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

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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 for sectoral shocks in inefficient economies when distortions are interdependent due to endogenous trade credit linkages and costs. A quantitative application to the U.S. 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 with a higher ratio of trade credit extended to 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 and creates demand for ex-ante liquidity. It is thus common practice for suppliers to offer payment terms in the form of trade credit, allowing customers to delay payment until after the delivery of the product. As a result, trade credit represents an important alternative source of short-term financing to bank and financial market debt. (see Petersen and Rajan, 1997; Cuñat and García-Appendini, 2012) 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

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supplier finance. (2) A tightening of supplier financing terms deteriorates the credit conditions for customers and has adverse effects on maintaining production. However, how these forces interact in general multisector production networks with endogenous credit linkages and map into macroeconomic outcomes both theoretically and quantitatively is less well understood.

This paper studies how trade credit affects the propagation of financial shocks and aggregate output in a network economy. Building on a standard static general equilibrium multisector model of intermediate good trade with working capital constraints, I develop a tractable framework with endogenous trade credit linkages across sectors. I derive an analytical characterization of aggregate output and its response to shocks, which yields two main results: First, I show that the sufficient statistics for the aggregation of sectoral productivity and financial shocks depend jointly on the production and credit network of the economy. Second, by decomposing the response of aggregate output into the contributions of changes in the cost and composition of credit, I show how sectoral heterogeneity in the use and provision of trade credit shapes the extent to which trade credit amplifies or dampens financial shocks.

In a quantitative application of the model, I evaluate how trade credit contributed to the response of U.S. aggregate output to the financial shock during the 2008-09 Great Recession. The model's simulation results suggest that the endogenous adjustment of both the volume and the cost of trade credit dampened the decline in output by about 22%. However, relative to a counterfactual economy with bank finance only, the presence of trade credit amplified the overall response to the financial shock.

The model developed in this paper features perfectly competitive intermediate good producing firms in each sector, who act simultaneously as suppliers of goods and financial intermediaries, and finance their working capital using both bank and supplier credit. Firms endogenously choose the share of input expenditures financed using trade credit and the share of sales extended on trade credit to customers, taking prices and the cost of supplier credit as given. Bank interest rates are sector-specific, subject to shocks, and increasing in the share of receivables in sales.[1] Building on Bigio and La'O (2020), I first derive the aggregate production function implied by the equilibrium of this multisector framework for given credit costs and shares. I show that in the presence of working capital constraints, the relevant sufficient statistics for the aggregation of sectoral productivities and credit wedges differ from standard Domar weights and instead depend on sectors' shares of distortion-adjusted gross sales in final good sales. Since a sector's distortion-adjusted gross sales equal its own revenues plus the bank interest expenditures incurred by its direct and indirect customers when financing input purchases from that sector, aggregation requires information on the production and trade credit network of the economy. The sectoral credit wedges in this paper are a function of interest rates on both types of credit and credit shares, and therefore a generalization of those characterized in Bigio and La'O (2020). In addition, trade credit affects the propagation of a financial shock increasing a firm's bank in-

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

terest rate as follows: (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 reduces the share of receivables in sales by internalizing the effect of delayed payments on their cost of bank finance, which increases the interest rate on receivables. This affects both the firm's revenues from financial intermediation and the cost of production of downstream customers. The latter creates an amplification mechanism by which idiosyncratic shocks to the cost of bank credit are propagated both up- and downstream.

Following the derivation of the aggregate production function, I am able to characterize the first-order elasticity of aggregate output with respect to both productivity and financial shocks and obtain sufficient statistics for the opposing amplification and smoothing forces of trade credit. These depend on the equilibrium interaction between input-output relationships, sectors' credit compositions and receivables, capturing the costs and revenue effects of trade credit in response to changes in credit costs and shares. The analysis shows that 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 - provides a useful new summary measure of cross-sectional heterogeneity in sectors' dual role as borrowers and lenders in the transmission of financial shocks, with the following insights: First, the adjustment of trade credit rates and shares is more likely to smooth the output response to shocks affecting sectors with higher net-lending positions. Second, shocks to these sectors have smaller aggregate output effects because they tend to be more upstream and have lower value-added shares. Third, relative to an economy with bank-finance only, trade credit amplifies the output response to shocks, particularly for sectors with higher net-lending positions.

While the model yields analytical insights on how trade credit both amplifies and dampens the effect of financial shocks on aggregate output, the overall effect is ambiguous and remains a quantitative question. To this end, I calibrate the model to the production structure and the equilibrium inter-industry credit flows of the U.S. and evaluate its response to financial shocks to bank interest rates imputed from sectoral bond spreads derived in Gilchrist and Zakrajšek (2012). To assess their macroeconomic impact, I rely both on the aggregation results derived in the theoretical part of the paper and on model simulations, which yield the following results: First, the model captures about 38.6% of the variation in aggregate output and 40.1% of the variation in supplier credit. It also accounts for 77.6% of the decline in real GDP and 95.1% of the decline in aggregate accounts payable during the Great Recession. Second, the endogenous adjustment of the volume and cost of trade credit reduced aggregate volatility by 19.2% and dampened the 2008-09 decline in output by 22.3%. Consistent with the theoretical predictions of the model, I show that the smoothing effects of trade credit are quantitatively more pronounced for sectors with a higher net-lending position. Third, to isolate the macroeconomic effect of the existence of trade credit linkages, I define the trade credit multiplier as the ratio between the response of aggregate output to the same financial shock in an economy with both trade and bank finance to that in an equivalent economy with bank finance only. The latter corresponds to the economy in Bigio and La'O (2020). This counterfactual exercise suggests that the existence of the trade credit network 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 a financial shock to the five sectors with the highest net-lending positions generates a larger trade credit multiplier than an identical shock to the five sectors with the lowest net-lending positions. This supports the theoretical insights that firms acting as important financial intermediaries for their customers are systemically important.

Related Literature. Trade credit differs from other forms of short-term financing in that it arises directly from supplier-buyer relationships. Its contractual features have been studied primarily in the corporate- and trade finance literature, which analyzes how firm heterogeneity, contractual frictions, and repeated interactions shape firms' incentives to engage in financial intermediation and affect trade flows. (see Cuñat and García-Appendini, 2012; Allen et al., 2013; Giannetti, 2023; Foley and Manova, 2015, for surveys) This paper connects to this literature by studying the aggregate effects of trade credit. It develops a multisector general equilibrium framework with working capital constraints in which firms take trade credit terms as given and choose both the share of sales extended on and the share of inputs financed through trade credit, substituting between bank and supplier financing. In this setting, trade credit is interpreted as a tool that facilitates firms' cash management (Ferris, 1981; Emery, 1984).

The paper relates to the macro-literature on misallocation, production, and financial networks. In particular, it contributes to the literature investigating the aggregate effects of micro-level distortions and the propagation of shocks in economies with intermediate goods trade. While earlier work relied on simpler production structures (i.a. Chari, Kehoe and McGrattan, 2007; Jones, 2011), Jones (2013), Baqaee and Farhi (2019*a*,*b*), Bigio and La'O (2020) and Liu (2019) develop further insights by allowing for more general input-output relations and production technologies. The aggregation results developed in these papers imply that the sufficient statistics for aggregation in inefficient economies differ from standard Domar weights derived in Hulten (1978), since the elasticity of output with respect to changes in productivity and distortions depends on the network and exogenous wedges. (see Baqaee and Rubbo, 2023, for a review) This paper derives an aggregation result for sectoral productivity and financial shocks in economies with working capital constraints and endogenous trade credit. I show that the sufficient statistics for aggregation depend jointly on the economy's network structure of production and credit linkages. In particular, I characterize how trade credit introduces endogenous interdependencies in distortions, yielding insights into how such interdependencies can both dampen and amplify the aggregate 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 and its effect on the real economy became the main focus of a large strand of literature. (see i.a. Acemoglu, Ozdaglar and Tahbaz-Salehi, 2015; Chodorow-

Reich, 2014) More recent work examines how financial shocks originating in the banking sector propagate through production networks. Using detailed firm-level data for Spain and Brazil, respectively, Huremović et al. (2026) and Cortes, Van Doornik and Silva (2019) provide empirical evidence that production networks substantially amplify the effects of financial shocks, without explicitly examining trade credit as a transmission channel. The role of trade credit in 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); Garcia-Appendini and Montoriol-Garriga (2013); Jacobson and von Schedvin (2015); Cingano, Manaresi and Sette (2016); Costello (2020), and Alfaro, García-Santana and Moral-Benito (2021) provide empirical insights into its relevance for the transmission of 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 and constitute a relatively new research agenda.

A few recent papers study the role of trade credit in the propagation of shocks and its effects on aggregate fluctuations and output. Shao (2025) studies a one-sector economy with heterogeneous entrepreneurs that simultaneously borrow from and lend to one another to examine the role of credit reallocation across firms and their net trade credit positions for aggregate outcomes. By contrast, this paper studies trade credit in a general production network and analyzes how the transmission of financial shocks is affected by heterogeneity in sectors' positions within the production and credit network. The latter is captured by sectors' net-lending positions, defined here as the ratio of accounts receivable to upfront financing needs. A related set of papers studies trade credit between firms in a vertical production chain featuring one upstream and one downstream sector. Cun et al. (2022) investigate the role of trade credit in the transmission of monetary policy, with an application to the Chinese economy. Bocola and Bornstein (2023) embed the mechanism developed in Cuñat (2007) into a standard macroeconomic model with non-competitive contracting, and study the response of output in the Italian economy during the Great Recession. Hardy, Saffie and Simonovska (2022) develop a model with heterogeneous firms that extend state-contingent credit to analyze the role of trade credit as a macroeconomic stabilizer in emerging markets. The model developed in this paper, however, considers a general input-output and credit network, which allows the analysis of the implications of firms simultaneously postponing payments to upstream suppliers and extending trade credit to downstream customers for the propagation of shocks across sectors.

In this sense, this paper is more closely related to recent work studying trade credit in richer production network environments, in particular the prior work by Altinoglu (2021) and Luo (2020). Altinoglu (2021) constructs a model of trade credit in a competitive contracting environment with borrowing constraints arising from moral hazard. While trade credit is a fixed fraction of firm revenue in equilibrium in Altinoglu (2021), this paper emphasizes the endogenous adjustment of both the cost and volume of trade credit for the propagation of shocks. Luo (2020) studies the liquidity-sharing channel of trade credit in a model where firms choose the proportion of input payments financed with trade credit and can delay repayment of their accounts payable at a cost, while abstracting from modeling the extension of trade credit as an explicit choice. By contrast, this paper models firms' joint decisions to use and extend trade credit, with both its volume and sectoral interest rates on trade credit determined endogenously in equilibrium. Finally, Miranda-Pinto and Zhang (2023) endogenize trade credit through an optimal contracting problem with asymmetric information to study sectoral comovements during recessions, while Cazzaniga, Pannella and Alencar (2025) develop a model of Nash bargaining and heterogeneous financing conditions at the firm-level, to analyze the role of trade credit in Brazil during 2019-2023 using transaction-level data.

Relative to existing work, the tractability of the framework developed in this paper permits a closed-form characterization of the first-order response of aggregate output to financial shocks, thereby allowing both a theoretical and quantitative analysis of how heterogeneity in sectors' roles as intermediaries affects their propagation. In particular, the paper contributes to this literature by deriving conditions under which trade credit acts as a stabilizer or an amplifier of financial shocks in a general production network, depending on sectors' net-lending positions and their positions within the production network.

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 U.S. economy during the Great Recession. The Online Appendix contains all proofs and supporting material.

2. Trade Credit in the U.S. Economy

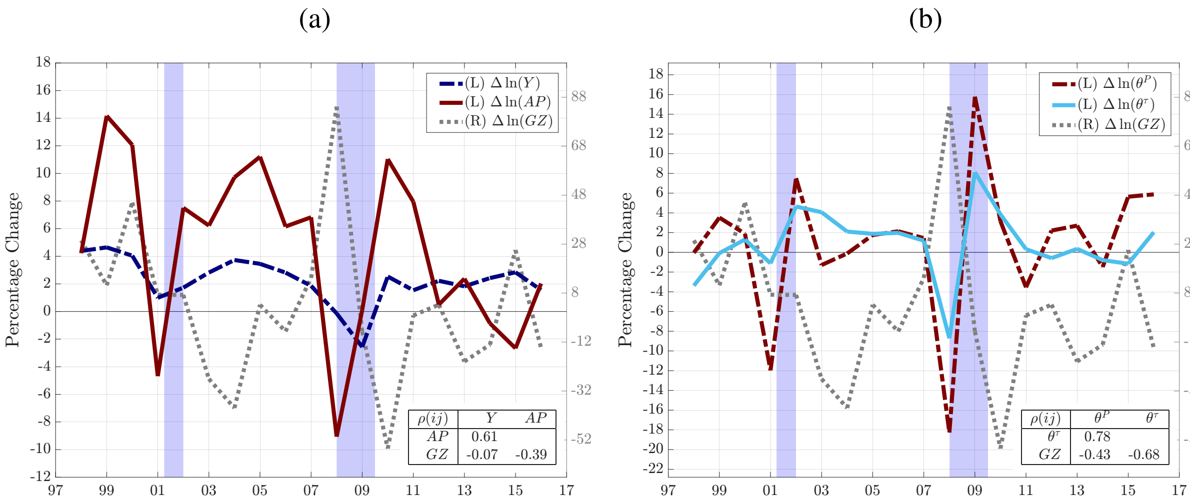
This section presents empirical facts on the magnitude and cyclical properties of trade credit and its relation to other external financing sources in the U.S. economy, with a focus on the 2008-09 financial crisis and recession. To this end, I obtain the aggregate credit spread index constructed by Gilchrist 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.[2] 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 quantitative relevance of supplier credit at the macro level.

Panel (a) of Figure 1 plots the evolution of log-changes in the aggregate GZ-spread, total accounts payable, AP, and GDP, Y, in 2007 dollars.[3] Panel (b) depicts the log-changes in the share of accounts payable in total costs of production, θ^P, as well as in current liabilities, θ^τ.

[2]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)

[3] The aggregate trade credit series in Figure 1 are constructed using a subset of firms from the calibration sample in Section 4 with non-missing observations over the entire period. This ensures that the log-changes in financial

Figure 1: Business Cycle Properties of Trade Credit in the U.S.



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 U.S. 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 U.S. 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 U.S. 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 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 toward 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. Figure 1b shows that the aggregate share of accounts payable in current liabilities declined during the 2008 financial crisis, indicating that liquidity in the trade credit market contracted. This observation is consistent with established empirical evidence that firms reduced their provision of supplier credit (Costello, 2020) while increasing their use of bank credit through drawdowns of pre-existing unused credit lines (Ivashina and Scharfstein, 2010), despite a tightening in overall credit conditions. These findings suggest that bank and trade credit serve 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)

Facts (F1)-(F3) document key aggregate patterns that motivate the modeling of trade credit and serve as empirical benchmarks for the quantitative analysis in Section 4. Together, they

variables are not driven by changes in the sample composition.

highlight the quantitative importance of trade credit in the U.S. economy as well as its potential to affect aggregate outcomes through changes in its level and the composition of current liabilities, particularly during periods of financial turmoil. The multisector model developed in the next section studies how trade credit shapes the propagation of financial shocks, allowing firms to substitute between bank and trade credit, consistent with the evidence above.

While the aggregate dynamics of payables in Figure 1 are informative about the cyclical behavior of trade credit, they provide limited insight into how its use varies across firms and sectors. Since trade credit arises from transactions between firms, its role in the propagation of financial shocks depends on the firms' positions within the production and credit network. A key contribution of this paper is to show both theoretically and quantitatively how cross-sectional heterogeneity in sectors' role as financial intermediaries interacts with the network structure to determine whether trade credit amplifies or dampens shocks. To capture 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.

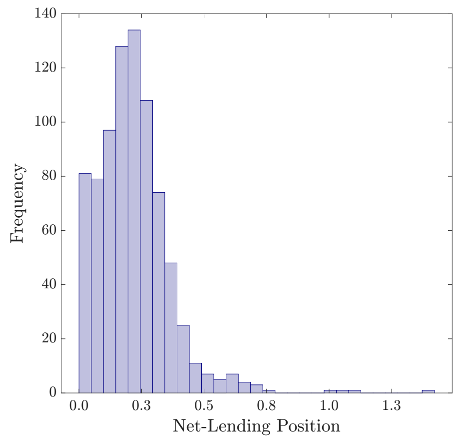
Definition 1. *The net-lending position of a firm i is defined as the ratio of total trade credit extended to customers (accounts receivable) to the difference between the total cost of production and trade credit obtained from suppliers (accounts payable).*

The net-lending position 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 sample of Compustat firms is depicted in Figure 2.[3]

(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 that 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 sectors for the propagation of financial shocks will be investigated in more detail in Sections 3 and 4.

Figure 2: TC-Usage of U.S. 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.

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 stated. 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 and diag(.) maps a vector into a diagonal 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.[4] 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

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

where $\boldsymbol{x}_{i:} = [x_{i1}\ x_{i2}\ \cdots\ x_{iN}]'$ and $\boldsymbol{c} = [c_1\ c_2\ \cdots\ c_N]'$ denote the vector of intermediate input purchases by firm i and the final good producer, respectively, and χ_i is a returns-to-scale parame-

[4] By abstracting from dynamics, this paper focuses on cross-sectional propagation patterns following a recent strand of literature, i.a. Baqaee and Farhi (2019*a*,*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 credit spreads increased sharply in the second half of 2008.

ter of intermediate production. 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. The technologies $\mathcal{Q}_i : \mathbb{R}^2_+ \to \mathbb{R}_+$, $\mathcal{X}_i : \mathbb{R}^N_+ \to \mathbb{R}_+$ for all $i \in \mathcal{V}$ and $\mathcal{F} : \mathbb{R}^N_+ \to \mathbb{R}_+$ are assumed to exhibit constant returns to scale (CRS), be twice continuously differentiable, feature positive and diminishing returns in all arguments, and satisfy $\mathcal{Q}_i(0,0) = \mathcal{X}_i(\mathbf{0}) = \mathcal{F}(\mathbf{0}) = 0$.

Financing Production. Intermediate good firms are subject to the following constraint:

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

Therefore, firms face a cash flow mismatch between input payments and the receipt of sales and the within-period timing is as follows: At the beginning of the period, both productivity and financial shocks to the cost of bank credit are realized such that there is no idiosyncratic or aggregate uncertainty. Firms then make their production and financing decisions. 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.[5] 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 until after receiving payments for its sales. At the same time, firm i also extends trade credit to its customers at an interest rate r_i^τ. In particular, firm i chooses the share of sales $\theta_i^c \in [0,1]$ for which payments are deferred, so that its accounts receivable are given by $AR_i = \theta_i^c p_i q_i$. Firms then receive these outstanding payments and repay their obligations to banks and suppliers at the end of the period. While the production network is fixed and represents a technological requirement, the trade credit shares, θ_{is}, capture bilateral financing relationships between intermediate good sectors that give rise to an endogenous credit network along the intensive margin.

[5] 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.

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 credit lines and extend trade credit to customers, as I discuss in more detail below. This allows me to keep the firm's optimization problem analytically tractable while capturing two features in data highlighted in Section 2: (1) Firms' short-term credit portfolios are composed of both bank and supplier credit, and (2) 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*

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

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 exogenous target 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 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, in the spirit of transactions-cost based explanations of trade credit (see e.g Ferris, 1981; Emery, 1984). Third, as in Luo (2020), the quadratic cost term captures the idea that it is costly for a firm to deviate from its target credit composition. If $\kappa_{0,is} = \kappa_{1,is} = 0 \ \forall is$, firms would be able to adjust their credit portfolios frictionlessly and choose only the cheapest credit source, $\theta_{is} \in \{0, 1\}$. Thus, the introduction of non-linear credit management costs ensures that firms maintain a credit portfolio mix of both bank and supplier credit in equilibrium, consistent with the empirical evidence in Section 2.[6]

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

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

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. Since asset-based loan contracts or trade finance agreements often involve accounts receivable (Lian and Ma, 2020; Ivashina, Laeven and Moral-Benito, 2022; Caglio, Darst and Kalemli-Özcan, 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, while the constant, d, corresponds to a component of their monitoring costs that does not vary with firms' receivable shares. Online Appendix B.1 presents a simple bank optimization problem that microfounds the functional form in Equation (7).[7]

[6]In a recent contribution, Kopytov et al. (2024) 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.

[7]I focus on the share of accounts receivable rather than payable based on the following reasoning: (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.[8] **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. 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

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

The aggregate wage is taken as the numeraire. In equilibrium, the household's income - consisting of the total wage bill and non-labor income - 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.

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 U.S. 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.

[8] The model abstracts from the possibility that the sensitivity of bank borrowing costs to receivables varies over the business cycle. In the limiting case in which bank interest rates are independent of a firm's receivable share, extending trade credit generates 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 the choice of its receivable share θ_i^c, which is instead determined in equilibrium by its customers' demand for trade credit and market clearing.

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

$$L = \sum_i \ell_i + \ell_i^\tau, \;\; q_i = c_i + \sum_c x_{ci}, \;\; \text{and} \;\; AR_i = \theta_i^c p_i q_i = \sum_c AP_{ci} \;\; \forall i \in \mathcal{V} \qquad (9, 10, 11)$$

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. This multisector model describes a short-run competitive economy with a fixed production network at the sectoral level. The economy features distortions in the form of working capital constraints, and production is financed using both bank and trade credit. 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.

Industries are perfectly competitive and populated by a fixed mass of homogeneous firms, so each industry can be represented by a 'representative firm'. The model thus abstracts from seller-buyer specific matching or contracting problems within industries. Consequently, firms transact at the industry rather than firm level: the supplier of inputs and associated delayed payments is an industry rather than a specific firm within that industry, and all customers of a given industry face the same goods price and trade credit terms.[9]

Firms take prices and trade credit interest rates as given when making production and financing decisions. Customers of industry i choose the quantity of inputs purchased, x_{ci}, and the *share of payments postponed*, θ_{ci}. Firm i chooses production, q_i, and the *share of total sales that is received late*, θ_i^c. Trade credit decisions therefore mirror standard input choices under perfect competition. 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).

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.

[9]While a number of studies show that sales and trade credit terms between individual buyers and sellers vary with relationship characteristics (see, e.g., Klapper, Laeven and Rajan, 2012; Costello, 2020; Benguria, Garcia-Marin and Schmidt-Eisenlohr, 2025), Klapper, Laeven and Rajan (2012) also show that, conditional on supplier fixed effects, credit terms offered by a given seller do not vary substantially across buyers. Relatedly, Cun et al. (2022) assume that upstream firms choose a uniform required down payment per unit of intermediate purchases across customers, motivated by the fact that a company's financial decisions - including trade credit policies - are often centralized. Since the unit of analysis in this paper is an industry, I abstract from any within-industry heterogeneity for tractability. Heterogeneity in credit relationships across industries is captured by industry-pair-specific parameters $\kappa_{0,is}$ and $\kappa_{1,is}$ in the credit management cost function.

3.1. Equilibrium Characterization

A realization of the aggregate state, $s = (\boldsymbol{\varepsilon}, \boldsymbol{z}) \in \mathcal{S}$, in this economy is given by vectors of exogenous and stochastic sectoral productivity and financial shocks, $\boldsymbol{\varepsilon} = [\varepsilon_1, ..., \varepsilon_N]'$ and $\boldsymbol{z} = [z_1, ..., z_N]'$, respectively. Furthermore, let an allocation, $\xi(s)$, and price system, $\varrho(s)$, 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 2. *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 is 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*

$$\phi_i^R \;=\; 1 + r_i^\tau \theta_i^c, \quad \phi_i^L \;=\; 1 + r_i^b \quad \textit{and} \quad \phi_{is}^X \;=\; 1 + (1-\theta_{is}) r_i^b + \theta_{is} r_s^\tau. \qquad (12, 13, 14)$$

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},

$$\textit{satisfy} \quad \frac{\phi_i^R}{\phi_i^L}\left(\chi_i \frac{q_i}{Q_i}\frac{\partial \mathcal{Q}_i}{\partial \ell_i}\right) = \frac{W}{p_i} \quad \textit{and} \quad \frac{\phi_i^R}{\phi_{is}^X}\left(\chi_i \frac{q_i}{Q_i}\frac{\partial \mathcal{Q}_i}{\partial x_{is}}\right) = \frac{p_s}{p_i} \quad \forall i, s \in \mathcal{V}. \qquad (15, 16)$$

(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

$$\frac{\partial \mathcal{M}_i}{\partial \theta_{is}} = \frac{r_i^b - r_s^\tau}{1 + r_i^b} p_s x_{is} \quad \textit{and} \quad r_i^\tau = \frac{\partial r_i^b}{\partial \theta_i^c}\frac{BC_i}{p_i q_i} \quad \forall i, s \in \mathcal{V}, \qquad (17, 18)$$

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

$$-\frac{U_L}{U_C} = \frac{W}{p_i}\frac{\partial \mathcal{F}}{\partial c_i} \quad \textit{and} \quad \left(\frac{\partial \mathcal{F}}{\partial c_i}\right)\left(\frac{\partial \mathcal{F}}{\partial c_j}\right)^{-1} = \frac{p_i}{p_j} \quad \forall i, j \in \mathcal{V}. \qquad (19, 20)$$

(d) the household's budget constraint (8) is satisfied, and markets (9),(10),(11) clear.

As an immediate corollary of Proposition 1, Corollary 1 characterizes the 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 $MP_i \equiv \frac{\partial q_i}{\partial \mathcal{Q}_i}$. The marginal cost function, $MC_i \equiv \mathcal{MC}_i(\,.\,) : (\mathbb{R}_+^{2(N+1)} \times [0,1]^N) \rightarrow \mathbb{R}_+$, is*

$$\mathcal{MC}_i(W, \boldsymbol{p}, \boldsymbol{r}_i, \boldsymbol{\theta}_{i:}) = \mathcal{Q}_i\left(\frac{\partial \ln(\mathcal{Q}_i)}{\partial \ln(\ell_i)}\frac{1}{\phi_i^L W}, \left\{\frac{\partial \ln(\mathcal{Q}_i)}{\partial \ln(x_{is})}\frac{1}{\phi_{is}^X p_s}\right\}_s\right)^{-1} \tag{21}$$

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 (15) and (16). 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 (19) and (20). While it is well known that distortions manifest themselves as wedges in equilibrium conditions (see Chari, Kehoe and McGrattan, 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 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 (15) and (16), 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.

Equation (17) 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 depends on the difference between the cost of bank and trade credit: when supplier credit is cheaper, a higher credit share lowers the marginal cost of production, 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. Finally, Equation (18) 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 revenues increase. On the other hand, the firm internalizes that its interest rate on bank credit and 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 induced by a higher receivable share to revenues net of interest income on receivables.

Aggregation in the Cobb-Douglas Economy. To obtain further analytical insights, I now parametrically specify the economy's production technologies

$$q_i = \Big(\exp(\varepsilon_i)\zeta_i \ell_i^{\eta_i} X_i^{1-\eta_i}\Big)^{\chi_i} \quad \text{with} \quad X_i = \prod_s x_{is}^{\omega_{is}} \quad \text{and} \quad F = \zeta_{N+1} \prod_i c_i^{\beta_i}, \tag{22}$$

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 sector i's total intermediate input use, with $\sum_s \omega_{is} = 1 \; \forall i \in \mathcal{V}$. 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 given by Corollary 2 and follow from the optimality conditions in Proposition 1.

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*

$$\theta_{is} = \underbrace{\left(\overline{\theta}_{is} - \frac{\kappa_{0,is}}{\kappa_{1,is}}\right)}_{\theta_{is}^{\kappa}} + \frac{1}{\kappa_{1,is}} \frac{(r_i^b - r_s^\tau) p_s x_{is}}{1 + r_i^b} \quad \textit{and} \quad r_i^\tau = \frac{\mu r_i^z}{d + \theta_i^c} \frac{BC_i}{p_i q_i}. \tag{23, 24}$$

Since the remainder of the paper focuses on the Cobb-Douglas case, I now introduce additional notation and definitions to simplify the exposition. [10]

Definition 3. *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

$$\gamma_{is} = \omega_{is}(1 - \eta_i)\chi_i = \frac{\phi_{is}^X p_s x_{is}}{R_i}, \quad \textit{and} \quad \tilde{\chi}_i = \frac{WL_i + \sum_s (1 + r_s^\tau \theta_{is}) p_s x_{is}}{R_i} \tag{25}$$

defines an entry of the vector of cost (net of bank interest payments) shares in revenues, $\tilde{\boldsymbol{\chi}}$. The revenue-based Leontief inverse is given by $\mathbf{L} = \big[\boldsymbol{I} - \mathbf{\Gamma}\big]^{-1}$. [11]

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

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

Let $\boldsymbol{R} = [R_1, ..., R_N]'$ *denote the vector of sectoral revenues. The vector of Domar weights is*

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

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

Next, I provide a characterization of equilibrium aggregate output by mapping the multisector framework to a representative firm and household economy, following Bigio and La'O (2020). As in Chari, Kehoe and McGrattan (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,* $\boldsymbol{r} = [\,[r_1^b, ..., r_N^b], [r_1^\tau, ..., r_N^\tau]\,]'$*, and credit shares,* $\boldsymbol{\Theta} = [\,\boldsymbol{\theta}_{1:}, ..., \boldsymbol{\theta}_{N:}\,]'$*, the multisector economy characterized in Proposition 1 with Cobb-Douglas production technologies (22) and intersectoral trade, aggregates to a representative household and firm economy. Let the aggregate labor income shares, and the vectors of (distortion-adjusted gross) Domar weights be as in Definition 3. Aggregate output satisfies*

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

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

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

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

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

Two main results follow from Proposition 2: First, the sufficient statistics for aggregating sectoral productivities and credit wedges are given by distortion-adjusted gross Domar weights, $\boldsymbol{\lambda}_\tau$. In contrast to standard Domar weights, these correspond to distortion-adjusted gross sales shares which include both a sector's own revenues and the bank interest payments of its direct and indirect customers associated with financing their input purchases as shown in Equation (26). The difference arises because firms finance working capital with costly bank credit, so that part of their revenues is used to service interest payments. As a result, both the production and credit network matter for aggregation. Note that 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 incur costs to manage credit lines, $\mathcal{m}_i = 0 \;\forall i$.[12] In the absence of working capital constraints, the equilibrium further simplifies to the frictionless case in Acemoglu et al. (2012) and the relevant sufficient statistic for aggregation again corresponds to the Domar weight.

Second, 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. Moreover, firms earn revenues from extending trade credit. This additional income lowers goods prices and partially offsets the misallocative effect of financing costs on aggregate output.

Proposition 2 thus complements related aggregation results for inefficient economies in Jones (2013), Baqaee and Farhi (2019*b*), Bigio and La'O (2020) and Liu (2019), where the sufficient statistics depend on the network and exogenous wedges, such that non-productivity shocks in these frameworks affect sectoral and aggregate wedges only via direct changes in exogenous mark-ups, taxes or bank financing costs. In contrast, wedges in this environment are interdependent through endogenous trade credit linkages. As firms adjust their trade credit shares, both credit costs and financial linkages evolve endogenously, altering the transmission of shocks. Financial shocks therefore have both direct and indirect effects on sectoral wedges, generating 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 contributions by Baqaee and Farhi (2019*b*); Bigio and La'O (2020) and Baqaee and Rubbo (2023).

3.2.1. The Micro-Propagation of Sectoral Shocks Revisited

With reference to the optimality conditions in Proposition 1, Corollary 3 first describes how trade credit can both dampen and amplify the first-round response of sectoral output to an idiosyncratic liquidity shock.[13]

[12]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.

[13] Lemma B.6.2 and B.6.3 in the Online Appendix characterize 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 shock propagation in Baqaee and Rubbo (2023)) in the Cobb-Douglas economy.

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 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 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 outlines 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. This corresponds to the propagation pattern of 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 responses of i's trade credit costs and shares distort the up- and downstream transmission of the financial shock: On the one hand, the increase in the interest rate on receivables amplifies the cost shock to downstream customers beyond the traditional price channel. On the other hand, the ability to substitute between bank and supplier credit dampens sector i's own cost increase and the upstream demand effects.

Two points are worth highlighting: First, the strength of the amplification channel depends on the elasticity of the bank interest premium with respect to the share of sales extended on trade credit, and thus on parameters μ and d. Second, the extent to which firms are able to smooth credit shocks depends on the parameter, $\kappa_{1,is}$, governing the convexity of the credit management cost function in Equation (6), as well as the type of shock. While an idiosyncratic financial shock to firm i affects its suppliers' trade credit rates only indirectly through general equilibrium effects, an aggregate shock directly affects the trade credit rates of all firms.

Corollary 3 further illustrates that financial shocks affect bank and trade credit interest rates directly, whereas 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 feedback effects through a credit cost multiplier. This multiplier is characterized in Online Appendix B.6 and used 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 (2019*b*) and decompose changes in aggregate output into contributions from technology, labor, and allocative efficiency: Let $\boldsymbol{\varphi} = \left[[r_1^b, ..., r_N^b], [r_1^\tau, ..., r_N^\tau], [\boldsymbol{\theta}_{1:}', ..., \boldsymbol{\theta}_{N:}'] \right]'$ denote the $(N(2+N) \times 1)$ vector of interest rates and credit shares. 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.[14] 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 4. *Let $\sum_s w_{is} dr_s^\tau$ denote the weighted average change in sector i's upstream interest costs on accounts payable, and $\sum_c w_{ci} dr_c^b$ the weighted average change in its customers' bank financing costs. The weights w_{is} and w_{ci} capture sector i's exposure to upstream suppliers and downstream customers, respectively, with $\sum_s w_{is} = 1$ and $\sum_c w_{ci} = 1$. Changes in sector i's relative up- and downstream interest rates, $d\rho_i^b$ and $d\rho_i^\tau$, respectively, are then defined as*

$$d\rho_i^b = dr_i^b - \sum_s w_{is} dr_s^\tau, \quad \textit{and} \quad d\rho_i^\tau = dr_i^\tau - \sum_c w_{ci} dr_c^b. \tag{30}$$

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 can either dampen or amplify 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 (2019*b*) and Baqaee and Rubbo (2023).

Proposition 3. *For given productivity shocks, $\boldsymbol{\varepsilon}$, 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 first-order change in real GDP is*

$$d\ln(Y) \;\approx\; \underbrace{(\boldsymbol{\lambda}_\tau \circ \boldsymbol{\chi})'\boldsymbol{\varepsilon} + (1-a)d\ln(L)}_{\Delta\ \textit{Technology and Labor}} \; \underbrace{+\Delta AE_{L,S}(d\ln(L), d\boldsymbol{S}_{\mathcal{X}}) + \Delta AE_{\varphi}(d\boldsymbol{\varphi})}_{\Delta\ AE \;=\; -(1-a)d\ln(\Lambda) - \boldsymbol{a}' d\ln(\boldsymbol{\lambda}) - \boldsymbol{\lambda}_\tau' d\ln(\boldsymbol{\phi})}. \tag{31}$$

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

Let changes in relative up- and downstream interest rates, $d\rho_i^b$ and $d\rho_i^\tau$, be as in Definition 4. Changes in allocative efficiency due to changes in credit costs and shares are decomposed as

$$\frac{\partial \ln(\mathcal{Y})}{\partial \boldsymbol{\varphi}} d\boldsymbol{\varphi} \approx \Delta AE_\varphi(d\boldsymbol{\varphi}) = \underbrace{\sum_i \frac{\partial \ln(\mathcal{Y})}{\partial r_i^b} dr_i^b}_{\Delta \textit{ Working Capital-Costs}} \underbrace{+ \sum_i \frac{\partial \ln(\mathcal{Y})}{\partial r_i^\tau} dr_i^\tau}_{\Delta \textit{ TC-Revenues}}$$
$$\underbrace{+ \sum_i \frac{\partial \ln(\mathcal{Y})}{\partial \rho_i^b} d\rho_i^b}_{\Delta \textit{ Rel. Upstream IRates}} \underbrace{+ \sum_i \frac{\partial \ln(\mathcal{Y})}{\partial \rho_i^\tau} d\rho_i^\tau}_{\Delta \textit{ Rel. Downstream IRates}} \underbrace{+ \sum_{i,s} \frac{\partial \ln(\mathcal{Y})}{\partial \ln(\theta_{is})} d\ln(\theta_{is})}_{\Delta \textit{ Credit Shares}}, \tag{32}$$

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

As in Baqaee and Farhi (2019*b*), aggregate changes can be decomposed into two components: (1) changes in technology and labor, and (2) changes in allocations. The decomposition in Proposition 3 allows for three main insights: First, the effects of sectoral technology shocks on aggregate output are proportional to sectors' expenditure shares on variable inputs, $\boldsymbol{\chi}$, and their distortion-adjusted gross Domar weights, $\boldsymbol{\lambda}_\tau$, characterized in Equation (26). As discussed following Proposition 2, these weights imply that the production and credit network jointly matters to a first order for aggregation.

Second, Equation (31) shows that the reallocation effect can be positive if the labor share in GDP, Λ, and the weighted sum of sectoral Domar weights, $\boldsymbol{\lambda}$, decrease sufficiently relative to an increase in the weighted sum of price wedges, $\boldsymbol{\phi}$. 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.

Third, Equation (32) decomposes the reallocation effects into contributions from interest rates and credit shares. The first term captures the effects of changes in bank financing costs that are also present in an economy with bank finance only. The remaining terms isolate the additional channels introduced by trade credit, operating through changes in interest rates on receivables, r_i^τ, relative up- and downstream interest rates, ρ_i^b and ρ_i^τ, and credit shares, θ_{is}. While Corollary 3 summarizes 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 they interact through changes in prices, revenues and income shares.[13]

Consider *sectoral prices* as characterized in Corollary 1. Both technology and financial shocks propagate downstream through changes in prices via demand- and cost-channels. The demand-channel arises due to DRS and dampens the effect 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, and when its bank financing costs rise by more than the weighted average interest rate on accounts payable, implying $d\rho_i^b > 0$. 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. In addition, increases in i's demand for or in its interest rate on receivables raise i's revenue from financial intermediation, lowering i's price. I refer to this as the revenue effect, which counteracts cost and demand effects increasing prices.

While such dampening effects on prices are not present in Baqaee and Farhi (2019*b*) 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 between prices and marginal costs are inversely related to marginal costs. In contrast, such wedges in the present framework arise from both DRS and interest income on receivables, and therefore depend on changes in demand and endogenously determined up- and downstream credit costs and shares.

Changes in the aggregate labor income share and sectoral Domar weights depend on how credit costs and their composition affect sectoral revenues and cost shares, $\tilde{\boldsymbol{\chi}}$, as characterized in Definition 3. First, consider the effect of changes in interest rates and credit shares on sectoral sales, taking cost shares as given. An increase in the bank interest rate faced by sector i's customers, r_c^b, unambiguously lowers their demand and i's sales. The effect of an increase in i's interest rate charged on receivables, r_i^τ, is twofold and ambiguous: On the one hand, i's revenues decline when the increase in the trade credit rate exceeds 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 revenue effects from trade credit, the decline in intermediate demand reduces sectoral sales and, in turn, also non-labor income of households and GDP. Second, changes in cost shares $\tilde{\boldsymbol{\chi}}$ determine the share of revenues accruing as non-labor income and thereby final demand: A decline in cost shares increases the share of revenues firms spend on interest payments on bank loans. Increases in bankers' income from financial intermediation increase final demand and subsequently sectoral sales and GDP.

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, effects operating through changes in labor income shares and Domar weights are shut down.[15] The elasticities of output with respect to sectoral interest rates and credit shares then capture only price effects and are as follows:

[15]In the CRS case, I assume that the variable management costs are exactly offset by a negative fixed management cost/subsidy in equilibrium. 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.

Corollary 4. *Consider the CRS case with $\chi_i = \tau = 1\ \forall i$. Evaluated at equilibrium, the combined price effects of changes in sectoral bank and trade credit rates on output can be summarized by the $(N \times 1)$ vectors $\boldsymbol{n}_b \equiv -\frac{\partial \ln(\mathcal{Y})}{\partial \ln(r_i^b)}$ and $\boldsymbol{n}_\tau \equiv -\frac{\partial \ln(\mathcal{Y})}{\partial \ln(r_i^\tau)}$, whose i-th entries are*

$$\boldsymbol{n}_{b,i}\Big|_{CRS} = \boldsymbol{\lambda}_{\tau,i}\frac{r_i^b BC_i}{R_i}, \quad \textit{and} \quad \boldsymbol{n}_{\tau,i}\Big|_{CRS} = \underbrace{\sum_c \boldsymbol{\lambda}_{\tau,c}\frac{r_i^\tau AR_{ci}}{R_c} - \boldsymbol{\lambda}_{\tau,i}\frac{r_i^\tau AR_i}{R_i}}_{\textit{Downstream Costs } - \textit{ i's Revenue Effects}}. \tag{33}$$

The elasticity of output with respect to changes in i's share of inputs financed using trade credit from supplier s is given by the (i,s)-th entry of the $(N \times N)$ matrix $\boldsymbol{n}_\theta \equiv \frac{\partial \ln(\mathcal{Y})}{\partial \ln(\theta_{is})}$ with

$$\boldsymbol{n}_{\theta,is}\Big|_{CRS} = \underbrace{\left[\boldsymbol{\lambda}_{\tau,i}(r_i^b - r_s^\tau) + \boldsymbol{\lambda}_{\tau,s} r_s^\tau \frac{R_i}{R_s}\right]\frac{AP_{is}}{R_i}}_{\textit{i's Costs } + \textit{ s's Revenue Effects}}. \tag{34}$$

Corollary 4 highlights that the impact of changes in trade credit rates and shares on output via changes in prices is governed by the relative strength of cost and revenue effects of obtaining and extending trade credit. The elasticities can take on both positive and negative values and depend on distortion-adjusted gross sales shares, as well as equilibrium accounts payable and receivable shares, reflecting that the response of output to financial shocks depends on how sectors are connected through trade credit relationships.[16]

Changes in interest rates and credit shares have so far been treated as exogenous. I now derive their first-order responses to financial shocks. Interest rates and credit shares are characterized in Equations (7), (23) and (24). Their interdependence gives rise to a credit-cost multiplier (see Online Appendix B.6), which I approximate to a first order. Proposition 4 characterizes the resulting elasticity of output, providing an aggregation formula for the macroeconomic effects of financial shocks in inefficient economies and 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. *Consider an idiosyncratic financial shock to sector i's interest premium. For given productivity, labor, and receivable composition, the first-order change in aggregate output reflects both direct effects of changes in financing costs and first-order feedback effects operating through endogenous adjustments in trade credit rates and credit shares, and is given by*

$$\frac{\partial \ln(\mathcal{Y})}{\partial z_i} \approx \underbrace{-\boldsymbol{n}_{b,i}\frac{r_i^z}{r_i^b} - \boldsymbol{n}_{\tau,i}}_{\textit{direct effects}} \overbrace{- \boldsymbol{n}_{\tau,i} - \text{FB}_{\tau,i} + \text{FB}_{\theta,i}}^{\textit{TC-Mechanism}} \tag{35}$$

[16] In the more general DRS-case, changes in prices also reflect changes in demand/income affecting the marginal product of the input composite. (see Corollary 1)

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

$$\mathrm{FB}_{\tau,i} = \underbrace{\boldsymbol{n}_{\tau,i}\left[\frac{r_i^\tau AR_i}{R_i} - \sum_{s\geq 0}\frac{BC_{is}}{BC_i}\frac{r_i^z BC_{is}}{TX_{is}}\right]}_{\Delta\ i\text{'s TC-Rate}} \underbrace{-\sum_c \boldsymbol{n}_{\tau,c}\frac{BC_{ci}}{BC_c}\frac{r_i^\tau AP_{ci}}{TX_{ci}}}_{\Delta\ i\text{'s customers' TC-Rates}}, \tag{36}$$

where $BC_{i0} = W\ell_i$ and $BC_{is} = (1-\theta_{is})p_s x_{is}$ for $s = 1, ..., N$ denote sector i's up-front input payments financed via bank credit; $TX_{i0} = \phi_i^L W\ell_i$ and $TX_{is} = \phi_{is}^X p_s x_s$ for $s = 1, \ldots, N$ denote the respective input expenditures including interest payments.
The feedback effects operating through changes in i's and i's customers' credit shares are

$$\mathrm{FB}_{\theta,i} = \underbrace{\sum_s n_{\theta,is}\frac{r_i^z \tilde{NP}_{is}}{AP_{is}} - \sum_c n_{\theta,ci}\frac{r_i^\tau \tilde{NR}_{ci}}{AR_{ci}}}_{\Delta\ \text{TC-Shares } (\Delta\ \text{Interest Rates})} + \underbrace{\sum_{c,s} n_{\theta,cs}\frac{NP_{cs}}{AP_{cs}}\frac{\partial\ln(R_c)}{\partial z_i}}_{\Delta\ \text{TC-Shares } (\Delta\ \text{Demand})}, \tag{37}$$

where $NP_{is} = (\theta_{is} - \theta_{is}^\kappa)p_s x_{is}$ denotes the excess accounts payable due to interest differentials, and $\tilde{NP}_{is}$ and $\tilde{NR}_{is}$ are given by

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

The effect of the financial shock on sector c's sales is characterized in the proof.

The decomposition in Proposition 4 shows how the elasticity of aggregate output with respect to financial shocks depends on firms' equilibrium interactions as borrowers and lenders in the production network: Following a financial shock to sector i's bank interest premium, consider the elasticities of output with respect to changes in sector i's interest rate charged on receivables, $\boldsymbol{n}_{\tau,i}$, and its share of inputs financed using trade credit from supplier s, $n_{\theta,is}$. Both are characterized in Corollary 4 for the CRS-case, and depend on sector i's, its customers' and suppliers' distortion-adjusted gross Domar weights and share of interest payments or income on receivables in sectoral revenues. Similarly, the first order feedback effects depicted in Equations (36) and (37) equal the product the elasticity of output with respect to changes in trade credit rates (shares), and 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:

In response to a financial shock to sector i's bank interest premium, sector i's *interest rate on receivables* unambiguously increases. While i's trade credit rate increases one-for-one with the financial shock, changes in i's bank loans-to-sales ratio alter its dependence on bank financing and can either dampen or amplify the initial response, as captured by the first term in braces in Equation (36): On the one hand, an increase in i's trade credit rate shifts i's revenue composition towards revenues from financial intermediation, further increasing its trade credit rate. On the other hand, an increase in financing costs reduces i's demand for inputs and therefore its demand for bank credit, thereby decreasing i's trade credit rate. 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 (36). Equation (37) summarizes how changes in relative credit costs and in the demand for sector i's output affect its *share of inputs obtained on trade credit* from supplier s. While the demand-induced effects are ambiguous, the direct cost effects captured by the first two terms are straightforward: For given intermediate expenditures, $p_s x_{is}$, an increase in i's cost of bank credit unambiguously induces a shift in its credit portfolio towards trade credit, whereas an increase in supplier s's trade credit rate decreases i's credit share.

Proposition 4 thus isolates the distinct channels through which trade credit affects the aggregate response to financial shocks and provides a sufficient-statistics characterization of these mechanisms. The following section uses this decomposition to derive conditions under which trade credit amplifies or smooths sectoral shocks, and to study how these effects depend on the heterogeneity in firms' reliance on bank financing and trade credit usage.

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 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*

$$\underbrace{\frac{\max\limits_{c\in\mathcal{C}_i}\{-\boldsymbol{n}_{\tau,c}\}}{-\boldsymbol{n}_{\tau,i}}}_{\frac{\Delta Y\,(\Delta c\text{'s TC-Rate})}{\Delta Y\,(\Delta i\text{'s TC-Rate})}} > \underbrace{\frac{1+\left(\eta_i^\tau - \min\limits_{s=0,..,N}\left\{\frac{BC_{is}}{TX_{is}}\right\}\frac{R_i}{BC_i}\right)\frac{r_i^z BC_i}{R_i}}{\sum_c \frac{BC_{ci}}{BC_c}\frac{r_i^\tau AP_{ci}}{TX_{ci}}}}_{-\frac{\Delta\ i\text{'s TC-Rate}}{\Delta\ i\text{'s customers' TC-Rates}}}, \quad \textit{where } \eta_i^\tau \equiv \frac{r_i^\tau AR_i}{r_i^z BC_i} \tag{38}$$

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

The sufficient condition (38) highlights that whether changes in trade credit rates improve allocative efficiency in response to a financial shock to sector i depends on the relative magnitude of the output effects of changes in the sector's own and its customers' trade credit costs:
The right-hand side takes on only positive values and captures how strongly sector i's trade credit rate responds relative to those of its customers. The elasticity of sector i's trade credit rate can be expressed in terms of its net-lending position η_i^τ: The more trade credit i extends relative to its bank financing needs - higher η_i^τ - the more sensitive its interest rate on receivables is to

financial shocks. The left-hand side of (38) equals the ratio of output elasticities with respect to changes in trade credit rates. To determine its sign, it is useful to rewrite the output elasticity with respect to changes in i's trade credit rate in the CRS-case (Corollary 4) as follows

$$\boldsymbol{n}_{\tau,i}\Big|_{\text{CRS}} = \underbrace{\left[\boldsymbol{n}_{b,i}\Big|_{\text{CRS}} \frac{r_i^z}{r_i^b}\right]}_{-\Delta Y(\Delta i\text{'s BC-Rate})} \cdot \eta_i^\tau \underbrace{\left[\sum_c \frac{AR_{ci}}{AR_i}\frac{\lambda_{\tau,c}/\lambda_c}{\lambda_{\tau,i}/\lambda_i} - 1\right]}_{\frac{i\text{'s customers Cost effects}}{i\text{'s Revenue Effects}} - 1}, \quad \text{where} \quad \frac{\lambda_{\tau,i}}{\lambda_i} = \left(1 + \frac{\sum_n [\mathbf{L}']_{in} T_n}{R_i}\right)\frac{PY}{PF}.$$

This decomposition shows that the elasticity can be expressed in terms of the elasticity of output with respect to changes in i's bank interest rate, scaled by its net-lending position, and the relative strength of the downstream cost- and i's revenue effect, discussed in Section 3.2.2. The downstream cost effects further depend on the composition of sector i's trade credit relationships. The sign of the elasticity is then governed by the relative strength of the cost- and revenue effects, which can be expressed in terms of ratio of the distortion-adjusted to standard Domar weights. The latter depends on the ratio of a sector's direct and indirect customers bank interest payments to its revenues. Thus, sectors that engage more intensively in financial intermediation and are more upstream in the production network tend to exhibit stronger revenue effects, as changes in their prices affect a larger share of aggregate activity.[17] Since net-lenders are relatively more upstream, the revenue effects on prices following an increase in a net-lender's trade credit rate are more likely to dominate downstream costs effects, implying a positive effect on output, with $\boldsymbol{n}_{\tau,i} < 0$. The opposite applies to net-borrowers. These observations, together with the differentiation between cases in Corollary 5, imply the following asymmetry related to a sector's net-lending position: For net-borrowers with $\boldsymbol{n}_{\tau,i} > 0$, the sufficient smoothing condition requires that all their customers satisfy $\boldsymbol{n}_{\tau,c} > 0$. For net-lenders with $\boldsymbol{n}_{\tau,i} < 0$, the inequality reverses. Since net-lenders by definition have larger η_i^τ, the condition is more easily satisfied.

Remarks. Taken together, this section shows that sectors differ not only in their importance in production, but also in their roles as financial intermediaries and in the composition of their trade credit relationships. The trade credit-channel is more likely to have a smoothing effect on output following a financial shock to net-lenders with stronger revenue effects relative to their customers. This reflects not only a sector's own net-lending position, but also the net-lending positions of its customers. Net-lending heterogeneity thus shapes not just the magnitude but also the direction of the trade credit-mechanism.

The analysis above yields three testable quantitative predictions. First, the smoothing mechanism is more likely to be driven by net-lenders. Second, since net-lenders are sectors that are more upstream with lower value-added shares, shocks to these sectors generate smaller aggregate output responses than shocks to more downstream sectors. Third, relative to an economy in which firms rely exclusively on bank credit, the presence of trade credit introduces additional

[17] See discussions in Sections 2 and 4, Footnote 29. 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 3.

propagation channels through endogenous adjustments in trade credit rates and credit relationships. As net lenders engage more in financial intermediation with higher receivable shares in equilibrium, financial shocks to such sectors generate systematic differences in output responses in an economy with both bank and trade credit relative to an economy with bank finance only. All three predictions are evaluated quantitatively in the subsequent section.

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. The quantitative analysis is conducted in an environment that reconciles the model with input-output (IO) accounts by introducing capital as a fixed factor in production to match factor-income shares. The corresponding equilibrium characterization, extending Proposition 2, is provided in Online Appendix C. These adjustments serve as an accounting device, preserving the model's equilibrium structure and optimality conditions, so that the insights of Section 3 remain unchanged.[18]

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 calibrated aggregate and sectoral parameters used in the subsequent simulations are reported in Table D.2 in the Online Appendix.

The **U.S. 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) and

[18] I rely on the summary tables on the "Use of Commodities by Industries After Redefinitions" provided by the BEA to calibrate the model. This requires reconciling the model's static, closed-economy structure 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, to ensure that final demand remains positive, 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. The consumption of both the providers of FIRE services and the residual trader is treated as a real resource cost. (see Bigio and La'O, 2020; Liu, 2019) The corresponding accounting equations used in the simulations are described in Online Appendices C and D. In the simulations, the shares of FIRE expenditures in capital income and the implied share of residual demand in sectoral production are held fixed at their pre-crisis (2004-07) averages.

firm-level financial data from Compustat.[19] Since data on trade-credit flows between sectors are not readily available, I rely on balance sheet data on accounts payable and receivable of U.S. Compustat-firms. Similar to Altinoglu (2021), I construct and combine sectoral accounts receivable shares in sales, θ_s^R, and accounts payables shares in production costs, θ_i^P, to obtain a proxy for the equilibrium share of input payments that sector i finances using trade credit from supplier s. Specifically, trade credit shares are constructed as the following weighted average [20]

$$\theta_{is} = \frac{R_s}{R_i + R_s}\theta_i^P + \frac{R_i}{R_i + R_s}\theta_s^R \;\; \forall i, s. \tag{39}$$

The model features an explicit interest rate on trade credit, whereas common trade credit agreements in the data instead involve implicit financing costs (see e.g. Cuñat, 2007). Accordingly, the cost of trade credit is treated as being embedded in the transaction values of intermediate inputs and therefore already reflected in the nominal intermediate expenditures reported in the IO-tables.

To match factor-income shares in the data, real capital owned by firms is included as a fixed factor in the production function (1) and set to its steady-state level rather than normalized to one. However, since gross operating surplus reported in the IO-tables is constructed as a residual, it includes capital expenditures, profits, and net interest income as a joint measure rather than as separate components (see Horowitz and Planting, 2009). I therefore combine IO data with income statements of a panel of U.S Compustat firms, to decompose sectoral gross profits and calibrate the parameters of the production function consistently with the sectoral income shares implied by the IO accounts. While, in the theoretical exposition, I assumed for simplicity that households receive the same share, $(1-\tau)$, of income from the fixed factor and the financial sector, the simulations instead redistribute only fixed-factor income to households, while 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

[19] To account for the timing restriction of the model - that financial markets and the real economy contract simultaneously - all financial variables applied in the calibration and measures of sectoral and aggregate credit spreads are used with a one-period lag.

[20] Since accounts payable and receivable are stock variables, the resulting measure therefore captures the average exposure of transactions within a sector to trade credit, aggregating over timings of payments and trade credit relationships. In this sense, the constructed proxy reflects both the intensive margin - the share of transactions financed using trade credit - but also the extensive margin - the fraction of supplier-buyer relationships in which trade credit is extended. Since the model abstracts from this extensive margin by featuring a representative firm in each sector, the empirical counterpart should therefore be interpreted as a reduced-form object combining both margins. When mapping the model to the data, these transactions may include cross-border trade credit payments. While trade credit also plays an important role in international transactions (see i.a. Foley and Manova, 2015; Schmidt-Eisenlohr, 2013; Castellares and Salas, 2019), the model abstracts from this margin. In particular, the model is a closed economy and features only domestic trade (credit) relationships. To reconcile this with data, while I treat all expenditures as domestic, I enforce aggregate market clearing for trade credit by interpreting the excess in imputed receivables as export-related trade credit and rescale sectoral receivables accordingly, as detailed in Online Appendix D.

and Wage Statistics (OEWS) published by the BLS.[21] The parameters of the cost function (6) are then calibrated in two steps. First, an estimate of the average cost parameter, $\overline{\kappa}_1$, is obtained by estimating an aggregated version of Equation (23).[22] Second, the link-specific cost parameters, $\kappa_{1,is}$, are parameterized as a monotone function of the imputed equilibrium trade credit shares, so that higher shares correspond to lower cost parameters. The parameter of the linear component, $\kappa_{0,is}$, is assumed to be negative and proportional to the firm's fixed credit management costs, $m_{0,i}$, using intermediate input shares. The fixed credit management costs, $m_{0,i}$ and benchmark credit shares, $\overline{\theta}_{is}$, are then solved for using Equation (23).

Financial Parameters and Shocks. As a proxy for the interest premium in Equation (7), I rely on sectoral credit spreads derived in Gilchrist and Zakrajšek (2012), adjusted to be consistent with bank interest payments imputed from the IO-tables. The risk-free rate is calculated as $\mathbb{r} = \min_{i,t}\{r^b_{it}\}$ over the entire sample period such that the implied premia are given by $r^z_{it} = r^b_{it} - \mathbb{r}$. Shocks to the interest premium, z_i, are then imputed directly using Equation (7).[23] The parameter d in Equation (7) is set equal to the average aggregate pre-crisis (2004-07) ratio of depository institution loans to sales, combining aggregate U.S. Flow of Funds Data (FF) with aggregated Compustat data described in Appendix D.1, so that it reflects the economy's baseline reliance on external financing. 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).[22]

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. In the following exercises, I employ the general aggregation results presented in the Online Appendix, evaluated under the restriction $M_i = 0 \forall i$ and $\tau = 1$, to focus on output-effects of trade credit operating through changes in prices rather than income shares. Second, using the same imputed financial shock series, I solve numerically for the equilibrium

[21] 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).

[22] To estimate the aggregated 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 use quarterly data to increase the sample size for estimation. A similar estimate was obtained using the same data at an annual frequency.

[23] 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.

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, as well as sectoral capital stocks at their four-year average (2004-07) prior to the crisis.[18] Therefore, variation in the simulated responses of the economy across periods is driven solely by changes in financial conditions.

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 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. 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. Table 1 also reports the first-order output effects based on Equation (35) in Proposition 4: The PE$_R$-effects are computed using the first term, while the PE$_T$-effects are computed using the first three terms of the elasticity of output in Equation (35). 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 case of Proposition 4, this difference reflects the feedback effects captured by 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.[24] While roughly half in size, the aggregation results of

[24] The percentages follow from calculating, $(GE-PE_R)/GE$, for both the 2009-response and standard deviation

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 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 sales 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-SIM) in Table 1 also reports the change in aggregate accounts payable (TC) and its share in total production costs (θ^{τ}). The simulations suggest that their decline was predominantly driven by the decline in credit shares, while the effects of changes in demand - holding trade credit rates and shares fixed - had a negative but small effect on either variable.

To further characterize how endogenous and interconnected wedges affect the response of aggregate output, Panel (B-SIM) of Table 1 reports the responses of the aggregate labor and efficiency wedge.[25] Both wedges decline in response to the financial shock. Equation (31) 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 responses of the model-implied wedges in partial and general equilibrium, the simulations show that the endogenous adjustment of trade credit dampened the decline in either wedge - consistent with the mechanism discussed above. Lastly, Panel (B-SIM) also 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 3, I define the trade credit network, $\mathcal{B}$, whose typical entry represents the expenditure share on accounts payable in total credit (including interest). The economy's aggregate measure of trade credit interconnectedness is then defined as the sum of sectoral credit centralities

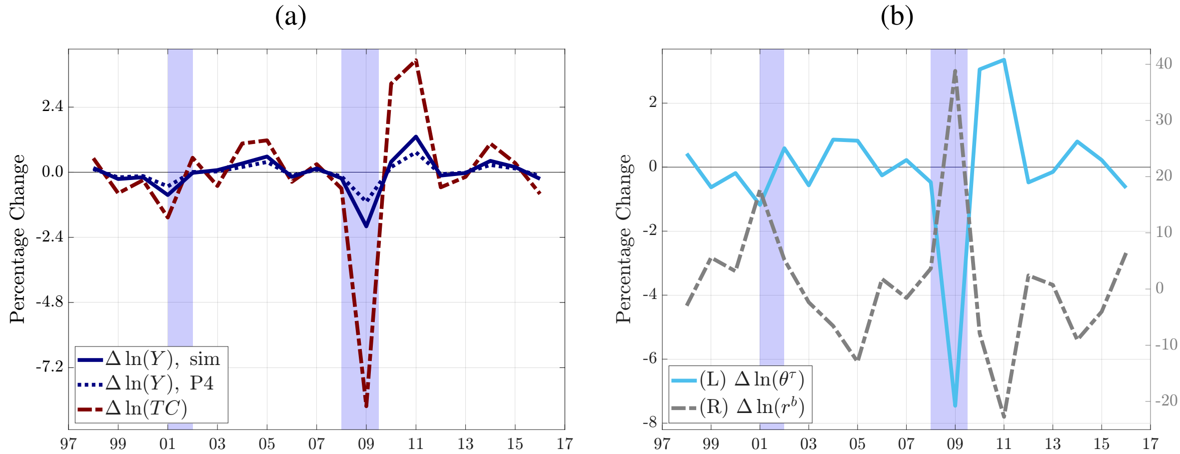
$$b^{\tau} = \boldsymbol{\beta}' \big[\boldsymbol{I} - \mathcal{B}\big]^{-1} \boldsymbol{\iota}, \quad \text{where} \quad [\mathcal{B}]_{is} = \frac{(1 + r_s^{\tau}) AP_{is}}{\textit{Total Loans}_i}, \tag{40}$$

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 as sectors adjust their credit portfolios in response to changes in financing conditions, the economy's interconnectedness via trade credit declined during the crisis. Since the underlying production network remains fixed, this decline reflects changes in the intensity of existing sectoral credit relationships.

of the respective variable reported in Table 1.

[25]Data counterparts for the model-generated wedges and measure of trade credit interconnectedness are constructed using the period-by-period mapping of the model to data.

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



Note: Similar to Figure 1, the panels in this figure plot the evolution of the log-change in percent of the following variables in response to financial shocks: $(Y)^{*}$ aggregate GDP using both model simulations and the more general DRS-aggregation results of Proposition 4 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 4 with $M_i = 0 \forall i$ and $\tau = 1$ using financial shocks only. Column (GE) reports the general equilibrium effects. Columns (PE$_R$) and (PE$_T$) report the responses obtained by holding constant (PE$_R$) both trade-credit interest rates and credit shares, and (PE$_T$) credit shares only, respectively. 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. The discussion following Corollary 5 suggests that sectors with a stronger net-lending position - i.e. sectors extending relatively more trade credit - tend to (i) dampen the propagation of financial shocks and (ii) generate smaller aggregate output responses, partly reflecting their smaller value-added share. To quantitatively evaluate these predictions, I simulate the economy's responses when each sector at a time experiences a financial shock to its interest-premium of size $z_i = 0.1$.

Panel (a) of Figure 4 depicts the results of this exercise by plotting the aggregate output responses - normalized by the affected sector's distortion-adjusted gross Domar weight, λ_i^{τ}, to account for differences in sector size - against the net-lending position of the sector (in log-scale). The simulations show that the decline in aggregate output in response to a financial shock to net-lenders is smaller than in response to the same shock affecting net-borrowers, also after controlling for a sector's size, indicating an additional smoothing effect through credit linkages.

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 4 then reports the group averages of the components of the aggregate output response following idiosyncratic financial shocks of size $z_i = 0.1$ applied to one sector at a time. The decomposition is based on the output elasticity derived in Proposition 4, evaluated using the 2004-2007 averages of the data counterparts of the elasticities. Each bar depicts two measures:

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, as in Proposition 4. 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, transmitted via its direct effects on credit rates and shares. (For details, see the discussion in Online Appendix B.6.) 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 4. This difference is due to the distortion-adjusted gross 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 therefore also the magnitude of the resulting output response.[26] 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 responses due to changes in trade credit costs and shares are more pronounced for shocks affecting net-lenders than 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 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 (38) 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.[27]

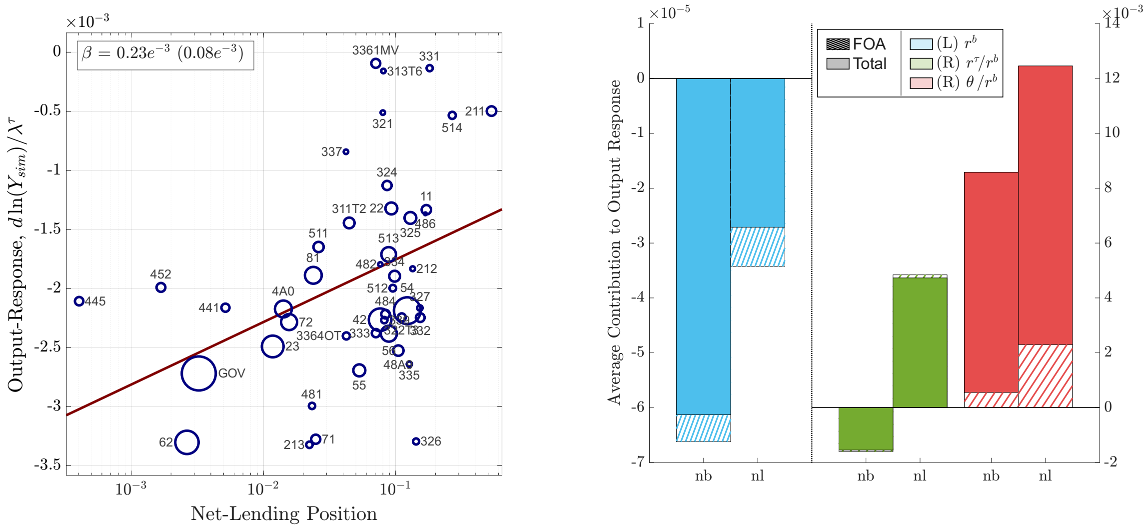
[26] The calibration implies that in equilibrium production costs are predominantly financed using bank loans since firms in the model do not have internal funds and their average trade credit share is about 10%.

[27] In each case, I take into account the directionality of the condition depending on the sign of the elasticity of output with respect to changes in trade credit rates.

The intuition behind this result is that in case of a shock to a net-lender, positive revenue effects dominate any negative effects on output: As a firm reduces trade credit extended to customers, its interest rate on receivables - and revenue wedge - increases. This dampens the increase in the firm's output price following the financial shock, thereby mitigating the decline in output.

Figure 4: 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 gross 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, sectors are classified as net-lenders (nl) and net-borrowers (nb) based on the median of their average net-lending position (2004-07); Panel (b) reports the group averages of the components of the output response following idiosyncratic financial shocks of size $z_i = 0.1$ applied to one sector at a time. The decomposition attributes output responses to changes in bank rates, trade credit rates, and credit shares, where the latter two are normalized by the elasticity with respect to bank rates. Elasticities are computed from Proposition 4 using the general aggregation results in the Online Appendix evaluated at $M_i = 0 \forall i$ and $\tau = 1$, to focus on output-effects of trade credit operating through changes in prices. Dashed bars show first-order feedback effects, while solid bars include the full effect of the credit multiplier. (see Online Appendix D.3 for details)

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.[28] This comparison allows to disentangle the output effects of the credit network from those of the inter-sectoral trade network alone. In the spirit of Bigio and La'O (2020), an equivalent economy, $\mathrm{E}(0)$, and the Trade Credit Multiplier are defined below:

Definition 5. *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 $\mathrm{E}(\theta)$.*

[28]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.

Definition 6. *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 based on the aggregation results in 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 so 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.

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 reports 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). The results are based on (a) model simulations and (b) the general aggregation results of Proposition 4 in the Online Appendix, evaluated at $M_i = 0 \forall i$ and $\tau = 1$. The multipliers, $\mathcal{M}$, are calculated as the ratio of output responses in E(θ) to their counterpart in E(0). Column (1) reports the results to an aggregate financial shock imputed from the data; Using Definition 1, sectors are classified as net-lenders (nl) and net-borrowers (nb) based on the median of their average net-lending position (2004-07). Columns (2,3) report the responses to symmetric financial shocks affecting the top five (2) net lenders and (3) net borrowers.

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.[29] 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 responses and corresponding credit multipliers for net-lenders are reported in Column (2) of Table 2, and those for net-borrowers in Column (3). Table 2 yields the following insight: Financial shocks to net-lenders are more amplified relative to an economy with bank-finance only.[30] The

[29] 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).

[30] Relatedly, Figure D.1 in Online Appendix D.3 plots the trade credit multipliers for sector-specific shocks of size $z_i = 0.1$, against the affected sector's net-lending position with the same insights.

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.

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 and Counterfactual Exercises. In the following, I discuss selected robustness and counterfactual exercises relative to the benchmark results. The results are reported in Online Appendix D.3, Tables D.4 and D.5. 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 log points 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 relative contribution of changes in trade credit rates and shares as well as 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 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.5 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 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 - though small - 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 an additional, though negligible, decline in aggregate output. Similarly, 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 gross sales shares, which by construction are nearly 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. 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 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 U.S. 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 costs and shares decreased both aggregate volatility and the 2009-output response by approximately 19.2% and 22.3%, respectively. Finally, I show that the smoothing effects of trade credit are quantitatively more pronounced for sectors with higher net-lending positions. At the same time, the comparison of aggregate output responses across economies with and without trade credit highlights that sectors with higher net-lending positions generate larger spillovers.

In this paper, I have focused on the macroeconomic effects of endogenous financial linkages between firms along the intensive margin. As shown in Giannetti, Serrano-Velarde and Tarantino (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., 2024), which I leave to future research.

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