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

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April, 2026 [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) Firms smooth financial shocks by substituting bank and supplier finance. (2) A tightening of

[*]I would like to thank Vasco Carvalho for his invaluable guidance and support throughout this project. I greatly appreciate the insightful conversations and comments from Tiago Cavalcanti and Dan Cao. I have particularly benefited from discussions with Anil Ari, Charles Brendon, Minsu Chang, Giancarlo Corsetti, Anna Costello, Behzad Diba, Julian Di Giovanni, Elisa Faraglia, Chryssi Giannitsarou, Louise Laage, Andrei Levchenko, Alexander Rodnyansky, Cezar Santos and Flavio Toxvaerd. I also thank the seminar participants at the University of Cambridge, Michigan, Oxford, Amsterdam, Surrey, Helsinki, Universitat Pompeu Fabra and CREi, Bocconi, the University of Pennsylvania, Georgetown University, Nottingham, NHH, St.Louis Fed, the Sveriges Riksbank, Columbia University, CUNY Hunter College, the Federal Reserve Board, Imperial College, IDB, and the conference participants at the NOeG Annual Meeting in Graz, the BGSE Summer Forum, the SED at St.Louis and the MacCalm Conference for their helpful comments and suggestions. Financial support from the Economic and Social Research Council, the NOeG Dissertation Fellowship and INET is gratefully acknowledged. This paper builds on and includes material from Reischer's Ph.D. dissertation at the University of Cambridge (2019).

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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 investigates 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 in sales by internalizing the effect of delayed payments on their cost of bank finance.[1] 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 the equilibrium interactions of input-output- and credit-relations when firms operate with Cobb-

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

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 38.6% of the variation in aggregate output and 40.1% of the variation in supplier credit. The model also accounts for 77.6% of the decline in GDP and 95.1% 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 19.2% and dampened the drop in output during the 2008-09 crisis by 22.3%. 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 35.6% 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 of trade credit linkages between firms in a production network 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 are 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 framework introduced in Bocola and Bornstein (2023).[2]

Contrary to existing work, the tractability 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

This section presents empirical facts on the magnitude and cyclical properties of trade credit and its relation to other external financing sources in the US economy, with a focus on the 2008-09 financial crisis and recession. These patterns subsequently serve as an empirical benchmark for the model's quantitative predictions in Section 4.

To this end, I obtain the aggregate credit spread index constructed by Gilchrist and Zakrajšek (2012) as an indicator of tensions in the financial system and annual balance sheet data from Compustat for a panel of publicly-traded, non-financial U.S. firms from 1997 to 2016.[3] Aggregating across firms, accounts payable account for approximately 11.4% of total liabilities and 34.8% of current liabilities, consistent with existing evidence (see e.g. Rajan and Zingales, 1995; Giannetti, 2003). Total accounts payable correspond to approximately 4.6% of U.S. GDP, highlighting the relevance of supplier credit at the macro level.

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.[4] Panel (b) further

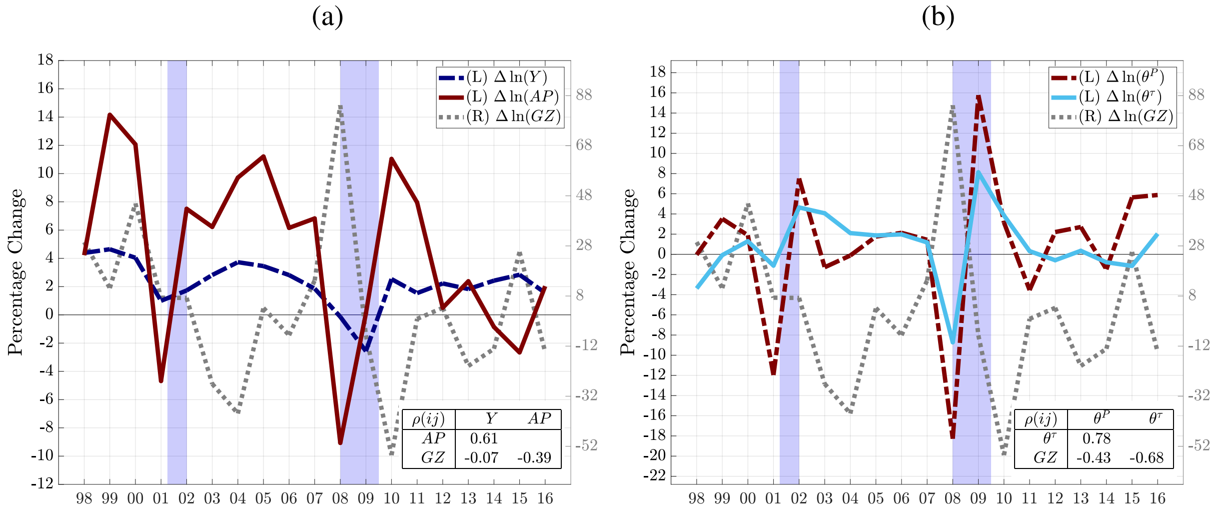
[2] Miranda-Pinto and Zhang (2023) also endogenize trade credit contracts in a non-competitive framework via nash-bargaining to study sectoral comovements during recessions.

[3] 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)

[4] The aggregate trade credit series in Figure 1 are constructed using a subset of firms with non-missing observations over the entire period of the sample of firms used to calibrate the model in Section 4. This ensures that the log-changes of financial variables are not driven by changes in the sample composition. I focus on total accounts payable since total accounts receivable 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.

depicts the log-changes of the share of accounts payable in total costs of production, θ^P, as well as in current liabilities, θ^τ.

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



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.

The three 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.

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

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

Third, 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 Scharfstein, 2010). The 2008 increase in C&I loans was followed by a sharp drop in 2009, as the tightening of lending standards in 2008 translated into a considerable decline in the availability of new credit lines.[5] Simultaneously, accounts payable increased, reversing the compositional shift as evident from Figure 1. These patterns suggests that trade credit and bank credit act as alternative sources of financing, with firms adjusting the composition of their liabilities in response to changes in financial conditions. (see e.g. Wilner, 2000; Cuñat, 2007; Amberg et al., 2021)

While the aggregate dynamics of total payables in Figure 1 are informative about the cyclical behavior of trade credit, they provide limited insight into cross-sectional heterogeneity in its use across firms. To capture this heterogeneity in a firm's simultaneous role as both a lender and a borrower, I now introduce the following summary measure derived from the theoretical framework in this paper.

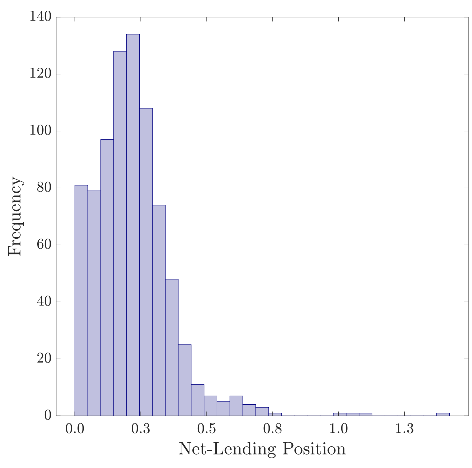
Definition 1. *The net-lending position of a firm i is defined as the ratio of total trade credit extended to customers (accounts receivable) to the difference between the total cost of production and trade credit obtained from suppliers (accounts payable).*

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.

Upon examining 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.

[5]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

Matrix Notation & Operations. In the remainder of the paper, matrices are denoted as bold capital and vectors as bold lower-case letters. Since the economy consists of N intermediate sectors, matrices are of dimension $(N \times N)$ and vectors of dimension $(N \times 1)$, unless otherwise specified. The transpose of a matrix $\boldsymbol{X}$ is denoted by $\boldsymbol{X}'$. The identity matrix is denoted by $\boldsymbol{I}$, and $\boldsymbol{\iota}$ denotes a vector of ones. In addition, the following matrix operations are used: $\circ$ denotes the Hadamard (element-wise) product, diag(.) maps a vector into a diagonal matrix, and inv(.) refers to the element-wise inverse of a matrix.

3. A Multisector Model with Financial Frictions

Motivated by the contraction of trade credit at the onset of the 2008-09 Great Recession, 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.[6] 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 the 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 in Bigio and La'O (2020) as a special case in the absence of credit linkages.

Production Structure. The economy consists of N intermediate sectors indexed by $i \in \mathcal{V} = \{1, ..., N\}$ producing N distinct 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. As the model is static, the mass of firms in each industry remains fixed. Since firms within a sector are assumed to be homogeneous, their behavior is summarized by means of a representative firm and the terms 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

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

[6]By abstracting from 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). In addition, I impose the timing restriction that credit markets and aggregate output contract simultaneously. Although output declined with a lag following the onset of the 2007-08 financial crisis (Figure 1a), this simplification reflects that (1) credit spreads increased sharply in the second half of 2008 and (2) the production plans of firms, and thus input demand, can be predetermined.

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, and χ_i is a returns-to-scale parameter of intermediate production. The technologies $\mathcal{Q}_i : \mathbb{R}^2_+ \rightarrow \mathbb{R}_+$, $\mathcal{X}_i : \mathbb{R}^N_+ \rightarrow \mathbb{R}_+$ for all $i \in \mathcal{V}$ and $\mathcal{F} : \mathbb{R}^N_+ \rightarrow \mathbb{R}_+$ 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 restrict $\chi_i \in (0,1]$, implying that q_i exhibits decreasing returns to scale (DRS) in its production inputs whenever $\chi_i < 1$. Productivity in each sector is given by $A_i = \exp(\varepsilon_i)\zeta_i$, where ε_i is a sector-specific productivity shock, and ζ_i is a normalization constant introduced for analytical convenience.

Intermediate good firms are also subject to the following constraint:

Assumption 1. *The production and delivery of products along the supply chain is such that 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 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 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 receive 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 input payments and the realization of revenues.

Financing Production. 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.[7] To manage its credit lines, a firm incurs administrative costs that require a non-productive labor input, ℓ_i^τ, discussed in more detail below. 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,

[7] Abstracting from internal funds simplifies the exposition without altering the mechanisms emphasized in this paper. If firms held liquidity at the beginning of a period, those internal funds would enter linearly into the working-capital constraint and result in a proportional reduction in external financing needs. Allowing for internal funds therefore leaves the structure of the credit wedges and the equilibrium conditions unchanged, while effectively rescaling the borrowing rates by the share of externally financed input costs.

firm i also extends trade credit to its customers at an interest rate r_i^τ. Its accounts receivable are given by $AR_i = \theta_i^c p_i q_i$, where the share of sales received after the delivery of goods and services, θ_i^c, is also chosen by firm i. While the production network is fixed and represents a technological requirement, the trade credit shares, θ_{is}, capture bilateral financing relationships between sectors that give rise to an endogenous credit network across intermediate good sectors along the intensive margin.

Intermediate Production and Trade Credit. Each industry constitutes a market in which transactions between firms involve the price of the goods sold and the cost of deferring payments in the form of trade credit. Neither sellers nor buyers have market power and take the price of the good and the interest rate on trade credit as given. The objective of the representative firm in sector i is to choose production inputs, $\ell_i, \boldsymbol{x}_{i:}$, its 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. Sectoral revenues are thus given by $R_i \equiv (1 + r_i^\tau \theta_i^c) p_i q_i$, and include both sales and interest income from trade credit. For the set of choice variables, $\mathcal{V}_i = \{\ell_i, \boldsymbol{x}_{i:}, \boldsymbol{\theta}_{i:}, \theta_i^c\}$, 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 face costs to manage their credit lines and extend trade credit to customers as I discuss in more detail below.[8] This allows 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 the cost function be given by*

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

[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).

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

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) and has three components. First, $\mathcal{m}_{0,i}$ represents fixed labor costs associated with the management of a firm's finances. Second, I introduce a linear cost component with a negative parameter, capturing that increased reliance on trade credit within existing supplier relationships reduces transaction costs, as suggested in the literature (Ferris, 1981). Third, as in Luo (2020), the quadratic cost term captures that it is costly for a firm to deviate from its targeted credit composition. If $\kappa_{0,is} = \kappa_{1,is} = 0 \ \forall i, s$, firms would able to adjust their credit portfolios frictionlessly and would choose only the cheapest credit source, $\theta_{is} \in \{0, 1\}$. Thus, the introduction of non-linear costs of managing 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.[9]

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, $\mathcal{R}_i(z_i, \theta_i^c) : (\mathbb{R}\times[0,1]) \rightarrow \mathbb{R}_+$, 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*

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

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 reduced form for analytical tractability, bank credit is supplied by a perfectly competitive banking sector with access to unlimited funds. Risk-neutral banks specialize in lending to a particular sector and incur monitoring costs. In this environment, the bank interest rate faced by firms in each sector is specified in Equation (7), which imposes that borrowing costs increase with the share of sales extended on trade credit.

The assumption that bank interest rates depend on the receivable share of firms, θ_i^c, is intended as a reduced-form representation of the monitoring and risk assessment costs of banks.

[9] In a recent contribution, Kopytov et al. (2022) endogenize 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 profit maximizing credit composition.

Since asset-based loan contracts or trade-finance agreements often involve accounts receivable (Lian and Ma, 2020; Ivashina et al., 2022; 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 sells its products on credit, its customers' failure to pay for already delivered goods and services jeopardizes the firm's ability to meet its own 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 summarized by the receivable share in sales.[10] The constant, d, captures a component of monitoring costs that is independent of firm-level cash flows. The functional form in Equation (7) can then be rationalized by solving the bank's profit maximization problem discussed in Online Appendix B.1.

A profit-maximizing firm in this model economy 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. Assumption 3 therefore limits the ability of firms to displace financial intermediaries and ensures an interior solution for the firm's choice of the share of receivables extended on trade credit.[11]

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 solves $\max_{\boldsymbol{c}} \ PF - \sum_i p_i c_i$, subject to the production function (2) and non-negativity constraints. The representative household derives utility from consumption, C, and disutility from labor supply, L. The utility function $U(C, L)$ is assumed to be separable in both arguments, with $U_C, (-U_L) > 0$ and $U_{CC}, U_{LL} < 0$, and satisfies the Inada conditions. The household chooses $\{C, L\}$ to maximize utility, $U(C, L)$, subject to the budget constraint

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

In equilibrium, the household's income - consisting of the total wage bill and non-labor income -

[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.

[11] While the sensitivity of bank borrowing costs to receivables may vary over the business cycle, the model abstracts from this margin. In a limiting case in which bank interest rates were independent of a firm's receivable share, extending more trade credit would generate additional intermediation revenues without increasing borrowing costs. The firm's optimality condition in Proposition 1 then implies that $r_i^\tau = 0 \forall i$. In this case, the firm is indifferent over its choice of trade credit share θ_i^c, which is instead determined in equilibrium by its customers' demand for trade credit and market clearing.

is spent on the aggregate consumption good. Following Liu (2019) and Bigio and La'O (2020), I allow for the possibility that only a fraction, $(1-\tau)$, of firm profits and bank interest payments is rebated to households, where $\tau \in [0,1]$. The remaining share of non-labor income, τ, accrues to bankers and the producers of the fixed factor, who spend it on the final good, H. I follow Liu (2019) and assume that bankers and the producers of the non-labor input incur costs such that they earn zero net utility. Their final consumption, H, then effectively constitutes a deadweight loss. As a result, aggregate output equals household consumption, $Y = C < F = C+H$, which is less than the quantity of the final good produced. While the parameter τ affects allocations, it is introduced as an accounting device to obtain a measure of aggregate GDP consistent with the data, and does not affect the model's propagation mechanisms qualitatively.

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

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

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

Summary and Discussion of Market Structure. The multisector-model introduced in this paper describes a short-run model of perfect competition with a fixed number of homogeneous firms in each industry. The production network is fixed and represents a technological requirement. The intermediate production technology exhibits decreasing returns to scale to account for a fixed factor in production in this static setting. As a result, firms earn positive profits used to cover non-productive labor expenditures and distributed to households. The economy features distortions in the form of working capital constraints, and production is financed using both bank and trade credit.

Since the paper focuses on the role of production and credit linkages at the sectoral level for the propagation of financial shocks, the model abstracts from any seller-buyer specific matching or contracting problems within each industry. Instead, I focus on industry aggregates by means of a 'representative firm'. As a result, the identity of a firm's supplier of inputs and associated delayed payments is an industry rather than a particular firm within that industry. Similarly, firms within an industry do not distinguish between customers when selling their output and extending trade credit. All customers of an industry thus face the same price of goods and interest rate on trade credit. This can also be interpreted as firms offering standardized payment terms to reduce their administrative burden.[12]

[12]Relatedly, in Cun et al. (2022), upstream firms choose the required down payment per unit of intermediate purchases, which is uniform across customers. Cun et al. (2022) motivate this modeling choice by the fact that a company's financial decisions - including trade credit policies - are often centralized. While transaction-level evidence suggests that payment terms can vary across customers (Costello, 2019), the unit of analysis in this paper is an industry, and I abstract from any within-industry heterogeneity to keep the model parsimonious and analytically tractable. However, I capture some heterogeneity in credit relationships between industries by imposing that the parameters $\kappa_{0,is}$ and $\kappa_{1,is}$ in the credit management cost function are specific to an industry-pair. These link-specific parameters can thus be interpreted as summarizing both the lender's and borrower's underlying characteristics at the industry level in a reduced form.

An industry in this model constitutes a market in which neither buyers nor sellers have market power. Firms take prices and trade credit interest rates as given, and production and financing decisions are determined by cost minimization. Customers of industry i choose the quantity of inputs to purchase, x_{ci}, while firm i chooses the quantity to produce, q_i. Trade credit decisions mirror standard input choices under perfect competition: Customer c chooses the *share of payments to postpone*, θ_{ci}, while firm i chooses the *share of total sales* that are received late, θ_i^c. Prices and trade credit rates are then determined to ensure market clearing in equilibrium. In the case of trade credit, this implies that in equilibrium firm i's receivable share equals the average share of payments postponed by i's customers, $\theta_i^c = \sum_c \frac{x_{ci}}{q_i}\theta_{ci}$.

As a result, changes in one customer industry's credit composition affect sector i's overall demand for trade credit and, in equilibrium, the interest rate on receivables faced by all customers. This captures that changes in extended trade credit to one customer will affect a firm's ability to lend to others, consistent with (Jacobson and von Schedvin, 2015; Costello, 2020).

Trade credit can also be interpreted 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 $\varrho(s) \equiv \left\{W, P, \{p_i, r_i^b, r_i^\tau\}_{i=1}^N\right\}$ and quantities $\xi(s) \equiv \left\{C, F, L, \{q_i, \ell_i, \ell_i^\tau, c_i, \theta_i^c, \{x_{is}, \theta_{is}\}_{s=1}^N\}_{i=1}^N\right\}$ 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 fully characterized in Proposition 1.

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

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

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 optimality conditions are satisfied $\forall s \in \mathcal{S}$:
(a) *the intermediate good producer i's 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 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 consumption-labor choice and the final good producer's 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.*

As an immediate corollary of Proposition 1, Corollary 1 characterizes the sectoral intermediate goods prices.

Corollary 1. *The goods price implied by firm i's first order conditions, $p_i = \frac{1}{\phi_i^R}\frac{MC_i}{MP_i}$, equals a mark-up over marginal costs including interest costs of financing production, where $MP_i \equiv \frac{\partial q_i}{\partial Q_i}$. The marginal cost function, $MC_i \equiv \mathcal{MC}_i(\,.\,) : (\mathbb{R}_+^{2(N+1)} \times [0,1]^N) \to \mathbb{R}_+$, is*

$$\mathcal{MC}_i(W, \boldsymbol{p}, \boldsymbol{r}_i, \boldsymbol{\theta}_{i:}) = \mathcal{Q}_i\left(\frac{\partial \ln(\mathcal{Q}_i)}{\partial \ln(\ell_i)}\frac{1}{\phi_i^L W}, \left\{\frac{\partial \ln(\mathcal{Q}_i)}{\partial \ln(x_{is})}\frac{1}{\phi_{is}^X p_s}\right\}_s\right)^{-1} \qquad (20)$$

and concave in interest rates, $\boldsymbol{r}_i = [r_i^b, r_1^\tau, ..., r_N^\tau]'$, and credit shares, $\boldsymbol{\theta}_{i:} = [\theta_{i1}, ..., \theta_{iN}]'$.

Consider first Equations (14) and (15). In each equation, the right-hand side denotes the relative marginal cost of labor and intermediate inputs, respectively, 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. This ratio of wedges distorts i's demand for inputs and subsequently also the household's and final good producer's equilibrium conditions in Equations (18) and (19). While it is well known that distortions manifest themselves as wedges in 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 offset such distortions.

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 equilibrium goods price characterized in Corollary 1. Since firm i finances its intermediate input expenditures using both bank and supplier credit, the resulting credit wedge, ϕ_{is}^X, is a weighted average of both interest rates, r_i^b and r_s^τ, with the weights depending on the credit share, θ_{is}. At the same time, the extension of trade credit increases the marginal revenue from an additional unit sold, as captured by the revenue wedge, ϕ_i^R. This revenue effect increases firm i's demand for inputs in Equations (14) and (15), while the goods price implied by firms' optimality conditions decreases. In equilibrium, the interest rate on trade credit and the goods price render firms indifferent between receiving their payments on delivery or with a delay.

Next, Equation (16) 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.

Lastly, Equation (17) characterizes the optimality condition corresponding to firm i's choice of the share of sales extended on trade credit and highlights the following trade-off: 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, as implied by Assumption 3. In equilibrium, the implied interest rate on trade credit, r_i^τ, equals the ratio of additional interest payments on bank loans following changes in the receivable share to revenues net of interest income from financial intermediation.

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 expenditures (including interest costs) 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 trade credit shares and costs in the Cobb-Douglas economy are then as in Corollary 2 and follow from Proposition 1.[13]

[13] A full characterization of the equilibrium in the Cobb-Douglas case is provided in Online Appendix B.3.

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

$$\theta_{is} = \underbrace{\left(\overline{\theta}_{is} - \frac{\kappa_{0,is}}{\kappa_{1,is}}\right)}_{\theta^{\kappa}_{is}} + \frac{1}{\kappa_{1,is}} \frac{(r^b_i - r^{\tau}_s)p_s x_{is}}{1+r^b_i} \quad \textit{and} \quad r^{\tau}_i = \frac{\mu r^z_i}{d+\theta^c_i}\frac{BC_i}{p_i q_i}. \tag{22, 23}$$

For ease of exposition, I now introduce additional notation and definitions.[14]

Definition 2. *Let $\mathbf{\Theta}$ denote the matrix of equilibrium trade credit shares with typical entry θ_{is}. The vector $\boldsymbol{\theta}_{i:}$ contains the i'th row and $\boldsymbol{\theta}_{:i}$ the i'th column entries of $\mathbf{\Theta}$.*
The vector of revenue wedges is given by $\boldsymbol{\phi}_R$, $\boldsymbol{\phi}_L$ denotes the vector of labor-credit wedges and $\mathbf{\Phi}_X$ equals the matrix of intermediate-credit wedges.
The vector of final demand shares is given by $\boldsymbol{\beta}$. The entries of the input-output (IO) matrix of expenditures shares, $\mathbf{\Gamma}$ are

$$\gamma_{is} = \omega_{is}(1-\eta_i)\chi_i \quad \textit{and} \quad \tilde{\chi}_i = \frac{WL_i + \sum_s (1+r^{\tau}_s\theta_{is})p_s x_{is}}{R_i} \tag{24}$$

defines an entry of the vector of costs (net of bank interest payments) shares in revenues, $\tilde{\boldsymbol{\chi}}$.
The revenue-based Leontief inverse is given by $\mathbf{L} = \left[\boldsymbol{I} - \mathbf{\Gamma}\right]^{-1}$.
The vector of sales shares in nominal output (Domar weights) is given by

$$\boldsymbol{\lambda} = \frac{\boldsymbol{R}}{PY} \quad \textit{and} \quad \boldsymbol{\lambda}_{\tau} = \mathbf{L}'\boldsymbol{\beta} = \frac{\boldsymbol{R} + \mathbf{L}'\boldsymbol{T}}{PF} \tag{25}$$

defines the vector of distortion-adjusted gross Domar weights, where $[\boldsymbol{T}]_i = \sum_c r^b_c(1-\theta_{ci})p_i x_{ci}$.
The aggregate labor income share in nominal GDP is defined as, $\Lambda = \frac{WL}{PY}$.

Next, I provide a characterization of equilibrium aggregate output by mapping the multi-sector framework to a representative firm and household economy, following Bigio and La'O (2020). As in Chari et al. (2007), the economy's distortions manifest themselves as aggregate efficiency and labor wedges, which in the present framework take the following form:

Proposition 2. *For given interest rates, $\boldsymbol{r} = [\,[r^b_1, ..., r^b_N], [r^{\tau}_1, ..., r^{\tau}_N]\,]'$, and credit linkages, $\mathbf{\Theta} = [\,\boldsymbol{\theta}_{1:}, ..., \boldsymbol{\theta}_{N:}\,]'$, the multisector economy characterized in Proposition 1 with Cobb-Douglas production technologies (21) and intersectoral trade, aggregates to a representative household and firm economy. Let Λ denote the aggregate labor income share, and let $\boldsymbol{\lambda}$ and $\boldsymbol{\lambda}_{\tau}$ denote the vectors of (distortion-adjusted gross) Domar weights as in Definition 2. The economy's aggregate production function is*

$$Y = Z\Phi_z L^{(1-a)}, \quad \textit{where} \quad \ln(\Phi_z) = -(1-a)\ln(\Lambda) - \boldsymbol{a}'\ln(\boldsymbol{\lambda}) - \boldsymbol{\lambda}'_{\tau}\ln(\boldsymbol{\phi}), \tag{26}$$

[14] I adopt the terminology introduced in Baqaee and Farhi (2019b) and Baqaee and Rubbo (2023) and distinguish between revenue- and cost-based IO-matrices as defined in both references.

and features DRS with non-labor share $a = \boldsymbol{a}'\boldsymbol{\iota} = \boldsymbol{\lambda}_\tau'\mathrm{diag}(\boldsymbol{\iota} - \boldsymbol{\chi})\boldsymbol{\iota}$*. The aggregate TFP wedge,* Φ_z*, introduces 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*

$$\ln(\boldsymbol{\phi}) \;=\; \mathrm{diag}(\boldsymbol{\eta} \circ \boldsymbol{\chi})\ln(\boldsymbol{\phi}_L) + (\boldsymbol{\Gamma} \circ \ln(\boldsymbol{\Phi}_X))\boldsymbol{\iota} - \ln(\boldsymbol{\phi}_R). \tag{27}$$

The aggregate labor wedge, Φ_λ*, is given by*

$$\frac{W}{P} \;=\; \Phi_\lambda(1-a)\frac{Y}{L}, \quad \textit{with} \quad \ln(\Phi_\lambda) \;=\; \ln(\Lambda) - \ln(1-a). \tag{28}$$

Proposition 2 characterizes how distortions in the form of working capital constraints shape aggregate wedges in this economy, and how decreasing returns to scale affect this mapping. The latter contribute to both the efficiency and labor wedges through $\boldsymbol{a}'\ln(\boldsymbol{\lambda})$ and $(1-a)$, respectively. The aggregate wedge due to financing frictions is a generalization of that in Bigio and La'O (2020) along two dimensions: (1) sectoral credit wedges are input-specific, and (2) credit costs are endogenous and interdependent. Furthermore, since firms earn revenues from extending trade credit, this additional income lowers goods prices, which partially offsets 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, $m_i = 0 \;\forall i$.[15] Finally, in the absence of working capital constraints, the equilibrium further simplifies to the frictionless case in Acemoglu et al. (2012).

Remarks. Proposition 2 complements previous work by Baqaee and Farhi (2019b) and Bigio and La'O (2020), in which non-productivity shocks affect sectoral wedges only directly via changes in exogenous mark-ups, taxes or bank financing costs. In contrast, in this paper firms endogenously adjust their trade credit shares, such that credit costs 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 the 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).

[15] 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.

3.2.1. The Micro-Propagation of Sectoral Shocks Revisited

With 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.[16]

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 both 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 introduces two opposing channels. The financial shock, c.p., leads to an increase in i's

(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 the corresponding 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 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 the interest rate charged on receivables increases, 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 noting: First, the strength of the amplification channel depends on the elasticity of the bank interest premium with respect to the share of revenues extended on trade credit, and thus on parametersμ and d. Second, the extent to which firms are able to smooth credit shocks depends on the cost parameter, $\kappa_{1,is}$, governing the convexity of the credit management cost function in Equation (6), 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.

[16] Lemmata B.6.2 and B.6.3 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.

Corollary 3 highlights that financial shocks affect bank and trade credit interest rates directly, while credit shares adjust only indirectly in response to changes in interest rates. Although financial shocks do not induce direct changes in credit shares, the interdependencies between interest rates and credit shares generate first-order feedback effects through a credit cost multiplier. This multiplier is characterized in detail in Online Appendix B.6.1 and subsequently applied in Proposition 4.

3.2.2. From Micro To Macro

While the previous exposition provided insights into the up- and downstream propagation channels induced 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 decompose changes in aggregate output into contributions from technology, labor, and allocative efficiency: Let $\boldsymbol{\varphi} = \big[[r_1^b, ..., r_N^b], [r_1^\tau, ..., r_N^\tau], [\boldsymbol{\theta}'_{1:}, ..., \boldsymbol{\theta}'_{N:}]\big]'$ denote the $(N(2+N)\times 1)$ vector of interest rates and credit shares. Further, let $\boldsymbol{\mathcal{X}}(\boldsymbol{\varepsilon}, L, \boldsymbol{\varphi})$ define a $(N+1)\times(N+1)$ allocation matrix with typical entry $\mathcal{X}_{ij} = \frac{x_{ij}}{q_j}$ denoting the share of output j used in the production of good i.[17] 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 $Y \equiv \mathcal{Y}(\boldsymbol{\varepsilon}, L, \boldsymbol{\mathcal{X}})$. Changes in output can then be decomposed as

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

In the following, I focus on how changes in credit costs and shares affect aggregate output. To characterize this mechanism, I introduce changes in relative interest rates, defined below.

Definition 3. *Let the expected changes in sector i's upstream interest costs on accounts payable be given by $\mathbb{E}_{\boldsymbol{w}}[d\boldsymbol{r}^\tau] = \sum_s w_{is} dr_s^\tau$, and let $\mathbb{E}_{\boldsymbol{w}}[d\boldsymbol{r}^b] = \sum_c w_{ci} dr_c^b$ denote the expected changes in downstream customers' interest costs on bank credit using the $(N\times 1)$- vector of weights $\boldsymbol{w}$ as the distribution. Changes in the relative upstream, $d\rho_i^b$, and downstream, $d\rho_i^\tau$, interest rates are then defined as*

$$d\rho_i^b(\boldsymbol{w}) = dr_i^b - \mathbb{E}_{\boldsymbol{w}}[d\boldsymbol{r}^\tau], \quad \textit{and} \quad d\rho_i^\tau(\boldsymbol{w}) = dr_i^\tau - \mathbb{E}_{\boldsymbol{w}}[d\boldsymbol{r}^b], \tag{29}$$

and characterize the response of sector i's bank and trade credit rate relative to expected changes in up- and downstream financing costs, respectively.

Building on Proposition 2, Proposition 3 provides a decomposition of first-order changes in real GDP. It shows how changes in up- and downstream credit costs and credit portfolio shares

[17] The first N rows and columns correspond to the intermediate goods producers, and the $(N+1)$'st to the final good producer. By construction, $\sum_i \mathcal{X}_{ij} = 1\ \forall j$.

can either dampen or amplify the effects of changes in allocative efficiency when firms extend costly trade credit to customers. The aggregation results in Proposition 3 thus complement those for inefficient economies in Baqaee and Farhi (2019b) and Baqaee and Rubbo (2023).

Proposition 3. *For given productivity shocks, ε, changes in labor $d\ln(L)$, credit costs and shares $d\boldsymbol{\varphi}$, and the sectoral composition of receivables, $dS_{\mathcal{X},i} = \sum_c \theta_{ci} d\mathcal{X}_{ci} \forall i$, the change in real GDP is*

$$d\ln(Y) = \underbrace{(\boldsymbol{\lambda}_\tau \circ \boldsymbol{\chi})'\boldsymbol{\varepsilon} + (1-a)d\ln(L)}_{\Delta \text{ Technology and Labor}} \underbrace{+\Delta AE_{L,S}(d\ln(L), d\boldsymbol{S}_{\mathcal{X}}) + \Delta AE_{\varphi}(\boldsymbol{\varphi})}_{\Delta AE \,=\, -(1-a)d\ln(\Lambda) - \boldsymbol{a}' d\ln(\boldsymbol{\lambda}) - \boldsymbol{\lambda}_\tau' d\ln(\boldsymbol{\phi})}. \tag{30}$$

Let changes in the upstream and downstream relative interest rates, $d\rho_i^b$ and $d\rho_i^\tau$, be as in Definition 3. Then changes in allocative efficiency due to changes in credit costs and shares can be decomposed as

$$\Delta AE_{\varphi}(\boldsymbol{\varphi}) = \frac{\partial \ln(\mathcal{Y})}{\partial \boldsymbol{\varphi}} d\boldsymbol{\varphi} = \underbrace{\sum_i \frac{\partial \ln(\mathcal{Y})}{\partial r_i^b} dr_i^b}_{\Delta \text{ Working Capital-Costs}} + \underbrace{\sum_i \frac{\partial \ln(\mathcal{Y})}{\partial r_i^\tau} dr_i^\tau}_{\Delta \text{ TC-Revenues}}$$
$$\underbrace{+\sum_i \frac{\partial \ln(\mathcal{Y})}{\partial \rho_i^b} d\rho_i^b}_{\Delta \text{ Upstream Rel. IRates}} \underbrace{+\sum_i \frac{\partial \ln(\mathcal{Y})}{\partial \rho_i^\tau} d\rho_i^\tau}_{\Delta \text{ Downstream Rel. IRates}} \underbrace{+\sum_{i,s} \frac{\partial \ln(\mathcal{Y})}{\partial \ln(\theta_{is})} d\ln(\theta_{is})}_{\Delta \text{ Credit Shares}}, \tag{31}$$

where the elasticities capture the combined first-order effects of changes in credit costs and shares on price wedges, labor income and sales shares, evaluated at equilibrium.

As in Baqaee and Farhi (2019b), aggregate changes can be decomposed into two components: (1) changes in technology and labor, and (2) changes in 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 to the sales-based Domar weights in efficient and the cost-based Domar weights in inefficient economies derived in Hulten (1978) and Baqaee and Farhi (2019b), respectively, the difference 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 (30) 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 sufficiently relative to the increase in the weighted sum of price wedges, ϕ. However, these effects do not arise from 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 are driven by changes in credit costs and shares, $d\boldsymbol{\varphi}$, and their indirect effects via changes in labor, $d\ln(L)$, and the composition of receivables, $d\boldsymbol{S}_{\mathcal{X}}$.

The direct effects are further decomposed into changes from interest rates and credit shares, as shown in Equation (31). The first term in Equation (31) 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 capture how trade credit can both dampen or amplify the initial negative output response to a financial shock. While Corollary 3 summarized the immediate up- and downstream effects of changes in interest rates and credit shares in response to an idiosyncratic financial shock, the following discussion focuses on how these channels interact through price and income effects.

Price Effects. Consider sectoral prices as characterized in Corollary 1. Both technology and financial shocks propagate downstream through changes in prices via cost- and demand channels. The demand-channel arises 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 lowering prices. The cost-channel is driven by changes in productivity, credit costs and shares: An increase in sector i's bank interest rate, r_i^b, unambiguously raises prices. This effect is mitigated when firm i obtains trade credit from its suppliers, and when i's bank interest rate rises by more than the weighted average interest rate paid on accounts payable such that $d\rho_i^b > 0$. Similarly, an increase in i's shares 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. Furthermore, higher interest income earned on receivables - arising from changes in i's interest rate charged on receivables or their composition - raises i's revenues from financial intermediation, thereby counteracting cost and demand effects that would otherwise increase 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, where wedges are inversely related to marginal costs. This contrasts the present set-up along two dimensions: (1) In this paper, changes in mark-ups (i.e. wedges between prices and marginal costs) arise from both revenue wedges and DRS, and are therefore 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 how credit costs and their composition affect sectoral revenues and cost shares, $\tilde{\boldsymbol{\chi}}$, which determine the share of revenues accruing as non-labor income and thus final demand. First, consider the effect of changes in interest rates and credit shares on sales, 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 thus 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, i's revenues decline when the increase in the trade credit rate exceed its customers' savings from postponing payments, $d\rho_i^\tau > 0$. On the other hand, i's revenues from financial intermediation increase. Changes in i's composition of receivables operate through the same channel. If the demand- outweigh the income effects from trade credit, the decline in intermediate demand for sectoral output decreases sales and, in turn, also non-labor income of households and GDP. Second, a decline in cost shares, $\tilde{\boldsymbol{\chi}}$, increases the share of revenues firms spend on interest payments on bank loans. Ceteris paribus, bankers' income from financial intermediation increases, thereby increasing final demand and subsequently sectoral sales and GDP.

Taken together, the previous discussion highlights that the aggregate effect of the trade credit-channel ultimately depends on the joint price and income effects of changes in interest rates on receivables, r_i^τ, up- and downstream relative interest rates, ρ_i^b and ρ_i^τ, and credit shares, θ_{is}.[16] To characterize the elasticities in Proposition 3 explicitly, I now consider the CRS case with $\boldsymbol{\chi} = \boldsymbol{\iota}$ such that $M_i = 0\, \forall i$, while imposing that all non-labor income represents a real resource cost. In this case, income effects vanish, so that the elasticities capture only price effects.[18] Closed-form expressions for the elasticities of output with respect to changes in sectoral interest rates and credit shares in the CRS case are given in Corollary 4.[19]

Corollary 4. *Consider the CRS case with $\chi_i = \tau = 1\, \forall i$. The elasticities of output with respect to changes in sectoral bank and trade credit interest rates are given by the $(N \times 1)$ vectors $\boldsymbol{n}_b$, and $\boldsymbol{n}_\tau$, whose i-th entries are*

$$\boldsymbol{n}_{b,i} \equiv -\frac{\partial \ln(\mathcal{Y})}{\partial \ln(r_i^b)}\bigg|_{CRS} = \boldsymbol{\lambda}_{\tau,i}\frac{r_i^b BC_i}{R_i}, \quad \text{and} \quad \boldsymbol{n}_{\tau,i} \equiv -\frac{\partial \ln(\mathcal{Y})}{\partial \ln(r_i^\tau)}\bigg|_{CRS} = \underbrace{\sum_c \boldsymbol{\lambda}_{\tau,c}\frac{r_i^\tau AR_{ci}}{R_c} - \boldsymbol{\lambda}_{\tau,i}\frac{r_i^\tau AR_i}{R_i}}_{\text{Downstream Costs } - \text{ Direct Revenue Effects}}.$$

The elasticity of output with respect to changes in i's share of inputs financed using trade credit

[18] In the CRS case, I effectively assume that, in equilibrium, the variable management costs are netted out by a negative fixed management cost/subsidy. If no non-labor income is re-distributed to households, i.e. $\tau = 1$, the aggregate labor share is equal to one and unaffected by any shocks. The DRS case, in which households receive both labor- and non-labor income, is discussed in the proof of Proposition 3 in the Online Appendix.

[19] 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)

from supplier s is given by the (i,s)-th entry of the $(N \times N)$ matrix $\boldsymbol{n}_\theta$ with

$$\boldsymbol{n}_{\theta,is} \equiv \left.\frac{\partial \ln(\mathcal{Y})}{\partial \ln(\theta_{is})}\right|_{CRS} = \underbrace{\left[\boldsymbol{\lambda}_{\tau,i}(r_i^b - r_s^\tau) + \boldsymbol{\lambda}_{\tau,s} r_s^\tau \frac{R_i}{R_s}\right] \frac{AP_{is}}{R_i}}_{i\text{'s Costs } + \text{ } s\text{'s Revenue Effects}} . \tag{32}$$

While the previous results treated the responses of interest rates and credit shares as exogenous, I now characterize their first-order equilibrium responses to financial shocks. The interdependencies of interest rates and credit shares give rise to a credit-cost multiplier (see Online Appendix B.6), which I approximate to first order to recover output responses to financial shocks. The resulting elasticity of output is characterized in Proposition 4 and provides an aggregation formula for the macroeconomic effects of financial shocks in inefficient economies, together with a decomposition of how allocative efficiency is affected when firms act as financial intermediaries. Each term in the elasticity has a direct empirical counterpart, which I exploit in Section 4.

Proposition 4. *For given productivity, labor, and receivable composition, the first-order change in aggregate output following an idiosyncratic financial shock to sector i's interest premium, evaluated under CRS, equals*

$$\left.\frac{\partial \ln(\mathcal{Y})}{\partial z_i}\right|_{\text{CRS}} \approx \underbrace{-\boldsymbol{n}_{b,i}\frac{r_i^z}{r_i^b} \overbrace{- \boldsymbol{n}_{\tau,i}}^{}}_{\text{direct effects}} \overbrace{-\text{FB}_{\tau,i} + \text{FB}_{\theta,i}}^{\text{TC-Mechanism}} \tag{33}$$

The first-order feedback effects operating through changes in trade credit interest rates are

$$\text{FB}_{\tau,i} = \underbrace{\boldsymbol{n}_{\tau,i}\left\{\frac{r_i^\tau AR_i}{R_i} - \left[\frac{W\ell_i}{BC_i}\frac{r_i^z W\ell_i}{TL_i} + \sum_s \frac{AP_{is}^-}{BC_i}\frac{r_i^z AP_{is}^-}{TX_{is}}\right]\right\}}_{\Delta\ i\text{'s TC-Rate}} \underbrace{- \sum_c \boldsymbol{n}_{\tau,c}\frac{AP_{ci}^-}{BC_c}\frac{r_i^\tau AR_{ci}}{TX_{ci}}}_{\Delta\ i\text{'s customers' TC-Rates}}, \tag{34}$$

and those through changes in i's and i's customers' credit shares along the intensive margin are

$$\text{FB}_{\theta,i} = \underbrace{\sum_s \boldsymbol{n}_{\theta,is}\frac{r_i^z \tilde{NP}_{is}}{AP_{is}} - \sum_c \boldsymbol{n}_{\theta,ci}\frac{r_i^\tau \tilde{NR}_{ci}}{AR_{ci}}}_{\Delta\text{ TC-Shares } (\Delta\text{ Interest Rates})} + \underbrace{\sum_{c,s} \boldsymbol{n}_{\theta,cs}\frac{NP_{cs}}{AP_{cs}}\frac{\partial \ln(R_c)}{\partial z_i}}_{\Delta\text{ TC-Shares } (\Delta\text{ Demand})}, \tag{35}$$

where $TL_i = \phi_i^L W\ell_i$ and $TX_{is} = \phi_{is}^X p_s x_s$ denote total expenditures on labor and intermediate inputs including interest payments, and $AP_{is}^- = (1-\theta_{is})p_s x_{is}$ denotes sector i's required up-front input payments. The interest-adjusted excess accounts payable, $\tilde{NP}_{is}$, and accounts receivable, $\tilde{NR}_{is}$, due to interest differentials, $NP_{is} = (\theta_{is} - \theta_{is}^\kappa)p_s x_{is}$, satisfy

$$\frac{\tilde{NP}_{is}}{NP_{is}} = \left[\frac{1}{(r_i^b - r_s^\tau)}\frac{1+r_s^\tau}{1+r_i^b} - \frac{(1-\theta_{is})}{\phi_{is}^X}\right], \quad \textit{and} \quad \frac{\tilde{NR}_{is}}{NP_{is}} = \left[\frac{1}{(r_i^b - r_s^\tau)} + \frac{\theta_{is}}{\phi_{is}^X}\right]. \tag{36}$$

The effect of changes in i's bank- and trade credit interest rates on sector c's sales is characterized in the proof.

Proposition 4 shows how the elasticity of aggregate output with respect to financial shocks depends on the equilibrium interactions of input-output- and credit-relations. Consider first the elasticities of output to changes in sector i's interest rate charged on receivables, $\boldsymbol{n}_{\tau,i}$, to changes in i's share of inputs financed using trade credit from supplier s, $\mathcal{n}_{\theta,is}$, characterized in Corollary 4. In both cases, the elasticities depend on the interaction between distortion-adjusted gross sales shares and the share of interest payments or income on receivables in sectoral sales.[20] Similarly, the first order feedback effects depicted in Equations (34) and (35) equal the product of two elasticities. The first is the elasticity of output with respect to changes in trade credit rates (shares), characterized by the entries of $\boldsymbol{n}_{\tau}$ ($\mathcal{n}_{\theta}$). The second is the elasticity of trade credit rates (shares) with respect to changes in interest rates following a financial shock. These elasticities depend on the composition of bank loans, payables and interest costs, capturing the following first order cost and demand effects.

Interest Rate Effects. Consider a financial shock to sector i's bank interest premium. Sector i's interest rate charged on receivables unambiguously increases. 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. This either dampens or amplifies the initial response, as captured by the first term in braces in Equation (34): On the one hand, an increase in i's interest rate on receivables shifts i's sales composition towards revenues from financial intermediation. This lowers i's product sales and further increases its trade credit rate. On the other hand, an increase in financing costs decreases i's demand for inputs and, consequently, the total amount of bank credit obtained, which decreases i's trade credit rate.[21] The latter mechanism also unambiguously decreases i's customers' interest rate charged on receivables to a first order, as captured by the second term in Equation (34).

Equation (35) summarizes how changes in relative credit costs and in the demand for sector i's output affect i's share of inputs obtained on trade credit from supplier s. While the demand-induced effects are ambiguous, the direct cost effects are straightforward and captured by the first two terms: For given intermediate expenditures, $p_s x_{is}$, an increase in i's cost of bank credit unambiguously induces a shift in the credit portfolio towards trade credit, whereas an increase in the interest rate charged on receivables by supplier s decreases the trade credit share. The compositional shift of short-term credit towards bank loans observed at the onset of the crisis discussed in Section 2 suggests that the cost of trade credit displayed a higher increase and may

[20]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)

[21]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.

be more volatile than bank lending rates.

3.2.3. Trade Credit-Channel Revisited

To resolve the ambiguity regarding the relative importance of its amplification and smoothing features, Corollary 5 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 5. *Let the aggregate output response to an idiosyncratic financial shock, $z_i > 0$, be given by Proposition 4 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*

$$\underbrace{\frac{\max\limits_{c\in\mathcal{C}_i}\big\{-\boldsymbol{n}_{\tau,c}\big\}}{-\boldsymbol{n}_{\tau,i}}}_{\frac{\Delta Y(\Delta c\text{'s TC-Rate})}{\Delta Y(\Delta i\text{'s TC-Rate})}} > \underbrace{\frac{1+\left(\eta_i^\tau - \min\left\{\frac{W\ell_i}{TL_i}, \frac{AP_{is}^-}{TX_{is}}\ \forall s\right\}\frac{R_i}{BC_i}\right)\frac{r_i^z BC_i}{R_i}}{\sum\limits_{c\in\mathcal{C}_i}\frac{AP_{ci}^-}{BC_c}\frac{r_i^\tau AR_{ci}}{TX_{ci}}}}_{-\frac{\Delta\ i\text{'s TC-Rate}}{\Delta\ i\text{'s customers' TC-Rates}}}, \quad \textit{where } \eta_i^\tau = \frac{r_i^\tau AR_i}{r_i^z BC_i} \tag{37}$$

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 (37) highlights that whether trade credit improves allocative efficiency in response to a financial shock depends on the relative magnitude of changes in 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 (37) 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 such that changes in their prices will have comparatively larger aggregate effects.[22] In particular, following an increase in a net-lender's interest rate on receivables, the

[22] See discussions in Sections 2 and 4, Footnote 34. 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.

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 (37) will be more frequently met by net-lenders, which is also confirmed quantitatively 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 D.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).[23] 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. Similar to the approach suggested in Altinoglu (2021), I construct a proxy of inter-industry credit flows as a weighted average of sectoral accounts receivable shares in sales, θ_s^R,and accounts payables shares

[23] Since I rely on the summary tables on the "Use of Commodities by Industries After Redefinitions" provided by the BEA, the model's static and closed-economy structure must be reconciled with national accounts that feature capital expenditures, a financial and real estate (FIRE) sector, and international trade. Specifically, capital is introduced as a fixed factor in production to match factor-income shares. FIRE expenditures are treated as a fixed share of capital income, and investments and net exports recorded in the IO tables are absorbed into final demand following Bigio and La'O (2020). However, in a small number of sectors, the discrepancies between domestic production and demand are treated as a residual, which can be interpreted as the activity of a competitive, zero-profit residual trader, to ensure that final demand remains positive. The consumption of the providers of FIRE services and the residual trader is then treated as a real resource cost. (see Bigio and La'O, 2020; Liu, 2019) Overall, these adjustments serve as a pure accounting device and do not affect the firms' or household's equilibrium choices and the model insights of Section 3 remain unchanged. The corresponding accounting equations used in the simulations are described in Online Appendices C and D.

in production costs, θ_i^P.[24]

$$\theta_{is} = \frac{R_s}{R_i + R_s}\theta_i^P + \frac{R_i}{R_i + R_s}\theta_s^R \tag{38}$$

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 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 - 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 treated as a real resource cost.

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. I discipline this fraction using sectoral data on employment and wages in occupations most directly related to the management of credit relationships with banks, customers, and suppliers provided by the Occupational Employment and Wage Statistics (OEWS) published by the BLS.[25]

The parameters of the cost function (6) are then calibrated in two steps. First, an estimate of average cost parameter, $\overline{\kappa}_1$, is obtained by estimating an aggregated version of Equation (22).[26] In a second step, the link-specific cost parameters, $\kappa_{1,is}$, are constructed using observed steady-state trade credit shares, imposing that a supplier-buyer relationship that exhibits a higher equilibrium trade credit share is associated with a lower cost parameter relative to the average. The linear component of the credit management costs represents any savings in transactions costs associated with obtaining trade credit from suppliers. (Ferris, 1981) These savings as given by the corresponding the cost parameter, $\kappa_{0,is}$, are disciplined by the firm's overall fixed credit management costs, $m_{0,i}$, and assumed to be proportional to observed intermediate input shares.

[24]Since accounts payable and receivable are stock variables, the resulting measure captures the average exposure of transactions within a sector to trade credit, aggregating over timings of payments and the prevalence of trade credit relationships. When mapping the model to the data, these transactions may include cross-border trade credit payments. However, the model is a closed economy and therefore features only domestic trade-credit relationships. To reconcile this with data, I enforce aggregate market clearing by interpreting the excess in imputed receivables as export-related trade credit and rescale sectoral receivables accordingly, as detailed in Online Appendix D.

[25]These occupation categories include: Financial Managers (11-3031), Credit (13-2041) and Financial Analysts (13-2051), First-Line Supervisors/Managers of Office and Admin Support Workers (43-1011), Billing and Posting Clerks (43-3021) and Bookkeeping, Accounting, and Auditing Clerks (43-3031).

[26] 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.

Equation (22) then implies that $m_{0,i}$ can be solved for directly and the linear cost parameters, $\kappa_{0,is}$, and benchmark credit shares, $\overline{\theta}_{is}$, follow.

Financial Parameters and Shocks. As a measure for the interest premium in Equation (7), I rely on 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 $\underline{r} = \min_{i,t}\{r^b_{it}\}$ over the entire sample period such that the implied premia are are given by $r^z_{it} = r^b_{it} - \underline{r}$. Shocks to the interest premium, z_i, are then imputed directly using Equation (7).[27]

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 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 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^z_t, calculated in Gilchrist and Zakrajšek (2012) at an quarterly frequency.[26]

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 4 and model simulations. First, I use the imputed financial shock series and the data counterparts of the respective variables to compute the 2004-07 average of the FOA of the elasticity of output in Proposition 4, for given productivity, labor, and composition of receivables. To this end, 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.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 is shut down by keeping the respective parameters at their four-year-average (2004-07) prior to the crisis.[23] Therefore, variation in the simulated responses of the economy across periods is driven solely by financial shocks.

[27] Interest premia constructed from data are equilibrium objects and may be determined by multiple underlying forces - including changes in firms' productivities - in addition to shifts in financial conditions. Therefore, the imputed financial shock series should be interpreted as capturing changes in sector-specific credit conditions, rather than 'pure' financial shocks orthogonal to real disturbances. In the quantitative analysis, these shocks then operate through changes in the cost of bank credit, which is the transmission channel emphasized in the model.

Model Fit. Figure 3 depicts the evolution of log-changes in aggregate output (Y), accounts payable including the costs of trade credit (TC), their share in short-term credit which equals total production costs in the context of the model (θ^{τ}), and the average sectoral bank interest rate obtained from model simulations (r^b). 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. The comparison of the model's aggregate predictions in column (GE) with their data counterparts across in Table 1 shows that, *quantitatively*, the model is able to account for 38.6% of the variation in output and 40.1% of the variation in supplier credit. The model also reproduces 61.6% of the fluctuations and accounts for 85.5% of the compositional shift towards bank credit during the crisis. The simulations further imply that changes in financial frictions alone account for approximately 77.6% of the decline in aggregate output during the 2008-09 Great Recession, suggesting that the contraction in output was largely driven by financial shocks. Notably, the first-order aggregation results based on Proposition 4 already capture 42.5% of the observed decline in the data.

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 sectoral trade credit linkages during the financial crisis.

TC-Mechanism. The first exercise addresses the question of whether, in an economy with both bank and trade finance, the smoothing or the amplification features of trade credit discussed in Section 3.2 dominate. To this end, I quantify its effect on aggregate outcomes during the crisis by comparing their responses and volatility in general and partial equilibrium. While the general equilibrium effects have been discussed in the context of the model-fit, the partial equilibrium effects - with slight abuse of language - refer to simulated responses obtained by holding either both trade credit rates and shares (PE$_R$), or the credit portfolio only (PE$_T$), at their pre-crisis (2004-07) averages. In reference to Proposition 4, Table 1 also reports the first-order output effects based on Equation (33), adjusted to account for price effects due to DRS: The PE$_R$-effects are computed using the first term, while the PE$_T$-are computed using the first three terms of the elasticity of output in Equation (33). The effect of endogenous adjustments in credit shares can then be isolated by comparing general equilibrium outcomes to those obtained when only the credit portfolio is held fixed (PE$_T$). In the context of Proposition 4, this difference reflects the feedback effects captured by the term FB$_\theta$.

The simulation results in Table 1 suggest that trade credit decreased aggregate volatility and the drop in real GDP by 19.2% and 22.3%, respectively, which was predominantly driven by the endogenous adjustment of credit shares.[28] While roughly half in size, the aggregation results of Proposition 4 yield similar insights and capture the decrease in allocative efficiency for given productivity, labor and composition of receivables. 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

[28]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.

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 following a decline in 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.

Panel (a) in Table 1 also reports the results of the same simulation exercise for changes in aggregate accounts payable (TC) and its share in total production costs (θ^{τ}). In either case, the PE_R-results imply that the effects of changes in demand had a negative but small effect on the respective variable. The simulations thus suggest that the decline in aggregate accounts payable and its share were predominantly driven by the decline in credit shares.

To further characterize how endogenous and interconnected wedges affect the response of aggregate output, Panel (b) of Table 1 also reports the responses of the aggregate labor and efficiency wedge, as defined in Proposition 2 and its counterpart in the online appendix for an economy including fixed capital, respectively.[29] First, the labor wedge declines, reflecting a decrease in the aggregate labor income share in final revenues. Second, the aggregate efficiency wedge also declines, consistent with the output response discussed above and its decomposition in Proposition 4. Equation (30) shows that the change in the efficiency wedge can be decomposed into changes in income shares, domar-weights, and the aggregate price wedge. The effect of the latter, $\Phi_{z|p} \equiv \exp(-\boldsymbol{\lambda}_{\tau}' \ln(\boldsymbol{\phi}))$, is also reported in Table 1 and suggests that the decline in the efficiency wedge was mainly driven by the increase in wedges affecting prices. By comparing the behavior of model-implied wedges in partial and general equilibrium, the simulations show that the endogenous adjustment of trade credit rates and shares dampened the decline in either wedge - consistent with the mechanism discussed above.

Lastly, Panel (b) of Table 1 reports the response of a measure of the economy's trade credit interconnectedness, b^{τ}. To this end, analogously to the input-output matrix in Definition 2, I define the trade credit network, $\mathcal{B}$, whose typical entry represents the expenditure share on accounts payable (including interest) in total credit. The economy's aggregate measure of trade credit interconnectedness is then defined as the sum of sectoral credit centralities

$$b^{\tau} = \boldsymbol{\beta}'\big[\boldsymbol{I} - \mathcal{B}\big]^{-1}\boldsymbol{\iota}, \quad \text{where} \quad [\mathcal{B}]_{is} = \frac{(1+r_s^{\tau})AP_{is}}{\mathit{Total\ Loans}_i}, \tag{39}$$

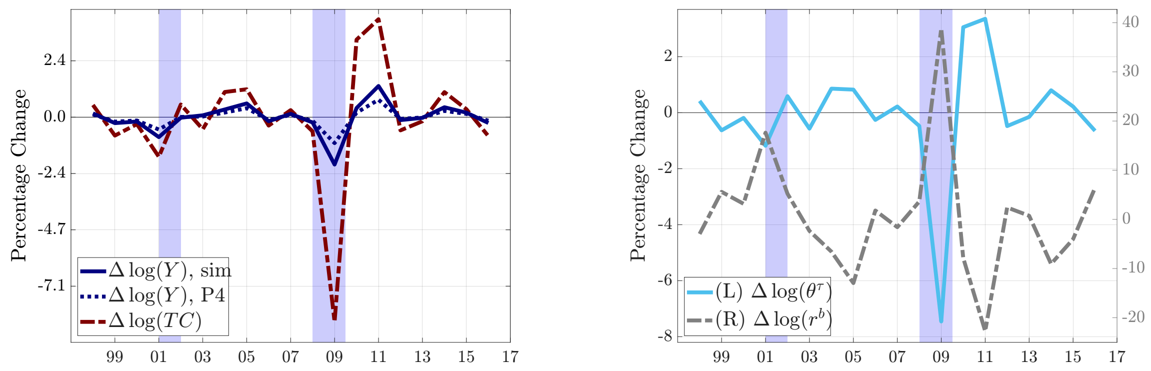
and an entry is of the inverse $\big[\boldsymbol{I} - \mathcal{B}\big]^{-1}$ captures all direct and indirect trade credit dependencies between sector i and s. The simulation results show that - consistent with the mechanism described above - as sectors adjust their credit portfolio in response to changes in financing conditions, the economy's interconnectedness via trade credit during the crisis declined. Since the underlying production network remains fixed and trade credit linkages adjust along the intensive

[29]Data counterparts for the model-generated wedges and the measure of trade credit interconnectedness are not directly observable and are thus constructed using the period-by-period mapping of the model to data described in Section 4.1.

margin, this decline reflects changes in the intensity of existing sectoral credit relationships.

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

(a) (b)



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.

Table 1: Decomposition of Trade Credit Mechanism

(a) 2009-Growth %

	Var	Data	Model		
			GE	PE_R	PE_T
P4	Y	-2.57	-1.09	-1.12	-1.11
(A) SIM	Y	-2.57	-1.99	-2.44	-2.40
	TC	-9.07*	-8.62	-2.88	7.21
	θ^τ	-8.72*	-7.46	-1.27	8.81
(B) SIM	Φ_λ	-0.85	-0.89	-1.81	-1.75
	Φ_z	-1.40	-1.53	-1.66	-1.63
	$\Phi_{z\|p}$	-0.97	-1.17	-1.54	-1.51
	b^τ	-9.50	-8.25	-1.21	10.14

(b) Volatility %

	Var	Data	Model		
			GE	PE_R	PE_T
P4	Y	1.67	0.37	0.38	0.38
(A) SIM	Y	1.67	0.65	0.77	0.76
	TC	6.20	2.49	0.90	2.21
	θ^τ	3.46	2.13	0.39	2.71
(B) SIM	Φ_λ	0.37	0.32	0.58	0.56
	Φ_z	3.10	0.49	0.52	0.51
	$\Phi_{z\|p}$	0.36	0.38	0.48	0.47
	b^τ	4.98	2.39	0.38	3.12

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 ($PE_{R,T}$) 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.

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 5 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 simulate the economy's responses when each sector at a time experiences an financial shock to its interest-premium of size $z_i = 0.1$

Panel (a) of Figure 3 depicts the results of this exercise by plotting the aggregate output responses against the net-lending position (in log-scales) of the affected sector. To account for the overall size of each sector, the aggregate output response is normalized by the affected sector's distortion adjusted-domar weight, λ_i^τ. The simulations show that 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, even after accounting for a sector's size.

To shed further light on the differential roles played by net-lenders and net-borrowers in the propagation of financial shocks, the 45 industries are split into net-lenders (NL) and net-borrowers (NB) based on the median of their net-lending position over 2004-2007 implied by a mapping of the model to the data and Definition 1 Panel (b) of Figure 3 then reports the group averages of the components of the output elasticity derived in Proposition 4 for the DRS case, following idiosyncratic financial shocks of size $z_i = 0.1$ applied to one sector at a time. Using the 2004-07 average of the data-counterparts of the elasticities of output, trade credit rates and shares, each bar depicts two measures of the average elasticity component in each group: The dashed bars correspond to the output-response to financial shocks due to direct and first order feedback effects of changes in the respective variable.The solid bars report the 'total effect', which equals the sum of the first-order response and all higher-order feedback effects. These higher-order effects are defined as the output effects of higher-order changes in the respective variable following a financial shock to a single sector, transmitted via their direct effects on credit rates and shares.[30]

The comparison of the blue bars in Panel (b), depicting the average output-response due to changes in bank-interest rates, shows that the response is stronger for net-borrowers than for net-lenders, consistent with the evidence presented in Panel(a) of Figure 3. This difference is due to the distortion-adjusted sales share and bank-dependency of net-borrowers being on average higher than those of net-lenders. A higher reliance on bank financing increases a sector's direct exposure to financial shocks and thus also the magnitude of the resulting output response.[31] The green and red bars in Panel (b) depict the output responses due to changes in trade credit rates and shares, respectively, normalized by the absolute value of the output elasticity with respect to bank rates. Three observations emerge. First, relative to bank interest rates, the output response due to changes in trade credit costs and shares is more pronounced following shocks to net-lenders than following shocks to net-borrowers. Second, declines in trade credit shares have a smoothing effect on output for both groups. Third, increases in trade credit rates exacerbate the negative

[30] Let $\boldsymbol{M} \equiv \frac{d\ln(\boldsymbol{\varphi})}{d\ln(\boldsymbol{\varphi})}$ denote the matrix of elasticities of interest rates and credit shares, $\boldsymbol{\varphi}$, and let $\boldsymbol{v}_i \equiv \frac{d\ln(\boldsymbol{\varphi})}{d\ln(\boldsymbol{z})}$ denote the vector of elasticities of financial variables to a financial shock to sector i. Let $\boldsymbol{n} \equiv \frac{d\ln(\mathcal{Y}}{d\ln(\boldsymbol{\varphi})}$ denote the vector of elasticities of aggregate output to interest rates and credit shares, $\boldsymbol{\varphi}$. The first-order and total output effects of changes in $v \in \boldsymbol{\varphi}$ are then given by

$$\text{FOA}_v \equiv [\boldsymbol{n}]_v[(\boldsymbol{I}+\boldsymbol{M})\boldsymbol{v}_i dz_i]_v \quad \text{and} \quad \text{Total Effect}_v \equiv \text{FOA}_v + \boldsymbol{n}'\boldsymbol{M}_{:v}[(\boldsymbol{\Psi}-\boldsymbol{I})\boldsymbol{v}_i dz_i]_v,$$

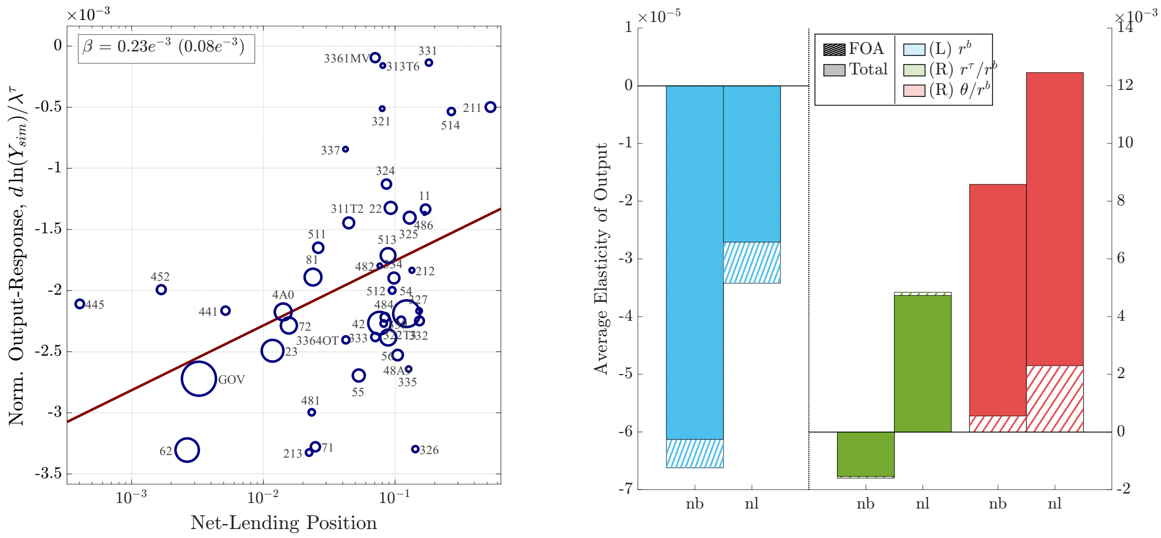
where $\boldsymbol{M}_{:v}$ corresponds to the columns of matrix $\boldsymbol{M}$ associated with variable v, and $\boldsymbol{\Psi} \equiv [\boldsymbol{I}-\boldsymbol{M}]^{-1}$ defines to the credit cost multiplier characterized in Online Appendix B.6.1. The first term FOA_v equals the first-order effects characterized in Proposition 4.

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

output response following shocks to net-borrowers, while they have a smoothing effect following shocks to net-lenders. This observation is consistent with Corollary 3, which provides a sufficient condition under which changes in trade credit rates improve allocative efficiency. Evaluating condition (37) for each sector using the 2004-07 average of the data-counterparts of each term, I find that about 4% of net-borrowers and 55% of net-lenders satisfy the condition.[32] A difference-in-means test further indicates 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. The intuition behind this result is that in case of a shock to a net-lender, the following positive income effect dominates any negative effects on output: As a firm reduces trade credit extended to customers, its interest rate on receivables increases. To make up for the loss in financial revenues, the firm shifts its sales composition towards product sales, lowering its output price thereby, ceteris paribus, mitigating any negative effects on output.

Figure 3: Quantitative Illustration of Proposition 4

(a) (b)



Note: Panel (a) plots the simulated response of real GDP (Y) to an idiosyncratic financial shocks $z_i = 0.1$ to sector i for $i \in \{1, ..., N\}$ scaled by the affected sector's distortion adjusted-domar weight, λ_i^{τ}, against the net-lending position (log-scale) of sectors. The size of one observation represents the relative importance of the sector in the economy measured by the share of a sector's average pre-crisis (2004-07) value added in total value added. The figure also reports the estimated slope of the fitted line and its standard-deviation in parenthesis. 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; Panel (b) reports the group averages of the components of the output elasticity in Proposition 4 for the DRS case, following idiosyncratic financial shocks of size $z_i = 0.1$ applied to one sector at a time for bank rates, trade credit rates and credit shares, where the latter are normalized by bank-rate elasticity. The dashed bars only take into account the first order feedback effects and the solid bars account for the total effect of the credit multiplier. (see Footnote 30)

[32]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.

TC-Multiplier. The last 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 the benchmark model with trade credit to those of an observationally equivalent economy without trade credit, in response to the same financial shock.[33] This comparison 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, $\mathrm{E}(0)$, and the Trade Credit Multiplier are defined below:

Definition 4. *An* ***equivalent economy****,* $\mathrm{E}(0)$*, to an economy with both production and credit linkages,* $\mathrm{E}(\theta)$*, features only production linkages but the same observed input prices net of any credit costs, nominal sales, input expenditures and value added as* $\mathrm{E}(\theta)$*.*

Definition 5. *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 (1) in Panel (a) of Table 2 reports the simulated percentage change in aggregate output in 2009 for the baseline economy introduced in Section 3 and its equivalent counterpart using the same financial shocks. Similarly, Column (1) in Panel (b) reports the results from the same exercise using the more general DRS-aggregation results of Proposition 4. The resulting trade credit multiplier for the aggregate output response is approximately 1.8, implying that the presence of a credit network substantially amplified the effects of financial distortions. Since the model featuring both production and credit linkages captures approximately 77.6% of the observed drop in real GDP, approximately 35.6% of the decline can be attributed to the existence of trade credit.

The intuition 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 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, the model simulations suggest that 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 financing, consistent with the data. 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, resulting in a multiplier greater than one.

Lastly, building on the previous exercise, I identify the top five net-borrowers and -lenders based on the 2004-07 average of their net-lending position.[34] A symmetric shock series, calculated as the average of shocks to sectoral interest premia, is then fed into both the baseline and bank-finance-only economy, affecting one group of sectors at a time. The aggregate output

[33] 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.

[34] 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).

responses and corresponding credit multipliers for net-lenders are reported in Column (2) of Table 2, and those for net-borrowers in Column (3). Relatedly, Figure 4 plots the trade credit multipliers for sector-specific shocks of size $z_i = 0.1$, against the affected sector's net-lending position. Table 2 and Figure 4 yield the following insight:

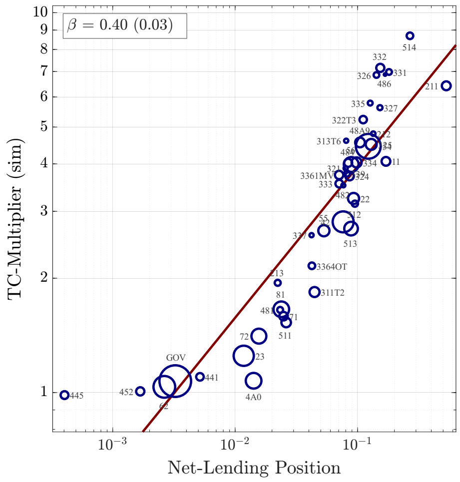
Financial shocks to net-lenders are more amplified relative to an economy with bank-finance only. The intuition behind this observation is that net-lenders have higher receivable shares in sales, such that their bank interest premia and immediate cost effects are significantly higher in comparison to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

Table 2: Trade Credit Multipliers

	$\Delta Y_{09}\%$	(1)	(2)	(3)
(A) SIM	E(θ)	-1.99	-0.09	-0.21
	E(0)	-1.08	-0.03	-0.19
	$\mathcal{M}$	1.85	2.94	1.09
(B) P4	E(θ)	-1.09	-0.02	-0.42
	E(0)	-0.52	-0.004	-0.39
	$\mathcal{M}$	2.12	6.12	1.07

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 4 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 (2) net-lenders and (3) net-borrowers.

Figure 4



Note: This figure plots the trade credit multipliers based on model simulations of aggregate output (Y) to an idiosyncratic financial shocks $z_i = 0.1$ affecting each sector at a time against the affected sector's 2004-07 average net-lending position (log-scales). The size of one observation represents the relative importance of the sector in the economy measured by the share of a sector's average pre-crisis (2004-07) value added in total value added. The estimated slope of the fitted line and corresponding standard-derviation in parenthesis are also reported.

Remarks. To summarize, the previous exercises highlight three key results: First, in an economy with both bank and trade credit, aggregate output would have declined even further if firms were unable to adjust trade credit obtained from suppliers and extended to customers. Second, while financial shocks affecting net-borrowers have a bigger effect on output than shocks to net-lenders, the smoothing feature of trade credit is more pronounced for net-lenders. Third, in comparison to an equivalent economy with bank-finance only, the existence of trade credit amplified the response of aggregate output via higher funding costs and interest premia, with a larger multiplier for net-lenders.

Robustness Exercises. In the following, I discuss various robustness exercises relative to the benchmark results. The results are reported in Online Appendix D.3, Table D.4.
First, to investigate how the *size of the imputed financial shocks* affects the benchmark results, I re-simulate the economy using financial shocks that are uniformly 10% smaller or larger than in the benchmark case. As expected, the responses of aggregate output, trade credit and wedges

are more muted for smaller shocks, and more pronounced for larger shocks. At the same time, the trade credit multipliers remain similar to the benchmark case. These results highlight that while the magnitude of financial shocks affects the quantitative response of the economy, the underlying propagation mechanism captured by the model remains qualitatively unchanged.

Second, I investigate the quantitative importance of *asymmetries* in trade credit linkages across sectors and in shocks to sectoral bank interest premia. The comparison of the benchmark economy to an economy featuring symmetric credit shares in equilibrium, and to an economy with symmetric shocks, suggests that either source of asymmetry plays a minor role in the propagation of liquidity shocks.

Third, when quantifying the effect of trade credit linkages on output, a potential concern is that the constant demand for non-productive labor in the equivalent bank-finance only economy dampens the output effect, thereby overstating the role of trade credit linkages. To address this concern, I alternatively consider an equivalent bank-finance only economy *without credit management costs*. The output responses reported in columns (1-3) in Table D.4 are similar in magnitude, suggesting that the inclusion of fixed credit management costs has only a minor effect on the implied trade credit multiplier.

In a final exercise, I investigate the response of the model economy to *productivity shocks* rather than financial shocks. To this end, I compare the results of two experiments. In the first, all sectors are subject to a uniform financial shock of $z_i = 0.1$, holding productivities fixed. In the second, all sectors experience a uniform 10 percent decline in productivity, $\varepsilon_i = -0.1$, while financial conditions remain at their 2004-07 pre-crisis average.

Productivity shocks have a substantially larger effect on output, as financial shocks of the same size are attenuated by a factor $(d+\theta_i^c)^\mu \mathbb{r}$ as implied by Equation (7). Unlike financial shocks, productivity shocks affect financial costs only indirectly through general equilibrium adjustments. The simulations suggest that negative productivity shocks induce an overall shift of the economy towards trade credit. As firms increase their share of sales extended on trade credit, their cost of bank-finance increase. In contrast to the case of financial shocks, the endogenous adjustment of credit shares generates a slightly larger decline in aggregate output.

However, the simulated aggregate output responses of an economy with both bank- and trade-finance and an otherwise equivalent economy with bank-finance only are nearly identical. This result is consistent with Proposition 3, which shows that the first-order output effects of productivity shocks depend on the distortion-adjusted sales shares, which by construction are identical across observationally equivalent economies.

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 77.6% 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 19.2% and 22.3%, respectively. Finally, I quantitatively show that a sector extending relatively more supplier credit than its upfront working capital requirements generates more spillovers compared to an economy without trade finance.

In this paper, I have focused on the macroeconomic effects of endogenous financial linkages between firms along the intensive margin. 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 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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