Production and credit networks: When does trade credit amplify shocks?

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ABSTRACT

Firms depend heavily on trade credit. This paper introduces a trade credit network into a structural model of a production network economy. In the empirical analysis of the model, we find that trade credit is an elusive insurance: as long as a firm is financially unconstrained and times are good, more trade credit enhances sales stability and insures against shocks to the firm's suppliers. However, if a firm becomes financially constrained or times are bad, trade credit fails to insure against supplier shocks. Moreover, if the firm is low on cash, trade credit propagates shocks from a supplier to its customer.

I Introduction

The importance of trade credit is indisputable. As reported by Williams (2008) and recounted in Barrot (2016), about 90% of global merchandise is purchased on trade credit. Trade credit with the associated credit and production networks have long been viewed as a channel

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propagating shocks (Long and Plosser (1983), Kiyotaki and Moore (1997)). Since then, many have taken upon themselves to rationalize the propagation of shocks in the first type of network - production network.[1] Others, like Kiyotaki and Moore (1997, 2002) predict propagation of shocks in the second type of networks - credit networks.[2] In contrast, only few attempt to reconcile the production and credit networks in one coherent picture.[3]

The goal of this paper is to study the role of credit networks, captured by trade credit, alongside production networks in propagation of shocks between firms in the economy. Here, we generalize the Acemoglu et al. (2012) production network economy to allow the pre-existing credit networks to take part in propagation of idiosyncratic productivity shocks. At first sight the role of credit networks in propagation of idiosyncratic *productivity* shocks might seems unfamiliar. After all, the recent literature - for example Luo (2015), or Lin and Ye (2017) - hints at credit networks being a channel propagating *financial* shocks rather than *productivity* shocks. But the concept of credit networks propagating *productivity* shocks is not new either. Shocks to technology, or income, are the starting point for a business-cycle-generating feedback loop between credit constraints and asset prices in Kiyotaki and Moore (1997). Also, recent developments in the smartphone market deliver anecdotal evidence that credit networks intertwined with production networks might play a role in propagation of *productivity* shocks. For example, in 2014, GTAT engaged in an elaborated credit contract with Apple to produce sapphire phone screens, which turned sour when GTAT's furnaces were unable to produce required quantities (Arthur (2014)). Also recently, Apple fighting to regain leadership in the smartphone market (Reisinger (2017), and Webb (2017)) turned to suppliers of new and innovative technologies, like organic light-emitting diode (OLED) produced by Universal Display.

Studying the credit network alongside the production network allows us to unravel three

[1]A long list of references includes Dupor (1999), Horvath (2000), Cohen and Frazzini (2008), Holly and Petrella (2012), Bigio and La'O (2016), and notably Acemoglu et al. (2012). Empirical evidence in support of production networks are delivered by Cohen and Frazzini (2008), or Bams, Pisa, and Wolff (2015).

[2]Balke (2000), Hertzel, Li, Officer, and Rodgers (2008), Jorion and Zhang (2009), or Jacobson and von Schedvin (2015) lend support to the role of credit networks in propagation of shocks.

[3]Seminal work by Shea (2002), and Raddatz (2010) propose a theoretically motivated but nevertheless empirical model which captures both networks: production and credit network.

empirical regularities related to the use of trade credit and propagation of shocks. First, trade credit matters for the propagation of shocks if introduced into the production network. A shock propagates from a supplier to its customer differently if a credit network is present alongside a production network. Second, this paper reconciles two strings of literature: one on production networks and one on credit networks, and finds that a credit network intertwined with a production network dampens productivity shocks from firm's suppliers. We sometimes refer to this dampening effect as an "insurance effect". In general, we find that more trade credit enhances firm's sales stability and insures against shocks from a firm's suppliers. This leads us to the third empirical regularity. Trade credit works as an insurance, but it is an elusive insurance, and it is lost in times of need. In particular, as soon as a firm becomes financially constrained, trade credit loses its stabilizing abilities and it may serve as a mechanism propagating productivity shocks downstream the production network.

With this paper, we contribute to the understanding of trade credit in three ways. First, we combine the production network and the credit network in a single theoretical model of a multi-sector economy. We investigate a mechanism described by Long and Plosser (1983) and Acemoglu et al. (2012), in which a business cycle arises as a result of an asymmetric production relationship. We then build on Raddatz (2010) and Balke (2000) to generalize the Acemoglu et al. (2012) model and allow the trade credit dimension to take part in propagation of productivity shocks.

Here, we draw on the literature that attributes trade credit to product qualities. Giannetti, Burkart, and Ellingsen (2011) deliver evidence that products bought on trade credit tend to be customized, or differentiated. Others like Lee and Stowe (1993), and Long, Malitz, and Ravid (1993) argue that products bought on trade credit have greater quality variation. Quality tests of customized products are more tedious than of standardized products. Thus, this literature postulates that cautious buyers of customized products have an incentive to delay the payment, and thus request trade credit, to be able to assess the product quality. As argued in Smith (1987), Lee and Stowe (1993), and Long, Malitz, and Ravid (1993), trade credit gives the buyer an opportunity to inspect the product or to inspect the supplier's quality before making the full payment. Our empirical evidence lends support to the theories linking trade credit to product quality variation. Moreover, we show that this quality variation is time variant. In times of hardship and financial constraints, the quality of products delivered on trade credit increases. On the other hand, financially unconstrained buyers are more relaxed with enforcing the quality levels.

Recent trends in the waste generation illustrate such time variation in product quality. If waste generation is any indicator of an intermediate product quality, we would expect that lower waste levels are associated with higher intermediate product quality. Figure 1 shows that in the 28 EU countries, Germany, and the UK such fall in waste generation was observed in the manufacturing sector during harsh times. This trend is present in the absolute level of waste production (Panel a), and waste levels relative to the economic activity (Panel b and c). Importantly, a similar trend is not present in the household sector.

Second, this study empirically answers the question if trade credit propagates or dampens shocks occurring elsewhere in the economy. Empirical test of the Acemoglu et al. (2012) model, augmented with a trade credit network, show that in many circumstances trade credit dampens shocks occurring upstream in a firm's network. On average, trade credit lowers the impact of a supplier shock by 20-25% and thus considerably stabilizes a firm's sales. This result demonstrates the empirical relevance of theories linking the existence of trade credit to the product characteristics.

Lastly, we contribute to a more thorough understanding of the dark side of trade credit. Our empirical tests reveal that the insurance properties of trade credit prove elusive when they are most urgently needed: during recessions, and for financially constrained firms. In their seminal work, Kiyotaki and Moore (1997, 2002) already postulate that, in the presence of trade credit, financially constrained firms co-move with their production partners. Recent empirical evidence further corroborates the causes of this dark side of trade credit. Barrot (2016) documents that long payment terms of trade credit are associated with liquidity risk which drives credit constrained firms more often to distress. Petersen and Rajan (1997) argue that credit constrained customers rely on the liquidity provided by their supplier, which we argue, can expose them to fluctuations in the supplier's performance. We provide empirical evidence that although unobservable during good times, the dark side of trade credit resurfaces once a firm becomes financially constrained.

To corroborate these findings, we provide evidence that the elusive nature of the insurance provided by trade credit is unlikely to come from common shocks. By distinguishing firms that operate in the same region or the same industry, we can exploit cross-sectional variation at the regional or industry level to more cleanly identify the relationship between trade credit and sales growth.

Our results rely on the features of a Cobb-Douglass economy. The Cobb-Douglass representation of technology and utility implies that shocks can propagate downstream, i.e. by changing costs of customers of the firm affected by the shock. But the same representation also means that as explained in Shea (2002) and Acemoglu et al. (2012), the shocks do not propagate upstream. It is a consequence of two competing effects that are assumed to cancel out: (1) demand for inputs rises following a raise in output price, but at the same time (2) demand for inputs falls following a fall in the production output. Although commonly accepted in the literature, we evaluate this assumption. To test if our results are affected by an upstream propagation of shocks, we distinguish firms that are large, strategic and have heavily reliant suppliers. If such a strategic customer grows at a high rate, under upstream propagation its suppliers should have a positive boost in their sales and be more likely to grow at a higher rate. In that case, the sub-sample of strategic customers should show a higher correlation between a customer and its suppliers and lower downstream propagation. However, we find no evidence of this reverse causality, suggesting that the downstream propagation of shocks from suppliers to customers prevails, as proposed in the economic model.

The remainder of this paper continues as follows. In Section II, we introduce a trade credit relationship into the model of Acemoglu et al. (2012). Section III describes our empirical approach, and in Section IV we detail our data. Section V contains our empirical analysis, before we conclude in Section VI.

II Theory

In this section, we introduce a structural model with explicit production and trade credit relationships. We consider a static version of the production network economy of Long and Plosser (1983), where the economy is populated by a representative household with given tastes and production possibilities. We assume the household has a Cobb-Douglas utility function over n distinct commodities produced by n distinct firms:

$$u(c_1, c_2, \ldots, c_n) = \prod_{i=1}^{n} (c_i)^{1/n}, \tag{1}$$

where c_i is the consumption of firms i's commodity. The household is endowed with one unit of labor, which is supplied inelastically. At the beginning of each period, the household decides about its consumption as well as commodity and labor inputs to various production transformations to be completed in this period. Those choices are constrained by the availability of labor and inputs. As we assume the commodities to be perishable, only the amount produced in a given period can be used as an input in the production process in that particular period.

During the period, the production transformation is subject to various exogenous shocks that alter the production possibilities and ultimately determine the amount of commodities available for consumption or as production input. These shocks affect the household through the production network and through the trade credit network.

The trade credit dimension is novel to the model. It enters the model through the firm's decision on the quantity of intermediate inputs it employs, x_{ij}, to produce output x_i. Whereas we assume that trade credit does not affect the production technology of firms, it does result in firms using an amount of inputs $\bar{x}_{ij}$ that may be different from the amount x_{ij} otherwise used. That quantity $\bar{x}_{ij}$ can be higher than the amount otherwise purchased, if the intermediate inputs purchased on trade credit are feared to have lower quality, if their quality is uncertain, or if the firm expects to generate more waste by employing these inputs. It can also be lower, if the firm expects intermediate inputs to be of good quality, with little waste (see also Figure 1).

Following Raddatz (2010), we allow a firm i to buy a fraction β_i of its input on trade credit.[4] The total amount of inputs $\bar{x}_{ij}$ is then equal to:

$$\bar{x}_{ij} = x_{ij}^{(1+\eta\beta_i)}, \tag{2}$$

where the impact of trade credit on a firm's production possibilities is governed by parameter η. If η assumes a value greater than zero, the inputs purchased on trade credit have greater output elasticity than the inputs purchased directly. In other words, such inputs have higher quality, and generate less waste. In the reverse situation, if η assumes a value less than zero, the inputs purchased directly have lower productivity. Such inputs have lower quality, and generate more waste. As explained in Appendix A, maintaining the assumption of constant returns to scale, in line with Acemoglu et al. (2012), ensures that the rate at which labor can be substituted for an intermediate good $\bar{x}_{ij}$ is not affected by trade credit.

Specifically, n firms buy intermediary inputs from one another and firm i produces a quantity x_i of commodity i according to a Cobb-Douglas technology with constant returns to scale:

$$x_i = z_i^{\alpha} l_i^{\alpha} \prod_{j=1}^{n} \bar{x}_{ij}^{(1-\alpha)w_{ij}}, \tag{3}$$

where $z_i = exp(\xi_i)$ is firm i's specific productivity shock distributed independently across firms, l_i is the amount of labor hired by firm i, x_{ij} is the amount of commodity j used in the production process of commodity i and parameter α is the output elasticity of labor in the economy. Next, the parameter $w_{ij} \geq 0$ denotes an element in the $(n \times n)$ input-output matrix W that measures the amount spent on input j per dollar of production of firm i. The column sums of W reflect the importance of a firm as a supplier to other firms' production processes. At the firm level, the diagonal of W is equal to zeroes since a firm does not deliver

[4] In particular, a fraction $(1 - \beta_i)$ is paid up-front or on delivery while payment of the fraction β_i is due at a later date and shows up in the customer's balance sheet as an account payable.

to itself.

The fact that a firm uses intermediate inputs from other firms is a basis for interconnectedness in this economy. The Cobb-Douglass representation of technology and utility implies that the transmission of firm-level shocks occurs only downstream through the input-output matrix from supplier to customers. In general, for a non-Cobb-Douglas production technology upstream propagation is possible and depends on two competing effects. For example, a negative shock to a firm has two effects on its demand for inputs. The first effect is an increase in the price of the firm's output, which in turn increases the firm's demand for intermediate inputs. At the same time, the second effect decreases the quantity produced, which in turn decreases the firm's demand for intermediate inputs. As shown before by Acemoglu et al. (2012) and Shea (2002), for a Cobb-Douglas production technology like the one employed here, these two effects cancel out, thus excluding the possibility of upstream shock transmission.

Let y denote the logarithm of real value added, also referred to as *aggregate output.* In Appendix B we show that the evolution of aggregate output follows:

$$y = \mu + u'\xi, \tag{4}$$

where μ is a constant that depends on model parameters only, ξ is a $(n \times 1)$ vector of firm-level input shocks and u is a $(n \times 1)$ vector that governs the transmission of firm-level shocks in the economy. Equation (4) shows how fluctuations in aggregate output originate from disturbances to a firm's production possibilities. Those disturbances are weighted by the importance of the production relationship and the trade credit relationship, reflected by the vector u. It holds that:

$$u = \frac{\alpha}{n} \left[I - (1-\alpha)(1+\eta B) W' \right]^{-1} \mathbf{1}, \tag{5}$$

where $B = diag(\beta_1, \ldots, \beta_n)$ and $\mathbf{1}$ is a $(n \times 1)$ vector of ones. Similarly to Raddatz (2010), the vector u reflects the impact of both the production relationship, through the input-output matrix W, and the trade credit relationship, through B, in transmitting the firm-level shocks. In particular, the parameter η is a measure for the importance of the trade credit relationship. If η assumes a value greater than zero it amplifies the transmission mechanism that occurs due to the direct production links. Values lower than zero decrease this transmission mechanism. If trade credit has no effect on the transmission of firm-level shocks, the parameter η assumes a value of zero and the above equation simplifies to the influence vector of Acemoglu et al. (2012) given by:

$$v = \frac{\alpha}{n} \left[I - (1-\alpha) W' \right]^{-1} \mathbf{1}. \tag{6}$$

In the latter case, fluctuations in aggregate output due to firm-level shocks are only transmitted through the production relationship.

We further disentangle the transmission effects by taking a first order Taylor approximation of u around $\eta = 0$ (see Appendix C). It follows that:

$$\begin{aligned} u \approx & \frac{\alpha}{n} \left[I - (1-\alpha) W' \right]^{-1} \mathbf{1} + \eta \frac{\alpha}{n} (1-\alpha) \left[I - (1-\alpha) W' \right]^{-1} B W' \left[I - (1-\alpha) W' \right]^{-1} \mathbf{1} \\ = & v + \eta (1-\alpha) \left[I - (1-\alpha) W' \right]^{-1} B W' v. \end{aligned} \tag{7}$$

The first term in equation (7) represents the production relationship, and the second term shows the effect of the trade credit relationship. In particular, in case of negative values for η, the larger the share of inputs provided on trade credit (B), the smaller the transmission of input shocks. In this case, trade credit acts as insurance against supplier-level input shocks. Positive values of η give greater weight to supplier shocks, and therefore magnify supplier-level input shocks felt by customer firms.

For a single firm i, equations (4) and (7) imply the following relationship to input shocks (see Appendix D for full derivation):

$$y_i = \mu_i + \frac{\alpha}{n} \sum_{j=1}^{n} D_{ij} \xi_j + \eta \beta_i \frac{\alpha(1-\alpha)}{n} \sum_{j=1}^{n} \left[D W' D \right]_{ij} \xi_j \tag{8}$$

where $D = [I_n - (1-\alpha)W']^{-1}$ and I_n is the $(n \times n)$ identity matrix. Equation (8) is the basis for the empirical specifications that we propose in the next section.

III Empirical approach

In this section, we explain our estimation procedure, after introducing our key variables, starting with firm activity. Various empirical proxies for firm activity have been proposed in the literature. These proxies include the value added per worker (Gabaix, 2011), total factor productivity (Carvalho and Gabaix, 2013)) and employment (Moscarini and Postel-Vinay, 2012). Since trade credit is measured as a proportion of sales supplied with a deferred payment, we follow di Giovanni, Levchenko, and Mejean (2014) and represent firm activity as follows:

$$y_i \equiv ln(sales_i). \tag{9}$$

Our interest is in particular with the transmission mechanism of shocks originating at a supplier's production processes. To that end we quantify firm-level shocks ξ_i in a manner similar to Gabaix (2011), that is we set the firm-level shock to be a deviation from a particular benchmark. Similar to Gabaix (2011), we set this benchmark to be equal to the average of $ln(sales_i)$ over all firms in the economy, denoted with $\bar{y}_E$. The firm-level input shock follows as the difference between a firm's sales and the average sales in the economy:

$$\hat{\xi}_i = y_i - \bar{y}_E. \tag{10}$$

Manski (1993) notices a *reflection problem*: firms' activity might be volatile due to common shocks, but not necessarily vice versa. To address this reflection problem, we use various measures for the firm-level input shocks. Alternative specifications include deviations relative to developments in an industry or in a region. The industry benchmark ($\bar{y}_I$) is given by the average of $ln(sales_i)$ over firms in a particular industry, based on the four digit SIC industry classification. The region benchmark is given by the average of $ln(sales_i)$ over firms in a region where the region is defined by the state ($\bar{y}_S$) or county ($\bar{y}_C$) of a firm's headquarter. Those specifications work under the assumption that firms respond to common shocks with the same sensitivity.

We follow the literature (Gabaix (2011), and di Giovanni, Levchenko, and Mejean (2014)) and look into the growth rate of a firm's activity and in particular into the growth rate of sales. Define the growth rate of sales for firm i as $g_i = \Delta y_i$, which is the difference in log sales from one year to the other. Also, define the difference in shock to firm i as $e_i = \Delta \xi_i$, which is the change in log sales from one year to the other relative to the change in their benchmark. The resulting empirical relationship follows by taking first differences in equation (8):

$$g_i = \phi \left\{ \sum_{j=1}^{n} \left(\frac{\alpha}{n} D_{ij} \right) e_j \right\} + \eta \left\{ \sum_{j=1}^{n} \beta_i \frac{\alpha(1-\alpha)}{n} \left[DW'D \right]_{ij} e_j \right\} + \varepsilon_i \qquad i = 1, \ldots, n \tag{11}$$

The first term in equation (11), which we refer to as the *production relationship exposure*, depicts the relationship between a customer's sales growth and production in the absence of trade credit, or if trade credit does not matter for transmission of firm-level shocks. It is a weighted sum of firm-level suppliers' shocks, where the weights depend on the relative importance of the suppliers for a customer's production process. A parameter ϕ has been included in this first term. From the theoretical model in equation (8) we expect the estimate of parameter ϕ to be equal to one.

The second term in equation (11), which we refer to as *trade credit exposure*, is a weighted sum of firm-level supplier input shocks with weights determined by a supplier's importance in delivering inputs and its position as a trade credit provider. In the second term, the parameter η indicates the importance of the trade credit relationship in the transmission of firm-level shocks. Positive values of η amplify the shocks to the production process, while negative values insure against them. If $\eta = 0$, the trade credit relationship is irrelevant for the transmission of shocks between firms.

Equation (11) includes parameters α, β_i, W and D. In the next section we will propose proxies for these parameters. The remaining parameters ϕ and η are the focus of this study, and will be estimated by minimizing the sum of squared residuals ($\sum_{i=1}^{n} \varepsilon_i^2$). In particular, we investigate the role of trade credit in transmitting firm-level shocks. In normal times, we expect the estimate of η to be negative and significantly associated with customers' sales growth. However, during recessions or in case of financially constrained firms, we expect η to be zero or positive as trade credit may amplify shocks to customers, similar to Kiyotaki and Moore (1997).

In the empirical analysis, we also verify that the correlation between shocks to suppliers and the sales growth of their customer is not driven by either a common shock or by a reverse causal relationship from customer to supplier.

In order to test that, we first evaluate if shocks to suppliers are spuriously correlated with a customer's sales growth as a result of exposure to common shocks. We address this problem by the way in which shocks to suppliers are computed: we disentangle the common component from the firm-level component by demeaning suppliers' growth rate on the economy, industry, state and county level. As a result, suppliers' shocks are equivalent to suppliers' excess growth relative to an economy, industry, state and county benchmark. The excess growth is meant to be firm-specific and represents the idiosyncratic component of their sales growth.

Moreover, we estimate a specification with time-varying industry and state fixed effects to capture common shocks which might have affected firms in one industry or state disproportionally to the rest of the economy. To illustrate this consider a supplier linked to two customers A and B by the same kind of production process relationship and a different trade credit relationship. Customer A operates in the same four digit SIC industry as the supplier and receives low trade credit. In contrast, customer B operates in another industry and receives high trade credit. Now, if a positive common shock affects the industry in which the supplier and customer A operate, the supplier experiences a positive excess growth shock relative to the economy benchmark and customer A grows at a higher rate. On the other hand, customer B does not reap the benefits of this positive common shock and grows at a lower rate. The lower growth rate of customer B may seem to be related to the higher trade credit ratio while in fact it is due to missing out on the positive common shock. If for some reason customers tend to have a lower trade credit relationship with their suppliers in the same industry or in the same region, the effect of common shocks can be controlled for by time varying industry effects or time varying region fixed effects.[5]

To address the second issue, we notice that a reverse causal relationship would imply a transmission mechanism that works from customer to supplier, where a high growth rate of a customer would trigger a positive shock to its supplier, but less so with an increase in trade credit. Cases where a development in customer growth is followed by a response in its suppliers' excess growth should intuitively involve customers that are important and strategic to their suppliers. Purchases from those strategic customers correspond to a high share of suppliers' sales and swings in customers' demand are more likely to be reflected in changes in the growth of their suppliers. By focusing on a sub-sample of customers that are strategic to their suppliers, we allow for the reverse causal relationship to be revealed. In this particular sub-sample, a reverse causal relationship would manifest itself by an increased correlation. In the results section we will explicitly investigate this case.

IV Data

At the heart of our data is a list of customer-supplier pairs. Under the Statement of Financial Accounting Standards (SFAS), rule no. 131, a firm needs to disclose certain information on its operating segments. In particular, a firm is required to reveal the identity of its major customers that purchase above 10% of its sales. We use a sample of such customer-supplier pairs identified by Cohen and Frazzini (2008) based on Compustat Segments information. We can identify each firm in this sample based on its CRSP *permno*. This allows us to match the customer-supplier pairs identified by Cohen and Frazzini (2008) with CRSP-Compustat's balance sheet information.

In particular, we focus our analysis on customer-supplier pairs in which customers operate in manufacturing, transportation, wholesale and retail trade (SIC code 2000-5999). The

[5]This can be the case, for example, if firms use trade credit to deal with information asymmetry of their production partners by screening firms in a different industry rather than those operating in the same industry (Smith, 1987).

customer-supplier pairs are required to have a match to Compustat balance sheet information, non-missing values of assets, non-missing values of cost of goods sold, and non-missing values of sales in two consecutive years. The final set contains 4,785 unique customer-year observations. Each of these observations is connected on average to 2.71 suppliers with a total of 12,985 unique customer-supplier-year observations over the years 1980 to 2004.

The customers reported in Panel A of Table I tend to be larger than the suppliers in Panel D. This discrepancy is partially due to the way the customer-supplier pairs are identified. The customers reported in Compustat Segments, and therefore in the Cohen and Frazzini (2008) sample, are those that correspond to at least 10% of sales. Those firms are inclined to be larger with assets on average almost 13 times higher and sales 14 times higher than the sample of suppliers. During the entire sample period, on average both customers and suppliers experience a positive sales growth rate (g) illustrated in Figure 2. For most of the time it stays positive with a short episode of negative growth in 2002.

In our analysis, we approximate three elements of equation (11): the weights attributed to suppliers that define the production relationship, the weights attributed to suppliers that define the trade credit relationship and finally the supplier shocks.

To compute the weights defining the production relationship, we approximate parameter w_{ij} and parameter α. Parameter w_{ij} is said to capture the amount spent on input j per dollar of production of firm i. On a firm level, we approximate it by the ratio of sales from supplier (firm j) to customer (firm i) over a customer's cost of goods sold (Compustat item *cogs*). It represents the amount customer i spent on inputs from supplier j per dollar amount of its production cost. On average, about 4.2% of a customer's input comes from one of its suppliers. The labor income share denoted by α is assumed to be constant over the whole economy and takes a value of 0.61. We compute it from the OECD data on Unit Labor Costs as the average of the Labor Income Share (Real ULC) between 1995 and 2004, the period for which it is available.

To compute the weights defining the trade credit relationship, we compute the share of trade credit received by a customer (β_i). To this end we follow Raddatz (2010) and measure

β_i as the ratio of a customer's accounts payable (Compustat item *ap*) over its cost of goods sold (Compustat item *cogs*). It depicts the proportion of purchased inputs with deferred payment and typically reflects the share of goods that the customer purchased on trade credit. Since we do not observe the share of trade credit contributed by individual suppliers, we assume this share to be equal across all suppliers delivering to a given customer. In our sample, customers buy about 15% of their inputs on trade credit. Their dependence on trade credit is comparable with the U.S. firms in Raddatz (2010), which finance about 13% of inputs with trade credit.[6] Figure 3 illustrates the time series development of the proportion of inputs delivered on trade credit. Over the sample period of 25 years there is an increase in the amount of trade credit used with a slight drop during recessions.

Lastly, we quantify supplier shocks e_j as a deviation from a benchmark. The benchmark is given by an average $ln(sales)$ growth among a group of firms to which the supplier belongs. We compute the economy $ln(sales)$ growth ($\bar{g}_E$) as the average growth among all the firms in the Compustat universe. Next, we categorize firms into industries based on the four digit SIC code to compute the industry benchmark as an average of sales growth over firms in the same industry. We repeat this exercise and compute the state benchmark as an average of $ln(sales)$ growth over firms in the same U.S. state and the county benchmark as an average of sales growth over all firms operating in the same county.

Figure 4 illustrates the time series evolution of the supplier shocks estimated relative to economy, industry, state and county benchmark. There is a considerable commonality between the supplier shocks and the average sales growth rate among suppliers. In general, their behavior is closely related and both values co-move together. For example, during the NBER recessions, illustrated by the shaded areas, both the benchmark and the average sales of suppliers tend to drop considerably.

In Table II we examine the correlations between customer and supplier sales growth, and the benchmarks. The correlations are computed from yearly observations pooled across all the customer and supplier firms. At the bottom of column (2) we report the correla-

[6] Raddatz's (2010) sample includes a universe of U.S. firms in Compustat over a similar time period.

tions between supplier sales growth and the shocks to customer sales growth using different benchmarks. The high correlation indicates that there is a considerable commonality between disturbances to customer sales growth and supplier sales growth.

V Empirical results

Our empirical analysis consists of four steps. First, we establish whether shocks to suppliers are indeed transmitted through the customer-supplier network and find out how different elements of that customer-supplier network - production network and trade credit network - contribute to the direction and magnitude of that transmission mechanism. Next, we investigate how common shocks affect the transmission mechanism of both elements. Third, we verify the robustness of the distinction between these two elements. Finally, we delve deeper into the role of trade credit as an elusive insurance mechanism.

A Shock transmission through a production relationship

From our theoretical model in Section II, we learn that, in general, the use of credit in the customer-supplier relationship may work as insurance against shocks to suppliers and may reduce disturbances to customers' sales. Whether those shocks to suppliers are transmitted through the customer-supplier network and what is the role of production relationship and trade credit relationship, is answered in Table III.

Based on the economic model, we hypothesize the relationship between sales growth and production relationship (ϕ) to be equal to one, as the change to customers' sales should be greater with a greater shock to its crucial suppliers of inputs. Likewise, we hypothesize the relationship between customers' sales growth and the trade credit relationship (η) to be negative since trade credit is expected to act as insurance against supplier shocks.

Column (1) of Table III allows for a basic test of both hypotheses. Indeed, we find that production relationship propagates shocks from a supplier onto its customer with a value for ϕ that is not statistically different from one. Also, the use of trade credit reduces the severity of shocks and acts as an insurance. When we control for fixed effects in Column (2), both results appear to be robust.

Both effects are also economically sizable. Depending on the specification, in the absence of trade credit a one standard deviation positive (negative) shock to all suppliers increases (decreases) customer's sales growth by about 0.50%. If trade credit accompanies that same production relationship the disturbance is lower and amounts to about 0.40%. In other words, a customer experiences about 20-25% lower disruption to its sales from a shock to its supplier if trade credit exists next to a production relationship.[7]

B *The transmission and common shocks*

In our analysis so far, we have implicitly assumed that a shock affects a single supplier, and has no direct impact on others other than through production and trade credit relationships. In the following, we deal with the possibility of same shock striking multiple firms. In particular, we address the possibility of a common shock to suppliers and customers in the same industry or state.

Imagine a positive common shock to a given industry (or state) at a given point in time. Contrast one customer-supplier pair that operates in the affected industry with a second customer-supplier pair in which the customer operates in another industry. In the former case, the high correlation between the state of the customer and the state of its supplier could result from their exposure to the common shock rather than from a trade credit relationship. In the latter case, however, the customer is not directly exposed to the shock and any correlation between its state and that of its supplier is more likely to come from trade credit usage in the absence of exposure to the common shock.

We therefore isolate the effect of common shocks from the effects of the production relationship and the trade credit relationship by means of time varying industry and state fixed effects. Results are reported in columns (3) and (4) of Table III and appear robust to common shocks. Customers are affected more by shocks to crucial suppliers of inputs but

[7] Note that our matrix of network is not exhaustive and we are missing the customer-supplier network that do not pass the 10% threshold to be reported in the Compustat Segments database. However, we believe that in the limit those connections could be approximated by the industry or state or county benchmark. In turn this leaves those connections with no impact on the analysis as their shocks are equal to zero.

less so if trade credit accompanies the production relationship. These results are in line with Gao (2014), who shows that in a tight network of customer-supplier relationships, a liquidity shock to one firm triggers a flow of liquidity from other parts of the network. One example is Bosch that supported its liquidity-constrained suppliers by offering them forward payments and reimbursement of raw materials. In this example behavior of Bosch comes from a tight customer-supplier relationship and aims at buffering the effects of shocks to its suppliers.

Alternatively in Table VII, Table VIII and Table IX we specify firm-level shocks as deviation from an industry, state or county benchmark. Those specifications should disentangle any common shock on industry, state or county level from a supplier-level shock. In Panel A of each of these tables we repeat our analysis and find robust evidence of trade credit insurance abilities.

C Distinguishing between trade credit and production relationship

Until now, we have established that a customer-supplier network, related to production and to trade credit, affects the transmission of shocks. Now, we put more effort into distinguishing between the strength of the production relationship and the trade credit relationship, respectively.

We start in Column (1) of Table IV by repeating our analysis for a sub-sample of firms with very low shares of trade credit. For these firms, the production process forms the base for their interconnections. Hence, we expect to find that the trade credit relationship has a negligible effect on sales growth for this sub-sample. Indeed, our results show that for this sub-sample the production relationship is the only channel through which shocks are transmitted.

In Column (2) of Table IV, we take the above examination one step further and drop the trade credit relationship from our analysis. As a result, we effectively estimate the Acemoglu et al. (2012) model, which assumes that only the production relationship can propagate shocks from suppliers onto customers. If trade credit has an insurance effect, we expect to understate the size of the production relationship in this estimation. Indeed, that is what we find.

Next, in Column (3) we provide a more direct comparison of our results with the predictions from the Acemoglu et al. (2012) model, by constraining the coefficient of the production relationship at its theoretical value, equal to one. From the Table, we observe that the economic magnitude of the trade credit relationship remains unchanged.

Finally, in Column (4) we focus on a sub-sample of strategic customers, who are of particular importance for their suppliers. Doing so, allows us to address possible reverse causality issues. After all, a change in a firm's state can originate on the supplier side (downstream propagation) or on the customer side (upstream propagation). In the economic model we allow for downstream propagation, not upstream propagation. In the latter case, if a strategic customer grows at a high rate, as a consequence its supplier is expected to have a positive boost in its sales and is likely to grow at a rate higher than the rest of the economy. Thus, focusing on a sub-sample of strategic customers should increase the scope of upstream propagation while diminishing the downstream propagation. This provides us with a perfect testing ground of possible reverse causality. For each customer, we find its minimum share in suppliers' sales. Next, we rank all customers according to that minimum. Results in Column (4) show that the top decile most strategic customers do not exhibit a higher correlation with their suppliers' excess growth, confirming that our analysis primarily captures the downstream propagation of shocks from suppliers onto their customers.

D Trade credit as an elusive insurance

In the final part of our analysis, we focus in more detail on the role of trade credit. Thus far, we have found that both the production relationship and the trade credit relationship play an important role in the downstream transmission of shocks. On the face of it, trade credit appears to act as an insurance against disruptions caused by supplier shocks: after a negative shock to its supplier, a customer grows at a higher rate than it would have grown had it not received any trade credit.

Here, we study how reliable the implicit insurance offered by trade credit is in practice by zooming in on those customers that are indeed financially constrained. Of course it is possible that suppliers end trade credit once a customer becomes financially constrained. However, Panels B and C of Table I provide evidence to the contrary: we do not observe a significant drop in trade credit provision during recessions. Therefore, we re-estimate equation (11) and include a measure of how financially constrained a customer is, which we then also interact with the trade credit relationship. If trade credit is a durable and reliable insurance against shocks from production partners, the interaction term should be negative and significant or at least insignificant.

Table V contains estimation results for three different measures of how financially constrained the customer is. The simplest measure is included in Column (1), in which we concentrate on recessions, when a large number of firms is expected to be financially constrained. As it turns out, during recessions trade credit does not insure customers against shocks propagated from their suppliers. Firms with high trade credit are systematically less able to reap the benefits of positive developments in good times and in bad times are in general less resilient to shocks propagating from their suppliers.

We continue this line of thought in Column (2), where we define firms to be financially constrained if in a given year their cash reserves relative to their sales are in the bottom 5 percentile. For such cash-poor firms, we observe a contagion effect similar to Kiyotaki and Moore (1997) where trade credit not only is a very poor insurance against shocks from suppliers but it also amplifies those shocks and further destabilizes customers' sales.

In Column (3), we consider firms to be financially constrained following Rajan and Zingales (1998), who measure firms' dependence on external finance.[8] Again, trade credit fails to provide insurance for the most vulnerable firms. For the top decile of most financially constrained firms, it does not matter if the firm is using trade credit or not: the shock to its supplier will hit it with the same strength.

As a final step, we challenge these results by once again controlling for common shocks

[8]They use the ratio of capital expenditures (Compustat item *capx*) reduced by the sum of funds from operations (*fopt*), inventory (*invch*), accounts receivable (*recch*) and accounts payable (*apalch*) to capital expenditures.

and reverse causality. Table VI reports the results for recession times and the Rajan and Zingales (1998) measure of firm's dependence on external finance. In Columns (1) and (2), we include time varying fixed effects and control for the effect of common shocks. Our findings and the economic magnitude of the effects remains unchanged. Columns (3) and (4) tackle the issue of reverse causality by including an indicator which is equal to one if a customer has many heavily reliant suppliers, and zero otherwise. With no increase in correlation for those customers we find no evidence of reverse causality. Results are also robust to using an industry benchmark where shocks are computed as a deviation from the industry average (Table VII), to using a state benchmark in which suppliers shocks are computed as a deviation from the state average (Table VIII) and to using a county benchmark in which suppliers shocks are computed as a deviation from the county average (Table IX).

VI Concluding remarks

This paper finds that the transmission of shocks downstream the customer-supplier relationship process depends both on the strength of the production relationship between suppliers and customers and on the extent to which the former provide trade credit to the latter. Not accounting for the trade credit relationship results in an overestimation of the importance of the production relationship, since the trade credit relationship on average mitigates the impact of shocks.

Once we delve deeper into these findings, however, we find that trade credit is an elusive insurance against shocks from production partners. The insurance aspect of trade credit only works if customers do not need it, i.e., if they are not financially constrained. In unfavorable situations, trade credit further lowers sales stability and provides no insurance against shocks propagating downstream from suppliers. Our results are robust to common shocks and appear not to be affected by possible upstream propagation of shocks. Also, the results hold for a broad range of measures of how financially constrained a firm is.

The main takeaway from our analysis is that firms may overestimate the importance of trade credit. The latter can be seen as an important element of building a relationship between customers and suppliers, and reflects the trust that both parties have in that relationship. However, the economic value of trade credit is in fact lowest when customers may need it the most: when they are financially constrained and/or find themselves in a recession.

Appendix A Production function

In order to assess relationship between the production function we use and the role of trade credit, we must start with the assumption of constant returns to scale. Imposing constant returns to scale on the production function in equation (3), implies that: $\sum_j w_{ij} = \frac{1}{1+\eta\beta_i}$. We note, however, that the constant returns to scale assumption does not necessarily imply that the marginal rate of technical substitution (MRTS) between labor and an intermediate input x_{ij} is constant. We start by simplifying notation on our production function:

$$x_i = z_i^\alpha l_i^\alpha \prod_{j=1}^{n} x_{ij}^{\beta_i^*}, \tag{A1}$$

noting that now $\beta_i^* = (1-\alpha)(1+\eta\beta_i)w_{ij}$ and $\alpha + \beta_i^* = 1$ implies CRS. We can then derive the marginal productivity of labor, MP_l:

$$MP_l = \alpha z_i^\alpha l_i^{\alpha-1} \prod_{j=1}^{n} x_{ij}^{\beta_i^*}. \tag{A2}$$

Likewise, the marginal productivity of an intermediate input, $MP_{x_{ij}}$ is:

$$MP_{x_{ij}} = \beta_i^* z_i^\alpha l_i^\alpha \prod_{j=1}^{n} x_{ij}^{\beta_i^*-1} \tag{A3}$$

Hence:

$$MRTS = \frac{MP_l}{MP_{x_{ij}}} = \frac{\alpha z_i^\alpha l_i^{\alpha-1} \prod_{j=1}^{n} x_{ij}^{\beta_i^*}}{\beta_i^* z_i^\alpha l_i^\alpha \prod_{j=1}^{n} x_{ij}^{\beta_i^*-1}} = \frac{\alpha l_i}{(1+\eta\beta_i)(1-\alpha)w_{ij}x_{ij}}. \tag{A4}$$

The CRS constraint that $\sum_j w_{ij} = \frac{1}{1+\eta\beta_i}$, then implies that:

$$MRTS = \frac{\alpha l_i}{(1-\alpha)x_{ij}}. \tag{A5}$$

Hence, our CRS constraint implies that the rate at which labor can be substituted for an intermediate good x_{ij} is not affected by the trade credit.

Appendix B Competitive equilibrium

We derive the competitive equilibrium by closely following Acemoglu et al. (2012). The competitive equilibrium is a set of commodity prices p_i, wage h and consumption choices c_i that satisfy the representative household's utility maximization problem; firms' profit maximization problem subject to condition that the commodity and labor markets clear, that is:

$$c_i + \sum_{j=1}^{n} x_{ij} = x_i \tag{B1}$$

$$\sum_{i=1}^{n} l_i = 1 \tag{B2}$$

From the firm i profit maximization problem subject to labor and input choices, l_i and x_{ij} respectively, we obtain:

$$l_i = \frac{\alpha x_i p_i}{h} \tag{B3}$$

$$x_{ij} = \frac{x_i p_i (1-\alpha)(1+\eta\beta_i)}{p_j} \tag{B4}$$

In the next step we substitute the optimal labor and input choices into the production function. By taking logs and simplifying we arrive at the following expression:

$$\begin{aligned} \alpha ln(h) = \alpha\xi_i + C + ln(p_i) + (1-\alpha)(1+\eta\beta_i)\sum_{j=1}^{n} w_{ij} ln(w_{ij}) \\ - (1-\alpha)(1+\eta\beta_i)\sum_{j=1}^{n} w_{ij} ln(p_j) \end{aligned} \tag{B5}$$

where C is a constant independent of prices, wage and consumption defined as:

$$C = \alpha ln(\alpha) + (1-\alpha) ln(1-\alpha) + (1-\alpha) ln(1+\eta\beta_i) \tag{B6}$$

Next we multiply by the ith element of the u vector and we sum over all i.

$$\begin{aligned}\sum_{i=1}^{n} u_i ln(h) = & \sum_{i=1}^{n} u_i \xi_i + \frac{C}{\alpha}\sum_{i=1}^{n} u_i + \frac{1}{\alpha}\sum_{i=1}^{n} ln(p_i) u_i \\ & + \frac{(1-\alpha)}{\alpha}\sum_{i=1}^{n}\sum_{j=1}^{n}(1+\eta\beta_i) u_i w_{ij} ln(w_{ij}) \\ & - \frac{(1-\alpha)}{\alpha}\sum_{i=1}^{n}\sum_{j=1}^{n}(1+\eta\beta_i) w_{ij} ln(p_j) u_i\end{aligned} \tag{B7}$$

Denote the vector of logarithm prices by $ln(p)$ and the diagonal matrix of trade credit shares as $B = diag(\beta_1, \ldots, \beta_n)$. Then the expression:

$$\frac{1}{\alpha}\sum_{i=1}^{n} ln(p_i) u_i - \frac{(1-\alpha)}{\alpha}\sum_{i=1}^{n}\sum_{j=1}^{n}(1+\eta\beta_i) w_{ij} ln(p_j) u_i \tag{B8}$$

from the above equation in vector notation is equal to:

$$\frac{1}{\alpha} ln(p) u - \frac{(1-\alpha)}{\alpha}(1+\eta B) ln(p) W' u = \frac{1}{\alpha} ln(p)\left[I - (1-\alpha)(1+\eta B) W'\right] u \tag{B9}$$

With $u = \frac{\alpha}{n}\left[I - (1-\alpha)(1+\eta B) W'\right]^{-1} \mathbf{1}$ the expression in (B9) simplifies to:

$$\frac{1}{\alpha} ln(p) u - \frac{(1-\alpha)}{\alpha}(1+\eta B) ln(p) W' u = \frac{1}{n} ln(p) \mathbf{1} \tag{B10}$$

From constant returns to scale we have that $\sum_{i=1}^{n} u_i = 1$. We use this property to obtain that:

$$y = \mu + u'\xi \tag{B11}$$

$$\text{where} \quad u = \frac{\alpha}{n}\left[I - (1-\alpha)(1+\eta B) W'\right]^{-1} \mathbf{1} \tag{B12}$$

$$\text{and} \quad \mu = \frac{1}{n}\sum_{i=1}^{n} p_i + \frac{C}{\alpha} + \frac{1-\alpha}{\alpha}\sum_{i=1}^{n}\sum_{j=1}^{n}(1+\eta\beta_i) u_i w_{ij} ln(w_{ij})$$

The aggregate fluctuations are equal to a sum of all firm-level shocks weighted by the importance of firms in their production and trade credit relationships.

Appendix C Taylor expansion

We approximate vector u by taking the first order Taylor approximation of u around $\eta = 0$:

$$u \approx u(0) + \frac{u'(0)}{1!}(\eta - 0) = \frac{\alpha}{n}\left[I - (1-\alpha)\, W'\right]^{-1} \mathbf{1} + \eta u'(o) \tag{C1}$$

To differentiate vector u we use the property that a derivative of a matrix inverse is equal to:

$$\frac{dM^{-1}}{d\eta} = -M^{-1}\frac{dM}{d\eta}M^{-1} \tag{C2}$$

With the matrix $M = [I - (1-\alpha)(1+\eta B)W']$ we get:

$$\begin{aligned}\frac{dM^{-1}}{d\eta} =& -\left[I - (1-\alpha)(1+\eta B)W'\right]^{-1} \\ &\times \frac{d\left[I - (1-\alpha)(1+\eta B)W'\right]}{d\eta}\left[I - (1-\alpha)(1+\eta B)W'\right]^{-1}\end{aligned} \tag{C3}$$

where the derivative of matrix M with respect to η is given by: $\frac{dM}{d\eta} = -(1-\alpha)BW'$. This yields that:

$$\begin{aligned}u \approx& \frac{\alpha}{n}\left[I - (1-\alpha)\, W'\right]^{-1} \mathbf{1} + \eta\frac{\alpha}{n}\left[I - (1-\alpha)\, W'\right]^{-1}(1-\alpha)BW'\left[I - (1-\alpha)\, W'\right]^{-1}\mathbf{1} \\ =& v + \eta\left[I - (1-\alpha)\, W'\right]^{-1}(1-\alpha)BW'v.\end{aligned} \tag{C4}$$

Appendix D Firm level relationship

We begin from the aggregate output relationship as in equation (4) in the index notation:

$$y = \mu + \sum_{j=1}^{n} u_j \xi_j, \tag{D1}$$

where u_j is the jth element of vector u defined as in equation (7):

$$u \approx v + \eta\left[I - (1-\alpha)\, W'\right]^{-1}(1-\alpha)BW'v, \tag{D2}$$

and the *influence vector* of Acemoglu et al. (2012) is defined as in equation (6):

$$v = \frac{\alpha}{n} \left[I - (1-\alpha) W' \right]^{-1} \mathbf{1}. \tag{D3}$$

Let us define matrix $D \equiv \left[I_n - (1-\alpha) W' \right]^{-1}$ such that the *influence vector* of Acemoglu et al. (2012) writes as $v = \frac{\alpha}{n} D\mathbf{1}$, then from (D1), (D2) and (D3) we have:

$$y = \mu + \frac{\alpha}{n} \sum_{j=1}^{n} \left[D\mathbf{1} \right]_j \xi_j + \eta \frac{\alpha(1-\alpha)}{n} \sum_{j=1}^{n} \left[DBW'D\mathbf{1} \right]_j \xi_j, \tag{D4}$$

or summing also in the i dimension:

$$y = \mu + \frac{\alpha}{n} \sum_{i=1}^{n} \sum_{j=1}^{n} D_{ij} \xi_j + \eta \frac{\alpha(1-\alpha)}{n} \sum_{i=1}^{n} \sum_{j=1}^{n} \left[DBW'D \right]_{ij} \xi_j. \tag{D5}$$

For $y = \sum_{i=1}^{n} y_i$ the expression in (D5) becomes:

$$\sum_{i=1}^{n} y_i = \mu + \frac{\alpha}{n} \sum_{i=1}^{n} \sum_{j=1}^{n} D_{ij} \xi_j + \eta \frac{\alpha(1-\alpha)}{n} \sum_{i=1}^{n} \sum_{j=1}^{n} \left[DBW'D \right]_{ij} \xi_j. \tag{D6}$$

which at the firm level is equivalent to:

$$y_i = \mu_i + \frac{\alpha}{n} \sum_{j=1}^{n} D_{ij} \xi_j + \eta \frac{\alpha(1-\alpha)}{n} \sum_{j=1}^{n} \left[DBW'D \right]_{ij} \xi_j. \tag{D7}$$

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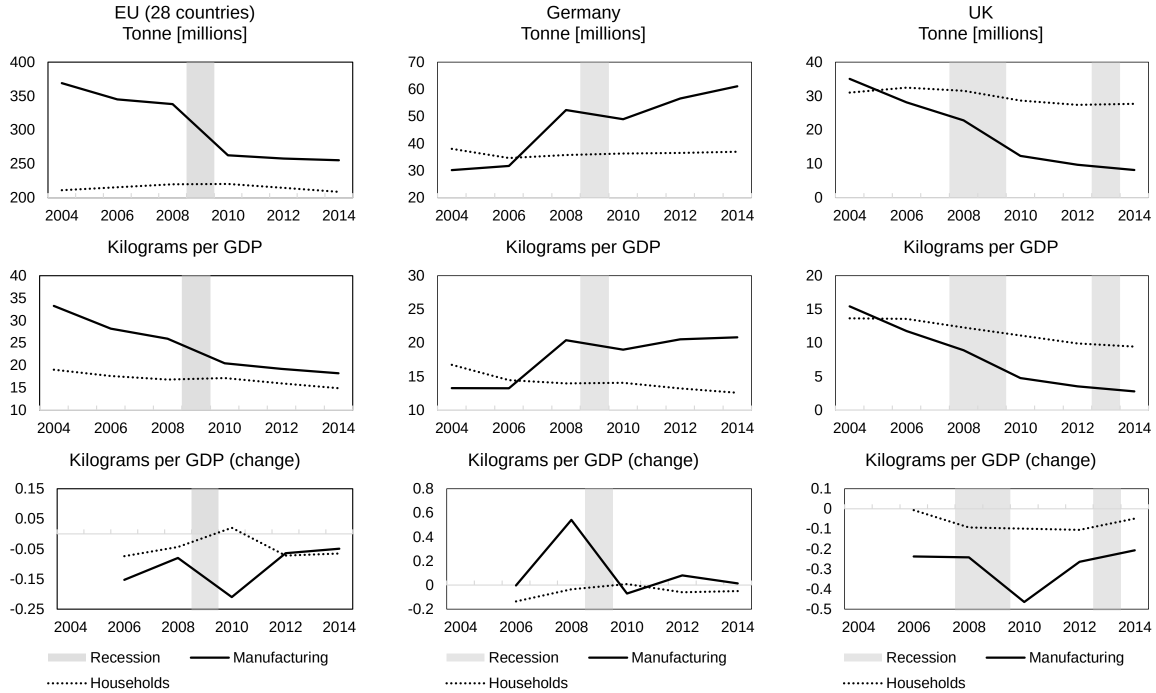


Figure 1: Waste generation in the EU. The figure shows the time series development of waste generation in the manufacturing and household sectors. In Panel b we divide the Waste Tonnage by the country's or region's Gross Domestic Product at market prices. Source: Eurostat: Generation of waste by economic activity, and own calculations.

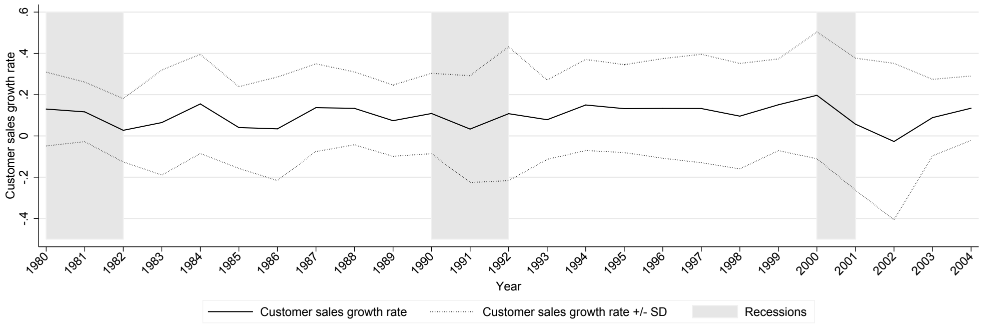


Figure 2: Customers sales growth rate. The figure shows the time series development of the average growth rate of sales among the customers.

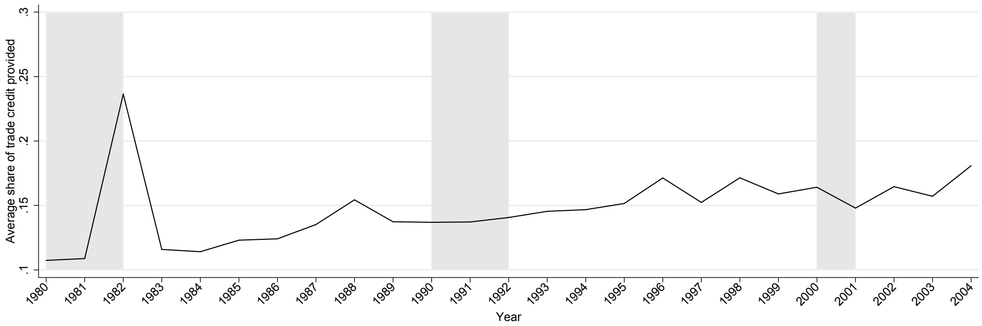
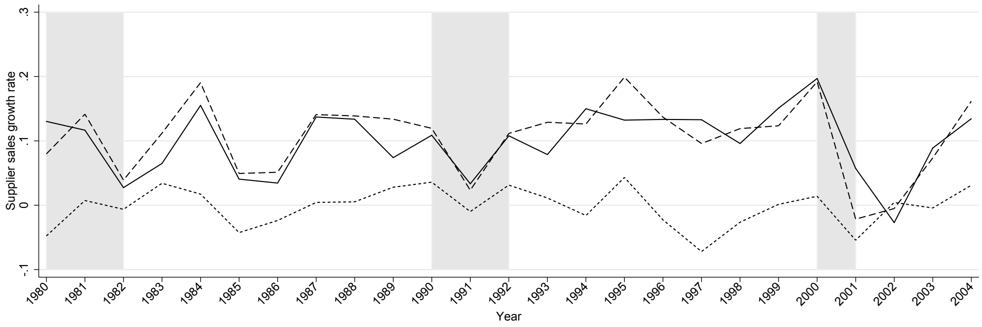
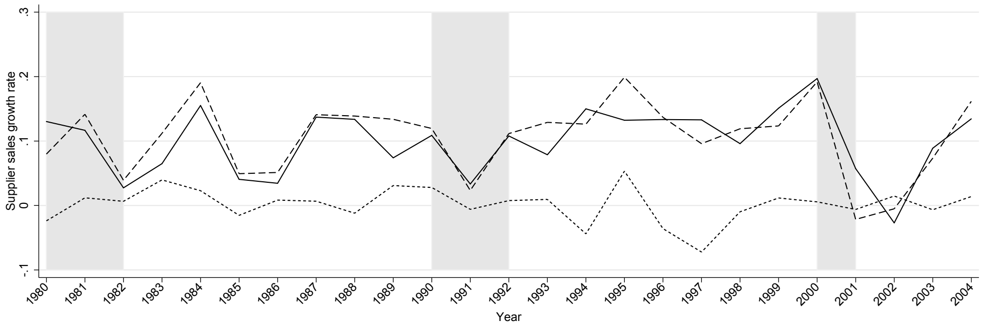


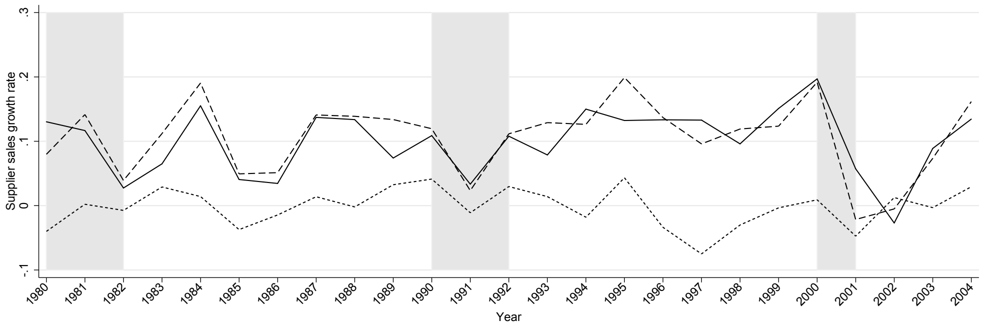
Figure 3: Share of trade credit received β_i**.** The figure shows the time series development of the average share of trade credit received β_i among the customers.



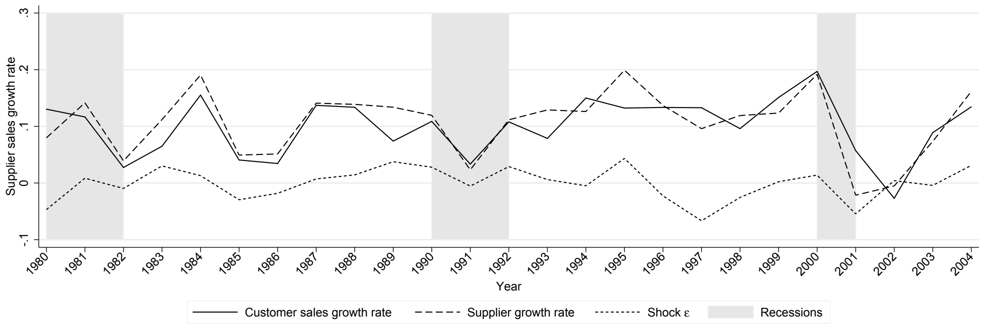
(a) Economy benchmark



(b) Industry benchmark



(c) State benchmark



(d) County benchmark

Figure 4: Suppliers sales growth rate and the benchmark. The figure shows time series development of average growth rate of sales among suppliers. It is benchmarked against the average growth rate in the economy (Panel a), in the industry (Panel b), in the state (Panel c), in the county (Panel d).

Table I

Descriptive statistics

The sample covers firms referred by Cohen and Frazzini (2008) as customers or suppliers with a match to Compustat balance sheet information and non-missing values of assets, cost of goods sold and non-missing values of sales in two consecutive years. Panels A, B and C summarize the sample of customers. Panels D, E and F summarize the sample of suppliers. Recession years are taken from the NBER business cycle reference dates and cover years: 1980, 1981, 1982, 1990, 1991 and 2001. The expansion years cover years: from 1983 to 1989, from 1992 to 2000 and from 2002 to 2004. The production relationship exposures are computed as $\left\{\sum_{j=1}^{n}\left(\frac{\alpha}{n}D_{ij}\right)e_j\right\}$ which is the first term in equation (11) and the trade credit exposures are computed as $\left\{\sum_{j=1}^{n}\beta_i\frac{\alpha(1-\alpha)}{n}\left[DW'D\right]_{ij}e_j\right\}$ which is the second term in equation (11).

	N	Mean	SD	Min	Max
Panel A: Customers descriptive statistics – Years 1980–2004					
Assets [$ billions]	4,785	12,693.430	29,418.350	1.987	479,921.000
EBIT [$ billions]	4,693	1,062.749	2,287.461	-10,537.000	35,872.000
Sales [$ billions]	4,785	11,664.360	23,008.660	0.436	286,103.000
Accounts payable	4,785	1,127.797	2,540.814	0.000	28,902.600
Cost of goods sold	4,785	8,238.192	17,858.070	0.977	240,391.000
w_{ij}	4,785	0.042	0.176	0.000	5.127
Share of trade credit received β_i	4,785	0.150	0.279	0.000	17.043
Dependent variable:					
Sales growth rate (g)	4,785	0.099	0.249	-2.832	3.765
Independent variables:					
1) production relationship exposures (first term in equation (11)) computed relative to:					
– economy benchmark	4,785	0.002	0.052	-0.781	1.142
– industry benchmark	4,785	0.001	0.067	-3.229	0.958
– state benchmark	4,785	0.002	0.054	-0.751	1.555
– county benchmark	4,785	0.002	0.051	-0.781	1.387
2) Trade credit exposures (second term in equation (11)) computed relative to:					
– economy benchmark	4,785	0.000	0.012	-0.266	0.710
– industry benchmark	4,785	0.000	0.012	-0.315	0.616
– state benchmark	4,785	0.000	0.011	-0.281	0.580
– county benchmark	4,785	0.000	0.012	-0.266	0.695
Panel B: Customers descriptive statistics – Expansion					
w_{ij}	3,782	0.041	0.182	0.000	5.127
Share of trade credit received β_i	3,782	0.151	0.145	0.000	4.369
Dependent variable:					
Sales growth rate (g)	3,782	0.106	0.251	-2.832	3.765
Independent variables:					
1) production relationship exposures (first term in equation (11)) computed relative to:					
– economy benchmark	3,782	0.002	0.054	-0.781	1.142
– industry benchmark	3,782	0.000	0.073	-3.229	0.958
– state benchmark	3,782	0.002	0.056	-0.751	1.555
– county benchmark	3,782	0.002	0.052	-0.781	1.387
2) Trade credit exposures (second term in equation (11)) computed relative to:					
– economy benchmark	3,782	0.000	0.007	-0.266	0.148
– industry benchmark	3,782	0.000	0.009	-0.315	0.149
– state benchmark	3,782	0.000	0.007	-0.281	0.152
– county benchmark	3,782	0.000	0.007	-0.266	0.148

Table I cont.

Panel C: Customers descriptive statistics – Recession					
w_{ij}	1,003	0.043	0.154	0.000	2.612
Share of trade credit received β_i	1,003	0.146	0.541	0.007	17.043
Dependent variable:					
Sales growth rate (g)	1,003	0.074	0.242	-2.045	2.311
Independent variables:					
1) production relationship exposures (first term in equation (11)) computed relative to:					
– economy benchmark	1,003	0.001	0.045	-0.397	0.541
– industry benchmark	1,003	0.003	0.043	-0.277	0.578
– state benchmark	1,003	0.002	0.045	-0.404	0.535
– county benchmark	1,003	0.001	0.045	-0.398	0.538
2) Trade credit exposures (second term in equation (11)) computed relative to:					
– economy benchmark	1,003	0.001	0.023	-0.021	0.710
– industry benchmark	1,003	0.001	0.020	-0.024	0.616
– state benchmark	1,003	0.001	0.019	-0.021	0.580
– county benchmark	1,003	0.001	0.022	-0.021	0.695
Panel D: Suppliers descriptive statistics – Years 1980–2004					
Assets [$ billions]	9,383	946.294	4,417.068	0.251	188,874.000
EBIT [$ billions]	9,292	76.940	492.240	-5,281.200	12,863.000
Sales [$ billions]	9,383	830.639	3,496.323	0.016	80,514.600
Accounts payable	9,380	79.916	376.951	0.000	8,946.788
Cost of goods sold	9,383	570.839	2,629.067	0.000	76,956.000
Sales growth rate (g)	9,383	0.101	0.452	-2.994	6.367
Shock (e) computed relative to:					
– economy benchmark	9,383	-0.002	0.448	-3.172	6.249
– industry benchmark	9,383	0.002	0.427	-3.038	6.136
– state benchmark	9,383	-0.001	0.444	-3.246	6.264
– county benchmark	9,383	-0.001	0.445	-3.172	6.250
Panel E: Suppliers descriptive statistics – Expansion					
Sales growth rate (g)	7,422	0.116	0.460	-2.994	6.367
Shock (e) computed relative to:					
– economy benchmark	7,422	0.003	0.457	-3.172	6.249
– industry benchmark	7,422	0.003	0.435	-3.038	6.136
– state benchmark	7,422	0.003	0.453	-3.246	6.264
– county benchmark	7,422	0.005	0.453	-3.172	6.250
Panel F: Suppliers descriptive statistics – Recession					
Sales growth rate (g)	1,961	0.043	0.418	-2.552	3.875
Shock (e) computed relative to:					
– economy benchmark	1,961	-0.021	0.415	-2.585	3.791
– industry benchmark	1,961	0.001	0.391	-2.414	3.715
– state benchmark	1,961	-0.017	0.410	-2.568	3.707
– county benchmark	1,961	-0.021	0.412	-2.585	3.787

Table II

Correlation between customer sales growth and supplier sales growth

Pairwise correlation coefficients are calculated over all 12,985 observations which cover customer–supplier pairs pooled over all years with non-missing values of assets, cost of goods sold and non-missing values of sales in two consecutive years. The sales growth among customers is denoted by g_{Cust} and among supplier by g_{Supp}. The economy benchmark is denoted by $\bar{g}_E$, the industry benchmark by $\bar{g}_I$, the state benchmark by $\bar{g}_S$, and the county benchmark by $\bar{g}_C$. The shock calculated relative to the economy benchmark is denoted by e_E, relative to the industry benchmark by e_I, relative to the state benchmark by e_S, and relative to the county benchmark by e_C

	g_{Cust}	g_{Supp}	$\bar{g}_E$	$\bar{g}_I$	$\bar{g}_S$	$\bar{g}_C$	e_E	e_I	e_S	e_C
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
g_{Cust}	1.000									
g_{Supp}	0.155	1.000								
$\bar{g}_E$	0.223	0.131	1.000							
$\bar{g}_I$	0.216	0.332	0.390	1.000						
$\bar{g}_S$	0.207	0.179	0.714	0.363	1.000					
$\bar{g}_C$	0.153	0.177	0.610	0.278	0.476	1.000				
e_E	0.128	0.992	0.005	0.286	0.090	0.102	1.000			
e_I	0.080	0.930	-0.013	-0.038	0.048	0.079	0.940	1.000		
e_S	0.118	0.982	-0.003	0.268	-0.009	0.090	0.991	0.936	1.000	
e_C	0.125	0.979	0.007	0.280	0.083	-0.028	0.987	0.928	0.979	1.000

Table III

Trade credit relationship as insurance against supplier's shocks

The table shows that in general trade credit works as insurance against suppliers' shocks by reducing disturbances to customer's sales growth. The table shows coefficient estimates of equation (11), in which the dependent variable is sales growth among customers and the supplier shock is computed relative to the economy benchmark. Column (2) shows that the effect exists even if controlling for firm, year, industry and state heterogeneity. Columns (3) and (4) show that the effect persist even if controlling for industry-year common shocks or state-year common shocks. Standard errors are given in parentheses. The figures in square brackets represent the economic effect of the production and trade credit relationships, which is the response in a customer's sales growth to a one standard deviation increase in the shock to all of its suppliers. It is given as the average over all suppliers of: $\left(\phi \frac{\alpha}{n} D_{ij} SD[e_j]\right)$ for the production relationship and by $\left(\eta \beta_i \frac{\alpha(1-\alpha)}{n} \left[DW'D\right]_{ij} SD[e_j]\right)$ for the trade credit relationship. The sample runs from 1980 to 2004. All regressions include a constant. Significance is denoted by * at the 90% level, ** at the 95% level and *** at 99% level.

	Dependent variable: Customers sales growth (g)			
	Baseline	F.E.	Time varying F.E.	
	(1)	(2)	(3)	(4)
Production relationship (ϕ)	1.111***	0.966***	0.976***	1.036***
	(0.070)	(0.075)	(0.087)	(0.071)
	[0.005]	[0.004]	[0.004]	[0.004]
Trade credit relationship (η)	-1.210***	-1.406***	-0.676*	-1.019***
	(0.301)	(0.337)	(0.353)	(0.303)
	[-0.001]	[-0.001]	[-0.001]	[-0.001]
Firm F.E.	No	Yes	No	No
Year F.E.	No	Yes	No	No
Industry F.E.	No	Yes	No	No
State F.E.	No	Yes	No	No
Year *Industry F.E.	No	No	Yes	No
Year*State F.E.	No	No	No	Yes
N	4,785	4,349	4,785	4,349
Adj.-R^2	0.050	0.352	0.137	0.127

Table IV

Trade credit and customer's importance

The table shows coefficient estimates of equation (11), in which the dependent variable is sales growth among customers and the supplier shock is computed relative to the economy benchmark. Column (1) shows that the effect disappears if the trade credit relationship between firms is negligible (β_i among bottom 10%). Columns (2) shows results for the model with only a production relationship. Column (3) shows results for the constrained regression in which ϕ is constrained to a value of one which is predicted by the theory. And column (4) focuses on a sub-sample of customers with suppliers highly dependent on their demand. We test here if the reverse causal relationship, in which the customer's growth drives positive shocks to suppliers, reveals itself by a significant coefficient on the 'Top 10% reliant suppliers' term. Standard errors in parentheses. The figures in square brackets represent the economic effect of the production and trade credit relationships, which is the response in a customer's sales growth to a one standard deviation increase in the shock to all of its suppliers. It is given as the average over all suppliers of: $\left(\phi \frac{\alpha}{n} D_{ij} SD[e_j]\right)$ for the production relationship and by $\left(\eta \beta_i \frac{\alpha(1-\alpha)}{n} \left[DW'D\right]_{ij} SD[e_j]\right)$ for the trade credit relationship. The sample runs from 1980 to 2004. All regressions include a constant. Significance is denoted by * at the 90% level, ** at the 95% level and *** at 99% level.

	Dependent variable: Customers sales growth (g)			
	Low β_i among bottom 10%	Production network only	Constrained regression	Strategic customers
	(1)	(2)	(3)	(4)
Production relationship (ϕ)	1.582***	1.040***	1.000	1.110***
	(0.351)	(0.068)	constrained	(0.070)
	[0.007]	[0.004]	[0.004]	[0.005]
Trade credit relationship (η)	19.501	-	-1.090***	-1.212***
	(28.354)		(0.291)	(0.301)
	[0.018]		[-0.001]	[-0.001]
Top 10% reliant suppliers				-0.011
				(0.012)
F.E.	No	No	No	No
N	489	4,785	4,785	4,785
Adj.-R^2 (MSE in column (3))	0.043	0.047	0.243	0.051

Table V

Trade credit and financial constraints

The table shows coefficient estimates of equation (11), in which the dependent variable is sales growth among customers and the supplier shock is computed relative to the economy benchmark. Column (1) shows that the trade credit relationship reduces disturbances to customer's sales growth during good times but not during recession. Recession years are taken from the NBER business cycle reference dates and cover years: 1980, 1981, 1982, 1990, 1991 and 2001. The expansion years cover years: from 1983 to 1989, from 1992 to 2000 and from 2002 to 2004. Column (2) shows that for cash poor customers, a trade credit relationship amplifies disturbances to sales growth. This stems from the positive sign on the interaction term between the trade credit relationship and a dummy for cash poor customers. The cash poor customers are defined as 5% of the customers which in the previous year had the lowest liquid assets relative to their sales. Column (3) illustrates that for financially constrained firms the existence of a trade credit relationship translates into higher disturbances in sales growth from suppliers shocks. Financial constraint is computed according to Rajan and Zingales (1998). Column (4) shows that trade credit relationship translates into higher disturbances in sales growth either during recession or for financially constrained firms. The sample runs from 1980 to 2004. Standard errors in parentheses. The figures in square brackets represent the economic effect of the production and trade credit relationships, which is the response in a customer's sales growth to a one standard deviation increase in the shock to all of its suppliers. It is given as the average over all suppliers of: $\left(\phi\frac{\alpha}{n}D_{ij}SD[e_j]\right)$ for the production relationship and by $\left(\eta\beta_i\frac{\alpha(1-\alpha)}{n}\left[DW'D\right]_{ij}SD[e_j]\right)$ for the trade credit relationship. The sample runs from 1980 to 2004. All regressions include a constant. Significance is denoted by * at the 90% level, ** at the 95% level and *** at 99% level.

	Dependent variable: Customers sales growth (g)			
	Recession	Cash reserves	Fin. dependence	Fin. dependence in recession
	(1)	(2)	(3)	(4)
Production relationship (ϕ)	1.310***	1.014***	1.237***	1.359***
	(0.075)	(0.093)	(0.074)	(0.077)
	[0.006]	[0.004]	[0.005]	[0.006]
Trade credit relationship (η)	-5.233***	-4.761***	-10.017***	-11.616***
	(0.629)	(0.860)	(1.287)	(1.373)
	[-0.005]	[-0.004]	[-0.009]	[-0.011]
Trade credit relationship*Recession	5.186***			7.418**
	(0.709)			(3.742)
	[0.005]			[0.007]
Recession	-0.031***			-0.031***
	(0.009)			(0.009)
Trade credit relationship*Top 10% dependent on ext. fin.			9.203***	7.710***
			(1.303)	(1.448)
			[0.009]	[0.007]
Top 10% dependent on ext. fin.			-0.071***	-0.069***
			(0.012)	(0.012)
Trade credit relationship*Recession $*$Top 10% dependent on ext. fin.				-3.528
				(3.798)
				[-0.003]
Trade credit relationship*Bottom 5% cash poor firms		72.219***		
		(20.554)		
		[0.068]		
Bottom 5% cash poor firms		0.035**		
		(0.016)		
F.E.	No	No	No	No
N	4,785	3,245	4,728	4,728
Adj.-R^2	0.063	0.039	0.065	0.073

Table VI

Trade credit and financial constraints - robustness

The table shows coefficient estimates of equation (11), in which the dependent variable is sales growth among customers and the supplier shock is computed relative to the economy benchmark. Column (1) and (2) control for customer level common shocks and show that during recession firms which high use of trade credit suffer higher disturbances to their sales growth than those with only small use of trade credit. Also, financially constrained firms with high use of trade credit will suffer higher disturbances than financially constrained firms with little trade credit. Recession years are taken from the NBER business cycle reference dates and cover years: 1980, 1981, 1982, 1990, 1991 and 2001. The expansion years cover years: from 1983 to 1989, from 1992 to 2000 and from 2002 to 2004. Column (3) and (4) show no significant relationship for customers with highly dependent supplier. The sample runs from 1980 to 2004. Standard errors in parentheses. The figures in square brackets represent the economic effect of the production and trade credit relationships, which is the response in a customer's sales growth to a one standard deviation increase in the shock to all of its suppliers. It is given as the average over all suppliers of: $\left(\phi \frac{\alpha}{n} D_{ij} SD[e_j]\right)$ for the production relationship and by $\left(\eta \beta_i \frac{\alpha(1-\alpha)}{n} \left[DW'D\right]_{ij} SD[e_j]\right)$ for the trade credit relationship. The sample runs from 1980 to 2004. All regressions include a constant. Significance is denoted by * at the 90% level, ** at the 95% level and *** at 99% level.

	Dependent variable: Customers sales growth (g)			
	Time varying F.E.		Strategic customers	
	Recession	Fin. dependence	Recession	Fin. dependence
	(1)	(2)	(3)	(4)
Production relationship (ϕ)	1.221***	1.150***	1.309***	1.236***
	(0.076)	(0.075)	(0.075)	(0.074)
	[0.005]	[0.005]	[0.006]	[0.005]
Trade credit relationship (η)	-4.936***	-10.599***	-5.235***	-10.023***
	(0.658)	(1.431)	(0.629)	(1.287)
	[-0.005]	[-0.010]	[-0.005]	[-0.009]
Trade credit relationship*Recession	4.917***		5.187***	
	(0.735)		(0.709)	
	[0.005]		[0.005]	
Recession	0.176		-0.031***	
	(0.462)		(0.009)	
Trade credit relationship*Top 10%		9.937***		9.208***
dependent on ext. fin.		(1.445)		(1.303)
		[0.009]		[0.009]
Top 10% dependent on ext. fin.		-0.070		-0.071***
		(0.013)		(0.012)
Top 10% reliant suppliers			-0.011	-0.012
			(0.012)	(0.012)
Year*State F.E.	Yes	Yes	No	No
N	4,349	4,308	4,785	4,728
Adj.-R^2	0.138	0.148	0.063	0.065

Table VII
Industry benchmark

Panel A shows that a trade credit relationship reduces disturbances to sales growth. It shows coefficient estimates of equation (11), in which the dependent variable is sales growth among customers and the supplier shock is computed relative to the industry benchmark. Panel B shows that the insurance effect is irrespective of the customer's importance, which suggests no reverse causality. Panel C shows that the trade credit insurance effect is absent during recession or for cash poor firms or for financially constrained firms. Panel D shows that the trade credit insurance effect is absent in those cases even if controlling for state-year common shocks. Standard errors in parentheses. The figures in square brackets represent the economic effect of the production and trade credit relationships, which is the response in a customer's sales growth to a one standard deviation increase in the shock to all of its suppliers. It is given as the average over all suppliers of: $\left(\phi\frac{\alpha}{n}D_{ij}SD[e_j]\right)$ for the production relationship and by $\left(\eta\beta_i\frac{\alpha(1-\alpha)}{n}\left[DW'D\right]_{ij}SD[e_j]\right)$ for the trade credit relationship. The sample runs from 1980 to 2004. All regressions include a constant. Significance is denoted by * at the 90% level, ** at the 95% level and *** at 99% level.

	Dependent variable: Customers sales growth (g)			
Panel A: Trade credit as insurance against supplier's shocks				
	Baseline	F.E.	Time varying F.E.	
	(1)	(2)	(3)	(4)
Production relationship (ϕ)	0.626***	0.539***	0.631***	0.573***
	(0.058)	(0.063)	(0.069)	(0.059)
	[0.003]	[0.002]	[0.003]	[0.002]
Trade credit relationship (η)	-1.531***	-1.552***	-1.283***	-1.420***
	(0.332)	(0.374)	(0.397)	(0.336)
	[-0.001]	[-0.001]	[-0.001]	[-0.001]
Firm F.E.	No	Yes	No	No
Year F.E.	No	Yes	No	No
Industry F.E.	No	Yes	No	No
State F.E.	No	Yes	No	No
Year *Industry F.E.	No	No	Yes	No
Year*State F.E.	No	No	No	Yes
N	4,785	4,349	4,785	4,349
Adj.-R^2	0.024	0.335	0.123	0.099
Panel B: Customer's importance				
	Low β_i among bottom 10%	Production network only	Constrained regression	Strategic customers
Production relationship (ϕ)	1.354***	0.518***	1.000	0.625***
	(0.365)	(0.053)	constrained	(0.058)
	[0.006]	[0.002]	[0.004]	[0.003]
Trade credit relationship (η)	-30.921		-2.400***	-1.531***
	(23.411)		(0.305)	(0.332)
	[-0.028]		[-0.002]	[-0.001]
Top 10% reliant suppliers				-0.013
				(0.012)
F.E.	No	No	No	No
N	489	4,785	4,785	4,785
Adj.-R^2 (MSE in column (3))	0.024	0.019	0.248	0.024

Table VII cont.

	Dependent variable: Customers sales growth (g)			
Panel C: Financial constraints				
	Recession	Cash reserves	Fin. dependence	Fin. dependence in recession
	(1)	(2)	(3)	(4)
Production relationship (ϕ)	0.861***	0.616***	0.636***	0.840***
	(0.066)	(0.082)	(0.059)	(0.067)
	[0.004]	[0.003]	[0.003]	[0.003]
Trade credit relationship (η)	-4.990***	-4.820***	-7.031***	-9.133***
	(0.584)	(0.856)	(1.520)	(1.562)
	[-0.004]	[-0.004]	[-0.006]	[-0.008]
Trade credit relationship*Recession	4.367***			7.404**
	(0.603)			(3.040)
	[0.004]			[0.007]
Recession	-0.034***			-0.034***
	(0.009)			(0.009)
Trade credit relationship*Top 10% dependent on ext. fin.			5.724***	4.724***
			(1.524)	(1.575)
			[0.005]	[0.004]
Top 10% dependent on ext. fin.			-0.076***	-0.074***
			(0.012)	(0.012)
Trade credit relationship*Recession *Top 10% dependent on ext. fin.				-4.106
				(3.566)
				[-0.004]
Trade credit relationship*Bottom 5% cash poor firms		14.932		
		(26.059)		
		[0.013]		
Bottom 5% cash poor firms		0.028*		
		(0.016)		
F.E.	No	No	No	No
N	4,785	3,245	4,728	4,728
Adj.-R^2	0.037	0.017	0.033	0.044

Panel D: Financial constraints - robustness	Time varying F.E.		Strategic customers	
	Recession	Fin. dependence	Recession	Fin. dependence
Production relationship (ϕ)	0.810***	0.584***	0.860***	0.635***
	(0.067)	(0.060)	(0.066)	(0.059)
	[0.003]	[0.002]	[0.004]	[0.003]
Trade credit relationship (η)	-5.015***	-8.422***	-4.989***	-7.037***
	(0.607)	(1.709)	(0.584)	(1.520)
	[-0.004]	[-0.007]	[-0.004]	[-0.006]
Trade credit relationship*Recession	4.397***		4.365***	
	(0.621)		(0.603)	
	[0.004]		[0.004]	
Recession	-0.167		-0.034***	
	(0.741)		(0.009)	
Trade credit relationship*Top 10% dependent on ext. fin.		7.228***		5.729***
		(1.712)		(1.524)
		[0.006]		[0.005]
Top 10% dependent on ext. fin.		-0.075		-0.076***
		(0.013)		(0.012)
Top 10% reliant suppliers			-0.012	-0.014
			(0.012)	(0.012)
Year*State F.E.	Yes	Yes	No	No
N	4,349	4,308	4,785	4,728
Adj.-R^2	0.112	0.115	0.037	0.033

Table VIII

State benchmark

Panel A shows that a trade credit relationship reduces disturbances to sales growth. It shows coefficient estimates of equation (11), in which the dependent variable is sales growth among customers and the supplier shock is computed relative to the state benchmark. Panel B shows that the insurance effect is irrespective of the customer's importance, which suggests no reverse causality. Panel C shows that the trade credit insurance effect is absent during recession or for cash poor firms or for financially constrained firms. Panel D shows that the trade credit insurance effect is absent in those cases even if controlling for state-year common shocks. Standard errors in parentheses. The figures in square brackets represent the economic effect of the production and trade credit relationships, which is the response in a customer's sales growth to a one standard deviation increase in the shock to all of its suppliers. It is given as the average over all suppliers of: $\left(\phi\frac{\alpha}{n}D_{ij}SD[e_j]\right)$ for the production relationship and by $\left(\eta\beta_i\frac{\alpha(1-\alpha)}{n}\left[DW'D\right]_{ij}SD[e_j]\right)$ for the trade credit relationship. The sample runs from 1980 to 2004. All regressions include a constant. Significance is denoted by * at the 90% level, ** at the 95% level and *** at 99% level.

	Dependent variable: Customers sales growth (g)			
Panel A: Trade credit as insurance against supplier's shocks				
	Baseline	F.E.	Time varying F.E.	
	(1)	(2)	(3)	(4)
Production relationship (ϕ)	1.049***	0.929***	0.943***	1.019***
	(0.069)	(0.074)	(0.085)	(0.071)
	[0.004]	[0.004]	[0.004]	[0.004]
Trade credit relationship (η)	-1.623***	-1.729***	-0.969**	-1.460***
	(0.345)	(0.383)	(0.419)	(0.348)
	[-0.002]	[-0.002]	[-0.001]	[-0.001]
Firm F.E.	No	Yes	No	No
Year F.E.	No	Yes	No	No
Industry F.E.	No	Yes	No	No
State F.E.	No	Yes	No	No
Year *Industry F.E.	No	No	Yes	No
Year*State F.E.	No	No	No	Yes
N	4,785	4,349	4,785	4,349
Adj.-R^2	0.046	0.351	0.135	0.126
Panel B: Customer's importance				
	Low β_i among bottom 10%	Production networks only	Constrained regression	Strategic customers
Production relationship (ϕ)	1.538***	0.951***	1.000	1.048***
	(0.335)	(0.066)	constrained	(0.069)
	[0.007]	[0.004]	[0.004]	[0.004]
Trade credit relationship (η)	44.904		-1.549***	-1.625***
	(29.239)		(0.329)	(0.345)
	[0.042]		[-0.001]	[-0.002]
Top 10% reliant suppliers				-0.012
				(0.012)
F.E.	No	No	No	No
N	489	4,785	4,785	4,785
Adj.-R^2 (MSE in column (3))	0.050	0.042	0.244	0.046

Table VIII cont.

	Dependent variable: Customers sales growth (g)			
Panel C: Financial constraints				
	Recession	Cash reserves	Fin. dependence	Fin. dependence in recession
	(1)	(2)	(3)	(4)
Production relationship (ϕ)	1.240***	0.947***	1.134***	1.270***
	(0.074)	(0.093)	(0.072)	(0.076)
	[0.005]	[0.004]	[0.005]	[0.005]
Trade credit relationship (η)	-5.129***	-4.976***	-9.063***	-10.753***
	(0.606)	(0.865)	(1.276)	(1.371)
	[-0.005]	[-0.005]	[-0.008]	[-0.010]
Trade credit relationship*Recession	4.221***			7.447**
	(0.597)			(3.721)
	[0.004]			[0.007]
Recession	-0.032***			-0.031***
	(0.009)			(0.009)
Trade credit relationship*Top 10% dependent on ext. fin.			7.903***	6.710***
			(1.296)	(1.429)
			[0.007]	[0.006]
Top 10% dependent on ext. fin.			-0.072***	-0.070***
			(0.012)	(0.012)
Trade credit relationship*Recession $*$Top 10% dependent on ext. fin.				-5.007
				(4.592)
				[-0.005]
Trade credit relationship*Bottom 5% cash poor firms		68.379***		
		(19.663)		
		[0.063]		
Bottom 5% cash poor firms		0.033**		
		(0.016)		
F.E.	No	No	No	No
N	4,785	3,245	4,728	4,728
Adj.-R^2	0.058	0.034	0.059	0.067

Panel D: Financial constraints - robustness				
	Time varying F.E.		Strategic customers	
	Recession	Fin. dependence	Recession	Fin. dependence
Production relationship (ϕ)	1.208***	1.102***	1.239***	1.133***
	(0.076)	(0.073)	(0.074)	(0.072)
	[0.005]	[0.005]	[0.005]	[0.005]
Trade credit relationship (η)	-5.055***	-9.962***	-5.132***	-9.073***
	(0.633)	(1.415)	(0.606)	(1.276)
	[-0.005]	[-0.009]	[-0.005]	[-0.008]
Trade credit relationship*Recession	4.168***		4.222***	
	(0.615)		(0.597)	
	[0.004]		[0.004]	
Recession	0.176		-0.032***	
	(0.462)		(0.009)	
Trade credit relationship*Top 10% dependent on ext. fin.		8.939***		7.911***
		(1.433)		(1.296)
		[0.008]		[0.007]
Top 10% dependent on ext. fin.		-0.070		-0.072***
		(0.013)		(0.012)
Top 10% reliant suppliers			-0.012	-0.013
			(0.012)	(0.012)
Year*State F.E.	Yes	Yes	No	No
N	4,349	4,308	4,785	4,728
Adj.-R^2	0.138	0.146	0.058	0.059

Table IX
County benchmark

Panel A shows that a trade credit relationship reduces disturbances to sales growth. It shows coefficient estimates of equation (11), in which the dependent variable is sales growth among customers and the supplier shock is computed relative to the county benchmark. Panel B shows that the insurance effect is irrespective of the customer's importance, which suggests no reverse causality. Panel C shows that the trade credit insurance effect is absent during recession or for cash poor firms or for financially constrained firms. Panel D shows that the trade credit insurance effect is absent in those cases even if controlling for state-year common shocks. Standard errors in parentheses. The figures in square brackets represent the economic effect of the production and trade credit relationships, which is the response in a customer's sales growth to a one standard deviation increase in the shock to all of its suppliers. It is given as the average over all suppliers of: $\left(\phi \frac{\alpha}{n} D_{ij} SD[e_j]\right)$ for the production relationship and by $\left(\eta \beta_i \frac{\alpha(1-\alpha)}{n} \left[DW'D\right]_{ij} SD[e_j]\right)$ for the trade credit relationship. The sample runs from 1980 to 2004. All regressions include a constant. Significance is denoted by * at the 90% level, ** at the 95% level and *** at 99% level.

	Dependent variable: Customers sales growth (g)			
Panel A: Trade credit as insurance against supplier's shocks				
	Baseline	F.E.	Time varying F.E.	
	(1)	(2)	(3)	(4)
Production relationship (ϕ)	1.181***	1.071***	1.051***	1.116***
	(0.071)	(0.078)	(0.088)	(0.073)
	[0.005]	[0.005]	[0.004]	[0.005]
Trade credit relationship (η)	-1.231***	-1.405***	-0.665*	-1.035***
	(0.305)	(0.341)	(0.359)	(0.307)
	[-0.001]	[-0.001]	[-0.001]	[-0.001]
Firm F.E.	No	Yes	No	No
Year F.E.	No	Yes	No	No
Industry F.E.	No	Yes	No	No
State F.E.	No	Yes	No	No
Year *Industry F.E.	No	No	Yes	No
Year*State F.E.	No	No	No	Yes
N	4,785	4,349	4,785	4,349
Adj.-R^2	0.054	0.357	0.142	0.133
Panel B: Customer's importance				
	Low β_i among bottom 10%	Production network only	Constrained regression	Strategic customers
Production relationship (ϕ)	1.586***	1.109***	1.000	1.179***
	(0.350)	(0.069)	constrained	(0.071)
	[0.007]	[0.005]	[0.004]	[0.005]
Trade credit relationship (η)	21.561		-1.038***	-1.232***
	(27.964)		(0.296)	(0.305)
	[0.020]		[-0.001]	[-0.001]
Top 10% reliant suppliers				-0.011
				(0.012)
F.E.	No	No	No	No
N	489	4,785	4,785	4,785
Adj.-R^2 (MSE in column (3))	0.044	0.051	0.243	0.054

Table IX cont.

	Dependent variable: Customers sales growth (g)			
Panel C: Financial constraints				
	Recession	Cash reserves	Fin. dependence	Fin. dependence in recession
	(1)	(2)	(3)	(4)
Production relationship (ϕ)	1.371***	1.118***	1.260***	1.388***
	(0.076)	(0.095)	(0.074)	(0.077)
	[0.006]	[0.005]	[0.005]	[0.006]
Trade credit relationship (η)	-5.144***	-4.575***	-8.665***	-9.989***
	(0.630)	(0.862)	(1.321)	(1.413)
	[-0.005]	[-0.004]	[-0.008]	[-0.009]
Trade credit relationship*Recession	4.983***			5.042
	(0.697)			(3.731)
	[0.005]			[0.005]
Recession	-0.031***			-0.031***
	(0.009)			(0.009)
Trade credit relationship*Top 10% dependent on ext. fin.			7.779***	5.841***
			(1.339)	(1.493)
			[0.007]	[0.005]
Top 10% fin. constrained firms			-0.071***	-0.069***
			(0.012)	(0.012)
Trade credit relationship*Recession *Top 10% dependent on ext. fin.				-1.015
				(3.870)
				[-0.001]
Trade credit relationship*Bottom 5% cash poor firms		71.442***		
		(20.701)		
		[0.066]		
Bottom 5% cash poor firms		0.035**		
		(0.016)		
F.E.	No	No	No	No
N	4,785	3,245	4,728	4,728
Adj.-R^2	0.066	0.044	0.066	0.074

Panel D: Financial constraints - robustness	Time varying F.E.		Strategic customers	
	Recession	Fin. dependence	Recession	Fin. dependence
Production relationship (ϕ)	1.293***	1.176***	1.370***	1.259***
	(0.077)	(0.075)	(0.076)	(0.074)
	[0.006]	[0.005]	[0.006]	[0.005]
Trade credit relationship (η)	-4.840***	-8.937***	-5.147***	-8.674***
	(0.659)	(1.485)	(0.630)	(1.321)
	[-0.004]	[-0.008]	[-0.005]	[-0.008]
Trade credit relationship*Recession	4.712***		4.984***	
	(0.723)		(0.697)	
	[0.004]		[0.005]	
Recession	0.176		-0.031***	
	(0.460)		(0.009)	
Trade credit relationship*Top 10% dependent on ext. fin.		8.205***		7.786***
		(1.501)		(1.339)
		[0.008]		[0.007]
Top 10% dependent on ext. fin.		-0.0693		-0.071***
		(0.013)		(0.012)
Top 10% reliant suppliers			-0.011	-0.012
			(0.012)	(0.012)
Year*State F.E.	Yes	Yes	No	No
N	4,349	4,308	4,785	4,728
Adj.-R^2	0.143	0.150	0.066	0.066