Finance-thy-Neighbor.
Trade Credit Origins of Aggregate Fluctuations[*]

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Abstract. This paper studies the role of endogenous trade-credit linkages for generating interdependent distortions and the propagation of shocks in a static quantitative multi-sector model where firms finance production using bank and trade credit. The adjustment in the volume and cost of trade credit in response to shocks to the cost of bank credit captures two counteracting mechanisms: (1) Firms smooth shocks by substituting bank and trade credit. (2) An increase in the cost of on trade credit amplifies financial shocks by tightening the financing condition of customers. In a quantitative application of the model to the US economy during the 2008-2009 crisis, simulations featuring only financial shocks show that: Trade-credit linkages generate large spillovers relative to an economy with bank finance only; The smoothing mechanism was operative, though small; Sectors extending relatively more trade credit to customers than their volume of bank loans are systemically important and generate large spillovers.

JEL Codes. C67, E32, G10. **Keywords.** Production Networks, Financial Frictions, Trade Credit, Aggregate Fluctuations.

1. Introduction

The flow of payments from customers to their suppliers plays a crucial role in maintaining the liquidity and turnover of products in a complex network of trade relations between firms. However, the time lag between the purchase of inputs and the receipt of payments for realized sales leads to a cash-flow mismatch for the producer and creates demand for ex-ante liquidity. In day-to-day operations, it is thus common practice for suppliers to offer payment terms in the form of trade credit, that allow customers to delay payments until after the delivery of the product. (see Cuñat and García-Appendini, 2012)

Trade credit as a form of short- and medium-term debt "gives [firms] and [their] suppliers more flexibility to manage [their] businesses effectively through better cash flow management"[1] and represents an alternative source of financing to bank and financial market debt for all types of firms (Petersen and Rajan, 1997). At the onset of the 2008-2009 Financial Crisis, the market for trade credit experienced a severe contraction, forcing firms to use other sources of credit to fund their operations. (see Costello, 2017; Ivashina and Scharfstein, 2010) Anecdotal and empirical evidence[2] highlights two countervailing features of trade credit: (1) Firms smooth interest rate shocks by substituting bank and supplier finance. (2) A tightening of supplier financing terms deteriorates the credit conditions for customers and has adverse and exacerbating effects on maintaining production.

This paper investigates the following two questions: Do trade credit linkages amplify or dampen the propagation of financial shocks? To what extent did the trade credit network contribute to the drop in output during the 2008-2009 Financial Crisis?
For this purpose, I first build a quantitative multisector model where representative firms in each sector face working capital constraints and which explicitly accounts for both the substitutability of bank- and supplier credit and the input-output relations between sectors. In particular, the model endogenizes the trade-credit intensity between firms and the cost of trade credit in order to capture the stabilizing and amplifying features outlined before. Subsequently, an application of the model to the US economy at a sector level quantitatively assesses the importance of the trade-credit channel for the real economy. Furthermore, I derive a new credit measure - the net-lending position of a sector - which is defined as the ratio of accounts receivable to the difference between the total

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[1]Kris Charles, Kellogg spokeswoman cited in Strom (2015), www.nytimes.com, 10/26/2018
[2]In 2008, there was considerable concern about the insolvency of GM and Chrysler and the resulting domino effect through the supply chain: "I don't think that suppliers will be able to get through the month without continued payments on their receivables" N.De Koker, CEO of the Original Equipment Suppliers Association. (see Vlasic and Wayne, 2008, www.nytimes.com, 10/26/2018); As sales have been declining since 2011, SEARS - an American retailer - faced a considerable tightening of payment terms offered by their suppliers: "We cut their credit line and shortened payment terms [...] If they pay one day late, we will cut them off. [...] We want them to stay in business, [b]ut not at the risk to MGA." I.Larian, CEO of MGA Entertainment Inc. (see Kapner, 2017, www.wsj.com, 10/26/2018)

cost of production and accounts payable.[3] It is shown that this novel measure helps to identify sectors which generate large spillovers through inter-firm credit linkages. This paper makes three contributions to the literature: (1) I present stylised facts on business cycle patterns and the heterogeneity of trade-credit usage in the US. (2) I then introduce a model which explicitly characterizes the smoothing and amplifying features of trade credit and the implications of interdependent distortions for the propagation of shocks, and (3) quantify the effect of trade-credit linkages in the US economy on aggregate output.

Trade Credit in the US Economy. Using yearly balance sheet data from Compustat of a panel of publicly-traded, non-financial US firms from 1997 to 2016, it is shown that the growth rate of the volume of trade finance is pro-cyclical with and more volatile than the growth rate of real GDP. At a firm level, there is heterogeneity in the net-lending position of US firms with the majority extending less trade credit than their own financing needs to cover their production costs net of trade credit obtained from suppliers. Only a few act as financial intermediaries by extending relatively more trade credit to customers.

A Multisector Model with Financial Frictions. In order to analyse the role trade credit for the propagation of financial shocks across firms, I build a static quantitative multisector model with trade in intermediate inputs and endogenous credit linkages between perfectly competitive intermediate good producing firms in each sector. The banking sector is introduced in a reduced form by means of a sector-specific interest rate on bank credit, which is subject to shocks and increases in the share of sales extended on trade credit to customers as suggested by the data. Since any sales are only realized after production has taken place, firms face working capital constraints and finance production using both bank and supplier credit.

At the beginning of a period, both productivity and financial shocks are realized. Profit-maximizing firms choose the share of input expenditures financed using trade credit to minimize their cost of production, optimally set the quantity produced and the share of sales extended on trade credit to their customers, given demand, prices and interest rates. The endogenous adjustment of the volume and cost of trade credit or "trade-credit channel" captures the two counteracting mechanisms discussed earlier as follows: (1) On the demand side, firms respond to shocks to their bank interest rate by adjusting their borrowing portfolio. Hence, firms are able to smooth any financial shocks and mitigate the negative effect of an increase in the cost of bank credit on output. (2) On the supply side, a firm acts both as a supplier of goods and as a financial intermediary. Since the interest rate on bank credit is increasing in the share of accounts receivable in sales, a firm will optimally reduce the share of delayed sales in response to an increase in its cost of bank loans. Consequently, the interest rate charged on trade credit increases, which

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[3]Accounts payable(receivable) are the total outstanding payments owed to suppliers (by customers) for already delivered goods and services.

directly affects the cost of credit and thus production of downstream customers. Similarly, a shift in a firm's borrowing-portfolio composition towards trade credit increases the cost of bank finance of upstream suppliers. This creates an amplification mechanism by which idiosyncratic shocks to the cost of bank credit are propagated both up- and downstream.

In equilibrium, the working capital constraint introduces a credit wedge between the firm's marginal revenue and costs thereby distorting a firm's optimal input choice. At the aggregate level, financial distortions manifest themselves as an aggregate efficiency and labor wedge as common to models with distortions. (see Bigio and La'O, 2019; Baqaee and Farhi, 2018) However, credit wedges in this paper are a weighted average of both interest rates on bank and supplier credit and the weights are the optimally chosen link-specific trade-credit shares. Therefore, this paper features endogenous and interdependent distortions affecting the propagation of financial shocks. It is shown that to a first order approximation, the net-lending position of a sector determines the relative importance of the smoothing and amplification mechanism of the trade-credit channel.

Quantitative Application. Whether financial linkages amplify or dampen the effect of credit-cost shocks on (aggregate) output is ambiguous and remains a quantitative question as the answer depends on the relative strength of the substitution and amplification effects outlined before. The production structure and the inter-industry credit flows of the model-economy are first calibrated to the US at a sector level. The model is then simulated by considering only shocks to a sector's interest rate on bank credit imputed from sector level bond spreads derived in Gilchrist and Zakrajšek (2012), GZ-spreads hereafter, while excluding any additional source of variation affecting the economy. Simulations show that the model reproduces - both qualitatively and quantitatively - business cycle patterns of trade credit observed in the data. In particular, the model captures approximately a quarter of the variation in aggregate output and can account for 34.3% of the decline in GDP documented during the crisis. This highlights the quantitative importance of changes in financial frictions and their effect on aggregate output. The quantification of the role of trade credit for the propagation of liquidity shocks during the 2008-2009 Great Recession yields the following the three main results:

To isolate the aggregate effect of the trade-credit network, the *trade-credit multiplier* is defined as the ratio between the percentage drop in the variable of interest generated by an economy with both trade and bank finance and an equivalent economy with bank finance only. The latter represents the benchmark economy discussed in Bigio and La'O (2019). The counterfactual exercise predicts a multiplier of around 1.9 for output, implying that the existence of the trade-credit network per se almost doubled the decline in output during the crisis relative to an economy with bank finance only. In other words, the model suggests that approximately 16% of the drop in output during the financial crisis can be accounted for by trade-credit linkages alone. Thus, the existence of an

inter-firm credit network increases aggregate fluctuations following an aggregate financial shock. The contribution of the *trade-credit channel* - the endogenous adjustment of the volume and cost of trade credit - to changes in aggregate output is evaluated by comparing the general to the partial equilibrium response of the variables of interest. The latter is obtained when both trade-credit interest rates and shares are kept at their steady state level. The difference can be attributed to the trade-credit channel. Simulations suggest that the trade-credit channel reduces aggregate volatility by 1.41% and dampened the drop in output during the financial crisis by 1.75%. The last exercise quantifies the main theoretical result of this paper and shows that the trade-credit multiplier implied by a financial shock to the top five sectors with the highest *net-lending ratio* is significantly higher than the trade-credit multiplier generated by the same financial shock to the five sectors with the lowest net-lending ratio, as predicted by the model.

Related Literature. Trade credit contracts have been studied more commonly in the corporate and trade-finance literature: While a growing theoretical (i.a. Emery, 1984; Smith, 1987; Biais and Gollier, 1997; Burkart and Ellingsen, 2004; Cuñat, 2007) and empirical (i.a. Petersen and Rajan, 1997; Huang et al., 2011; Giannetti et al., 2018) literature investigates the characteristics and motives of firms to engage in financial intermediation, the literature on trade finance has focused on the optimal payment contract choice to finance international transactions (Schmidt-Eisenlohr, 2013; Antras and Foley, 2015) and their implications for trade flows (Chor and Manova, 2012). In the macro-literature, distortions in financial markets affecting the borrowing constraints of firms have been studied extensively, starting with Bernanke et al. (1996). This paper studies the role trade-credit linkages between firms in a production chain for the propagation of shocks, the relevance of which for the domestic macroeconomy is still understudied.

The paper contributes to an extensive literature investigating the *effects of micro-level distortions* on aggregates outcomes, which can be broadly classified into two substrands: The first sub-strand abstracts or limits the extent of inter-sectoral trade (i.a. Chari et al., 2007), the second sub-strand explicitly accounts for (some degree of) intermediate goods trade (i.a. Jones, 2011). Recent contributions by Baqaee and Farhi (2018, 2019) develop a more unified framework for the aggregation of micro-level distortions. Since my model builds on Bigio and La'O (2019), BL(2019) hereafter, it is clearly related to the second strand. While BL(2019) treat the distortions as exogenous, my contribution to this literature is the emphasis of the role of interdependent distortions for the propagation of shocks in the form of endogenous credit linkages among firms.

Foremost, this paper contributes to the growing literature studying *distortions in the context of a production network*. Since the seminal contribution of Long and Plosser (1983), a growing literature investigates the importance of input-output relations for aggregate dynamics in an economy. (see Carvalho, 2014; Carvalho and Tahbaz-Salehi, 2018,

for an overview) Following the 2008-2009 recession, the interconnection of banking institutions and their role in the propagation of financial shocks have been studied extensively (see i.a. Acemoglu et al., 2015). The financial crisis also spurred empirical contributions on the real effects of credit shocks focusing on the link between banks and firms (i.a. Chodorow-Reich, 2014; Iyer et al., 2014; Cingano et al., 2016; Alfaro et al., 2018). However, the financial aspect of inter-firm trade as a transmission mechanism is a relatively new research agenda. While the effect of interconnected customer-supplier relations on a firm's financial policy has received more attention in the corporate-finance literature (Hertzel et al., 2008; Banerjee et al., 2008; Gao, 2014), this paper is related to the strand of literature focusing on the role of production and financial linkages for the propagation of shocks to the real economy. Recent empirical contributions by Raddatz (2010), Jacobson and von Schedvin (2015), Costello (2017), Cortes et al. (2018), Dewachter et al. (2018) confirm the relevance of trade-credit linkages among firms for the propagation of liquidity shocks and real outcomes. Despite their quantitative importance, trade-credit linkages have received little attention in the existing theoretical literature on business cycle fluctuations, with the exceptions most related to this paper discussed in the following.

The relevance of trade credit for the propagation of liquidity shocks in a credit chain due to trade-credit defaults was first recognized in the seminal contribution by Kiyotaki and Moore (1997). However, the role of the network of trade-credit relationships for the propagation of shocks and business cycle fluctuations was first highlighted in Altinoglu (2018). Subsequent contributions by Zhang (2017), Shao (2017) and Luo (2019) investigate the effect of trade-credit on sectoral comovement, aggregate fluctuations and up- and downstream sectoral outcomes, respectively. While Shao (2017) and Luo (2019) discuss some aspects of the attenuating and amplifying features of trade credit, this paper contributes to the literature by providing a theoretical and quantitative characterization of trade credit as a stabilizer and an amplifier of financial shocks, and its effect on aggregate and sectoral outcomes. The emphasis on the counteracting features of trade credit relates to the mixed empirical evidence on the role of trade credit for firm level outcomes presented in Garcia-Appendini and Montoriol-Garriga (2013) and Costello (2017). Therefore, this paper also contributes to a sub-strand of the networks literature investigating the contagion and stabilization potential of linkages which have been discussed extensively in the context of banking networks (i.a Allen and Gale, 2000; Acemoglu et al., 2015).

The main novelty of this paper is the study and introduction of interdependent and endogenous distortions via trade-credit linkages in a multisector model. In contrast to existing set-ups (Altinoglu, 2018; Luo, 2019; Shao, 2017; Zhang, 2017), trade credit is incorporated into the model as follows: Since the price of trade credit is modeled explicitly, the effective price paid by a customer is a bundle of the actual price and the interest rate charged on delayed payments. Therefore, firms receive income from both selling their

output and extending trade credit to customers. The assumption that the interest rate on bank credit is increasing in the share of delayed sales introduces a direct upstream cost-effect independent of any additional frictions in the banking sector. In equilibrium, profit-maximizing firms choose the share of input expenditures financed using trade credit by trading-off the relative cost of bank and trade credit while taking input prices and interest rates as given. Simultaneously, firms internalize the effect of delayed payments on their cost of bank finance and choose the share of revenues extended on trade credit to maximize profits taking the demand for trade credit as given. This contrasts the set-up in Zhang (2017) and Luo (2019), who abstract from modeling the price and market for trade credit. Instead, while Zhang (2017) relies on nash-bargaining, Luo (2019) imposes two assumptions: First, the optimal portfolio composition is solely determined by firms minimizing their unit cost of production. Second, a firm's cost of bank loans is affected by customers negotiating to defer repaying a share of their past outstanding payables. On the contrary, in this paper, the cost of trade credit and share of intermediate inputs obtained on trade credit are determined in general equilibrium: The optimal interest rate clears the market for trade credit and sectorsal trade-credit linkages are endogenous along the intensive margin rather than a fixed proportion of sales (Altinoglu, 2018). Finally, unlike (Shao, 2017), this model allows to study the role of firms simultaneously borrowing and lending from other firms for the transmission of financial shocks by considering a more general network structure. In particular, since this paper assumes that a firm charges all customers the same interest rate on trade credit, any effects induced by changes in the composition of a customer's credit portfolio propagate both up- and downstream as well as horizontally due to the existence of common suppliers (see Costello, 2017).

To summarize, I contribute to the literature on trade-credit linkages in a production network by providing a tractable model that allows to study (a) the role of trade credit as both an stabilizing and a contagion device of financial shocks and (b) the relationship between bank and supplier finance over the business cycle by explicitly modeling the price of trade credit. To the best of my knowledge, this paper is the first to explicitly characterize and quantify non-linearities in the effect of endogenous and interlinked distortions on aggregate outcomes while taking into account the direct interaction between bank and supplier credit via prices in a general equilibrium setting.

Outline. This paper is organized as follows. Section 2 discusses empirical regularities of trade credit over the business cycle and the heterogeneity in trade-credit usage across firms. Section 3 introduces the model and derives the net-lending position as a determinant of the strength of the trade-credit channel. Section 4 presents a quantitative assessment of the role of trade credit in the US economy during the Great Recession. The Online Appendix contains all proofs and supporting material.

2. Trade Credit in the US Economy

The 2008-2009 Financial Crisis was characterized by a global collapse of credit markets that quickly transmitted to the corporate sector and led to a contraction of real (US) GDP in advanced economies by 3.4(2.6)%[4]. An important role in the transmission of the liquidity shock from the banking to the real sector was played by trade-credit relations among firms. (see i.a. Jacobson and von Schedvin, 2015; Costello, 2017) This section summarizes stylized facts on the relevance and cyclical properties of trade credit and its relation to other external financing sources such as bank and financial market debt in the US economy, that will be informative for the set-up of the model in Section 3. For this purpose, I obtain yearly balance sheet data from Compustat of a panel of publicly-traded, non-financial firms from 1997 to 2016, whose nominal sales represent approximately 34% of total gross output in the US.[5] Although trade credit is more intensively used by small and medium-sized enterprises with a lower degree of access to both bank finance and financial markets (Petersen and Rajan, 1997), supplier credit still represents a non-negligible source of financing for large publicly-traded firms. In particular, total accounts payable (receivable) account for approximately 11.2(9.5)% of total liabilities (assets) and make up approximately 5.0(6.5)% of US GDP[6]. While these magnitudes represent a lower bound for the usage of trade credit by US firms, they highlight the quantitative importance of supplier credit for the aggregate US economy and are consistent with related statistics documented in Rajan and Zingales (1995) and Giannetti (2003). The sample is further restricted to consist only of firms with non-missing observations over the entire sample period to ensure that the log-changes in the level of financial variables presented in Figure 2.1 are not driven by any changes in the composition of the sample.

Panel (a) of Figure 2.1 plots the log-changes of real GDP, Y, total accounts payable, AP, and accounts receivable, AR, in terms of 2007 dollars using the implied GDP-deflator provided by the BEA. Panel (b) presents the log-changes of real accounts payable and both, total, LT, and current, LC, liabilities. Table 2.1 reports the standard-deviation and the pairwise correlation of the respective series. Figure 2.1a and 2.1b highlight three business cycle features of trade credit in the US:

(F1) The growth rate of the volume of trade finance is pro-cyclical with the growth rate of current real GDP. In other words, the growth rate of accounts payable and receivable increases during expansions and decreases during recessions.

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[4]Source: World Economic Outlook and BEA

[5]Details on the sample of firms selected are presented in Online Appendix C.

[6]Since both accounts payable and receivable are likely to contain trade credit volumes from foreign transactions, I also calculate the share of the respective balance sheet item in US GDP adjusted for exports and imports, respectively. Then, accounts payable (receivable) make up approximately 4.4(5.9)% of US GDP including imports (exports).

(F2) Trade credit is more volatile than the growth rate of total value added.

(F3) Trade credit is more volatile than firms' total liabilities and exhibits a volatility of similar magnitude of current liabilities.

The same cyclical patterns of trade credit have been found in Cun et al. (2018) for a sample of Chinese industrial enterprises, which suggests similarities in the usage of trade credit of firms in advanced and emerging markets. (see i.a. Love et al., 2007) In addition, it should be noted that the level of total accounts payable and receivable are strongly positively correlated. This should not come as a surprise as the same outstanding payment will be recorded on the balance sheet of both the customer as accounts payable and of the supplier as accounts receivable. Even though total accounts payable and receivable will not be equal in the selected sub-sample of US firms, their dynamics track each other closely due to market clearing.

Trade versus Bank Credit. Since the focus of this paper is the role of trade credit for the transmission of liquidity shocks during the Great Recession, I now discuss the relationship between the usage of supplier and bank credit during this period of financial turmoil. For this purpose, two aggregate measures of frictions in the financial market are obtained. The first measure is the aggregate credit spread index derived in Gilchrist and Zakrajšek (2012). The GZ-spread is defined as the average difference in the yields on corporate bonds and yields on Treasury securities of comparable maturities and represents an important indicator of the degree of tensions in the financial system. The second measure reports the net percentage of domestic banks tightening their lending standards for commercial and industrial (C&I) loans, LS, as reported in the Senior Loan Officer Opinion Survey on Bank Lending Practices conducted by the Federal Reserve. Panel (c) of Figure 2.1 plots the log-change of the share of accounts payable in total costs of production and the share of accounts receivable in revenues at an aggregate level on the left axis as well as the change in logs of credit spreads on the right axis:

(F4) The share of accounts payable and receivable in total costs of production and sales are negatively correlated with aggregate credit spreads in the economy.

In other words, as credit markets tighten, both the share of production costs financed using trade credit and the share of sales extended on trade credit decline. This highlights that the drop in the level of real accounts receivable and payable depicted in Panel (a) and (b) was not driven by a pure reduction in demand but coincided with the tightening of credit markets, which preceded the decline in aggregate output. The log-change of the share of accounts payable in current liabilities, θ^T, is then calculated and captures the evolution of the composition of short-term borrowing. Panel (d) of Figure 2.1 plots both measures of financial frictions (right axis) and the log-change in the share of accounts payable in current liabilities (left axis). Figure 2.1d thus implies the following:

(F5) As credit spreads rose and lending standards tightened at the onset of the financial crisis in 2008, liquidity in the trade-credit market contracted immediately and firms drew down their bank-credit lines. The composition of short-term borrowing shifted towards bank credit as firms substituted supplier with bank finance.

This observation is consistent with the empirical evidence on the evolution of bank lending during 2008 documented in Ivashina and Scharfstein (2010) and on supplier credit presented in Costello (2017). Using data on syndicated loans from Reuter's Dealscan, Ivashina and Scharfstein (2010) show that, while syndicated lending fell, C&I loans as reported on the balance sheets of US banks rose due to an increase in drawdowns of existing credit lines at the onset of the financial crisis. At the same time, receivables contracted significantly along the intensive margin as documented in Costello (2017) using detailed transaction data at a firm level in the US. Thus, the compositional shift of short-term borrowing towards bank credit in 2008 was due to the joint occurrence of the reduction in the provision of supplier credit and drawdowns of unused credit lines. However, the increase in C&I loans by approximately 17% in 2008 was followed by a sharp drop of 6.5% in 2009[7], as the tightening of lending standards in 2008 translated into a considerable decline in the availability of new credit lines. Simultaneously, accounts payable and receivable increased such that the compositional shift reversed and firms substituted bank with trade credit as evident from Figures 2.1a and 2.1d. A reasonable explanation for the differences in the speed of adjustment between credit markets in response to a deterioration of financial conditions is the contractual enforceability or rather the lack thereof in the case of supplier credit. While existing credit lines are prior commitments by banks to lend to corporations any amount up to a preset limit at prespecified rates (see Ivashina and Scharfstein, 2010), trade credit is not subject to formal contracts (see Cuñat, 2007). The empirical observation on the substitutability[8] of supplier and financial market debt is consistent with the findings of a large body of literature on the relationship between trade and bank credit over the business cycle starting with Meltzer (1960). It is argued that during a contractionary period, firms with access to liquidity will increase the amount of trade credit extended to customers, thereby providing funds to credit rationed firms. (see i.a. Meltzer, 1960; Schwartz, 1974; Kohler et al., 2000; Nilsen, 2002) As a result, trade credit serves as a liquidity insurance across firms (see Cuñat, 2007; Wilner, 2000). In particular, Amberg et al. (2016) show that firms manage liquidity shortfalls by increasing trade credit obtained from suppliers and rationing credit extended to customers.

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[7]Source: Board of Governors of the Federal Reserve System (US), Commercial and Industrial Loans, All Commercial Banks [BUSLOANS], retrieved from FRED, Federal Reserve Bank of St. Louis; 10/06/18

[8]A few papers find evidence of a complementarity between bank and trade credit (see Giannetti et al., 2011) consistent with a theoretical argument of the signalling function of trade credit on the solvency of borrowers (see Biais and Gollier, 1997). The co-existence of the substitutability and complementarity of bank and trade credit and its cyclical pattern is investigated further in a recent contribution by Huang et al. (2011).

Figure 2.1: Business Cycle Properties of Trade Credit in the US

(a) Fact 1-2

(b) Fact 3

(c) Fact 4

(d) Fact 5
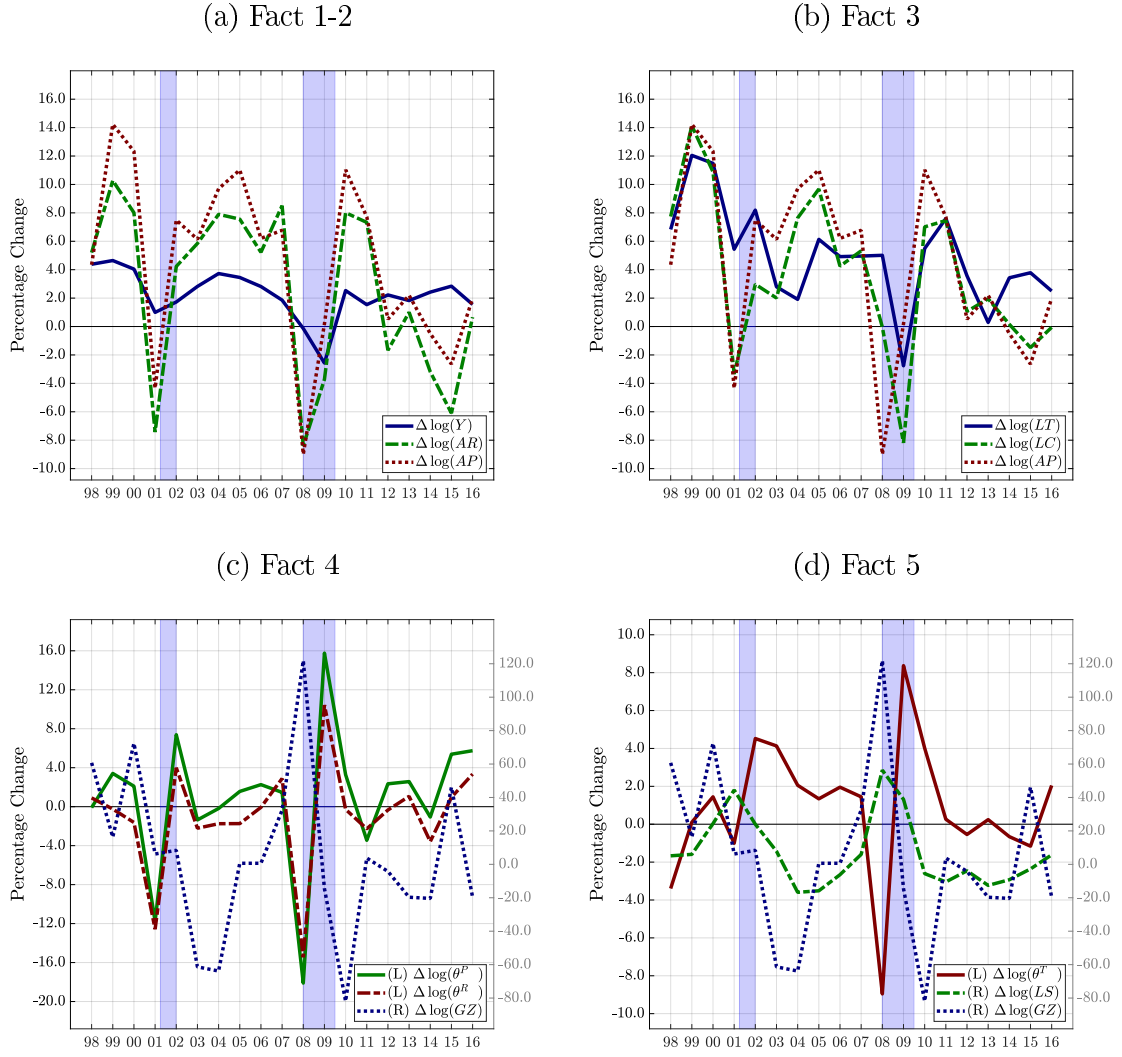
Note: The panels in this figure plot the evolution of the log-change in percent of aggregate US GDP (Y), Accounts Payable (AP) and Receivable (AR), Total (LT) and Current (LC) Liabilities, the share of AP in Current Liabilities (θ^T), the aggregate credit spread index derived in Gilchrist and Zakrajšek (2012) (GZ), the net percentage of domestic banking institutions tightening their standards for C&I loans (LS), the share of AP in Total Costs of Goods Sold (θ^P) and the share of AR in Total Sales (θ^R). All variables are reported in real terms using the aggregate price-index. The sample includes all Compustat firm-year observations from 1997 to 2016 of firms - excluding financial firms (NAICS 52 and 53) - with their head-quarter in the US and positive and non-missing observations of the respective variables of interest and non-missing observations over the entire time period 1997-2016. This yields a panel of 15,920 firm-year observations for 796 unique firms whose total nominal sales represent approximately 19% of total gross output in the US. For details on the sample, see Online Appendix C.

Table 2.1: Time Series Correlations 1997-2016

(a) Fact 1-2		Y_t	Y_t	AR_t	$\sigma(\%)$	(b) Fact 3		Y_t	LT_t	LC_t	$\sigma(\%)$
	Y_t	1.000			1.63		LT_t	0.606			3.42
	AR_t	0.614	0.614		5.85		LC_t	0.808	0.750		5.27
	AP_t	0.613	0.613	0.957	5.99		AP_t	0.613	0.505	0.822	5.99

(c) Fact 4		Y_{t+1}	θ_t^P	θ_t^R	$\sigma(\%)$	(d) Fact 5		Y_t	θ_t^T	LS_t	$\sigma(\%)$
	θ_t^P	0.454			6.80		θ_t^T	-0.172			3.43
	θ_t^R	0.435	0.965		5.42		LS_t	-0.569	-0.183		20.56
	GZ_t	-0.508	-0.384	-0.343	47.55		GZ_t	-0.038	-0.678	0.525	47.55

Note: Each subtable presents the pairwise correlations between the log-changes as well as the standard-deviation in percent of the log-changes of the time series plotted in the corresponding panel of Figure 2.1.

Cost of Credit. These observed patterns raise the following two questions: (a) Does the extension of trade credit affect a firm's cost of bank credit? and (b) What is the relationship between the share of a firm's cost of production financed by delaying payments to suppliers and the cost of credit? To address the first question, I relate to a strand of literature explicitly modeling financial intermediaries and incorporating credit markets into quantitative macro-models (i.a. Bernanke and Gertler, 1989; Bernanke et al., 1999; Gertler and Kiyotaki, 2010). In particular, I exploit the fact that the interest rate on bank loans faced by firms and determined in equilibrium will include a risk premium and will be an increasing function of (default) risk in the economy. Since firms that sell their products on credit are subject to the credit risk of their customers (Jacobson and von Schedvin, 2015; Costello, 2019), the extent to which the risk premium, r_k^Z, is positively correlated with the share of accounts receivable in total sales, θ_k^R, is investigated in the following. Using a panel of 45 sectors from 2000-2014, Equation (2.1a) is estimated by OLS including sector and year fixed effects.

$$\ln(r_{kt}^Z) \;=\; \beta_0 + \beta_1 \ln(\theta_{kt}^R) + \boldsymbol{\beta}\boldsymbol{x}_{kt} + FE + \epsilon_{kt} \tag{2.1a}$$

The estimation results are reported in Table C.2a in Online Appendix C and suggest a positive relationship between the credit spread and the share of accounts receivable, which is robust to the inclusion of additional control variables following related empirical work (Petersen and Rajan, 1997; Jacobson and von Schedvin, 2015; Costello, 2017). The second question is addressed by estimating the relationship between the share of production costs financed using trade credit, θ_{kt}^P, and the cost of bank credit, r_{kt}^B, depicted in Equation (2.1b).

$$\theta_{kt}^P \;=\; \beta_0 + \beta_1 r_{kt}^B + \boldsymbol{\beta}\boldsymbol{x}_{kt} + FE + \epsilon_{it} \tag{2.1b}$$

Using the same panel of 45 sectors from 2000-2014, the estimated OLS-coefficients and corresponding clustered standard errors at the sector level reported in Table C.2b suggest a significant and positive relationship between the cost of bank credit and the share of production costs financed by postponing payments to suppliers. This empirical evidence is in line with the strand of literature modeling bank and trade credit as substitutes, which will be exploited in the set-up of the model presented in Section 3.

Heterogeneity in Trade Credit Usage. While the dynamics of log-changes of total payables and receivables presented in Figure 2.1 are informative for the business cycle properties of trade credit, they contain little information on the heterogeneity of the utilization of trade credit across firms. In order to provide a summary measure of the trade-credit usage of a firm from both its perspective as a lender and a borrower, I first define the net-lending position of firm k, θ_{kt}^τ.

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Definition 2.1. *The net-lending position of a firm k is defined as the ratio of total trade credit extended to customers (accounts receivable) and bank loans obtained to finance total cost of production net of trade credit obtained from suppliers (accounts payable).*

In other words the net-lending position reflects a firm's ability to extend trade credit to their customers and obtain trade credit from their suppliers: How many future dollars does firm k receive per dollar it needs to finance today. An increase in the net-lending position of firm k implies that firm k extends relatively more trade credit to its customers (accounts receivable) compared to its total cost of production net of trade credit (accounts payable) obtained from its suppliers. Figure 2.2 plots the distribution of the average net-lending position in 2004-2007 of the same sample of Compustat firms used to generated Figure 2.1. While there is heterogeneity in the trade credit usage of US firms, one key pattern emerges:

(F6) The majority of firms extends less trade credit than their own financing needs to cover their production costs net of trade credit obtained from suppliers. Only a few act as financial intermediaries by extending relatively more trade credit to customers.

By taking a closer look at the industry-affiliation of firms, it becomes apparent that firms which are more upstream in the production chain (e.g. primary-industries, manufacturing) tend to have a higher net-lending position than more downstream firms (e.g. retail, services). This observation highlights that the structure of inter-sectoral trade plays a crucial role in determining which aspect of trade finance dominates and confirms the findings in Kalemli-Özcan et al. (2014), that upstream firms have higher accounts receivable in comparison to final product firms.

Figure 2.2: Trade-Credit Usage of US Firms
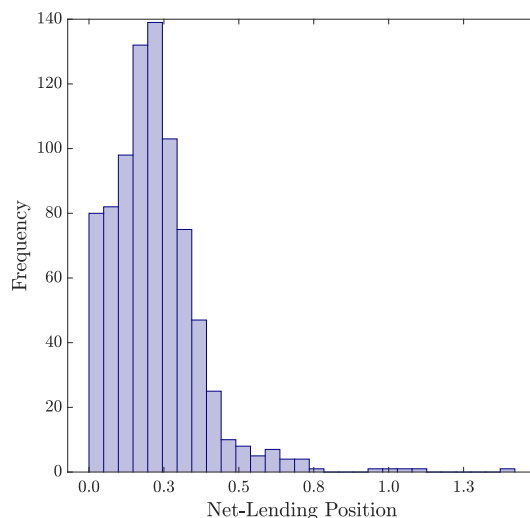
Note: The figure plots the distribution of the average net-lending position defined in 2.1 over 2004-2007 of the sample of firms described in Online Appendix C.

In addition, the data suggests that sectors with a stronger decline in their net-lending position also faced a stronger decline in output during the crisis, implying that a sector's overall exposure to trade credit is positively correlated with a sector's economic performance as found in the literature (see e.g. Jacobson and von Schedvin, 2015; Costello, 2017). The role of the net-lending position of firms (sectors) for the propagation of financial shocks will be investigated in more detail in Section 3 and 4.

To summarize, the evolution of the composition and heterogeneity of short-term borrowing presented in Figure 2.1 suggests that trade credit is an important source of short- to medium term credit as an alternative to bank finance used by all types of firms. In particular, the data shows that liquidity in the market for trade credit was severely affected the onset of the 2008-2009 Financial Crisis inducing a shift of the composition of short-term credit towards bank finance and therefore plays a crucial role for the propagation of financial shocks. In foresight of the implications of the model, I propose a novel credit measure - the net-lending position - defined as the ratio of trade credit extended customers and bank loans obtained to finance total production costs net of trade credit obtained from suppliers, which captures the heterogeneity of trade-credit usage across firms.

In the next section I build a model which focuses on the contraction of liquidity in the trade-credit market at the onset of the 2008-2009 crisis in order to investigate the role of credit linkages in the propagation of the financial shock. To this end, any dynamics are abstracted from by imposing the timing restriction that financial markets contracted at the same time as aggregate output such that the share of accounts payable (receivable) in total production costs (sales) is now positively correlated with current output. Although output declined with a time lag in response to the deterioration of credit conditions as shown in Figure 2.1a, this simplification may be justifiable as (1) the sharp increase in credit spreads occurred in the second half of 2008 and (2) a firm's production plans and therefore intermediate demand might be pre-determined. This allows me to focus on the effect of a decline in supplier credit on aggregate output during the crisis.

3.   A Multisector Model with Financial Frictions

This section introduces a static[9] quantitative multisector model in the tradition of Long and Plosser (1983) with trade in intermediate inputs and endogenous credit linkages between sectors. Representative firms in each sector face working capital constraints and finance their input expenditures using both bank and supplier credit, while being subject to sectoral productivity and financial shocks to the cost of bank credit. The model nests the economy introduced in BL(2019) if no credit linkages are considered. In contrast to previous work, as outlined in the introduction, the main novelty in this set-up is the introduction of endogenous credit linkages between sectors along the intensive margin by explicitly modeling the price of trade credit and introducing a direct link between the cost of bank finance and the amount of trade credit extended to customers. The model set-up is as follows.

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[9]By abstracting from savings and investment dynamics, this paper focuses on cross-sectional propagation patterns, which also have been the focus of a recent strand of literature see Bigio and La'O (2019), Baqaee and Farhi (2019) and Baqaee and Farhi (2018) among others.

Production Structure. The economy consists of M intermediate sectors indexed by $k = 1, ..., M$ producing M differentiated goods, a final good sector indexed by 0 producing a composite final good and a representative household. A continuum of perfectly competitive firms within each sector produce an identical good using the same technology such that there exists a representative firm per sector. Therefore, the words firm and sector are used interchangeably. An *intermediate goods* firm k produces output, q_k, using capital, k_k, productive labor, ℓ_k^Q, and a composite of intermediate inputs, X_k, with the Cobb-Douglas technology

$$q_k = \left(A_k k_k^{\alpha_k \eta_k} V_k^{1-\alpha_k \eta_k} \right)^{\chi_k} \tag{3.1}$$

where the composite of (productive) labor and intermediate inputs, V_k, as well as the composite of intermediate inputs, X_k are defined as

$$V_k = \overline{A}_k^V \left(\ell_k^Q \right)^{v_k} \left(X_k \right)^{1-v_k} \quad \text{and} \quad X_k = \overline{A}_k^X \prod_s x_{ks}^{\omega_{ks}^X}, \quad \text{with} \quad v_k = \frac{(1 - \alpha_k)\eta_k}{1 - \alpha_k \eta_k}. \tag{3.2}$$

While A_k denotes sector-specific productivity and is subject to productivity shocks, $\overline{A}_k^V$ and $\overline{A}_k^X$ represent normalization constants as a function of the production parameters. The intermediate production technology exhibits decreasing returns to scale (DRS), $\chi_k \in (0, 1)$, in its production inputs. Due to the Cobb-Douglas technology, the production parameter $\omega_{ks}^X \in [0, 1]$ denotes the share of good s in the total intermediate input use of sector k and it is assumed that $\sum_s \omega_{ks}^X = 1 \ \forall k \in \{1, ..., M\}$. The output of firm k is used both as an intermediate input in production and to produce a composite final good, F, consumed by the household such that $F = C$ holds in equilibrium. The *final good* firm assembles the consumption good using the constant returns to scale (CRS) technology

$$F = A_0 \prod_m x_{0m}^{\omega_m^F} \tag{3.3}$$

with productivity A_0, where $\sum_m \omega_m^F = 1$. Similarly, the production parameters $\omega_m^F \in [0, 1]$ denote the expenditure share on good m by the final good firm. Productivity in the intermediate and final sector is subject to sector-specific, normally distributed shocks, z_i^q, and is given by $A_i = \exp(z_i^q)\overline{A}_i \ \forall i \in \{0, 1, ..., M\}$. The sector-specific normalization constants, $\overline{A}_i$, are functions of the production parameters introduced for analytical convenience and are defined in Online Appendix D. For the purpose of the model, I am abstracting from any shocks to final demand such that $z_0^q = 0$. The following constraint for intermediate good producing firms is now imposed.

Assumption 3.1 (Working Capital). *The production and delivery of products along the supply chain is such that any sales are only realized after production has taken place.*

The timing of events is depicted in Figure 3.1: At the beginning of a period both productivity, z_k^q, and financial shocks to the cost of bank credit, z_k^b, are realized. There is no idiosyncratic or aggregate uncertainty in the model. Within period, two stages are considered: the pre-production and the post-production stage. Due to the working capital constraint, firms make their production and borrowing portfolio decisions prior to producing their output. Once firms produced, they sell their output to both intermediate and final good producers and retrieve the share of sales paid on delivery. At the end of the period, firms repay their debt obligations and receive the remaining share of revenues.

Figure 3.1: Timing of the Intermediate Good Firm's Problem
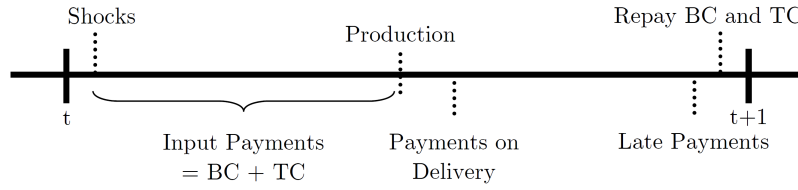
Financing Production. The representative intermediate good producing firm in sector k faces a cash flow mismatch between input payments at the beginning of the period and the realization of revenues. Wlog, I assume that firms have no internal funds available such that firm k needs to finance production using

(1) an intraperiod bank loan, BC_k, at an interest rate, r_k^B, and

(2) trade credit from its suppliers (accounts payable) at an interest rate r_s^T

$$AP_k \;=\; \sum_s AP_{ks} \;=\; \sum_s \theta_{ks} p_s x_{ks} \tag{3.4}$$

where $\theta_{ks} \in [0,1]$ represents the share of payments to supplier s that firm k postpones paying until after its sales are realized. As evident from Equation (3.4), firms can only postpone payments to intermediate good suppliers while any productive, ℓ_k^Q, and non-productive, ℓ_k^T, labor expenditures have to be paid upfront. Therefore, labor costs will be financed using bank credit only since firms are assumed to have no internal funds. Thus, the financial constraint of firm k can be written as

$$w\left(\ell_k^Q + \ell_k^T\right) + \sum_s p_s x_{ks} \;\leq\; BC_k + AP_k \tag{3.5}$$

which is binding in equilibrium. Note that a micro-foundation of the incentives of firms to engage in financial intermediation in the form of trade credit has been abstracted from (see Cuñat and García-Appendini, 2012, for an overview). Therefore, two simplifying assumptions are introduced, which allow me to capture the following two main features of the relationship between bank and trade credit presented in Section 2 while ensuring the analytical tractability of a firm's optimization problem: (1) A firm's short-term credit

portfolio is composed of both bank and supplier credit; and (2) The cost of bank credit are increasing in the share of sales extended on trade credit to customers. Both assumptions are discussed in detail below.

Assumption 3.2 (Management Cost of Credit Lines). *The adjustment of a firm's credit portfolio is subject to a combination of convex and non-convex frictions.*

$$C_k^T(\{\theta_{ks}\}_s) \ = \ w\ell_k^T \ = \ \kappa_k^B + \sum_s \kappa_{0,ks}^T \theta_{ks} + \frac{\kappa_{1,ks}^T}{2}\left(\frac{\theta_{ks} - \overline{\theta}_k^S}{\overline{\theta}_k^S}\right)^2 \tag{3.6}$$

such that firms face additional management costs of credit lines in the form of a non-productive labor input, ℓ_k^T.

In order to manage its credit lines, a firm needs to hire non-productive labor, $w\ell_k^T$. Its cost function is given by Equation (3.6) which adapts the functional form of the adjustment costs of capital applied in the literature (see Cooper and Haltiwanger, 2006): The quadratic adjustment cost part - similar to Luo (2019) - captures the fact that it is costly to change the credit composition and is assumed to be positive. In contrast, the linear cost parameter, $\kappa_{0,ks}^T$, may take on both positive and negative values. This highlights, that in adjusting the credit relationship with one's supplier s, firm k may undergo an organizational restructuring of its supplier relationship. Notably, the variable adjustment cost parameters are assumed to be specific to a firm-supplier pair. Furthermore, the term $\overline{\theta}_k^S$ denotes the average share of intermediate input payments obtained on trade credit and κ_k^B captures any fixed management costs. In the absence of uncertainty[10] from the model and allowing for a frictionless adjustment of the credit portfolio, the choice between bank and supplier credit will be such that firms will finance their expenditures using only the cheapest credit source and $\theta_{ks} \in \{0, 1\}$. While at the firm and transaction level this is a reasonable outcome - e.g. a firm either settles its payment on delivery or not - a mixture of both bank and trade credit is maintained at the sector level as highlighted in Section 2, even if the interest costs of bank finance might be cheaper than supplier credit as discussed in Cuñat and García-Appendini (2012). Therefore, the introduction of non-linear adjustment costs of credit lines ensures that the representative firm in each sector optimally chooses a credit portfolio of both bank and supplier credit consistent with the empirical evidence.

Assumption 3.3 (Cost of Bank Credit). *The cost of bank credit, r_k^B, be given by*

$$r_k^B \ = \ \mathrm{r}_0^B + r_k^Z, \ \ where \ r_k^Z \ = \ \exp(z_k^b)(\,\theta_k^Z\,)^\mu \mathrm{r}_0^B \ \ and \ \theta_k^Z \ = \ \overline{\theta}_0^D + \theta_k^C, \tag{3.7}$$

and $\partial r_k^B/\partial\theta_k^C \ \partial^2 r_k^B/(\partial\theta_k^C)^2 \ > \ 0$ holds.

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[10]In models where agents face a portfolio choice between e.g. equities (see e.g. Engel and Matsumoto, 2006), agents typically maintain a mixed portfolio, due to the existence of uncertainty.

The banking sector is introduced in a reduced form by imposing that each sector is charged a risk premium, r_k^Z, over the federal funds rate, r_0^B, which is a convex function in the average trade credit share extended to customers, θ_k^C. Assumption 3.3 captures that firms are subject to the default risk of their customers by selling their products on credit and thereby accounts for the empirical observations presented in Section 2. Similarly, the additional parameter, $\overline{\theta}_0^D$, captures a notion of aggregate default probability and is introduced to ensure that the equilibrium interest rate on trade credit is well behaved and of similar magnitude relative to the cost of bank credit as documented in the literature (Cuñat and García-Appendini, 2012). In general, the positive relationship between the interest rate charged on bank loans and the probability of default is a common modeling assumption (see i.a. Khan et al., 2016). Clearly, this set up introduces a direct upstream credit link between the cost of bank credit of firm k and trade credit extended to its customers: the higher the share of delayed payments by firm k's customers, the higher the interest rate on bank credit that firm k is charged. The intermediate good firm's profit maximization problem is as follows. (see Online Appendix D.2.2 for details)

Intermediate Production. Firms are price takers in both goods and credit markets. It is assumed that capital is exogenously given in the short-run and at its steady state value, $\overline{k}_k$. The objective of the representative firm in sector k is to choose production inputs, the credit portfolio as well as the optimal level of production and the share of its sales to extend on trade credit to maximise profits, while taking demand as given. Therefore, the set of choice variables is given by $\mathcal{V} = \{\ell_k^Q, \{x_{ks}\}_{s=1}^M, V_k, \{\theta_{ks}\}_{s=1}^M, \theta_k^C\}$. Taking into account the production (3.12) and credit (3.13) feasibility constraints, the intermediate good firm k's profit maximization problem can be formulated as

$$V(z_k^q, z_k^b) = \max_{\mathcal{V}} \pi_k, \text{ st } \pi_k = (1 + r_k^T \theta_k^C) p_k q_k - (1 + r_k^B) BC_k - \sum_s (1 + r_s^T) AP_{ks}, \quad (3.8)$$

the production function (3.1), total bank (3.5) and supplier credit (3.4), the credit management cost function (3.6), the interest rate on bank credit (3.7), feasibility constraints on trade credit shares $\theta_k^C, \theta_{ks} \forall s \in [0, 1]$ and non-negativity constraints.

Final Demand. The final good producer is required to pay its input expenditures at the time of the delivery of the product and maximizes

$$\max_{\{x_{0m}\}_m} PF - \sum_m p_m x_{0m} \quad (3.9)$$

subject to the production function (3.3) and non-negativity constraints. The household chooses consumption expenditures, C, and labor supply, L, to maximize utility

$$U(C, L) = \frac{C^{1-\epsilon_C}}{1 - \epsilon_C} - \frac{L^{1+\epsilon_L}}{1 + \epsilon_L}. \quad (3.10)$$

subject to the budget constraint

$$PC \leq wL + \Pi + T, \text{ where } \Pi = \sum_m \pi_m, \text{ and } T = \sum_m r_m^B BC_m. \quad (3.11)$$

The parameter $\epsilon_C > 0$ denotes the income elasticity and $\epsilon_L > 0$ denotes the inverse Frisch elasticity of labor supply. The budget constraint of the household indicates that total income of the household - total wage bill, profits and interest income from extending bank credit to firms - is spent on the aggregate consumption good.[11]

Market Clearing. Since the intermediate good of sector k is used both in the production of intermediate goods as well as in the production of the final good, market clearing for sector k requires that

$$q_k = \sum_c x_{ck}. \quad (3.12)$$

The labor market clears if $L = \sum_k \ell_k^Q + \ell_k^T$ holds. Similarly, the interest rate on trade credit charged by sector k in equilibrium is such that total accounts receivable of sector k equal total accounts payable owed by its customers to sector k

$$AR_k = \theta_k^C p_k q_k = \sum_c AR_{ck} = \sum_c AP_{ck} \quad (3.13)$$

where $AR_{ck} = \theta_{ck} p_k x_{ck}$. A competitive equilibrium, $\mathfrak{E}$, in this economy is defined as:

Definition 3.1. *A competitive equilibrium, $\mathfrak{E}$, in this economy is a set of aggregate and sector level prices $(w, P, \{p_m, r_m^T\}_{m=1}^M)$, quantities $(C, F, L, \{q_m, \ell_m^Q, x_{0m}, \{x_{ms}\}_{s=1}^M\}_{m=1}^M)$ and sector level trade credit shares $\{\theta_m^C, \{\theta_{ms}\}_{s=1}^M\}_{m=1}^M$ such that*

(1) *The representative household maximizes utility.*

(2) *Intermediate and Final-Good producers maximize profits.*

(3) *Goods and Factor markets clear.*

(4) *Financial markets clear.*

3.1. Equilibrium Characterization

Following the introduction of the model set-up, this section elaborates on the impact of working capital constraints and the existence of trade credit on the optimal intermediate input choice, credit costs and the composition of the credit portfolio. The effect of distortions on the optimal input demand by the representative intermediate good producing

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[11]The cases of rebated and wasted distortions, T, are discussed in detail in Bigio and La'O (2019).

firm is first described in Lemma 3.1 while taking both credit costs and the composition of the borrowing portfolio as given. To simplify notation, define the vector of interest rates on bank and trade credit and credit links as $\boldsymbol{\tau} = [\boldsymbol{r}^B, \boldsymbol{r}^T, \boldsymbol{\theta}]$.

Lemma 3.1 (Optimal Input Choice)**.** *Given a vector of prices, $\boldsymbol{p}$, the wage rate, w, interest rates and credit links, $\boldsymbol{\tau}$, firm k's optimal demand for intermediate input s, x_{ks}, and labor, ℓ_k^Q, is*

$$x_{ks} = \omega_{ks}^X (1 - \eta_k) \chi_k \frac{\phi_k^R}{\phi_{ks}^X} \frac{p_k}{p_s} q_k \quad (3.14) \qquad \ell_k^Q = (1 - \alpha_k) \eta_k \chi_k \frac{\phi_k^R}{\phi_k^L} \frac{p_k}{w} q_k \quad (3.15)$$

where the credit wedges are given by

$$\phi_k^L = 1 + r_k^B \quad (3.16) \qquad \phi_{ks}^X = 1 + (1 - \theta_{ks}) r_k^B + \theta_{ks} r_s^T \quad (3.17)$$

and the revenue wedge is $\phi_k^R = 1 + r_k^T \theta_k^C$ such that total revenues of firm k are $R_k = \phi_k^R p_k q_k$.

Proof. See Online Appendix D.2. □

The requirement to finance total input expenditures prior to the realization of any sales introduces a credit wedge between the firm's marginal cost and marginal revenue of the respective input, thereby distorting the first order conditions. As a result, a firm's nominal expenditures on production inputs include interest payments and are proportional to its revenues due to the Cobb-Douglas production technology. While labor expenditures are exclusively financed by bank credit, firm k finances its expenditures on intermediate inputs obtained from supplier s using both bank and supplier credit. The resulting credit wedge, ϕ_{ks}^X, is a weighted average of both credit costs and the weights are equal to the trade-credit share. Both credit wedges are increasing in the cost of credit, r_k^B and r_s^T. In addition, the intermediate credit wedge, ϕ_{ks}^X, decreases in the trade-credit share, θ_{ks}, if the interest rate differential $(r_k^B - r_s^T)$ is positive and increases otherwise. It follows that credit costs associated with the working capital constraint aggregate to a Cobb-Douglas composite of the individual credit wedges, ϕ_k^V, increasing marginal cost of production and consequently the optimal goods price charged as shown in Corollary 3.1 and Lemma 3.2.

Corollary 3.1 (Marginal Costs of Production)**.** *Given a vector of interest rates and credit links, $\boldsymbol{\tau}$, the marginal cost of production, $p_k^V = \phi_k^V mc_k^V$, can be decomposed into a composite of input prices, mc_k^V, and credit cost wedges, $\phi_k^V > 1$,*

$$mc_k^V = \left(w \right)^{\upsilon_k} \left(\prod_s (p_s)^{\omega_{ks}^X} \right)^{(1 - \upsilon_k)} \quad and \quad \phi_k^V = \left(\phi_k^L \right)^{\upsilon_k} \left(\prod_s (\phi_{ks}^X)^{\omega_{ks}^X} \right)^{(1 - \upsilon_k)}. \quad (3.18)$$

Proof. See Online Appendix D.2. □

As discussed previously, the effective price paid by a customer is a bundle of the actual goods price and the cost of the financial service provided by its supplier. Consequently, firms receive income from both selling their output and extending trade credit to their customers as captured by the revenue wedge, ϕ_k^R, in Equation (3.8). Therefore, an increase in either trade credit extended to customers or the interest rate charged on trade credit, ceteris paribus, increases sector k's revenues and thus also k's demand for production inputs as shown in Lemma 3.1. Simultaneously, the extension of trade credit increases the marginal revenue generated by an additional unit sold thereby decreasing the optimal price charged on the actual good in Lemma 3.2.

Lemma 3.2 (Optimal Price). *The optimal goods price is a mark-up over marginal costs*

$$p_k \;=\; \frac{MC_k^V}{MP_k^V} \;=\; \frac{\phi_k^V}{\phi_k^R} \frac{mc_k^V}{(1-\alpha_k\eta_k)\,\chi_k q_k V_k^{-1}} \tag{3.19}$$

and is increasing the composite credit, ϕ_k^V, and decreasing in the revenue wedge, ϕ_k^R.

Proof. See Online Appendix D.2. $\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ □

Lemma 3.1 and 3.2 show that the working capital constraint introduces credit and revenue wedges which reduce the demand for productive inputs and increase prices. At the aggregate level, distortions manifest themselves as an aggregate efficiency and labor wedge presented in Lemma 3.3. While taking the nominal wage rate as the numeraire and treating capital as a constant, the derivation[12] of Lemma 3.3 largely follows BL(2019) with an important difference: credit wedges are also functions of the interest rates and the share of input expenditures obtained on trade credit which are both determined in equilibrium. The equilibrium collapses to that presented in BL(2019), if there are no trade-credit linkages ($\theta_{ks} = 0 \forall k, s$) and firms do not require the non-productive labor input ($\ell_k^T = 0 \forall k$). Although both the cost of credit as well as the credit portfolio are interdependent and endogenous in the model, the model only admits an analytical solution in partial equilibrium when taking interest rates as well as trade-credit linkages as given. Consequently, there exists almost a one-to-one mapping of the partial equilibrium in this section to the general equilibrium analysis presented in BL(2019).

Lemma 3.3 (PE-Aggregate Efficiency and Labor Wedge). *Given interest rates and credit linkages, $\boldsymbol{\tau}$, an economy consisting of individual sectors operating with Cobb-Douglas production technologies and engaging in intersectoral trade aggregates to a Cobb-Douglas aggregate production function characterized by decreasing returns to scale*

$$Y \;=\; Z_z \Phi_\phi^Z L^{(1-\lambda)} \tag{3.20}$$

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[12]For a detailed partial equilibrium analysis, see Online Appendix E and the discussion in BL(2019).

Z_z denotes aggregate productivity and Φ_ϕ^Z represents the aggregate efficiency wedge which is a non-linear combination of all sectoral distortions. The aggregate labor wedge, Φ_ϕ^L, is defined as a wedge between the household's marginal rate of substitution between consumption and labor and the aggregate marginal product of labor

$$\frac{L^{\epsilon_L}}{C^{-\epsilon_C}} = \Phi_\phi^L(1-\lambda)\frac{Y}{L}. \tag{3.21}$$

Proof. See Online Appendix E. (see also Bigio and La'O, 2019, for a comparison) □

To summarize, the presence of working capital constraints in this economy leads to a misallocation of resources and an efficiency loss. The respective wedges are functions of the interest rate charged on bank and trade credit as well as trade-credit shares which are determined endogenously in equilibrium by firms maximizing profits as discussed in the following. Lemma 3.4 summarizes the results.

A profit-maximizing firm k chooses the share of input expenditures financed using trade credit, θ_{ks}, such that the combined change in the cost of production and managing credit lines associated with changing the share of trade credit obtained from k's supplier is zero at the optimum. The trade-off that a firm faces when choosing the composition of its credit portfolio is governed by the difference in the cost of bank and trade credit. In particular, if the interest rate on trade credit offered by supplier s is cheaper than the interest rate on bank credit, then an increase in the trade-credit share obtained from supplier s reduces the marginal cost of production but increases expenditures on non-productive labor. However, if the interest differential is negative, then an increase in the trade-credit share increases total cost of production such that firm k chooses the composition of the credit portfolio to minimize total costs. The optimal demand for trade credit is given by Equation (3.22).

Since firms operate under perfect competition, the individual customer's demand for trade credit is taken as given, when choosing the profit-maximizing share of sales to extend on trade credit. A firm faces the following trade off: On the one hand, an increase in sales extended on trade credit increases its revenues due to an increase in the interest income from lending to its customers. On the other hand, the firm internalises that it also increases its interest rate on bank credit due to Assumption 3.3 and therefore total marginal costs of production.[13] In equilibrium, the implied profit maximizing interest rate on trade credit, r_k^T, equalizes the marginal revenue and the marginal cost of extending trade credit to customers and is depicted by Equation (3.23).

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[13]This economy does not feature any pecuniary externalities: While customers do not internalize the effect of their portfolio choice on the cost of bank credit of their supplier, suppliers will adjust the interest rate charged on trade credit accordingly. An efficiency constrained social planner subject to the same working capital constraints in each sector will choose the same allocations as agents in the decentralised equilibrium.

Lemma 3.4 (Optimal Trade Credit Demand and Costs). *Firm k chooses the credit composition $\{\theta_{ks}\}_{s=1}^{M}$ to finance intermediate inputs obtained from suppliers and the share of revenues extended on trade credit to customers, θ_k^C, to maximise profits.*

(a) *The optimal demand for trade credit is*

$$\theta_{ks} = \bar{\theta}_{ks}^{\kappa} + \frac{(\bar{\theta}_k^S)^2}{\kappa_{1,ks}^T} \frac{\Delta_{ks} p_s x_{ks}}{1 + r_k^B} \quad where \quad \bar{\theta}_{ks}^{\kappa} = \left(1 - \frac{\kappa_{0,ks}^T}{\kappa_{1,ks}^T} \bar{\theta}_k^S\right) \bar{\theta}_k^S. \tag{3.22}$$

and $\Delta_{ks} = r_k^B - r_s^T$ denotes the interest differential between bank and trade credit.

(b) *The optimal interest rate on trade credit extended by sector k is*

$$r_k^T = \frac{\mu r_k^Z}{\theta_k^Z} \frac{BC_k}{p_k q_k} \tag{3.23}$$

where $BC_k = w\ell_k + \sum_s (1 - \theta_{ks})p_s x_{ks}$ denotes total bank loans obtained.

Proof. See Online Appendix D.2. □

Sector k's profit maximizing *share of inputs obtained on trade credit* from supplier s is determined by the cost parameters of the credit management cost function, and the difference in interest expenditures associated with obtaining output from supplier s, as evident from Equation (3.22).While an increase in the linear cost parameter, $\kappa_{0,ks}^T$, unambiguously decreases sector k's optimal trade-credit share, the effect of an increase in the quadratic cost parameter, $\kappa_{1,ks}^T$, governing the flexibility of firms in adjusting their credit portfolio is ambiguous. Similarly, the elasticity of sector k's optimal share of inputs obtained on trade credit with respect to changes in input expenditures, $p_s x_{ks}$, is also ambiguous. In both cases, the ambiguity is due to the fact that the effect of changes in the trade-credit share on marginal cost of production depends on the difference in the cost of bank and trade credit. The direct effects of changes in credit costs are straightforward: An increase in the interest rate on either bank or trade credit increases the marginal cost of production. While the increase in the cost of bank credit unambiguously induces a shift of the optimal credit portfolio towards trade credit, the increase in the interest rate charged on trade credit by supplier s decreases the trade-credit share for given intermediate expenditures, $p_s x_{ks}$. Therefore, the equilibrium adjustment of the credit portfolio in response to changes credit costs will depend on the relative change in the cost of bank and trade credit. In particular, if the interest rate on trade credit displays a higher increase than that on bank credit, firms will shift their credit portfolio towards bank loans in response to a financial shock to the bank risk premium. This pattern has been observed in the data at the onset of the crisis as discussed in Section 2, suggesting that the cost of trade credit may be more volatile than the interest rate on bank credit.

Equation (3.23) highlights that the optimal interest rate charged on trade credit is directly affected by exogenous financial shocks to a sector's risk premium, r_k^Z. Furthermore, it depends on the elasticity of sector k's interest rate on bank credit with respect to changes in the risk premium: For a given share of bank loans, the optimal interest rate on trade credit is increasing in both the responsiveness, μ, of the bank interest rate to the share of sales extended on supplier credit and in θ_k^C directly. The interest rate is also affected by changes in the share of bank loans in total revenues net of interest income from financial intermediation. It follows that an increase in the cost of production decreases k's demand for inputs and subsequently total bank credit obtained. Intuitively, the interest rate charged on trade credit decreases as k's dependency on bank loans and therefore it's exposure to financial shocks decrease. Note that firm k sets a *common* contract rather than a link-specific contract. This implies, if customer c of firm k increases its trade-credit share such that - all equal - θ_k^C increases, the interest charged on trade credit by firm k to all customers rises. In other words, the existence of common suppliers leads to spillovers from one customer of supplier s to another via an increase in the interest rate of trade credit. A common contract is assumed for simplicity - this should capture that it is costly to maintain link-specific contracts. As suggested in Jacobson and von Schedvin (2015) or Costello (2017), an increase in the borrowing of one customer might affect the ability of firm k to lend to others such that the introduction of spillovers via a common contract may be justified. Appendix D.3 provides a summary of all equilibrium conditions.

3.2. Propagation of Financial Shocks

It has been shown that - as common to models with distortions (i.a. Bigio and La'O, 2019; Baqaee and Farhi, 2018, 2019) - working capital constraints introduce an aggregate efficiency and labor wedge, thereby generating an efficiency loss as resources are diverted from being used for production. Since firms are both lenders and borrowers of trade credit at the same time, distortions in this model are not only endogenous but also interdependent. In particular, as firms adjust both their lending rates and their borrowing portfolio, credit cost of production and credit linkages are subject to changes along the intensive margin and consequently distort the transmission of shocks.

Section 3.2.1 highlights that trade credit can both dampen and amplify the response of output following an idiosyncratic liquidity shock. The first round response of a representative firm in sector k to an increase in its cost of bank credit illustrates how a financial shock propagates both up- and downstream, generating counteracting output responses. Section 3.2.2 discusses the equilibrium response of output by elaborating on the determinants of its elasticity with respect to shocks to the cost of bank credit. The log-linearization of the model around its steady state allows a decomposition of the log-

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change of all variables of interest into changes attributed to (1) productivity shocks, (2) general equilibrium adjustments in the aggregate labor supply and (3) changes in credit wedges. The credit wedges summarize the composite effect of changes in credit costs and the composition of the credit portfolio on sales, prices and output. The interdependency of distortions in this model implies the existence of a credit multiplier capturing the total effect of shocks to the bank risk premium on interest rates and the credit portfolio. It is shown that, to a first order approximation, the structural elasticities are functions of equilibrium expenditures, accounts payable and receivables, which determines the strength of the trade-credit channel introduced in Section 3.2.1.

3.2.1. Trade Credit Mechanism

In order to develop some intuition on how changes in credit costs propagate both up- and downstream, I consider the following demand structure between sector k, its customer c and its supplier s as depicted in Figures 3.2a and 3.2b: (1) sector k does not supply output to itself ($\omega_{kk}^X = 0$), (2) the flow of goods between a pair of sectors is directed such that each sector identifies as either the customer or the supplier ($\omega_{sk}^X = \omega_{kc}^X = 0$) and (3) none of the sectors' output is used in the production of the final good ($\omega_s^F = \omega_k^F = \omega_c^F = 0$). Using standard graph theoretical notation (see e.g. Carvalho, 2010), this subgraph of the production network defined by the intermediate and final demand input-output matrices, $\mathbf{\Omega} = \{\mathbf{\Omega}^X, \mathbf{\Omega}^F\}$, will be referred to as the line-subgraph, $G_L(\mathbf{\Omega})$:

Definition 3.2 (Line-Subgraph). *Let $G(\mathbf{\Omega}) = G(\mathcal{V}, \mathcal{E})$ be a directed sectoral trade linkages graph, where $\mathcal{V}$ is the vertex set of M intermediate and one final good producing sectors labeled $\{v_0, v_1, ..., v_M\}$ and $\mathcal{E}$ is set of all ordered pairs of vertices $\{v_i, v_j\}$ for which $\omega_{ij} > 0$ holds. Define the line-subgraph as $G_L(\mathcal{V}_L, \mathcal{E}_L) \subset G(\mathcal{V}, \mathcal{E})$, with $\mathcal{V}_L = \{v_s, v_k, v_c\}$ and $\mathcal{E}_L = \{\{v_s, v_k\}, \{v_k, v_c\}\}$.*

Let the demand structure be given by $G_L(\mathbf{\Omega})$. Consider now a financial shock to the bank risk premium of the representative firm in sector k, $z_k^b = \epsilon_k^b > 0$, such that k's interest rate on bank credit defined in Equation (3.7) increases. Using the results of the Section 3.1, Corollary 3.2 to 3.4 elaborate on the direct propagation of an idiosyncratic shock to the risk premium of the representative firm in sector k, r_k^Z, to its customer c and supplier s, while abstracting from any feedback and general equilibrium effects. The respective proofs are provided in Appendix A.1.

Corollary 3.2 (Effects of Changes in k's Interest Rate on Bank Credit). *An increase in sector k's interest rate on bank credit, r_k^B, increases k's marginal cost of production. Sector k's demand for inputs and therefore supplier s's output decrease. Sector k's price charged for k's output and therefore customer c's marginal cost of production increase, decreasing c's demand for inputs. Sector k's output decreases.*

Corollary 3.2 describes how an increase in sector k's interest rate on bank credit, r_k^B, affects sector k's cost of production and translates into demand effects upstream and cost effects downstream as shown in Figure 3.2a. Output in all three sectors declines. Note that a shock to the interest rate on bank credit exhibits the same propagation pattern as an increase in exogenous sectoral distortions in the model economy introduced in BL(2019) or a negative productivity shock to sector k. Inter-firm credit linkages introduce additional propagation channels via changes in both the cost of trade credit and trade-credit shares, as discussed in the following. Corollary 3.3 summarizes the effect of an increase in sector k's bank risk premium on k's interest rate charged on trade credit.

Figure 3.2a: Effects of Changes in the Cost of Bank Credit
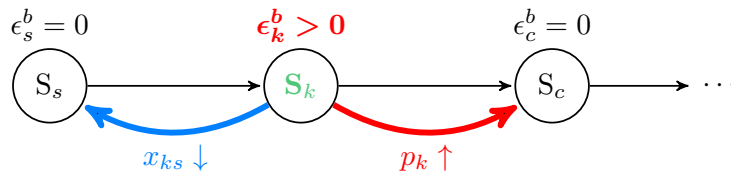
Note: This figure illustrates the demand and price effects of an increase in sector k's interest rate on bank credit following a shock to k's risk premium, $z_k^b = \epsilon_k^b > 0$, along the supply chain formed by sector k, supplier s and customer c. Productivity remains at its equilibrium level such that $z_i^q = \epsilon_i^q = 0$ for $i \in \{s, k, c\}$.

Corollary 3.3 (Effects of Changes in k's Interest Rate on Trade Credit). *The increase in sector k's bank risk premium, r_k^Z, - ceteris paribus - increases k's interest rate charged on trade credit, r_k^T, and customer c's marginal cost of production. Sector c's demand for inputs and thus sector k's output decrease.*

Using the results of Lemma 3.4, Corollary 3.3 describes how a shock to sector k's risk premium, r_k^Z, translates into cost effects downstream, operating in addition to the traditional cost effect via prices described in Corollary 3.2. In other words, while abstracting from any general equilibrium effects, an increase in sector k's interest rate on trade credit increases customer c's production costs beyond the initial increase induced by a rise in the price of k's output. Therefore, sector c decreases its demand for k's output even further. Note that changes in k's interest rate on trade credit have no immediate income and cost effects affecting supplier s's sales, prices and output. Similarly, Corollary 3.4 describes the effect of changes in the credit composition of sector k.

Corollary 3.4 (Effects of Changes in k's Trade-Credit Share). *An increase in sector k's interest rate on bank credit, r_k^B - ceteris paribus - increases sector k's share of inputs obtained on trade credit from supplier s and consequently dampens k's initial increase in marginal cost of production and decrease in output induced by the financial shock.*

Corollary 3.3 and 3.4 summarize how the direct response of trade-credit costs and shares of the affected sector distorts the up- and downstream transmission of a shock to

its interest rate on bank credit, as depicted in Figure 3.2b: On the one hand, as firms also increase the interest rate charged on trade credit, the cost shock to their customers is amplified beyond the traditional price channel. On the other hand, the ability of firms to substitute bank and supplier credit implies that the own cost effect and therefore upstream demand effect of an increase in bank financing costs is dampened. Based on the previous discussion of the direct effects of changes in the cost of credit and the input-specific borrowing portfolio, the Trade-Credit Channel is defined as follows:

<div align="center">

Figure 3.2b: Trade Credit Channel

</div>
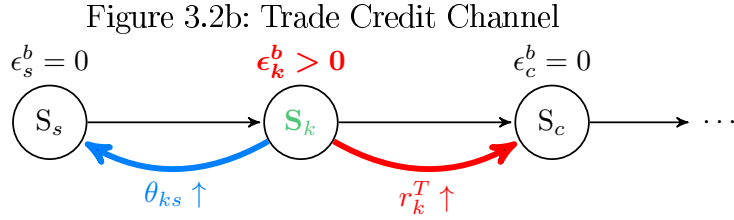
Note: This figure illustrates the trade credit channel for a shock to sector k's risk premium, $z_k^b = \epsilon_k^b > 0$, along the supply chain formed by sector k, supplier s and customer c. Productivity remains at its equilibrium level such that $z_i^q = \epsilon_i^q = 0$ for $i \in \{s, k, c\}$.

Definition 3.3 (Trade Credit Channel). *Consider an economy with working capital constraints and two sources of external funds: bank and trade credit. Let the optimal interest rate on trade credit and the optimal credit share be defined in Lemma 3.4. The ability of firms to delay input payments to their suppliers introduces two opposing channels via which trade credit affects economic outcomes:*

(a) *(Amplification) An increase in the cost of bank finance of a firm directly translates into an increase in the interest rate charged on trade credit, thereby tightening the financing terms for its customers.*

(b) *(Smoothing) The existence of two external financing sources allows firms to smooth any interest rate shocks via an adjustment of their borrowing portfolio by optimally trading-off credit costs.*

In foresight of the quantitative application of the model, two observations are worth mentioning: First, the strength of the amplification channel will be influenced by the elasticity of the bank risk premium with respect to the share of revenues extended on trade credit, μ. Second, the extent to which firms are able to smooth credit shocks will depend on two conditions: (1) the parameter governing the convexity of the credit management cost function, $\kappa_{1,ks}^T$, defined in Equation (3.6) and (2) the type of shocks present in this economy. The first condition implies that a lower cost parameter increases the ability of firms to substitute credit sources and thus increases the smoothing channel in this economy. The second circumstance relates to the fact that, in the case of an aggregate shock, firm k's supplier s of trade credit and consequently s's interest rate charged on

trade credit will also be directly affected by the shock. Ultimately, the question of which effect dominates remains an quantitative question and will be investigated in Section 4.

3.2.2. Equilibrium Effect on Output

While the previous section provided an insight into the up- and downstream propagation channels introduced by trade credit, this section elaborates on the determinants of the elasticity of output with respect to financial shocks. For this purpose, I first discuss how changes in output can be attributed to changes in the cost of credit and the credit portfolio by log-linearizing the model around its equilibrium featuring both bank and trade credit. Before continuing with the main exposition, the hat-notation is introduced to depict log-deviations of the respective variable from its equilibrium value, denoted using the bar-notation. Appendix A describes the matrix notation adopted in this section. In addition, the following matrices are defined which capture total equilibrium cost, $\boldsymbol{W}_P$, and demand, $\boldsymbol{W}_R$, interactions resulting from the input-output structure of the economy

$$\boldsymbol{W}_P \; = \; \left[\boldsymbol{I} - \mathrm{diag}\left(\boldsymbol{\chi} \circ (\boldsymbol{\iota} - \boldsymbol{\eta})\right)\boldsymbol{\Omega}^X\right]^{-1} \text{ and } \boldsymbol{W}_R \; = \; \left[\boldsymbol{I} - (\boldsymbol{W}_R^X)' - \boldsymbol{W}_R^F \boldsymbol{J} \boldsymbol{W}_F^R\right]^{-1}. \quad (3.24)$$

Note that while the equilibrium cost interdependencies, $\boldsymbol{W}_P$, are determined by the production parameters only, the demand interactions, $\boldsymbol{W}_R$, depend on the equilibrium sales and income ratio, respectively, with

$$[\boldsymbol{W}_R^X]_{ck} = \overline{x}_{ck}(\overline{q}_k)^{-1}, \; [\boldsymbol{W}_R^F]_{kk} = \overline{x}_{0k}(\overline{q}_k)^{-1}, \text{ and } [\boldsymbol{W}_F^R] = (\overline{\pi}_k + \overline{T}_k)(\overline{R}_0)^{-1}.$$

The log-linearization of the equilibrium further allows to define the vector of changes in price, $\hat{\boldsymbol{\phi}}^P(\hat{\boldsymbol{\tau}})$, and sales wedges, $\hat{\boldsymbol{\phi}}^S(\hat{\boldsymbol{\tau}})$, summarizing the joint effect of changes in the cost of credit and the credit portfolio, $\hat{\boldsymbol{\tau}} = [\hat{\boldsymbol{r}}^B, \hat{\boldsymbol{r}}^T, \hat{\boldsymbol{\theta}}]'$, on prices and sales as shown in Lemma 3.5. For the ease of notation, I drop the dependency of the respective wedges on $\hat{\boldsymbol{\tau}}$ in the following. However, it should be kept in mind that any wedges are functions of the interest rates on bank and trade credit, and trade-credit shares, which are endogenously determined by profit-maximizing firms as shown in Lemma 3.4.

Lemma 3.5 (Price and Sales Wedges)**.** *The total effect of changes in the cost of credit and the credit portfolio, $\hat{\boldsymbol{\tau}}$, on prices is given by a weighted average of changes in credit wedges affecting the cost of labor, $\hat{\boldsymbol{\phi}}^L$, and intermediate cost of production, $\hat{\boldsymbol{\phi}}^X$.*

$$\hat{\boldsymbol{\phi}}^P \; = \; \mathrm{diag}((\boldsymbol{\iota} - \boldsymbol{\alpha}) \circ \boldsymbol{\eta} \circ \boldsymbol{\chi})\hat{\boldsymbol{\phi}}^L + \mathrm{diag}((\boldsymbol{\iota} - \boldsymbol{\eta}) \circ \boldsymbol{\chi})\mathring{\boldsymbol{\Omega}}^X \hat{\boldsymbol{\phi}}^X - \hat{\boldsymbol{\phi}}^R \quad (3.25)$$

Due to the Cobb-Douglas production technology (3.1), the weights are determined by the output elasticities of the respective production inputs. Similarly, the total effect on sales is a weighted average of changes in credit wedges affecting intermediate, $\hat{\boldsymbol{\phi}}^X$, and final,

$\hat{\boldsymbol{\phi}}_F^S$, *demand, where the weights reflect the share of each customer in total sales.*

$$\hat{\boldsymbol{\phi}}^S \;=\; (\boldsymbol{W}_R^X)'\hat{\boldsymbol{\phi}}^X - \hat{\boldsymbol{\phi}}^R + \boldsymbol{W}_R^F \boldsymbol{J} \hat{\boldsymbol{\phi}}_F^S \tag{3.26}$$

The additional revenue generated by the interest income from extending trade credit implies that revenue wedges, $\hat{\boldsymbol{\phi}}^R$, decrease both price and sales wedges.

Proof. See Online Appendix F.1. □

Lemma 3.5 highlights that the existence of trade credit and resulting interdependency of distortions introduce counteracting cost and income effects affecting the propagation of shocks to customers and suppliers. The following paragraphs discuss the different channels through which changes in the cost of credit and the credit composition affect sales, prices and ultimately output, while imposing restrictions on the degree of DRS. Note that the presence of DRS implies that prices will be increasing in sales. As a result, any changes in sales counteract the respective cost and demand effects of changes in credit costs and the credit composition on prices and output. Assumption 3.4 ensures that the standard cost and demand channels discussed in the following are preserved.

Assumption 3.4. *The vector of parameters governing the degree of decreasing returns to scale in each sector, $\boldsymbol{\chi}$, is such that (1) an increase in the cost of the production function increases prices and (2) a decrease in sales decreases output.*

It follows from Lemma 3.5 that changes in sectoral *prices* induced by changes in credit costs and in the credit portfolio are the result of two channels: the cost- and the demand channel. While the latter is present due to DRS and dampens any cost effects, an increase in sector k's cost of credit, $\hat{\boldsymbol{\phi}}^X$, increases the cost of production and therefore the price charged on output of sector k. Similarly, intermediate *revenues* are affected by changes in the credit costs of customers, $\hat{\boldsymbol{\phi}}^X$, and household's income, $\hat{\phi}_F^R$: An increase in customer c's interest rate on bank credit as well as in sector k's interest rate charged on trade credit, increases c's cost of production. Consequently, the demand for k's output and thus sales decline. Changes in the interest and profit income of households due to changes in credit costs and shares are captured by the final demand wedge, $\hat{\phi}_F^R$. On the one hand, an increase in c's bank rate increases the interest income of households and subsequently intermediate sales. On the other hand, an increase in either sector k's interest rate charged on trade credit or trade-credit share obtained by sector c lowers the profit income of households, and ultimately both final and intermediate sales.

The existence of trade credit also implies that a sector obtains revenues from both selling its output and acting as a financial intermediary by extending trade credit to its customers. The latter introduces an income effect from financial intermediation, $\hat{\boldsymbol{\phi}}^R$, in

addition to the standard cost and demand effects of credit wedges as shown in Lemma 3.5. In other words, an increase in the interest rate charged on trade credit as well as an increase in the customers' share of inputs payments obtained on trade credit increases k's marginal revenues from selling its output on credit. As a result, k's interest income from financial intermediation increases thereby increasing revenues and decreasing prices. Thus, the reduction in the price of input k counteracts any previously discussed negative cost and demand effects. In general, the effect of an increase in the share of input payments obtained on trade credit on the cost of production and subsequently prices, output and sales depends on the relative price of bank and trade credit and is ambiguous.

Proposition 1 now shows that the log-linearized sectoral output response can be decomposed into changes attributed to changes in productivity, credit costs and the credit composition and general equilibrium effects, $GE_\tau(\hat{L}, \hat{\boldsymbol{W}})$. The latter refer to changes in the aggregate labor supply, $\hat{L}$, and the composition of sales, $[\hat{\boldsymbol{W}}]_{ck} = \hat{x}_{ck} - \hat{q}_k$. To simplify notation, the vector of equilibrium bank credit obtained by sector k, $\overline{\boldsymbol{BC}}_k$, is defined as

$$\overline{\boldsymbol{BC}}_k = [\overline{\boldsymbol{BC}}_k^Q \,,\, \overline{BC}_k^T] \text{ where } \overline{\boldsymbol{BC}}_k^Q = [\overline{w\ell}_k^Q, \overline{AP}_{k1}^- \cdots \overline{AP}_{kM}^-] \text{ and } \overline{BC}_k^T = \overline{w\ell}_k^T. \quad (3.27)$$

The respective entries refer to the productive, $\overline{w\ell}_k^Q$, and non-productive labor, $\overline{w\ell}_k^T$, and intermediate expenditures, $\overline{AP}_{ks}^- = (1 - \overline{\theta}_{ks})\overline{p}_s\overline{x}_{ks}$, financed using bank credit.

Proposition 1 (Sectoral Output Reponse)*. The response of sectoral output is given by*

$$\hat{\boldsymbol{q}} = \boldsymbol{W}_P \mathrm{diag}(\boldsymbol{\chi})\hat{\boldsymbol{z}}^q - \hat{\boldsymbol{\phi}}^Q + GE_Q(\hat{L}) \quad (3.28)$$

and the effect of distortions on output is summarized by the output wedge

$$\hat{\boldsymbol{\phi}}^Q = \boldsymbol{W}_P\hat{\boldsymbol{\phi}}^P + \hat{\boldsymbol{\phi}}^R + (\boldsymbol{I} - \boldsymbol{W}_P\mathrm{diag}(\boldsymbol{\iota} - \overline{\boldsymbol{\chi}}))\boldsymbol{W}_R\hat{\boldsymbol{\phi}}^S = \boldsymbol{E}_Q^\tau\hat{\boldsymbol{\tau}} + GE_\tau(\hat{L}, \hat{\boldsymbol{W}}) \quad (3.29)$$

capturing the joint effect of changes in credit costs and the credit portfolio on prices and demand, $\hat{\boldsymbol{\tau}}$, and general equilibrium effects, GE. The entries of matrix $\boldsymbol{E}_Q^\tau = [\boldsymbol{E}_Q^B, \boldsymbol{E}_Q^T, \boldsymbol{E}_Q^\theta]$ represent the elasticity of the output wedge of sector k wrt changes in the interest rate on bank credit, $\hat{r}_m^B$,

$$[\boldsymbol{E}_Q^B]_{km} = \overline{r}_m^B \sum_i [\boldsymbol{W}_Q^B]_{k,mi}\overline{BC}_{mi}^Q$$

and in the interest rate on trade credit, $\hat{r}_m^T$, and trade-credit shares, $\hat{\theta}_{ms}$,

$$[\boldsymbol{E}_Q^T]_{km} = \overline{r}_m^T \sum_c [\boldsymbol{W}_Q^T]_{k,cm}\overline{AR}_{cm} \,\,,\,\, [\boldsymbol{E}_Q^\theta]_{k,ms} = -[\boldsymbol{W}_Q^\theta]_{k,ms}\overline{AP}_{ms}.$$

The weight matrices, $\boldsymbol{W}_{\ddot{Q}}$, are defined in the proof and are functions of the equilibrium, $\mathfrak{E}$, and the input-output price, $\boldsymbol{W}_P$, and demand, $\boldsymbol{W}_R$, relations given in (3.24).

Proof. See Online Appendix F.1. □

It follows from Proposition 1 that the output wedge of sector k, $\hat{\phi}_k^Q$, captures the combined effect of distortions on the cost of production and demand as summarized by the respective price and sales wedges defined in Lemma 3.5. To the extent that the cost effects on prices dominate any counteracting income effects, output decreases. Equation (3.29) highlights that the change in the sectoral output wedge is ultimately a linear combination of changes in the interest rates on bank and trade credit as well as the credit composition, $\hat{\tau}$. The elasticities of the output wedge with respect to changes in credit costs faced by sector m and its credit composition are a weighted linear combination of sector m's equilibrium bank credit obtained for productive inputs, m's trade credit extended to customers and obtained from its suppliers. The weights reflect sector k's total direct and indirect cost and demand interactions with customers and suppliers of sector m as captured by the respective matrices $\boldsymbol{W}_{\ddot{Q}}$.[14]

However, changes in credit costs are not exogenous but the result of firms maximizing profits as discussed in Section 3.1. Similar to Proposition 1, it follows from the interdependency of the interest rate on bank and trade credit and the credit composition that the respective elasticities of the log-linearized responses are linear combinations of the equilibrium production costs that need to be financed using bank loans, $\overline{BC}^Q$, accounts receivable, $\overline{AR}$, and payable, $\overline{AP}$, as shown in Online Appendix F.2. The interdependency of credit costs and the credit composition introduces a credit multiplier capturing total direct and indirect effects of changes in credit conditions on the variables of interest. Proposition 2 derives the structural responses of credit costs and the composition of the credit portfolio, $\hat{\tau}$, as well as the credit multiplier, $\boldsymbol{\Psi}_\tau$.

Proposition 2 (Structural Credit Responses and Credit Multiplier)**.** *The vector of log-linearized structural responses of interest rates on bank and trade credit, and trade-credit shares between sectors, $\hat{\tau}$, is*

$$\hat{\boldsymbol{\tau}} \;=\; \boldsymbol{\Psi}_\tau \boldsymbol{E}_\tau^{Z_b} \boldsymbol{\epsilon}_b + \boldsymbol{\Psi}_\tau G E_\tau(\hat{L}, \hat{\boldsymbol{W}}). \tag{3.30}$$

The credit multiplier and its first order approximation are given by

$$\boldsymbol{\Psi}_\tau \;=\; (\boldsymbol{I} - \boldsymbol{E}_\tau^\tau)^{-1} \;\approx\; \widetilde{\boldsymbol{\Psi}}_\tau \;=\; \boldsymbol{I} + \boldsymbol{E}_\tau^\tau. \tag{3.31}$$

The entries of the elasticity matrices of the interest rate on bank and trade credit with respect to shocks to the bank risk premium, $\boldsymbol{E}_\tau^{Z_b}$, and those of the remaining elasticity matrices in, $\boldsymbol{E}_\tau^\tau$, are defined in the proof and capture direct cost and indirect demand effects of changes in credit costs and the credit composition on $\hat{\tau}$.

Proof. See Online Appendix F.2. □

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[14]Similar arguments can be derived for aggregate GDP as shown in Online Appendix F.1.

The previous discussions highlight how shocks to the cost of bank credit are passed on through the input-output network both up- and downstream and affect the cost of credit and portfolio choices. By combining the results of Proposition 1 and 2, I am now able to provide a characterization of the log-linearized structural output response while taking into account the interdependencies of trade-credit costs and shares up to a first order. The following analysis is simplified by abstracting from productivity shocks[15] and by considering the partial equilibrium case defined in 3.4.

Definition 3.4 (Partial Equilibrium). *In partial equilibrium assume that $\hat{L} = 0$ and abstract from any feedback effect of changes in the composition of sales on the average trade-credit share extended to customers, $[\hat{\boldsymbol{W}}]_{ck} = \hat{x}_{ck} - \hat{q}_k = 0 \ \forall c, k$.*

Proposition 3 shows that the total effect of financial shocks on sectoral output will depend on the interactions of the input-output- and the credit-relations in the economy capturing all cost-, demand- and effects of changes in credit costs and the credit composition. The first part of Proposition 3 illustrates that the partial equilibrium sectoral output response is ultimately a function of the structural output wedge. The elasticity thereof with respect to shocks to the bank risk premium can be decomposed into effects attributed to exogenous changes in the interest rate on bank credit, $\widetilde{\boldsymbol{S}}_B^Q$, and endogenous changes in the credit composition and the interest rate on trade credit, $\widetilde{\boldsymbol{S}}_T^Q$. The latter summarizes the effect of the trade-credit channel and thus interdependent distortions on output.

Proposition 3 (PE-Structural Output Response). *Consider the partial equilibrium in Definition 3.4 and let the first order approximation of the response of the interest rate on bank and trade credit and trade credit shares be given in Equation (3.30) in the absence of productivity shocks, $\epsilon_k^q = 0$.*

(a) The first order approximation of the structural output response to shocks to the cost of bank credit, ϵ_m^b, equals the sum of total effects of

$$\widetilde{\boldsymbol{q}} = \begin{cases} -\widetilde{\boldsymbol{S}}_B^Q \boldsymbol{\epsilon}^b & \text{(1) exogenous changes in the cost of bank credit} \\ -\widetilde{\boldsymbol{S}}_T^Q \boldsymbol{\epsilon}^b & \text{(2) endogenous changes in trade-credit costs and linkages} \end{cases} \tag{3.32}$$

on output.

(b) The partial equilibrium structural elasticity of output wrt to exogenous changes in sector m's bank interest rate following a financial shock, ϵ_m^b,

$$[\widetilde{\boldsymbol{S}}_B^Q]_{km} = +\bar{r}_m^Z \sum_i [\boldsymbol{S}_{Q,B}^B]_{k,mi} \overline{BC}_{mi}^Q \tag{3.33}$$

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is a linear combination of sector m's production costs that need to be financed at the beginning of the period, $\overline{BC}_m^Q$. Similarly, the elasticity of output wrt to endogenous changes in sector m's interest rate on trade credit and its credit composition,

$$[\widetilde{\boldsymbol{S}}_T^Q]_{km} = -\bar{r}_m^Z \sum_i [\boldsymbol{S}_{Q,T}^B]_{k,mi} \overline{BC}_{mi} + \bar{r}_m^T \bar{\phi}_m^R \sum_c [\boldsymbol{S}_{Q,T}^T]_{k,cm} \overline{AR}_{cm} \qquad (3.34)$$

is a linear combination of sector m's production costs that need to be financed using bank loans, $\overline{BC}_m$, and accounts receivable, $\overline{AR}$. The matrices $\{\boldsymbol{S}_{Q,B}^B, \boldsymbol{S}_{Q,T}^B, \boldsymbol{S}_{Q,T}^T\}$ are defined in the proof and are functions of the elasticity of the output response wrt changes in the interest rate on bank and trade credit, and the trade credit share.

Proof. See Online Appendix F.3. □

Equation (3.33) and (3.34) show that the elasticity of sector k's output response with respect to financial shocks affecting sector m is a function of:

(1) m's production costs that need to be financed using bank loans, $\overline{BC}$, as well as m's accounts receivable, $\overline{AR}$.

(2) k's elasticities of output with respect to credit costs and shares summarized by matrices $\boldsymbol{S}_{\ddot{Q},:}$.

The latter matrices, $\boldsymbol{S}_{\ddot{Q},:}$, capture the interaction of direct and indirect cost- and demand effects operating via the input-output structure weighted by the strength of trade-credit relations between sectors and those affecting credit variables directly. To summarize, Proposition 3 highlights that the relationship between a sector's equilibrium total up-front financing needs and trade credit extended determines the structural elasticities of the variables of interest with respect to financial shocks. Therefore, the net-lending position of a sector is defined as the ratio of total trade credit extended to customers (accounts receivable) to bank loans obtained to finance the difference between total cost of production and accounts payable (see Definition 2.1). I conclude this section by elaborating on how the dependency of an economy on trade credit can affect the response of output following a financial shock. In particular, the question is posed: How does a sector's net-lending position affect the elasticity of sectoral output with respect to changes in the interest rate on trade credit and the credit composition?

Proposition 4 (Financial Determinants of Changes in Sectoral Output). *Let the partial equilibrium elasticity of output wrt shocks to the cost of bank credit, ϵ_m^b, be defined in Proposition 3. Let sector m be a net-borrower (net-lender) in the economy such that*

$$+\bar{r}_m^Z \sum_i [\boldsymbol{S}_{Q,T}^B]_{k,mi} \overline{BC}_{mi} \; > (<) \; +\bar{r}_m^T \bar{\phi}_m^R \sum_c [\boldsymbol{S}_{Q,T}^T]_{k,cm} \overline{AR}_{cm}$$

holds and the total effect of the endogenous trade credit channel is $[\widetilde{\boldsymbol{S}}_{B,T}^{Q}]_{km} < (>) 0$. Then, the adjustment of trade credit costs and credit shares will smooth (amplify) the negative effect of an increase in the interest rate on bank credit affecting sector m on (partial equilibrium) output of sector k.

Proof. Proposition 4 follows from Proposition 3. □

In other words, if a sector is affected by a financial shock whose (weighted) upfront total financing costs are larger than its (weighted) trade credit extended to customers - the sector classifies as a net-borrower according to Definition 2.1 and trade credit has a smoothing effect on output. On the contrary, if a sector is affected whose volume of bank loans are smaller than its accounts receivable - the sector classifies as a net-lender and trade credit has an amplifying effect on output. The intuition thereof is as follows: A sector's interest rate on trade credit will be more sensitive to financial shocks, the more trade credit is extended to customers. Therefore, the cost effect on output discussed above will be amplified. Similarly, a sector with a higher equilibrium dependency on bank credit will experience a stronger cost effect and therefore a greater reduction in its demand for inputs and thus in its share of bank loans in total sales. As a result, the interest rate on trade credit declines and dampens the output response to a financial shock. In the case of trade-credit shares, the effects are ambiguous and depend on the relative cost of bank and trade credit: While an increase in the cost of bank credit increases the share of inputs obtained on trade credit from suppliers and thus raises their income from financial intermediation and output, a simultaneous increase in the interest rate charged on trade credit counteracts this positive income effect. As a result of Proposition 3 and 4, the following additional observations can be made:

First, in the case of exogenous distortions - eg. the benchmark economy introduced in Bigio and La'O (2019) featuring bank finance only - the elasticity of output with respect to financial shocks depends only on the exogenous response of the interest rate on bank loans, $\widetilde{\boldsymbol{S}}_{Q}^{B}$. Second, an economy featuring both bank and trade credit introduces additional counteracting effects captured by the output elasticity with respect to endogenous changes in the cost of trade credit and trade credit shares, $\widetilde{\boldsymbol{S}}_{T}^{Q}$. Take $\boldsymbol{S}_{Q,T}^{B}$ and $\boldsymbol{S}_{Q,T}^{T}$ as given and positive. It follows that an increase in the dependency on trade credit by either increasing trade credit obtained from suppliers or extended to customers, increases the structural elasticity of output with respect changes in the interest rate on trade credit and the credit composition. In either case, output will be more sensitive to increases in a sector's cost of production which reduces the smoothing effect of trade credit on output.

3.3.   The Macroeconomic Effects of Trade Credit - A Roadmap

This section introduced a static quantitative multisector model with trade in intermediate inputs and endogenous credit linkages and costs between perfectly competitive intermediate good producing firms in each sector. Firms finance their working capital using both bank and trade credit. The three main theoretical insights of this section are summarized below and provide a roadmap for the quantitative analysis of the effects of trade credit on macroeconomic outcomes in the US during the 2008-2009 financial crisis in Section 4.

(a) The reliance on external credit sources to finance production implies that resources are diverted from a productive use. As a result, the cost of financing production expenditures translate into cost-, aggregate efficiency- and labor-wedges, distorting the first order conditions of agents as shown in Section 3.1. While this result is common to any model featuring distortions, the nature of trade credit introduces an interdependency of credit costs and portfolio choices. Therefore, the first exercise evaluates the quantitative importance of the existence of trade-credit linkages for the propagation of financial shocks in an economy relative to a counterfactual economy featuring bank finance only.

(b) Section 3.2.1 shows that trade credit distorts the transmission of financial shocks and has both smoothing and amplifying effects. In particular, as credit conditions tighten in an economy, the endogenous adjustment in the volume and cost of trade credit captures two counteracting mechanisms: (1) Firms smooth interest rate shocks by substituting bank and supplier finance. (2) Any increase in the interest rate that a firm charges on trade credit tightens the financing terms of its customers thereby amplifying financial shocks. The second exercise conducts both a general and partial equilibrium simulation in order to evaluate the relative importance of both features of the trade-credit channel.

(c) Section 3.2.2 derives that the log-linearised responses of real quantities can be decomposed into the total effect of distortions on prices and demand. Taking into account the interdependency of credit costs and portfolios captured by the credit multiplier presented in Proposition 2, structural output responses are decomposed into effects attributed to exogenous changes in the cost of bank credit and endogenous changes in the cost of trade credit and trade-credit linkages as shown in Proposition 3. The latter elasticity captures both smoothing and amplifying features of trade credit. Their relative importance is determined by the extent to which sectors have to finance their input expenditures using bank credit, their provision of trade credit to customers and the interactions of the input-output- and the credit-relations in economy. Proposition 4 highlights that sectors extending relatively more trade credit to customers than their own upfront financing needs play a crucial role in the transmission of shocks to the cost of external funds. Thus, the third exercise evaluate the role of net-lenders for the propagation of financial shocks by considering idiosyncratic shocks to different groups of sectors.

4. A Quantitative Assessment of Trade Credit and Aggregate Fluctuations

Based on the model insights derived in Section 3, this section quantifies the role of trade credit for business cycle comovement and aggregate fluctuations during the 2008-2009 financial crisis. To this end, the equilibrium of the model is first calibrated to the US economy at a sector level in Section 4.1. The US production and trade-credit network is mapped using the input-output tables provided by the Bureau of Economic Analysis and balance sheet data on accounts receivable and payable of a panel of US firms from Compustat. The time series of shocks to a sector's bank risk premium are inferred from sectoral credit spreads derived in Gilchrist and Zakrajšek (2012) and used to simulate the model economy while abstracting from any shocks to sectoral productivity in Section 4.2. A comparison of the model-simulations with the fluctuation patterns presented in Section 2 suggests, that the model reproduces - both qualitatively and quantitatively - business cycle features of trade credit as observed in the data. In particular, the model captures approximately a quarter of the variation of, and one third of the drop in aggregate output during the financial crisis. The simulation exercises derive the three main results: First, the existence of trade credit linkages almost doubled the decline in output relative to an equivalent economy with bank finance only and can account for approximately 16% of the drop in aggregate output during the 2008-2009 crisis. Second, the endogenous adjustment of the volume and cost of trade credit only reduced aggregate volatility by 1.4%, which suggests that the smoothing mechanism of trade credit was operative, though small. Third, firms which act as important financial intermediaries for their customers are systemically important and generate large spillovers.

4.1. Calibration Strategy

The static nature of the model and its analytical tractability allow for a period-by-period mapping of the equilibrium of the model to the empirical counterparts of the US economy at a sector level using the model's first order conditions, similar to BL(2019). The calibration of the production structure and the credit network are discussed in the following.

Production and Financial Network Data . The input-output tables from the Bureau of Economic Analysis (BEA) are used to map the production structure of the US economy at the 3-digit NAICS industry level at an annual frequency, covering the time period 1997-2016. In total 45 sectors (excluding FIRE) are included in the analysis. While data on the production structure of the US economy is readily available, data on trade-credit flows between production units at a firm or sectoral level is not. In order to overcome

these data-limitations[16], I construct a proxy of inter-industry credit flows using balance sheet data on accounts payable and receivable of a panel of US firms from Compustat and follow the approach suggested in Altinoglu (2018). The second complication in mapping the model to the data is the consistent assignment of interest rate costs on bank and trade credit: As part of the effective price paid, interest payments on trade credit are already accounted for in the nominal intermediate expenditures reported in the IO-tables. Bank interest rate expenditures, however, are recorded as part of the gross operating surplus net of interest-income. (see Horowitz and Planting, 2009) Using information on the composition of gross operating profits reported in the income statements of the same panel of US firms, the gross-operating surplus recorded in the IO-tables is decomposed into capital expenditures, dividend payments and bank interest rate expenditures. Only then, the parameters of the production function (3.1) - the labor, intermediate input shares and returns to scale parameter - can consistently be calibrated using the model's first order conditions. Details on the data adjustments and calibration procedure are provided in Online Appendix G.1.

Prices and Labor Costs. Data on total hours worked and sectoral prices are provided by the Bureau of Labor Statistics (BLS). Total hours worked are then used to infer an aggregate wage rate from total labor expenditures recorded in the IO-tables. In order to ensure consistency with the choice of the numeraire in the model, all prices are normalized by the common wage rate. Sector-specific prices are treated as input prices net of any interest cost on trade credit. They are subsequently used to construct the aggregate price index based on the model and real quantities from the IO-tables. Since capital owned by firms is included into the model as a constant and set to its steady state level, the real interest rate on capital implied by a time preference rate of $\beta = 0.96$ is an annualized risk-free rate of 4 percent. The household's preference parameters, ϵ_L and ϵ_C are set such that $\epsilon_C : \epsilon_L = 0.4$, which implies that ϵ_L and ϵ_C vary around the values 0.5 and 0.2, a standard calibration used in macroeconomics also applied in BL(2019).

While the calibration of the production parameters, prices and quantities is rather straight forward, the remainder of this section discusses (a) the imputation of the shocks to the sector-specific risk premium on bank credit in Equation (3.7) and (b) the calibration of the parameters of the credit management cost function in Equation (3.6).

Credit and Financial Shock Identification. As shown in Section 3, it is assumed that each sector is charged a risk premium, r_k^Z, over the federal funds rate:

$$r_k^Z = \exp(z_k^b)(\,\theta_k^Z\,)^\mu r_0^B \text{ and } \theta_k^Z = \overline{\theta}_0^D + \theta_k^C, \tag{4.1}$$

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[16]Exceptions are Costello (2017) for the US, Jacobson and von Schedvin (2015) for Sweden, Dewachter et al. (2018) for Belgium, Giannetti et al. (2018) for Italy or Cortes et al. (2018) for Brazil, who use proprietary firm-to-firm transaction data in their empirical analysis.

As a baseline measure for the risk premium, I employ the sectoral credit spreads derived in Gilchrist and Zakrajšek (2012) adjusted to match the bank interest rate expenditures imputed from the IO-tables. The risk-free interest rate, r_0^B, is set equal to the average federal funds rate over the period 1997-2016. The average leverage in the economy, $\overline{\theta}_0^D$, as well as the sectoral average trade credit share, θ_k^C, can be directly calculated from the data. The parameter μ is set equal to the weighted average of the corresponding estimated coefficient of sector-by-sector OLS-regressions of Equation (4.1) as described in Online Appendix G.1. As a result μ equals 1.2 such that a one percent increase in θ_k^Z increases the bank risk premium by 1.2 percent.[17] The implied shocks to the risk premium, z_k^b, are imputed directly from Equation (4.1). The interest rate on trade credit is calcuated using Equation (3.7). As a result, the calibrated equilibrium interest rates on trade credit exceed the interest rate on bank credit for the majority of sectors, thereby mapping the empirical observation on the relative cost of supplier and bank finance discussed in Cuñat and García-Appendini (2012).

Credit Management Costs. The expenditures on non-productive labor or credit management costs, $w\ell_k^T$, are calibrated to be a fraction of total sectoral labor expenditures recorded in the IO-tables, using the share of combined expenditures on management (NAICS = 55) and administrative services (NAICS = 561) in total intermediate input costs. The parameters of the credit management cost function (3.6), $\{\kappa_k^B, \kappa_{0,ks}^T, \kappa_{1,ks}^T\}$, are then calibrated in three steps as described in more detail in Online Appendix G.1: First, Equation (3.22) is used to calculate a sector's share of total accounts payable in total intermediate cost of production excluding interest rate payments, θ_k^P, while imposing the assumption of common cost parameters such that

$$\theta_k^P = \left[\overline{\theta}_0^S - (\overline{\theta}_0^S)^2 \frac{\overline{\kappa}_0^T}{\overline{\kappa}_1^T}\right] + \left[\frac{(\overline{\theta}_0^S)^2}{\overline{\kappa}_1^T}\right] pq_k^E = \beta_0 + \beta_1 pq_k^E \tag{4.2}$$

The variable pq_k^E denotes the effective net-interest expenditures on intermediate production inputs. As a result, Equation (4.2) implies that the share of total intermediate cost of production obtained on trade credit is increasing in the effective net-interest cost of production, since the cost-parameter (κ_1^T) is assumed to be positive following the discussion in Section 2. In a second step, Equation (4.2) is estimated by OLS using a panel of 45 sectors from 2000-2014, while controlling for time and sector fixed effects. In the third and last step, the link-specific parameters are then calibrated by matching the estimated coefficient $\hat{\beta}_1$ in Equation (4.2) to the coefficient of the interest rate expenditures determining sector k's trade credit share obtained from supplier s in Equation (3.22). The remaining cost parameters, $\kappa_{0,ks}^T$ and κ_k^B, are calculated as a residual to ensure that Equation (3.22) and (3.6) hold.

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[17] The exponent, μ, is required to be greater than one to be consistent with the profit-maximization problem of the representative firm in sector k.

At this point, it should be highlighted that three parameters are central in determining the magnitude of fluctuations in the economy with both bank and trade credit. The degree of convexity of the risk premium in the joint default probability measure, μ, as well as the average leverage in the economy, $\overline{\theta}_0^D$, determine (1) the relative size of the equilibrium interest rate on trade credit and (2) its volatility in response to bank credit shocks. In other words, an increase in the convexity of the mark-up function and in the relative importance of the accounts receivable share in revenues for the cost of bank finance, increase the level and volatility of the trade-credit interest rate and subsequently reinforce the trade-credit channel. Similarly, a decrease in the adjustment cost parameter $\kappa_{1,ks}^T$, increases the ability of firms to adjust the composition of their borrowing portfolio, thereby increasing the smoothing feature of trade credit.

Table 4.1: Calibrated Parameters

VAR		Description	All	NB	NL	p-Value
HH	ϵ_C	Income Elasticity	0.215			
	ϵ_L	Inv. Frisch Elasticity	0.546			
Production	α	Capital Share	0.344	0.275	0.417	0.002
	η	Value Added	0.465	0.512	0.416	0.062
	χ	DRS	0.833	0.834	0.832	0.917
	Ω^X	Intermediate	0.025	0.025	0.026	0.757
	Ω^F	Final	0.022	0.035	0.009	0.023
	z^q	Productivity	2.972	3.365	2.561	0.056
	k	Capital	13.66	15.81	11.42	0.355
Financial	μ	Bank Credit - Convex	1.2			
	$\overline{\theta}_0^D$	Bank Credit - Leverage	0.3			
	κ^B	CMan.Cost - Fixed	0.448	0.620	0.269	0.305
	κ_0^T	CMan.Cost - Linear	0.061	0.070	0.051	0.096
	κ_1^T	CMan.Cost - Quadratic	0.047	0.048	0.046	0.515
	$\overline{\theta}$	Av.TC-Demand	0.102	0.096	0.108	0.078
		#OBS	45	23	22	

Note: This table describes the aggregate and the mean of the cross-sectional parameters used in the model simulations. The production and financial parameters, capital and productivity levels reported in this table represent the four-year-average (2004-2007) prior to the crisis. In case of sector-specific parameters the column (ALL) reports the mean of the parameter for the entire sample. The columns (NB) and (NL) report the mean for a subgroup of sectors based on the net-lending position - see Definition 2.1. The p-values for the differences in means between the two groups are reported in the last column.

Table 4.1 lists the (average) values of the calibrated production and financial parameters used in the simulations of the model. The values reported in this table are calculated as the four-year-average (2004-2007) prior to the crisis. In addition, the sample is split into net-lenders and net-borrowers according to the median net-lending position based on Definition 2.1 obtained from the data presented in Section 2. The p-values for the

differences in means between the two groups are reported in the last column when applicable. The p-values for the differences in means between net-borrowing and net-lending sectors suggest that the two groups of sectors differ in their capital, value-added and final demand shares at a 1-10% significance level. Net-borrowers tend to have a lower capital (α) and composite intermediate input ($1 - \eta$) share while their final demand share is significantly higher. This is in line with the empirical observation that sectors which are further downstream and thus closer to the final consumer are sectors producing with a more labor intensive technology (e.g. service industry). In the case of the credit management technology, net-borrowers are calibrated to have a higher linear cost parameter while the quadratic cost parameter is of similar magnitude in both groups.

4.2. Quantitative Application

The first part of this section examines the model's performance and quantitatively evaluates the effect of interdependent distortions on business cycle fluctuations and economic outcomes. The second part focuses on the assessment of the role of trade-credit linkages for the propagation of financial shocks during the 2008-2009 Financial Crisis through the lens of the model. The model-implied time series are obtained by feeding in the financial shock series imputed from the GZ-spreads and solving numerically for the equilibrium of the static economy. Any additional variation originating from changes in (1) production and financial parameters, (2) capital and (3) productivity and foreign trade shocks is excluded by keeping the respective variables at their four-year-average (2004-2007) prior to the crisis as reported in Table 4.1. The data-counterparts of the variables of interest are obtained via a direct period-by-period mapping of the equilibrium of the static economy presented in Section 3 to the data as described in Section 4.1.

### 4.2.1. Business Cycle Properties Through the Lens of the Model

A first assessment of the ability of the model to generate business cycle patterns of both real and financial variables as shown in Section 2, is provided by reproducing Figure 2.1 using the model-implied series only.[18] As evident from Figure 4.1, the model *qualitatively* captures the business cycle features of trade credit and the changes in the short-term borrowing portfolio observed in the data when accounting for the timing restrictions discussed in Section 2. First and foremost, the model replicates a key feature of the recent financial crisis: (M5) As credit spreads rose during the crisis, the market for trade credit contracted immediately and firms substituted supplier with bank credit. In addition, the

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[18]As shown and discussed in Online Appendix G.3 the model also captures both qualitatively and quantitatively the business cycle features of trade credit presented in Figure 2.1b and 2.1c with respect to firms' liabilities and the share of trade credit in total costs of production and sales.

model-simulated series also imply that in response to financial shocks to the bank risk premium only: (M1-2) The growth rate of the volume of trade finance is pro-cyclical with and more volatile than the growth rate of current real GDP. *Quantitatively*, the simulations based on the imputed financial shock series demonstrate that the model is able to account for 25.5% of the variation in output and 25.6% of the variation in supplier credit. Taking a closer look at the credit composition, the model also reproduces 37.6% of the fluctuations in the credit composition of short-term borrowing. Consequently, the model is a reasonable tool for the analysis of trade credit linkages and the effect on business cycle comovements and aggregate fluctuations.

Figure 4.1: Model-Implied Business Cycle Properties of Trade Credit

(a) Model Prediction 1-2   (b) Model Prediction 5
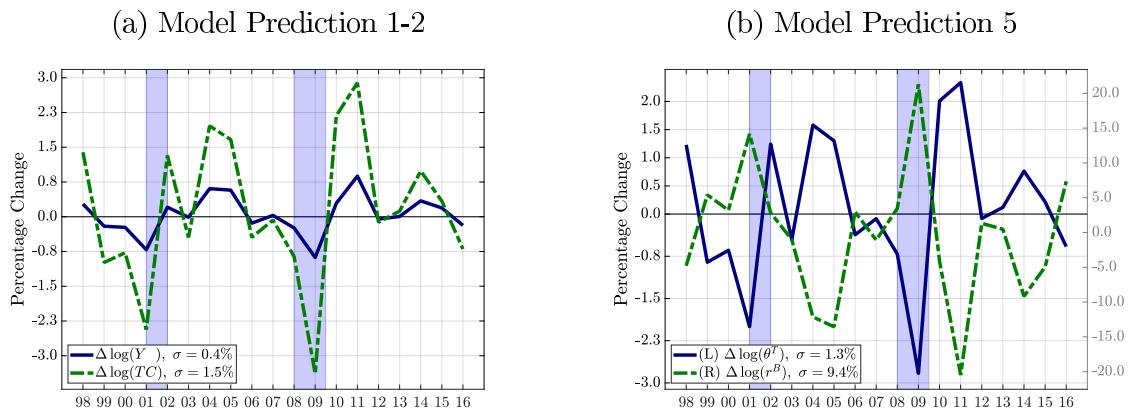
Note: The panels in this figure replicate Figure 2.1a and Figure 2.1d and plot the evolution of the log-change in percent of the simulated time series of aggregate US GDP (Y), aggregate Accounts Payable (TC), the share of AP in Current Liabilities (θ^T) and the aggregate GZ-spread (RB). All variables are reported in real terms using the aggregate price-index. The model-simulations are based on financial shocks only. The figures also report the standard deviation of the respective series in percent.

4.2.2. The Role of the Credit Network during the Great Recession

Financial Frictions and The Business Cycle. Recall from Section 3 that the cost of financing production affect aggregate output through two channels: changes in the aggregate TFP and the labor wedge. To evaluate the effects of trade credit linkages on aggregate distortions and business cycle fluctuations in the US economy during the 2008-2009 Financial Crisis, Figure 4.2 depicts the evolution of the aggregate TFP wedge and output obtained from model simulations. Panel (a) plots the predicted percentage changes in the aggregate TFP wedge in response to a shock to the cost of bank credit as well as the log-changes in observed aggregate output and labor measured against the right axis. Panel (b) presents the model-predicted percentage changes of aggregate output on the left axis against those observed in the data. Figure 4.2 shows that changes in the aggregate TFP wedge co-move strongly with aggregate output. Furthermore, the model predicts that changes in the financial frictions alone account for approximately 34.2% of

the actual drop in output during the 2008-2009 Great Recession reported in Section 2.[19]

Figure 4.2: Model-Fit - Aggregate Outcomes

(a) Aggregate TFP-Wedge $\Phi(Z)$ (b) Output
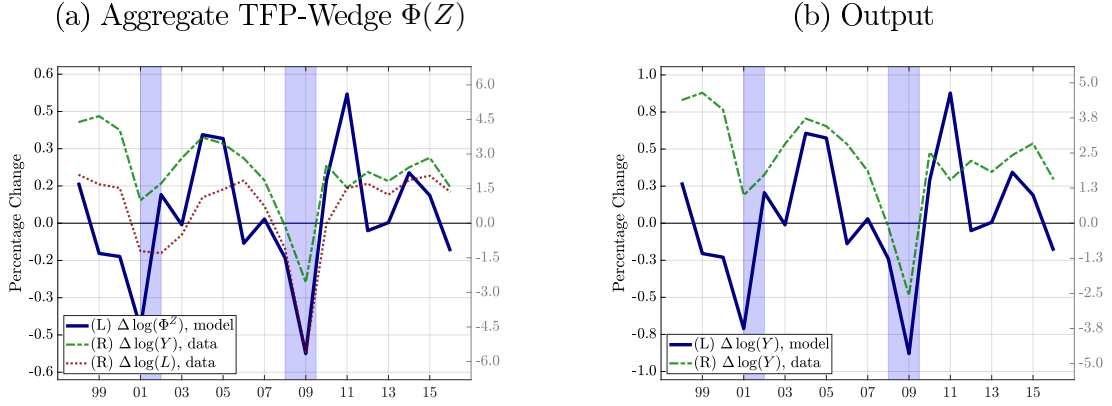
Note: Panel (a) in this figure plots the model-implied log-changes in the aggregate TFP wedge in response to shocks to the cost of bank credit only. The log-changes of observed aggregate output and labor are measured against the right axis. Panel (b) plots the log-changes of aggregate output as implied by the model simulations in response to shocks to the cost of bank credit on the left axis against those observed in the data. All log-changes are reported in percent.

While financial frictions are able to account for a non-negligible fraction of movements in aggregate output, the remainder of this section quantifies the role played by interlinked distortions in the form of trade-credit linkages among firms during the financial crisis. In particular, the theoretical predictions of the model summarized in Section 3.3 are quantitatively evaluated by conducting the following three simulation exercises.

(a) TC-Multiplier. The first simulation evaluates the contribution of the existence of trade-credit linkages to the drop in output during the recent recession. To this end, the comparison of the predictions produced by a model with trade credit to the otherwise equivalent model without any credit linkages provides a clear way to disentangle the effects of the credit network from those of the inter-sectoral trade network alone. Following BL(2019), an equivalent economy, $\mathcal{E}(0)$, and the Trade-Credit Multiplier are defined as:

Definition 4.1 (Equivalent Economies). *Let $\mathcal{E}(0)$ be an equivalent economy to an economy with both production and credit linkages, $\mathcal{E}(\theta)$, with production linkages only. Then $\mathcal{E}(0)$ features the same observed input prices net of any credit costs and the same observed nominal sales, input expenditures and value added as in $\mathcal{E}(\theta)$.*

Definition 4.2 (Trade-Credit Multiplier). *Let $\mathcal{E}(\theta)$ be an economy in which firms finance production using both trade and bank credit and let $\mathcal{E}(0)$ be the corresponding equivalent economy. Consider the same sector-specific shocks across both economies. The "trade-credit multiplier" is the ratio between the percentage change in a variable generated by an economy with trade and bank finance and an equivalent economy with bank finance only.*

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[19]The evolution of the simulated aggregate labor wedge and labor is presented in Online Appendix G.3 and suggests that changes in frictions account for approx. 9.7% of the drop in labor during the crisis.

Both economies, an economy with bank and supplier credit, $\mathcal{E}(\theta)$, and an equivalent economy with bank credit only, $\mathcal{E}(0)$, are simulated using the same financial shocks to the sector-specific risk premia. The first two rows of Table 4.3 report the percentage change in aggregate output, labor and both the efficiency and labor wedge in 2009 for the economy introduced in Section 3 and its equivalent counterpart. In addition, column (5) to (7) report the average percentage change in sectoral output, labor and credit wedges. The resulting trade-credit multiplier ranges from 1.63 for aggregate labor to 2.19 for the aggregate efficiency wedge, and from 2.11 to 4.19 for the average sectoral labor and output response, implying that the credit network itself generates a considerable amplification of distortions. Since the model featuring both production and credit linkages captures approximately one third for the drop in aggregate real GDP, approximately 16 percent of the drop in aggregate output can be attributed to the existence of trade credit per se.

The intuition of this result is as follows: In an economy with bank finance only, a shock to the cost of external funds increases the cost production and subsequently prices. Output decreases. As discussed in detail in Section 3.2, in an economy featuring both bank and supplier credit, an increase in sectoral bank risk premia also translates into an increase in the cost of trade credit. Consequently, total credit cost increase by more relative to an economy with bank credit only. As observed in the data and captured by the model, firms adjust their credit portfolio by moving towards bank finance during the crisis since the interest rate on trade credit exhibits a stronger increase than the interest rate on bank credit. However, these adjustments are not enough to undo the exacerbating effecting of credit linkages on the drop in output *relative* to an economy without credit relations among firms. This observation therefore translates into a trade-credit multiplier greater than one as recorded in Table 4.3. Interestingly, credit linkages reduce the effect of financial shocks on the aggregate labor wedge. This suggests that the credit network increases both the volatility and comovement of the marginal product of labor and the real wage rate, subsequently reducing the volatility of the aggregate labor wedge.

(b) TC-Mechanism. The second exercise addresses the question whether in an economy with both bank and trade credit the smoothing or the amplification mechanism of the trade-credit channel discussed in Section 3 dominates. The effect of the trade credit channel on the volatility and response of output during the crisis is quantified by decomposing the general equilibrium response of the variables into their partial equilibrium counterpart derived by keeping the interest rate on trade credit as well as the trade-credit shares at their steady state level (PE_R). The difference between the general and partial equilibrium response is attributed to the trade-credit channel. The effect of an endogenous adjustment of the credit portfolio on output is isolated by comparing the respective statistic in general equilibrium to its counterpart in partial equilibrium where only the credit portfolio remained at its equilibrium value (PE_T).

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Table 4.2 reports the results of both partial equilibrium exercises for aggregate and average sectoral output: Overall, the total effect of the trade-credit channel on both the volatility of output across sectors and sectoral output growth during the crisis is negative, but rather small. The endogenous adjustment of the interest rates charged on trade credit and of the credit composition increased sectoral output volatility by 2.30% in 1997-2016 and increased the drop in sectoral output by 1.74% on average. This is due to the fact that the amplification channel of the adjustment of the cost of trade credit dominated and was only partially off-set by the adjustment of credit shares.

In case of aggregate output, the model predicts that the trade credit channel introduced in Section 3.2 reduces aggregate volatility by 1.41% and decreased the drop in GDP by 1.75%. The endogenous adjustment of credit linkages led to a reduction in the volatility of output and the decline in output during the crisis and contributed between 83% (1.18:1.41) and 77% (1.35:1.75) to the smoothing effect of the trade-credit channel. The remaining 17-23% of the total effect can be attributed to changes in the interest rate on trade credit. This result is complementary to the trade-credit channel defined in 3.3, which highlights the propagation pattern of changes in credit costs and shares from the perspective of an individual firm. At the aggregate level, an increase in the interest rate on trade credit reduces the demand for trade credit and subsequently decreases the share of revenues extended on trade credit. The latter effect counteracts the increase in risk premia on bank credit due to the financial shock. Therefore, at the aggregate level, the overall ability of firms to adjust both its price of trade credit and its credit portfolio dampens the effect of shocks to the cost of bank credit.

Table 4.2: Decomposition of Trade Credit Mechanism

(a) Output Volatility

	$\sigma, \%$	GE	PE	TC
Y	PE_R	0.4271	0.4332	-1.41
	PE_T	0.4271	0.4321	-1.18
q	PE_R	0.3547	0.3486	$+2.30$
	PE_T	0.3547	0.3595	-1.32

(b) Output Growth, 2009

|	$\Delta_{09}, \%$	GE	PE	TC
Y	PE_R	-0.8798	-0.8952	-1.75
	PE_T	-0.8798	-0.8917	-1.35
q	PE_R	-0.7183	-0.7058	$+1.74$
	PE_T	-0.7183	-0.7291	-1.50

Note: This table presents the decomposition of (a) the volatility, σ, and (b) the drop in output during the 2008-2009 Financial Crisis, Δ_{09}, into general and partial equilibrium effects for aggregate output (Y) and of the mean response of sectoral output (q). The row (PE_R) reports the general equilibrium effect in column (GE) and the partial equilibrium effect from holding both interest rates on trade credit and trade credit shares constant (PE). Similarly, the row (PE_T) also reports the general equilibrium effect in column (GE) and the partial equilibrium effect from holding trade credit shares constant (PE). The column entries of (TC) are calculated as (1-PE/GE) and therefore summarize the effect of the non-adjusting variable(s) on the general equilibrium. All numbers are reported in percent.

(c) Heterogeneity in Net-Lending Position. Section 2 highlighted that there is heterogeneity in the net-lending position of sectors defined as the ratio of accounts receivable to bank credit. (see Definition 2.1) In the context of the model proposed in

Section 3, Proposition 4 derived that sectors extending relatively more trade credit will generate more spillovers and thus play a more central role in the propagation of liquidity shocks in an economy featuring both production and credit linkages.

In order to quantitatively evaluate the relevance of asymmetries in the trade credit usage of sectors for the propagation of liquidity shocks, the top five net-borrowers and net-lenders are first identified based on their net-lending position implied by the mapping of the model to the data: The top net-lenders are { 211, 514, 331, 486, 11 } and the top net-borrowers { 445, 452, 62, GOV, 441 }. As discussed in Section 2, the set of net-lenders is characterised as more upstream in the supply chain of the US economy than the top net-borrowers. A symmetric shock series calculated as the average of shocks to sectoral risk premia is then fed into the model affecting only one group of sectors at a time. The results of this exercise are reported in the last two rows of Table 4.3 and suggest that sectors classifying as net-lenders almost tripled the effect of credit linkages on output.

Figure 4.3: Quantitative Illustration of Proposition 4

(a) GDP   (b) Sectoral Output
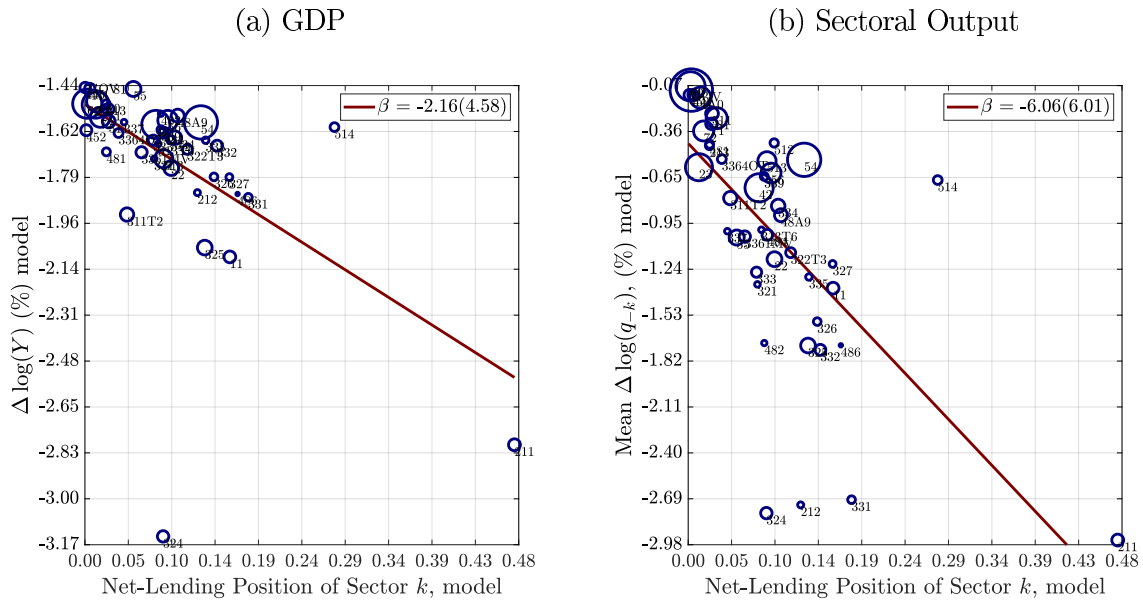
Note: This figure plots the response of (a) real GDP and of (b) average sectoral output of directly unaffected sectors ($-k$) to a 10% increase in the shock to the bank risk premium of sector k for $k \in \{1, ..., M\}$ against the net-lending position of the affected sector k for $k \in \{1, ..., M\}$. All response are normalized by the response of aggregate labor. The size of one observation represents the relative importance of the affected sector in the economy measured by the share of a sector's average pre-crisis (2004-2007) value added in total value added.

In addition, a 10% increase in the shock to the bank risk premium of sector k for $k \in \{1, ..., M\}$ is considered. The normalized response[20] of (a) real GDP and (b) the average sectoral output response of unaffected sectors are then plotted against the net-lending position of the affected sector k in Figure 4.3. The decline in output of unaffected sectors will be stronger in case of financial shocks affecting sectors who are relatively more

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[20] The general and partial equilibrium responses of output are normalized by (the absolute value of) the log-change of aggregate labor to control for differences in equilibrium demand effects as either group of sectors exhibits a different degree of the proximity to the end consumer.

engaged in inter-firm financial intermediation. Since their interest rate on trade credit is more sensitive to financial shocks (see Proposition 3), the amplification effect of the trade-credit channel and therefore the reduction in output will be more pronounced. A difference in means test confirms that the negative output effect generated by shocks to net-lenders is stronger and significantly differs from that generated by shocks to net-borrowers.

Table 4.3: Trade Credit Multipliers of Counterfactual Simulations

			Aggregate				Sectors		
			(1)	(2)	(3)	(4)	(5)	(6)	(7)
CF	EN		$\Delta\%(Y)_{09}$	$\Delta\%(L)_{09}$	$\Delta\%(\Phi^Z)_{09}$	$\Delta\%(\Phi^L)_{09}$	$\Delta\%(q)_{09}$	$\Delta\%(\ell)_{09}$	$\Delta\%(\phi^V)_{09}$
(a) TC0	$\mathcal{E}(\theta)$		-0.880	-0.548	-0.525	-0.037	-0.718	-0.786	0.556
	$\mathcal{E}(0)$		-0.457	-0.336	-0.239	-0.105	-0.172	-0.373	0.174
	$\mathcal{M}$		1.926	1.632	2.196	0.355	4.185	2.105	3.200
(c) NL	$\mathcal{E}(\theta)$		-0.045	-0.022	-0.031	0.008	-0.096	-0.093	0.068
	$\mathcal{E}(0)$		-0.010	-0.007	-0.005	-0.003	-0.013	-0.046	0.012
	$\mathcal{M}$		4.695	3.030	6.318	-2.871	7.352	2.040	5.825
(c) NB	$\mathcal{E}(\theta)$		-0.236	-0.162	-0.131	-0.034	-0.046	-0.077	0.049
	$\mathcal{E}(0)$		-0.170	-0.127	-0.088	-0.042	-0.015	-0.030	0.030
	$\mathcal{M}$		1.386	1.276	1.491	0.818	3.069	2.605	1.659

Note: This table documents the model simulated log-change of the following variables to aggregate and idiosyncratic shocks to sector-specific bank risk premia in an economy with bank and supplier credit, $\mathcal{E}(\theta)$ and in an equivalent economy with bank credit only, $\mathcal{E}(0)$: aggregate output (Y), labor (L), the aggregate efficiency (Φ^Z) and labor wedge (Φ^L), the average sectoral output (q), labor (ℓ) and credit cost wedge (ϕ^V). The trade credit multipliers ($\mathcal{M}$) are calculated as the ratio of responses of the variable in $\mathcal{E}(\theta)$ to their counterparts in $\mathcal{E}(0)$, respectively. The three counterfactual exercises considered feature an economy with bank finance only (TC0); (NL/NB) an economy in which only net-lenders (net-borrowers) experience an increase in their bank interest rates using Definition 2.1. All log-changes are reported in percent.

Robustness Exercises. In order to address the concern that the results might be driven by asymmetries in (1) trade-credit linkages across sectors and (2) shocks to sectoral bank risk premia, the results of two additional counterfactual exercises are reported in Online Appendix G.3. The comparison of the responses of the benchmark economy with those of an economy featuring symmetric credit linkages and symmetric shocks suggest that both sources of asymmetries play a minor role in the propagation of liquidity shocks. Furthermore, the trade credit multipliers are also calculated for an equivalent economy without any credit management costs in order to address the concern that a constant demand for non-productive labor dampens the output effect in the bank-finance only economy and thus overestimates the effect of trade-credit linkages on output. The trade-credit multiplier of all variables are of similar magnitudes.

5. Conclusion

Trade credit plays a central role in day-to-day business operations and generates interdependencies between firms, beyond the pure exchange of goods and services. This paper studies the role of endogenous trade-credit linkages for the propagation of liquidity shocks and contributes to the literature in three ways: First, the paper documents that trade credit comoves strongly with GDP and was severely affected at the onset of the 2008-2009 Financial Crisis inducing a compositional shift of short-term borrowing towards bank credit. It is shown that firms differ in their usage of trade credit and tend to extend less trade credit to customers than their cost of production net of trade credit obtained from suppliers.

Second, a static quantitative multisector model is introduced in which profit-maximizing firms choose the composition of their borrowing portfolio to finance production and extend a share of their sales on trade credit to customers. As a result, the model features endogenous and interdependent distortions while capturing the characteristics of trade credit as a smoothing and as an amplification mechanism. It is shown that the net-lending position of a firm, defined as the ratio of a firm's accounts receivable and bank credit obtained to finance any working capital requirements, determines its systemic importance in the transmission of liquidity shocks.

Third, in a quantitative application of the model to the US economy during the crisis, simulations featuring only financial shocks show that the model captures approximately a third of the drop in output, half of which can be attributed to the existence of trade-credit linkages alone. In response to an aggregate shock, the trade-credit channel - the endogenous adjustment of trade-credit cost and shares - decreased aggregate volatility by less than two percent, suggesting that the smoothing mechanism was operative though rather small. Finally, the amplification mechanism of trade credit is more pronounced following an idiosyncratic financial shock to a sector extending relatively more supplier credit than its upfront working capital requirements.

While the implications of production linkages have been extensively investigated, this paper contributes to the literature by analysing the role of financial linkages between firms for the macroeconomy and suggests interesting paths for future research: In particular, even though this paper features endogenous credit linkages, firms are only able to adjust their credit links along the intensive margin. However, the ability of firms to access other credit markets and obtain trade credit also affects the formation of customer-supplier relationship between firms (see e.g. Giannetti et al., 2018; Giovannetti, 2016) which may provide further insights for the new growing literature investigating the endogenous link formation between economic agents (see Oberfield, 2018).

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Appendix for "Finance-Thy-Neighbor.
Trade Credit Origins of Aggregate Fluctuations."

Margit Reischer

A: Proof Appendix for Section 3.2

The following notation is applied in the main text: Matrices are denoted as bold capital letters (e.g. $\boldsymbol{X}$) and vectors as bold small letters (e.g. $\boldsymbol{x}$). Since the economy consists of M sectors, matrices are of size $[M \times M]$ and vectors of size $[M \times 1]$, unless they are associated with the vectorized matrices, $\boldsymbol{\phi}^X = \mathrm{vec}(\boldsymbol{\Phi}^X)$ or $\boldsymbol{\theta} = \mathrm{vec}(\boldsymbol{\Theta})$, where $\mathring{\boldsymbol{\Omega}}^X = (\boldsymbol{I} \otimes \boldsymbol{\iota}') \circ (\boldsymbol{\iota}' \otimes \boldsymbol{\Omega}^X)$. The matrix operation $[\circ]$ denotes the Hadamard, and $[\otimes]$ denotes the Kronecker product. The operation $[\mathrm{diag}(.)]$ either extracts the diagonal entries of matrix $\boldsymbol{X}$ or generates diagonal matrix using vector $\boldsymbol{x}$. Additional definitions are provided in the Online Appendix.

A.1. Propagation

Let the demand structure be given by $G_L(\boldsymbol{\Omega})$. Consider a financial shock to the bank risk premium of the representative firm in sector k, $z_k^b = \epsilon_k^b > 0$, such that k's risk premium, r_k^Z, and interest rate on bank credit, r_k^B, defined in Equation (3.7) increase.

Proof of Corollary 3.2. The proof follows directly from the properties of the marginal cost of production derived in Corollary 3.1, the optimal input demand derived in Lemma 3.1 and the profit maximizing price derived in Lemma 3.2. □

Proof of Corollary 3.3. The proof follows from the properties of the optimal interest rate charged on trade credit as shown in Lemma 3.4, the marginal cost of production derived in Corollary 3.1 and the optimal input demand derived in Lemma 3.1. □

Proof of Corollary 3.4. The optimal share of intermediate inputs obtained on trade credit from supplier s by sector k is derived in Lemma 3.4. Given intermediate expenditures and its supplier's interest rate charged on trade credit, the optimal trade credit share is increasing in the interest rate on bank loans as evident from Equation (3.22).

The second part of the statement follows from Corollary 3.1 and

$$
\begin{aligned}
0 \; &< \; \frac{\partial p_k^V}{\partial r_k^B} \; = \; + \left\{ \frac{\upsilon_k}{\phi_k^L} + (1 - \upsilon_k) \frac{(1 - \theta_{ks})}{\phi_{ks}^X} \right\} p_k^V \\
0 \; &> \; \frac{\partial^2 p_k^V}{\partial r_k^B \partial \theta_{ks}} \; = \; - \left\{ 1 + \upsilon_k \left[1 - (1 - \theta_{ks}) \frac{\phi_k^L}{\phi_{ks}^X} \right] \frac{\Delta_{ks}}{\phi_k^L} \right\} (1 - \upsilon_k) \frac{p_k^V}{\phi_{ks}^X}
\end{aligned}
$$

This completes the proof of Corollary 3.4. □

A.2. Determinants of Output Responses

The Lemmata and Propositions in Section 3.2.2 follow from the log-linearization of the equilibrium of the model featuring both bank and trade credit and straightforward but tedious algebra. The following paragraph only provides an outline of the proofs while a details are discussed in Online Appendix F.

Outline of Proofs. The price and sales wedges presented in Lemma 3.5 are derived by log-linearizing equilibrium revenues and prices. Auxiliary lemmata are derived in Appendix F.1 expressing any changes in credit, sales and price wedges in terms of changes in credit costs and the credit composition, $\hat{\tau}$. Proposition 1 then follows from the log-linearization of output and applying the results of Lemma 3.5 and the auxiliary lemmata. Similarly, Proposition 2 follows from the log-linearization of the interest rate on bank and trade credit and trade-credit shares. Combining the results of Proposition 1 and 2 yields Proposition 3 and 4. □