $\frac{1}{t}x_k = \frac{m-1}{4}c_k$ and $w_k = \frac{m+1}{2}c_k$ gives the desired result.

**Proof of Proposition 1a**

Suppose $t \to 0$ and $\alpha_k > \alpha_l$. It follows from Eq. (63) that $\frac{T_k}{w_k x_k} > \frac{T_l}{w_l x_l}$ if and only if

$$\frac{2\theta_S(w_k - c_k) + \theta_T c_k + \frac{1}{t}\frac{\partial x_k}{\partial T_k}(w_k - c_k)c_k}{2\theta_S w_k}$$
$$> \frac{2\theta_S(w_l - c_l) + \theta_T c_l + \frac{1}{t}\frac{\partial x_l}{\partial T_l}(w_l - c_l)c_l}{2\theta_S w_l} \quad (72)$$

$$\iff (2\theta_S - \theta_T)\frac{w_k}{c_k} + \frac{1}{t}\frac{\partial x_k}{\partial T_k}(w_k - c_k)\frac{w_l}{c_l}$$
$$> (2\theta_S - \theta_T)\frac{w_l}{c_l} + \frac{1}{t}\frac{\partial x_l}{\partial T_l}(w_l - c_l)\frac{w_k}{c_k}. \quad (73)$$

Given that $2\theta_S > \theta_T$, which follows from Eq. (10), it is enough to show that $\frac{w_k}{c_k} > \frac{w_l}{c_l}$ and $\frac{1}{t}\frac{\partial x_k}{\partial T_k}(w_k - c_k)\frac{w_l}{c_l} > \frac{1}{t}\frac{\partial x_l}{\partial T_l}(w_l - c_l)\frac{w_k}{c_k}$. The first inequality follows directly from Eq. (64). The second inequality can be rewritten using (53) as

$$\left(1 - \frac{1}{w_k}\frac{\gamma\sum_{i=1}^N w_i}{(1 - \gamma + \gamma N)}\right)(w_k - c_k)c_k$$
$$> \left(1 - \frac{1}{w_l}\frac{\gamma\sum_{i=1}^N w_i}{(1 - \gamma + \gamma N)}\right)(w_l - c_l)c_l. \quad (74)$$

This last inequality follows from the fact that $c_k > c_l$ and Eq. (64). Thus, we have shown that $\alpha_k > \alpha_l \iff \frac{T_k^*}{w_k^* x_k^*} > \frac{T_l^*}{w_l^* x_l^*}$, and it remains to show that $\alpha_k > \alpha_l \iff w_k^* x_k^* > w_l^* x_l^*$. It follows directly from Eq. (64) that $\alpha_k > \alpha_l \iff w_k^* > w_l^*$. Combining Eqs. (64) and (48) yields

$$\frac{1}{t}x_k \to \frac{1}{2(1-\gamma)}\left(c_k(m-1) - \frac{1}{t}2\gamma\sum_{i=1}^{N}x_i\right)\frac{1 - \frac{\gamma}{1-\gamma+N\gamma}}{2 - \frac{\gamma}{1-\gamma+N\gamma}}. \tag{75}$$

Thus, $\alpha_k > \alpha_l \iff x_k^* > x_l^*$, which completes the proof.

**Proof of Proposition 2a**

When suppliers are symmetrical, the share of each decreases in the total number of suppliers. Thus, we need to prove $\frac{d}{dN}\frac{T^*}{w^*x^*} < 0$. It follows from Eqs. (48) and (64) that as $t \to 0$,

$$w \to \frac{\alpha(1-\gamma) + c(1-2\gamma+\gamma N)}{2-3\gamma+\gamma N}, \text{ and} \tag{76}$$

$$\frac{1}{t}x \to \frac{1}{2}\frac{(\alpha-c)(1-2\gamma+N\gamma)}{(2-3\gamma+\gamma N)(1-\gamma+\gamma N)}. \tag{77}$$

It further follows from Eqs. (53) and (63) that

$$\frac{T}{wx} \to \frac{\theta_S(w-c) + \frac{\theta_T}{2}c}{\theta_S w - \theta_R c\frac{(1-\gamma)c}{N(1-2\gamma+\gamma N)}}. \tag{78}$$

We have $\frac{d}{dN}\frac{T}{wx} = \frac{\partial}{\partial N}\frac{T}{wx} + \frac{\partial w}{\partial N}\frac{\partial}{\partial w}\frac{T}{wx}$. It follows from Eq. (78) that $\frac{\partial}{\partial N}\frac{T}{wx} < 0$. Using Eq. (76), we have

$$\frac{\partial w}{\partial N} = -\frac{(1-\gamma)\gamma(\alpha-c)}{(2-3\gamma+\gamma N)^2} < 0. \tag{79}$$

Finally, using Eq. (78), we have

$$\frac{\partial}{\partial w}\frac{T}{wx} = \theta_S\frac{\left(\theta_S w - \theta_R\frac{(1-\gamma)c}{N(1-2\gamma+\gamma N)}\right) - \left(\theta_S(w-c) + \frac{\theta_T}{2}c\right)}{\left(\theta_S w - \theta_R\frac{(1-\gamma)c}{N(1-2\gamma+\gamma N)}\right)^2}. \tag{80}$$

The fact that $\frac{T}{wx} \in (0,1)$ implies $\theta_S w - \theta_R\frac{(1-\gamma)c}{N(1-2\gamma+\gamma N)} > \theta_S(w-c) + \frac{\theta_T}{2}c$, which in turn implies $\frac{\partial}{\partial w}\frac{T}{wx} > 0$. Therefore, $\frac{d}{dN}\frac{T}{wx} < 0$.

**Proof of Proposition 3**

From Eq. (78), we have $\frac{d}{d\gamma}\frac{T}{wx} = \frac{\partial}{\partial\gamma}\frac{T}{wx} + \frac{\partial w}{\partial\gamma}\frac{\partial}{\partial w}\frac{T}{wx}$. It also follows from Eq. (78) that $\frac{\partial}{\partial\gamma}\frac{T}{wx} < 0$. Using Eq. (76), we have

$$\frac{\partial w}{\partial\gamma} = -\frac{(\alpha-c)(N-1)}{(2-3\gamma+\gamma N)^2} < 0. \tag{81}$$

Finally, we know from the proof of Proposition 2a that $\frac{\partial}{\partial w}\frac{T}{wx} > 0$. Therefore, $\frac{d}{d\gamma}\frac{T}{wx} < 0$.

**Proof of Lemma 2**

We know from (78) and (76) that as $t \to 0$,

$$w^* \to \frac{\alpha(1-\gamma) + c(1-2\gamma+\gamma N)}{2-3\gamma+\gamma N}, \text{ and} \tag{82}$$

$$\frac{T^*}{w^*x^*} \to \frac{\theta_S(w^*-c) + \frac{\theta_T}{2}c}{\theta_S w^* - \theta_R\frac{(1-\gamma)c}{N(1-2\gamma+\gamma N)}}. \tag{83}$$

It is straightforward to show that the single-supplier solution satisfies

$$w^M \to \frac{\alpha+c}{2}, \text{ and} \tag{84}$$

$$\frac{T^M}{w^M x^M} \to \frac{\theta_S(w^M-c) + \frac{\theta_T}{2}c}{\theta_S w^M - \theta_R c}. \tag{85}$$

We know from the proof of Proposition 2a that $\frac{\partial}{\partial w}\frac{T}{wx} > 0$, and it is straightforward to show that $w^* < w^M$ and $\frac{(1-\gamma)}{N(1-2\gamma+\gamma N)} < 1$. Therefore, as $t \to 0$, we have

$$\frac{T^*}{w^*x^*} = \frac{\theta_S(w^*-c) + \frac{\theta_T}{2}c}{\theta_S w^* - \theta_R c\frac{(1-\gamma)}{N(1-2\gamma+\gamma N)}} < \frac{\theta_S(w^M-c) + \frac{\theta_T}{2}c}{\theta_S w^M - \theta_R c\frac{(1-\gamma)}{N(1-2\gamma+\gamma N)}}$$

$$< \frac{\theta_S(w^M-c) + \frac{\theta_T}{2}c}{\theta_S w^M - \theta_R c} = \frac{T^M}{w^M x^M}, \tag{86}$$

which completes the proof.

**Proof of Lemma 3**

It is straightforward to show that the solution to problem (17) satisfies

$$\frac{T^{FB}(w,x)}{wx} = \frac{\theta_S(w-c) + \theta_R c}{\theta_S w + \theta_R c}. \tag{87}$$

Using Eqs. (85) and (87), as $t \to 0$, we have

$$\frac{T^M}{w^M x^M} > \frac{T^{FB}(w^M, x^M)}{w^M x^M} \tag{88}$$

$$\iff \frac{\theta_S(w^M-c) + \frac{\theta_T}{2}c}{\theta_S w^M - \theta_R c} > \frac{\theta_S(w^M-c) + \theta_R c}{\theta_S w^M + \theta_R c} \tag{89}$$

$$\iff \theta_S\theta_R(w^M-c) + \frac{\theta_T}{2}(\theta_S w^M + \theta_R c) > (\theta_S - \theta_R)\theta_R c. \tag{90}$$

Using Eq. (84) and $\alpha = cm$, the last inequality is equivalent to

$$m > \frac{3\theta_S\theta_R - 2\theta_R^2 - \theta_T\theta_R - 0.5\theta_T\theta_S}{\theta_R\theta_S + 0.5\theta_T\theta_S}, \tag{91}$$

and the result follows.

**Proof of Proposition 4**

Using (10) and the fact that $m > 1$, it is easy to see that $\frac{\theta_T}{2}(\theta_S + \theta_R)c - \theta_R\theta_S c < 0$. Using Eq. (83) and Eq. (87), as $t \to 0$, we have

$$\frac{T^*}{w^*x^*} < \frac{T^{FB}(w^*, x^*)}{w^*x^*} \tag{92}$$

$$\iff \frac{\theta_S(w^*-c) + \frac{\theta_T}{2}c}{\theta_S w^* - \theta_R\frac{(1-\gamma)c}{N(1-2\gamma+\gamma N)}} - \frac{\theta_S(w^*-c) + \theta_R c}{\theta_S w^* + \theta_R c} < 0 \tag{93}$$

$$\iff \frac{\theta_R(\theta_S(w^*-c) + \theta_R c)(1-\gamma)}{N(1-2\gamma+\gamma N)}$$
$$- \theta_R\theta_S c + \frac{\theta_T(\theta_S w^* + \theta_R c)}{2} < 0, \tag{94}$$

where $w^*$ is defined in Eq. (82). It is straightforward to show that the left-hand-side of (94) is decreasing in $\gamma$ and $N$. Furthermore, as $\gamma \to 1$ or $N \to \infty$, the LHS of (94) approaches $\frac{\theta_T}{2}(\theta_S + \theta_R)c - \theta_R\theta_S c < 0$. Thus, there are $\bar{\gamma} < 1$ and $\bar{N} < \infty$ such that inequality (94) holds if and only if $\gamma > \bar{\gamma}$ or $N > \bar{N}$.

## Appendix B. Numerical solution used for calibration

In this appendix, we provide details on the numerical procedure used in the model's calibration. In particular, we describe how we match equilibrium quantities – the Herfindahl index of supplier shares and the mean profit margin of suppliers – to their empirical counterparts.

Note that when $N_j > 2$ and $\alpha_1$ is normalized to one, the number of parameters that we can vary $(\alpha_2, \ldots, \alpha_{N_j}, m)$ exceeds the number of equilibrium quantities that we are trying to match to the data ($HHI_j^*$ and $\frac{\sum_{i=1}^{N_j}(\frac{w_i^*}{c_i}-1)}{N_j}$). In other words, there are multiple combinations of demand intercepts that lead to the same equilibrium HHI of supplier shares. Ideally, we would like to find the values of demand intercepts that match each supplier's equilibrium share of customer's revenues, $SH_i^*$, to that in the data. However, as we discuss below, this is, in general, computationally infeasible. Thus, to narrow down the set of possible combinations of demand intercepts, we make the following identifying assumption: out of $N_j$ suppliers, $N_j'$ suppliers have a common demand intercept $\alpha'$, whereas $N_j'' = N_j - N_j'$ suppliers have a common demand intercept $\alpha''$. The identification of $N_j'$ is discussed below.

For each retailer-level observation and for given values of $m, N_j, N_j', \alpha'$, and $\alpha''$, we solve the model numerically using the following steps:

(i) We assume starting values of wholesale prices and trade credit limits of each supplier, $w_i$ and $T_i$, respectively, for supplier $i$; starting values are symmetrical across all suppliers;

(ii) We find the optimal quantities demanded by the retailer, $x_1, x_2, \ldots, x_{N_j}$, by maximizing its profit, $\Pi_j$, given in (4);

(iii) We vary the wholesale price and trade credit limit of one supplier, $k$, with demand intercept $\alpha'$, $w_i'$, and $T_i'$, respectively; repeat step (ii), compute the resulting profit of supplier $k$, $\Pi_{S_k}$ given in (7); and find the combination of $w_k^*$ and $T_k^*$ that maximizes $\Pi_{S_k}$;

(iv) If $N_j' > 1$, we assign the values of $w_k^*$ and $T_k^*$ to all suppliers whose demand intercept is $\alpha'$;

(v) We vary the wholesale price and trade credit limit of one supplier, $l$, with demand intercept $\alpha''$, $w_i''$, and $T_i''$, respectively; repeat step (ii), compute the resulting profit of that supplier, $\Pi_{S_l}$, and find the combination of $w_l^*$ and $T_l^*$ that maximizes $\Pi_{S_l}$;

(vi) If $N_j'' > 1$, we assign the values of $w_l^*$ and $T_l^*$ to all suppliers whose demand intercept is $\alpha''$;

(vii) We repeat steps (iii) and (vi) until convergence, which occurs when the absolute difference in $|w_k + T_k + w_l + T_l|$ between two adjacent iterations is lower than a certain limit. With a limit of $10^{-6}$, the typical number of iterations until convergence is between five and 20. Note that allowing for larger heterogeneity of demand intercepts, i.e., more than two values of $\alpha_i$, raises the number of iterations until convergence and thus the computational time dramatically.

We repeat the procedure above for each integer $N_j'$ between 1 and $N_j - 1$ and for a fine grid of values of $m, \alpha'$, and $\alpha''$. For each $N_j'$ we pick the combination of $m, \alpha'$, and $\alpha''$ that matches the model-based HHI of equilibrium supplier shares of customer $j$, $HHI_j^*$, and the equilibrium mean profit margin of customer $j$'s suppliers, $\frac{\sum_{i=1}^{N_j}(\frac{w_i^*}{c_i}-1)}{N_j}$, to their empirical counterparts. The procedure concludes when the absolute difference between the model $HHI_j^*$ and its empirical counterpart is below $10^{-3}$ and the absolute difference between $\frac{\sum_{i=1}^{N_j}(\frac{w_i^*}{c_i}-1)}{N_j}$ and the mean profit margin in the data, 0.093, is below $10^{-3}$ as well. Given the available degrees of freedom, we choose $N_j'$ to match as closely as possible the share of customer $j$'s purchases from the supplier with the largest share. We denote the chosen values of model parameters for customer $j$ as $\widehat{N_j'}$, $\widehat{m_j}$, $\widehat{\alpha_j'}$, and $\widehat{\alpha_j''}$.

We record the following equilibrium values of the model's numerical solution that uses the parameters equal to $\widehat{N_j'}$, $\widehat{m_j}$, $\widehat{\alpha_j'}$, and $\widehat{\alpha_j''}$:

(i) the equilibrium proportion of sales of each supplier financed by trade credit, $\frac{T_i^*}{w_i^* x_i^*}$ for supplier $i$;

(ii) the equilibrium proportion of purchases of customer $j$ financed by trade credit: $\frac{\sum_{i=1}^{N_j} T_i^*}{\sum_{i=1}^{N_j} w_i^* x_i^*}$;

(iii) the number of customer $j$'s suppliers, $N_j$;

(iv) the mean product substitutability of customer $j$'s suppliers, $\overline{\gamma_j}$;

(v) the Herfindahl index of customer $j$'s supplier shares, $HHI_j^*$.

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