Aggregate Fluctuations and the Role of Trade Credit

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Abstract

In an economy where production takes place in multiple stages and is subject to financial frictions, how firms finance intermediate inputs matters for aggregate outcomes. This paper focuses on trade credit—the lending and borrowing of input goods between firms—and quantifies its impact on aggregate output during a financial crisis. Motivated by empirical evidence, our model shows how trade credit alleviates financial frictions through a process of credit redistribution and creation, leading to a higher steady-state output. However, in the face of financial market distress, suppliers reduce trade credit lending, further tightening their customers' borrowing constraints, resulting in an amplification of the initial financial shock. Our model simulation suggests that the decrease in trade credit during the Great Recession can account for almost one-fourth of the observed decrease in output.

JEL classification: E32, E44, L23, L14

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1 Introduction

Financial shocks are often associated with severe contractions in real economic activity. Most of the academic research on financial shocks has focused on the disruption of credit flows from the formal financial sector to the real economy. Relatively little attention has been paid to the role of trade credit—suppliers' lending of inputs to their customers. In 2006, the year before the 2007–09 financial crisis, total trade credit liabilities (accounts payable) of the nonfinancial corporate sector were approximately the same size as its monthly gross value added, and in the same sector, approximately 70 percent of the decrease in short-term liabilities during the 2007–09 crisis was attributable to trade credit.

In this paper, we document empirical patterns of trade credit in the cross section and during the 2007–09 financial crisis. We show that there is heterogeneity in the distribution of trade credit, with financially-advantaged firms being net lenders of trade credit and disadvantaged firms net borrowers. The willingness of firms to provide trade credit to their customers is sensitive to disruptions in financial markets, which acts to amplify the impact of financial shocks. We quantitatively evaluate the size of the amplification effect during the 2007–09 crisis in a dynamic general equilibrium model with heterogenous entrepreneurs and financial frictions and show the decrease in trade credit during the Great Recession can account for almost one-fourth of the observed decrease in output.

Using a sample of firms from Compustat and the Survey of Small Business Finances, we document empirically that the net lending of trade credit is significantly higher for unconstrained firms than constrained firms. The documented pattern on net lending of trade credit is driven mostly by the sensitivity of borrowing (rather than lending) of trade credit to financial constraints, which can be explained by the existence of accounts receivable financing.

We also show the supply of trade credit decreases when firms' access to the financial market is disrupted. To isolate the supply-side effect, we adopt the strategy of Chodorow-Reich (2014) by using the performance of firms' relationship banks during the 2007-09 financial crisis as an exogenous variation in firms' access to financing. Using a sample of Compustat firms that borrowed in the syndicated loan market, we find that firms that had pre-crisis relationships with an unhealthy bank reduced their lending of trade credit significantly more than other firms during the crisis.

Motivated by the empirical evidence, our quantitative model incorporates two important features: 1) firm heterogeneity in financial constraints and 2) interaction between trade credit and firms' access to the financial market.

In the model, production of the final good takes place in two stages: intermediate good production and final good production. In each stage, there is a continuum of entrepreneurs who differ by their wealth and productivity, which creates heterogeneity in financial constraints across firms. Trade credit and bank credit coexist, and trade credit flows—together with intermediate input goods—from intermediate good entrepreneurs to final good entrepreneurs. The process also creates collateral (accounts receivable), which can be used by the lenders of trade credit to obtain bank loans. Hence, trade credit redistributes credit across entrepreneurs with different degrees of financial frictions and increases the overall level of credit in the economy. The consequence of the redistribution and creation of credit is a better allocation of resources among the heterogenous entrepreneurs, which leads to a higher aggregate productivity.

We model the financial crisis as a negative shock to firms' collateral constraints. A negative shock makes intermediate good entrepreneurs more constrained and lowers the collateral value of their receivables from final good entrepreneurs. Intermediate good entrepreneurs reduce their trade credit lending, further tightening the constraint of the final good entrepreneurs. The spillover effect through endogenous changes in the provision of trade credit amplifies the impact of the financial shock.

To quantify the amplification effect, we first calibrate the steady state of our model to match the distribution of firms in the U.S. economy following Buera, Fattal-Jaef and Shin (2015). The collateral value of wealth and accounts receivable are respectively pinned down by the size of credit market liabilities and trade credit in the nonfinancial corporate sector. In the calibrated model, the equilibrium interest rate of trade credit is 11.2 percent, which is near the estimated range of 12 to 16 percent in Costello (2014) using the Compustat dataset. Our calibrated model also shows that the credit creation channel is quantitatively important: 87 percent of accounts receivable are used as collateral to obtain bank loans, while only 13 percent is pure redistribution of unused credit among entrepreneurs. Together, the credit redistribution and creation channel lead to an aggregate productivity gain of 8.4 percent, which reflects the difference in productivity due to better allocation of resources between the benchmark model and a counterfactual economy where trade credit is shut down.

Using the calibrated model, we simulate the 2007–09 financial crisis by introducing a shock process to the collateral constraints, such that the model (upon impact) delivers the same magnitude decrease in credit market liabilities and accounts receivable as observed in the data. Following the shock, the aggregate dynamics of the model match the data well, and the shock has a differential impact on the trade credit of constrained and unconstrained firms.

The same shock process, when applied to the counterfactual economy without trade credit, generates a decrease in output that is 23 percent smaller than the benchmark economy. The amplification effect of trade credit hinges on the underlying entrepreneur heterogeneity. The contraction in trade credit disproportionately affects the constrained entrepreneurs who rely on trade credit for financing, causing a more severe misallocation. While the trade credit channel improves the allocation of credit and increases steady-state output, this mechanism makes the economy more susceptible to financial shocks.

Lastly, we show that while the presence of trade credit amplifies financial shocks, it does not amplify productivity shocks because trade credit moves very little relative to output following productivity shocks. Khan and Thomas (2013) and Zetlin-Jones and Shourideh (2017) show that a model with heterogeneous producers and a fixed collateral constraint does not significantly amplify the impacts of productivity shocks. Our model with trade credit conveys a similar message and shows financial and productivity shocks generate different dynamics of trade credit that could help in identifying shocks over the business cycle.

Related literature There exists a long theoretical and empirical literature on trade credit.[1] Theoretically, our paper builds on the insight that the existence of trade credit reflects a certain comparative advantage of suppliers in lending inputs to their customers compared with financial intermediaries (Biais and Gollier, 1997; Burkart and Ellingsen, 2004; Cuñat, 2007). Empirically, our results confirm the "redistributive view" of trade credit (Meltzer, 1960; Love, Preve and Sarria-Allende, 2007). That is, trade credit helps channel resources to flow from financially advantaged firms to

[1]See Petersen and Rajan (1997) and Cuñat and Garcia-Appendini (2012) for excellent surveys of the literature.

disadvantaged firms. Our results contribute to this literature by emphasizing an additional "credit creation" channel of trade credit. We also find that the decrease in trade credit during the 2007–09 financial crisis can be attributed to the disruption of firms' access to the financial market. A similar finding is documented in Love, Preve and Sarria-Allende (2007) for financial crises in the emerging market economies; however, our paper differs from Love, Preve and Sarria-Allende (2007) by using a new identification strategy to isolate the supply-side forces of changes in trade credit.

This paper is also related to the literature on the propagation of shocks through trade credit. In a seminal paper, Kiyotaki and Moore (1997) build a model illustrating how shocks to one firm propagate in a network through a chain of trade credit default. This theory is tested by Raddatz (2010) using cross-country sector-level data, and by Jacobson and von Schedvin (2015) using Swedish matched firm-to-firm data.[2] The theoretical framework developed in our paper differs from the papers mentioned above in two ways. First, it models jointly the production and the lending of inputs, whereas the above papers abstract from production. Second, the propagation of shocks does not depend on trade credit default, but works through changes in the supply of and demand for trade credit on the intensive margin.[3]

More broadly, our paper contributes to two recent developments in the literature on the real impacts of financial shocks. One development is the inclusion of input-output linkages in production. Among these papers, Zetlin-Jones and Shourideh (2017) show that financial shocks can be amplified if there is strong enough complementarity among intermediate input goods. Kalemli-Ozcan et al. (2014) build on Kim and Shin (2012), in which trade credit helps sustain long production chains that are more productive than short ones, and show that financial shocks are amplified because longer production chains are less viable in financial crises. Bigio and La'O (2014) and Altinoglu (2018) show that the input-output structure itself can amplify financial shocks because the multiple financing of inputs increases the aggregate liquidity needed to sustain production. Our paper complements this strand of lit-

[2]The framework of Kiyotaki and Moore (1997) is also used to study the interbank lending market (see Boissay and Cooper, 2016;Lee, 2015; Zhang, 2014).

[3]The only exception is perhaps Boissay and Cooper (2016), who find that in the process of lending to firms, banks create "inside collateral," which can be used to borrow in the interbank lending market. The creation of collateral gives rise to multiple equilibria in the interbank lending market and makes it more fragile.

erature. Instead of studying the input-output structure, we use a simple two-stage production chain to explore the role played by trade credit in the presence of firm heterogeneity.

The second development in this literature is the incorporation of producer heterogeneity into a quantitative dynamic general equilibrium model (see for example Buera and Moll, 2015, Buera, Fattal-Jaef and Shin, 2015, Jermann and Quadrini, 2012, and Khan and Thomas, 2013). We contribute to this development by including trade credit in the analysis. Our model extends the heterogeneous entrepreneurs framework in Buera, Fattal-Jaef and Shin (2015) and Buera and Moll (2015) into a two-stage production process. It also extends the working capital constraint in Jermann and Quadrini (2012) by incorporating a trade credit component.

The rest of the paper is organized as follows: section 2 presents the empirical motivation for the model, section 3 describes the model, section 4 defines and analyzes the recursive competitive equilibrium, section 5 provides a quantitative analysis of the model, and section 6 concludes.

2 Empirical motivation

This section presents empirical evidence that motivates our model. Section 2.1 examines the distribution of trade credit across firms with different degrees of financial constraints, and section 2.2 studies the channels through which the 2007–09 financial crisis affected trade credit.

Following the literature, we use accounts receivable (AR) to measure a firm's gross lending of trade credit to other firms, accounts payable (AP) to measure gross borrowing of trade credit from other firms, and net accounts receivable (Net AR=AR-AP) to measure net lending of trade credit.

2.1 Trade credit in the cross section

Data description Our sample of firms combines the Compustat North America annual database with the Survey of Small Business Finances (SSBF) database for the years when the SSBF data are available (1987, 1993, 1998 and 2003).[4]

We first consider the Compustat North America annual database. We assess four separate criteria for designating a firm as financially constrained in a given year: 1) it pays zero dividend, 2) it has no bond rating from Standard & Poor's, 3) it is below the 30th percentile of the asset size distribution, or 4) it uses external financing (it is a borrower).[5] These four separate characteristics of firms are shown in Almeida and Campello (2007) and Gomes (2001) each to be associated with financial constraints.

Second, we augment the Compustat sample with a sample of firms from the Survey of Small Business Finances (SSBF) database, which contains smaller and private firms and is available for the years 1987, 1993, 1998, and 2003. The combined Compustat-SSBF sample offers greater coverage of the population of U.S. firms. For this sample, we identify financially constrained firms based only on size (firms below the 30th percentile of the asset size distribution).[6]

Empirical specification We estimate the effects of financial constraints on firms' trade credit activities with the following empirical specification,

$$y_{it} = \alpha I\_constrained_{it} + \chi_i + \phi_{st} + \epsilon_{it}, \tag{1}$$

where y_{it} is one of the three measures of trade credit—$\frac{net\ AR}{sales}$, $\frac{AP}{sales}$, and $\frac{AR}{sales}$—of firm i in year t,[7] $I\_constrained_{it}$ is a dummy variable indicating whether the firm is financially constrained in year t, ϕ_{st} is a set of sector-year fixed effects, χ_i is a set of other time-invariant firm characteristics such as whether it is a corporation, and ϵ_{it} is the error term. The coefficient α of the dummy variable $I\_constrained_{it}$ is the object of interest.

[4]Firms in the financial sector (SIC 60-69) and wholesale and retail sector (SIC 50-59) are dropped. The result does not change by much if we include the retail and wholesale sector.

[5]In Gomes (2001), the author developed a model showing that firm size and cash flow might not be informative about the severity of financial frictions. In this model, the most constrained firms use external financing, which he labeled as "borrowers." In our data, we say a firm uses external financing (is a borrower) if its capital expenditure exceeds its available funds (cash flow net of dividend payment).

[6]In this Compustat–SSBF sample, 22 percent of the financially constrained firms are from Compustat.

[7]The estimation results are similar if we scale AP using cost of goods sold (cogs) instead of sales.

Results In Panel (A) of Table 1, we run specification 1 with $\frac{net\ AR}{sales}$ as the dependent variable. Columns 1-4 use the Compustat sample, and in each column, the dummy variable $I\_constrained_{it}$ is constructed using one of the four indicators of financial constraint. Column 5 shows the result with the Compustat-SSBF sample. Net lending of trade credit is 5.8 to 17.1 percentage points higher for unconstrained firms than constrained firms.

The estimates in Panel (B) and (C) of Table 1 show that being financially constrained increases a firm's borrowing of trade credit (i.e., AP) but has no significant effect on the lending of trade credit (i.e., AR).[8] In other words, the correlation between net AR and being constrained is driven mostly by the borrowing of trade credit, not by the lending.

One possible explanation for the weaker correlation between financial constraints and the lending of trade credit is the availability of accounts-receivable-collateralized loans for trade credit lenders.[9] Without accounts receivable financing, lending one dollar of trade credit reduces the cash flow available to the lending firm by one dollar. However, if the lending firm can use the accounts receivable as collateral for a bank loan, the lending firm can provide trade credit to its customers without contributing as much of its own liquidity. Therefore, even constrained firms can often afford to provide trade credit to their customers.[10]

The existence of accounts receivable financing changes the nature of trade credit. Without accounts receivable financing, trade credit serves merely as a redistribution channel, redirecting credit from firms with access to financing to those without. With accounts receivable financing, a collateralizable asset (accounts receivable) is created whenever firms lend trade credit to their customers. Through the process of collateral creation, accounts receivable financing increases the collective access to

[8]The results in this table do not change significantly when we control for $\frac{inventory}{sales}$.

[9]Accounts receivable financing in the United States was a financial innovation first appeared in the early 1900s (see Murphy, 1992).

[10]If the advance rate of accounts receivable is x percent, lending one dollar of trade credit means a $1 - \frac{x}{100}$ dollar loss of liquidity. If the advance rate of accounts receivable is 100 percent, there is no liquidity loss when firms lend trade credit.

Table 1: **Trade credit and being financially constrained**

Panel A: Net AR/Sales

	(1)	(2)	(3)	(4)	(5)
Financially Constrained based on Payout Ratio	-6.198***				
	(0.208)				
Financially Constrained Based on S&P Rating		-5.766***			
		(0.316)			
Financially Constrained Based on Size			-11.49***		
			(0.281)		
Financially Constrained Based on Borrower Status				-10.31***	
				(0.347)	
Financially Constrained Based on Size					-17.07***
					(0.445)
Dependent variable	Net AR/S	Net AR/S	Net AR/S	Net AR/S	Net AR/S
Sample	Compustat	Compustat	Compustat	Compustat	Compustat+SSBF
N	26036	26036	26036	12997	34705
AR2	0.130	0.113	0.183	0.138	0.219

Panel B: AP/Sales

	(1)	(2)	(3)	(4)	(5)
Financially Constrained based on Payout Ratio	6.552***				
	(0.192)				
Financially Constrained Based on S&P Rating		6.964***			
		(0.294)			
Financially Constrained Based on Size			10.05***		
			(0.264)		
Financially Constrained Based on Borrower Status				11.78***	
				(0.319)	
Financially Constrained Based on Size					12.30***
					(0.426)
Dependent variable	AP/S	AP/S	AP/S	AP/S	AP/S
Sample	Compustat	Compustat	Compustat	Compustat	Compustat+SSBF
N	26036	26036	26036	12997	34705
AR2	0.137	0.120	0.173	0.136	0.161

Panel C: AR/Sales

	(1)	(2)	(3)	(4)	(5)
Financially Constrained based on Payout Ratio	0.354***				
	(0.118)				
Financially Constrained Based on S&P Rating		1.198***			
		(0.187)			
Financially Constrained Based on Size			-1.435***		
			(0.145)		
Financially Constrained Based on Borrower Status				1.465***	
				(0.153)	
Financially Constrained Based on Size					-4.765***
					(0.224)
Dependent variable	AR/S	AR/S	AR/S	AR/S	AR/S
Sample	Compustat	Compustat	Compustat	Compustat	Compustat+SSBF
N	26036	26036	26036	12997	34705
AR2	0.150	0.151	0.154	0.137	0.288

Notes: Our sample includes all but wholesale, retail, and financial firms in the Compustat and the SSBF data set for the fiscal years 1987, 1993, 1998, and 2003. All regressions include two-digit SIC industry-year fixed effects. Column (5) of every panel includes two dummy variables indicating whether the firm is a corporation or a Compustat firm, respectively. The dependent variables are winsorized at the top and bottom 5% for each year. Standard errors are clustered at the firm level.

bank credit for both trade credit lenders and borrowers.[11]

2.2 Trade credit during the 2007–09 financial crisis

In this section we explore how financial shocks impacted the provision of trade credit during the 2007–09 financial crisis.

To isolate the supply-side forces, we adopt a similar strategy as in Chodorow-Reich (2014), which uses the performance of a firm's pre-crisis relationship bank as an exogenous variation in the firm's access to financing. This identification strategy requires an assumption that firms and banks form relationships primarily to overcome asymmetric information or moral hazard problems, and that it is therefore costly for firms to switch to a new lender when their relationship bank is in financial distress (see Chodorow-Reich, 2014 for a detailed discussion and evidence). Therefore, the financial health of a firm's pre-crisis lending partner, which is uncorrelated with the trade credit choices of the firm's customers, provides an exogenous source of variation in the access to external financing during the crisis.

Data description We use a sample of Compustat firms that borrow from the syndicated loan market, which, over the past several decades, has become one of the most important channels for large U.S. firms to obtain financing. The contraction in the syndicated loan market was severe during the 2007–09 financial crisis, with significant decreases in the number, size, and maturity of new credit facilities, as shown in Figure A1.[12]

We follow Sufi (2007) and Chodorow-Reich (2014) to construct the DealScan-Compustat sample of firms and their relationship banks. We first drop any observation (a loan facility) in the DealScan database that falls into one of the following categories: 1) the borrower was in the financial, insurance, retail, or wholesale trade sector, 2) the facility had multiple lead lenders, 3) the facility was not open during

[11] The Thomson Reuters DealScan data on loans issued in the syndicated loan market indicate that accounts receivable financing is quantitatively important. Of all the secured loan facilities opened during 2004–06, 46.3 percent are collateralized by accounts receivable. Accounts receivable has the highest advancing rate at 87 percent, which is much higher than "inventory of all kinds" (59 percent) and "property, plant, and equipment" (29 percent).

[12] A detailed discussion of the syndicated loan market during the 2007–09 financial crisis can be found in Ivashina and Scharfstein (2010).

the period from January 1, 2004 to December 31, 2006, or 4) the lead lender was not among the top 43 lenders as defined in Chodorow-Reich (2014). We then use the link table provided by Chava and Roberts (2008) to match the lead lender of each loan facility in the DealScan database with the borrower from the Compustat database. If a firm had only one open facility from January 1, 2004 to December 31, 2006, we define the lead lender of that facility to be its pre-crisis relationship bank. If a firm had multiple facilities during that period, we define the lead lender of the newest facility as its relationship bank.

The above process yields a panel of 1,219 firm-bank pairs over the period 2007Q1 to 2009Q4 at a quarterly frequency. The sample is a good representation of the universe of Compustat firms in terms of sectoral composition. However, the average DealScan-Compustat firm is eight times larger in terms of total assets than the average of the rest of the Compustat firms. The DealScan-Compustat sample thus consists of the very largest U.S. firms with the best access to external financing.

Empirical specification We define a crisis indicator Crisis_t, which takes value 1 during the period of crisis (2007Q4 to 2009Q4). For each firm-bank pair in the DealScan-Compustat sample, we define a dummy variable $\mathsf{Unhealthy}_i$, which takes value 1 if the bank is below the 50th percentile in terms of the percentage drop in the issuance of new loans during the crisis period.[13]

The dependent variable is $\frac{AR_{it}}{Sales_{it}}$. Our specification is a fixed-effect regression of the following form,

$$\begin{aligned} \frac{AR_{it}}{Sales_{it}} &= \beta_1 \frac{AP_{it}}{Sales_{it}} + \beta_2 Crisis_t + \beta_3 Crisis_t \times Unhealthy_i \\ &\quad + \beta_4 Crisis_t \times Rating_i + Crisis_t \times \gamma_s + Crisis_t \times \psi_i \\ &\quad + \chi_i + \epsilon_{it}, \end{aligned} \tag{2}$$

where χ_i is a set of firm-level fixed effects, which absorb time-invariant differences across firms. We include $\frac{AP_{it}}{Sales_{it}}$ to control for firms' borrowing of trade credit. The crisis indicator Crisis_t captures the average change in $\frac{AR}{Sales}$ during the crisis. The

[13]The information about banks' new loan issuance is taken from Chodorow-Reich (2014). Unhealthy banks in the DealScan-Compustat sample include BMO Capital Markets, Banco Santander, Bank of New York Mellon, Bear Stearns, CIT Group, CIBC, Citi, Credit Suisse, Deutsche Bank, GE Capital, Goldman Sachs, JP Morgan, KeyBank, Lehman Brothers, M&T Bank, Merrill Lynch, Morgan Stanley, National City, Scotiabank, UBS, and Wachovia.

interaction term of $\mathtt{Crisis}_t \times \mathtt{Unhealthy}_i$ captures the additional change in trade credit lending for firms with an unhealthy relationship bank. Other control variables include the interaction of the crisis indicator with (i) the sectoral fixed effects (γ_s), (ii) the third-party bond rating indicator ($\mathtt{Rating}_i$), and (iii) the firm size fixed effects (ψ_i), capturing, respectively, the sectoral-level trend, and the different responses of large firms and firms with access to the bond market during the crisis.

The coefficient of the interaction term $\mathtt{Crisis}_t \times \mathtt{Unhealthy}_i$, β_3, is the object of interest, which reflects the impact of a financial shock on the provision of trade credit.

Table 2: **Effects of bank health on trade credit lending**

	(1)	(2)	(3)	(4)
Crisis X Unhealthy	-1.274*	-1.502**	-1.545**	-1.837**
	(0.681)	(0.696)	(0.714)	(0.718)
Crisis	0.446	0.0672	0.243	2.680
	(0.483)	(0.537)	(1.423)	(6.087)
AP to sales ratio	0.381***	0.382***	0.382***	0.382***
	(0.0294)	(0.0294)	(0.0293)	(0.0292)
Dependent variable	AR/S	AR/S	AR/S	AR/S
Crisis X Credit rating FE	N	Y	Y	Y
Crisis X Firm size bin FE	N	N	Y	Y
Crisis X SIC FE	N	N	N	Y
N	15275	15275	15275	15275
AR2	0.171	0.171	0.172	0.176

Notes: The dependent variables in these regressions are AR/Sales (percent). The sample includes quarterly data of 1,219 firms from 2007Q1 to 2009Q4. All regressions include a set of firm fixed effects. Standard errors are clustered at the firm level.

Results The results of specification 2 are displayed in Table 2. The estimated coefficient on the interaction term $\mathtt{Crisis}_t \times \mathtt{Unhealthy}_i$, shows that having an unhealthy bank significantly reduced a firm's lending of trade credit during the crisis. Firms in our sample with an unhealthy pre-crisis relationship bank reduced their lending of trade credit as a percent of sales by 1.3 to 1.8 percentage points more than other firms. The estimated results hold with the inclusion of different sets of control variables.

The coefficient on $\mathtt{Crisis}_t$ is insignificant, and therefore we find no evidence that firms with a healthy relationship bank changed their provision of trade credit during the crisis.[14] Thus, the data suggest that the reduction in trade credit during the crisis was primarily isolated to those firms with an unhealthy relationship bank, providing evidence of the negative impacts of financial shocks on firms' supply of trade credit.

3 Model

In this section, we introduce trade credit into a standard macroeconomic model with heterogeneous entrepreneurs and financial frictions. Sections 3.1 and 3.2 describe the economic environment and the production technology. Section 3.3 discusses the financial frictions that lead to the coexistence of bank credit and trade credit as a means of financing working capital, which is where our model diverges from the standard model.

3.1 Economic environment

Time is discrete with an infinite horizon. There are two types of goods in the economy. The final good is used for consumption and investment. The intermediate good is used as inputs to produce final good.

The production of final good takes place in two stages. Each stage is populated by a measure 1 of heterogeneous entrepreneurs. Entrepreneurs in the same stage differ from each other by wealth (a) and productivity (z). The stochastic productivity process z is exogenous and parameterized by a Poisson process with death rate π and new productivity draws from distribution $G(z)$. Wealth a is endogenously chosen by the entrepreneurs.

There is a measure N of homogeneous workers, who provide labor and consume. They do not have access to the asset markets; i.e., they are "hand-to-mouth."

The banking sector is perfectly competitive, with a representative bank making zero profit.

[14]This is not suprising because the Dealscan-Compustat sample is a selective sample of very large and financially integrated firms.

3.2 Preferences, endowments, and production technology

The preferences of workers are time separable, with instantaneous utility function $u(c^h_t, h_t)$ of the GHH form (Greenwood, Hercowitz and Huffman, 1988), such that,

$$U^h(c^h, h) = \sum_t \beta^t u(c^h_t, h_t),\ u(c_t, h_t) = c^h_t - \psi \frac{h_t^{1+\theta}}{1+\theta},$$

where β is the discount factor, ψ represents disutility from working, and θ is the inverse of Frisch elasticity.[15]

The preferences of entrepreneurs are time separable with instantaneous utility function of $\log(c_t)$. The expected utility of the entrepreneur can be written as

$$U^e(c) = \mathbb{E}\sum_t \beta^t \log(c_t),$$

where the expectation is taken over the stochastic processes of productivity z and wealth a.

Intermediate good entrepreneurs operate a decreasing returns to scale production technology ($\mu_x < 1$) that transforms capital and labor into intermediate good x, such that

$$x = A_x z(k^\alpha l^{1-\alpha})^{\mu_x},$$

where A_x is the aggregate productivity of the intermediate good sector and z is the entrepreneur's idiosyncratic productivity.

Final good entrepreneurs operate a decreasing returns to scale production technology ($\mu_y < 1$) that transforms capital, labor, and intermediate good into final goods y, such that

$$y = A_y z((k^\alpha l^{1-\alpha})^{1-\chi} x^\chi)^{\mu_y},$$

where A_y is the aggregate productivity of the final good sector and z is the idiosyncratic productivity of the entrepreneur.

[15]Workers do not face idiosyncratic or aggregate shocks; hence, there are no expectation terms in their utility.

Since the production technologies are decreasing returns to scale, for a given productivity z, there exists an optimal production scale.

3.3 Financing production

In this section, we discuss the financial frictions that lead to the coexistence of bank credit and trade credit and derive the working capital constraints faced by the entrepreneurs.

Similar to Buera, Fattal-Jaef and Shin (2015), entrepreneurs rent capital k at an interest rate r from a capital rental market and receive a return ra on their wealth.[16] Following Jermann and Quadrini (2012), we assume that entrepreneurs need to fund all outflows in advance and thus must take out an intra-temporal loan m. Since this is an intra-temporal loan and the representative bank earns zero profit, the equilibrium interest rate on the intra-temporal loan is zero.

Timing At the beginning of each period, entrepreneurs carry over from the previous period their wealth a. After the idiosyncratic productivity shock z is realized, entrepreneurs choose their current period production (k, l, x), their borrowing or lending of trade credit (AR, AP), their current period consumption (c), and their next period wealth (a').

Based on these choices, entrepreneurs obtain the required intra-temporal working capital bank loan, production occurs, and entrepreneurs and workers consume and save. At that point, entrepreneurs decide whether to default on their bank loans. If an entrepreneur decides to default, a renegotiation process occurs between the entrepreneur and the bank, with the ultimate settlement determined by the bank's expected proceeds from liquidating the entrepreneur's collateral. After the bank loan is settled, trade credit is repaid, and the entrepreneurs carry their wealth a' into the next period. The timing is summarized in Figure 1.

[16] In net, the entrepreneurs' interest payment is $r(k - a)$. This setup is equivalent to allowing entrepreneurs to own their capital k and borrow an inter-temporal loan d at interest rate r, in which wealth (net worth) is $a = k - d$ and the interest payment is $rd = r(k - a)$.

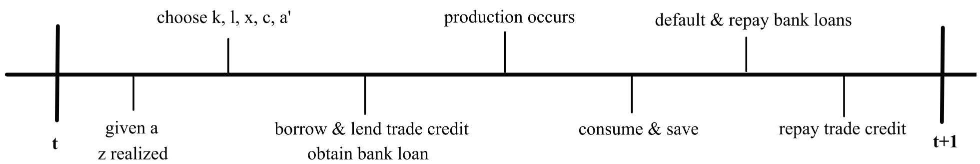

Figure 1: **Timing**

Financial frictions and bank loan limits The fundamental financial friction in the economy is the bank's limited enforcement over the repayment of bank loans. Upon default, the bank can liquidate the entrepreneur's collateral, and, with some probability, the liquidation will be successful and the bank will recover the full value of the collateral. In equilibrium, entrepreneurs will simply make a take-it-or-leave-it offer equal to the expected liquidation value of the collateral to the bank. This gives rise to a bank loan borrowing constraint as a function of the collateral value of the entrepreneur's assets, which will ensure no default in equilibrium. Let m_x and m_y be the the size of the intra-temporal bank loans of the intermediate and final goods entrepreneurs, respectively. We can write the bank loan limits as the following:

$$\begin{aligned} m_x &\leqslant \gamma_1 a' + \gamma_2 AR, \\ m_y &\leqslant \gamma_1 a', \end{aligned}$$

where γ_1 and γ_2 are the probability of liquidating wealth a' and accounts receivable AR upon the entrepreneur's default.

Trade credit Building on the idea from the literature that trade credit exists because intermediate inputs suppliers have a comparative advantage, compared with the bank, in lending inputs to their customers, we assume intermediate good entrepreneurs have perfect enforcement over the repayment of trade credit.

There is a Walrasian market for both the intermediate good and trade credit. Intermediate good entrepreneurs supply to the market intermediate good of value px and a trade credit loan of size $AR \in [0, px]$, and expect to collect a payment of $px + (1 + r^{tc})AR$ at the end of the period, where p is the price of the intermediate good and r^{tc} is the trade credit interest rate. Final good entrepreneurs purchase intermediate good of value px and borrow trade credit of size $AP \in [0, px]$, and they make a payment of $px + (1 + r^{tc})AP$ to the market at the end of the period.[17]

The budget constraints of the entrepreneurs in the presence of trade credit can be written as

$$c + a' = (1 + r)a + pA_x z(k^{\alpha} l^{1-\alpha})^{\mu_x} - (r + \delta)k - wl + r^{tc} AR, \tag{3}$$

$$c + a' = (1 + r)a + A_y z((k^{\alpha} l^{1-\alpha})^{1-\chi} x^{\chi})^{\mu_y} - (r + \delta)k - wl - px - r^{tc} AP. \tag{4}$$

Working capital constraints Similar to Jermann and Quadrini (2012), the outflows must be financed intratemporily by bank loans m_x and m_y, such that

$$\begin{aligned} m_x &= a' - a + c + r(k - a) + \delta k + wl + AR, \\ m_y &= a' - a + c + r(k - a) + \delta k + wl + px - AP. \end{aligned}$$

Using the budget constraints of the entrepreneurs (equations 3 and 4), we can rewrite the size of the intra-temporal bank loans as

$$\begin{aligned} m_x &= pA_x z(k^{\alpha} l^{1-\alpha})^{\mu_x} + (1 + r^{tc})AR \\ m_y &= A_y z((k^{\alpha} l^{1-\alpha})^{1-\chi} x^{\chi})^{\mu_y} - (1 + r^{tc})AP. \end{aligned}$$

Therefore, the working capital constraints faced by the entrepreneurs are:

$$pA_x z(k^{\alpha} l^{1-\alpha})^{\mu_x} + (1 + r^{tc})AR \leqslant \gamma_1 a' + \gamma_2 AR, \tag{5}$$

$$A_y z((k^{\alpha} l^{1-\alpha})^{1-\chi} x^{\chi})^{\mu_y} - (1 + r^{tc})AP \leqslant \gamma_1 a'. \tag{6}$$

Equation 5 shows that, in the presence of trade credit activities, the intermediate good entrepreneurs' needs for intra-temporal loans increase by $(1 + r^{tc})AR$, while their bank loan limit increases by $\gamma_2 AR$. On the other hand, equation 6 shows that the final good entrepreneurs' needs for intra-temporal loans decrease by $(1+r^{tc})AP$. Figure 2 summarizes the flow of goods and credit in the economy.

[17]Trade credit in reality is an implicit loan—a delay of payments, but trade credit here is modeled in an abstract way, only trying to capture the impacts of trade credit on firms' liquidity positions. We show an alternative model of trade credit in Appendix A.2, in which trade credit is modeled explicitly as a delay of payment. Compared with this alternative model, our current model of trade credit is more tractable computationally while generating similar working capital constraints for the entrepreneurs.

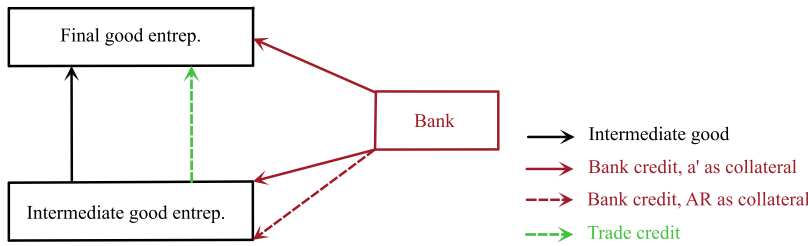

Figure 2: **Flow of goods and credit**

Notes: This figure shows the flow of goods and credit in the model. Intermediate good entrepreneurs provide intermediate good (black solid arrow) and trade credit (green dashed arrow) to final good entrepreneurs. The bank provides credit to both intermediate good entrepreneurs and final good entrepreneurs with either wealth (a', red solid arrow) or accounts receivable as collateral (AR, red dashed arrow).

4 Recursive competitive equilibrium

In this section, we present the problem of the workers and the entrepreneurs, define recursive competitive equilibrium, and analyze entrepreneurs' optimal choice of trade credit in section 4.1.

The problem of the workers is stationary. It can be written simply as follows:

$$\max_{c^h, h} c^h - \psi \frac{h^{1+\theta}}{1+\theta}, \text{ s.t. } c^h = wh. \tag{7}$$

Let $V_x(a, z)$ be the value function of the intermediate good entrepreneur with state variables (a, z). Intermediate good entrepreneurs choose inputs of production (k, l), accounts receivable (AR), consumption (c), and next period wealth (a'). The choices are subject to a budget constraint (equation 9) and a working capital constraint (inequality 10). We also require that entrepreneurs' wealth be non-negative. The problem of the intermediate good entrepreneur can be written recursively as follows:

$$V_x(a, z) = \max_{c,k,l,AR,a'} \log(c) + \beta \mathbb{E}_{z'} V_x(a', z'), \tag{8}$$

$$\text{s.t.} \quad c + a' = (1+r)a + pA_x z(k^\alpha l^{1-\alpha})^{\mu_x} - (r+\delta)k - wl + r^{tc} AR, \tag{9}$$

$$pA_x z(k^\alpha l^{1-\alpha})^{\mu_x} + (1 + r^{tc})AR \leqslant \gamma_1 a' + \gamma_2 AR, \tag{10}$$

$$0 \leqslant AR \leqslant pA_x z(k^\alpha l^{1-\alpha})^{\mu_x}, a' \geqslant 0.$$

Similarly, let $V_y(a,z)$ be the value function of the final good entrepreneur. The problem can be written as follows:

$$\begin{aligned} V_y(a,z) &= \max_{c,k,l,x,AP,a'} \log(c) + \beta \mathbb{E}_{z'} V_y(a',z'), & (11)\\ \text{s.t.} \quad & c + a' = (1+r)a + A_y z((k^{\alpha} l^{1-\alpha})^{1-\chi} x^{\chi})^{\mu_y} \\ & -(r+\delta)k - wl - p_1 x_1 - r^{tc} AP, & (12)\\ & A_y z((k^{\alpha} l^{1-\alpha})^{1-\chi} x^{\chi})^{\mu_y} - (1+r^{tc})AP \leqslant \gamma_1 a', & (13)\\ & 0 \leqslant AP \leqslant px, a' \geqslant 0, \end{aligned}$$

where equation 12 is the budget constraint and inequality 13 is the working capital constraint.

We are now ready to define the recursive competitive equilibrium.

Definition 1 *The recursive competitive equilibrium consists of the interest rate of the rental capital* r, *wage rate* w, *intermediate good price* p, *and the interest rate of trade credit* r^{tc}, *value functions of entrepreneurs* $V_x(a,z)$ *and* $V_y(a,z)$, *policy functions of entrepreneurs* $c_x(a,z)$, $c_y(a,z)$, $k_x(a,z)$, $k_y(a,z)$, $a'_x(a,z)$, $a'_y(a,z)$, $l_x(a,z)$, $l_y(a,z)$, $x(a,z)$, $AR(a,z)$, $AP(a,z)$, *consumption and labor supply of workers* $\{c^h, h\}$, *and CDFs of the distributions of entrepreneurs* $\Phi_x(a,z)$ *and* $\Phi_y(a,z)$, *such that,*

1. *Given prices, value functions and policy functions solve the optimization problems of entrepreneurs 8 and 11.*

2. *Given prices, consumption and labor supply solve the workers' optimization problem 7.*

3. *The labor market clears,*

$$\int l_x(a,z) d\Phi_x(a,z) + \int l_y(a,z) d\Phi_y(a,z) = N \cdot h.$$

4. *The capital rental market clears,*

$$\int (k_x(a,z) - a) \cdot d\Phi_x(a,z) + \int (k_y(a,z) - a) \cdot d\Phi_y(a,z) = 0.$$

5. *The intermediate good market and trade credit market clear,*

$$\int A_x z(k_x(a,z)^\alpha l_x(a,z)^{1-\alpha})^{\mu_x} d\Phi_x(a,z) = \int x(a,z) d\Phi_y(a,z),$$
$$\int AR(a,z) d\Phi_x(a,z) = \int AP(a,z) d\Phi_y(a,z).$$

6. *The stationary distributions evolve according to the following law of motion;*

$$\Phi_x(a',z') = \int \mathbb{I}_{a'=a'_x(a,z)} \pi(z'|z) d\Phi_x(a,z),$$
$$\Phi_y(a',z') = \int \mathbb{I}_{a'=a'_y(a,z)} \pi(z'|z) d\Phi_y(a,z).$$

4.1 Trade credit choices

In this section, we characterize entrepreneurs' choices of trade credit with the following three propositions.

Proposition 1 *There exist functions $g_x(z)$ and $g_y(z)$ such that*

1. *For intermediate good entrepreneurs with wealth a and productivity z, the working capital constraint 10 is binding if and only if $a \leqslant g_x(z)$.*

2. *For final good entrepreneurs with wealth a and productivity z, the working capital constraint 13 is binding if and only if $a \leqslant g_y(z)$.*

The proof can be found in Appendix B.2.

Proposition 2 *There exist functions $h_x(z)$ and $h_y(z)$ such that,*

1. *For intermediate good entrepreneurs with wealth a and productivity z, $AR > 0$ if $a \geqslant h_x(z)$, and $AR = 0$ if $a < h_x(z)$.*

2. *For final good entrepreneurs with wealth a and productivity z, $AP = 0$ if $a > h_y(z)$, and $AP > 0$ if $a \leqslant h_y(z)$.*

This proposition says that entrepreneurs' trade credit choices follow a cut-off rule in their wealth. Consider the intermediate good entrepreneurs. The marginal

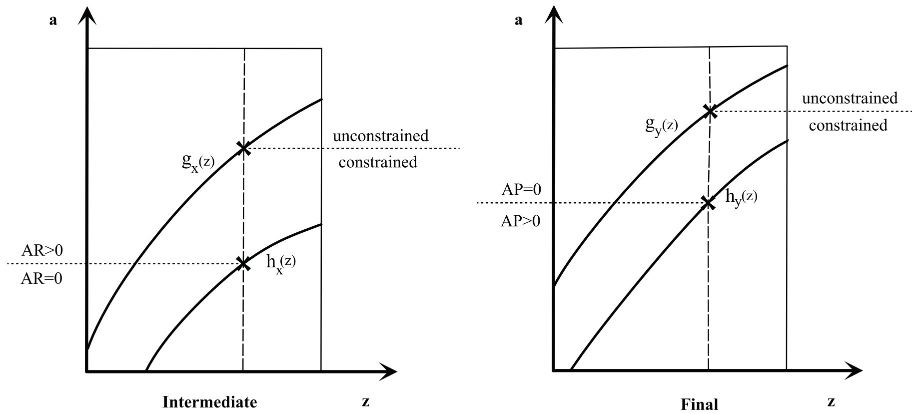

Figure 3: **A graphic illustration of Propositions 1–3**

Notes: The left panel of this figures illustrates the cut-off properties for intermediate good entrepreneurs. The two cut-off functions $g_x(z)$ and $h_x(z)$ intersect with the vertical line at two points, which are the cut-off value of wealth that separate constrained entrepreneurs from unconstrained ones, and entrepreneurs who lend trade credit and those who do not, respectively. Similarly, the right panel shows the two cut-off functions $g_y(z)$ and $h_y(z)$ for the final good entrepreneurs.

cost of lending trade credit is the loss in cash flow $(1-\gamma_2)$ times the shadow value of cash flow, which declines with wealth.[18] The marginal benefit, on the other hand, is simply the interest rate of trade credit r^{tc}. Hence, there exists a threshold value for wealth, above which the marginal benefit of lending trade credit exceeds the marginal cost. A similar argument can be made for the final goods entrepreneurs. The proof can be found in Appendix B.3.

Figure 3 provides a graphic illustration of these three propositions.

Proposition 3 *The following properties hold if* $r^{tc} > 0$*:*

1. *If* $\gamma_2 \in [0, 1]$, *for any* z, $h_x(z) \leqslant g_x(z)$.

2. *For any* z, $h_y(z) \leqslant g_y(z)$.

This proposition characterizes the relationship between entrepreneurs' trade credit choices and financial constraints. If the trade credit interest rate is strictly positive, all unconstrained and some constrained intermediate good entrepreneurs lend trade credit to their customers, and only the very constrained final good entrepreneurs borrow trade credit from their suppliers. The proof can be found in Appendix B.4.

[18]Mathematically, the shadow value of cash flow is the Lagrangian multiplier on the working capital constraint.

5 Quantitative analysis

In this section, we provide a quantitative analysis of trade credit using the model. We first discuss the calibration strategy and some quantitative properties of the calibrated model in section 5.1. We then use the calibrated model to quantify the role of trade credit in normal times (section 5.2), during the 2007–09 financial crisis (sections 5.3 and 5.4), and under productivity shocks (section 5.5).

5.1 Calibration strategy and results

One period of the model corresponds to one quarter in the data. The workers' utility function has the GHH form (Greenwood, Hercowitz and Huffman, 1988). We pick $\theta = 0.5$, which gives a Frisch elasticity of 2 and is well within the standard range of macro estimates (Chetty et al., 2011 and Keane and Rogerson, 2012). The disutility of providing labor, ψ, is calibrated such that 30 percent of workers' time is spent working, i.e., $h = 0.3$. Entrepreneurs' instantaneous utility function is in log form. We calibrate the discount factor β of entrepreneurs to match an annual interest rate of 4 percent. Since the share of entrepreneurs in the data is around 10 percent and the measure of entrepreneurs in the model is two (one each for intermediate good producers and final good producers), we set the measure of workers at $N = 18$.

There are two sectoral production functions in the model. In both sectors, we fix the capital share $\alpha = 1/3$. Consequently, the labor share is $2/3$. Following Yi (2003), the intermediate good share is $\chi = 2/3$. The capital depreciation rate δ is chosen to be 0.025 so that the annual depreciation rate of capital is approximately 10 percent. The Poisson death rate π, which governs the persistence of the idiosyncratic productivity shock, is fixed at 10 percent, following Buera, Kaboski and Shin (2011).

We assume that scale parameters in the two sectors are the same, i.e., $\mu_x = \mu_y$. The productivity distribution $G(z)$ is Pareto with scale parameter 1 and tail parameter ν. Following Buera, Kaboski and Shin (2011), we calibrate the scale parameters (μ_x, μ_y) and the Pareto tail (ν) to match the earnings share of the top 5 percent of individuals and the employment share of the top 10 percent of firms, respectively. Lastly, we pick γ_1 and γ_2, the collateral constraints on wealth a' and accounts receivable AR, respectively, such that the model delivers the ratio of credit market liabilities to nonfinancial assets and the ratio of accounts receivable to gross value added observed in the data.[19] Our calibrated model moments match the data moments very well. Table 3 presents a summary of the calibrated parameters, targets, and calibration results.[20]

Table 3: **Summary of calibration**

Parameter		Value	Target/Source	Data	Model
θ	inverse of Frisch elasticity	0.5	standard	-	-
α	capital share in production function	1/3	capital share of 1/3	-	-
χ	intermediate goods share	2/3	Yi (2003)	-	-
π	Poisson death rate	0.1	Buera, Kaboski and Shin (2011)	-	-
N	measure of workers	18	share of entrepreneurs	10%	10%
ψ	disutility from working	1.9	hours	0.3	0.3
δ	depreciation rate	0.025	annual 10% depreciation rate	10%	10%
β	discount rate	0.95	annual 4% interest rate	4%	4%
μ_x, μ_y	scale parameter	0.85	top 5 percent earning share	0.3	0.3
ν	Pareto tail	4.0	top 10 percent employment share	0.69	0.69
γ_1	collateral value of wealth	0.28	credit market liabilities/nonfinancial assets	0.36	0.36
γ_2	collateral value of AR	0.95	trade receivable/gross value added	0.31	0.31

Notes: The data moment for credit market liability to nonfinancial asset and accounts receivable to gross value-added ratio is computed for the nonfinancial corporate sector, averaged over 4 quarters in year 2006. Credit market liability is taken from Flow of Funds Table L.103 line 23. Nonfinancial asset size is taken from Flow of Funds Table B.103 line 2. Trade receivable is taken from Flow of Funds Table L.103 line 15. Gross value added is taken from NIPA Table 1.14 line 17.

In the following paragraphs, we discuss some quantitative properties of the calibrated model in the steady state.

Trade credit and entrepreneur heterogeneity Table 4 shows that more productive intermediate good entrepreneurs lend less trade credit to their customers and more productive final good entrepreneurs borrow more from their suppliers. The most productive intermediate good producers are less willing to lend trade credit because the opportunity cost of diverting resources from their own production is higher. Similarly, the most productive final good producers are more eager to borrow trade credit because their marginal product is high.

[19] The model moment of credit market liability is the sum of borrowing from the capital rental market and the intra-temporal bank loans. Entrepreneurs' borrowing from the capital rental market is $\int \max(k_x(a,z) - a, 0) d\Phi_x(a,z) + \int \max(k_y(a,z) - a, 0) d\Phi_y(a,z)$. The intra-temporal loan for intermediate good entrepreneurs is $\int [pA_x z(k_x(a,z)^\alpha l_x(a,z)^{1-\alpha})^{\mu_x} + AR(a,z)] d\Phi_x(a,z)$, and for the final good entrepreneurs, it is $\int [A_y z((k_y(a,z)^\alpha l_y(a,z)^{1-\alpha})^{1-\chi} x^\chi)^{\mu_y} - AP(a,z)] d\Phi_y(a,z)$. The intra-temporal loan in total is $\int pA_x z(k_x(a,z)^\alpha l_x(a,z)^{1-\alpha})^{\mu_x} d\Phi_x(a,z) + \int A_y z((k_y(a,z)^\alpha l_y(a,z)^{1-\alpha})^{1-\chi} x^\chi)^{\mu_y} d\Phi_y(a,z)$, because in equilibrium $\int AR(a,z) d\Phi_x(a,z) = \int AP(a,z) d\Phi_y(a,z)$.

[20] An algorithm to solve the stationary equilibrium can be found in Appendix C.1.

Table 4: **Trade credit activities of heterogeneous entrepreneurs**

Panel A: $\frac{AR}{\text{output}}$(%)

	$a \leqslant p50$	$a > p50$
$z \leqslant p50$	100	100
$z > p50$	79.9	79.7

Panel B: $\frac{AP}{\text{output}}$(%)

	$a \leqslant p50$	$a > p50$
$z \leqslant p50$	29.8	0
$z > p50$	47.9	53.0

Another noticeable pattern in Table 4 is that the choice of $\frac{AP}{\text{output}}$ is more sensitive to entrepreneurs' wealth and productivity compared with $\frac{AR}{\text{output}}$. This is consistent with the data (Table 1) and can be attributed to the high collateral value of accounts receivable.

Interest rate of trade credit In the data, trade credit is very expensive. Petersen and Rajan (1997) shows that the effective annual interest rate is around 43 percent for one of the most commonly used trade credit contracts in the retail sector. Costello (2014) uses Compustat to estimate the interest rate on trade credit by comparing firms' gross profit margin before and after the use of trade credit, and finds an annual interest rate of 12 to 16 percent. In our calibrated model, the annual interest rate is 11.2 percent, which is near the range of estimates in Costello (2014).

Through the lens of our model, the high interest rate on trade credit suggests that the entrepreneurs who borrow from their suppliers must be highly productive in order to justify borrowing at elevated rates.

A decomposition of trade credit by its nature Using the calibrated model, we can decompose trade credit into (i) pure redistribution of unused credit from unconstrained to constrained entrepreneurs and (ii) credit creation through accounts receivable financing. The decomposition shows that 87 percent of trade credit is used for creating credit, while only 13 percent is pure redistribution of credit.[21]

[21] The credit creation part of trade credit $\bar{AR}^c$ is the amount of trade credit used by intermediate good entrepreneurs as collateral to obtain bank loans. More specifically, it is calculated as $\bar{AR}^c = \frac{1}{\gamma_2} \int \max\{0, pA_x z(k_x(a,z)^\alpha l_x(a,z)^{1-\alpha})^{\mu_x} + (1+r^{tc})AR(a,z) - \gamma_1 a'\} d\Phi_x(a,z)$. Consequently, the credit redistribution part of trade credit is calculated by $\bar{AR}^r = \int AR(a,z) d\Phi_x(a,z) - \bar{AR}^c$.

5.2 Reallocation effects of trade credit in normal times

To quantify the role of trade credit in normal times, we consider a counterfactual economy with the same calibrated parameters in which the trade credit channel is shut down.[22]

Table 5 presents the differences between the counterfactual economy and the benchmark economy in terms of the aggregate and sectoral level output, hours, capital stock, and TFP. Compared to the benchmark, aggregate output of the counterfactual economy is 23.9 percent lower, which can be decomposed into a 15.3 percent lower capital stock, a 24.4 percent lower hours worked, and 8.4 percent lower aggregate TFP.

Table 5: **Difference between counterfactual and benchmark economy (%)**

	output	capital	labor	input goods	TFP
Intermediate sector	-26.4	-23.8	-32.2	—	-0.9
Final sector	-23.9	-0.2	-10.6	-26.4	-7.5
Aggregate	-23.9	-15.3	-24.4	—	-8.4

Notes: This table displays the percent difference of the counterfactual economy relative to the benchmark economy. A negative number in the table suggest that aggregate statistics of the counterfactual economy is lower than that of the benchmark economy.

Output is higher in the benchmark economy because trade credit relaxes the entrepreneurs' borrowing constraints and allows resources to be allocated more efficiently. The difference in aggregate TFP between the benchmark and counterfactual economies is almost completely explained by the final good sector (7.5 percent), while the intermediate good sector TFP is mostly unchanged (0.9 percent) because trade credit mainly relaxes the borrowing constraints of the final good entrepreneurs. Although trade credit has a small impact on the TFP of the intermediate good sector, it has a sizable impact on its output (26.4 percent) because of the impact of demand from the final good sector.

[22] See section A.3 for the definition of the recursive competitive equilibrium of the counterfactual economy.

5.3 Simulation of the 2007–09 financial crisis

In this section, we engineer a financial crisis in the calibrated model by reducing the collateral values of assets to match the decrease in credit of the U.S. nonfinancial corporate sector during the 2007–09 financial crisis.[23]

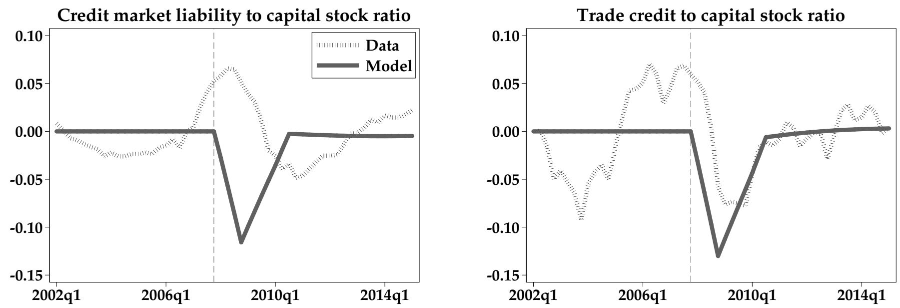

Figure 4: **Dynamics of credit market liability and trade credit**

Notes: The data used in the above figures are for the U.S. nonfinancial corporate sector. Among them, credit market liability is taken from Flow of Funds Table L.103 line 23. Trade credit is calculated as the average of trade payable (line 30 of Flow of Funds Table L.103) and trade receivable (line 15 of Flow of Funds Table L.103). Capital stock is constructed as the sum of equipment (line 46 of Flow of Funds Table B.103), intellectual property products (IPP) (line 47 of Flow of Funds Table B.103), and nonresidential structural capital (line 51 of Flow of Funds Table B.103), all valued at historical prices. Both credit market liability and trade credit to capital stock ratio are HP-filtered with a smoothing parameter of 1,600, and the percentage derivation from trend is plotted in the figures. The corresponding model moments are normalized to be 0 at $t = 0$.

We calibrate a shock process ρ_t to the collateral value γ_1 and γ_2 to match the decrease in credit market liabilities and trade credit in the data.[24] The left panel of Figure 4 shows that, under the calibration, our model generates an 11 percent decrease in the ratio of credit market liabilities to nonfinancial assets, closely matching the 10 percent decrease from peak to trough in the data. In addition, the right panel of Figure 4 shows that the decrease in the ratio of trade credit to nonfinancial assets is approximately 13 percent in the data and the model. Figure 5 shows that the model performs well in matching other moments of the aggregate data series,

[23] An algorithm to solve the transitional dynamics can be found in Appendix C.2.

[24] That is, $\gamma_{1,t} = \rho_t \gamma_1$ and $\gamma_{2,t} = \rho_t \gamma_2$, in which γ_1 and γ_2 take their steady state value. The calibrated ρ_t process is: $\{\rho_1, \rho_2, \rho_3, \rho_4\} = \{0.975, 0.95, 0.925, 0.9\}$, $\rho_t = \rho_{t-1} + 0.014$ for $t = 5, ..., 10$, and $\rho_t = 1$ for $t \geqslant 11$.

slightly understating the peak-to-trough decrease in output, TFP, and capital stock, and matching well the decrease in hours.

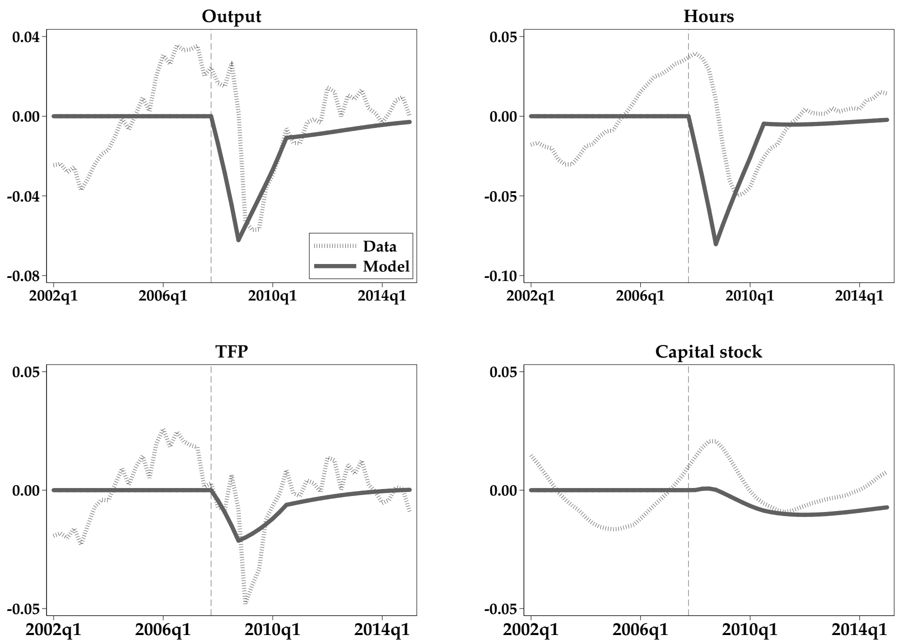

Figure 5: **Dynamics of real economic indicators**

Notes: The data used in the above figures are for the U.S. nonfinancial corporate sector. Among them, output (gross value added) is taken from NIPA Table 1.14 line 17. Data for hours worked is an index taken from Bureau of Labor Statistics Labor Productivity and Costs database (BLS code PRS88003033). Data for capital stock are constructed in the same way as Figure 4. TFP is then constructed as a Solow-type residual using output, hours, and capital stock.

Figure 6 plots the dynamics of trade credit. Following the financial shock, entrepreneurs become more constrained, therefore intermediate good entrepreneurs are less willing to lend trade credit, while final good entrepreneurs are more eager to borrow trade credit. The inward shift in the supply of trade credit and outward shift in demand for trade credit lead to an increase in the trade credit interest rate (left panel) and, under the calibrated parameters, a decrease in the ratio of trade credit to output (right panel). A direct consequence of these changes is that, as trade credit becomes costlier and scarcer during the financial crisis, some of the constrained entrepreneurs can no longer rely on trade credit from their suppliers to finance their production.

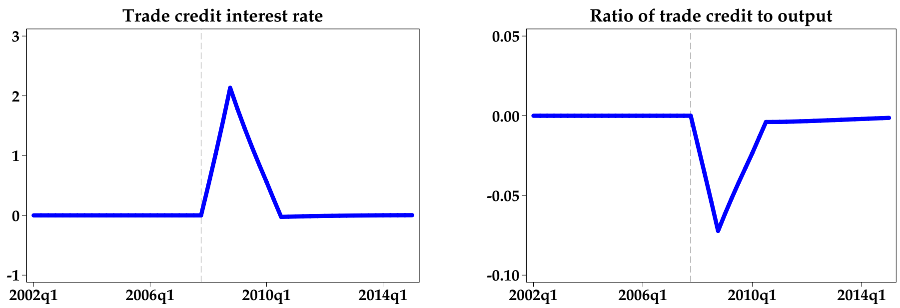

Figure 6: **Dynamics of the interest rate and the size of trade credit**

Notes: The figures show the changes in trade credit in the benchmark economy after the financial crisis. The left panel shows the trade credit interest rate, and the right panel shows the ratio of trade credit to output. The lines are normalized to 0 at the beginning of the crisis.

5.4 Amplification effect of trade credit during the 2007–09 crisis

In this section, we quantify the amplification effect of trade credit during the 2007–09 financial crisis by introducing the same financial shock ρ_t to the counterfactual economy and comparing the dynamics of the benchmark and counterfactual economies following the shock.

We first recalibrate the steady state of the counterfactual economy so that it is comparable to the benchmark. The calibration shows that an increase in the collateral value of wealth in the counterfactual economy to $\tilde{\gamma}_1 = 0.4$ would generate the same output as the benchmark economy.[25]

Figure 7 shows that the recession generated by the same ρ_t shock is milder in the counterfactual economy than in the benchmark economy, with a total output reduction 1.4 percentage points smaller, or a 23 percent smaller decline than in the benchmark.[26]

The amplification effect of trade credit hinges on the underlying entrepreneur heterogeneity. Compared with a contraction in bank credit, the negative impact of a contraction in trade credit is disproportionately borne by the most constrained

[25]Under this recalibration, the shares of constrained entrepreneurs weighted by output in the benchmark and the counterfactual economy are also very similar.

[26]We also performed the quantitative analysis without recalibrating the steady state of the counterfactual model. We find the same amplification effect of trade credit during the financial crisis, only with a smaller magnitude (17 percent instead of 23 percent).

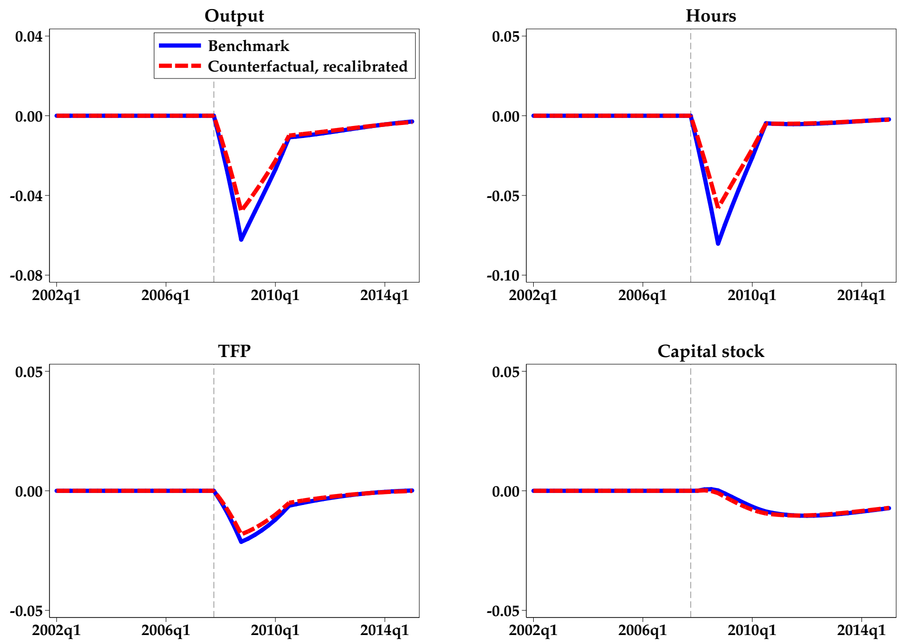

Figure 7: **Dynamics after the financial crisis: Benchmark vs. counterfactual**

Notes: The figures show the changes in the aggregate economy in terms of output, hours, aggregate TFP, and capital stock after the financial crisis. The solid blue lines represent the benchmark economy (with trade credit), while the dashed red lines represent the counterfactual economy (without trade credit). All lines are normalized to 0 at the beginning of the crisis. The blue solid lines in this figure, which are the dynamics of the benchmark economy following the ρ_t shock, are identical to the solid lines in Figure 5.

entrepreneurs. For example, in our model, the decrease in $\frac{AP}{output}$ from the financial shock for the constrained final good entrepreneurs is approximately 10 percent, whereas the unconstrained final good entrepreneurs are unaffected. This means that the reallocation role played by trade credit is impaired by the financial shock, which amplifies the impact of the financial shock on the aggregate economy.

5.5 Productivity shocks

While trade credit amplifies financial shocks, it does not amplify productivity shocks. Figure 8 shows the dynamics of aggregate output are indistinguishable between the benchmark and counterfactual economies following sector-level productivity shocks.[27]

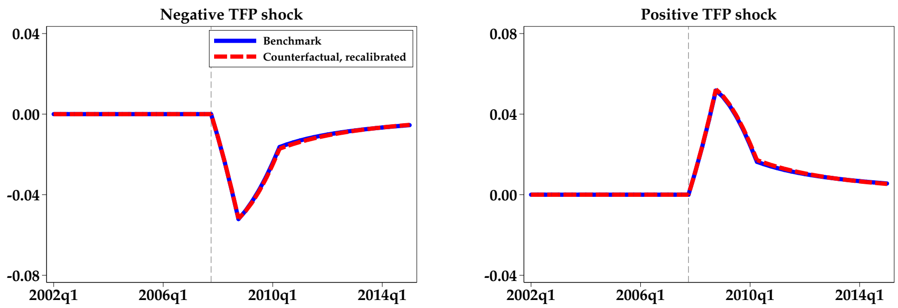

Figure 8: **Output following TFP shocks**

Notes: The figures show the changes of output in the benchmark economy and the counterfactual economy after a negative and a positive TFP shock. The solid blue lines represent the benchmark economy (with trade credit) while the dashed red lines represent the counterfactual economy (without trade credit). All lines are normalized to 0 at the beginning of the crisis.

As shown in Figure A2 , trade credit does not amplify productivity shocks because trade credit relative to output does not change significantly.[28] In contrast, the changes in trade credit are almost twice as large as the changes in output following positive or negative financial shocks.

The different dynamics of trade credit under financial and productivity shocks can help identify the drivers of business cycle fluctuations. Figure A3 shows that, in the data, trade credit is strongly pro-cyclical and has a standard deviation almost twice as large as the standard deviation of GDP. This is consistent with the dynamics of trade credit under financial shocks and suggests that financial shocks are important drivers of the U.S. business cycle.

[27]The negative shock process ξ_t to A_x and A_y in Figure 8 and A2 is $\{\xi_1, \xi_2, \xi_3, \xi_4\} = \{0.925, 0.85, 0.775, 0.7\}$, $\xi_t = \xi_{t-1} + 0.05$ for $t = 5, ..., 10$, and $\xi_t = 1$ for $t \geqslant 11$. The positive shock process is $\{\xi_1, \xi_2, \xi_3, \xi_4\} = \{1.0075, 1.015, 1.0225, 1.3\}$, $\xi_t = \xi_{t-1} - 0.05$ for $t = 5, ..., 10$, and $\xi_t = 1$ for $t \geqslant 11$. The findings in this section do not depend on the magnitude or the persistence of ξ_t .

[28]Trade credit interest rate is also almost unchanged following productivity shocks.

6 Conclusion

In this paper, we show that trade credit—which exists because inputs suppliers have a comparative advantage over banks in lending to their customers—helps alleviate the misallocation of production inputs. However, this channel is dependent on the suppliers' access to financing, including their ability to finance trade credit lending by borrowing against the resulting accounts receivable. In a financial crisis, their access to financing is disrupted, resulting in a decrease in trade credit lending, a reduction in the effectiveness of the trade credit reallocation channel, and an amplification of the original financial shock. Trade credit thus improves overall productivity by alleviating misallocation while also increasing aggregate volatility.

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Online Appendix

Not for Publication

A Model

A.1 Deriving the working capital constraint

The amount of intra-temporal bank loan needed for the entrepreneurs is,

$$\begin{aligned} \text{intermediate}: \quad & \hat{m}_x = a' - a + c + r(k-a) + \delta k + wl + AR, \\ \text{final}: \quad & \hat{m}_y = a' - a + c + r(k-a) + \delta k + wl + px - AP. \end{aligned}$$

Using budget constraints of the entrepreneurs,

$$\begin{aligned} \text{intermediate}: \quad & c + a' = (1+r)a + pA_x z(k^\alpha l^{1-\alpha})^{\mu_x} \\ & -(r+\delta)k - wl + r^{tc}AR, \text{ and} \\ \text{final}: \quad & c + a' = (1+r)a + A_y z((k^\alpha l^{1-\alpha})^{1-\chi} x^\chi)^{\mu_y} \\ & -(r+\delta)k - wl - p_1 x_1 - r^{tc}AP, \end{aligned}$$

we derive the need for intra-temporal bank loans for intermediate goods entrepreneurs as $\hat{m}_x = pA_x z(k^\alpha l^{1-\alpha})^{\mu_x} + (1+r^{tc})AR$, and for final goods entrepreneurs it is $\hat{m}_y = A_y z((k^\alpha l^{1-\alpha})^{1-\chi} x^\chi)^{\mu_y} - (1+r^{tc})AP$.

Upon default, a renegotiation process begins. Intermediate goods entrepreneurs would propose a take-it-or-leave-it offer to repay only $\gamma_1 a' + \gamma_2 AR$, where $\gamma_2 AR$ is the expected liquidation value of accounts receivable for the bank. The value of default for intermediate goods entrepreneurs is therefore $pA_x z(k^\alpha l^{1-\alpha})^{\mu_x} + AR - (\gamma_1 a' + \gamma_2 AR)$, and the value of non-default is $pA_x z(k^\alpha l^{1-\alpha})^{\mu_x} + AR - \hat{m}_1$. The incentive compatibility constraint gives $\hat{m}_x \leqslant \gamma_1 a' + \gamma_2 AR$.

Similarly, for final goods entrepreneurs, the incentive compatibility constraint leads to a constraint on intra-temporal bank loan $\hat{m}_y \leqslant \gamma_1 a'$.

A.2 An alternative way of modeling trade credit

In this section, we show an alternative way of modeling trade credit as a delay of payments.

Timing Consider a different timing for the model, in which the output of the intermediate goods entrepreneur is carried over into the next period. The output is sold at the beginning of next period to generate cash flow.

Suppose that the intermediate goods entrepreneur has two choices regarding selling its goods. First, the goods can be sold on the spot, generating instant cash flow. Second, the goods can be extended as a trade credit loan, which is repaid at the end of the period.

Financial frictions and the existence of trade credit Suppose that at the beginning of each period, the entrepreneurs need to finance working capital. Without loss of generality, assume that working capital includes interest $r_t k_t$, wage bills $w_t l_t$, and for the final goods entrepreneur, also the input goods px. The entrepreneurs can finance working capital from two sources: 1) borrow from the bank, and 2) use the cash flow generated by selling goods on the spot market.

First let us consider the case where a bank loan is the only source of financing. Let a_t be the amount of collateral that the entrepreneurs provide to obtain bank loans. Suppose that at the beginning of the period after having been granted the bank loan, the entrepreneur can default. A renegotiation process begins after default. The value of the collateral to the bank is $\chi_t a_t$, where $\chi_t \in (0, 1)$. Let λ be the bargaining power of the entrepreneur and $(1 - \lambda)$ the bargaining power of the bank. The renegotiation contract would specify that the entrepreneur only needs to repay γa_t. Therefore, a renegotiation-proof bank loan contract has a limit of γa_t.

Second, consider the scenario in which the suppliers have a certain comparative advantage in lending input goods. Following Burkart and Ellingsen (2004), we assume that unlike bank loans, input goods cannot be diverted. Under the assumptions, 1) supplies will lend trade credit because it is secured, and 2) bank will internalize the comparative advantage by lending against accounts receivable.

Therefore, we can write the working capital constraint of the two entrepreneurs as the following:

$$
\begin{aligned}
r_t k_t + w_t l_t &\leqslant \overbrace{\gamma_1 a_t + \gamma_2 AR_t}^{\text{bank loan}} + \overbrace{(p_t x_t - AR_t)}^{\text{cash flow}}, \\
r_t k_t + w_t l_t + p_t x_t - AP_t &\leqslant \underbrace{\gamma_1 a_t}_{\text{bank loan}}.
\end{aligned}
$$

Rearranging the above two equations, we get

$$
\begin{aligned}
r_t k_t + w_t l_t - p_t x_t + AR_t &\leqslant \gamma_1 a_t + \gamma_2 AR_t, \\
r_t k_t + w_t l_t + p_t x_t - AP_t &\leqslant \gamma_1 a_t.
\end{aligned}
$$

Similar to the working capital constraints in our benchmark model (equations 5 and 6), we see that lending trade credit AR_t essentially tightens the borrowing constraint of the intermediate goods entrepreneurs by $(1-\gamma_2)AR$. They lose an instant cash flow of size AR but gain additional access to bank loan of size $\gamma_1 AR$. Borrowing trade credit AP_t, on the other hand, relaxes the borrowing constraint of the final goods entrepreneur by AP_t.

Recursive representation of the entrepreneurs' problem Let $V_x(a,x,z)$ be the value function of the intermediate goods entrepreneur and $V_y(a,z)$ the value function of the final goods entrepreneur.[29] We can write their problem recursively as follows.

For the intermediate goods entrepreneurs,

$$
\begin{aligned}
V_x(a,x,z) \quad = \quad & \max_{c,AR,k,l,a'} u(c) + \beta \mathbb{E}_{z'} V_x(a',x',z'), \\
\text{s.t.} \quad & c + a' = (1+r)a + px - AR + (1+r^{tc})AR - (r+\delta)k - wl, \\
& rk + wl - px + AR \leqslant \gamma_1 a + \gamma_2 AR, \\
& 0 \leqslant AR \leqslant px, \\
& a' \geqslant 0, \\
& x' = A_x z (k^\alpha l^{1-\alpha})^{\mu_x}.
\end{aligned}
$$

[29]We assume that the intermediate goods entrepreneurs carry their output to the beginning of the next period while the final goods entrepreneurs sell their output at the end of the current period. This is why output x enters as a state variable for the intermediate goods entrepreneurs but not for the final goods entrepreneurs.

For the final goods entrepreneurs,

$$
\begin{aligned}
V_y(a,z) \quad = \quad & \max_{c,AP,k,l,x,a'} u(c) + \beta \mathbb{E}_{z'} V_y(a',z'), \\
\text{s.t.} \quad & c + a' = (1+r)a + A_y z((k^{\alpha} l^{1-\alpha})^{1-\chi} x^{\chi})^{\mu_y} \\
& -(r+\delta)k - wl - px - r^{tc} AP, \\
& rk + wl + px - AP \leqslant \gamma_1 a, \\
& 0 \leqslant AP \leqslant px, \\
& a' \geqslant 0.
\end{aligned}
$$

A.3 Equilibrium definition of the counterfactual economy

The stationary equilibrium of the counterfactual economy is defined as follows:

Definition 2 *The recursive competitive equilibrium without trade credit consists of interest rate $\tilde{R}$, wage rate $\tilde{w}$, and intermediate goods price $\tilde{p}$, value functions of entrepreneurs $\tilde{V}_x(a,z)$ and $\tilde{V}_y(a,z)$, policy functions of entrepreneurs $\tilde{c}_x(a,z)$, $\tilde{c}_y(a,z)$, $\tilde{k}_x(a,z)$, $\tilde{k}_y(a,z)$, $\tilde{a}'_x(a,z)$, $\tilde{a}'_y(a,z)$, $\tilde{l}_x(a,z)$, $\tilde{l}_y(a,z)$, $\tilde{x}(a,z)$, consumption and labor supply of workers $\{\tilde{c}^h, \tilde{h}\}$ and distributions of entrepreneurs $\tilde{\Phi}_x(a,z)$ and $\tilde{\Phi}_y(a,z)$, such that,*

1. *Given prices, value functions and policy functions solve the optimization problem of entrepreneurs.*

$$
\begin{aligned}
\tilde{V}_x(a,z) \quad = \quad & \max_{c,k,l,a'} \log(c) + \beta \mathbb{E}_{z'} \tilde{V}_x(a',z'), \\
\text{s.t.} \quad & c + a' = (1+r)a + pA_x z(k^{\alpha} l^{1-\alpha})^{\mu_x} - (r+\delta)k - wl, \\
& pA_x z(k^{\alpha} l^{1-\alpha})^{\mu_x} \leqslant \tilde{\gamma}_1 a', a' \geqslant 0.
\end{aligned}
$$

$$
\begin{aligned}
\tilde{V}_2(a,z) \quad = \quad & \max_{c,k,l,x_1,a'} \log(c) + \beta \mathbb{E}_{z'} \tilde{V}_2(a',z'), \\
\text{s.t.} \quad & c + a' = (1+r)a + A_y z((k^{\alpha} l^{1-\alpha})^{1-\chi} x^{\chi})^{\mu_y} \\
& -(r+\delta)k - wl - px, \\
& A_y z((k^{\alpha} l^{1-\alpha})^{1-\chi} x^{\chi})^{\mu_y} \leqslant \tilde{\gamma}_1 a', a' \geqslant 0.
\end{aligned}
$$

2. *Given prices, consumption and labor supply solve workers optimization problem 7.*

3. *Labor market clears,*

$$\int \tilde{l}_x(a,z)d\tilde{\Phi}_x(a,z) + \int \tilde{l}_y(a,z)d\tilde{\Phi}_y(a,z) = N \cdot \tilde{h}.$$

4. *Capital market clears,*

$$\int (\tilde{k}_x(a,z) - a) \cdot d\tilde{\Phi}_x(a,z) + \int (\tilde{k}_y(a,z) - a) \cdot d\tilde{\Phi}_y(a,z) = 0.$$

5. *Intermediate goods market clears,*

$$\int A_x z F_x(\tilde{k}_x(a,z), \tilde{l}_x(a,z))d\tilde{\Phi}_x(a,z) \quad = \quad \int \tilde{x}(a,z)d\tilde{\Phi}_y(a,z).$$

6. *The stationary distributions evolve according to,*

$$\begin{aligned}
\tilde{\Phi}_x(a',z') &= \int \mathbb{I}_{a'=\tilde{a}'_x(a,z)} \pi(z'|z)d\tilde{\Phi}_x(a,z), \\
\tilde{\Phi}_y(a',z') &= \int \mathbb{I}_{a'=\tilde{a}'_y(a,z)} \pi(z'|z)d\tilde{\Phi}_y(a,z).
\end{aligned}$$

B Proofs

In order to prove the propositions, we first lay out the optimization problem of the entrepreneurs and derive the first-order conditions (FOCs). We prove the first part of each proposition regarding the intermediate goods entrepreneurs. The proof of the second part regarding the final goods entrepreneurs is very similar and hence is omitted.

Intermediate goods entrepreneurs Consider the following problem:

$$
\begin{aligned}
V_x(a,z) \quad &= \quad \max_{c,k,l,AR,a'} \log(c) + \beta \mathbb{E}_{z'} V_x(a',z') \\
\text{s.t.} \quad & c + a' = (1+r)a + pA_x z(k^\alpha l^{1-\alpha})^{\mu_x} - (r+\delta)k - wl + r^{tc}AR, \quad (14)\\
& pA_x z(k^\alpha l^{1-\alpha})^{\mu_x} + (1+r^{tc})AR \leqslant \gamma_1 a' + \gamma_2 AR, \quad (15)\\
& 0 \leqslant AR \leqslant pA_x z(k^\alpha l^{1-\alpha})^{\mu_x}, \quad (16)\\
& a' \geqslant 0.
\end{aligned}
$$

Denote $F(k,l) = (k^\alpha l^{1-\alpha})^{\mu_x}$ as the production function of the intermediate goods. The Lagrangian of the problem can be written as,

$$
\begin{aligned}
\mathcal{L} \quad = \quad & \log((1+r)a + pA_x zF(k,l) - (r+\delta)k - wl + r^{tc}AR - a') \\
& +\beta \mathbb{E}_{z'} V_x(a',z') + \mu(\gamma_1 a' + \gamma_2 AR - pA_x zF(k,l) - (1+r^{tc})AR) \\
& +\chi_1(pA_x zF(k,l) - AR) + \chi_2 AR \\
& +\tau a'.
\end{aligned}
$$

The FOCs are:

$$
\begin{aligned}
k: \quad & p_1 A_1 z F_k = \frac{r+\delta}{1 - c\mu + c\chi_1}, \quad (17)\\
l: \quad & p_1 A_1 z F_l = \frac{w}{1 - c\mu + c\chi_1}, \quad (18)\\
AR: \quad & \frac{1}{c} r^{tc} = \mu(1 + r^{tc} - \gamma_2) + \chi_1 - \chi_2, \quad (19)\\
a': \quad & \frac{1}{c} = \beta \mathbb{E}_{z'} V_{x,a'} + \mu\gamma_1 + \tau. \quad (20)
\end{aligned}
$$

Together with the envelope condition $V_{1,x} = \frac{1}{c}(1+r)$, we derive the Euler equation,

$$\frac{1}{c} = \beta \mathbb{E}_{z'}[\frac{1}{c'}(1+r)] + \mu\gamma_1 + \tau. \tag{21}$$

In addition, according to the Kuhn-Tucker condition, the Lagrangian multipliers and the constraints have the following properties:

$$\begin{aligned}
&\mu \geqslant 0, \gamma_1 a' - pA_x zF(k,l) - (1 + r^{tc} - \gamma_2)AR \geqslant 0, \\
&\chi_1 \geqslant 0, pA_x zF(k,l) - AR \geqslant 0 \\
&\chi_2 \geqslant 0, AR \geqslant 0 \\
&\tau \geqslant 0, a' \geqslant 0,
\end{aligned}$$

with complementary slackness.

Notice that the above problem is a rather standard stochastic optimization problem. According to Theorem 9.7 and 9.8 of Stokey and Lucas (1989), we know that given z, the value function $V_x(\cdot, z)$ is strictly increasing and strictly concave.[30]

Before proceeding to the proofs of the propositions, we discuss the monotonicity of the optimal policy function in the following lemma.

Lemma 1 *Given z, the policy functions $AR(a,z)$ and $a'(a,z)$ both increase in a.*

B.1 Proof of Lemma 1

First, we intend to show that given z, $a'(a,z)$ increases with a. For any $a^h > a^l$ and for any z, with a slight abuse of notation, denote $\{k^h, l^h, AR^h, c^h, a'^h\}$ and $\{k^l, l^l, AR^l, c^l, a'^l\}$ as the optimal choices, respectively. We need to show that $a'^h \geqslant a'^l$.

Suppose not, i.e., $a'^h < a'^l$, it has to be true that $c^h > c^l$ because otherwise $V_x(\cdot, z)$ cannot be a strictly increasing function.

Since $V_x(\cdot, z)$ is strictly concave. In order for equation (20) to hold, it has to be true that $\mu^h < \mu^l$, which means that $\mu^l > 0$; i.e., the working capital constraint is binding for (a^l, z). From equation 19 and the complementary slackness conditions, it is easy to see that if $\mu^h < \mu^l$, then $\chi_1^h \geqslant \chi_1^l$ and $\chi_2^h \leqslant \chi_2^l$. Therefore, according

[30] Stokey, Nancy L. and Robert E. Lucas. 1989. *Recursive Methods in Economic Dynamics*. Harvard University Press.

to equations 17 and 18, it holds that $pA_x zF_{k^h} < pA_x zF_{k^l}$ and $pA_x zF_{l^h} < pA_x zF_{l^l}$. Because the production function $F(k, l)$ is DRS, the above two conditions give that $k^h > k^l$ and $l^h > l^l$. Also because $\chi_1^h > \chi_1^l$, we can infer that $AR^h \geqslant AR^l$. As a result, the following inequalities hold:

$$a'^h \geqslant pzA_x F(k^h, l^h) + (1 + r^{tc} - \gamma_2)AR^h > pzA_x F(k^l, l^l) + (1 + r^{tc} - \gamma_2)AR^l = a'^l.$$

which contradicts the assumption that $a'^h < a'^l$.

Next we show that given (a, z), the optimal AR increases with a'. Note that given (a, z), the optimization problem of the entrepreneur can be reduced to a combination of static profit maximization problem and a inter-temporal choice of optimal a'. Given any choice of a', the static profit maximization problem can be written as,

$$\begin{aligned} \max_{k,l,AR} \quad & pzA_x F(k, l) - (r + \delta)k - wl + r^{tc}AR, \\ \text{s.t.} \quad & pzA_x F(k, l) + (1 + r^{tc} - \gamma_2)AR \leqslant \gamma_1 a', \\ & 0 \leqslant AR \leqslant pzA_x F(k, l). \end{aligned}$$

We can show that the optimal choices of the above optimization problem increase with a' using Theorem 2.8.1 from Topkis (1989).[31] It is easy to see that the feasibility set increases strictly with a'; therefore, we only need to show that equation 2.8.1 from Topkis (1989) is satisfied.

Denote $W(k, l, AR) = pzA_x F(k, l) - (r + \delta)k - wl + r^{tc}AR$. Consider two sets of choices $\{k_1, l_1, AR_1\}$ and $\{k_2, l_2, AR_2\}$. We need to show that

$$\begin{aligned} W(k_1, l_1, AR_1) + W(k_2, l_2, AR_2) \quad \leqslant \quad & W(k_1 \wedge k_2, l_1 \wedge l_2, AR_1 \wedge AR_2) + \\ & W(k_1 \vee k_2, l_1 \vee l_2, AR_1 \vee AR_2), \end{aligned}$$

which reduces to

$$\begin{aligned} pzA_x F(k_1, l_1) + pzA_x F(k_2, l_2) \quad \leqslant \quad & pzA_x F(k_1 \wedge k_2, l_1 \wedge l_2) + \\ & pzA_x F(k_1 \vee k_2, l_1 \vee l_2). \end{aligned}$$

This is straightforward to prove because $\frac{\partial^2 F}{\partial k \partial l} > 0$, i.e., F satisfies strictly increasing

[31]Topkis, Donald M. 1998. *Supermodularity and Complementarity.* Princeton University Press.

differences in (k,l). As a result of Theorem 2.8.1, the optimal AR increases with a'. Since we already showed that the optimal a' increases with a. It follows that the policy function $AR(a,z)$ is increasing in a. *Q.E.D.*

B.2 Proof of Proposition 1

Given z, define set $\mathbf{U}^z = \{a|\mu(a,z) = 0\}$. We intend to show that the set $\mathbf{U}^z$ is in the following form $(\underline{a}, \infty)$.[32] To do this, we first show that $\mathbf{U}^z$ has the following property: if $a \in \mathbf{U}^z$ and $\hat{a} > a$, then $\hat{a} \in \mathbf{U}^z$.

Let $a \in \mathbf{U}^z$. According to the definition of $\mathbf{U}^z$, we know that $\mu(a,z) = 0$. The complementary slackness condition then implies that for entrepreneur (a,z), the working capital constraint is not binding,

$$pA_x zF(k,l) + (1 + r^{tc})AR < \gamma_1 a' + \gamma_2 AR.$$

According to equation 19, $\mu = 0$ implies that $\chi_2 = 0$ and $\chi_1 = \frac{1}{c} r^{tc}$. Taking the value of μ, χ_1, χ_2 back into equations 17 and 18, we get

$$\begin{aligned} k: \quad & pA_x zF_k = \frac{r+\delta}{1+r^{tc}}, \\ l: \quad & pA_x zF_l = \frac{w}{1+r^{tc}}. \end{aligned}$$

Since production function F is decreasing return to scale, there exist optimal k and l that solve the above system of two equations. Denote the solution as k^* and l^*. Since $\chi_1 = 0$, the complementary slackness condition implies that $AR = pA_x zF(k^*, l^*)$.

Now consider the budget constraint 14. Let $m = pA_x zF(k,l) - (r+\delta)k - wl + r^{tc}AR$, and the budget constraint can be re-written as,

$$c + a' = (1+r)a + m.$$

It is clear that m is maximized when $k = k^*$, $l = l^*$, and $AR = pA_x zF(k^*, l^*)$. In other words, entrepreneurs will always choose $k = k^*$, $l = l^*$, and $AR = pA_x zF(k^*, l^*)$ if

[32] Notice that this statement is equivalent to that of Proposition 1.

they are feasible under the working capital constraint (equation 15).

Consider an entrepreneur with productivity z and wealth $\hat{a} > a$. According to Lemma 1, $a'(\hat{a}, z) \geqslant a'(a, z)$. Therefore, since $k = k^*$, $l = l^*$, and $AR = pA_x zF(k^*, l^*)$ are feasible for entrepreneur (a, z), they must be feasible for entrepreneur $(\hat{a}, z)$ as well. Following the above analysis, we know that entrepreneurs will choose $k = k^*$, $l = l^*$, and $AR = pA_x zF(k^*, l^*)$, and the working capital constraint holds with strict inequality. Using the complementary slackness condition, this implies that $\mu(a', z) = 0$.

With the help of this property, we show that $\mathbf{U}^z$ is an interval. Suppose that it is not; then there exists $x < w < y$, such that $x, y \in \mathbf{U}^z$ but $w \notin \mathbf{U}^z$. This violates the property, since it means $x \in \mathbf{U}^z$, $w < x$, but $w \notin \mathbf{U}^z$.

Finally, we show that $\mathbf{U}^z$ is unbounded from above. Suppose that it is not; then there exists $w \notin \mathbf{U}^z$ but $w > a$ for all $a \in \mathbf{U}^z$, which is a violation of the property. *Q.E.D.*

B.3 Proof of Proposition 2

Define a set $\mathbf{H}^z = \{a | AR(a, z) > 0\}$. We show that $\mathbf{H}^z$ is in the form of $(\underline{a}, \infty)$. The proof is very similar to proof of Proposition 1. Essentially, we need to prove that the set $\mathbf{H}^z$ has the following property: if $a \in \mathbf{H}^z$ and $\hat{a} > a$, then $\hat{a} \in \mathbf{H}^z$. It is clear that this property holds since according to Lemma 1, $AR(a, z)$ is an increasing function in a. Therefore, for any $\hat{a} > a$, we have $AR(\hat{a}, z) \geqslant AR(a, z) > 0$. *Q.E.D.*

B.4 Proof of Proposition 3

Proving this proposition is equivalent to showing that $\mathbf{U}^z \subseteq \mathbf{H}^z$. Take any $a \in \mathbf{U}^z$; we know that $\mu(a, z) = 0$ according to the definition of $\mathbf{U}^z$. Next we show that $AR(a, z) > 0$.

According to equation 19, if $\mu(a, z) = 0$ then $\frac{1}{c(a,z)} r^{tc} = \chi_1(a, z) - \chi_2(a, z)$. Since $\frac{1}{c(a,z)} r^{tc} > 0$, it has to be the case that $\chi_2(a, z) = 0$. Because otherwise if $\chi_2(a, z) > 0$, the complementary slackness condition implies that $AR(a, z) = 0$, which in turn implies that $\chi_1(a, z) = 0$. The equation $\frac{1}{c(a,z)} r^{tc} = \chi_1(a, z) - \chi_2(a, z)$ therefore cannot hold because the left-hand side is positive but the right-hand side is negative. *Q.E.D.*

C Computation

In this section, we describe the algorithms for computing the benchmark model. Section C.1 contains the algorithms to compute the stationary equilibrium. Section C.2 contains the algorithms to compute the transitional dynamics. The algorithms to compute the counter-factual model are very similar to the benchmark model, only with different sets of FOCs, budget constraint, and working capital constraint. Hence they are omitted here.

C.1 Stationary equilibrium

- Guess equilibrium prices r, w, p, r^{tc}.
- Given the prices, solve the household problem.
- Given the prices, solve the entrepreneurs problem as follows:
  - Discretize the state space.
  - Guess policy function $c(a, z)$.
  - For each (a, z), assume that the entrepreneur is unconstrained, i.e., $\mu(a, z) = 0$. Solve for the system of equations that consists of FOCs and budget constraint.
  - Check whether the working capital constraint is satisfied with the solution to the above system of equations.
  - If the working capital constraint is not satisfied, it means that $\mu(a, z) > 0$ and working capital constraint holds with equality. Solve the system of equations that consists of FOCs, budget constraint, and working capital constraint (with equality).
  - Use the Euler equation to update the policy function $c(a, z)$ until it converges.
- Given any arbitrary distribution of (a, z), iterate using the policy functions derived above until a stationary distribution is reached.

- Generate the aggregate statistics of the four markets: capital, labor, intermediate goods, and trade credit market.
- Update (r, w, p, r^{tc}) until the four markets clear simultaneously.

C.2 Transitional dynamics

To compute the transitional dynamics of the economy, we consider a transition path of $T = 100$ periods. The economy is at the initial stationary equilibrium level in period $t = 1$, and we assume that it converges back to the initial stationary equilibrium at period $t = T$.

- Guess a sequence of prices $\{r_t, w_t, p_t, r_t^{tc}\}_{t=2}^{T-1}$.
- Backward induction. For each $t = T-1, T-2, ..., 2$,
  - Discretize the state space.
  - Given prices, solve the household problem for period t.
  - Given prices, solve the entrepreneurs policy functions for period t.
    1. Guess $c_t(a, z)\mu_t(a, z) = 0$, solve the system of equations that consists of FOCs of period t, budget constraint, and Euler equations (with the next period policy function $c_{t+1}(a, z)$ known).
    2. Check whether the working capital constraint is satisfied under the above solution.
    3. If the working capital is not satisfied, $c_t(a, z)\mu_t(a, z) > 0$ and the working capital constraint holds with equality. Solve the system of equations that consists of FOCs of period t, budget constraint, Euler equations (with the next period policy function $c_{t+1}(a, z)$ known), and working capital constraint with equality.
- Forward induction. The first period stationary distribution $\Phi_{x,1}(a, z)$ and $\Phi_{y,1}(a, z)$ is set to be the stationary equilibrium distribution. Using the policy functions for period $t = 2, ..., T-1$, compute the distribution along the transition path ($\Phi_{x,t}(a, z)$ and $\Phi_{y,t}(a, z)$).

- Generate aggregate statistics for the four markets in every period $t = 2, ..., T-1$ using the policy functions and the distributions.

- Update $\{r_t, w_t, p_t, r_t^{tc}\}_{t=2}^{T-1}$ until the four markets clear simultaneously in each period $t = 2, ..., T - 1$.

D Additional tables and figures

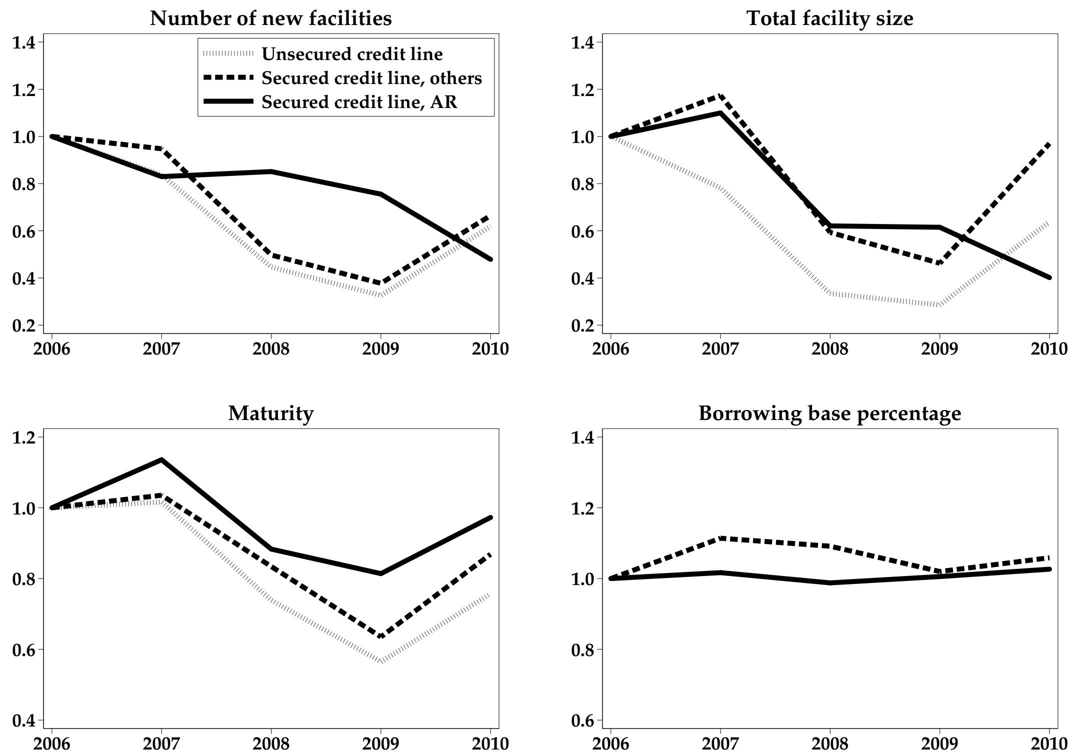

Figure A1: **Characteristics of new credit line facilities**

Notes: We compute the characteristics of the newly opened credit line facilities of each year as the average of all credit line facilities that are opened in that year. The solid lines in these figures are credit line facilities that require accounts receivable as collateral. The dashed lines are credit line facilities that require other types of assets as collateral. The dotted lines are unsecured credit line facilities. The time series are normalized such that they are 1 in year 2006.

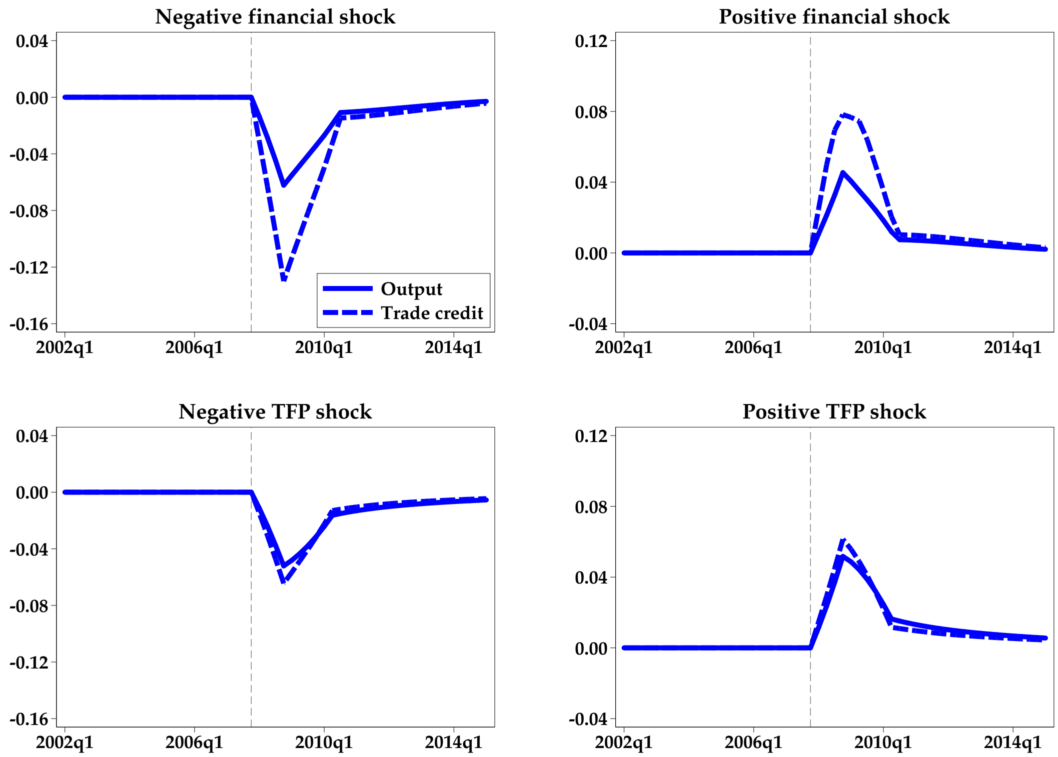

Figure A2: **Dynamics of Trade credit and output following financial/TFP shocks**

Notes: The figures show the changes in trade credit and output in the benchmark economy after a negative financial shock, a positive financial shock, a negative TFP shock, and a positive TFP shock. The solid blue lines represent output, while the dashed blue lines represent trade credit. All lines are normalized to 0 at the beginning of the shock.

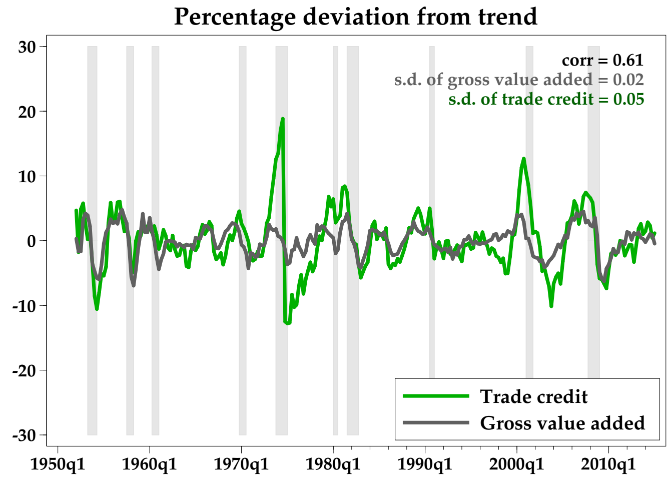

Figure A3: **Trade credit over the U.S. business cycle**

Notes: The data are for the nonfinancial corporate sector. Gross value added is taken from NIPA Table 1.14 line 17. Trade credit is computed as the average of accounts receivable (line 15 of Flow of Funds Table L.103) and accounts payable (line 30 of Flow of Funds Table L.103). Both time series are HP-filtered with a smoothing parameter of 1,600.