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

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[Link to Latest Version]

ABSTRACT. This paper studies the smoothing and amplifying features of trade credit for the propagation of shocks in a multisector economy with working capital constraints. I derive aggregation results of sectoral shocks for inefficient economies when distortions are interdependent due to endogenous trade credit linkages and costs. A quantitative application to the US during the 2008-09 Great Recession suggests that trade credit smooths financial shocks, while generating large spillovers relative to an economy with bank finance only. Sectors extending more trade credit than their volume of bank loans are systemically important.

KEYWORDS. Production Networks, Financial Frictions, Trade Credit, Aggregate Fluctuations. JEL CODES. C67, E32, G10.

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) While trade credit represents an important alternative source of short-term financing to bank and financial market debt for all types of firms (Petersen and Rajan, 1997), the contraction of liquidity in the market for trade credit at the onset of the 2007-08 Financial Crisis (Costello, 2020), emphasized two countervailing features of trade credit: (1)

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Firms smooth financial 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. In light of the widespread use of trade credit in an economy, this paper investigate the following two questions to provide insights on how trade credit affects macroeconomic outcomes: 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 aggregate output during the 2008-09 Great Recession?

To answer these questions, I build a static quantitative multisector model with trade in intermediate inputs, where perfectly competitive intermediate good producing firms in each sector face working capital constraints that are financed using both bank- and supplier credit. Thus, a firm acts simultaneously as a supplier of goods and as a financial intermediary. I endogenize both the cost and the share of input expenditures financed using trade credit, while each firm faces a sector-specific bank interest rate. The latter is increasing in the share of sales extended on trade credit to customers and subject to shocks. Profit-maximizing firms optimally choose the share of input expenditures financed using trade credit to minimize their cost of production, the amount of output produced and the share of sales extended on trade credit to their customers, for given demand and prices. The endogenous adjustment of the volume and cost of trade credit captures its stabilizing and amplifying features as follows. Consider an exogenous increase in a firm's bank interest rate: (1) On the demand side, firms are able to mitigate the negative effect on output by adjusting their credit portfolio. (2) On the supply side, a firm optimally reduces the share of receivables[1] in sales by internalizing the effect of delayed payments on their cost of bank finance. The interest rate charged on receivables increases, which directly affects the cost of production of downstream customers. Simultaneously, a shift in a firm's credit portfolio towards trade credit also increases the cost of bank finance of upstream suppliers. Since a firm charges all customers the same interest rate on trade credit, any effects induced by changes in the composition of one of its customer's credit portfolio also propagate horizontally due to common suppliers. Overall, this creates an amplification mechanism by which idiosyncratic shocks to the cost of bank credit are propagated both up- and downstream.

As common to models with distortions (see Chari et al., 2007; Bigio and La'O, 2020), financial distortions in the form of working capital constraints also manifest themselves in equilibrium as sectoral and aggregate labor and efficiency wedges in first-order conditions and resource constraints. However, the wedges in this paper are a generalization of those characterized in Bigio and La'O (2020) as they are a function of interest rates on both types of credit and credit shares, which are determined endogenously in equilibrium by profit maximizing firms. The implications of the resulting interdependency of distortions for the propagation of shocks are the primary focus of this paper. In particular, I provide novel aggregation results of sectoral productivity and financial shocks and characterize how the first order elasticity of aggregate output depends on

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

the equilibrium interactions of input-output- and credit-relations when firms operate with Cobb-Douglas production technologies in inefficient economies. The aggregation results highlight that such interdependencies can both dampen or amplify the effects of financial shocks and that the network structure matters to a first order. It follows that a new credit measure - the net-lending position of a sector defined as the ratio of accounts receivable to the difference between the total cost of production and accounts payable - is informative to identify sectors which generate large spillovers through inter-firm credit linkages.

Whether trade credit linkages amplify or dampen the effect of financial shocks on aggregate output is ambiguous and ultimately remains a quantitative question. To this end, I first calibrate the production structure and the equilibrium inter-industry credit flows of the model-economy to the US at a sector level. In order to evaluate the implications of trade credit generating endogenous interdependencies in financial distortions for the US economy during the 2008-09 Great Recession, I focus exclusively on shocks to a sector's bank interest rate imputed from sectoral bond spreads derived in Gilchrist and Zakrajšek (2012). I then rely on both the aggregation results derived in the theoretical part of the paper as well as model simulations.

The main results are as follows. First, by feeding in a sequence of sectoral financial shocks and repeatedly solving for the economy's equilibrium, simulations show that the model reproduces business cycle patterns of output and trade credit similar to those observed in the data. In particular, the model captures about a quarter of the variation in aggregate output and 37.7% of the variation in supplier credit. The model also accounts for 39.3% of the decline in GDP and 65.7% of the decline in aggregate accounts payable documented during the Great Recession.

In a second exercise, I compare the output response in general equilibrium to that resulting from the same shock while holding the cost of trade credit and the credit composition at their pre-crisis levels. The comparison suggests that the endogenous adjustment of the volume and cost of trade credit reduced aggregate volatility by 14.8% and dampened the drop in output during the 2008-09 crisis by 17.5%. Third, to isolate the macroeconomic effect of the existence of trade credit linkages, I define the trade credit multiplier as the ratio between the percentage drop in aggregate output in response to the same financial shock generated by an economy with both trade and bank finance and an equivalent economy with bank finance only. The latter corresponds to the economy in Bigio and La'O (2020). The counterfactual exercise suggests that the existence of the trade credit network per se almost doubled the drop in aggregate output and thus accounts for approximately 20% of its decline during the Great Recession.

Lastly, I show that the trade credit multiplier implied by a financial shock to the top five sectors with the highest net-lending position is higher than the multiplier generated by the same financial shock to the five sectors with the lowest net-lending position. This supports the theoretical insights that firms who act as important financial intermediaries for their customers are systemically important.

Related Literature. Trade credit contracts have been studied more commonly in the corporate- and trade-finance literature investigating i.a. the characteristics and motives of firms to engage in financial intermediation, and their implications for trade flows. (see Cuñat and García-Appendini, 2012; Giannetti, 2023; Foley and Manova, 2015, for surveys) This paper analyses the role trade credit linkages between firms in a production chain for the propagation and aggregation of microeconomic shocks and thus relates to the literature on misallocation, production and financial networks.

Foremost, this paper contributes to the literature investigating the effects of micro-level distortions on aggregate outcomes and the propagation of idiosyncratic shocks in economies with trade in intermediate goods. While earlier contributions in this literature relied on simpler production structures (i.a. Chari et al., 2007; Jones, 2011), more recent work by Jones (2013); Liu (2019); Baqaee and Farhi (2019a,b) and Bigio and La'O (2020) develop further insights by allowing for more general input-output relations and production technologies. (see Baqaee and Rubbo, 2023, for a review).

The main contribution of this paper relative to the existing literature is a novel aggregation result of sectoral productivity and financial shocks for inefficient disaggregated economies with Cobb-Douglas production technologies, when distortions are interdependent due to trade credit relations between firms. While such interdependencies are not present in closely related work by Baqaee and Farhi (2019b) and Bigio and La'O (2020), this paper provides new insights on how they can both dampen and amplify the macroeconomic effects of financial shocks.

Since the seminal contribution of Long and Plosser (1983), a growing literature investigates the importance of input-output relations for aggregate dynamics. (see Carvalho and Tahbaz-Salehi, 2019, for a review) Following the 2007-09 financial crisis and recession, the interconnectedness of banking institutions for the propagation of financial shocks and their effects on the real economy via bank-firm linkages have been the main focus of analysis in a vast number of papers. (see i.a. Acemoglu et al., 2015; Chodorow-Reich, 2014). However, the exchange of payments that occur in relation to inter-firm trade as a transmission mechanism is a relatively new research agenda. The role of trade credit for the propagation of liquidity shocks in a credit chain due to trade credit defaults was first analyzed in the seminal contribution by Kiyotaki and Moore (1997). Subsequent work by Raddatz (2010); Jacobson and von Schedvin (2015); Costello (2020) and Alfaro et al. (2021) provide further empirical insights on the relevance of trade credit for the propagation of liquidity shocks and real outcomes. Despite their quantitative importance, trade credit linkages have received less attention in the literature on the macroeconomic effects of financial shocks in general equilibrium. Exceptions related to this paper are Altinoglu (2021), Bocola and Bornstein (2023), and Luo (2020), who study the effects of trade credit on aggregate fluctuations and output. The main differences between the model-set up in this paper and those listed previously is how trade credit is incorporated into the model along the following dimensions:

First, this paper allows for a generic input-output and credit network in which firms simultaneously borrow and lend from other firms. This complements the two-sector economy set-up in Bocola and Bornstein (2023), where downstream firms obtain trade credit from upstream firms but not vice versa. Second, while trade credit linkages are a fixed proportion of sales in Altinoglu (2021), I endogenize both the share of input expenditures financed using trade credit and unlike related work also the cost of trade credit. This complements the model set-up in Luo (2020) who abstracts from modeling the decision of firms to extend trade credit, while suppliers make a take-it-or-leave-it offer to customers in the non-competitive[2] framework introduced in Bocola and Bornstein (2023).

Contrary to existing work, the tractablity of the model presented in this paper implies that I am able to obtain a closed-form characterization of the response of aggregate output to financial shocks as a function of the relationship between bank and supplier finance leading to novel insights. In particular, this paper contributes to this strand of literature by deriving conditions under which trade credit can act as either a stabilizer or an amplifier of financial shocks in a general production network which are shown to be related to a firm's net-lending position.

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 novel aggregation results for financial shocks in an economy where firms act as financial intermediaries. 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

In the following, I provide motivational facts on the relevance and cyclical properties of trade credit in the form of accounts payable[3] and its relation to other external financing sources in the US economy. For this purpose, I obtain the aggregate credit spread index derived in Gilchrist and Zakrajšek (2012) as an indicator of tensions in the financial system[4] and annual balance sheet data from Compustat of a panel of publicly-traded, non-financial firms from 1997 to 2016. Their total accounts payable (receivable) account for approximately 11.4 (9.4)% of total and 34.8% of current liabilities (assets) consistent with related statistics documented in Rajan and Zingales (1995) and Giannetti (2003), and make up approximately 4.6 (6.0)% of US GDP, suggesting that trade credit represents a non-negligible source of financing for large firms.

While the same sample of firms is used to calibrate the model in Section 4, I now consider only a subset with non-missing observations over the entire period to construct aggregate trade credit series that are unaffected by changes in the sample composition. Panel (a) of Figure 1 plots the evolution of log-changes in the aggregate credit risk indicator, GZ, in total accounts payable, AP, and GDP, Y, in terms of 2007 dollars. Panel (b) further depicts the log-changes

[2] Miranda-Pinto and Zhang (2023) also endogeneize trade credit contracts in a non-competitive framework via nash-bargaining to study sectoral comovements during recessions.

[3] Total accounts receivable unsurprisingly display very similar properties as the same outstanding payment will be recorded on both the customer's balance sheet as accounts payable and on the supplier's as accounts receivable.

[4] The GZ-spread is defined as the average difference in the yields on corporate bonds and yields on Treasury securities of comparable maturities. (see Gilchrist and Zakrajšek, 2012, for details)

of the share of accounts payable in total costs of production, θ^P, as well as in current liabilities, θ^τ. Each panel also reports the unconditional pairwise correlations between the respective series over the entire period[5]. The first two main observations from Figure 1 are as follows.

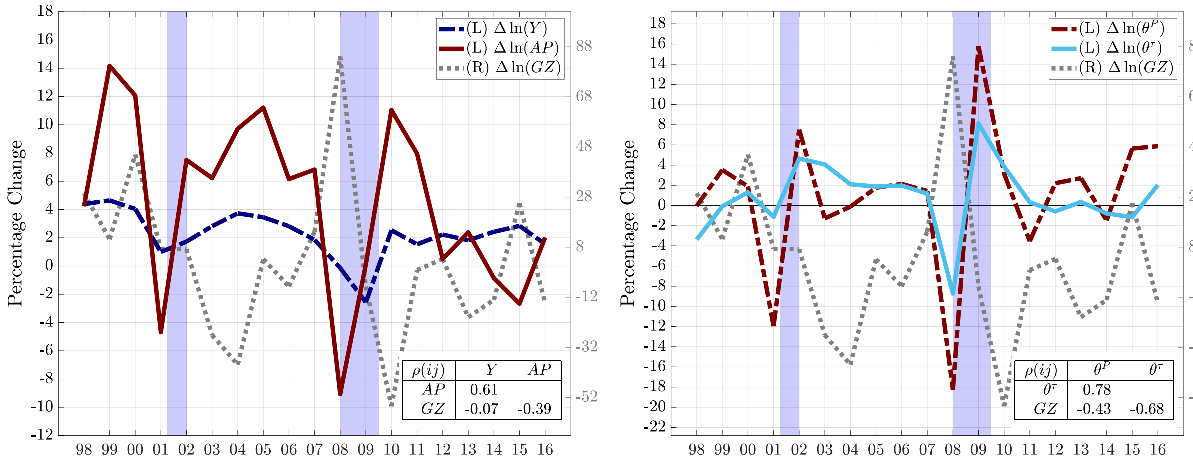
(F1) The growth rate of the volume of trade finance in real terms is pro-cyclical with and more volatile than the growth rate of real GDP.

(F2) The share of accounts payable in total costs of production is negatively correlated with the aggregate credit risk in the economy.

The first observation relates to and complements findings in the existing literature (Covas and Den Haan, 2011; Schwartzman, 2013; Bocola and Bornstein, 2023). Second, while trade credit is by design tightly linked to a firm's expenditures and sales, the dynamics of the aggregate share of production costs financed using trade credit suggest that changes in the level of real accounts payable are not exclusively driven by changes in demand.

Figure 1: Business Cycle Properties of Trade Credit in the US

(a) (b)



Note: The figures plot the evolution of the log-change in percent of the aggregate credit spread index (GZ) against the right axis, and aggregate US GDP (Y), Accounts Payable (AP), the share of AP in Total Costs of Goods Sold (θ^P) and in Current Liabilities (θ^τ) against the left axis. All variables are reported in real terms using the GDP-deflator. The aggregate financial variables are constructed using data of only a subset of the sample of non-financial Compustat firms with their head-quarter in the US. In addition to selection criteria outlined in Online Appendix A, only firms with non-missing observations over the entire period are included. The restricted sample equals a panel of 16,320 Compustat firm-year observations from 1997 to 2016 for 816 unique firms, whose nominal sales represent approx. 19% of US gross output.

(F3) As credit spreads rose during the 2007-08 financial crisis, the composition of short-term borrowing shifted towards bank credit in 2008.

Figure 1b shows that the aggregate share of accounts payable in current liabilities declined during the 2008 period of financial turmoil, implying that liquidity in the trade credit market contracted. This observation is consistent with established empirical evidence, suggesting that the compositional shift was due to the joint occurrence of the reduction in the provision of supplier credit (Costello, 2020) and a rise in C&I loans due to drawdowns of unused credit lines (Ivashina and

[5]Table 1 in Section 4 reports the standard deviation and 08/9 log-changes of the variables in Figure 1.

Scharfstein, 2010). The 2008 increase in C&I loans was followed by a sharp drop in 2009[6], as the tightening of lending standards in 2008 translated into a considerable decline in the availability of new credit lines. Simultaneously, accounts payable increased, reversing the compositional shift as evident from Figure 1. A reasonable explanation for the differences in the speed of adjustment between credit markets 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 (see Ivashina and Scharfstein, 2010), trade credit is not subject to formal contracts (see Cuñat, 2007). Thus, the substitutability of supplier and financial market debt highlights that trade credit serves as a liquidity insurance across firms (Wilner, 2000; Cuñat, 2007) such that firms manage liquidity shortfalls by increasing trade credit obtained from suppliers and rationing credit extended to customers as shown by Amberg et al. (2021).

To further characterize the trade credit usage of a firm from both its perspective as a lender and a borrower, I now introduce the following concept:

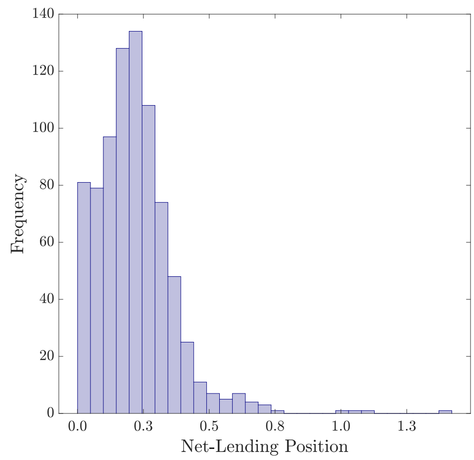
Definition 1. *The net-lending position of a firm i is defined as the ratio of total trade credit extended to customers (accounts receivable) to the difference between the total cost of production and trade credit obtained from suppliers (accounts payable).*

The net-lending position thus captures how many future dollars firm i receives per dollar it needs to finance today. The distribution of the average net-lending position in 2004-07 of the previous sample of Compustat firms is depicted in Figure 2.

(F4) 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 is consistent with the findings in Kalemli-Özcan et al. (2014), that upstream firms have higher accounts receivable in comparison to final product firms. The role of the net-lending position of firms (sectors) for the propagation of financial shocks will be investigated in more detail in Sections 3 and 4.

Figure 2: TC-Usage of US Firms



Note: The figure plots the distribution of the 2004-07 average net-lending position defined in 1 of the sample of firms described in Online Appendix A.

[6]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

3. A Multisector Model with Financial Frictions

Motivated by the contraction of trade credit at the onset of the 2008-09 Great Recession as documented in Section 2, I build a static quantitative multisector model in the tradition of Long and Plosser (1983) with trade in intermediate inputs and endogenous credit linkages between sectors to investigate the role of supplier credit in the propagation of financial shocks.[7] Representative firms in each sector face working capital constraints and finance their input expenditures using both bank and trade credit, while being subject to sectoral productivity and financial shocks to the cost of bank credit. The main difference to related work with regard to endogenizing credit relations between sectors, is the explicit introduction of a price of trade credit and modeling of the choice of firms to extend trade credit along the intensive margin in a competitive setting. The model set-up is characterized in the following and nests the economy introduced in Bigio and La'O (2020), if no credit linkages are considered.

Production Structure. The economy consists of N intermediate sectors indexed by $i \in \mathcal{V} = \{1, ..., N\}$ producing N differentiated goods, a final good sector indexed by $N+1$ 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. Thus, the words firm and sector are used interchangeably in the following. An *intermediate good* firm i produces output, q_i, using labor, ℓ_i, and a composite of intermediate inputs, X_i. The output of firm i is used both as an intermediate input and in the production of the composite *final good*, F, consumed by the household. The production technologies of the intermediate and final good firms are

$$q_i = (A_i \mathcal{Q}_i(\ \ell_i, X_i\ ))^{\chi_i}\,, \text{ with } X_i \equiv \mathcal{X}_i(\ \boldsymbol{x}_{i:}\ )\ \forall i, \quad \text{and} \quad F = \mathcal{F}(\ \boldsymbol{c}\ ) \qquad (1, 2)$$

where $\boldsymbol{x}_{i:} = [x_{i1}\ x_{i2}\ \cdots\ x_{iN}]'$ and $\boldsymbol{c} = [c_1\ c_2\ \cdots\ c_N]'$ denote the vector of intermediate input purchases by firm i and the final good producer, respectively. The technologies $\mathcal{Q}_i : \mathbb{R}_+^2 \to \mathbb{R}_+$, $\mathcal{X}_i : \mathbb{R}_+^N \to \mathbb{R}_+$ for all $i \in \mathcal{V}$ and $\mathcal{F} : \mathbb{R}_+^N \to \mathbb{R}_+$ are assumed to exhibit constant returns to scale (CRS), be twice continuously differentiable, feature positive and diminishing returns in all arguments, and satisfy $\mathcal{Q}_i(0,0) = \mathcal{X}_i(\mathbf{0}) = \mathcal{F}(\mathbf{0}) = 0$. By abstracting from other factors of production such as physical, organizational capital or land, I impose that $\chi_i \in (0, 1]$. As a result, q_i has decreasing returns to scale (DRS) in its production inputs when $\chi_i < 1$. Productivity in each sector is given by $A_i = \exp(\varepsilon_i)\zeta_i$ and subject to sector-specific, normally distributed shocks, ε_i, while ζ_i represents a normalization constant for analytical convenience. In addition, intermediate good firms face the following constraint:

[7] By abstracting from any dynamics, this paper focuses on cross-sectional propagation patterns following a recent strand of literature: i.a. Baqaee and Farhi (2019a,b), Bigio and La'O (2020). Furthermore, the timing restriction is imposed that credit markets contracted at the same time as aggregate output. Although output declined with a lag (Figure 1a), this simplification takes into account that (1) the sharp increase in credit spreads occurred in the second half of 2008 and (2) the production plans of firms and thus input demand might be pre-determined.

Assumption 1. *The production and delivery of products along the supply chain is such that any sales are only realized after production has taken place, while firms are required to finance their working capital upfront.*

The within-period timing of events is thus as follows: At the beginning of a period, both productivity, ε_i, and financial shocks to the cost of bank credit, z_i, are realized such that there is no idiosyncratic or aggregate uncertainty in the model. The working capital constraint further implies that each period features two stages: In the pre-production stage, firms make their production and borrowing portfolio decisions. In the post-production stage, firms sell their output and retrieve the share of sales paid on delivery. At the end of the period, firms repay their debt obligations to banks and their suppliers and receive the remaining share of revenues extended on trade credit to customers. Hence, intermediate good producers face a cash flow mismatch between required input payments and the realization of revenues.

Financing Production. Wlog, I assume that firms have no internal funds available such that firm i needs to finance production costs using (1) an intraperiod bank loan, BC_i, at an interest rate, r_i^b, and (2) trade credit from its supplier s, AP_{is}, at an interest rate r_s^τ. To manage its credit lines, a firm further incurs administrative costs and requires a non-productive labor input, ℓ_i^τ. Any productive and non-productive labor expenditures, $\ell_i + \ell_i^\tau = L_i$, have to be paid upfront and are financed using bank credit only. Firm i's binding financial constraint is then given by

$$W\left(\ell_i + \ell_i^\tau\right) + \sum_s p_s x_{is} \leq BC_i + AP_i, \text{ where } AP_i = \sum_s AP_{is} = \sum_s \theta_{is} p_s x_{is} \qquad (3,4)$$

equals firm i's total accounts payable and $\theta_{is} \in [0,1]$ denotes the share of payments to supplier s that firm i chooses to postpone paying until after i's sales are realized. At the same time, firm i also extends trade credit to its customers at an interest rate r_i^τ. Its total accounts receivable are given by $AR_i = \theta_i^c p_i q_i$, where the share of sales received after the delivery of good and services, θ_i^c, is also chosen by firm i. The trade credit shares, $\theta_{is} \forall is$, thus represent the credit network among intermediate good producing firms which is endogenous along the intensive margin.

Intermediate Production and Trade Credit. Taken together, the objective of the representative firm in sector i is to choose production inputs, $\ell_i, \boldsymbol{x}_{i:}$, the optimal level of production, Q_i, the credit portfolio, $\boldsymbol{\theta}_{i:} = [\theta_{i1}, \theta_{i2} \cdots \theta_{iN}]'$, as well as the share of sales to extend on trade credit, θ_i^c, to maximize profits from product sales and financial intermediation while taking demand, input prices and its suppliers' interest rate charged on trade credit as given. For the set of choice variables, $\mathcal{V}_i = \{\ell_i, \boldsymbol{x}_{i:}, Q_i, \boldsymbol{\theta}_{i:}, \theta_i^c\}$, firm i's profit maximization problem formally is

$$\mathrm{V}(\varepsilon_i, z_i) = \max_{\mathcal{V}_i} \pi_i \quad \text{subject to} \quad \pi_i = (1 + r_i^\tau \theta_i^c) p_i q_i - (1 + r_i^b) BC_i - \sum_s (1 + r_s^\tau) AP_{is}, \quad (5)$$

the production function (1), total bank (3) and supplier credit (4), the credit management cost function (6), the interest rate on bank credit (7), feasibility constraints on trade credit shares $\theta_i^c, \theta_{is} \forall s \in [0,1]$ and non-negativity constraints. The financial intermediation technologies

(6,7) are introduced via two simplifying assumptions. In particular, I assume that firms also face costs to manage their credit lines and extend trade credit to customers as I discuss in more detail below.[8] This allow me to keep the firm's optimization problem analytically tractable while capturing two features in data highlighted in Section 2: (1) The short-term credit portfolio of firms is composed of both bank and supplier credit; and (2) Firms extend less than a hundred percent of their sales on trade credit such that their receivable share in sales is less than one.

Assumption 2. *The adjustment of a firm's credit portfolio is subject to a combination of convex and non-convex frictions such that the firm requires a non-productive labor input, ℓ_i^τ, to manage credit lines. The cost function of the credit management technology is, $\mathcal{M}_i(\boldsymbol{\theta}_{i:}) : [0,1]^N \to \mathbb{R}_+$, where $\boldsymbol{\theta}_{i:} = [\theta_{i1}, \theta_{i2} \cdots \theta_{iN}]'$ denotes the vector of firm i's shares of intermediate input expenditures financed using trade credit. Let such a function be given by*

$$\mathcal{M}_i(\boldsymbol{\theta}_{i:}) \;=\; \mathcal{M}_{0,i} + \sum_s \kappa_{0,is}\theta_{is} + \frac{\kappa_{1,is}}{2}\left(\frac{\theta_{is} - \overline{\theta}_i^s}{\overline{\theta}_i^s}\right)^2 \;\equiv\; W\ell_i^\tau, \tag{6}$$

which is twice continuously differentiable and convex in all arguments, with $\mathcal{M}_i' \lesseqgtr 0$, $\mathcal{M}_i'' > 0$, and fixed costs, $\mathcal{M}_{0,i}$. The variable cost parameters $\{\kappa_{0,is}, \kappa_{1,is}\}_s$ are specific to a firm-supplier pair and $\overline{\theta}_i^s$ denotes a firm's targeted average share of input payments obtained on trade credit.

Assumption 2 establishes that a firm faces additional costs of managing credit lines diverting resources from productive use. Since the intermediate production technology exhibits DRS, total payments to the fixed factor are thus split between a productive and non-productive component, where the former is normalized to one in real terms. The credit management cost function (6) adapts the functional form of the adjustment costs of capital commonly used in the literature (i.a. Cooper and Haltiwanger, 2006)[9]: As in Luo (2020), the quadratic adjustment cost part, $\kappa_{1,is}$, captures that it is costly for a firm to change its credit composition. In addition, I introduced a non-convex component which accounts for additional costs associated with the restructuring of a firm's supplier relationships when adjusting trade credit terms. If $\kappa_{0,is} = \kappa_{1,is} = 0 \;\forall i, s$, firms were able to adjust their credit portfolios frictionless and would choose only the cheapest credit source, $\theta_{is} \in \{0, 1\}$. Thus, the introduction of non-linear adjustment costs of credit lines ensures that a firm maintains a credit portfolio mix of both bank and supplier credit in equilibrium, consistent with the empirical evidence in Section 2.

Assumption 3. *The cost of bank credit depends on sector specific financial shocks, z_i, the share of receivables in product sales, $\theta_i^c = \frac{AR_i}{p_i q_i}$, and is given by function, $\mathcal{R}_i(z_i, \theta_i^c) : (\mathbb{R}\times[0,1]) \to \mathbb{R}_+$,*

[8] While I have abstracted from providing a micro-foundation for the existence of trade credit in this economy (see Cuñat and García-Appendini, 2012, for an overview), I view either assumption as being more closely related to a pure transaction motive reducing the cost of a firm's cash-management (see Ferris, 1981).

[9] In a recent contribution, Kopytov et al. (2022) endogeneize sectoral production linkages by allowing firms to choose the vector of factor input shares in production summarizing the firm's technology. The choice of factor input shares affects a firm's productivity via a log-concave function, whose explicit functional form is similar in spirit to the credit management cost function used in this paper to solve for the optimal credit composition.

which is assumed to be twice continuously differentiable and convex in all arguments, $\mathcal{R}_i',\ \mathcal{R}_i'' > 0$*. Let such a function be*

$$r_i^b \equiv \mathcal{R}_i(z_i, \theta_i^c) = \mathbb{r} + \underbrace{\exp(z_i)(\ d + \theta_i^c\ )^{\mu}\mathbb{r}}_{=r_i^z}, \quad with \quad \mathcal{R}_i(0,0) = (1 + d^{\mu})\mathbb{r} > 0 \tag{7}$$

where $\mathbb{r}$ *denotes the risk-free rate,* $d \in [0, 1]$ *is a constant and* $\mu > 1$*.*

While the banking sector is introduced in a reduced form for analytical tractability, the bank interest rate faced by firms in each sector as characterized in Equation (7) imposes that a firm's cost of funds increase as it extends more credit to customers. As such, Assumption 3 effectively limits the ability of firms to displace financial intermediaries in the model and can be micro-founded as follows. To this end, consider a perfectly competitive banking sector with access to unlimited funds, where risk-neutral banks specialize in lending to a particular sector and face additional costs to monitor and collect loans. In particular, I assume that a bank's monitoring costs are a convex function in a firm's receivable share, θ_i^c. Since asset-based loan contracts or trade-finance agreements often involve accounts receivable as documented in Lian and Ma (2020), Ivashina et al. (2022) and Caglio et al. (2021), they are part of the banks' costly risk-assessment at debt issuance and subject to continued monitoring. This captures that banks take into account that when a firm sell its products on credit, its customers' failure to pay for already delivered goods and services jeopardizes the firm's ability to repay any debt obligations as shown in Jacobson and von Schedvin (2015). The extent to which banks are exposed to a firm's customers' credit risk is measured by the receivable share in sales.[10] Lastly, the constant, d, relates to the banking sector's overall monitoring costs independent of a firm's cash-flows. Equation (7) then follows from solving the bank's profit maximization problem discussed in Online Appendix B.1. A profit-maximizing firm in this model economy then optimally chooses the share of sales to extend on trade credit, θ_i^c, by trading off the increase in the cost of bank loans with the increase in revenues from financial intermediation. It follows that, in response to a financial shock a firm will decrease its receivable share to counteract the increase in borrowing costs which ultimately captures the decline in trade credit during the financial crisis presented in Section 2 as I discuss in greater detail in Sections 3.1 and 3.2.

Final Demand. Both, the final good producer and its customers are required to pay for inputs and the consumption good at the time of delivery. Furthermore, the final good firm does not face any working capital constraints and maximizes $\max_{\boldsymbol{c}}\ PF - \sum_i p_i c_i$, subject to the production

[10] I focus on the share of accounts receivable rather than payable based on the following reasoning: (1) When extending trade credit, the firm and its creditors are exposed to the default risk of the firm's customers (see also Mateos-Planas and Seccia, 2021). In contrast, the postponement of payments to suppliers does not prevent the firm from continuing production and generating sales; and (2) Under the US bankruptcy code as amended in 2005, in the event of a firm's bankruptcy, secured creditors have priority up to the value of their collateral (i.e. secured bank loans) while the supplier's ability to recover its claims for unpaid amounts owed on goods sold to the firm is limited to a specific subset of transactions. See the June 28, 2006, Holland & Knight Newsletter, by Xerras, L.B. available at: https://www.hklaw.com/en/insights/publications/2006/06/bapcpa-spells-relief-for-certain-trade-creditors-i (Accessed: July 31st, 2024) for a legal discussion.

function (2) and non-negativity constraints. The household chooses consumption expenditures, C, and labor supply, L, to maximize utility, $U(C, L)$, subject to the budget constraint

$$PC \leq WL + (1-\tau)\sum_i (\pi_i + r_i^b BC_i), \tag{8}$$

where the utility function $U(C, L)$ is assumed to be separable in consumption and labor with $U_C, (-U_L) > 0$ and $U_{CC}, U_{LL} < 0$. In equilibrium, the household's income - the total wage bill and non-labor income - is spent on the aggregate consumption good. Since $\tau \in (0, 1]$, non-labor income consists of partially rebated interest income from extending bank credit to firms, and payments to the fixed factor used in production. To obtain a measure for aggregate GDP, I follow Liu (2019) and Bigio and La'O (2020), and impose that some payments and thus income from distortions are discarded. In particular, I adopt the approach in Liu (2019) and assume that bankers and the producers of the non-labor input incur costs such that they earn zero net utility and their final consumption, H, is effectively treated as a deadweight loss.As a result, aggregate output in this economy then equals aggregate consumption by households, $Y = C < F = C + H$, which is less than the quantity of the final good produced.

The **market clearing** conditions for the labor and intermediate goods market are as follows

$$L = \sum_i \ell_i + \ell_i^\tau, \;\; q_i = c_i + \sum_c x_{ci}, \;\; \text{and} \;\; AR_i = \theta_i^c p_i q_i = \sum_c AP_{ci} \;\; \forall i \in \mathcal{V}. \tag{9, 10}$$

implies that the equilibrium trade credit rate is such that a firm's total accounts receivable equal accounts payable owed by its customers.

Remarks. The model introduced in this paper features distortions in the form of working capital constraints and DRS to account for a fixed factor in production given the static nature of the set-up. Working capital is financed using bank and trade credit. Either type of credit is costly and requires interest payments. Thus, trade credit can also be viewed as a costly subsidy of a firm's customers' bank loans obtained to finance input purchases. The introduction of endogenous financial linkages between firms by means of trade credit relations implies that distortions in this economy are endogenous and interdependent. The implications thereof for the propagation of shocks and aggregate outcomes are the focus of the subsequent analysis.

3.1. Equilibrium Characterization

A realization of the aggregate state, $s = (\boldsymbol{\varepsilon}, \boldsymbol{z}) \in \mathcal{S}$, in the previously introduced economy is given by a vector of exogenous and stochastic sectoral productivities, $\boldsymbol{\varepsilon} = [\varepsilon_1, ..., \varepsilon_N]'$, and financial shocks, $\boldsymbol{z} = [z_1, ..., z_N]'$. Furthermore, let an allocation, $\xi(s)$, and price system, $\varrho(s)$, in this economy denote a set of functions that map the realization of shocks to the respective aggregate and sectoral quantities and prices. A competitive equilibrium is then defined as follows, where I omit the state dependency in the remaining exposition to simplify notation.

Definition 1. *For any realization of the aggregate state* $s = (\boldsymbol{\varepsilon}, \boldsymbol{z}) \in \mathcal{S}$*, a competitive equilibrium in this economy is a set of aggregate and sector level prices* $\varrho(s) \equiv \{W, P, \{p_i, r_i^b, r_i^\tau\}_{i=1}^N\}$ *and quantities* $\xi(s) \equiv \{C, F, L, \{q_i, \ell_i, \ell_i^\tau, c_i, \theta_i^c, \{x_{is}, \theta_{is}\}_{s=1}^N\}_{i=1}^N\}$ *such that (i) intermediate and final good producers maximize profits; (ii) the representative household maximizes utility; and (iii) goods, factor and financial markets clear.*

The set of equilibrium conditions are characterized in Proposition 1.

Proposition 1. *Let sectoral revenue,* ϕ_i^R*, and credit wedges,* ϕ_i^L, ϕ_{is}^X*, be*

$$\phi_i^R = 1 + r_i^\tau \theta_i^c, \quad \phi_i^L = 1 + r_i^b \quad \text{and} \quad \phi_{is}^X = 1 + (1-\theta_{is}) r_i^b + \theta_{is} r_s^\tau. \qquad (11, 12, 13)$$

For given production (1, 2) and financial intermediation technologies (6, 7), an allocation $\xi(s)$*, and price system,* $\varrho(s)$*, constitute an equilibrium iff the following conditions are satisfied* $\forall s \in \mathcal{S}$
(a) *the intermediate good producer* i*'s optimal demand for labor,* ℓ_i*, and sector* s*'s output,* x_{is}*,*

$$\text{satisfy} \quad \frac{\phi_i^R}{\phi_i^L}\left(\chi_i \frac{q_i}{Q_i}\frac{\partial \mathcal{Q}_i}{\partial \ell_i}\right) = \frac{W}{p_i} \quad \text{and} \quad \frac{\phi_i^R}{\phi_{is}^X}\left(\chi_i \frac{q_i}{Q_i}\frac{\partial \mathcal{Q}_i}{\partial x_{is}}\right) = \frac{p_s}{p_i} \quad \forall i, s \in \mathcal{V}. \qquad (14, 15)$$

(b) *the intermediate good producer* i*'s optimal credit composition to finance intermediate inputs,* θ_{is}*, and share of sales extended on trade credit,* θ_i^c*, follow from*

$$\frac{\partial \mathcal{M}_i}{\partial \theta_{is}} = \frac{r_i^b - r_s^\tau}{1 + r_i^b} p_s x_{is} \quad \text{and} \quad r_i^\tau = \frac{\partial r_i^b}{\partial \theta_i^c}\frac{BC_i}{p_i q_i} \quad \forall i, s \in \mathcal{V}, \qquad (16, 17)$$

where $BC_i = W(\ell_i + \ell_i^\tau) + \sum_s (1-\theta_{is}) p_s x_{is}$.
(c) *the household's optimal consumption-labor choice and the final good producer's optimal demand for sector* i*'s output imply*

$$-\frac{U_L}{U_C} = \frac{W}{p_i}\frac{\partial \mathcal{F}}{\partial c_i} \quad \text{and} \quad \left(\frac{\partial \mathcal{F}}{\partial c_i}\right)\left(\frac{\partial \mathcal{F}}{\partial c_j}\right)^{-1} = \frac{p_i}{p_j} \quad \forall i, j \in \mathcal{V}. \qquad (18, 19)$$

(d) *the household's budget constraint (8) is satisfied, and markets (9),(10) clear.*

Consider first Equations (14) and (15), where the right-hand side denotes the relative marginal cost of labor and intermediate inputs, while the left-hand side represents their marginal benefit. The latter equals the marginal product of the respective input times the ratio of firm i's revenue and credit wedge. The wedge ratio distorts i's demand for inputs and subsequently also the household's and final good producer's optimal choices in Equations (18) and (19). While it is commonly known that distortions manifest themselves as wedges in the equilibrium conditions (see Chari et al., 2007), Proposition 1 highlights that the presence of trade credit affects the composition of wedges and introduces revenue effects that partially alleviate such distortions as I elaborate on in the following.

As usual, credit costs associated with the working capital constraint increase the marginal cost of production which decreases the demand for productive inputs and increases the optimal goods price characterized in Corollary 1. Since firm i in this economy finances its intermediate input expenditures using both bank and supplier credit, the resulting credit wedge, ϕ^X_{is}, is a weighted average of both credit costs with the weights equal to the credit shares. The credit wedge increases in interest rates, r^b_i and r^τ_s, and decreases in the share, θ_{is}, if the interest rate differential, $(r^b_i - r^\tau_s)$, is positive and increases otherwise.

At the same time, the effective price paid by a customer is a bundle of the actual goods price and the cost of delaying payments to its supplier. The extension of trade credit thus increases the marginal revenue generated by an additional unit sold as captured by the revenue wedge, ϕ^R_i, in Equation (5). Ceteris paribus, firm i's demand for inputs given by Equations (14) and (15) increases while its optimal goods price in Corollary 1 decreases.

Corollary 1. *The optimal goods price,* $p_i = \frac{1}{\phi^R_i}\frac{MC_i}{MP_i}$ *, equals a mark-up over marginal costs including interest costs of financing production, where* $MP_i \equiv \frac{\partial q_i}{\partial \mathcal{Q}_i}$*. The marginal cost function,* $MC_i \equiv \mathcal{MC}_i(\,.\,) : (\mathbb{R}^{2(N+1)}_+ \times [0,1]^N) \to \mathbb{R}_+$*, is*

$$\mathcal{MC}_i(W, \boldsymbol{p}, \boldsymbol{r}_i, \boldsymbol{\theta}_{i:}) = \mathcal{Q}_i \left(\frac{\partial \ln(\mathcal{Q}_i)}{\partial \ln(\ell_i)} \frac{1}{\phi^L_i W}, \left\{ \frac{\partial \ln(\mathcal{Q}_i)}{\partial \ln(x_{is})} \frac{1}{\phi^X_{is} p_s} \right\}_s \right)^{-1} \tag{20}$$

and concave in interest rates, $\boldsymbol{r}_i = [r^b_i, r^\tau_1, ..., r^\tau_N]'$*, and credit shares,* $\boldsymbol{\theta}_{i:} = [\theta_{i1}, ..., \theta_{iN}]'$.

Next, consider Equation (16) which shows that the optimal share of i's expenditures on supplier s's output financed using trade credit, θ_{is}, equates the change in the cost of managing credit lines with the change in the cost of production. The latter is governed by the difference in the cost of bank and trade credit: If the interest rate on trade credit offered by supplier s is cheaper, then an increase in the credit share reduces the marginal cost of production but increases expenditures on non-productive labor and vice versa if the interest differential is negative. The parameterization of the credit management cost function ensures that θ_{is} has an interior solution and maximizes profits.

The equilibrium condition with respect to the profit-maximizing share of sales extended on trade credit (17) effectively pins down the optimal interest rate charged on receivables. Taking the individual customer's demand for trade credit as given, firm i faces the following trade off when considering an increase in its receivable share, θ^c_i, all else equal: On the one hand, firm i's interest income from lending to its customers and thus revenues increase. On the other hand, the firm internalizes that its interest rate on bank credit and thus marginal costs of production also increase due to Assumption 3. In equilibrium, the marginal revenue and cost of extending trade credit to customers are equalized. The implied profit maximizing interest rate on trade credit, r^τ_i, is then given by the ratio of additional interest payments on bank loans following changes in the receivable share to revenues net of interest income from financial intermediation.

Lastly, since firm i charges all customers the same interest rate on trade credit, changes in one customer's credit composition that affect i's interest rate on receivables impact the cost of financing of all. This captures that changes in extended trade credit to one customer will affect a firm's ability to lend to others (Jacobson and von Schedvin, 2015; Costello, 2020).

3.1.1. Aggregation in the Cobb-Douglas Economy

To obtain further analytical insights, I now parametrically specify the economy's production and focus on the Cobb-Douglas case in remainder of paper,

$$q_i = \Big(\exp(\varepsilon_i)\zeta_i \ell_i^{\eta_i} X_i^{1-\eta_i}\Big)^{\chi_i} \quad \text{with} \quad X_i = \prod_s x_{is}^{\omega_{is}} \quad \text{and} \quad F = \zeta_{N+1}\prod_i c_i^{\beta_i}, \tag{21}$$

where ζ_i for $i = 1, ..., N, N+1$ are normalization constants. The parameter $\omega_{is} \in [0,1]$ denotes the share of gross (including interest costs) expenditures on good s in the total intermediate input use of sector i, and $\sum_s \omega_{is} = 1 \; \forall i \in \mathcal{V}$. Similarly, $\beta_i \in [0,1]$ equals the final good firm's expenditure share on good i, where $\sum_i \beta_i = 1$. In addition, let the parametric form of the financial technologies be as defined in Assumptions 2 and 3. The optimal trade credit shares and costs in the Cobb-Douglas economy[11] are then as in Corollary 2 and follow from Proposition 1.

Corollary 2. *In the Cobb-Douglas economy, sector i's optimal share of expenditures obtained on trade credit from supplier s and interest rate on receivables are*

$$\theta_{is} = \underbrace{\left(1 - \frac{\kappa_{0,is}}{\kappa_{1,is}}\overline{\theta}_i^s\right)\overline{\theta}_i^s}_{\theta_{is}^{\kappa}} + \frac{(\overline{\theta}_i^s)^2}{\kappa_{1,is}}\frac{(r_i^b - r_s^\tau)p_s x_{is}}{1+r_i^b} \quad \textit{and} \quad r_i^\tau = \frac{\mu r_i^z}{d+\theta_i^c}\frac{BC_i}{p_i q_i}. \tag{22, 23}$$

For ease of exposition, I now introduce additional concepts, where all vectors and matrices are of size $(N \times 1)$ and $(N \times N)$, respectively, unless otherwise specified.

Definition 2. (a) *The vector $\boldsymbol{\theta}_{i:}$ contains the i'th row and $\boldsymbol{\theta}_{:i}$ the i'th column entries of the matrix of equilibrium trade credit shares, $\boldsymbol{\Theta}$.* (b) *Let $\boldsymbol{\beta}$ $(\tilde{\boldsymbol{\beta}} = \boldsymbol{\phi}_R \circ \boldsymbol{\beta})$ denote the vector of (distortion-adjusted) final demand shares. The entries of the input-output (IO) matrix of expenditures shares are $[\boldsymbol{\Gamma}]_{is} = \gamma_{is} = \omega_{is}(1-\eta_i)\chi_i$, while the distortion-adjusted IO-matrix is*

$$\tilde{\boldsymbol{\Gamma}} = \big(\text{inv}(\boldsymbol{\Phi}_X) \circ \boldsymbol{\Gamma}\big)\text{diag}(\boldsymbol{\phi}_R), \quad \textit{with typical entry} \quad \tilde{\gamma}_{is} = \frac{\phi_s^R}{\phi_{is}^X}\gamma_{is} = \frac{p_s x_{is}}{p_i q_i}, \tag{24}$$

where $\boldsymbol{\phi}_R$ equals the vector of revenue and $\boldsymbol{\Phi}_X$ the matrix of credit wedges.
(c) *The revenue-based*[12]*, $\mathbf{L}$, and distortion- and income-adjusted, $\tilde{\mathbb{L}}$, Leontief inverses are*

$$\mathbf{L} = \big[\boldsymbol{I} - \boldsymbol{\Gamma}\big]^{-1} \textit{and } \tilde{\mathbb{L}} = \big[\boldsymbol{I} - \tilde{\boldsymbol{\Gamma}} - (\boldsymbol{\iota} - \tilde{\boldsymbol{\chi}})\,\tilde{\boldsymbol{\beta}}'\big]^{-1}, \textit{ where } \tilde{\chi}_i = \frac{WL_i + \sum_s (1 + r_s^\tau \theta_{is})p_s x_{is}}{R_i} \tag{25}$$

[11] A full characterization of the equilibrium in the Cobb-Douglas case is provided in Online Appendix B.3.
[12] Revenue- and cost-based IO-matrices are defined in Baqaee and Farhi (2019b) and Baqaee and Rubbo (2023).

equals an entry of the vector of cost (net of bank interest payments) shares in revenues, $\tilde{\boldsymbol{\chi}}$.
(d) *The vector of sales shares in nominal output, or Domar weights, is given by*

$$\boldsymbol{\lambda} \;=\; \frac{\boldsymbol{R}}{PY} \quad \text{and} \quad \boldsymbol{\lambda}_{\tau} \;=\; \mathbf{L}'\boldsymbol{\beta} \;=\; \frac{\boldsymbol{R}+\mathbf{L}'\boldsymbol{T}}{PF} \tag{26}$$

defines the vector distortion-adjusted gross Domar weights which are calculated as the ratio of sectoral sales and a sector's direct and indirect customers' interest payments on bank loans, $T_i = \sum_c r_c^b(1-\theta_{ci})p_i x_{ci}$*, to final revenues.*

Next, I provide a characterization of equilibrium aggregate output by mapping the multisector framework introduced in this paper to a representative firm and household economy similar to Bigio and La'O (2020). Unsurprisingly, the economy's distortions also manifest themselves in equilibrium as an aggregate efficiency and labor wedge defined in Chari et al. (2007), which in the present model-set up are as follows.

Proposition 2. *For given interest rates,* $\boldsymbol{r} \;=\; [\,[r_1^b,...,r_N^b],[r_1^\tau,...,r_N^\tau]\,]'$*, and credit linkages,* $\boldsymbol{\Theta} = [\,\boldsymbol{\theta}_{1:},...,\boldsymbol{\theta}_{N:}\,]'$*, an economy consisting of individual sectors operating with Cobb-Douglas production technologies (21) and engaging in intersectoral trade whose equilibrium conditions are given in Proposition 1 aggregates to a representative-household and -firm economy. Let* Λ *denote the aggregate labor income share and* $\boldsymbol{\lambda}(\boldsymbol{\lambda}_\tau)$*, the vector of (gross) Domar weights as characterized in Definition 2. The economy's aggregate production function is*

$$Y = Z\Phi_z L^{(1-a)}, \quad \text{where} \quad \ln(\Phi_z) = -(1-a)\ln(\Lambda) - \boldsymbol{a}'\ln(\boldsymbol{\lambda}) - \boldsymbol{\lambda}_\tau'\ln(\boldsymbol{\phi}), \tag{27}$$

and features DRS with non-labor share $a \;=\; \boldsymbol{a}'\boldsymbol{\iota} = \boldsymbol{\lambda}_\tau'\mathrm{diag}(\boldsymbol{\iota}-\boldsymbol{\chi})\boldsymbol{\iota}$*, and an aggregate TFP wedge,* Φ_z*, introducing a multiplicative shift in TFP,* $\ln(Z) = \boldsymbol{\lambda}_\tau'\mathrm{diag}(\boldsymbol{\chi})\boldsymbol{\varepsilon}$*. The aggregate credit wedge,* $\boldsymbol{\lambda}_\tau'\ln(\boldsymbol{\phi})$*, is a non-linear combination of all sectoral credit and revenue wedges*

$$\ln(\boldsymbol{\phi}) \;=\; \mathrm{diag}(\boldsymbol{\eta}\circ\boldsymbol{\chi})\ln(\boldsymbol{\phi}_L) + (\boldsymbol{\Gamma}\circ\ln(\boldsymbol{\Phi}_X))\boldsymbol{\iota} - \ln(\boldsymbol{\phi}_R). \tag{28}$$

The aggregate labor wedge, Φ_λ*, follows from*

$$\frac{W}{P} \;=\; \Phi_\lambda(1-a)\frac{Y}{L}, \quad \text{with} \quad \ln(\Phi_\lambda) \;=\; \ln(\Lambda) - \ln(1-a). \tag{29}$$

As evident from Proposition 2, the aggregate wedges in this economy are the result of decreasing returns and distortions in the form of working capital constraints. The former affect both, the efficiency, $\boldsymbol{a}'\ln(\boldsymbol{\lambda})$, and labor wedge, $(1-a)$. The aggregate wedge due to financing frictions is a generalization of that implied by the economy in Bigio and La'O (2020)[13] as: (1) sectoral credit wedges are input-specific, and (2) credit costs are endogenous and interdependent. Furthermore, since firms also obtain revenues from extending trade credit at a cost,

[13]Note that, while Bigio and La'O (2020) consider the CRS-case in the main text of their paper, additional results for the DRS Cobb-Douglas economy are provided in their Online Appendix.

the resulting income lowers actual goods prices which counteracts the misallocative effect of financing costs on aggregate output. The equilibrium collapses to that presented in the main text of Bigio and La'O (2020) if production technologies are CRS and firms neither act as financial intermediaries, $\theta_{is} = 0 \ \forall i, s$, nor require a non-productive labor input to manage credit lines, $m_i = 0 \ \forall i$. Lastly, if firms also do not face any working capital constraints, the equilibrium further simplifies to the frictionless case presented in Acemoglu et al. (2012).

Remarks. Proposition 2 complements previous work by Baqaee and Farhi (2019b) and Bigio and La'O (2020), where non-productivity shocks affect sectoral wedges only directly via changes in exogenous mark-ups, taxes or bank financing costs. In this paper, however, as firms endogenously adjust both their lending rates and borrowing portfolios, credit cost and linkages are subject to change which distorts the transmission of shocks. Financial shocks thus have both direct and indirect effects on sectoral wedges that generate non-trivial effects on aggregate output, which are the focus of the remainder of paper.

3.2. The Macroeconomic Effects of Sectoral Shocks in a Trade Credit Economy

This section develops an analytic characterization of the first order macroeconomic effects of financial shocks when firms act as financial intermediaries by extending trade credit to customers. In the following, I first discuss the Trade Credit-Channel introduced in this model prior to presenting the main aggregation result for sectoral shocks, which complements recent contributions by Baqaee and Farhi (2019b); Bigio and La'O (2020) and Baqaee and Rubbo (2023).

3.2.1. The Micro-Propagation of Sectoral Shocks Revisited

In reference to the optimality conditions in Proposition 1, Corollary 3 summarizes the main propagation mechanism and illustrates how trade credit can both dampen and amplify the first round response of sectoral output to an idiosyncratic liquidity shock.[14]

Corollary 3. *Let the economy's equilibrium be given by Proposition 1. A financial shock, $z_i > 0$, increasing firm i's bank interest premium, r_i^z, c.p. increases i's*

(a) *bank interest rate, r_i^b, and thus i's marginal cost of production. Sector i's demand for inputs and supplier s's output decrease. Sector i's output price increases, decreasing customer c's demand for inputs. Sector i's output decreases.*

The ability of firms to delay input payments to their suppliers further introduces two opposing channels, such that the financial shock, c.p., increases i's

[14] Lemmata D.2 and D.3 in the online appendix provide a full analytical characterization of the cost- and demand-effects by showing how changes in productivity, interest rates and credit shares affect sectoral prices and sales (i.e. the forward and backward propagation of shocks as per Baqaee and Rubbo (2023)) in the Cobb-Douglas economy.

(*b*) *interest rate on receivables, r_i^τ, and thus customer c's marginal cost of production. Sector c's demand for inputs and thus sector i's output decrease.* (*Amplification*)

(*c*) *share of inputs obtained on trade credit from supplier s which dampens i's initial increase in marginal cost of production and decrease in output.* (*Smoothing*)

Part (a) of Corollary 3 describes how an increase in sector i's bank interest rate, r_i^b, affects i's cost of production and translates into demand effects upstream and cost effects downstream. Output in all three sectors declines on impact. Note that the shock to i's bank interest premium exhibits the same propagation pattern as an increase in sectoral distortions in the model economy in Bigio and La'O (2020) or a negative productivity shock to sector i. Part (b) and (c) summarize how the direct response of trade credit costs and shares of the affected sector distorts the up- and downstream transmission of the financial shock: On the one hand, as firms also increase the interest rate charged on receivables, the cost shock to their customers is amplified beyond the traditional price channel. On the other hand, the ability to substitute bank and supplier credit implies that the own cost and therefore upstream demand effects are dampened.

At this point, two observations are worth mentioning: First, the strength of the amplification channel will be influenced by the elasticity of the bank interest 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 the cost parameter, $\kappa_{1,is}$, governing the convexity of the credit management cost function in Equation (6), and thus ability of firms to substitute credit sources as well as the type of shock. In particular, while an idiosyncratic financial shock to firm i has only an indirect general equilibrium effect on its suppliers' interest rates charged on receivables, an aggregate shock affects the trade credit rates of all firms directly.

Next, I show that changes in bank and trade credit rates and credit shares can be decomposed into changes from financial shocks, labor and weighted sales compositions, where the interdependencies of interest rates and credit shares give rise to a credit cost multiplier, $\boldsymbol{\Psi}$.

Proposition 3. *Let $\boldsymbol{\varphi} = \left[[r_1^b, ..., r_N^b], [r_1^\tau, ..., r_N^\tau], [\boldsymbol{\theta}'_{1:}, ..., \boldsymbol{\theta}'_{N:}]\right]'$ denote the $(N(2+N) \times 1)$ vector of interest rates and credit shares that follow from the optimality conditions in Proposition 1 and define the change of sector i's weighted sales composition as $dS_{\mathcal{X},i} = \sum_c \theta_{ci} d\mathcal{X}_{ci}$ with $\mathcal{X}_{ci} = \frac{x_{ci}}{q_i}$. For given financial shocks, changes in labor and the weighted sales composition, changes in interest rates and credit shares are decomposed as*

$$d\ln(\boldsymbol{\varphi}) = \underbrace{\left[\boldsymbol{I} - \frac{\partial \ln(\boldsymbol{\varphi})}{\partial \ln(\boldsymbol{\varphi})}\right]^{-1}}_{\text{Credit Cost Multiplier}(\boldsymbol{\Psi})} \Bigg\{ \underbrace{\frac{\partial \ln(\boldsymbol{\varphi})}{\partial \boldsymbol{z}} \boldsymbol{z} + \frac{\partial \ln(\boldsymbol{\varphi})}{\partial \ln(L)} d\ln(L)}_{\text{Financial Shocks and Labor}} + \underbrace{\frac{\partial \ln(\boldsymbol{\varphi})}{\partial \boldsymbol{S}_{\mathcal{X}}} d\boldsymbol{S}_{\mathcal{X}}}_{\text{Reallocation}} \Bigg\} \tag{30}$$

where the block elasticity matrices

$$\frac{\partial \ln(\boldsymbol{\varphi})}{\partial \ln(\boldsymbol{\varphi})} = \begin{bmatrix} \boldsymbol{0} & \boldsymbol{0} & +\frac{\partial \ln(\boldsymbol{r}^b)}{\partial \boldsymbol{\theta}} \\ -\frac{\partial \ln(\boldsymbol{r}^\tau)}{\partial \boldsymbol{r}^b} & +\frac{\partial \ln(\boldsymbol{r}^\tau)}{\partial \boldsymbol{r}^\tau} & +\frac{\partial \ln(\boldsymbol{r}^\tau)}{\partial \boldsymbol{\theta}} \\ +\frac{\partial \ln(\boldsymbol{\theta})}{\partial \boldsymbol{r}^b} & -\frac{\partial \ln(\boldsymbol{\theta})}{\partial \boldsymbol{r}^\tau} & +\frac{\partial \ln(\boldsymbol{\theta})}{\partial \boldsymbol{\theta}} \end{bmatrix} \quad \text{and} \quad \frac{\partial \ln(\boldsymbol{\varphi})}{\partial \boldsymbol{z}} = \begin{bmatrix} \frac{\partial \ln(\boldsymbol{r}^b)}{\partial \boldsymbol{z}} \\ \frac{\partial \ln(\boldsymbol{r}^\tau)}{\partial \boldsymbol{z}} \\ \boldsymbol{0} \end{bmatrix} \tag{31}$$

are characterized in detail in the proof of Proposition 3. The first order approximation (FOA) of the multiplier is given by $\mathbf{\Psi} \approx \boldsymbol{I} + \frac{\partial \ln(\boldsymbol{\varphi})}{\partial \ln(\boldsymbol{\varphi})}$.

Proposition 3 highlights that financial shocks directly affect bank and trade credit interest rates only. As a result, the feedback effects implied by the credit cost multiplier are such that changes in interest rates have first order, while changes in the credit network only have second order effects. The elasticities of trade credit costs and shares based on the FOA of the credit multiplier are subsequently applied in Proposition 5, where it is explicitly shown that they are functions of the composition of sectoral bank loans, the composition of total interest costs per dollar spent on inputs and the share of receivables in sales evaluated at the equilibrium.

3.2.2. From Micro To Macro

While the previous exposition provided insights into the up- and downstream propagation channels introduced by trade credit, this section develops novel results on the aggregation of sectoral productivity and financial shocks in an inefficient economy featuring endogenous and interdependent distortions due to trade credit. To this end, I follow Baqaee and Farhi (2019b) and first decompose changes in aggregate output into changes from technology, labor and allocative efficiency: Let $\boldsymbol{\mathcal{X}}(\boldsymbol{\varepsilon}, L, \boldsymbol{\varphi})$ define a $(N+1) \times (N+1)$ allocation matrix[15] with typical entry $\mathcal{X}_{ij} = \frac{x_{ij}}{q_j}$ denoting the share of output j used in the production of good i. For a given vector of realizations of productivity shocks, $\boldsymbol{\varepsilon}$, labor, L, and the vector of credit costs and shares, $\boldsymbol{\varphi}$, the level of output equals $Y \equiv \mathcal{Y}(\boldsymbol{\varepsilon}, L, \boldsymbol{\mathcal{X}})$ such that changes in output can be decomposed as

$$d\ln(Y) = \underbrace{\frac{\partial \ln(\mathcal{Y})}{\partial \boldsymbol{\varepsilon}}\boldsymbol{\varepsilon} + \frac{\partial \ln(\mathcal{Y})}{\partial \ln(L)} d\ln(L)}_{\Delta \text{ Technology and Labor}} + \underbrace{\frac{\partial \ln(\mathcal{Y})}{\partial \boldsymbol{\mathcal{X}}}\left[\frac{\partial \boldsymbol{\mathcal{X}}}{\partial \boldsymbol{\varepsilon}}\boldsymbol{\varepsilon} + \frac{\partial \boldsymbol{\mathcal{X}}}{\partial \ln(L)} d\ln(L) + \frac{\partial \boldsymbol{\mathcal{X}}}{\partial \boldsymbol{\varphi}} d\boldsymbol{\varphi}\right]}_{\Delta \text{ Allocative Efficiency (AE)}}.$$

Using the insights on changes in prices, sales and financial costs presented in Section 3.2.1, Proposition 4 provides a first characterization of changes in real GDP. It highlights how changes in up- and downstream credit costs and the credit network can either dampen or amplify the effect of changes in allocative efficiency when firms extend costly trade credit to customers. The aggregation results in Proposition 4 thus complement those for inefficient economies presented in Baqaee and Farhi (2019b) and Baqaee and Rubbo (2023).

Proposition 4. *For observable changes in productivity, labor supply, interest rates, credit shares and sectoral sales compositions, the change in real GDP is*

$$d\ln(Y) = \underbrace{(\boldsymbol{\lambda}_\tau \circ \boldsymbol{\chi})'\boldsymbol{\varepsilon} + (1-a)d\ln(L)}_{\Delta \text{ Technology and Labor}} + \underbrace{\Delta AE(d\ln(L), d\boldsymbol{S}_{\mathcal{X}}) + \Delta AE(\boldsymbol{\varphi})}_{\Delta AE \,=\, -(1-a)d\ln(\Lambda) - \boldsymbol{a}' d\ln(\boldsymbol{\lambda}) - \boldsymbol{\lambda}_\tau' d\ln(\boldsymbol{\phi})} \qquad (32)$$

[15] Note that the first N rows/columns refer to the intermediate goods producers whereas the $(N+1)$'th row/column refers to the final good producer. It holds that $\sum_i \mathcal{X}_{ij} = 1 \; \forall j$.

where $dS_{\mathcal{X},i} = \sum_c \theta_{ci} d\mathcal{X}_{ci}$. Changes in allocative efficiency due to changes in credit costs and shares, $\boldsymbol{\varphi}$, are decomposed as

$$
\begin{aligned}
\Delta AE(\boldsymbol{\varphi}) = & \frac{\partial \ln(\mathcal{Y})}{\partial \boldsymbol{\varphi}} d\boldsymbol{\varphi} = \underbrace{-\sum_i \frac{\partial \ln(\mathcal{Y})}{\partial r_i^b} dr_i^b}_{\Delta \text{ Working Capital-Costs}} + \underbrace{\sum_i \frac{\partial \ln(\mathcal{Y})}{\partial r_i^\tau} dr_i^\tau}_{\Delta \text{ TC-Revenues}} \\
& \underbrace{+\sum_i \frac{\partial \ln(\mathcal{Y})}{\partial \rho_i^b} d\rho_i^b - \sum_i \frac{\partial \ln(\mathcal{Y})}{\partial \rho_i^\tau} d\rho_i^\tau}_{\Delta \text{ Upstream and Downstream Relative IRates}} + \underbrace{\sum_{i,s} \frac{\partial \ln(\mathcal{Y})}{\partial \ln(\theta_{is})} d\ln(\theta_{is})}_{\Delta \text{ Credit Shares}}. \qquad (33)
\end{aligned}
$$

Changes in the relative upstream, $d\rho_i^b$, and downstream, $d\rho_i^\tau$, interest rates are

$$
d\rho_i^b(\boldsymbol{w}) = dr_i^b - \mathbb{E}_{\boldsymbol{w}}[d\boldsymbol{r}^\tau], \quad \textit{and} \quad d\rho_i^\tau(\boldsymbol{w}) = dr_i^\tau - \mathbb{E}_{\boldsymbol{w}}[d\boldsymbol{r}^b], \textit{ respectively}, \qquad (34)
$$

and characterize the response of sector i's bank rate relative to expected changes in i's upstream interest costs on accounts payable, $\mathbb{E}_{\boldsymbol{w}}[d\boldsymbol{r}^\tau] = \sum_s w_{is} dr_s^\tau$, and of sector i's trade credit rate relative to expected changes in i's downstream customers' interest costs on bank credit, $\mathbb{E}_{\boldsymbol{w}}[d\boldsymbol{r}^b] = \sum_c w_{ci} dr_c^b$, using the $(N \times 1)$- vector of weights $\boldsymbol{w}$ as the distribution.

As in Baqaee and Farhi (2019b), there are two sources of aggregate changes: changes in (1) technology and labor and (2) allocations. First, the direct contribution of sectoral technology shocks to aggregate output is proportional to the Hadamard product of the vector of distortion-adjusted gross Domar weights in Definition 2 and the expenditure shares on the variable production factor, $(\boldsymbol{\lambda}_\tau \circ \boldsymbol{\chi})$. While similar in spirit, the difference relative to the sales-based for efficient and the cost-based Domar weights for inefficient economies derived in Hulten (1978) and Baqaee and Farhi (2019b), respectively, is due to (1) DRS, and (2) firms spending part of their sales on interest payments on bank loans to finance working capital requirements. The latter implies that the effect of sectoral shocks on aggregate real activity depends on distortion-adjusted gross sales which include a sector's direct and indirect customers' bank interest payments. As a result, the network structure matters to a first order. This differs from Baqaee and Farhi (2019b), where the sufficient statistic for the aggregation of sectoral shocks - the cost-based Domar weight - can be obtained without knowledge of underlying network structure.

Second, Equation (32) implies that the reallocation effect can be positive if the labor share in GDP, Λ, and the weighted sum of sectoral sales shares, $\boldsymbol{\lambda}$, decrease faster than the weighted sum of price wedges, $\boldsymbol{\phi}$, increases. However, these effects are not the result of compositional changes due to substitution as in the CES-case discussed in Baqaee and Rubbo (2023). Instead, the labor share decreases mechanically as firms spend a higher share of their revenues on bank interest payments and changes in Domar weights matter due to DRS. Ultimately, the combined reallocation effects result from changes in credit costs and shares, $d\boldsymbol{\varphi}$, and their indirect effects via changes labor, $d\ln(L)$, and a sector's weighted sales composition, $\sum_c \theta_{ci} d\mathcal{X}_{ci}$.

The direct effects are further decomposed into changes from interest rates and the credit network as depicted in Equation (33): The first term summarizes the combined cost and demand effects of an increase in the bank interest rate which decrease allocative efficiency the same way as in an economy with bank-finance only (Bigio and La'O, 2020). The remaining terms formalize that in the present model-set up, trade credit can both dampen or amplify the initial negative output response to a financial shock. While the immediate up- and downstream effects of an idiosyncratic financial shock were summarized in Corollary 3, their interplay is the main focus of following discussion. In particular, the sign of the aggregate effect of the trade credit-channel will depend on the joint price and income effects[14] of changes in interest rates on receivables, r_i^τ, up-, ρ_i^b, and downstream, ρ_i^τ, relative interest rates and the credit network, θ_{is}, as reflected in the respective elasticities in Equation (33).

Price Effects. Both technology and financial shocks propagate downstream through changes in prices via the cost- and the demand channel. The latter is due to DRS and has a dampening effect on the transmission of changes in productivity or credit wedges: A decrease in the demand for inputs increases the marginal product of the variable production factor thereby decreasing prices in Corollary 1. The cost-channel is induced by changes in productivity, credit costs and shares: An increase in sector i's bank interest rate, r_i^b, unambiguously raises prices. However, the effect is dampened when firm i obtains trade credit from its suppliers, and if i's bank interest rate rises by more than the weighted average interest rate payed on accounts payable such that $d\rho_i^b > 0$. Similarly, an increase in i's share of intermediate input expenditures financed using trade credit, $\boldsymbol{\theta}_{i:}$, lowers i's price as long as the interest differential between bank and trade credit is positive in equilibrium. The additional income effect following an increase in i's interest rate charged on receivables, r_i^τ, i's customers' credit shares, $\boldsymbol{\theta}_{:i}$, or weighted sales composition, $S_{\mathcal{X},i}$, also counteracts any cost and demand effects increasing prices.

While such dampening effects on prices are not present in Baqaee and Farhi (2019b) or the benchmark economy in Bigio and La'O (2020), Baqaee and Rubbo (2023) allow for this case in an extension featuring sticky prices which results in wedges being inversely related to marginal costs. This contrasts the present set-up along two dimensions: (1) In this paper, changes in mark-ups are due to DRS and inversely related to changes in demand rather than costs; and (2) As firms act as financial intermediaries, wedges depend on endogenously determined up- and downstream credit costs and shares.

Income Effects. Changes in the aggregate labor share and sectoral Domar weights depend on changes in credit costs, their composition, and net cost shares, $\tilde{\boldsymbol{\chi}}$. First, consider the effect of changes in interest rates and credit shares on sales and nominal GDP taking cost shares as given. An increase in the bank interest rate faced by i's customers, r_c^b, unambiguously lowers their demand and i's sales. The effect of an increase in i's interest rate charged on receivables, r_i^τ, is twofold and ambiguous: On the one hand, sales decrease if i's trade credit rate increases by more than its customers' average saving on bank interest payments when postponing payments to i such that $d\rho_i^\tau > 0$. On the other hand, it increases i's revenues from financial intermediation, thereby increasing sales. Additional income effects follow from increases in i's customers' credit shares or weighted sales composition. If the demand- outweigh income effects, the subsequent decline in intermediate demand for sectoral output decreases sales and in turn also non-labor income of households and GDP, as long as $\tau < 1$.[16]

Second, a decrease in net cost shares implies that firms spend a higher share of their revenues on interest payments on bank loans. Ceteris paribus, bankers' income from financial intermediation increases, thereby increasing final demand and subsequently sectoral sales and GDP.

By combining Propositions 3 and 4, Proposition 5 provides an aggregation formula for the first-order macroeconomic effects of financial shocks in inefficient economies as well as an interpretable decomposition of how allocative efficiency is affected when firms act as financial intermediaries. For ease of exposition and without compromising the intuitions, I evaluate the elasticities at the CRS-case with $\boldsymbol{\chi} = \boldsymbol{\iota}$ such that $M_i = 0\ \forall i$[17], while imposing that all non-labor income is discarded, $\tau = 1$. The DRS-case with $\tau < 1$ can be found in the online appendix.

Proposition 5. *For given productivity, labor supply, and weighted sales compositions, the change in aggregate output following an idiosyncratic financial shock to sector i's interest premium to a first order evaluated at the CRS case with $\chi_i = \tau = 1 \forall i$ is*

$$\left.\frac{\partial \ln(\mathcal{Y})}{\partial z_i}\right|_{\text{CRS}} \approx \underbrace{-\boldsymbol{\lambda}_{\tau,i}\frac{r_i^z BC_i}{R_i} - \overbrace{\left(\sum_c \boldsymbol{\lambda}_{\tau,c}\frac{r_i^\tau AR_{ci}}{R_c} - \boldsymbol{\lambda}_{\tau,i}\frac{r_i^\tau AR_i}{R_i}\right)}_{\text{direct effects}} - \text{FB}_{\tau,i} + \text{FB}_{\theta,i}}^{\textit{TC-Mechanism}} \tag{35}$$

Output changes due to first order feedback effects of changes in trade credit interest rates are

$$\text{FB}_{\tau,i} = \underbrace{\boldsymbol{n}_{\tau,i}\left\{\frac{r_i^\tau AR_i}{R_i} - \left[\frac{W\ell_i}{BC_i}\frac{r_i^z W\ell_i}{TL_i} + \sum_s \frac{AP_{is}^-}{BC_i}\frac{r_i^z AP_{is}^-}{TX_{is}}\right]\right\}}_{\Delta\ i\text{'s TC-Rate}} \underbrace{- \sum_c \boldsymbol{n}_{\tau,c}\frac{AP_{ci}^-}{BC_c}\frac{r_i^\tau AR_{ci}}{TX_{ci}}}_{\Delta\ i\text{'s customers' TC-Rates}} \tag{36}$$

and due to changes in i's and i's customers' credit shares along the intensive margin are

$$\text{FB}_{\theta,i} = \underbrace{\sum_s \boldsymbol{n}_{\theta,is}\frac{r_i^z \tilde{NP}_{is}}{AP_{is}} - \sum_c \boldsymbol{n}_{\theta,ci}\frac{r_i^\tau \tilde{NR}_{ci}}{AR_{ci}}}_{\Delta\ \text{TC-Shares}\ (\Delta\ \text{Interest Rates})} \underbrace{- \sum_{c,s} \boldsymbol{n}_{\theta,cs}\frac{NP_{cs}}{AP_{cs}}[\mathcal{E}_{sr}]_{ci}}_{\Delta\ \text{TC-Shares}\ (\Delta\ \text{Demand})}. \tag{37}$$

The $(N \times 1)$ vector $\boldsymbol{n}_\tau \equiv -\frac{\partial \ln(\mathcal{Y})}{\partial \ln(\boldsymbol{r}^\tau)}$, and the $(N \times N)$ matrix $\boldsymbol{n}_\theta \equiv \frac{\partial \ln(\mathcal{Y})}{\partial \ln(\boldsymbol{\theta})}$, summarize the cost and income effects of changes in credit costs and shares on output in the CRS-case, with entries

$$\boldsymbol{n}_{\tau,i} = \underbrace{\sum_c \boldsymbol{\lambda}_{\tau,c}\frac{r_i^\tau AR_{ci}}{R_c} - \boldsymbol{\lambda}_{\tau,i}\frac{r_i^\tau AR_i}{R_i}}_{\text{Downstream Costs}\ -\ \text{Direct Revenue Effects}}, \quad \textit{and}\quad \boldsymbol{n}_{\theta,is} = \underbrace{\left\{\boldsymbol{\lambda}_{\tau,i}(r_i^b - r_s^\tau) + \boldsymbol{\lambda}_{\tau,s} r_s^\tau \frac{R_i}{R_s}\right\}\frac{AP_{is}}{R_i}}_{i\text{'s Costs}\ +\ s\text{'s Revenue Effects}}. \tag{38}$$

[16]If $\tau = 1$ such that no non-labor income is re-distributed to households, the aggregate labor share is equal to one and unaffected by any shocks.

[17]In the CRS-case, I effectively assume that in equilibrium the variable management costs are netted out by a negative fixed management costs/subsidy. The proof of Proposition 4 also discusses the more general DRS-case.

The interest-adjusted excess accounts payable, $\tilde{NP}_{is}$, and accounts receivable, $\tilde{NR}_{is}$, due to interest differentials, $NP_{is} = (\theta_{is} - \theta_{is}^{\kappa})p_s x_{is}$, follow from

$$\frac{\tilde{NP}_{is}}{NP_{is}} = \left[\frac{1}{(r_i^b - r_s^\tau)}\frac{1+r_s^\tau}{1+r_i^b} - \frac{(1-\theta_{is})}{\phi_{is}^X}\right], \quad \textit{and} \quad \frac{\tilde{NR}_{is}}{NP_{is}} = \left[\frac{1}{(r_i^b - r_s^\tau)} + \frac{\theta_{is}}{\phi_{is}^X}\right], \tag{39}$$

respectively. Finally, the effect of changes in n's bank- and trade credit interest rates on i's sales is summarized by the in'th entry of matrix $\boldsymbol{\mathcal{E}}_{sr}$, characterized in Lemma D.4, Appendix D.1.

Proposition 5 shows that the elasticity of aggregate output with respect to financial shocks depends on the equilibrium interactions of input-output- and credit-relations. Each term can ultimately be mapped to data which I exploit in Section 4. For example, consider Equation (38) characterizing the FOA of the elasticity of output to changes prices following an increase in sector i's interest rate charged on receivables, $\boldsymbol{n}_{\tau,i}$, and i's credit share obtained from supplier s, $\boldsymbol{n}_{\theta,is}$. In either case, the elasticities depend on the product of the distortion-adjusted gross sales shares and the share of interest payments and income on receivables in sales, respectively.[18] Similarly, the first order feedback effects in Equations (36) and (37) equal the product of the elasticity of output with respect to changes in trade credit rates and shares and their elasticity with respect to changes in interest rates following a financial shock. While the former is characterized by the entries of $\boldsymbol{n}_\tau$ and $\boldsymbol{n}_\theta$, respectively, the latter[19] are functions of the composition of bank loans, payables and interest costs, and capture the following cost and demand effects.

Interest Rate Effects. Consider a financial shock to sector i's bank interest premium. Sector i's optimal interest rate charged on receivables unambiguously increases. However, while i's trade credit rate increases one-for-one with the financial shock, changes in i's ratio of bank loans to revenues from product sales alter its dependency on bank credit, which either dampens or amplifies the initial response as captured by the first term in braces in Equation (36): On the one hand, an increase in i's interest rate on receivables, ceteris paribus, shifts i's sales composition towards revenues from financial intermediation, thereby lowering their product sales and further increasing i's trade credit rate. On the other hand, an increase in financing costs decreases i's demand for inputs and subsequently total bank credit obtained, decreasing i's trade credit rate.[20] The same effect also unambiguously decreases i's customers' interest rate charged on receivables to a first order as captured by the second term in Equation (36).

Equation (37) summarizes the effect of changes in relative credit costs and the demand for sector i's output on i's share of inputs obtained on trade credit from supplier s. The latter is

[18] The elasticities of output with respect to changes in trade credit rates and shares can take on both positive and negative values depending on the relative strength of the cost- and revenue-effects affecting prices. In the more general DRS-case, the latter also accounts for changes in demand/income affecting the marginal product of the input composite. (see Corollary 1)

[19] See also Proposition 3 and its proof in Online Appendix D.1.

[20] The decrease in i's trade credit rate - i.e. increase in i's receivable share - is the result of the decline in i's bank to product sales ratio. While the compositional effect is mechanical, it relates to the empirical findings in Petersen and Rajan (1997) who document that firms who see a decline in their sales increase their extension of trade credit in an attempt to preserve their sales.

ambiguous and depends on the effects of changes in interest rates on sales. In contrast, the direct cost effects are straightforward and captured by the first two terms: For given intermediate expenditures, $p_s x_{is}$, the increase in the cost of bank credit unambiguously induces a shift of the optimal credit portfolio towards trade credit, whereas the increase in the interest rate charged on receivables by supplier s decreases the trade credit share. The observed compositional shift of short-term credit towards bank loans at the onset of the crisis discussed in Section 2, suggests that the cost of trade credit displayed a higher increase and may be more volatile than the interest rate on bank loans.

3.2.3. Trade Credit-Channel Revisited

To resolve the ambiguity regarding the relative importance of its amplification and smoothing features, Corollary 4 provides a sufficient condition under which changes in trade credit rates improve allocative efficiency. A related condition with similar interpretation can be derived for changes in credit shares, which I leave to the online appendix.

Corollary 4. *Let the aggregate output response to an idiosyncratic financial shock, $z_i > 0$, be given by Proposition 5 and let $\mathcal{C}_i$ denote sector i's set of customers. If $n_{\tau,i} > 0$ in equilibrium, a sufficient condition for changes in trade credit interest rates to improve allocative efficiency to a first order such that, $(-n_{\tau,i} - \mathrm{FB}_{\tau,i}) > 0$, is*

$$\underbrace{\frac{\max\limits_{c\in\mathcal{C}_i}\left\{-\boldsymbol{n}_{\tau,c}\right\}}{-\boldsymbol{n}_{\tau,i}}}_{\frac{\Delta Y\,(\Delta c\text{'s TC-Rate})}{\Delta Y\,(\Delta i\text{'s TC-Rate})}} > -\underbrace{\frac{1+\left(\eta_i^\tau - \min\left\{\frac{W\ell_i}{TL_i}, \frac{AP_{is}^-}{TX_{is}}\ \forall s\right\}\frac{R_i}{BC_i}\right)\frac{r_i^z BC_i}{R_i}}{-\sum\limits_{c\in\mathcal{C}_i}\frac{AP_{ci}^-}{BC_c}\frac{r_i^\tau AR_{ci}}{TX_{ci}}}}_{-\frac{\Delta\ i\text{'s TC-Rate}}{\Delta\ i\text{'s customers' TC-Rates}}}, \quad \textit{where } \eta_i^\tau = \frac{r_i^\tau AR_i}{r_i^z BC_i} \tag{40}$$

denotes sector i's net-lending position in financing costs and captures i's degree of engagement in financial intermediation relative to its own external financing needs. If $n_{\tau,i} < 0$, the inequality condition is reversed.

The sufficient condition (40) highlights that whether trade credit improves allocative efficiency in response to a financial shock depends on the relative magnitude of changes the sector's and its customers' trade credit costs and their price effects on output. The former are given by the right-hand side of the inequality and can be expressed in terms of the net-lending position of a sector. In particular, if $\eta_i^\tau < \min\left\{\frac{W\ell_i}{TL_i}, \frac{AP_{is}^-}{TX_{is}}\forall s\right\}\frac{R_i}{BC_i}$, then i can be thought of as a net-borrower with a higher equilibrium dependency on bank credit. As a result, the initial increase in i's trade credit rate is dampened by a reduction in i's demand for inputs and has a smaller effect on i's customers if they are less dependent on trade credit obtained from i. The effects are reversed if i is a net-lender, since a sector's interest rate on receivables will be more sensitive to financial shocks the more trade credit is extended to customers.

While the right-hand side of (40) only takes on positive values, the sign of the ratio of output elasticities with respect to changes in trade credit rates affecting prices depends on the difference between a sector's income effect from financial intermediation and the downstream cost-effects on its customers. Net-lenders by definition engage more in financial intermediation and are relatively more upstream[21] such that changes in their prices will have comparatively larger aggregate effects. In particular, following an increase in a net-lender's interest rate on receivables, the income effects on prices will dominate downstream costs effects such that the overall output effect is positive. The opposite applies to net-borrowers.

These observations suggest that the maximum elasticity of output with respect to changes in trade credit rates across firms will be positive and that of a net-lender. The LHS-ratio of changes in output is thus more likely to be positive for net-lenders than net-borrowers. As a result, the smoothing condition in (40) will be more frequently met by net-lenders, which is also confirmed quantitatively in Column (4) of Table 2 in Section 4.2.

4. A Quantitative Assessment of Trade Credit and Aggregate Fluctuations

Building on the insights of the model, this section quantifies the role of trade credit for the propagation of shocks and aggregate fluctuations during the 2008-09 Great Recession. To this end, I first calibrate the model to the US economy.

4.1. Calibration Strategy

The static nature of the model and its analytical tractability allow me to conduct a period-by-period mapping of the equilibrium to its empirical counterparts using the model's equilibrium conditions, similar to Bigio and La'O (2020). In the following, I provide a short summary with focus on the calibration strategy concerning the production and credit network, financial parameters and the imputation of financial shocks. A full description and further details on the necessary data adjustments and calibration steps can be found in Online Appendix E.1.

The **US production and trade credit network** are mapped to the data at the 3-digit NAICS level at an annual frequency, covering the time period 1997-2016 and 45 sectors (excluding FIRE), using the input-output tables provided by the Bureau of Economic Analysis (BEA). Since data on trade-credit flows between firms are not readily available, I rely on balance sheet data on accounts payable and receivable of a panel of US Compustat-firms and follow the approach suggested in Altinoglu (2021) to construct a proxy of inter-industry credit flows. A second challenge concerns the consistent assignment of interest payments: The cost of trade credit are included in the effective price paid on inputs and thus already accounted for in the nominal intermediate expenditures reported in the IO-tables. Bank interest payments, however, are part of the gross operating surplus net of interest-income. (see Horowitz and Planting, 2009) Using

[21] See discussions in Sections 2 and 4, Footnote 27. Upstreamness is measured by the supply-side centrality, $\mathbf{L}'\boldsymbol{\iota}$, similar to Antràs et al. (2012), where $\mathbf{L}$ denotes the revenue-based Leontief inverse in Definition 2.

information on the composition of gross operating profits reported in the income statements of the same panel of US Compustat-firms, I decompose sectoral gross operating surpluses into capital expenditures, dividend and bank interest payments. Therefore, (real) capital owned by firms is included as a constant and set it to its steady state level[22] - rather than normalized to one - to ensure a consistent calibration of the parameters of the production function (1).

To simplify the theoretical exposition, I imposed that the same share, $(1-\tau)$, of income of the fixed factor and the financial sector is re-distributed to households. In the following simulations, however, the income of the fixed factor is re-distributed to households whereas all bank interest income is excluded from the calculation of aggregate GDP.

The expenditures on **Credit Management Costs**, $W\ell_i^{\tau}$, are calibrated to be a fraction of sectoral labor expenditures recorded in the IO-tables, using the share of expenditures on management and administrative services (NAICS = 55,561) in total intermediate input costs.[23] The parameters of the cost function (6) are then calibrated by first estimating[24] an aggregated version of Equation (22) and matching the estimated to the model-implied coefficients to recover the link-specific parameters, $\kappa_{1,is}$. The remaining parameters, $\kappa_{0,is}$ and $m_{0,i}$, are calculated as residuals using Equations (22) and (6). In the calibration, I ensure that both, the quadratic adjustment cost parameter, $\kappa_{1,is}$, and the fixed cost component are strictly positive. In contrast, the linear cost parameter, $\kappa_{0,is}$, may take on both positive and negative values which ensures that the equilibrium credit shares match the data. This allows for the case that firm i may also undergo a possible cost-beneficial restructuring of its relationship with supplier s when increasing the share of postponed input payments to the supplier.

Financial Parameters and Shock Identification. As a measure for the interest premium in Equation (7), I employ sectoral credit spreads derived in Gilchrist and Zakrajšek (2012) adjusted to match the bank interest payments imputed from the IO-tables. The risk-free rate is calculated as $\underline{r} = \min_{i,t}\{r_{it}^b\}$ over the entire sample period such that the implied premia are $r_{it}^z = r_{it}^b - \underline{r}$. Shocks to the interest premium, z_i, are then imputed directly using Equation (7).

As discussed in Section 3, the parameter d in Equation (7) is linked to the banking sector's monitoring technology that affects the interest premium independently from receivables. I calibrate the parameter d to the average aggregate pre-crisis (2004-07) depository institution loans to sales ratio to reflect the economy's overall ability to repay bank loans from current sales. Since I

[22] While the model remains static and a closed economy, I account for both, capital as a fixed factor in production (1) and imports to ensure a more accurate mapping of the model to the data. In particular, capital is set equal to its equilibrium level that follows from the firm's extended optimization problem. Imports on selected sectors also had to be accounted for as a demand residual to ensure market-clearing. While the main model insights of Section 3 remain unchanged, the modified model-equations to account for equilibrium capital and the demand residual in the simulations are discussed in Online Appendix E.1.

[23] As an alternative, I also used the share of expenditures on management and Federal Reserve banks, credit intermediation, and related activities (NAICS = 55,521CI) in total intermediate input costs. The results are similar to the benchmark case.

[24] To estimate the aggregate(d) version of Equation (6) and (7), I rely on the time period 1997-2007 in either case to capture their pre-crisis relationship. To calibrate the parameter μ, I further use quarterly data to increase the sample size for estimation. A similar estimate was obtained using the same data at an annual frequency.

rely on Compustat data for the mapping of the equilibrium trade credit shares, I calculate aggregate bank loans and subsequently their share in sales, d, by imposing that the ratio of aggregate accounts receivable to depository institutions loans of the sample Compustat firms in Appendix A with no missing observations is equal to that of all non-financial US corporations from US Flow of Funds Data (FF).

The parameter μ is calibrated by estimating[24] Equation (7) at the aggregate level with OLS using FF-Data on accounts receivable, depository institution loans and sales of all non-financial corporate businesses and the aggregate credit spread, r_t^z, calculated in Gilchrist and Zakrajšek (2012) at an quarterly frequency.

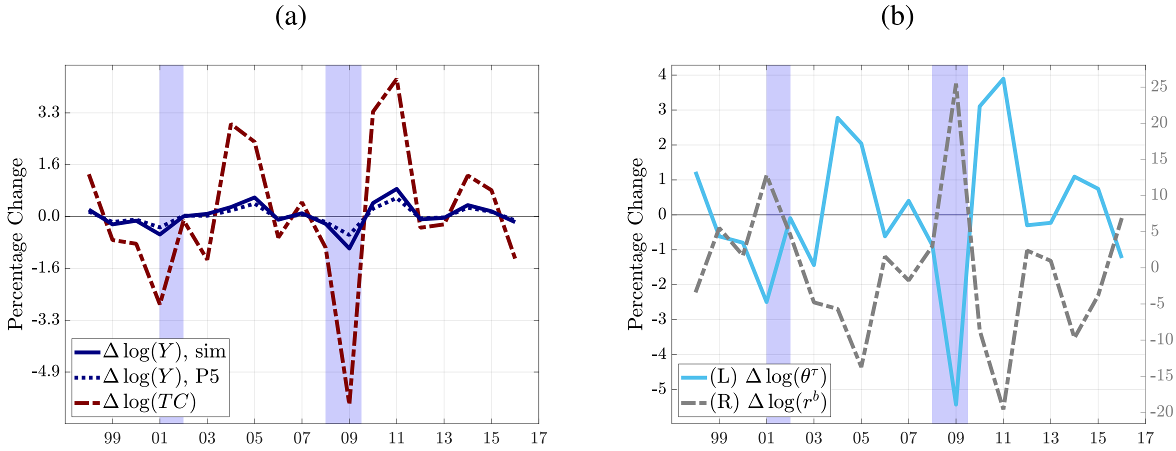
4.2. Trade Credit during the Great Recession

To quantify the role of the trade credit during the Great Recession and its effect on real aggregate output, I rely on both Proposition 5 and model simulations. First, I use the imputed financial shock series and the data-counterparts of the respective variables to calculate the 2004-07 average of the FOA of the elasticity of output in Proposition 5 for given productivity, labor and weighted sales compositions. Note, however, that in the following, I employ the more general DRS-aggregation results presented in the Online Appendix while imposing $M_i = 0 \forall i$ and $\tau = 1$ as in the CRS-case for simplicity. Second, using the same imputed financial shock series, I solve numerically for the equilibrium of the static economy while abstracting from any shocks to sectoral productivity. In addition, any variation originating from changes in production and financial parameters, capital[22], and foreign trade shocks, is also excluded by keeping the respective parameters and variables at their four-year-average (2004-07) prior to the crisis.

Model Fit. Figure 3 depicts the evolution of log-changes in aggregate output, accounts payable including the costs of trade credit, their share in short-term credit which equals total production costs in the context of the model, and the average sectoral bank interest rate obtained from model simulations. Accounting for the timing restrictions discussed in Section 2, Figure 3 shows that the model *qualitatively* captures the business cycle features of trade credit observed in the data and depicted in Figure 1. Table 1 further documents that *quantitatively*, the model is able to account for 25.0% of the variation in output and 37.7% of the variation in supplier credit. The model also reproduces 61.5% of the fluctuations and accounts for 62.3% of the compositional shift towards bank credit during the crisis. Table 1 suggests that changes in financial frictions alone account for approximately 39.3% of the actual drop in output during the 2008-09 Great Recession reported in Section 2.

Simulations and Counterfactuals. 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 interdependent distortions due to trade credit linkages among firms during the financial crisis in following three exercises.

Figure 3: Model-Implied Business Cycle Properties of Trade Credit



Note: Similar to Figure 1, the panels in this figure plot the evolution of the log-change in percent of the following variables in response to financial shocks: $(Y)^*$ aggregate GDP using both model simulations and the more general DRS-aggregation results of Proposition 5 with $M_i = 0 \forall i$ and $\tau = 1$; $(TC)^*$ aggregate accounts payable including the cost of trade credit and $(\theta^{\tau} = \theta^{P})$ their share in total cost of production (i.e. current liabilities); and (r^b) the average interest rate on bank credit against the right axis. *The variables are reported in real terms using the model implied aggregate price-index.

(a) TC-Mechanism. The first exercise addresses the question whether in an economy with both bank and trade finance the smoothing or the amplification features of trade credit as discussed in Section 3.2 dominate. To this end, I quantify its effect on the volatility and response of aggregate output during the crisis by calculating the difference of the respective variable in general and partial equilibrium. While the general equilibrium effects have already been discussed in the context of the model-fit, the partial equilibrium effects - with slight abuse of language - refer to the variable's response that results from keeping either both trade credit rates and shares (PE_R), or the credit portfolio only (PE_T), at their average pre-crisis (2004-07) levels. In reference to Proposition 5, the PE_R-elasticity corresponds to the first and the PE_T-elasticity to the first four terms in Equation (35), respectively, which are adjusted to account for price effects due to DRS. The simulation results in Table 1 suggest that trade credit decreased aggregate volatility and the drop in real GDP by 14.8% and 17.5%, respectively, which was predominantly driven by the endogenous adjustment of credit shares.[25] While about half in size, the aggregation results of Proposition 5 yield similar insights and capture the decrease in allocative efficiency for given productivity, labor and the weighted sales composition. The intuition is as discussed in Section 3.2: In response to a financial shock, sector i's interest rate on trade credit increases. On the one hand, this increases the financing cost of production for downstream customers. On the other hand, it dampens the sector's price response due to revenue effects, and further counteracts the initial increase in bank interest premia by reducing the share of revenues extended on trade credit. The overall ability of firms to adjust both their receivable shares in sales and credit portfolios thus dampens the effect of shocks to the cost of bank credit.

Table 1 also reports the results of the same simulation exercise for changes in aggregate accounts payable (including the cost of trade credit) and its share in total production costs. In

[25]The percentages follow from calculating, $(GE-PE_R)/GE$, for both the 2009-response and standard deviation of the respective variable reported in Table 1.

either case, the PE_R-results imply that the effects of changes in demand had a negative but small effect on the respective variable. Thus, the simulations suggest that the decline in aggregate accounts payable and is share were predominantly driven by the decline in credit shares.

Table 1: Decomposition of Trade Credit Mechanism

(a) 2009-Growth %

	VAR	DATA	MODEL		
			GE	PE_R	PE_T
P5	Y	-2.570	-0.583	-0.630	-0.621
SIM	Y	-2.570	-1.010	-1.187	-1.179
SIM	TC	-9.065*	-5.955	-1.404	3.880
SIM	θ^τ	-8.718*	-5.428	-0.674	4.597

(b) Volatility %

	VAR	DATA	MODEL		
			GE	PE_R	PE_T
P5	Y	1.672	0.267	0.285	0.284
SIM	Y	1.672	0.417	0.479	0.478
SIM	TC	6.201	2.335	0.554	1.498
SIM	θ^τ	3.462	2.129	0.263	1.786

Note: This table presents the (a) 2009 (*2008) log-change and (b) standard deviation of the respective variables in the data (Section 2), based on model simulations and the more general DRS-aggregation results of Proposition 5 with $M_i = 0 \forall i$ and $\tau = 1$ using financial shocks only. Column (GE) reports the general and ($\text{PE}_{R,T}$) the effects from holding (PE_R) both trade credit interest rates and shares and (PE_T) credit shares only constant. All numbers are in percent.

(b) TC-Multiplier. The second simulation evaluates the contribution of the existence of trade credit linkages to the drop in output during the 2008-09 recession. To this end, I compare the predictions produced by a model with trade credit to those obtained in an equivalent[26] economy without in response to the same shock. This allows to disentangle the output effects of the credit network from those of the inter-sectoral trade network alone. Following Bigio and La'O (2020), an equivalent economy, $\text{E}(0)$, and the Trade Credit Multiplier are defined below:

Definition 3. *An* ***equivalent economy****,* $\text{E}(0)$*, to an economy with both production and credit linkages,* $\text{E}(\theta)$*, features only production linkages but the same observed input prices net of any credit costs, nominal sales, input expenditures and value added as* $\text{E}(\theta)$*.*

Definition 4. *The* ***trade credit multiplier*** *is the ratio between the percentage change in a variable in response to the same sector-specific shocks in an economy with trade and bank finance and an equivalent economy with bank finance only.*

Column (1a) in Table 2 reports the simulated percentage change in aggregate output in 2009 for the economy introduced in Section 3 and its equivalent counterpart using the same financial shocks. Similarly, Column (1b) reports the results from the same exercise using the more general DRS-aggregation results of Proposition 5 as before. The resulting trade credit multiplier for the aggregate output response is approximately two, implying that the presence of a credit network alone generated a considerable amplification of distortions. Since the model featuring both production and credit linkages captures approximately 39.3% of the drop in real GDP, approximately 20% can thus be attributed to the existence of trade credit per se.

The intuition of this result follows from the discussion in Section 3.2: In an economy featuring both bank and supplier credit, sectoral bank interest premia are higher such that the same

[26]The parameters of the observationally equivalent bank finance economy are calibrated using the same strategy described in Section 4, while imposing $\boldsymbol{\theta}_i = \mathbf{0} \forall i$ such that all production costs are financed with bank loans.

financial shock translates into a higher increase in overall credit costs compared to an economy with bank finance only. In response to the 2009 financial shock, according to model simulations, the cost of trade credit rose by more relative to the cost of bank credit such that firms adjusted their credit portfolio by moving towards bank finance as observed in the data and captured by the model. However, these adjustments were not enough to undo the exacerbating effects of credit linkages on the drop in output relative to an economy without trade credit, translating into a multiplier greater than one.

Remarks. To summarize, the previous two exercises suggest the following: First, in response to the same financial shocks, aggregate output declined in either economy. Second, in comparison to the equivalent economy with bank-finance only, the existence of trade credit amplified the response of aggregate output via higher funding costs and interest premia. Third, in the economy with both bank and trade credit, output would have declined even further if firms were unable to adjust trade credit interest rates and shares.

(c) Heterogeneity in Net-Lending Position. As highlighted in Section 2, firms display heterogeneity in their net-lending positions defined as the ratio of accounts receivable to bank credit. In the context of the model proposed in Section 3, Corollary 4 suggests that sectors extending relatively more trade credit will generate more spillovers in an economy featuring both production and credit linkages. To quantitatively evaluate the relevance of asymmetries in the trade credit usage of sectors for the propagation of liquidity shocks, I first identify the top five net-borrowers and -lenders based on the 2004-07 average of their net-lending position implied by a mapping of the model to the data and Definition 1.[27] A symmetric shock series calculated as the average of shocks to sectoral interest premia is then fed into the model affecting only one group of sectors at a time. The results of this exercise are reported in Table 2, Columns (2-3a,b) and provide the following two insights:

First, financial shocks to net-lenders are more amplified relative to an economy with bank-finance only. The intuition behind this observation is that net-lenders have a higher receivable share in sales such that their bank interest premia and immediate cost effects will be significantly higher in comparison to an economy without trade credit.

Second, in an economy with both bank and trade credit, the decline in aggregate output in response to a financial shock to net-borrowers is larger than in response to the same shock affecting net-lenders. A quantification of the individual components of the elasticity of output characterized in Proposition 5 suggests that this is due to the distortion-adjusted sales share and bank-dependency of net-borrowers being on average greater than those of net-lenders. A higher bank-dependency[28] of sectors increases their direct exposure to the financial shock and thus unsurprisingly also the magnitude of the output response.

[27] The top net-lenders are: Oil and Gas (211), Information Services (514), Primary Metals (331), Agriculture (11), Pipeline Transport (486). The top net-borrowers are: Food and Beverage Stores (445), General Merchandise Stores (452), Health Care (62), Government and Education (GOV), Motor Vehicle and Parts Dealers (441).

[28] The calibration of the model implies that in equilibrium the cost of production are predominantly financed using bank loans since firms do not have any internal funds and their average trade credit share is about 10%.

In a final exercise, I shed further light on the difference between the role played by net-lenders and net-borrowers for the propagation of financial shocks in a trade credit network. To this end, I quantify the sufficient condition in Corollary 4 that illustrates when changes in trade credit interest rates improve allocative efficiency in response to idiosyncratic financial shocks. Using the 2004-07 average of the data-counterparts of the elasticities of output, trade credit rates and shares, I first evaluate the inequality condition (40) for each sector.[29] I then divide the 45 sectors into net-lenders (NL) and net-borrowers (NB) based on the median of their 2004-07 net-lending position and report the share of sectors that satisfy the condition in each group in Table 2. Column (4) shows that about 4% of net-borrowers and 32% of net-lenders satisfy the sufficient condition corresponding to changes in trade credit rates. A difference in means test further suggests that the effects of changes in interest rates on receivables following a financial shock to a net-lender are significantly more likely to have a positive effect on output, confirming the prediction of the discussion of Corollary 4. The economic intuition behind this observation is that in case of a shock to a net-lender, the following positive income effect dominates any negative effects on output: By increasing its interest rate on receivables in response to a financial shock, a firm will reduce trade credit extended to customers. To make up for the loss in financial revenues, the firm shift its sales composition towards product sales by lowering its output price thereby, ceteris paribus, dampening any negative effects on output.

Table 2: Trade Credit Multipliers and Heterogeneity

	Simulations			Proposition 5			Corollary 4	
$\Delta Y_{09}\%$	(1a)	(2a)	(3a)	(1b)	(2b)	(3b)	$\frac{\Sigma_i \mathbb{1}_i}{N}\%$	(4)
E(θ)	-1.010	-0.050	-0.129	-0.583	-0.015	-0.325	NB	4.3
E(0)	-0.508	-0.022	-0.119	-0.283	-0.003	-0.303	NL	31.8
$\mathcal{M}$	1.988	2.282	1.083	2.060	5.140	1.073	p-val	0.015

Note: This table documents the log-change in percent of aggregate output (Y) to financial shocks to sectoral bank interest premia in an economy with bank and supplier credit, E(θ) and with bank credit only, E(0) based on (a) model simulations and (b) the more general DRS-aggregation results of Proposition 5 with $M_i = 0 \forall i$ and $\tau = 1$. The multipliers, $\mathcal{M}$, are calculated as the ratio of output responses in E(θ) to their counterpart in E(0). Columns (1a,b) report the results to an aggregate financial shock imputed from the data; Using Definition 1, I divide sectors into net-lenders (NL) and -borrowers (NB) based on the median of their 2004-07 average net-lending position. Columns (2,3) consider a symmetric financial shock to only the top five (2a,b) net-lenders and (3a,b) net-borrowers. Columns (4) reports the percentage share of sectors in each group that satisfy the smoothing conditions ($\mathbb{1} = 1$) for changes in trade credit rates in Corollary 4 as well as the p-value of a difference in means test. The inequality conditions for each sector are evaluated by using the 2004-07 average of the data-counterparts of the respective elasticities.

Robustness Exercises. To address the concern that the results might be driven by asymmetries in trade credit linkages across sectors or shocks to sectoral bank interest premia, I report the results of two additional counterfactual exercises in Online Appendix E.4, Table E.3. The comparison of the responses of the benchmark economy with those of an economy featuring symmetric credit shares in equilibrium and symmetric shocks, respectively, suggests that both sources of asymmetries play a minor role in the propagation of liquidity shocks. Furthermore,

[29]In each case, I take into account the directionality of the condition depending on the sign of the more general DRS-elasticity of output with respect to changes in trade credit rates and shares.

the counterfactual exercises corresponding to Columns (1-3a) of Table 2, are also conducted for an equivalent economy without any credit management costs. This exercise addresses the concern that a constant demand for non-productive labor dampens the output effect in economy with bank finance only and thus overestimates the effect of trade credit linkages on output. The output responses reported in Table E.3 are similar in magnitudes, suggesting that the inclusion of fixed credit management costs had only little effects on the model comparisons and thus implied trade credit multiplier.

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. In this paper, I first show 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. During the 2007-08 Financial Crisis, liquidity in the trade credit market was severely affected and initially induced a compositional shift of short-term borrowing towards bank credit.

This paper introduces a multisector model in which profit-maximizing firms choose the composition of their borrowing portfolio to finance production and the share of their sales extended on trade credit to customers. The model thus features endogenous and interdependent distortions while capturing the characteristics of trade credit as a smoothing and amplification mechanism. I first provide novel aggregation results for financial shocks in an economy where firms act as financial intermediaries and effectively offer a costly subsidy of bank-finance to their customers in the form of trade credit. I then show that the net-lending position of a firm, defined as the ratio of a firm's accounts receivable to bank credit obtained to finance any working capital requirements, is informative for its systemic importance in the transmission of liquidity shocks.

In a quantitative application of the model to the US economy during the 2008-09 Great Recession, model simulations using only financial shocks capture approximately 39.3% 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 endogenous adjustment of trade credit cost and shares decreased both aggregate volatility and the 2009-output response by approximately 14.8% and 17.5%, respectively. Finally, I also quantitatively illustrate that a sector extending relatively more supplier credit than its upfront working capital requirements generates more spillovers.

In this paper, I have focused on the macroeconomic effects of endogenous financial linkages between firms along the intensive margin. However, as shown in Giannetti et al. (2021) or Giovannetti (2016), the ability of firms to access other credit markets and obtain trade credit also affects the formation of customer-supplier relationships between firms. This observation taken together with the analysis presented in this paper may provide interesting paths for the new growing literature investigating the endogenous link formation between economic agents (i.a. Oberfield, 2018; Acemoglu and Azar, 2020; Kopytov et al., 2022), which I leave to future research.

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