Industry Structure and the Strategic Provision of Trade Credit by Upstream Firms*

Alfred Lehar†
University of Calgary
Haskayne School of Business

Victor Y. Song
Simon Fraser University
Beedie School of Business

Lasheng Yuan
University of Calgary
Department of Economics

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Abstract

Trade credit can serve as a collusion mechanism for competing supply chains to increase producer surplus in medium concentrated industries. We analyze theoretically how the form of financing influences retailers' behavior in the product market, study incentives to deviate and show evidence consistent with the predictions of the model. Trade credit use is inversely U-shaped in industry concentration and this pattern is more pronounced in industries more prone to collusion and when incentives to deviate are smaller.

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†Corresponding author, Haskayne School of Business, University of Calgary, 2500 University Drive NW, Calgary, Alberta, Canada T2N 1N4. e-mail: alfred.lehar@haskayne.ucalgary.ca, Tel: (403) 220 4567.

1 Introduction

Trade credit financing is one of the largest and most important short-term financing options in the United States and other countries. (Cunat 2007) shows that trade credit accounts for 25% of total assets and 47% of total short-term debt for a US representative firm. Trade credit accounts for 17% of total assets and 50% of short debt for a representative UK firm. Yet trade credit use varies, as we will document in this paper, with the degree of competition. Figure 1 shows mean and median trade credit use, defined as receivables over total sales, for quintiles of industry concentration for a sample of Compustat firms. Trade credit uses peaks in medium competitive industries.

In this paper we provide an explanation for this inter-industry pattern of trade credit use. We argue that trade credit can be used by supply chains as a collusion mechanism which is most effective in oligopolistic industries. In our model, in the first stage supply chains collude to use trade credit financing. To sustain collusion, firms have to coordinate on the use but not the extent of trade credit financing. In the second stage, supply chains are myopic and suppliers and retailers maximize profit given the form of financing. We show that relative to financing with straight debt, trade credit influences the retailers' behavior in the product market and distorts product market competition. When the supply chains in an industry all use trade credit financing, they increase producer surplus due to the changes trade credit brings for product market competition. Trade credit financing can thus be seen as a collusion mechanism. The increase in total producer surplus from trade credit financing relative to bank financing depends on the degree of competition and is highest in oligopoly markets; there is no benefit of trade credit financing for producers under monopoly or perfect competition. Our model thus implies an inverse U-shaped relationship between the benefit of extending trade credit and the degree of competition.

In our empirical analysis, we confirm the inverse U-shaped pattern between competition and receivables for a sample of U.S. non-financial firms from Compustat. Consistent with collusion being the channel for this pattern in trade credit use we find that the inverse U-shaped pattern between competition and trade credit use is more pronounced in environments that favor collusion such as stable or declining industry growth or high barriers to entry, when the products that firms offer are more similar, or for industries that have been identified in the literature as being more susceptible to cartels.

The increased producer surplus of trade credit can only be realized when all firms in an industry collude to use trade credit. Like with many collusive equilibria, given that all other firms use trade credit, one supply chain has an incentive to deviate and use bank financing for a short-term gain. For example, financially flexible retailers can deviate by paying off trade credit obligations with set-aside cash in bad states of the world. Consistent with our model we find the inverse U-shaped pattern to be less pronounced among firms with large cash holdings. We compare a one-time benefit of deviation to the benefit of sustaining the collusive trade credit equilibrium and derive conditions under which deviation is not optimal. Comparing trade credit as a collusion mechanism to classic collusion where output quotas are allocated to cartel members, we find that collusion via trade credit is easier to maintain in most cases. Instead of having to coordinate on often unobservable prices or quantities the collusion mechanism in this paper only relies on all firms offering trade credit to their retailers, which is much easier to police by other cartel members. We also document why trade credit relies on the supplier-retailer relationship and cannot be easily replicated by a competitive banking sector.

As further evidence consistent with the predictions of our model we find that the inverse U-shaped pattern is more pronounced in industries with high demand volatility. We extend our baseline model to allow for a simple bargaining game between the supplier and the retailer; the model predicts that increased retailer-bargaining power decreases the benefit of trade credit financing as most of the surplus that the retailer can extract gets competed away in the product market. Consistent with this prediction we find that the inverse U-shaped pattern is more pronounced when downstream industry concentration is low.

Trade credit influences product market competition because of the different structure of interest payments. In contrast to straight debt where interest is proportional to the time money is borrowed under trade credit financing, retailers borrow goods from their suppliers free of charge for a certain period of time and have to pay a very high interest rate, set by the supplier, should they need to extend their financing. When demand is high and the retailer can sell his whole inventory within the free financing period, the retailer does not have to make any payments for financing the inventory. When demand is low, however, the trade credit penalty rate, at which leftover inventory has to be financed, will influence the retailers optimal behavior in the product market. Therefore, trade credit penalty rate can be used strategically by the supplier to influence her retailer's state contingent behavior in the retail market.

To illustrate our intuition how trade credit financing alters competition suppose two supply chains in the car industry collude to use trade credit financing. Two competing car producers each supply one car dealership in a city facing uncertainty about demand for cars by local residents. The car manufacturer provides trade credit to the dealership under which the latter gets free financing when they sell all cars this period but face a high interest rate for financing all cars that the dealer rolls over for sale in the future. When ex-post realized consumer demand is low the dealer has to roll over some inventory for sale in the next period. Yet for every additional car that he sells this period he can save the high financing costs from the trade credit contract. Thus, he will optimally be more aggressive in the market. This period he will sell more cars at a lower price compared to the outcome of a standard Cournot model and obtain a lower profit.

Ex-ante, before consumer demand is realized, the dealer anticipates that he could end up in the unprofitable low demand state, facing low sales and high financing costs, and he therefore orders a smaller inventory from the manufacturer. Thus, when consumer demand turns out to be strong, he is constrained by his inventory and can only supply a limited number of cars to the market. Because the two supply chains collude, his competitor follows the same inventory policy and has only limited supply as well. Prices for cars are, due to the limited inventory of both dealers, higher than in a standard Cournot game and dealers can earn large profits.[1] We show that these distortions that trade credit financing creates in the product market competition result in higher combined expected profits for the manufacturer and the dealer compared to straight debt financing.

While it is hard to observe actual trade credit or floor plan financing contracts, we can find anecdotal evidence, mostly from court cases, that is consistent with our idea that suppliers want to influence retailer behavior. A home appliance retailer[2] obtained a floor plan financing contract with a free financing period of three to six months after which the rate would jump to 18%. The court notes that *'... the free floor plan program created an interest-free span of time which served as an incentive for a dealer to rapidly sell his inventory and pay off his obligation to the company. If the dealer failed to dispose the merchandise within the designated time, he was penalized for not moving it quickly enough...'*. A similar incentive program by Fiat motors offered a 120 day free financing period.[3] A recent industry publication notes that car dealerships can take *'...advantage of programs in which factories repay them for interest [of inventory financing]. By selling a vehicle faster than a factory-set target number of days, which varies by manufacturer, a dealer can actually make money on floorplanning.'*[4]

The discrete jump in the interest rate that the manufacturer charges after the free financing period, which is unique to trade credit financing, is essential for the mechanism of our model. (Ng, Smith, and Smith 1999) report that typical payment terms are industry specific; most firms in their survey claim to demand payment within 30 days. Examining actual trade credit contracts (Klapper, Laeven, and Rajan 2012) document that payment terms are often much longer and suppliers provide free financing in that period. Late payment penalties

[1](Zettelmeyer, Morton, and Solva-Risso 2007) find that car dealers earn scarcity rents when demand for cars is high.

[2]Romine vs. Philco Finance Corporation, United States Court of Appeals, Eighth Circuit, No 76-1535, 1977.

[3]Fiat Motors of North America vs. Mellon Bank, United States Court of Appeals, Third Circuit, Nos 86-3588 and 86-3606, 1987.

[4]Jamie LeReau, Interest spike would trim inventories, Automotive News, July 15, 2013.

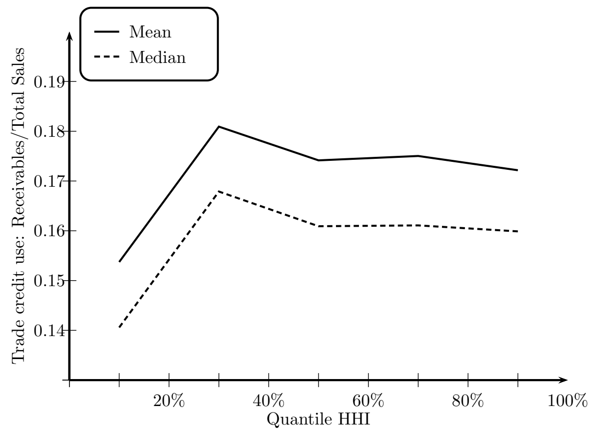

Figure 1. Trade Credit use and industry concentration
The graph shows the mean (solid line) as well as the median (dashed line) of receivables over total sales for quintiles of industry concentration as measured by the Herfindahl-Hirschman Index of sales (HHI) based on Compustat data.

arise either explicit, when the buyer pays the invoice after the payment due date, or implicit, when the payment is made after the discount period. Late payment penalty rates are usually very high; in the EU, for example, the Late Payments Directive 2011/7/EU enacts 8% plus a (central bank) reference rate as contractual default penalty rate. Indirect penalties arise when firms miss the discount period. For example, the commonly quoted scheme of 2/10 net 30 means that the retailer has to pay 2% more if he pays within 30 days rather than the first 10 days, which is equivalent to an annual interest rate of around 46%—a huge penalty for the delayed payment (see also (Smith 1987), (Ng, Smith, and Smith 1999), and (Petersen and Rajan 1997)). Using actual contracts (Klapper, Laeven, and Rajan 2012) find that for 30% of the two-part contracts in their sample, the discount period ends exactly one day before the payment due date imposing a huge penalty for paying late. Economically, under both commonly found payment terms, suppliers provide a period of free financing combined with a high rate imposed on late payments. We argue that the high interest rate only applies when demand is low and inventory gets rolled over and can thus be seen as a state contingent financing cost that allows the supply chain to fine tune the retailer's optimal state contingent product market strategy. When all supply chains in an industry alter competition by using trade credit they can increase producer surplus.

We contribute to the existing literature in three ways: First, we show that trade credit can be used as a collusion mechanism in oligopolistic industries. Compared to classic collusion mechanisms that require coordination on unobservable output quantities or prices, trade credit only needs implicit agreement on the use of trade credit, which is easy to verify for other cartel members. Second, we document a link between trade credit use and industry structure. In line with the predictions of our model we find that trade credit use is higher in medium concentrated industries, industries that are more prone to collusion when incentives to deviate are smaller, and when downstream industry concentration is low. Third, we provide a novel justification for the specific structure of trade credit which differs from traditional debt. The two-tier rate structure with free financing for a certain period followed by a very high interest rate create the distortions in the product market competition that will allow colluding supply chains to extract more producer surplus.

Our research relates to recent papers on trade credit and competition. (Chod, Lyandres, and Yang 2019) analyze a free riding problem in trade credit financing with multiple suppliers that arises as each supplier wants to provide trade credit financing only for her own product but can end up subsidizing other suppliers. In their setting, providing trade credit financing is costly for the supplier. (Singh 2018) documents that Indian manufacturing firms use trade credit as strategic tool to defend market share and deter entry by rival firms. We focus on a different channel to document how trade credit can influence product market competition for the purpose of collusion which fits into a recent stream of research on collusion and finance. (Azar, Schmalz, and Tecu 2018) and (Azar, Raina, and Schmalz 2016) analyze how common ownership decreases competition in the airline and banking industry, respectively. (Lyandres, Fu, and Li 2016) analyze competition among underwriters in IPOs.

A related stream of research analyzes the interaction of financial structure and product market competition that builds on (Brander and Lewis 1986). They show that debt financing makes firms with limited liability more aggressive in Cournot competition. A rich literature examines the empirical relation between leverage and capital structure. (Phillips 1995) documents that in three out of four industries studies output decreases in leverage. (Kovenock and Phillips 1997) document that debt increases in concentrated industries are associated with plant closures and reduced investment. Using data on the casino industry (Cookson 2017) documents low leverage incumbents can successfully deter entry with capacity expansion while highly levered ones do not expand capacity in response to entry threats. While most of the work in this field examines how levels of debt change firms' behavior in imperfect competition, our paper analyzes how different types of debt affect firms' behavior in a strategic setting.[5] Our approach also differs because we do not utilize default or conflicts between shareholders and bondholders in our model.[6]

Our paper relates to the broader trade credit literature (see (Petersen and Rajan 1997) for

[5]Another stream of research relates industry structure to debt maturity - another dimension of debt structure. (Xu 2017) documents that firms with low credit rating frequently refinance outstanding bonds before maturity to extend the maturity of their debt, while investment grade firms do not manage maturity this way. (Parise 2018) find that incumbents in the airline industry increase debt maturity as a response to increased threats of entry.

[6]Our paper is also related to the huge literature on contracting and competition in vertical relationships based on (Hart and Tirole 1990) and to papers identifying other mechanisms for price discrimination such as resale price maintenance (e.g. (Chen 1999)), or slotting allowances (e.g. (Shaffer 1991)).

a survey).[7] (Uchida, Udell, and Watanabe 2013) document that trade credit use is increasing in the length of a relationship between small firms and their suppliers even when many other financing resources such as short- and long-term bank loans are available. Our paper is also close to the work of (Brennan, Maksimovic, and Zechner 1988). In their model, a producer price-discriminates between consumer types. Low type consumers finance goods with expensive trade credit but default with a high probability on their debt, effectively making a low expected payment to the vendor. High type customers never default and prefer to pay cash to avoid the high interest rate, and thus pay an ex-ante higher price for the good. In our model, suppliers use trade credit to effectively charge different prices across demand states for the purpose of collusion. The mechanism in our model also requires no default.

Predictions of our model are also consistent with the findings of previous empirical studies. Analyzing provision of trade credit of Indonesian suppliers, (Hyndman and Serio 2010) find a hump shaped pattern as predicted by our model with a very sharp increase in trade credit provision when moving from monopoly to duopoly. Their paper, however, analyzes the optimal strategy of a revenue maximizing supplier facing credit contained and unconstrained buyers in the presence of monitoring costs for trade credit. Our predicted positive relationship of trade credit use and competition in highly concentrated markets is consistent with the findings of (Fisman and Raturi 2004), who examine supply chain relationships in five African countries and find that monopoly power is negatively associated with credit provision. Our predicted negative relationship of trade credit use and competition in more competitive markets is consistent with (McMillan and Woodruff 1999), who find trade credit to decrease as competition intensifies for a sample of Vietnamese firms, and (Giannetti, Burkart, and Ellingsen 2011), who find that sellers of differentiated goods, which are subject to less competition, carry higher receivables than producers of homogeneous goods.

[7] Previous studies point out that suppliers have a comparative advantage to control their retailers (suppliers can stop supplying goods to retailers, see (Cunat 2007); it is easier for suppliers to re-possess collateral than banks, see (Frank and Maksimovic 2005); suppliers also have an informational advantage relative to outside financiers since it is less costly for suppliers to monitor retailers' financial status ((Jain 2001)). In addition, trade credit can mitigate a moral hazard problem on the side of retailers ((Cunat 2007) and (Burkart and Ellingsen 2004)), trade credit might also serve as a quality-guarantee mechanism for intermediate goods ((Lee and Stowe 1993), (Long, Malitz, and Ravid 1993)), relaxes budget constraint due to the possibility of a postponed debt payment ((Ferris 1981)), and help retailers overcome credit rationing problems if asymmetric information makes banks unwilling to lend to retailers ((Biais and Gollier 1997)). (Allen, Qian, and Xie 2019) examine trade credit in the more general context of informal financing. (Peura, Yang, and Lai 2017) study trade credit in Bertrand competition with random, exogenous liquidity shocks. Under trade credit financing firms split the market to improve their liquidity. We focus on collusion and abstract from financial constraints. (Liang and Qin 2017) analyze revenue sharing agreements and fairness in supply chains. (Tang, Yang, and Wu 2017) model trade credit as mechansim to mitigate supplier moral hazard.

2 Baseline model

In this section of the paper we present the basic model and solve for the product market equilibrium for a given form of financing. The optimal choice of financing will be discussed in Section 4.

We consider an infinitely repeated three-stage game in which n supply chains produce and sell a homogeneous, non-depreciating good to consumers. We assume that each supply chain consists of one supplier and one retailer, who sells the product in a local market.[8] Consumer demand is either high (good state) with probability q or low (bad state) with probability $1 - q$. The price in the product market is given by $A_s - Q$, where the intercept is state dependent and Q denotes aggregate quantity supplied to the market. Our model can be seen as a special case of a double marginalization problem.

In stage 1, at the beginning of each period, each upstream supplier chooses whether to supply trade credit or not and given the financing scheme (bank financing or trade credit financing), sets a wholesale price P for the good as well as the trade credit interest rate r_s, if applicable. Suppliers can produce unlimited quantities of the good at zero marginal cost. In stage 2, each retailer orders goods from his own upstream supplier to fill his inventory, taking the price (and trade credit interest rate if applicable) as given. We assume that each retailer can only purchase inventory from their own supplier and vice visa. In stage 3, at the end of each period, consumer demand is realized and retailers sell their goods to the product market, competing in quantity.

The key friction that we assume is that a retailer cannot acquire inventory from his supplier instantly (e.g. goods take time to build or require transportation); each retailer's end of period sales are therefore bound by his inventory. However, retailers can store any unsold inventory for the next period at no cost, except financing costs. We assume retailers to have zero fixed costs. To simplify the exposition of the paper and to create a need for financing we assume that profits are distributed to shareholders at the end of each period so that retailers require external financing for their inventory. This assumption can be relaxed without changing the findings of the model. Our results hold as long as the marginal good sold in the bad state is financed externally.

The purpose of our paper is to show the impact that trade credit financing has on product market competition.[9] We analyze product market competition under two external financing

[8] In reality a supplier, e.g. a car manufacturer, will have a global network of multiple retailers in many markets. We focus on the effect of trade credit as mechanism to influence product market competition between retailers and for simplicity we analyze the situation with only one retailer. The supplier could have retailers in other markets which would not change our findings as long as these markets are separated. Alternatively, we could interpret the model as each supplier having a representative retailer in a region.

[9] Other contracts might also influence competition. It is not the purpose of our paper to find the optimal contract

mechanisms for the retailers, straight debt provided by a competitive banking sector (or a bond market) and trade credit financing offered by their own suppliers. Under bank financing, the retailer pays the supplier in cash at the time of the order and finances the inventory with a bank. Since retailers have no fixed costs and are on average profitable, they will never default and can thus borrow at the risk-free rate. Under trade credit financing, the retailer gets free financing from the vendor for the goods that are sold at the end of the period, while he has to pay the trade credit interest rate r_s, which is optimally chosen by the supplier, to finance any unsold inventory that is rolled over to the next period. In this infinite horizon game, the end of the current period equals the beginning of the next period. We assume that all agents are risk neutral.

To rule out trivial solutions we assume that the demand state is observable but not contactable. This assumption has two important implications: first, it prevents suppliers from directly charging demand state contingent prices to their retailers. In the U.S., for example, the Robinson-Patman Act prevents suppliers to price discriminate against their retailers.[10] Suppliers might, in reality, also be poorly informed about changes in local demand to create an effective system of price discrimination. Second, in our model, retailers cannot write state contingent financing contracts with the bank. Such contracts are not observed very often in practice, we would argue because it is very hard to verify the demand state in court.[11]

The retailer will offer fewer goods in the bad state when the choke price decreases. To rule out a corner solution in which the retailer offers zero goods in the bad state and only sells in the good state we impose a lower bound on the choke price in the bad state, A_b,

between supplier and retailer. In Section 5.5 and in Appendix E we discuss why the trade credit contract cannot be replicated by a competitive banking sector.

[10]In 1994, for example, the American Booksellers Association and independent bookstores filed a federal complaint in New York against several publishers alleging that they offered more advantageous promotional allowances and price discounts to certain large national chains and buying clubs. Eventually, seven publishers entered consent decrees to stop predatory pricing.

[11]The assumptions of our model rule out several other theories of trade credit in the literature. In (Murfin and Pratt 2019) financing provided by a monopolist producer to consumers serves as commitment device to keep prices high over time. In their model the producer competes with herself over time in the presence of a used goods market. We do not allow for used consumer goods to directly compete with newly produced goods and we focus on wholesale rather than consumer financing. In our model retailers and consumers never default which is central to the price discrimination in (Brennan, Maksimovic, and Zechner 1988). We rule out liquidity shocks (as e.g. in (Cunat 2007)), financial constraints (e.g. (Petersen and Rajan 1997)), or the need to support a retailer to maintain a profitable business relationship ((Wilner 2000)). In our model we do not require that the supplier has some advantage over the bank in liquidating collateral (e.g. (Frank and Maksimovic 2005) or (Longhofer and Santos 2003)), in our setting no player has an incentive to default strategically ((Burkart and Ellingsen 2004)), and there is no asymmetric information (e.g. (Biais and Gollier 1997)).

which ensures that non-negative sales occur in both states (see also footnote 14):

$$A_b \geq \frac{2A_g q}{2q + n + 1} \tag{1}$$

2.1 Solution

Our model is a dynamic game with demand uncertainty and the solution could be path dependent as current orders depend on last period sales and inventory levels. As we will show below, because of the infinite horizon, we are able to rearrange the cash flows and inventory valuation in such a way that each period is identical. With identical periods, one possible, not necessarily unique strategy that maximizes the overall expected profit, is to maximize the profit in each period. We therefore solve the game as a time independent static game, which is much more tractable. We will explain our approach in more detail in the following subsections. We solve for the equilibrium by backward induction starting with the retailers' decision problem.

2.1.1 Stage 3: The retailer's end of period problem – ex-post competition

At the end of the period, each retailer i maximizes its profit ω_i by competing in quantity Q_s^f given the demand state s, the chosen form of financing f, and the amount of inventory I^f obtained before the state of the demand is realized. Superscript $f \in \{B, T\}$ indicates a retailer's financing choices, either bank financing (B) or trade credit financing (T); subscript $s \in \{b, g\}$ denotes the demand states, either a good state (g) or a bad state (b). In a bad state, the choke price is A_b; in a good state, the choke price is A_g, where $A_g > A_b$. The retailer's problem is

$$\max_{Q_s^f} \omega_s^f = (A_s - Q_s^f - Q_s^{-i,f})Q_s^f - C_s^f, \quad f \in \{B, T\}; s \in \{b, g\} \tag{2}$$

$$\text{s.t. } Q_s^f \leq I^f \tag{3}$$

where $Q_s^{-i,f}$ is the aggregate quantity offered by the other retailers except i and C_s^f is the retailer's total cost measured in the end of period values. The total cost for the retailer includes the purchase cost of the good as well as the financing cost of keeping the good in inventory until it is sold. Holding excess inventory is costly under both forms of financing and therefore the retailer will never optimally hold more inventory than what he sells in the good state. In the good state, the constraint (3) is therefore binding and $Q_g^f = I^f$. We solve the third stage game assuming the inventory constraint to be binding in good states and not binding in bad states and later verify that this assumption is indeed true.

Table 1. State dependent inventory levels, cashflows, and financial obligations for the retailer under bank (panel A) and trade credit financing (panel B), respectively.

Panel A: Bank Financing

	Good state			Bad state		
	Inventory	CF Retailer	Loan balance	Inventory	CF Retailer	Loan Balance
Starting balance	Q_g		Q_gP	Q_g		Q_gP
Sale	$-Q_g$	Q_gP_m		$-Q_b$	Q_bP_m	
Repay loan		$-Q_gP$	$-Q_gP$		$-Q_bP$	$-Q_bP$
Interest		$-rQ_gP$			$-rQ_gP$	
Restock inventory	Q_g		Q_gP	Q_b		Q_bP
Ending balance	Q_g	ω_g	Q_gP	Q_g	ω_b	Q_gP

Panel B: Trade Credit Financing

	Good state			Bad state		
	Inventory	CF Retailer	payables	Inventory	CF Retailer	payables
Starting balance	Q_g		Q_gP	Q_g		Q_gP
Sale	$-Q_g$	Q_gP_m		$-Q_b$	Q_bP_m	
Repay supplier		$-Q_gP$	$-Q_gP$		$-Q_bP$	$-Q_bP$
Interest		0			$-\frac{r_s}{1+r}(Q_g - Q_b)P$	
Restock inventory	Q_g		Q_gP	Q_b		Q_bP
Ending Balance	Q_g	ω_g	Q_gP	Q_g	ω_b	Q_gP

By allocating cashflows and valuing inventory as presented in the tables we make inventory levels and financial obligations at the beginning of the period independent of the state in the previous period. The total cash flow at the end of the period only depends on this period's demand state that is realized in that period. Q_g and Q_b denote the quantity sold in the good state and the bad state, P denotes the wholesale price charged by the supplier, P_m is the price achieved in the retail market, and ω_g and ω_b are the retailer's profit in the good and bad state, respectively. All superscripts, which are used to indicate bank financing or trade credit financing throughout the text, are omitted for simplicity.

We analyze the bank financing case first. The retailer's profit in the bad state is

$$\omega_b^B = (A_b - Q_b^B - Q_b^{-i,B})Q_b^B - PQ_b^B - PQ_g^B r, \tag{4}$$

where the first term is the revenue from selling Q_b^B units to the market, the second term is the cost of restocking the inventory at a cost of P^B per unit and the third term is the cost of financing the inventory with value $P^B Q_g^B$ at the bank rate r. The retailer's profit in the good state is similar except that he sells the whole inventory Q_g^B for a total profit of

$$\omega_g^B = (A_g - Q_g^B - Q_g^{-i,B})Q_g^B - PQ_g^B - PQ_g^B r. \tag{5}$$

Panel A in Table 1 provides an overview of a retailer's cash flows and inventory levels under bank financing. Our model would also work if the retailer used a part of his profit to reduce his debt by more than $P^B Q_b^B$ to save on future financing costs as long as the marginal unit sold in the bad state is still financed with debt. Our debt repayment policy is consistent with industry practice. For example, the U.S. Small Business Administration defines floor plan financing as "Floor plan financing is a revolving line of credit that allows the borrower to obtain financing for retail goods. These loans are made against a specific piece of collateral (i.e. an auto, RV, manufactured home, etc.). When each piece of collateral is sold by the dealer, the loan advance against that piece of collateral is repaid."[12]

Now we turn to analyze the trade credit financing case as shown in Panel B of Table 1. The retailers profit in the bad state is

$$\omega_b^T = (A_b - Q_b^T - Q_b^{-i,T})Q_b^T - PQ_b^T - P^T r_s(Q_g^T - Q_b^T)/(1+r), \tag{6}$$

where again the first term is the revenue, the second term is the cost of restocking the inventory at a cost of P^T per unit. The third term is the cost of financing any leftover inventory with value $P^T(Q_g^T - Q_b^T)$ at the trade credit penalty rate r_s. Since the trade credit interest payment is due only next period it gets discounted by one period. The retailer's profit in the good state is similar except that there are no financing costs as he sells the whole inventory Q_g^B within the free financing period for a total profit of

$$\omega_g^T = (A_g - Q_g^T - Q_g^{-i,T})Q_g^T - PQ_g^T. \tag{7}$$

As noted above in a good state the constraint (3) is binding and the sales are constrained by the inventory I^f which is determined in stage 2. In a bad state, however, the constraint is not binding and the first order conditions to solve for the optimal quantity offered by the retailer are derived from Equations (4) and (6) for bank financing and trade credit, respectively. In Appendix A we derive the first order conditions and the optimal quantity of sales in the bad state.

2.1.2 Stage 2: The retailer's start of period problem —ex-ante inventory decision

Given the price of the good, P^f (and trade credit interest rate, r_s, if applicable) set by each supplier, each retailer makes an ex-ante inventory decision to maximize their expected total profits. No cash flows occur for the retailer at the beginning of the period because inventory is externally financed either through straight debt or through trade credit financing. As illustrated in Table 1 retailers enter and exit each period with the optimal inventory level and payment obligations either to the bank or to the supplier independent of the demand state in the previous period. We can therefore transform the potentially complex dynamic optimization problem to a state-independent static optimization problem in which all periods are ex-ante identical.

[12]see *U.S. Small Business Administration, Special Purpose Loans Program, http://www.sba.gov/content/what-floor-plan-financing*

To determine the inventory and thus the sales quantity in the good state the retailer maximizes the expected payoff, which is the probability weighted average of the retailers profit in the good state, ω_g^f, and in the bad state, ω_b^f, respectively. Given the sales quantity in the bad state, Q_b^f, as the solution of the optimization problem (2), the retailer maximizes his expected profit ω^f to determine inventory and thus sales in the good state Q_g^f.

$$\max_{Q_g^f} \omega^f = \left[(1-q)\omega_b^f + q\omega_g^f\right] \quad f \in \{B, T\}, \tag{8}$$

2.1.3 Stage 1: The supplier's problem

Given the optimal inventory policy of the retailer the supplier sets the price (and the trade credit interest rate, if applicable) to maximize her profit. We again structure cash flows such that each period is identical for the supplier and examine the strategy to maximize each period's profit, π^f, as one way to maximize her overall profit.

Under bank financing, the supplier only has the wholesale price as a choice variable to maximize her expected profit

$$\max_{P^B} \pi^B = (1+r)P^B Q_g^B - (1-q)P^B(Q_g^B - Q_b^B) \tag{9}$$

When selling Q_g^B goods to their retailer, the supplier immediately obtains the cash payment, which will be worth $(1+r)P^B Q_g^B$ at the end of the period. However, with probability $(1-q)$ a bad state will occur and the retailer will buy fewer goods when re-stocking for the next period as he keeps $Q_g - Q_b$ goods in hand. Thus, the supplier will lose in expectation $(1-q)P^B(Q_g^B - Q_b^B)$.

Under trade credit financing, each supplier maximizes the expected profit through simultaneous choice of price P^T and trade credit interest rate r_s.

$$\max_{P^T, r_s} \pi^T = qP^T Q_g^T + (1-q)\left(P^T Q_b^T + \frac{r_s P^T(Q_g^T - Q_b^T)}{1+r}\right) \tag{10}$$

With probability q a good state occurs and each supplier obtains a cash payment of $P^T Q_g^T$ at the end of the period for all the goods she has lent to the retailer. With probability $(1-q)$ a bad state occurs and each supplier gets paid for the sold goods $P^T Q_b^T$ in the current period and collects the penalty payment in the next period, which has a present value of $r_s P^T(Q_g^T - Q_b^T)/(1+r)$.

Given the solutions for the optimal sales quantities for the good and the bad states from the optimization problems (2) and (8), respectively, we can determine the suppliers optimal wholesale price under bank financing by solving problem (9). Similarly, under trade credit financing we can find the optimal wholesale price and trade credit interest rate by solving the optimization problem (10). To simplify the exposition of the paper, we focus for most of the remaining analysis of the baseline model to the case when the risk free rate goes to zero.[13] The following propositions summarize the game solutions for bank financing and trade credit financing, respectively.

Proposition 1 *There exists a subgame perfect Nash equilibrium under bank financing such that each supplier charges* $P^B = \frac{2(qA_g+(1-q)A_b)}{3+n}$*, each retailer orders an inventory* $Q_g^B = \frac{(3+n-2q)A_g-2(1-q)A_b}{(n+3)(n+1)}$*, and sells* Q_g^B *in a good state and* $Q_b^B = \frac{2qA_g+(1+n+2q)A_b}{(n+3)(n+1)}$ *in a bad state, respectively.*[14]

Proposition 2 *There exists a subgame perfect Nash equilibrium under trade credit financing such that each supplier charges* $P^T = \frac{2(qA_g+(1-q)A_b)}{3+n}$ *and sets the trade credit interest rate at* $r_s = \frac{q(A_g-A_b)}{qA_g+(1-q)A_b}$*, each retailer orders an inventory* $Q_g^T = \frac{A_g}{n+3}$*, and sells* Q_g^T *in a good state and* $Q_b^T = \frac{A_b}{n+3}$ *in a bad state, respectively.*

We can immediately see that the form of financing has an effect on the quantities firms offer and thus will influence the overall profitability of the firms in the supply chain. It is also noteworthy that the trade credit interest rate is always positive as $A_g > A_b$ by assumption.

The expected quantity sold is identical under both forms of financing as the risk-free interest rate goes to zero. In Appendix D, however, we show numerically that with positive interest rates expected, sales under trade credit financing are larger than under bank financing for a large region of the parameter space. This finding is consistent with the empirical results of (Breza and Liberman 2017) who document that an exogenous restriction on trade credit for selected firms resulted in a reduced probability of trade of affected suppliers to a major supermarket.

[13] Our results with one exception also hold for a positive risk free rate but the expressions are significantly more complex without providing any major insights. When the risk free rate r is too high holding inventory under bank financing is very costly for the retailer and at some point, when $r > r^* := q(A_g - A_b)/A_b > 0$, optimal inventory and thus sales in the good state under bank financing are less than under trade credit financing. For this reason, the results of Proposition 3 only hold as long as $r < r^*$ while the other findings of the paper hold for any positive interest rate. The corresponding condition for Equation (1) with positive interest rate is $A_b > (2A_g q(q+r))/(2(n+3)qr + q(n+2q+1) + (n+3)r^2)$. A Mathematica workbook with the solutions for the general case is available from the authors upon request. Wholesale prices are independent from the form of financing only when the risk-free rate goes to zero.

[14] Requiring $Q_b^B \geq 0$ yields assumption in Equation (1).

3 Financing choice and product market behavior

In this section, we first illustrate how financing choices affect a retailer's behavior in imperfect competition, how they affect profits, and why both suppliers and retailers prefer trade credit to bank financing.

3.1 The retailer's decision in the bad state

We start with examining the retailer's marginal financing cost in the bad state. Under bank financing, the marginal financing cost is zero in a bad state, because the financing cost depends only on the inventory level and is independent of the retailers sales decision in the bad state. Under trade credit financing, however, the value of any unsold inventory has to be financed at the trade credit interest rate r_s. Selling an additional good saves the trade credit interest payment which is due at the end of next period. Since $r_s > 0$, the marginal financing cost is negative, $-P^T r_s/(1+r)$. Trade credit financing therefore effectively lowers the marginal cost for the retailer in bad states and makes him more aggressive in sales. By changing the trade credit interest rate, the supplier can thus strategically influence the retailer's aggressiveness in a bad state.

3.2 The retailer's inventory decision and behavior in a good state

The trade credit penalty also affects the retailer's behavior in a good state through the ex-ante inventory decision. We present the main intuition in this section, a more formal exposition and a discussion of how trade credit allows the supplier to price discriminate against the retailer can be found in Appendix H.

Adding an extra unit to inventory will enable the retailer to sell this extra unit in the good state but it will also increase inventory financing costs. Since the inventory must be financed in both demand states the retailer must trade off the marginal revenue of selling an extra unit in the *good* state with the financing costs in *both* states. Consider the case of bank financing *conditional on the good state*: the marginal revenue is offset by the financing cost in the good state, which is rP^B, but also by the financing cost that the extra inventory causes should the bad state be realized, which is $\frac{1-q}{q}rP^B$. The total marginal financing cost conditional on being in the good state is therefore $rP^B\frac{1}{q}$. The friction that the inventory has to be ordered before the state is realized implies that any marginal revenue in the good state has to offset the inventory holding cost in both good and bad states. The inventory constraint (3) is therefore always binding in the good state, i.e. retailers would never hold excess inventory. Higher marginal costs also imply that competition is softened in the good state.

Under trade credit financing the marginal cost of adding a unit of inventory is zero in the good state as the retailer obtains free financing for one period. Yet when the retailer chooses inventory, he has to factor in the penalty financing costs should the bad state occur. Total marginal financing costs conditional on being in the good state are then $\frac{r_s}{(1+r)}\frac{1-q}{q}P^T$, which is the product of the current period value of the trade credit penalty, the ratio of the probabilities of the bad and the good state, and the value of another unit in the inventory, respectively. Under trade credit financing the supplier can fine tune the retailer's marginal financing cost and thus his behavior in the product market by adjusting the trade credit penalty rate r_s, while under bank financing the interest rate r is exogenously given. In most cases the supplier will set the trade credit penalty rate such that the marginal costs for the retailer are higher compared to bank financing, further softening competition in the good state.

We summarize the above results in the following proposition.

Proposition 3 *Under trade credit financing, the retailers' marginal cost is lower (higher) in the bad (good) state, competition is intensified (softened), and aggregate state contingent supply increases (decreases) relative to bank financing.*

3.3 The trade credit interest rate

From Proposition 2, we know that the trade credit interest rate is $r_s = \frac{q(A_g-A_b)}{qA_g+(1-q)A_b}$ as r goes to zero, which has several noteworthy properties: First, r_s is always positive, i.e., the solution is consistent with the empirical facts that the retailers have to pay a penalty rate if they cannot repay their suppliers on time. Second, r_s increases when a good state becomes more significant (q or $A_g - A_b$ is high) or a bad state is less significant (A_b or $1-q$ is low). As the relative importance of the good state increases, protecting the good state profit (softening the competition) becomes more important, which requires a rise in r_s.

Corollary 1 *Under trade credit financing, the penalty rate r_s increases with the probability of a good state and the gap of choke prices in both states.*

4 Financing choice and industry structure

We now look into the incentive of a supplier to offer trade credit financing, the effect of industry structure, and the producer surplus.

From Proposition 3 we know that under trade credit competition increases in the bad state relative to bank financing as retailers want to avoid the penalty payment, thus lowering

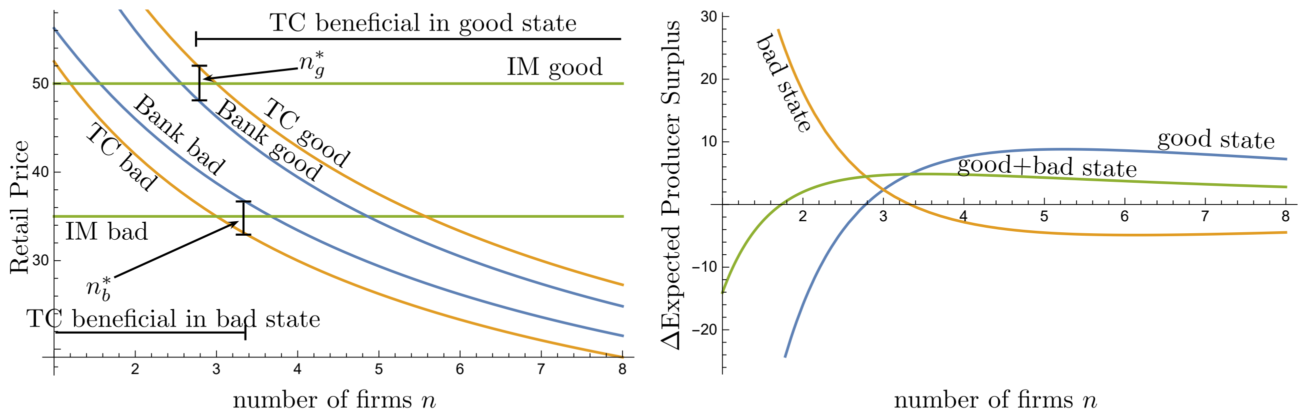

Figure 2. Decomposition of the benefit of trade credit by state
Retail prices for the integrated monopolist (IM) and under bank financing and trade credit (TC) financing as a function of number if supply chains for the good and the bad state, respectively (left panel). Difference in the expected producer surplus between bank and TC financing for the good and the bad state, respectively, as a function of the number of supply chains in the industry (right panel). The parameters for the graph are, unless otherwise specified: $A_g = 100, A_b = 70, q = 1/2, r = 0.05$.

prices in the retail market. In the good state competition is softened under trade credit due to retailers' optimal choice of smaller inventories, causing retail prices to be higher than under bank financing. The left panel of Figure 2 shows the relationship between retail prices and industry concentration for bank and trade credit financing, respectively.

The graph also shows the retail price that an integrated monopolist (IM) would set in each state to maximize producer surplus. Depending on the number of supply chains in an industry, n, either the retail price under trade credit financing or under bank financing is closer to the optimal price of the integrated monopolist. In the bad state, retail prices under trade credit financing are closer to the integrated monopolist's when industry concentration is high (low n). In contrast, in the good state retail prices under trade credit financing are closer to the integrated monopolists when industry concentration is low (high n). Assume for now that n is continuous and denote as n_g^* and n_b^* the number of supply chains where the retail prices under trade credit and bank financing are equidistant from the integrated monopolist's price in the good and bad state, respectively (see Appendix F for a formal derivation of the results in this section). The financing mechanism that results in retail prices being closer to the one of the integrated monopolist, will also create a higher producer surplus.

Trade credit is beneficial in the bad state whenever n is below n_B^* and is beneficial in the good state whenever $n > n_g^*$. We show that $n_g^* \leq n_b^*$ and hence for most parameter values there are three regions of the parameter space.[15] For medium concentrated industries with

[15]For most parameters n_b^* is finite but it can diverge to infinity. Yet the overall benefit of trade credit always declines in n as the economy approaches perfect competition.

$n_g^* \leq n \leq n_b^*$ trade credit is most beneficial as it increases producer surplus in both states. For industries with $n < n_g^*$ or $n > n_b^*$ the gains of trade credit in one state are offset with losses in the other state. This intuition generalizes and we find that for the supply chains the relative advantage of trade credit financing over bank financing is inversely U-shaped in industry concentration. The following proposition formalizes this intuition.[16]

Proposition 4 *The difference in expected producer surplus per supply chain between trade credit financing and bank financing is an inverse U-shaped function in the number of supply chains.*

The right panel of Figure 2 shows the difference between the producer surplus under the two forms of financing by state as well as the combined effect. When the number of supply chains is low, benefits from trade credit financing are realized in the bad state as the increased aggressiveness induced by trade credit financing shifts retailers' optimal behavior closer towards the first best, i.e. the integrated monopolist. As the number of supply chains increases, the benefit of trade credit comes predominantly from the good state as competition drives down retail prices and the less aggressive retailers, under trade credit financing, keep retail prices closer to the ones of the integrated monopolist. With at least two supply chains the benefit of trade credit in the good state generally outweighs the cost in the bad state and trade credit allows the supply chains to increase producer surplus. This gain comes at the expense of consumers. This intuition is summarized in the following proposition.[17]

Proposition 5 *In imperfect competition expected consumer surplus is lower under trade credit financing than under bank financing. With at least two supply chains the expected producer surplus per supply chain is higher under trade credit financing.*

5 Stability of the collusive mechanism

In our model, trade credit financing is a collusion mechanism that allows producers to extract rents from consumers. However, like for most other collusion mechanisms there exists an incentive for firms to deviate from the collusive equilibrium for short-term gain. In this section we will analyze possible deviations from the collusive equilibrium and compare trade credit as a collusion mechanism with classic collusion based on output coordination.

[16] Appendix I provides a more detailed example of how trade credit finance changes marginal costs and producer surplus.

[17] Within the confined setting of our model we can show that total welfare under trade credit financing is also lower than under bank financing.

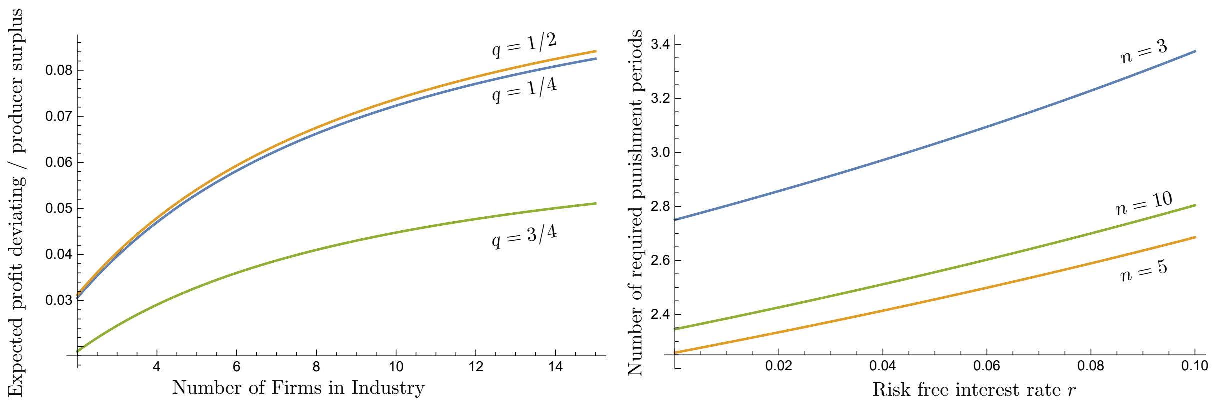

Figure 3. Deviation of a supply chain form the trade credit equilibrium
Short term gain as a fraction of producer surplus for a supply chain to deviate to bank financing given that the other supply chains stick with trade credit financing for different probabilities of the good state q (left panel). Number of periods that players must be committed to play the bank financing equilibrium after a deviation by one firm to deter deviations from the trade credit equilibrium (right panel). The parameters for the graph are: $A_g = 100, A_b = 60, q = 1/2, r = 0.05$.

5.1 Deviations of a supply chain

One way to deviate is that a whole supply chain might move from trade credit financing to bank financing. To analyze the robustness of trade credit as a collusion mechanism in our paper, we numerically analyze the incentives to deviate. We extend the baseline model to allow $m < n$ supply chains to finance retailers' inventory with bank financing while the other $n - m$ firms use trade credit financing (see Appendix B). We allow retailers that use bank financing to offer different quantities than retailers under trade credit financing and similarly allow suppliers to offer prices that are contingent on the financing model. Assume that all supply chains use trade credit financing. The incentive to deviate for the supply chain, G^{sp}, is then defined as the producer surplus of the first deviating supply chain ($m = 1$), minus the producer surplus when all firms use trade credit financing.

The left panel in Figure 3 shows the one time gain of deviation as a fraction of the one period producer surplus under trade credit financing for different industry concentrations. The relative payoff for deviation increases in the number of firms because producer surplus declines faster than the payoff of deviation. The benefit of deviation is highest when both states are equally likely as this case offers the highest benefit from charging state specific marginal costs. Overall the one-time gain is relatively small staying below 9% in our example. This one-time gain has to be seen in relation to the present value of any future losses from the shift to a new product market equilibrium as well as against any transaction costs that occur when moving from bank financing to trade credit financing.

To make collusion a sustainable equilibrium much of the literature (following (Green and Porter 1984)) implements a punishment mechanism should a player deviate from the collusive equilibrium. Most empirical evidence on punishment by other firms in an industry is anecdotal and comes from competition authorities' prosecutions of cartels. In response to cheating by a cartel member, previous research funds episodes of outright price war eroding almost all profits for a certain time as well as more measured and targeted punishments. Citing police recorded phone conversations from a cartel prosecution against gas stations in Quebec, (Clark and Houde 2014) document that over five consecutive weeks in 2005, prices in Victoriaville were within 1 cent of the floor set by the government as a punishment towards a dissident. (Porter 1983) documents price wars in response to suspected cheating in an American railroad cartel, (De Roos 2006) discusses punishment price-wars in the market for lysine. (Roux and Thöni 2015) examine targeted retaliation as a punishment mechanism in cartels where cartel companies would enact specific measures to hit deviating firms. One such targeted punishment is reported by (Harrington Jr et al. 2006) where in the industrial and medical gases, cartel suppliers would set up "hit lists" to target a deviator's consumers. (Genesove and Mullin 2001) document several cases in which deviating firms in the American Sugar Cartel were punished by the other cartel members "in degree and in kind".

We focus on a measured, "in kind", punishment strategy for which we assume that the players commit to bank financing for a certain number of periods should one firm deviate from the trade credit equilibrium. The right panel in Figure 3 illustrates the required length of such a punishment phase to make deviation unprofitable. The present value of the losses from collusion in the punishment phase decline in the discount rate, causing the required length of the punishment phase to increase in r. Collusion from trade credit is most valuable for medium concentrated industries (n=5) which therefore require a shorter punishment phase. A required punishment phase of three to four periods documents at least in this example that the gain from collusion through trade credit financing is large relative to the short term benefit of a one time deviation.[18]

Another deterrent for deviation is potential switching costs. Abandoning vendor financing will in some industries impose significant costs on producers. In practice companies create an institutional framework for vendor financing. For example, almost all car companies have financing arms – separate corporations – that offer favorable financing for car dealers' inventory (floor plan financing). Set-up costs of these finance companies and long-

[18] In unreported results we find that under a "price war" punishment strategy, where the producer surplus is competed away, one punishment period is enough to deter deviation for a wide range of parameter values. We also find that with a harsher punishment strategy trade credit can be maintained as collusive equilibrium even when very few firms refuse to participate in the cartel or for reasons outside of the model (e.g. legal restrictions) use bank financing.

term financing contracts with dealers make it very costly for car manufacturers to deviate from the trade credit equilibrium for short term gain. For example, in the second quarter of 2014, Ford Motor Credit Company received $424m or 19.8% of its financing revenue from dealer financing and it had about 6300 employees. Shutting down such an institution and laying off several thousand employees is costly, which will reduce or eliminate any short-term gains from deviation. Setting up finance subsidiaries could therefore also serve as a commitment device to the collusive trade credit equilibrium

5.2 Deviation by the retailer

Another possible deviation from the collusive equilibrium can be initiated by the retailer. Since demand states are assumed to be observable but not contactable, the retailer can theoretically avoid paying the high trade credit interest rate by financing the unsold inventory in the bad state with either cash or bank debt at the lower rate r and repaying the supplier in full. The payment can be financed by hoarding cash or raising debt in our model. The retailer is financially unconstrained, never defaults, and thus has always access to debt markets. However, while such a strategy would bring an immediate reward, the short-term gain, as outlined above, has to be seen in relation to forgone long-term gains from collusion.[19]

In our model a deviation from the collusive equilibrium would be noted by both the supplier and the competitors and the game would revert back to bank financing. Assuming a similar punishment mechanism as above the retailer might not find it optimal to deviate when the short-term gain from deviation is less than the present value of the forgone profits during the punishment period. The left panel in Figure 4 shows the minimum required length of the punishment period to deter deviation for different levels of the risk free rate, r.[20] Similarly to the findings of the previous section we find that a punishment of five periods is sufficient to deter deviation for a wide range of parameter values.

For reasons outside of the model, holding cash might be associated with an opportunity cost larger than the risk-free rate. One reason could be agency costs as managers extract

[19]The supplier can make the retailer indifferent with respect to the financing scheme with transfer payments. Car manufacturers, for example, make ex-post transfer payments called "holdbacks" to their retailers on a monthly or quarterly basis which are based on past sales volume. The IRS describes holdbacks in the following way: 'When dealers acquire their new car inventory from manufacturers, usually the invoice includes a separately coded charge for "holdbacks." Dealer holdbacks generally average two to three percent of the Manufacturer's Suggested Retail Price (MSRP) excluding destination and delivery charges. These amounts are returned to the dealer at a later date. The purpose of the "holdbacks" is to assure the dealer of a marginal profit.', see *New Vehicle Dealership Audit Technique Guide 2004 - Chapter 14 - Other Auto Dealership Issues (12-2004), Internal Revenue Service.* Suppliers can then refuse to pay holdbacks when retailers deviate to bank financing. Another potential transfer mechanism is advertising which is often paid by the supplier and benefits the retailers' sales.

[20]For the graph it is assumed that the opportunity cost of cash is the risk free rate r. All results are computed numerically.

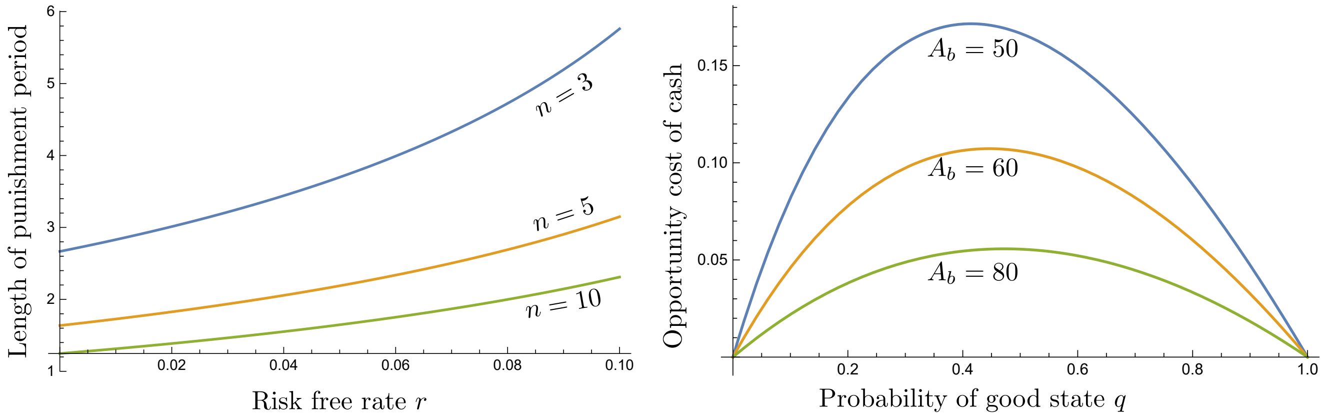

Figure 4. Deviation by the retailer
Left panel: minimum length of the punishment period, i.e. the number of periods that players must be committed to play the bank financing equilibrium after a deviation by one retailer, to deter deviations from the trade credit equilibrium. Right panel: the critical opportunity cost of cash holdings for which holding cash is suboptimal. Unless otherwise specified the parameters for the graph are: $A_g = 100, A_b = 60, q = 1/2, r = 0.05$.

private benefits from firms with excessive cash. (Pinkowitz, Stulz, and Williamson 2006) document that corporate cash holdings are substantially discounted when investor protection is weak. A dollar inside the firm is valued at $0.91 in countries with above-median investor protection and only worth $0.33 in other countries.[21] (Duchin, Gilbert, Harford, and Hrdlicka 2017) document that managers in poorly governed firms are more likely to invest cash holdings into risky assets and in the process destroy shareholder value. Another reason might be that firms hold cash to invest in value creating projects without delay when future access to capital markets is uncertain (see for example (Harford, Klasa, and Maxwell 2014) or (Bates, Kahle, and Stulz 2009)). Diverting cash from its intended purpose to refinance inventory creates an opportunity cost.

Assume that holding a dollar of cash costs r_c per period as an opportunity cost. The benefit of holding a dollar occurs only in the bad state, which happens with probability $(1 - q)$, and allows the retailer to save the trade credit interest rate cost r_s on that dollar, which would be due next period. The expected benefit of holding a dollar of cash is thus $(1 - q)r_s/(1 + r)$ as long as the marginal good in the bad state is still financed with trade credit. Once the whole leftover inventory in the bad state can be financed with cash the marginal benefit of holding cash is zero. The right panel in Figure 4 plots the opportunity cost r_c for which the firm is indifferent with respect to holding cash or not. Firms are

[21] In a cross country comparison (Dittmar, Mahrt-Smith, and Servaes 2003) find that firms hold up to twice as much cash in countries with poor shareholder protection and that cash holdings are less correlated with typical explanatory variables. (Kalcheva and Lins 2007) show that in countries with weak shareholder protection firm values are lower when managers hold more cash.

eager to hold cash even when the opportunity cost is high whenever the difference between choke prices is high (low A_b for given A_g) or when demand uncertainty is high (medium q). When the good state gets realized very often (high q) holding cash is expensive as it will rarely get deployed and thus firms only hold cash when the opportunity cost is low. The trade credit interest rate converges to zero as the probability of the good state goes to zero (see Proposition 2). With low trade credit penalties for holding cash, it is not advantageous unless it is very cheap (low opportunity cost). Overall we notice that depending on the opportunity cost associated with holding cash then the firm might find it optimal not to pay off the supplier in the bad state.

5.3 Trade credit vs. classic collusion

Without any restrictions on their ability to collude, the supply chains can maximize their profit if they coordinate their aggregate output to match that of an integrated monopolist. We refer to the case where n supply chains equally split quantities and thus profits that an integrated monopolist could obtain as classic collusion. In contrast, in our setting the competitive Cournot outcome would be the bank financing case discussed above.[22] In the left panel of Figure 5 we compare the benefit of trade credit relative to bank financing and classic collusion. We normalize a firm's profit under classic collusion to one and the firm's profit under bank financing to zero. In the example in the left panel we can see that profit under trade credit financing is in general lower than under classic collusion especially in dispersed industries but can come close to the profit under classic collusion in concentrated industries (three firms in this example).

Collusion through trade credit is also in many cases more stable than classic collusion. We define the gain of deviation under classic collusion, G^{cc}, as the incremental profit that a firm can obtain by optimizing its output decision given that all other players stick with their output under classic collusion (see Appendix C). The right panel of Figure 5 shows the region of the parameter space for which the gain of deviation from trade credit to bank financing (G^{sp} as defined in Section 5.1) exceeds the gain from deviation in classic collusion (G^{cc}). In other words, in this region collusion using trade credit is harder to maintain than classic collusion. In our numerical analysis we only found such a region for a duopoly when the good state is very unlikely and the bad state has very low demand. For industries with more than two supply chains we found that under trade credit the incentive to deviate is smaller than for classic collusion.

Trade credit as collusion mechanism also differs from classical collusion with respect to the ease of coordination. (Levenstein and Suslow 2006) show that successful cartels invest

[22](Lyandres, Fu, and Li 2016) follow a similar approach to examine collusion mechanisms in IPO pricing.

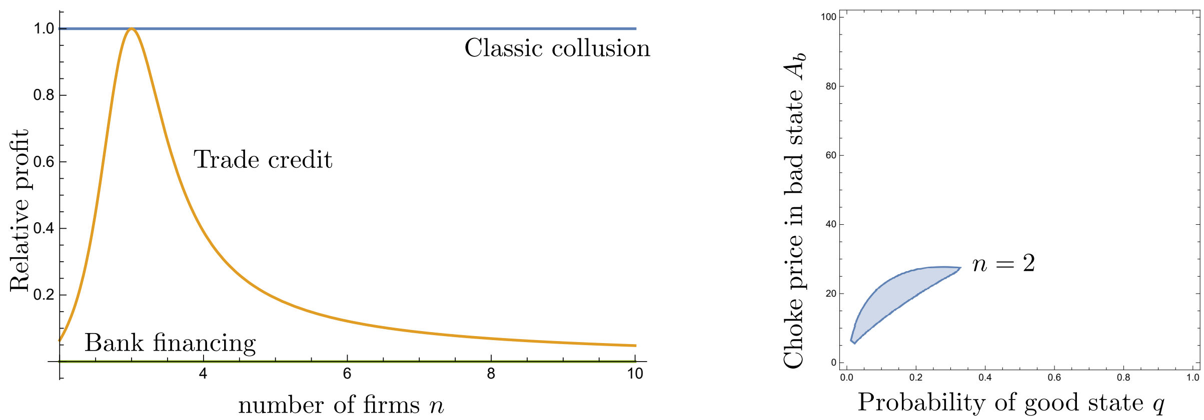

Figure 5. Stability of collusion with trade credit and classic collusion
Profits under trade credit financing and bank financing relative to perfect collusion and a standard Cournot oligopoly (left panel) and region of the parameter space for which deviation from trade credit financing to bank financing is more profitable relative to the deviation from a collusive oligopoly. The parameters for the graph are, unless otherwise specified: $A_g = 100, A_b = 60, q = 1/2, r = 0.05$.

in monitoring capacity to ensure that cartel members stick to the collusive strategy. Under the classical collusion, firms need to coordinate and enforce allocated output quantities as each firm would find it profitable to deviate from their allocated quota. Output quantities and prices are often unobservable and hence hard to police by cartel members. The trade credit contract in our paper does not require any coordination except for the mutual agreement to provide and use trade credit financing. Conditional on all firms in the industry using trade credit to finance inventories, retailers and suppliers behave myopically and maximize their profits, yet still achieve the collusive outcome.[23]

Another possibility to restrict competition is for the supplier to limit the amount she sells to the retailer. In such an agreement it would again be optimal for the supply chain to deviate and the points outlined in Section 5.1 would apply. We believe, however, that collusion through trade credit is easier to maintain than collusion through supply restrictions. A shift from trade credit financing to bank financing incurs transaction costs and is easier to observe by competitors. Under classic collusion a deviation in the form of increased sales to a retailer might be harder to observe. Furthermore, while restricting inventory levels would restrict competition in the good state such a mechanism cannot make retailers more aggressive in the bad state. Other, more elaborate schemes to achieve a collusive outcome similar to the trade credit equilibrium might exist. However, our objective is not to derive an optimal contract but to document that trade credit can lead to collusion in the product

[23]As stated in Equations (2) and (8) the retailer maximizes his expected profit for the bad state and for the optimal choice of inventory, respectively. Similarly, the producer maximizes her profit given the chosen form of financing as stated in Equations (9) and (10) for bank financing and trade credit financing, respectively.

market at the expense of the consumer.

5.4 Emergence of trade credit

While our model explores the benefits of trade credit financing over bank financing our model like many other papers on collusion can only offer limited insights into the specific mechanisms on how firms coordinate on the collusive equilibrium. We extend our model to analyze the stability of the bank financing equilibrium in Appendix G. We extend the baseline model such that one supply chain provides a small amount of trade credit to its retailer while still mostly relying on bank financing while all other supply chains use pure bank financing. When the amount of trade credit supplied is very small (less than the sales in the bad state) then a penalty never materializes as the trade credit can always be repaid within one period – even in the bad state. Therefore, the effect of trade credit financing on the retailer's product market behavior analyzed in the main body of the paper, is absent. However, when the risk-free rate is positive, the deviating supply chain is better off by providing a small amount of trade credit financing. Intuitively by providing trade credit the supplier decreases the retailer's funding costs for the marginal good, which incentivizes him to hold a larger inventory and hence be more aggressive in the product market. Assuming that the other supply chains stick with pure bank financing, the supply chain offering a bit of trade credit financing can increase its producer surplus. Therefore pure bank financing is inherently unstable and supply chains have an incentive to introduce trade credit.

5.5 Replicating the trade credit contract

Another issue to consider is why banks cannot offer a contract that replicates the trade credit contract. The provision of trade credit is not a zero NPV project and can therefore not be replicated easily by a competitive banking sector. If financing is profitable it will be competed away by a competitive banking sector changing the financing rates and thus product market competition. When pure financing has a negative NPV, banks will not offer such a contract while a supplier can offset any financing losses with the gains in the product market. Even if all obstacles could be overcome with a long-term contract that would provide trade-credit- type financing, while breaking even on average for the banks, such a contract would not have the same penalty rate and would thus have lower producer surplus. In Appendix E we provide a detailed analysis with numerical examples and provide more arguments why replication by outside financiers will not be easy to obtain.

6 Empirical evidence and extensions

6.1 Baseline evidence

We start with providing empirical evidence that trade credit use is inversely U-shaped in industry concentration consistent with Proposition 4. For our analysis, we collect data on US non-financial firms between 1980 and 2017 from Compustat and regress trade credit use on industry concentration. We define trade credit usage as the logarithm of accounts receivables over total sales[24] and compute the Herfindahl Hirschmann index (HHI) based on each firms share of total sales, where industry is defined based on 4-digit SIC codes.[25] We include control variables commonly used in the literature: *firm size* is the logarithm of sales, *book leverage* is book value of total liabilities over total assets, *Cash/TA* is the amount of cash over total assets, *market/book* is the ratio of market value over book value of equity, return on assets (*ROA*) is net income over total assets, *tangibility* is net property plant and equipment over total assets, *profit margin* is sales minus costs of goods sold over sales, free cash flow over total assets is defined as earnings before interest and taxes (EBIT) minus taxes plus depreciation minus capital expenditures over total assets, acquisition is a dummy equal to one if the company conducted an *acquisition*, and *dividend paying* is a dummy indicating that the firm paid dividends. To control for outliers, we winsorize our data at the 5% level for each variable.

For our analysis we run two regression specifications: first we regress trade credit use on the HHI and on the squared HHI to capture the nonlinear relationship between trade credit use and industry concentration. Second, we regress trade credit use on the HHI and allow for a change in slope above the median by multiplying a dummy that equals one if the HHI is above the median with the change in the HHI beyond the median. Formally, let $q50$ be the median of the HHI distribution we estimate the following model

$$TC = a\,\text{HHI} + b\,\mathbf{1}_{\text{HHI}>q50}(\text{HHI} - q50) + controls + \epsilon \tag{11}$$

[24]While our model assumes that one supplier only contracts with one retailer, in practice one supplier might deliver goods to several retailers that serve different (potentially overlapping) markets, e.g. Ford and GM sell cars to several dealerships that serve a large city. The benefit of trade credit in our model is mainly driven by competition between suppliers, e.g. car producers. Therefore we use receivables of suppliers as a measure of trade credit use. Trade credit use of retailers is harder to measure as many retailers are private and it might vary due to local competition in their markets.

[25]In unreported results we check for robustness by downloading the HHI of the largest 50 companies from the U.S. Economic Census for manufacturing companies. (Ali, Klasa, and Yeung 2009) point out that Compustat excludes private companies which might lead to mismeasurement of industry concentration. Census concentration data is classified based on 4-digit SIC codes for the years 1982, 1987, and 1992, and uses the NAICS classification for the 1997, 2002, 2007, and 2012 censuses. We merge our datasets based on the respective industry classifications. Industry concentration in years between censuses is set to the closest available census data point. We find the basic results of our analysis confirmed for this smaller sample.

Table 2. Summary statistics of firm and industry data

	Mean	Std.Dev.	Median	Min.	Max.
Trade credit	-2.048	0.752	-1.892	-4.213	-0.868
HHI	0.260	0.192	0.210	0.011	1.000
Firm Size	5.502	2.128	5.478	0.411	9.053
Book Leverage	0.491	0.185	0.502	0.112	0.857
Cash/TA	0.089	0.097	0.051	0.002	0.470
Market/Book	2.205	1.628	1.724	0.447	10.618
ROA	0.014	0.099	0.037	-0.512	0.153
Tangible assets/TA	0.289	0.205	0.240	0.016	0.802
Profit Margin	0.351	0.169	0.330	-0.031	0.792
FCF/TA	0.021	0.074	0.037	-0.327	0.137
Acquisition	0.400	0.490	0.000	0.000	1.000
Dividend paying	0.457	0.498	0.000	0.000	1.000

Trade credit use is defined as logarithm of receivables over total sales. HHI is the Herfindahl-Hirschman Index based on sales. Firm size is the logarithm of sales, book leverage is total book value of total liabilities over total assets, Cash/TA is the amount of cash over total assets, market/book is the ratio of market value over book value of equity, return on assets (ROA) is net income over total assets, tangibility is net property plant and equipment over total assets, profit margin is sales minus costs of goods sold over sales, free cash flow over total assets is defined as EBIT after taxes plus depreciation minus capital expenditures over total assets, acquisition is a dummy equal to one if the company conducted an acquisition, and dividend paying is a dummy indicating that the firm paid dividends.

where $\mathbf{1}_{\text{HHI}>q50}$ is an indicator function equal to one if HHI is above the median. In all our regressions we control for time fixed effects to control for time variation in credit demand through the business cycle and report clustered standard errors.[26]

Our baseline regression results are presented in Table 3. We confirm our prediction of an inverse U-shaped use of trade credit over industry concentration for our sample of U.S. firms. The results in Table 3 confirm a concave, quadratic relationship between trade credit and industry concentration. For the piecewise linear regression specification, we find that trade credit first increases in industry concentration and then drops once industry concentration is high. Most control variables are of similar magnitude as in (Dass, Kale, and Nanda 2014), who use a similar sample. Since the HHI is very stable it alone explains

[26]We do not include firm or industry fixed effects as they would pick up the variation in trade credit use across industries that we seek to identify. A firm fixed effects model would essentially relate inter-temporal changes in trade credit use to inter-temporal changes in industry concentration. We refrained from using such a specification because, first, we are not too sure how fast trade credit use will respond to changes in industry concentration and, second, in many industries concentration does not change by much relative to possible measurement errors in HHIs. We are concerned that most year-to-year changes in measured industry concentration are of a similar magnitude than the ones resulting from new firms getting listed or other firms going private and thus entering or leaving the Compustat database.

little of the variation in overall trade credit use as indicated by its low R^2. This effect could be further attenuated due to imperfect controls (see (Oster 2019)). The goal of our paper is not to find an important determinant of trade credit for all firms but to find evidence consistent with the existence of trade credit as collusion mechanism.

6.2 Benefits of collusion and trade credit use

Our findings should be more pronounced if there is a greater ability or willingness by the firms in an industry to sustain collusion. From a well developed literature in IO we know that collusion in general is more sustainable when products are more homogenous, barriers to entry exist, and demand is stable.[27]

To start we test if the inverse U-shape is more pronounced in industries with homogenous products using the data of (Hoberg and Phillips 2010) and (Hoberg and Phillips 2016) on product similarity. Based on text analysis of 10-K filings they measure how close two companies' products are and then construct an aggregate index on how similar competitors' products are for each firm. Merging their data with ours reduces the size and length of or sample.[28]

To check how the inverse U-shaped pattern of trade credit varies with similarity we run the following regression model:

$$\begin{aligned} TC &= a + \quad b_1 \text{ HHI} + b_2 \mathbf{1}_{\text{Tercile1}} \text{ HHI} + b_3 \mathbf{1}_{\text{Tercile3}} \text{ HHI} + \\ &\qquad b_4 \text{ HHI}^2 + b_5 \mathbf{1}_{\text{Tercile1}} \text{ HHI}^2 + b_6 \mathbf{1}_{\text{Tercile3}} \text{ HHI}^2 + controls + \epsilon \end{aligned} \tag{12}$$

where $\mathbf{1}_{\text{Tercile1}}$ and $\mathbf{1}_{\text{Tercile3}}$ are dummy variables set to one if the product similarity measure is in the first and third tercile, respectively. Table 4 illustrates the results for the new sample. In line with the idea that collusion is more beneficial when products are more homogeneous we find that the inverse U-shape is only present when the firm's competitors offer similar products while the relation between trade credit use and HHI is not significant in industries where companies are able to differentiate their products.[29] We show all regressions with and without control variables as some of the control variables such as, for example, ROA could be an outcome of the collusive trade credit equilibrium.

Under our mechanism the collusion benefit of trade credit increases in demand volatility. Figure 6 plots the relative difference of the producer surplus of trade credit relative to bank financing for different measures of demand volatility in our model. The left panel

[27] See surveys in e.g. (Scherer and Ross 1990), (Feuerstein 2005), or (Grout and Sonderegger 2005).

[28] The merged data ranges from 1996-2017 while the original data spans a period from 1980-2017.

[29] For simplicity we only present the specification with the squared HHI, the results of the piece wise regression specification are available from the authors upon request.

Table 3. Regression results of trade credit use on market concentration.

Number Obs.	93,901	93,901	93,901	93,901	93,901	93,901
HHI^2	-0.87***	-0.24**	-0.22**			
	(0.1301)	(0.0960)	(0.0954)			
HHI	0.90***	0.18*	0.20**	1.40***	0.33**	0.36**
	(0.1343)	(0.0983)	(0.0971)	(0.2071)	(0.1518)	(0.1500)
(HHI $\geq$ q50)				-1.49***	-0.42**	-0.42***
$\times$ (HHI-q50)				(0.2248)	(0.1659)	(0.1643)
Firm Size		-0.06***	-0.05***		-0.06***	-0.04***
		(0.0027)	(0.0027)		(0.0027)	(0.0027)
Book Leverage		0.06***	0.05**		0.06***	0.05**
		(0.0207)	(0.0198)		(0.0207)	(0.0198)
Cash/TA		-0.71***	-0.64***		-0.71***	-0.63***
		(0.0342)	(0.0348)		(0.0343)	(0.0346)
Market/Book		-0.01***	-0.01***		-0.01***	-0.01***
		(0.0022)	(0.0021)		(0.0022)	(0.0021)
ROA		0.10**	0.04		0.09**	0.03
		(0.0453)	(0.0428)		(0.0456)	(0.0429)
Tangible assets/TA		-1.09***	-1.11***		-1.08***	-1.10***
		(0.0343)	(0.0342)		(0.0331)	(0.0329)
Profit Margin		0.69***	0.72***		0.69***	0.72***
		(0.0281)	(0.0279)		(0.0286)	(0.0284)
FCF/TA		-0.35***	-0.35***		-0.35***	-0.36***
		(0.0690)	(0.0667)		(0.0689)	(0.0666)
Acquisition		0.16***	0.16***		0.16***	0.16***
		(0.0070)	(0.0070)		(0.0070)	(0.0070)
Dividend paying		0.07***	0.07***		0.07***	0.07***
		(0.0084)	(0.0077)		(0.0084)	(0.0077)
R^2	0.0139	0.1474	0.1538	0.0168	0.1477	0.1541
Year fixed effects	Yes	No	Yes	Yes	No	Yes

The dependent variable is trade credit use, which is defined as logarithm of receivables over total sales, HHI is the Herfindahl-Hirschman Index based on sales. The control variables are defined as in Table 2. One, two, and three stars indicate significance at the 10%, 5%, and 1% level, respectively.

Table 4. Regression results of trade credit use on market concentration.

Number of Obs.	68,282	68,282	68,282	45,520	68,282
HHI^2 * T1 similarity		0.53 ***	0.13		-0.08
		(0.1311)	(0.1180)		(0.1120)
HHI^2	-0.93 ***	-0.48 ***	-0.06	0.05	0.12
	(0.1419)	(0.1292)	(0.1102)	(0.0830)	(0.1187)
HHI^2 * T3 similiarity		-1.47 ***	-0.63 **	-0.74 ***	-0.58 **
		(0.3336)	(0.2657)	(0.2752)	(0.2705)
HHI * T1 similiarity		-0.52 ***	-0.11		0.02
		(0.1259)	(0.1128)		(0.1109)
HHI	0.96 ***	0.41 ***	0.02	-0.07	-0.10
	(0.1477)	(0.1292)	(0.1087)	(0.0842)	(0.1140)
HHI * T3 similiarity		1.38 ***	0.45 **	0.54 **	0.42 *
		(0.2805)	(0.2184)	(0.2293)	(0.2221)
T1 similiarity		0.20 ***	0.06 ***		0.05 **
		(0.0241)	(0.0215)		(0.0216)
T3 similiarity		-0.25 ***	-0.11 ***	-0.17 ***	-0.10 ***
		(0.0463)	(0.0355)	(0.0380)	(0.0362)
Firm Size			-0.05 ***	-0.05 ***	-0.06 ***
			(0.0030)	(0.0037)	(0.0030)
Book Leverage			0.02	0.09 ***	0.05 **
			(0.0227)	(0.0279)	(0.0232)
Cash/TA			-0.61 ***	-0.49 ***	-0.73 ***
			(0.0386)	(0.0452)	(0.0378)
Market/Book			-0.01 ***	-0.01 ***	-0.01 **
			(0.0024)	(0.0028)	(0.0025)
ROA			0.00	-0.05	0.11 **
			(0.0477)	(0.0558)	(0.0480)
Tangible assets/TA			-1.08 ***	-1.09 ***	-1.07 ***
			(0.0381)	(0.0455)	(0.0384)
Profit Margin			0.70 ***	0.77 ***	0.66 ***
			(0.0323)	(0.0387)	(0.0324)
FCF/TA			-0.33 ***	-0.43 ***	-0.34 ***
			(0.0709)	(0.0834)	(0.0729)
Acquisition			0.17 ***	0.18 ***	0.17 ***
			(0.0078)	(0.0097)	(0.0078)
Dividend paying			0.05 ***	0.06 ***	0.07 ***
			(0.0084)	(0.0099)	(0.0091)
R^2	0.0150	0.0270	0.1671	0.1848	0.1600
Year fixed effects	Yes	Yes	Yes	Yes	No
Terciles in Similiarity	all	all	all	1 and 3	all

The dependent variable is trade credit use, which is defined as logarithm of receivables over total sales, HHI is the Herfindahl–Hirschman Index based on Compustat data. The control variables are defined as in Table 2. The T1 and T3 dummies are one for firms in the bottom and top terciles of firms' product similarity measure from Hoberg and Phillips (2010), respectively. One, two, and three stars indicate significance at the 10%, 5%, and 1% level, respectively.

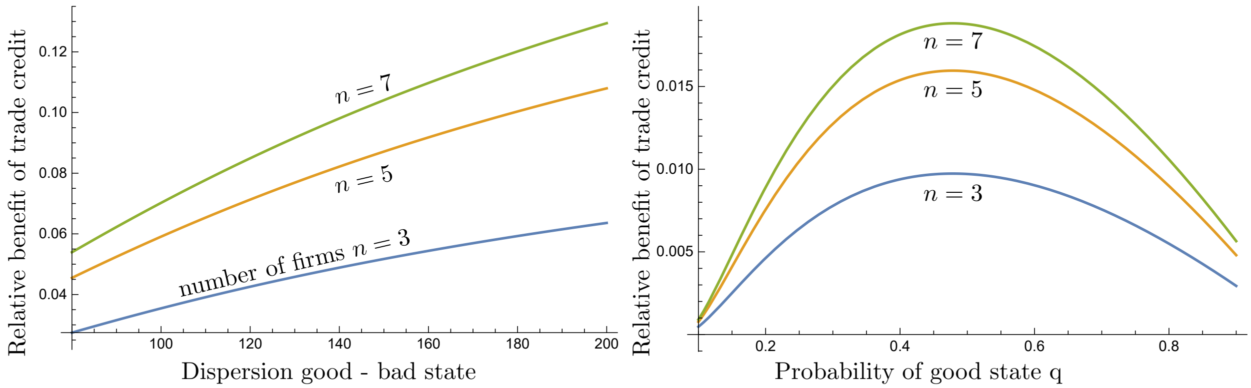

Figure 6. Relative difference in producer surplus of trade credit relative to bank financing for different measures of demand volatility.
The relative benefit of trade credit financing as a function of the absolute difference between the good and the bad demand states keeping the choke price in the bad state fixed (left panel), and as a function of the probability of the good state q. The parameters for the graph are, unless otherwise specified: $A_g = 100, A_b = 60, q = 1/2, r = 0.05$.

shows that trade credit is more beneficial as the difference in choke prices, $A_g - A_b$, increases. Intuitively higher demand volatility increases the benefit of state contingent marginal costs that is achieved by trade credit. The right panel shows by means of an example that the benefit of trade credit is increasing in uncertainty about the demand state, i.e. when the good and the bad state are of similar likelihood (q near $1/2$).

To test this prediction empirically we measure the volatility of changes in aggregate sales per industry over the last three years. Table 5 documents that the inverse U-shape of trade credit use in industry concentration can only be found in volatile industries and is not present in industries with stable demand. While being no causal proof, the evidence is consistent with the idea that trade credit is more valuable as a collusion mechanism in industries with more demand uncertainty.

We also examine other suggestions that are summarized in (Grout and Sonderegger 2005). As they point out, collusion is more sustainable in stable or shrinking industries. In growing industries gains from obtaining a higher market share by deviating are more likely to outweigh the benefits of collusion. In our framework we would therefore expect to see a more pronounced hump-shape in stable or declining industries. In line with our prediction Table 6 documents that the inverse U-shape relation between trade credit use and industry concentration is only present in the low tercile of past industry demand growth.

Collusion is also more sustainable when barriers to entry are high. Incumbent firms can enjoy oligopoly rents as long as entry of new firms, who could compete away a substantial part of these rents, is unlikely. One commonly used measure of barriers to entry is the ratio of tangible assets to total assets. Table 7 presents our results for different asset tangibility.

Table 5. Regression results of trade credit use on market concentration for different halves of demand volatility.

Number of Obs.	87,169	87,169	87,169	87,169
HHI^2	-0.87 ***	-0.49 **	0.05	0.03
	(0.1383)	(0.1955)	(0.1425)	(0.1468)
HHI^2 * High Volatility		-0.76 ***	-0.49 **	-0.47 **
		(0.2700)	(0.2156)	(0.2163)
HHI	0.89 ***	0.57 ***	-0.01	-0.01
	(0.1409)	(0.1976)	(0.1415)	(0.1467)
HHI * High Volatility		0.66 **	0.36 *	0.33
		(0.2770)	(0.2200)	(0.2205)
High Volatility		-0.13 **	-0.04	-0.03
		(0.0560)	(0.0444)	(0.0442)
Firm Size			-0.05 ***	-0.06 ***
			(0.0028)	(0.0027)
Book Leverage			0.05 ***	0.07 ***
			(0.0204)	(0.0210)
Cash/TA			-0.61 ***	-0.69 ***
			(0.0351)	(0.0350)
Market/Book			-0.01 ***	-0.01 ***
			(0.0022)	(0.0023)
ROA			-0.01	0.07
			(0.0419)	(0.0443)
Tangible assets/TA			-1.10 ***	-1.09 ***
			(0.0357)	(0.0358)
Profit Margin			0.71 ***	0.68 ***
			(0.0288)	(0.0290)
FCF/TA			-0.24 ***	-0.24 ***
			(0.0652)	(0.0679)
Acquisition			0.16 ***	0.16 ***
			(0.0073)	(0.0073)
Dividend paying			0.07 ***	0.08 ***
			(0.0080)	(0.0085)
Year FE	yes	yes	yes	no
R^2	0.0129	0.0145	0.1532	0.1476

Demand volatility is estimated as standard deviation of industry wide sales in three years preceding the observation year. The control variables are defined as in Table 2. The high volatility dummy is equal to one for the upper half of the volatility distribution. One, two, and three stars indicate significance at the 10%, 5%, and 1% level, respectively.

Table 6. Regression results of trade credit use on market concentration comparing the highest and the lowest tercile of past demand growth.

Number of Obs.	59,397	59,397	59,397	59,397
HHI^2	-0.66 ***	-0.09	0.25	0.29
	(0.1614)	(0.2538)	(0.1853)	(0.1878)
HHI^2 * T1 growth		-1.13 ***	-0.55 **	-0.61 **
		(0.3193)	(0.2564)	(0.2554)
HHI	0.66 ***	-0.01	-0.37 **	-0.44 **
	(0.1650)	(0.2479)	(0.1791)	(0.1825)
HHI * T1 growth		1.32 ***	0.64 **	0.71 ***
		(0.3220)	(0.2591)	(0.2587)
T1 growth		-0.23 ***	-0.08	-0.12 **
		(0.0643)	(0.0526)	(0.0519)
Firm Size			-0.05 ***	-0.06 ***
			(0.0033)	(0.0035)
Book Leverage			0.05 **	0.06 ***
			(0.0241)	(0.0247)
Cash/TA			-0.69 ***	-0.77 ***
			(0.0432)	(0.0435)
Market/Book			-0.01 ***	-0.01 ***
			(0.0026)	(0.0027)
ROA			0.00	0.06
			(0.0525)	(0.0566)
Tangible assets/TA			-1.07 ***	-1.07 ***
			(0.0411)	(0.0416)
Profit Margin			0.68 ***	0.65 ***
			(0.0346)	(0.0352)
FCF/TA			-0.25 ***	-0.26 ***
			(0.0793)	(0.0819)
Acquisition			0.16 ***	0.16 ***
			(0.0087)	(0.0087)
Dividend paying			0.07 ***	0.07 ***
			(0.0095)	(0.0100)
Year FE	yes	yes	yes	no
R^2	0.0145	0.0185	0.1496	0.1440

Demand growth is measured over the last three years of industry wide sales. The control variables are defined as in Table 2. The T1 growth-dummy is set to one for firms in the lower tercile of demand growth. One, two, and three stars indicate significance at the 10%, 5%, and 1% level, respectively.

In line with our prediction we observe that the inverse U-shape is most pronounced when asset tangibility is high.

In their paper, (Grout and Sonderegger 2005) predict the likelihood of a cartel for each industry in their sample based on Rev 1.1 on the European NACE industry classification. We take the 37 industries with the highest probability of having a cartel of Table 4.4 in their paper and translate them to NAICS codes using the mapping table from the US Census Bureau website.[30] Label firms in these 37 NACE industries as cartel firms. Cartel firms and non-cartel firms in our sample have comparable distributions of industry concentration with a mean HHI of 0.219 and 0.259 and a HHI standard deviation of 0.180 and 0.194 for cartel and con cartel firms, respectively. To check whether the inverse U-shaped pattern of trade credit use and industry concentration coincides with evidence of collusion we run the following regression model:

$$TC = a + b_1 \text{ HHI} + b_2 \text{ HHI}^2 + b_3 \mathbf{1}_{\text{Cartel}} \text{ HHI} + b_4 \mathbf{1}_{\text{Cartel}} \text{ HHI}^2 + controls + \epsilon \quad (13)$$

where $\mathbf{1}_{\text{Cartel}}$ is a dummy variable set to one if an industry has a high likelihood of being in a cartel .

Table 8 summarizes our findings from estimating the model in Equation (13) as well as some simplified specifications. With control variables the inverse U-shape is only significant for industries that (Grout and Sonderegger 2005) identify as likely to have a cartel.

6.3 Relative bargaining power of downstream industries

One important assumption of our baseline model is that suppliers can unilaterally set the price and the trade credit interest rate. In reality, large retailers such as Walmart, have substantial bargaining power and might therefore extract terms that are substantially better than what the supplier wants to charge. Bargaining over price and over the trade credit interest rate has a similar effect in our model. We start with negotiations over the wholesale price. While bargaining for a lower price might be optimal for a myopic retailer, it is not beneficial overall, in our model, for the industry. A lower purchase price for the retailer will not automatically translate in a higher producer surplus as competition in the retail market will intensify and retail prices will drop.

To explore this idea, we extend our model to incorporate a simple bargaining game between the supplier and a myopic retailer. Assume that just before the retailer places the order with the supplier, they engage in a bilateral Nash bargaining game over the price

[30] Available at *https://www.census.gov/eos/www/naics/concordances/2002_NAICS_to_NACE_Rev._1.1.xls. We map the tree digit NACE codes from (Grout and Sonderegger 2005) into 6-digit NAICS codes allowing for a relative precise matching.*

Table 7. Regression results of trade credit use on market concentration for different tangible assets.

Number of Obs.	93,901	93,901	93,901	93,901
HHI^2	-0.87 ***	0.18 *	-0.02	-0.02
	(0.1301)	(0.1028)	(0.0870)	(0.0938)
HHI^2 * High Tangibility		-1.27 ***	-0.43 ***	-0.47 ***
		(0.1846)	(0.1572)	(0.1598)
HHI	0.90 ***	-0.20 *	0.02	-0.01
	(0.1343)	(0.1010)	(0.0836)	(0.0919)
HHI * High Tangibility		1.32 ***	0.38 **	0.43 ***
		(0.1892)	(0.1587)	(0.1614)
High Tangibility		-0.62 ***	-0.14 ***	-0.14 ***
		(0.0383)	(0.0288)	(0.0295)
Firm Size			-0.04 ***	-0.06 ***
			(0.0027)	(0.0027)
Book Leverage			0.05 **	0.06 ***
			(0.0200)	(0.0208)
Cash/TA			-0.64 ***	-0.72 ***
			(0.0347)	(0.0340)
Market/Book			-0.01 ***	-0.01 ***
			(0.0021)	(0.0022)
ROA			0.04	0.10 **
			(0.0425)	(0.0451)
Tangible assets/TA			-0.93 ***	-0.93 ***
			(0.0444)	(0.0450)
Profit Margin			0.71 ***	0.68 ***
			(0.0277)	(0.0279)
FCF/TA			-0.35 ***	-0.34 ***
			(0.0663)	(0.0688)
Acquisition			0.16 ***	0.16 ***
			(0.0069)	(0.0070)
Dividend paying			0.07 ***	0.08 ***
			(0.0078)	(0.0084)
Year FE	yes	yes	yes	no
R^2	0.0135	0.0893	0.1545	0.1485

The control variables are defined as in Table 2. The High Tangibility-dummy is set to one for firms in the upper half of the tangibility distribution. One, two, and three stars indicate significance at the 10%, 5%, and 1% level, respectively.

Table 8. Trade Credit use and likelihood of being in a cartel

Number of Obs.	93,901	93,901	93,901	91,130
HHI^2	-0.87 ***	-0.58 ***	0.03	0.00
	(0.1301)	(0.1305)	(0.0957)	(0.0962)
HHI	0.90 ***	0.64 ***	-0.03	-0.04
	(0.1343)	(0.1317)	(0.0953)	(0.0964)
$\mathbf{1}_{\text{Cartel}}\ HHI^2$		-1.12 ***	-0.93 ***	-0.89 ***
		(0.1078)	(0.0836)	(0.0840)
$\mathbf{1}_{\text{Cartel}}\ HHI$		1.08 ***	0.94 ***	0.92 ***
		(0.0749)	(0.0561)	(0.0571)
Firm Size			-0.04 ***	-0.05 ***
			(0.0026)	(0.0026)
Book Leverage			0.05 **	0.06 ***
			(0.0197)	(0.0206)
Cash/TA			-0.64 ***	-0.72 ***
			(0.0344)	(0.0339)
Market/Book			-0.01 ***	-0.01 ***
			(0.0021)	(0.0022)
ROA			0.05	0.11 **
			(0.0424)	(0.0448)
Tangible assets/TA			-1.11 ***	-1.10 ***
			(0.0335)	(0.0337)
Profit Margin			0.69 ***	0.66 ***
			(0.0272)	(0.0274)
FCF/TA			-0.36 ***	-0.36 ***
			(0.0654)	(0.0678)
Acquisition			0.16 ***	0.16 ***
			(0.0069)	(0.0069)
Dividend paying			0.06 ***	0.07 ***
			(0.0076)	(0.0083)
Year FE	yes	yes	yes	no
R^2	0.0139	0.0249	0.1626	0.1560

Trade credit use and market concentration with an interaction dummy of firms that are likely to be in a cartel as predicted by the analysis of Grout and Sonderegger (2005). The control variables are defined as in Table 2. One, two, and three stars indicate significance at the 10%, 5%, and 1% level, respectively.

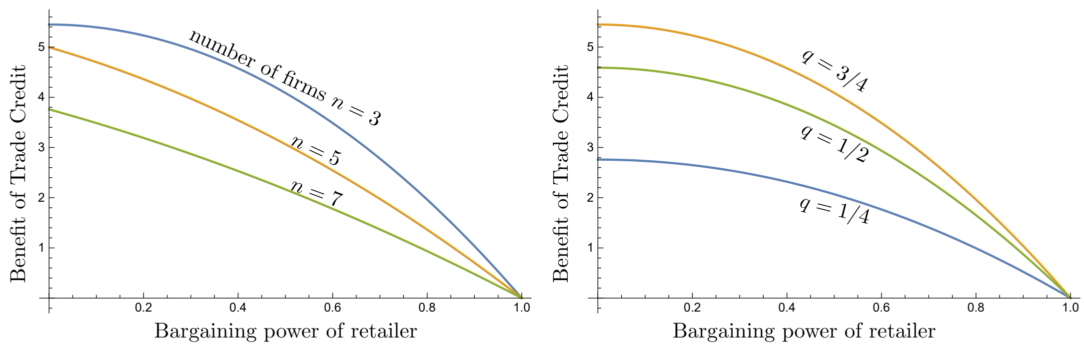

Figure 7. Benefit of trade credit defined as the producer surplus under trade credit financing minus the producer surplus under bank financing as a function of the retailers' bargaining power. The parameters for the graph are, unless otherwise specified: $A_g = 100, A_b = 50, q = 1/2, r = 0.05, n = 3$.

P where the retailer is assumed to have a relative bargaining power of $\gamma \in [0,1]$. If the retailer has all the bargaining power, he will offer the reservation price of the supplier which is the marginal cost of producing the good that we set to zero in our model. When all the bargaining power is with the supplier, as it is the case in the basic model of the paper, she sets the price to, P^B and P^T, as derived in Propositions 1 and 2 for bank financing and trade credit, respectively. Assume that the supplier and the retailer settle for a γ-weighted average price between those two values, γP^B and γP^T, for bank and trade credit financing, respectively.[31]

Figure 7 shows the benefit of trade credit defined as the producer surplus under trade credit financing minus the producer surplus under bank financing as a function of γ. When retailers have all the bargaining power and drive the price of the good in the wholesale market to zero, no financing is needed and the form of financing has no impact on the outcome in the product market. When the supplier has all the bargaining power, we obtain the result of the basic model in the paper that trade credit can work as collusion mechanism. We find a similar effect when we extend the model to allow for bargaining over the trade credit interest rate r_s. The benefit of trade credit over bank financing decreases in the retailer's bargaining power. When the retailer can extract a lower rate, the marginal cost difference between states diminishes and the retailer's optimal sales become less sensitive to the demand state similar to the bank financing equilibrium.

Our model predicts that trade credit is less useful as a collusion mechanism when the bargaining power of the retailer is high. Empirically we use downstream industry concen-

[31] We take this approach to provide some intuition and rely on many limiting assumptions. Amongst others the retailer is assumed to be myopic and does not take the actions of other retailers into account, all retailers are assumed to have the same bargaining power, suppliers are assumed to all have zero production cost, and the bargaining is modeled as a standalone game. We rule out any dynamic, path dependent, and other more complex bargaining strategies.

tration as a proxy for the retailers relative bargaining power. We start with identifying the downstream industries based on the Bureau of Economic Analysis (BEA) make-use tables, which contain data on 71 industries. We map to 54 downstream industries in our sample as some industry classifications in the BEA tables relate to different branches of government or industries, which are not in our sample. We then find for each industry the fraction of its output used in the downstream industries and compute the downstream HHI as the weighted average of the downstream industries' HHIs. Table 9 shows the results for the overall sample and with the inclusion of the downstream HHI as a control variable. While the downstream HHI itself is insignificant as a control variable (column 3), we get interesting results from including dummies for terciles of downstream industry concentration in a specification similar to Equation (12). The inverse U-shape is more pronounced the lower the downstream industry concentration is. When downstream industry concentration is high the inverse U-shape is significantly less pronounced which is consistent with the idea that firms in a more concentrated downstream industry have more bargaining power and thus make trade credit as a collusion mechanism less attractive.

As a second way to control for downstream industry concentration we use fuzzy text-matching as well as manual matching to identify the names of each firm's largest customers in the segment data of the Compustat database. Our sample size is dramatically reduced as we lose 30 years of data (segment data starts in 2009) and because we cannot match some customers to firms in the Compustat database. We then compute the average HHI for all downstream firms as simple average because sales data to individual customers is not always available and we do not want to lose any more observations. Table 10 summarizes our findings. For this sample the downstream HHI is significant as a control variable (column 4) indicating that higher downstream industry concentration corresponds to less use of trade credit, and the significance of the hump shape disappears for the whole sample. Partitioning the sample according to the downstream HHI however, again reveals that even in this drastically reduced sample the inverse U-shape is present when downstream industry concentration is low.

6.4 Cash holdings and trade credit

Based on the discussion in Section 5.2 we would expect that trade credit is less useful as a collusion mechanism in industries that for some reason outside of the model have high cash holdings. To take this idea to the data we compute the average annual industry cash holdings by computing total cash held by firms in an industry in a year over total assets in an industry and repeat our main analysis for different subsamples based on the average industry cash holdings. Table 11 presents our findings. In line with the intuition that incentives to deviate

Table 9. Trade credit use and market concentration controlling for downstream industry concentration, which is measured as the weighted average HHI of downstream industries according to the BEA make-use tables.

Number of Obs.	73,574	73,574	73,574	73,574	73,574	73,574
HHI^2 * T1 dstr HHI				-2.40***	-1.42***	-1.35***
				(0.4011)	(0.2748)	(0.2857)
HHI^2	-1.19***	-0.64***	-0.64***	-0.36***	-0.28***	-0.31***
	(0.1561)	(0.1039)	(0.0931)	(0.1238)	(0.0985)	(0.1023)
HHI^2 * T3 dstr HHI				0.60***	0.52***	0.51***
				(0.1653)	(0.1351)	(0.1431)
HHI * T1 dstr HHI				2.23***	1.36***	1.29***
				(0.4058)	(0.2751)	(0.2866)
HHI	1.21***	0.59***	0.59***	0.48***	0.23***	0.24**
	(0.1632)	(0.1070)	(0.0933)	(0.1148)	(0.0892)	(0.0939)
HHI * T3 dstr HHI				-0.85***	-0.55***	-0.55***
				(0.1630)	(0.1315)	(0.1422)
T1 dstr HHI				-0.47***	-0.30***	-0.31***
				(0.0752)	(0.0517)	(0.0526)
T3 dstr HHI				0.11***	0.03	0.00
				(0.0337)	(0.0266)	(0.0285)
Dstr HHI			0.00			
			(0.0734)			
Firm Size		-0.03***	-0.03***		-0.03***	-0.04***
		(0.0029)	(0.0029)		(0.0028)	(0.0029)
Book Leverage		0.06***	0.06***		0.09***	0.11***
		(0.0209)	(0.0211)		(0.0211)	(0.0221)
Cash/TA		-0.64***	-0.64***		-0.61***	-0.70***
		(0.0357)	(0.0356)		(0.0353)	(0.0343)
Market/Book		-0.01***	-0.01***		-0.01***	-0.01***
		(0.0022)	(0.0022)		(0.0022)	(0.0023)
ROA		0.17***	0.17***		0.18***	0.26***
		(0.0440)	(0.0438)		(0.0437)	(0.0461)
Tangible assets/TA		-1.33***	-1.33***		-1.29***	-1.28***
		(0.0407)	(0.0400)		(0.0380)	(0.0385)
Profit Margin		0.77***	0.77***		0.76***	0.73***
		(0.0315)	(0.0322)		(0.0321)	(0.0324)
FCF/TA		-0.54***	-0.54***		-0.58***	-0.58***
		(0.0676)	(0.0675)		(0.0674)	(0.0701)
Acquisition		0.12***	0.12***		0.12***	0.11***
		(0.0069)	(0.0069)		(0.0068)	(0.0068)
Dividend paying		0.02**	0.02**		0.02***	0.03***
		(0.0075)	(0.0074)		(0.0075)	(0.0082)
Year FE	yes	yes	yes	yes	yes	no
R^2	0.0204	0.2146	0.2146	0.0438	0.2239	0.2172

The control variables are defined as in Table 2. The T1 dstr HII and T3 dstr HHI-dummies are set to one for firms in the lower and upper tercile of the downstream HHI distribution, respectively. One, two, and three stars indicate significance at the 10%, 5%, and 1% level, respectively.

Table 10. Trade credit use and market concentration controlling for downstream industry concentration measured using information on large customers from the Compustat segment data.

Number of Observations	1,794	1,794	1,794	1,794	1,794	1,794
HHI^2 * T1 dstr HHI				-2.34***	-1.53**	-1.43**
				(0.6708)	(0.6097)	(0.6000)
HHI^2	0.11	-0.11	-0.25	0.59	0.11	0.03
	(0.2748)	(0.2401)	(0.2363)	(0.4778)	(0.4381)	(0.4377)
HHI^2 * T3 dstr HHI				0.39	0.12	0.24
				(0.5446)	(0.4984)	(0.5082)
HHI * T1 dstr HHI				2.11***	1.13**	1.03*
				(0.6465)	(0.5758)	(0.5727)
HHI	-0.14	0.05	0.22	-0.42	0.05	0.11
	(0.2845)	(0.2500)	(0.2423)	(0.4644)	(0.4106)	(0.4150)
HHI * T3 dstr HHI				-0.60	-0.24	-0.35
				(0.5512)	(0.4976)	(0.5143)
T1 dstr HHI				-0.25**	0.00	0.01
				(0.1118)	(0.0963)	(0.0970)
T3 dstr HHI				0.01	-0.07	-0.04
				(0.1062)	(0.0927)	(0.0975)
Dstr HHI			-0.39***			
			(0.0703)			
Firm Size		-0.02*	-0.03**		-0.03*	-0.02*
		(0.0141)	(0.0134)		(0.0134)	(0.0136)
Book Leverage		0.26**	0.29***		0.29***	0.28***
		(0.1018)	(0.0980)		(0.0976)	(0.0986)
Cash/TA		-0.05	-0.13		-0.17	-0.19
		(0.1741)	(0.1731)		(0.1731)	(0.1771)
Market/Book		-0.08***	-0.08***		-0.08***	-0.07***
		(0.0133)	(0.0130)		(0.0127)	(0.0132)
ROA		0.22	0.26		0.20	0.25
		(0.2541)	(0.2461)		(0.2460)	(0.2478)
Tangible assets/TA		-0.46***	-0.62***		-0.61***	-0.63***
		(0.1297)	(0.1325)		(0.1368)	(0.1373)
Profit Margin		0.67***	0.64***		0.67***	0.65***
		(0.1367)	(0.1344)		(0.1295)	(0.1337)
FCF/TA		-0.40	-0.41		-0.28	-0.45
		(0.3895)	(0.3735)		(0.3661)	(0.3558)
Acquisition		-0.01	-0.02		-0.02	-0.02
		(0.0331)	(0.0319)		(0.0323)	(0.0328)
Dividend paying		-0.09***	-0.09***		-0.09***	-0.08**
		(0.0338)	(0.0324)		(0.0316)	(0.0317)
Year FE	yes	yes	yes	yes	yes	no
R^2	0.0042	0.1519	0.1791	0.0382	0.1875	0.1751

The control variables are defined as in Table 2. The T1 dstr HII and T3 dstr HHI-dummies are set to one for firms in the lower and upper tercile of the downstream HHI distribution, respectively. One, two, and three stars indicate significance at the 10%, 5%, and 1% level, respectively.

are higher when cash is readily available, we find that our inverse U-shaped relationship between trade credit and industry concentration is only significant for forms that are in the lower half of the cash holdings distribution.

Another potential mechanism for a supply chain to deviate from the collusive equilibrium is to re-allocate inventory. Suppose, for example, that one producer supplies two retailers in segmented markets. When demand in one market is low and is high in the other market the supplier could re-allocate inventory to avoid penalties and inventory restrictions. Another possibility to deviate can be by speeding up production. If the supplier could instantaneously create new goods and ship them to the retailer without delay when demand is high, the supply chain can generate a one-time extra payoff by deviating from the equilibrium. Similar to the argument above with cash buffers and the discussion in Section 5 each supply chain has to balance the short-term gain from deviation with the long-term benefit of collusion. If a supplier, for some exogenous reason related to the industry has to hold larger inventories it might be harder to sustain the collusive equilibrium. Consistent with this idea we find in unreported results that the inverse-u shape between trade credit use and industry concentration is more pronounced when supplier-inventory levels are low.

7 Conclusion

We investigate how different kinds of debt affect output market equilibrium by comparing bank and trade credit financing, and offer a novel explanation that why trade credit exists even though it is often viewed as an expensive financing option. We argue that trade credit financing modifies a retailer's ex-ante inventory policy and ex-post product market strategy, respectively, in an uncertain demand environment. When demand is low the retailer sells more to avoid financing the unsold inventory at the high trade credit rate ex-ante the possibility of having to pay the high trade credit interest rate induces the retailer to reduce his optimal inventory level, which in turn limits competition in the product market when demand is high.

The distortions that trade credit financing introduces to product markets allows producers to increase their profits at the expense of consumer surplus. We can therefore see trade credit as a collusion mechanism between supply chains that mitigates competition. We offer a novel explanation why financially unconstrained firms finance their inventories with expensive trade credit and why suppliers are able to offer a financing contract that cannot be replicated by banks.

Our findings also have important policy implications for industries that rely heavily on vendor financing, often through institutionalized finance companies, such as the auto-

Table 11. Trade credit use and market concentration for different levels of industry cash holdings.

Number of Observations	81,389	81,389	81,389	81,389
HHI^2	-0.95 ***	-0.59 ***	-0.07	-0.07
	(0.1314)	(0.0997)	(0.0854)	(0.0858)
HHI^2 * Low Cash		-0.88 ***	-0.30 **	-0.29 **
		(0.1791)	(0.1472)	(0.1475)
HHI	1.00 ***	0.63 ***	0.04	0.00
	(0.1363)	(0.1040)	(0.0881)	(0.0888)
HHI * Low Cash		0.87 ***	0.28 **	0.30 **
		(0.1676)	(0.1382)	(0.1381)
Low Cash		-0.07 **	-0.08 ***	-0.09 ***
		(0.0309)	(0.0267)	(0.0261)
Firm Size			-0.05 ***	-0.06 ***
			(0.0035)	(0.0033)
Book Leverage			0.07 ***	0.08 ***
			(0.0215)	(0.0222)
Cash/TA			-0.82 ***	-0.94 ***
			(0.0743)	(0.0698)
Market/Book			-0.01 ***	-0.01 ***
			(0.0024)	(0.0025)
ROA			0.02	0.06
			(0.0472)	(0.0503)
Tangible assets/TA			-1.06 ***	-1.04 ***
			(0.0334)	(0.0336)
Profit Margin			0.74 ***	0.71 ***
			(0.0303)	(0.0304)
FCF/TA			-0.32 ***	-0.31 ***
			(0.0713)	(0.0737)
Acquisition			0.16 ***	0.16 ***
			(0.0073)	(0.0074)
Dividend paying			0.08 ***	0.08 ***
			(0.0083)	(0.0089)
Year FE	yes	yes	yes	no
R^2	0.0158	0.0190	0.1537	0.1477

The control variables are defined as in Table 2. The Low Cash-dummy is set to one for firms in the lower half of the industry cash holdings distribution. One, two, and three stars indicate significance at the 10%, 5%, and 1% level, respectively.

mobile industry. All major car producers own finance companies that provide financing of their retailers' inventories, often referred to as floorplan financing. Our analysis shows that allowing commercial firms to engage in financing activities can reduce competition. Our paper also contributes to the long ongoing discussion in the U.S. on the separation of banking and commerce. The recent Dodd-Frank enacted a three-year moratorium on the creation of industrial loan companies (ILCs) in the U.S., which are often owned by large industrial producers and provide financing to the firms clients. Our analysis provides an argument that separation of banking and commerce can help in shutting down a potential collusion mechanism amongst producers.

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A Proofs.

Proof of Proposition 1:

There exists a subgame perfect Nash equilibrium under bank financing such **Proof.** According to Equation (2), the first order condition to solve Q_b^B is

$$\frac{\partial}{\partial Q_b^B}\left[(A_b - Q_b^B - Q_b^{-i,B})Q_b^B - C_b^B\right] = 0 \tag{14}$$

Solving the partial derivative and substituting the cost C_g^B, Equation (14) becomes

$$A_b - 2Q_b^B - Q_b^{-i,B} + P^B = 0 \tag{15}$$

which yields the best response function

$$Q_b^B = \frac{A_b - Q_b^{-i,B} + P^B}{2} \tag{16}$$

Assuming that all firms are symmetric we set $Q_b^{-i,B} = (n-1)Q_b^B$ and solve for the optimal quantity that the retailer offers in the bad state which is

$$Q_b^B = \frac{A_b - P^B}{n+1} \tag{17}$$

According to Equation (8), the first order condition to solve Q_b^B is

$$\frac{\partial}{\partial Q_g^B}\left[(1-q)\omega_b^B + q\omega_g^B\right] = 0 \tag{18}$$

By substituting the cost C_g^B and the optimal quantity that the retailer offers in the bad state, Q_b^B, and solving the partial derivative, Equation (18) becomes

$$A_g - 2Q_g^B - Q_g^{-i,B} + P^B = 0 \tag{19}$$

which yields the best response function

$$Q_g^B = \frac{A_g - Q_b^{-i,B} + P^B}{2} \tag{20}$$

Assuming that all firms are symmetric, we set $Q_g^{-i,B} = (n-1)Q_g^B$ and solve for the optimal quantity that the retailer offers in the good state which is

$$Q_g^B = \frac{A_g - P^B}{n+1} \tag{21}$$

According to Equation (9), the first order condition to solve P^B is:

$$\frac{\partial}{\partial P^B}\left[(1+r)P^B Q_g^B - (1-q)P^B(Q_g^B - Q_b^B))\right] = 0 \tag{22}$$

By substituting the optimal quantities, Q_b^B, Q_g^B, that the retailer offers in a bad state and a good state, respectively, and solving the partial derivative, Equation (22) becomes

$$\frac{A_g q + A_b(1-q) - 2P^B}{n+1} = 0 \tag{23}$$

which yields the price charged by a supplier under bank financing,

$$P^B = \frac{2}{n+3}[A_g q + A_b(1-q)] \tag{24}$$

By substituting the equilibrium price into the Equation (17) and Equation (21), the quantities sold in the good state and the bad state are $\frac{(3+n-2q)A_g - 2(1-q)A_b}{(n+3)(n+1)}$ and $\frac{2qA_g + (1+n+2q)A_b}{(n+3)(n+1)}$, respectively.

■

Proof of Proposition 2

Proof. According to Equation (2), the first order condition to solve Q_b^T is:

$$\frac{\partial}{\partial Q_b^T}\left[(A_b - Q_b^T - Q_b^{-i,T})Q_b^T - C_b^T\right] = 0 \tag{25}$$

Solving the partial derivative and substituting the cost C_b^T, Equation (25) becomes:

$$A_b - 2Q_b^T - Q_b^{-i,T} + P^T(1-r_s) = 0 \tag{26}$$

which yields the best response function

$$Q_b^T = \frac{A_b - Q_b^{-i,T} + P^T(1-r_s)}{2} \tag{27}$$

Assuming that all firms are symmetric we set $Q_b^{-i,T} = (n-1)Q_b^T$ and solve for the optimal quantity that the retailer offers in the bad state which is

$$Q_b^T = \frac{A_b - P^T(1-r_s)}{n+1} \tag{28}$$

According to Equation (8), the first order condition to solve Q_b^T is

$$\frac{\partial}{\partial Q_g^T}\left[(1-q)\omega_b^T + q\omega_g^T\right] = 0 \tag{29}$$

By substituting the cost C_g^T and the optimal quantity that the retailer offers in the bad state, Q_b^T, and solving the partial derivative, Equation (29) becomes

$$q(A_g - 2Q_g^T - Q_g^{-i,T} - P^T) - (1-q)P^T r_s = 0 \tag{30}$$

which yields the best response function

$$Q_g^T = \frac{q(A_g + P^T) - (1-q)P^T r_s - Q_b^{-i,T}}{2} \tag{31}$$

Assuming again that all firms are symmetric, we set $Q_g^{-i,T} = (n-1)Q_g^T$ and solve for the optimal quantity that the retailer offers in the good state which is

$$Q_g^T = \frac{(A_g - P^T)q - (1-q)P^T r_s}{n+1} \tag{32}$$

According to Equation (10), the first order condition to solve P^T and r_s is:

$$\frac{\partial}{\partial P^T}\left[qP^T Q_g^T + (1-q)\left(P^T Q_b^T + \frac{r_s P^T (Q_g^T - Q_b^T)}{1+r}\right)\right] = 0 \tag{33}$$

$$\frac{\partial}{\partial r_s}\left[qP^T Q_g^T + (1-q)\left(P^T Q_b^T + \frac{r_s P^T (Q_g^T - Q_b^T)}{1+r}\right)\right] = 0 \tag{34}$$

By substituting the optimal quantities, Q_b^T, Q_g^T, that the retailer offers in a bad state and a good state, respectively and solving the partial derivative, Equations (33) and (34) become

$$\frac{A_b(1-q)q(1-r_s) + A_g q(q + r_s - qr_s) - 2P^T(q + (1-q)r_s^2)}{n+1} = 0 \tag{35}$$

$$\frac{P^T(1-q)[(A_g - A_b)(1-q) + 2P^T r_s]}{(n+1)q} = 0 \tag{36}$$

Simultaneously solving Equations (35) and (36) yields the price and trade credit interest rate charged by a supplier under trade credit financing,

$$P^T = \frac{2(qA_g + (1-q)A_b)}{3+n} \tag{37}$$

$$r_s = \frac{q(A_g - A_b)}{qA_g + (1-q)A_b} \tag{38}$$

By substituting the equilibrium price and trade credit interest rate into the Equation (28) and Equation (32), the quantities sold in the good state and the bad state are $\frac{A_g}{n+3}$ and $\frac{A_b}{n+3}$, respectively.

■

Proof of Proposition 3

Proof. The marginal cost in the bad state

At the optimal quantity determined by the first order condition of Equation (2), the marginal revenue (MR_b) from selling one more unit must equal the total marginal cost (MC_b), which we can write as the sum of the marginal purchasing (MPC) and marginal financing costs (MFC_b),

$$MR_b = MC_b = MPC + MFC_b^f. \tag{39}$$

Under both forms of financing marginal revenue and marginal purchase costs are given by $MR_s = A_s - 2Q_s^f - Q_s^{-i,f}$, and $MPC = P^f$, respectively.

Under bank financing, Equation (39) becomes

$$MC_b^B = P^B + MFC_b^B \tag{40}$$

The marginal financing cost is zero in the bad state, thus, the marginal cost is equal to P^B.

Under trade credit financing, Equation (39) becomes

$$MC_b^T = P^T + MFC_b^T \tag{41}$$

The marginal financing cost is $-\frac{P^T r_s}{(1+r)}$ in the bad state, thus, the marginal cost is equal to $P^T - \frac{P^T r_s}{(1+r)}$,since $P^B = P^T$ at the equilibrium, the marginal cost under trade credit is lower in the bad state.

The marginal cost in the good state

Rearrange Equation (98), it becomes

$$MC_g = MPC + MFC_g^f + \frac{(1-q)}{q} MFC_b^f. \tag{42}$$

under bank financing, the marginal cost is equal to P^B since the marginal financing costs in both states are zero by assuming $r = 0$.

Under trade credit financing, the marginal product cost is P^T, the marginal financing cost in the good state is 0; and the marginal financing cost in the bad state is $\frac{(1-q)}{q}\frac{P^T r_s}{(1+r)}$, thus the marginal cost in a good state is $P^T(1 + \frac{(1-q)}{q}\frac{r_s}{(1+r)})$. Again, as $P^B = P^T$ at the equilibrium, the marginal cost under trade credit is higher in a good state.

■

Proof of Corollary 1

Proof. As $r_s = \frac{q(A_g - A_b)}{qA_g + (1-q)A_b}$, thus the partial derivative with respect to q is given by

$$\frac{\partial r_s}{\partial q} = \frac{A_b(A_g - A_b)}{(qA_g + (1-q)A_b)^2} > 0 \tag{43}$$

and the partial derivative with respect to $(A_g - A_b)$ is given by

$$\frac{\partial r_s}{\partial (A_g - A_b)} = \frac{q}{qA_g + (1-q)A_b} > 0 \tag{44}$$

■

Proof of Proposition 5

Proof. By using the solutions obtained from Proposition 1 and Proposition 2, we have the explicit solutions of supplier and retailer's profits as well as consumer surplus for both bank financing and trade credit financing cases. Under bank financing, by substituting the equilibrium price, quantities sold by the retailer in both good and bad states into Equation 4 and 6, the profits obtained by the retailer and the supplier as well as the total producer surplus are shown as:

$$\begin{aligned} \omega^B &= \frac{1}{(1+n)^2(3+n)^2}[A_g^2(9+n^2+n(6-4q)-8q)q - \\ &\quad 8A_gA_b(2+n)(1-q)q + A_b^2(1-q)(1+n^2+8q+n(2+4q))] \end{aligned} \tag{45}$$

$$\pi^B = \frac{2(A_b(1-q)+A_gq)^2}{(3+n)^2} \tag{46}$$

$$\begin{aligned} \omega^B + \pi^B &= \frac{1}{(1+n)^2(3+n)^2}[A_g^2(9+6n-6q+n^2(1+2q)) + \\ &\quad 4A_gA_b(n^2-3)(1-q) + A_b^2(1-q)(3+6n+6q+n^2(3-2q)] \end{aligned} \tag{47}$$

Similarly, under trade credit financing, by substituting the equilibrium price, trade credit interest rate and quantities sold by the retailer in both good and bad states into Equation 4 and 7, the profits obtained by the retailer and the supplier as well as the total producer surplus are shown as:

$$\omega^T = \frac{A_b^2(1-q) + A_g^2 q}{(3+n)^2} \tag{48}$$

$$\pi^T = \frac{2(A_b^2(1-q) + A_g^2 q)}{(3+n)^2} \tag{49}$$

$$\omega^T + \pi^T = \frac{3(A_b^2(1-q) + A_g^2 q)}{(3+n)^2} \tag{50}$$

Thus, the difference of producer surplus between trade credit financing and bank financing is

$$(\omega^T + \pi^T) - (\omega^B + \pi^B) = \frac{2(A_g - A_b)^2(n^2-3)(1-q)q}{(3+4n+n^2)^2} \tag{51}$$

From the above equation, we can find that when $n = 1$ (one supply chain or monopoly industry), the total producer surplus is smaller under trade credit financing than bank financing; however, if $n \geq 2$ (at least two supply chains or duopoly industry), the total producer surplus is greater under trade credit financing than bank financing. ■

Proof of Proposition 4

Proof. For Equation (51), we take the partial derivative with respect to n, and then the first order condition is shown as:

$$\frac{\partial[(\omega^T + \pi^T) - (\omega^B + \pi^B)]}{\partial n} = \frac{4(A_g - A_b)^2(12+9n-n^3)(1-q)q}{(3+4n+n^2)3} \tag{52}$$

then, when $n = 1$,we have $\frac{\partial[(\omega^T+\pi^T)-(\omega^B+\pi^B)]}{\partial n} = \frac{88(A_g-A_b)^2(1-q)q}{3375} > 0$ and when $n = \infty$, then $\frac{\partial[(\omega^T+\pi^T)-(\omega^B+\pi^B)]}{\partial n} = 0$. From this finding, we can see that the partial derivative is rising initially when n is very small but declines when n becomes very large, therefore, there exists an inverse U-shaped relationship between the advantage of trade credit financing and the number of supply chains. ■

B Deviation by a supply chain

We extend the basic model in the paper assuming that m supply chains with bank financing compete with (n-m) supply chains using bank financing. We allow the two types of supply chains to follow different strategies in the product market. We solve for the subgame perfect Nash equilibrium by backward induction starting with the retailers' decision problem. Compute the trade-off for the supply chain using bank financing.

Stage 3: One of m retailers' end of period problem —ex-post competition in a bad state

At the end of the period, each retailer i maximizes its profit ω_b^B by competing in quantity

Q_b^B. The retailer's problem is

$$\max_{Q_b^B} \omega_b^B = (A_b - (m-1)Q_b^{OB} - (n-m)Q_b^T - Q_b^B)Q_b^B - (rP^BQ_g^B + P^BQ_b^B) \quad (53)$$

According to Equation (53), the first order condition to solve Q_b^B is

$$\frac{\partial}{\partial Q_b^B}\left[(A_b - (m-1)Q_b^{OB} - (n-m)Q_b^T - Q_b^B)Q_b^B - (rP^BQ_g^B + P^BQ_b^B)\right] = 0 \quad (54)$$

Solving the partial derivative, Equation (54) becomes

$$A_b - P^B - 2Q_b^B - (n-m)Q_b^T - (m-1)Q_b^{OB} = 0 \quad (55)$$

which yields the best response function

$$Q_b^B = \frac{1}{2}(A_b - P^B + (n-m)Q_b^T - (m-1)Q_b^{OB}) \quad (56)$$

Stage 2: One of m retailers' ex-ante inventory decision

We first define the profit in the good state under bank financing, ω_g^B,

$$\omega_g^B = (A_g - (m-1)Q_g^{OB} - (n-m)Q_g^T - Q_g^B)Q_g^B - (rP^BQ_g^B + P^BQ_g^B) \quad (57)$$

and then compute the ex-ante expected profit:

$$\max_{Q_g^B}\left[(1-q)\omega_b^B + q\omega_g^B\right] \quad (58)$$

According to Equation (58), the first order condition to solve Q_g^B is

$$\frac{\partial}{\partial Q_g^B}\left[(1-q)\omega_b^B + q\omega_g^B\right] = 0 \quad (59)$$

By substituting the optimal quantity that the retailer offers in the bad state, Q_b^B, and solving the partial derivative, Equation (56) becomes

$$q(A_g - P^B - 2Q_g^B - (n-m)Q_g^T - (m-1)Q_g^{OB}) - P^Br = 0 \quad (60)$$

which yields the best response function

$$Q_g^B = \frac{1}{2}(A_g - P^B - (n-m)Q_g^T - (m-1)Q_g^{OB}) - \frac{P^Br}{2q} \quad (61)$$

Stage 1: the supplier decides on the price

Under bank financing, each supplier only has the wholesale price as a choice variable to maximize their expected profits

$$\max_{P^B} \pi^B = (1+r)P^B Q_g^B - (1-q)P^B(Q_g^B - Q_b^B) \tag{62}$$

According to Equation (62), the first order condition to solve P^B is:

$$\frac{\partial}{\partial P^B}\left[(1+r)P^B Q_g^B - (1-q)P^B(Q_g^B - Q_b^B))\right] = 0 \tag{63}$$

By substituting the optimal quantities, Q_b^B, Q_g^B, that the retailer offers in a bad state and a good state, respectively, and solving the partial derivative and setting it equal to zero, the price charged by a supplier under bank financing is:

$$P^B = \frac{1}{2(q+2qr+r^2)}[A_g(q+r)+A_b(1-q)-(n-m)((1-q)Q_b^T+(q+r)Q_g^T)+(m-1)((1-q)Q_b^{OB}+(q+r)Q_g^{OB}] \tag{64}$$

Then compute the trade-off for the supply chain using trade credit financing.

Stage 3: One of n-m retailers' end of period problem —ex-post competition in a bad state

At the end of the period, each retailer i maximizes its profit ω_b^T by competing in quantity Q_b^T. The retailer's problem is

$$\max_{Q_b^T} \omega_b^T = (A_b - mQ_b^B - (n-m-1)Q_b^{OT} - Q_b^T)Q_b^T - (P^T Q_b^T + P^T r_s(Q_g^T - Q_b^B)/(1+r)) \tag{65}$$

According to Equation (65), the first order condition to solve Q_b^T is

$$\frac{\partial}{\partial Q_b^T}\left[(A_b - mQ_b^B - (n-m-1)Q_b^{OT} - Q_b^T)Q_b^T - (P^T Q_b^T + P^T r_s(Q_g^T - Q_b^T)/(1+r))\right] = 0 \tag{66}$$

Solving the partial derivative, Equation (66) becomes

$$A_b - P^T - mQ_b^B - 2Q_b^T - (n-m-1)Q_b^{OT} - P^T r_s/(1+r) = 0 \tag{67}$$

which yields the best response function

$$Q_b^T = \frac{1}{2}(A_b - P^B - mQ_b^B + (n-m-1)Q_b^{OT} - P^T r_s/(1+r)) \tag{68}$$

Stage 2: One of m retailers' ex-ante inventory decision

We first define the profit in the good state under trade credit financing, ω_g^T,

$$\omega_g^T = (A_g - mQ_g^{OB} - (n-m-1)Q_g^{OT} - Q_g^T)Q_g^T - P^T Q_g^T \tag{69}$$

and then compute the ex-ante expected profit:

$$\max_{Q_g^T} \left[(1-q)\omega_b^T + q\omega_g^T\right] = 0 \tag{70}$$

According to Equation (70), the first order condition to solve Q_g^T is

$$\frac{\partial}{\partial Q_g^T}\left[(1-q)\omega_b^T + q\omega_g^T\right] = 0 \tag{71}$$

By substituting the optimal quantity that the retailer offers in the bad state, Q_b^T, and solving the partial derivative and setting it equal to zero, the inventory the retailer chooses is:

$$Q_g^T = \frac{1}{2}[A_g - P^T - mQ_g^B - (n-m-1)Q_g^{OT}) - \frac{P^T r_s(1-q)}{q(1+r)}] \tag{72}$$

Under trade credit financing, each supplier maximizes the expected profit through simultaneous choice of price P^T and trade credit interest rate r_s.

$$\max_{P^T, r_s} \pi^T = qP^T Q_g^T + (1-q)\left(P^T Q_b^T + \frac{r_s P^T (Q_g^T - Q_b^T)}{1+r}\right) \tag{73}$$

According to Equation (10), the first order condition to solve P^T and r_s is:

$$\frac{\partial}{\partial P^T}\left[qP^T Q_g^T + (1-q)\left(P^T Q_b^T + \frac{r_s P^T (Q_g^T - Q_b^T)}{1+r}\right)\right] = 0 \tag{74}$$

$$\frac{\partial}{\partial r_s}\left[qP^T Q_g^T + (1-q)\left(P^T Q_b^T + \frac{r_s P^T (Q_g^T - Q_b^T)}{1+r}\right)\right] = 0 \tag{75}$$

By substituting the optimal quantities, Q_b^T, Q_g^T, that the retailer offers in a bad state and a good state, respectively and solving the partial derivative and then simultaneously solving Equations (74) and (75) yields the price and trade credit interest rate charged by a supplier under trade credit financing,

$$P^T = \frac{q(1+r)}{2q(1+r)^2 + 2(1-q)r_s^2}[A_b(1-q) + A_g q - m(1-q)Q_b^B - mqQ_g^B - (n-m-1)Q_b^{OT}] \tag{76}$$

$$r_s = \frac{q(1+r)}{2P^{T^2}(1-q)}[A_g - A_b + (n-m-1)(Q_g^{OT} - Q_b^{OT}) - m(Q_g^B - Q_b^B)] \quad (77)$$

Solving all equations yields

$$r_s = \frac{(A_g - A_b)(3+n)q}{(n+2m+3)(A_g q - A_b(1-q))} \quad (78)$$

$$P^T = \frac{2(A_g q + A_b(1-q))}{(n+3)} \quad (79)$$

$$Q_g^T = \frac{A_g(n+2mq+3) + 2A_b m(1-q)}{(n+2m+3)(n+3)} \quad (80)$$

$$Q_b^T = \frac{2A_g mq + A_b(n+3+2m(1-q))}{(n+2m+3)(n+3)} \quad (81)$$

$$P^B = \frac{2(A_g q + A_b(1-q))}{(n+3)} \quad (82)$$

$$Q_g^B = \frac{A_g(n(3-2q) - 2(m-3)q + 9) + 2A_b(n-m+3)}{(n+2m+3)(n+3)} \quad (83)$$

$$Q_b^B = \frac{A_b((n+3)(1+2q) + 2m(1-q)) - 2A_g(n-m+3)q}{(n+2m+3)(n+3)} \quad (84)$$

Given the results obtained above, we can calculate the producer surplus for one supply chain deviating to bank financing and we compare the difference with the producer surplus under trade credit financing and the difference is: $\frac{6(A_g-A_b)^2(1-q)q(n(n+4)+1)}{(n+3)^2(n+5)^2}$, which is positive, meaning that one-time deviation for a supply chain is beneficial; however, if we compare the benefit from deviation in terms of producer surplus under trade credit financing, the benefit is very small. A detailed Mathematica file with all results is available from the authors upon request.

C Classic collusion—the Integrated Monopolist

Start with considering an integrated monopolist. Assume that the firm produces goods at a marginal cost of zero at the beginning of each period. The firm then sells the goods at the end of the period. Since goods cost zero to produce, no financing is needed for production. We know that the solution is to sell $\frac{A_b}{2}$ in the bad state and $\frac{A_g}{2}$ in the good state. If we assume n identical vertically integrated supply chains collude together, then each supply chain sells $Q_b = \frac{A_b}{2n}$in the bad state and $Q_g = \frac{A_g}{2n}$ in the good state—we refer to this case as classic collusion in the paper. What is the incentive to deviate from this collusive equilibrium?

The deviating supply chain sales in a bad state

At the end of the period, each retailer i maximizes its profit ω_b^B by competing in quantity Q_b^B. The retailer's problem is

$$\max_{Q_b} \omega_b = (A_b - Q_b - (n-1)Q_b^O)Q_b \tag{85}$$

Solving the partial derivative with respect to Q_b, which yields the best response function:

$$Q_b = \frac{1}{2}(A_b + (n-1)Q_b^O) \tag{86}$$

Similarly in the good state the best response function is:

$$Q_g = \frac{1}{2}(A_g + (n-1)Q_g^O) \tag{87}$$

Assuming the other firms still stick to the cartel output, i.e.: $Q_g^O = \frac{A_g}{2n}$ in a good state and $Q_b^O = \frac{A_b}{2n}$ in a bad state, then the optimal sales for the deviating firm in a bad state are $Q_b = \frac{A_b(n+1)}{4n}$ and $Q_g = \frac{A_g(n+1)}{4n}$ in a good state, respectively. According to the sales, the ex-ante expected profit i.e. $(1-q)\omega_b^B + q\omega_g^B$ for the deviating firm is $\frac{(A_g^2 q + A_b^2(1-q))(n+1)^2}{16n^2}$.

D Expected quantities sold

For a large set of parameters expected sales for the supplier are larger under trade credit financing than under bank financing. In the left panel of Figure 8 we show the region of the parameter space where the expected number of goods sold, $qQ_g^f + (1-q)Q_b^f$, is higher for trade credit financing. Unless the difference between the good state and the bad state is small or the probability of the good state is very low the number of goods sold under trade credit exceed those under bank financing. The region of the parameter space where this is true increases as interest rates decrease.

For expected sales in dollar terms (right panel) the result is stronger. Here expected sales for the supplier, $P^f(qQ_g^f + (1-q)Q_b^f)$ under trade credit financing exceed sales under bank financing unless the difference between states is extremely large and the good state is very unlikely.

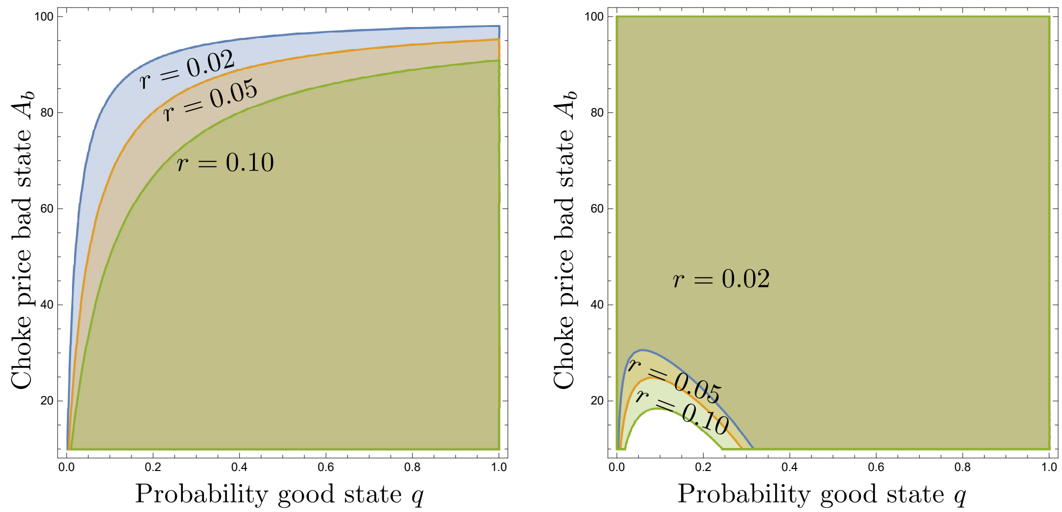

Figure 8. Region where expected sales under trade credit exceed those of bank financing. The regions indicate for which parameter values expected sales in number of goods (left) and in dollar terms (right) under trade financing are larger than under bank financing. The parameters for the graph are unless otherwise specified: $A_g = 100, n = 5$.

E Banks mimicking the trade credit contract

If the trade credit contract is a beneficial collusion mechanism, why can the same arrangement not be replicated through state contingent bank financing? Start by observing that the provision of trade credit financing is not a zero NPV project for the supplier. In the limiting case when $r = 0$, which is analyzed through most of the paper, it is easy to see that a positive trade credit interest rate will result in a positive contribution to the supplier's profit. It is easy to find other parameters, like when the probability of the bad state is very low and r is high, under which providing free financing in the good state is on average costly for the supplier. Figure 9 shows the expected profit of the supplier from providing trade credit financing, which is the value of the unsold inventory, $P(Q_g - Q_b)$, times the trade credit interest rate, which is paid in the bad state and one period later, minus the opportunity cost of providing free financing for the value of the inventory, rPQ_g:

$$\left(\frac{(1-q) r_s (Q_g - Q_b)}{1+r} - rQ_g \right) P$$

The expected payoff from trade credit is declining in the risk-free rate as a higher interest rate makes the free financing period more costly for the supplier. Price discrimination is more profitable when both states occur with equal probability and so is trade credit financing (left panel). The same is true when the difference between the good state and the bad state is more pronounced, i.e. lower A_b (right panel).

The nonzero NPV of the trade credit contract makes it harder to replicate by the banking

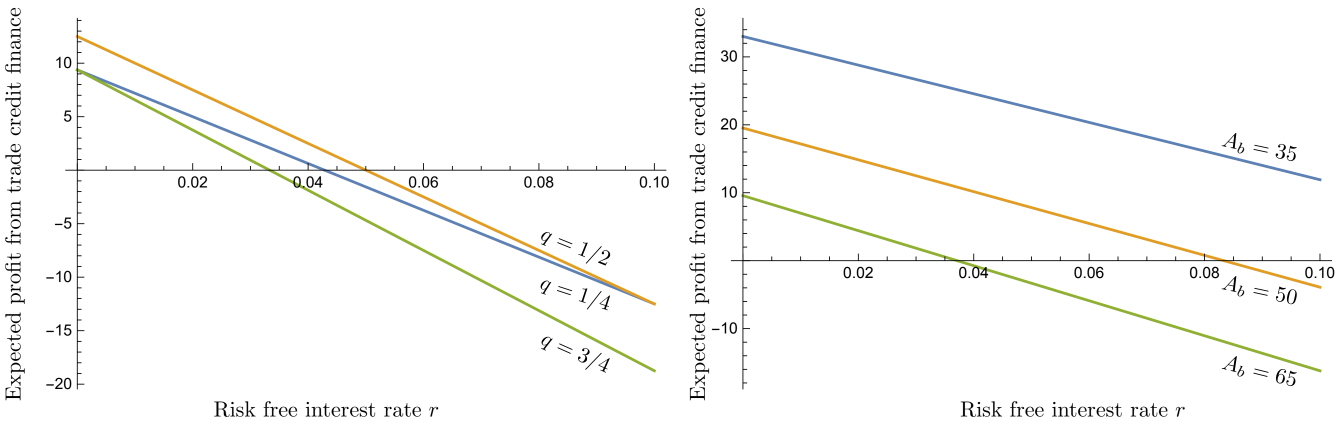

Figure 9. Expected per period profit for the supplier from providing trade credit financing. The parameters for the graph are unless otherwise specified: $A_g = 100, A_b = 60, q = 1/2, n = 3$.

sector for three reasons: first, when the supplier then sets the wholesale price P she will take the profits from financing into account and will set a different price than when all financing cash flows go towards outside financiers. Second, the positive or negative NPV of the financing component makes it hard for a competitive banking sector to replicate exactly the trade credit contract. If the NPV was positive, it would get competed away, if the NPV from trade credit financing was negative, the banking sector would not offer such a contract.

Finally, a trade credit style financing contract provided by a competitive banking sector is much less robust to deviation from the collusive equilibrium than trade credit provided by the supplier. Unless banks and retailers can form a long-lasting committed relationship for reasons outside the model retailers have an incentive to deviate in the bad state. Suppose that a bank replicates the trade credit contract and offers a low interest rate in the good state and asks for a high interest rate in the bad state. The retailer could deviate in the bad state and borrow from another bank. Since the retailer can never default, he can borrow funds from a new bank at the risk-free rate and repay the old bank instead of paying the penalty rate on the unsold inventory. To prevent such a deviation the bank and the financier would have to write a binding, long-term contract or build a long-lasting relationship for reasons outside of the model, otherwise there are no repercussions in a competitive banking sector. Such a deviation is less of a concern under the trade credit mechanism analyzed in the main section of this paper. Should a retailer deviate to bank financing to avoid the penalty rate in the bad state the supplier will not provide trade credit financing going forward, the bank financing equilibrium would be implemented, resulting in a lower producer surplus.

Suppose that still all three obstacles could somehow be overcome. Assume that for reasons outside of the model the retailer can enter a committed lending relationship with a bank who offers, similar to a trade credit contract, a rate of $r_L \geq 0$ if the inventory is

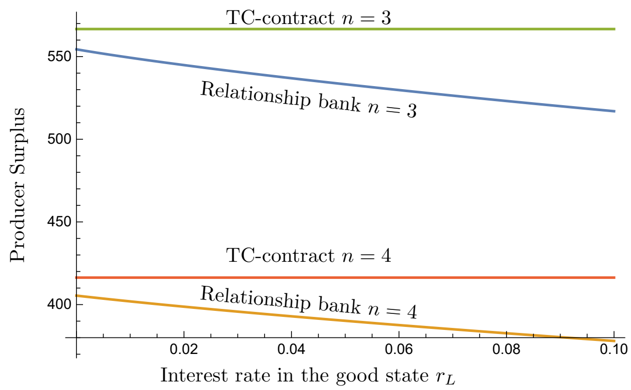

Figure 10. Producer surplus under trade credit financing and under a hypothetical contract with state contingent interest rates offered by competitive outside financiers as a function of the interest rate offered in the good state. The parameters for the graph are: $A_g = 100, A_b = 60, q = 1/2, r = 0.05$.

sold within the period and charges $r_H > r_L$ to finance any unsold inventory. Furthermore, assume that the bank sets the two interest rates such that its expected profit is zero to address the first two concerns mentioned above. Note that the game differs from the model in the main part of the paper as the supplier cannot obtain any gains from financing and will therefore set a different price.

We are not able to solve such a model analytically but we found, for all parameters that we analyzed, the producer surplus to be lower than under a traditional trade credit contract. Figure 10 shows an example for three and four firms, respectively. The graph shows the producer surplus under trade credit financing and under the forced relationship banking contract for different values of the interest rate in the good state, r_L. The interest rate in the bad state is then set such that outside investors break even in expectation. The trade credit contract results in a higher producer surplus than the relationship banking contract.

F Decomposing the trade credit benefit

Define the number of supply chains n where retail prices under bank and trade credit financing are equidistant from the retail price of an integrated monopolist in the good state as n_g^*. Since the demand function is linear, we formulate the problem in term of aggregate quantities. The average of the aggregate quantities offered in the good state under bank financing, nQ_g^B, and under trade credit, nQ_g^T, has to equal the quantity the integrated monopolist would offer, $A_g/2$.

$$\frac{nQ_g^B + nQ_g^T}{2} = \frac{A_g}{2} \tag{88}$$

Substituting for Q_g^B and Q_g^G from Proposition 1 and 2, respectively, and solving for n yields a quadratic equation in n where we only consider the positive solution, which is

$$n_g^* = \frac{A_b(1-q) + A_g q + \sqrt{3{A_g}^2 + (A_b(1-q) + A_g q)^2}}{A_g} \tag{89}$$

The same approach for the bad state leads to

$$n_b^* = \frac{A_b(1-q) + A_g q + \sqrt{3{A_b}^2 + (A_b(1-q) + A_g q)^2}}{A_b} \tag{90}$$

Because the choke price in the good state is higher than in the bad state. $A_g > A_b$, it is easy to show that $n_g^* < n_b^*$. Because $A_g > 0, A_b > 0$, and $0 < q < 1$ it is also straightforward to see that $n_g^* > 0$. Therefore there always exists a region, $0 < n < n_g^*$ where any benefit of trade credit over bank financing only comes from the bad state followed by a region $n_g^* < n < n_b^*$ where trade credit financing is beneficial in both states.

There is an upper limit for n_g^*. Note that since $A_g > A_b$, n_g^* is increasing in q. Setting $q = 1$ and simplifying yields $n_g^* \leq 3$. There is, however, no upper limit for n_b^*. Set $A_b = 2A_g q/(2q + n + 1)$ so that Assumption (1) is binding and substitute into Equation (90). Simplifying yields $n_b^* = (3 + n + \sqrt{21 + 6n + n^2})/2$ which goes to infinity when n becomes large. Intuitively in the region close to where Assumption (1) is binding sales under bank financing in the bad state are close to zero, as the retail price is close to the wholesale price and retailers do not find it worthwhile to offer the product to the market. The trade credit penalty causes retailers to accept retail prices that are below the wholesale price to avoid the penalty. They offer a positive quantity to the market at a loss to them but still at a profit for the supply chain as the production cost is zero. If n_b^* is finite, as in most cases and as in the examples plotted in Figure 2, there exists a third region of the parameter space where for $n > n_b^*$ trade credit financing only creates more producer surplus than bank financing in the good state.

G Emergence of trade credit

In the main body of the paper we compare pure bank financing of inventory with pure trade credit financing. In this section we analyze one possible explanation for the emergence of trade credit by analyzing the stability of the bank financing equilibrium. Given that all other supply chains use bank financing, we find that when the risk-free rate is positive, one supply chain benefits from deviating and offering a small amount of trade credit financing, making the pure bank financing equilibrium inherently unstable.

Intuitively providing a bit of trade credit financing will not change the retailers product market behavior directly. When the amount of trade credit financing is small the marginal good sold in both, the good and the bad state, is still financed by a bank loan. For the supplier, however, even a small amount of trade credit financing will change the optimal wholesale price. While cash sales are paid to the supplier at the beginning of the period, trade credit sales are settled at the end of the period. The supplier, when providing free financing, effectively forgoes interest on any trade-credit-financed revenue. Because the sales proceeds cannot be invested to earn interest the marginal gain from raising the wholesale price is lower under partial trade credit financing than under bank financing, which will cause the supplier to optimally set a lower wholesale price than under pure bank financing. The lower wholesale price, in turn, makes the retailer of the partially trade credit financed supply chain more aggressive and the optimal response of the other supply chains is to reduce the quantities offered. The deviating supply chain will thus capture a larger market share at the expense of its rivals. As we will more formally show below an individual supply chain can increase its producer surplus by offering a bit of trade credit financing given that all other supply chains use pure bank financing.

Assume that out of the n supply chains in the economy $n-1$ use pure bank financing while one supply chain considers to finance $\iota < Q_b$ units with trade credit. Note that we only look at cases where the amount of trade-credit-financed goods is smaller than the amounts of goods sold in the bad state, so firms can always – even in the bad state – repay the supplier and a trade credit penalty will never be realized. Therefore the trade credit interest rate is irrelevant.

Start with the $n-1$ supply chains that use only bank financing. The retailers problem in the bad state will determine the quantity offered in the bad state, Q_b, and is similar to the pure bank financing case in Equation (4) with the notable exception that he must take into account that the firm that relies on partial trade credit financing might use a different product market strategy and will offer a quantity Q_b^ι in the bad state:

$$\max_{Q_b} \omega_b = (A_b - Q_b - Q_b^{-i} - Q_b^\iota)Q_b - PQ_b - PQ_g r \tag{91}$$

where Q_b^{-i} no represents the aggregate output offered by the $n-2$ other retailers that use pure bank financing.

Analogous to Equation (5) the retailer earns in the good state

$$\omega_g = (A_g - Q_g - Q_g^{-i} - Q_g^\iota)Q_g - PQ_g - PQ_g r.$$

and will as in Equation (8) determine his optimal inventory based on expected profit solving

$$\max_{Q_g} \omega = [(1-q)\omega_b + q\omega_g] \tag{92}$$

The supplier will maximize expected profit as in Equation (9), which will determine the wholesale price P.

$$\max_{P} \pi = (1+r)PQ_g - (1-q)P(Q_g - Q_b) \tag{93}$$

The deviating supply chain finances ι units of the good with trade credit. In the bad state the goods on trade credit are always repaid first and since we assume that ι is less than the units sold in the bad state, no penalty is realized. The partial trade credit makes the retailer better off by providing partial free financing. The retailer only has to pay interest on the bank financed portion of his inventory, $P^{\iota}(Q_g^{\iota} - \iota)$. Since the marginal good sold in both states is financed by the bank, partial trade credit financing will not influence the retailer's optimal sales directly. However, as we will see below, partial trade credit financing will change the financing cost of inventory which will impact the retailer's optimal product market strategy. The corresponding equations for the retailer in the deviating supply chain are

$$\max_{Q_b^{\iota}} \omega_b^{\iota} = (A_b - Q_b - Q_b^{-i} - Q_b^{\iota})Q_b^{\iota} - P^{\iota}Q_b^{\iota} - P^{\iota}(Q_g^{\iota} - \iota)r \tag{94}$$

$$\omega_g^{\iota} = (A_g - Q_g - Q_g^{-i} - Q_g^{\iota})Q_g^{\iota} - P^{\iota}Q_g^{\iota} - P^{\iota}(Q_g^{\iota} - \iota)r.$$

$$\max_{Q_g^{\iota}} \omega^{\iota} = \left[(1-q)\omega_b^{\iota} + q\omega_g^{\iota}\right] \tag{95}$$

The supplier of the deviating supply chain will carry the cost of free trade credit financing. She will collect payment on the goods financed on trade credit, $P^{\iota}\iota$, at the end of the period while she will collect the payment on bank financed goods, $P^{\iota}(Q_g^{\iota} - \iota)$, at the beginning of the period and can hence collect interest on the latter.

$$\max_{P^{\iota}} \pi^{\iota} = (1+r)P^{\iota}(Q_g^{\iota} - \iota) + P^{\iota}\iota - (1-q)P^{\iota}(Q_g^{\iota} - Q_b^{\iota}) \tag{96}$$

When $\iota = 0$ the problems of the two types of supply chains become identical and the solution collapses to the pure bank financing equilibrium. We solve the first order conditions corresponding to the six optimization problems (91)-(96) and assume symmetry amongst all pure bank financed firms to get:[32]

$$
\begin{aligned}
Q_b &= \frac{3A_b\left(2(n+3)qr+q(n+2q+1)+(n+3)r^2\right)-6A_gq(q+r)-2\iota(n+1)qr}{3(n+1)(n+3)\left(2qr+q+r^2\right)}, \\
Q_g &= \frac{6A_b(q-1)(q+r)+3A_g\left(2(n+1)qr+q(n-2q+3)+(n+1)r^2\right)-2\iota(n+1)r(q+r)}{3(n+1)(n+3)\left(2qr+q+r^2\right)}, \\
\text{P} &= \frac{2q(-3A_b(q-1)+3A_g(q+r)-2\iota r)}{3(n+3)\left(2qr+q+r^2\right)}, \\
Q_b^\iota &= \frac{3A_b\left(2(n+3)qr+q(n+2q+1)+(n+3)r^2\right)-6A_gq(q+r)+2\iota(n+1)(n+2)qr}{3(n+1)(n+3)\left(2qr+q+r^2\right)}, \\
Q_g^\iota &= \frac{6A_b(q-1)(q+r)+3A_g\left(2(n+1)qr+q(n-2q+3)+(n+1)r^2\right)+2\iota(n+1)(n+2)r(q+r)}{3(n+1)(n+3)\left(2qr+q+r^2\right)}, \\
\text{P}\iota &= \frac{2q(3A_b(1-q)+3A_g(q+r)-\iota(n+5)r)}{3(n+3)\left(2qr+q+r^2\right)}
\end{aligned}
$$

We plug the above solution into the profit of the supplier and retailer and add them to obtain the producer surplus. Our main interest is to find out if the deviating supply chain has an incentive to supply trade credit given that all other supply chains use bank financing. We compute the gain for the deviating supply chain from offering an infinitesimal amount of trade credit financing given that all other supply chains use bank financing.

$$
\left.\frac{\partial(\omega^{\iota,*}+\pi^{\iota,*})}{\partial\iota}\right|_{\iota=0} = \frac{2(n+1)qr(A_b(1-q)+A_g(q+r))}{(n+3)^2\left(2qr+q+r^2\right)} > 0 \qquad (97)
$$

We can see that the bank financing equilibrium is not stable. Each supply chain has an incentive to offer some trade credit financing to their retailer. This is one potential explanation for the existence of trade credit. Once trade credit exists supply chains might find it easier to collude on a trade credit financing equilibrium as analyzed in the paper.

H Trade credit and state specific marginal costs

We will show that sales are always bound by inventory in good states and that constraint (3) is binding. The retailer's quantity choice in good states is therefore made when he chooses inventories before the state of demand is realized.

We can rewrite the first order condition of Equation (8) for the retailer's optimal level of inventory as

$$
qMR_g = qMC_g^f = q(MPC+MFC_g^f)+(1-q)MFC_b^f. \qquad (98)
$$

[32] A Mathematica workbook with the details on the derivation is available from the authors upon request. Everything can be solved closed form but the expressions are long and provide no intuitive insights.

The retailer obtains a marginal revenue, MR, from an increased unit of inventory only in the good state which occurs with probability q because not all of the inventory is sold in a bad state. Increasing inventory incurs two ex-ante marginal costs: the marginal cost of purchasing (MPC) and financing (MFC) the additional good when it gets sold in the good state and the marginal cost of financing the additional good in the bad state when it stays in inventory. The marginal revenue and purchase costs are $MR_s = A_s - 2Q_s^f - Q_s^{-i,f}$, and $MPC = P^f$. Under bank financing, the ex-ante marginal financing cost equals to the interest paid for the value of the additional good in both demand states, $MFC_g^B = MFC_b^B = rP^B$. Substituting into Equation (98) we get $qMC_g^B = q(P^B + rP^B) + (1 - q)rP^B$. The total marginal cost is then $MC_g^B = P^B(1 + \frac{1}{q}r)$.

Under trade credit financing, the retailer gets free financing for the good state in which all goods are sold but has to finance the unsold goods at the trade credit interest rate in the bad state: $MFC_g^T = 0$, $MFC_b^T = P^T r_s/(1+r)$ and $MC_g^T = P^T(1 + \frac{r_s}{1+r}\frac{1-q}{q})$.

In good states, if we were to ignore the inventory constraints, the retailer's optimal level of sales should be given by $MR_g = MC_g^f$. Comparing to the inventory decision problem, the retailer would choose to sell more than the inventory under both bank financing and trade credit financing. The shadow price of the inventory is $r\frac{1}{q}P^B$ and $\frac{r_s}{(1+r)}\frac{1-q}{q}P^T$, for bank financing and trade credit financing, respectively. The retail competition in good states therefore is softened under both financing schemes. However, there are two differences between bank financing and trade credit financing. First, r_s is a choice variable optimally set by the supplier while r is exogenously given. As a result, the trade credit financing scheme enables the supplier to strategically influence her retailer's aggressiveness in both demand states, specifically how much to intensify the competition in a bad state and how much to soften the competition in a good state. Second, under trade credit financing, r_s explicitly reduces the marginal cost in bad states and increases the marginal cost in good states, while r does not have an explicit effect on the marginal cost in the bad state under bank financing.

There are potentially two stages of price discrimination. First, retailers price discriminate against consumers in different states of demand. Second, and the main focus of this paper, the suppliers price discriminate against their retailers. Trade credit financing implicitly allows the supplier to charge the retailer state contingent marginal costs and thus price discriminate between demand states. On appearance, the supplier seems to charge the retailer a low price (free financing) in good states and a high price (due to a higher trade credit interest rate) in bad states, which seems to contradict the typical pricing pattern in price discrimination theory: a high (low) price is charged when a demand is high (low). To find the correct state contingent prices rewrite the supplier's expected costs as:

$$
\begin{aligned}
& qP^TQ_g^T + (1-q)\left(P^TQ_b^T + \frac{r_sP^T(Q_g^T - Q_b^T)}{1+r}\right) \\
= & \left(qP^TQ_g^T + (1-q)\frac{r_sP^TQ_g^T}{1+r}\right) + \left((1-q)\left(P^TQ_b^T - \frac{r_sP^TQ_b^T}{1+r}\right)\right) \\
= & q\left(P^T + \frac{1-q}{q}\frac{r_sP^T}{1+r}\right)Q_g^T + (1-q)\left(P^T - \frac{r_sP^T}{1+r}\right)Q_b^T \\
= & qP_g^TQ_g^T + (1-q)P_b^TQ_b^T
\end{aligned}
$$

where $P_g^T = P^T(1 + \frac{1-q}{q}\frac{r_s}{1+r})$ and $P_b^T = P^T(1 - \frac{r_s}{1+r})$ are the supplier's effective prices in good and bad states, respectively. The price charged by the supplier in the good state is clearly higher than that in the bad state. Notice that P_g^T and P_b^T are exactly the retailer's total marginal costs for the equilibrium sales in good and bad states, respectively.

The incentive for a supplier to provide trade credit is hence to price-discriminate to her retailer between strong and weak demand states. In our model the rationale for a supplier to set state contingent prices is to change the marginal cost for the retailer to influence his behavior in the final product market. The supplier's price discrimination in our analysis is a double price discrimination, or a price discrimination to influence the retailer's price discrimination against the consumers. We summarize our findings in the following proposition:

Proposition 6 *Under trade credit financing, the supplier optimally price discriminates the retailer between the states of demand: charging a high effective price* $P_g^T = P^T(1 + \frac{1-q}{q}\frac{r_s}{1+r})$ *in good states and a low effective price* $P_b^T = P^T(1 - \frac{r_s}{1+r})$ *in bad states. As a result, compared to bank financing, the profits of the supplier are higher under trade credit financing.*

I Trade credit as double marginalization problem

Figure 11 illustrates the basic mechanism of our model by means of an example. The graph shows the marginal cost curves under trade credit and bank financing (horizontal lines), the inverse demand curve (bold line), and the marginal revenue for the integrated monopolist. Each point in the line labeled "equilibrium marginal revenue oligopoly" corresponds to an equilibrium in a Cournot oligopoly game with three firms and shows the marginal revenue (along the vertical axis) and aggregate output (along the horizontal axis) in that equilibrium. To derive this line we solve a simple Cournot game for marginal costs ranging from zero to

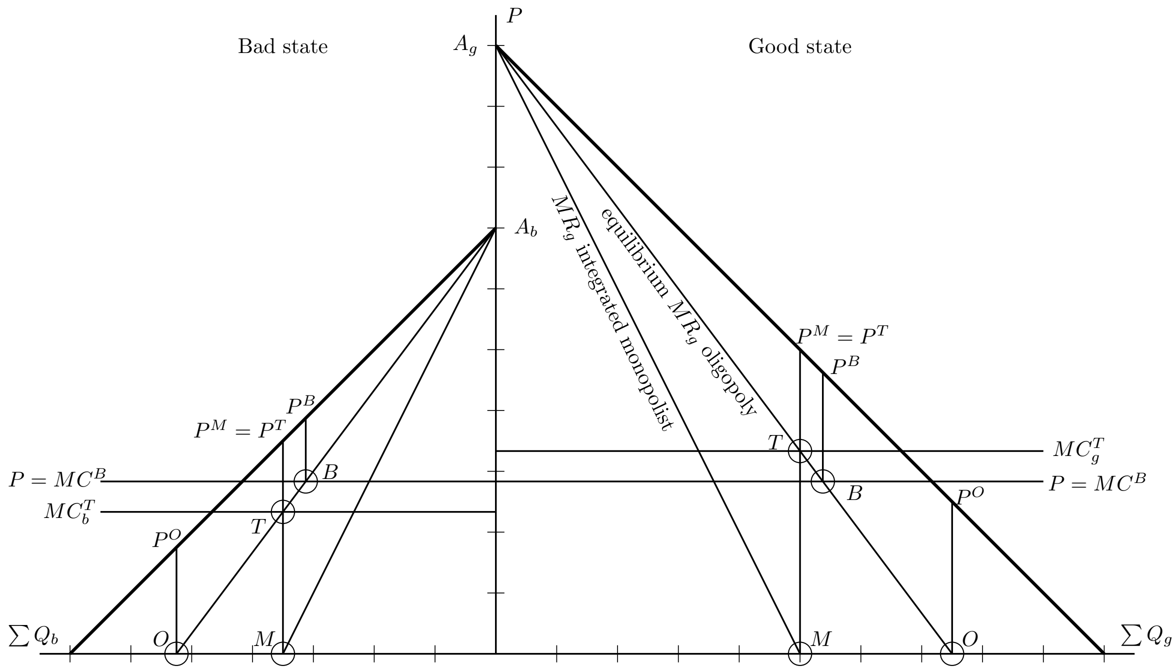

Figure 11. Product market equilibria, marginal revenues and costs under alternative financing arrangements. The graph shows the inverse demand curve (bold line), the marginal revenue of the integrated monopolist, and the equilibrium marginal revenue line for an oligopoly, for which each point corresponds to an equilibrium in an oligopoly game and represents the marginal revenue and aggregate supply in that equilibrium. The point M, O , B, and T denote the equilibrium points where marginal revenue equals marginal cost of the integrated monopolist, the integrated oligopolist, the n supply chains under bank financing, and the n supply chains under trade credit financing, respectively. The parameters for the graph are: $A_g = 10, A_b = 7, q = 1/2, r = 0, n = 3$.

the choke price. We then plot for each equilibrium a point defined by marginal revenue and the aggregate output.

We start as a reference case with a single, vertically integrated monopolist. Since production cost of the good is assumed to be zero, the optimal quantity that the vertically integrated monopolist offers can be found where the marginal revenue line hits the x-axis (point M) and the corresponding price in the consumer product market is given by P^M. When more vertically integrated firms enter the industry, competition flattens the equilibrium marginal revenue curve under oligopoly and integrated firms offer more in aggregate (point O) which decreases their equilibrium revenue as products in the consumer market are sold for P^O.

The retailers of an oligopoly supply chain face the same marginal revenue function but their marginal costs increase because they have to purchase the intermediate goods at the wholesale price P from the supplier. When r goes to zero, as in the example of the graph, the retailers – using bank financing – pay no financing costs and thus their marginal cost equals the price set by the supplier, P, and the overall equilibrium in the product market is at point B. The aggregate output of the supply chain comes closer to the quantity that is offered by the vertically integrated monopolist, however under bank financing we see that relative to the integrated monopolist the output is too high in the good state and too low in the bad state, respectively. This is exactly the problem that trade credit can overcome. By optimally choosing the trade credit interest rate, the supplier can increase her retailer's marginal cost in the good state to MC_g^T and lower the marginal cost in the bad state to MC_b^T. In some cases it is possible – as in this specific example – to achieve exactly the output of a vertically integrated monopolist. In general, trade credit financing, with its ability to charge state dependent marginal costs, can make the retailer choose an output closer to the output of the integrated monopolist than bank financing, and thereby increase producer surplus at the expense of consumers.