Profitability, Trade Credit and Institutional Structure of Production

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Abstract

Using a novel dataset of supplier-customer relationships, I develop measures of vertical position of public and private firms in the US economy in order to test trade credit theories. Firms at higher vertical positions have higher profit margins and hold more net trade credit even after controlling for the number of competitors, suppliers, and customers. A structural estimation of the optimal contract between firms provides a strong support for the recursive moral hazard theory of trade credit (Kim and Shin, 2012). I conclude that contracting between firms and trade credit practices might have a broader scope than previously thought.

Keywords: trade credit, institutional structure of production, production networks, moral hazard, product quality

JEL Codes: G32, L14, L15

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1 Introduction

Trade credit is a loan provided by a supplier to its customer. Trade credit constitutes a large part of an average firm's balance sheet and is comparable to the size of borrowing from banks.[1] This paper empirically investigates why firms use and provide trade credit. To address this question I use a novel database to identify thousands of supplier-customer relationships among a large sample of public and private firms operating in five sectors of the US economy. From these relationships I construct the structure of supply chains that produce automobiles, household durables, leisure equipment, textiles, apparel and luxury goods. I develop a methodology to measures vertical position for firms in the supply chains. The resulting production structure (Figures 2 and 3) has multiple layers of production such that most of the firms in the economy are producers of intermediate inputs. It is different from the two-layers structure assumed implicitly or explicitly in most theories of trade credit. Producers of intermediate inputs both use and provide trade credit resulting in a complex structure of interconnected financial contracts that facilitate the flow of inputs along the production chains.

The recursive moral hazard theory by Kim and Shin (2012) is successful to explain a wide range of empirical facts based on reduced-form tests and structural estimation. The theory relates the question why firms use and provide trade credit to another seemingly unrelated question of optimal incentives mechanism in complex production chains. The transformation of natural resources into final products is not done by a single firm but by a number of firms that constitute a production chain. However, each of the firms is operating in its self-interest and a mechanism is required to align

[1] For example Rajan and Zingales (1995) document that accounts receivable constitute 17.8% of total assets and accounts payable constitute 15% of total assets on average for non-financial firms in the United States. These ratios are more than double the ratio of short-term debt to total assets (7.4%) for the same sample.

the incentives of each firm to the success of the final good. In their model profits are used as a mechanism to provide incentives to the firms and trade credit improves the feasibility of the long supply chains. To test their theory more directly I derive empirical predictions based on the optimal contract solution proposed by the theoretical model. Consistent with these predictions, I find that firms at higher vertical position on average have more profits and net receivables divided by cost of goods sold, which are referred as normalized incentives. I also document a positive relationship between the relative position between more than 190,000 pairs of firms in the supply chain and the difference in their incentives, exactly as it is predicted by the theory. The role of incentives in the theoretical model is to address a concern that firms in the supply chain can exert low effort levels in the production of intermediary inputs that eventually result in low quality final goods. The model requires that the effort level is not observable by the next firm in the chain and that the effort level of all firms in the chain affects the success of the final good.[2] The magnitude of the moral hazard problem varies with the vertical position of the firm in the supply chain. Firms that are further up in the supply chain are less sensitive to the success of the final product because their cost of shirking is going to be realized at the further period while the benefit is realized instantaneously. Therefore the optimal level of incentives is different for firms positioned differently in the chain. The reason that trade credit and profits serve as incentives is because firms risk their profits and trade credit balances when they economize on costs of production and thereby increase the probability of liquidation of the supply chain.

The novelty of the empirical analysis applied in this paper is that it focuses on

[2]For example, malfunctioning of lithium-ion batteries, produced by a Japanese battery manufacturer, resulted in two fire incidents on board of Boeing 787 Dreamliner; what kept the whole fleet of the aircraft grounded for more than three months in 2013.

institutional structure of production chains and position of firms in this structure. Previous empirical studies tested only bilateral theories of trade credit. These theories suggest that suppliers have an advantage over financial institutions when providing loans because of a relationship between a supplier and a customer.[3] The relationship can generate an informational advantage about the prospects of the customer (Biais and Gollier 1997), allow for better enforcement of repayment (Cuñat 2007), provide an advantage in liquidating collateral (Frank and Maksimovic 1998, Santos and Longhofer 2003), allow for trade credit renegotiation by a distressed customer (Wilner 2000), or generate customer-specific inputs that are harder to divert relative to the cash lent by banks (Burkart and Ellingsen 2004). Petersen and Rajan (1997) show that small firms use trade credit more when they lack access to cheaper sources of financing from financial institutions. If suppliers have access to bank loans then they are more likely to extend trade credit to financially constrained customers, but suppliers might use trade credit as a means of price discrimination.

However, these theories of trade credit describe an economy with only two types of firms: input supply firms with access to capital and financially constrained final good producers. They do not explicitly address the following facts observed in the data: (i) most firms buy inputs from their suppliers and sell intermediary inputs to their customers (ii) firms simultaneously borrow from suppliers and lend to their customers, (iii) firms with better access to capital still use trade credit and firms that are more likely to be financially constrained still provide trade credit. Moreover, most of the theories would not be able to explain why firms use trade credit along with bank credit

[3]An early theory of trade credit by Ferris (1981) suggests that trade credit allows suppliers and customers to smooth cash flows. This theory does not explain simultaneous use of trade credit and banks credit, and is less likely to apply to large public firms. Smith (1987) suggested that a trade credit contract can be used by a supplier to screen out the credit quality of the customer. This theory does not explain why large and liquid customers prefer to use trade credit over other sources of financing, such as credit lines, which are cheaper.

and public debt.[4]

The recursive moral hazard explanation for the use of trade credit in the supply chain is consistent with these empirical facts. According to this theory most of the firms produce intermediary inputs. I construct a vertical position measure for 990 firms. Only 187 firms belong to the consumer discretionary sector which I define as producers of final goods. Other firms are connected to these firms via many supply chains. The moral hazard explanation of trade credit allows to reconcile why firms borrow and lend simultaneously, why usage and provision of trade credit is not explained purely by access to capital and why there is a positive relationship between the amount that the firm borrows from its suppliers and the amount that it lends to its customers.

The idea that an unobservable product quality can affect trade credit practices is not new (Long, Malitz, and Ravid 1993, Lee and Stowe 1993). The assumption used in these papers is that it is easier to return a low quality product if it was bought on trade credit versus cash.[5] However, the previous studies assumed that the quality of the supplied good can be verified by the customer, and that trade credit terms are used to separate firms that produce high quality products from firms that produce low quality products. The recursive moral hazard theory assumes that the low quality intermediate goods cannot be identified immediately, and that the reason for low quality goods is a moral hazard problem and not an asymmetric information problem. The

[4]Burkart and Ellingsen (2004) present a model that reconciles a simultaneous use of bank and trade credit. However, this model is based on the assumption that inputs are harder to divert than cash. The diversion is likely to be important for small firms but is less likely to be very important for large public firms with public debt. In addition, most of the firms in the economy are not producers of final goods as assumed by their model.

[5]The challenge to test these theories is that the data about product quality is not easily available. Long, Malitz, and Ravid (1993) find that firms manufacturing goods with a long production time extend more trade credit, which they interpret as a support for their theory. However, the production time, defined as sales − accounts receivable divided by total assets, is not a direct measure of product quality. This evidence is also consistent with the recursive moral hazard theory.

difference between suppliers' inability to produce high quality goods and their unwillingness to do it is important because the latter case can be solved using incentives in the form of profit margins and trade credit policies that defer payments to suppliers. As other theories of trade credit, the previous product quality theories do not provide any prediction about the amount of trade credit provided by firms at different layers of production. Therefore, my tests of the recursive moral hazard theory using vertical position of firms provides a powerful test of this theory.

The recursive moral hazard theory is more complex than bilateral theories that focus on pairs of firms.[6] In spite of its complexity, four qualitative and quantitative tests, and various robustness tests, presented in this paper support the theory. In addition, other empirical facts documented in other studies can be explained by the theory. The use of trade credit as an incentives device may explain why firms do not use early payment discounts as reported by Ng, Smith, and Smith (1999), why suppliers of differentiated products and of services have larger accounts receivable than suppliers of standardized goods as documented by Burkart, Ellingsen, and Giannetti (2011), or why the strong positive relationship between accounts receivable and accounts payable documented in this paper holds also in the large sample of Chinese firms as reported by Fabbri and Klapper (2008).[7]

More broadly, my results suggest that to understand financial contracting between the firms we need to extend the bilateral analysis to an analysis of the entire production chains. The structure of the production chains constructed in this paper

[6] The recent financial crisis taught us that analyzing and regulating individual financial institutions is not sufficient to understand a build up of a systemic risk in the system. I study whether corporate finance decisions can be better explained by a systemic view of the institutional structure of production instead of focusing on each firm in isolation.

[7] Kim and Shin (2012) refer to a longer version of their paper that used cross-country regressions to motivate the theory.

can also be important to address issues such as propagation of liquidity shocks and contagion in the supply chains (Kiyotaki and Moore 1997, Hertzel, Li, Officer, and Rodgers 2008, Jorion and Zhang 2009, Boissay and Gropp 2013, Garcia-Appendini and Montoriol-Garriga 2013, Jacobson and Von Schedvin 2013). The contagion can be triggered by an idiosyncratic event, such as a negative demand shock to the producer of a final good like in Kim and Shin (2012), or as a result of an aggregate shock like during the recent financial crisis. The focus of the current paper is to understand the usage and provision of trade credit in normal times. We can expect that during a crisis trade credit can be used by large and small firms not only to provide incentives, but also to share liquidity. The analysis of trade credit practices during the recent financial crisis is outside the scope of this paper.

The paper identifies and organizes supplier-customer links that create a natural "space" for the analysis of the boundaries of the firm (Coase 1937) and the institutional structure of production (Coase 1992, Antràs and Chor 2013). The vertical position measures allow us to study firms in a different dimension, instead of the standard cross-sectional or time-series analysis we can study how firms' financial policies and M&A activities depend on their vertical position. On one side, a recent fast growing literature has stressed the importance of production networks structure for understanding aggregate volatility, aggregation and propagation of idiosyncratic shocks in presence of financial frictions (Gabaix 2011, Acemoglu, Carvalho, Ozdaglar, and Tahbaz-Salehi 2012, Bigio and Jennifer 2013). On the other side, models emerge that attempt to explain the formation process of the production networks (Oberfield 2013). Therefore, documenting the structure of real production networks at the firm-level is important both for calibrating or testing existing theories and for guiding new theories. For example, Battiston, Delli Gatti, Gallegati, Greenwald, and Stiglitz (2007) study propagation of defaults in a production network via trade credit linkages. They analyze a production structure with several production levels and the same number of firms at each level. The institutional structure of production that I document (see Figure 2) is quite different from the conjectured perfectly-balanced structure because the number of firms at each layer is different. Using the real production network can be beneficial because it would generate more realistic cascade scenarios.

The remainder of the paper is organized as follows: In the next section I introduce the sample and the novel data source to identify supplier-customer relationships. Section 3 describes the patterns of trade credit for the firms in the sample. In Section 4, I construct the supply chains and the measures of the vertical position. I derive the structural equations in Section 5. The estimation results appear in Section 6. Section 7 concludes.

2 Data

In this paper I use data available through the Capital IQ platform. One important feature of this data source is that it collects information on suppliers and customers from financial reports and public client announcements. This large scale firm-level database on supplier-customer relationships allows me to construct the supply chains between a large sample of firms and to assign a vertical position for each firm in the supply chain.

The sample selection is based on each firm's primary sector and primary industry[8]. The sample only includes companies that belong to the Consumer Discretionary, Industrials, Materials, Energy and IT sectors. It excludes companies in the Financials,

[8]The sector and industry definitions used by Capital IQ are based on the Global Industry Classification System (GICS) developed by S&P and MSCI.

Healthcare, Consumer Staples, Utilities and Telecommunication services sectors. In addition, I refine the list of industries based on the approach discussed below.

The final sample includes 2,735 firms that belong to the five sectors mentioned earlier, public or private, operate in US (but are not necessarily incorporated in the US), are either independent or an operating subsidiary of another firm, and have financial information for total assets or trade credit in any of the last three years. For each of the 2,735 firms, I get the information about their suppliers and customers, as well as financial information for fiscal year 2007 to capture the normal times for lending and borrowing between firms. Both the financial statements and the supplier-customer relationships could be affected by the financial crisis that started as a sub-prime crisis in 2007, but unfolded into the Great Recession in 2009. Given that the goal of this paper is to understand provision and usage of trade credit in normal times, I use the latest financial reports and supplier-customer relationships available prior to the recession.

I define firms that belong to the consumer discretionary sector as 'producers of final goods'. These firms belong to the following industries: automobiles and components, household durables, leisure equipment and products, textiles, apparel and luxury goods. Firms that belong to these industries are likely to produce complex, durable goods and to be involved in larger supply chains. The moral hazard considerations described by Kim and Shin (2012) might be more pronounced in this sample and thus increase the power of the tests. I exclude firms that provide general goods or services such as transportation, media, legal and business services. These firms have customers throughout the supply chain(s) and therefore their position in the supply chain is hard to define. I exclude industrial conglomerates because not only is it difficult to measure their absolute position in the economy correctly, but including them in the sample may also assign an erroneous positions to other firms that are connected to them via supplier-customer relationships.

Next section documents some stylized facts about trade credit practices that motivate the further tests presented in this paper.

3 Patterns of Trade Credit Usage and Provision

The descriptive statistics of usage and provision of trade credit by the firms in the sample suggest that firms with good access to capital borrow substantial amounts from their suppliers, firms with relatively poor access to capital lend to their customers and there is a strong positive relationship between the amount that a firm borrows from its suppliers and the amount it lends to its customers. These patterns of trade credit practices suggest that the difference in access to capital between the supplier and the customer can not be the only explanation of the high levels of trade credit. If a company is financially constrained we expect it to borrow from its suppliers because of their advantages as a lenders of last resort, but then it should not lend to its customers. If a company has publicly traded stocks and bonds and relatively large amounts of undrawn revolving credit then we should not expect that suppliers have any advantage in providing finance to this firm and therefore this type of firms should not borrow from their suppliers.

The summary statistics presented in Table 1 show that on average accounts receivable constitute 16.5% of total revenues and 15.5% of total assets[9]. The level of

[9] When computing financial ratios, I disregard observations with non-positive total revenues or total assets, observations with receivables or payables to total revenues or to total assets that are below 0 or greater than or equal to 1. For the profitability measures, I define observations with profit margins (EBITDA, EBIT, Net Income to Total Revenues) that are greater than or equal to 1 or less than or

accounts receivables is comparable to the level of total bank debt (15.7% of total assets). Accounts payable for the firms in the sample constitute 10.9% of total assets which is comparable to the levels of short-term debt (10.7% of total assets). Therefore, the levels of trade credit are significant comparing to other sources of finance. The average firm has a large exposure to its customers and an average 60 days of credit. This is a suggestive evidence that trade credit is not just a loan for a period required to deliver a good from a seller to a buyer.

The following statistics suggest that not only trade credit usage and provision levels are significant, but also that firms with comparably good access to finance use trade credit and firms that might be financially constrained provide trade credit.[10] The median firm in the sample has book value of total assets of 191 ($mm) and 563 employees. As reported in Table 2, firms with above the median book value of total assets still use trade credit (mean ratio of accounts payable to total assets is 9%), and firms with below median book value of total assets provide trade credit (accounts receivable to total assets ratio is 16.3%). Firms with less than 500 employees[11] provide trade credit (accounts receivable to total assets ratio is 14.4%) and firms with above 500 employees use trade credit (mean ratio of accounts payable to total assets is 7.6%). Therefore, if size is a measure of access to capital, firms that are less likely to be financially constrained still use trade credit and firms that are more likely to be financially constrained still

equal to -1 as missing. I also define observations with Short-Term Debt to Total Assets ratios greater than 1 or less than 0 as missing and I use the same principal for the Revolving Credit to Total Assets ratio. I winsorize financial ratios at the 1% and 99% levels. Accounts Receivable Balances are net after allowances for bad debt.

[10] McMillan and Woodruff (1999) documents that small credit constrained Vietnamese firms in Vietnam provide trade credit. In a recent paper Murfin and Njoroge (2012) uses a panel of one thousand buyer-supplier relationships and document that 41 large investment-grade buyers borrow from 702 smaller, credit-constrained suppliers.

[11] Less than 500 employees is one of the criteria for a firm to be defines as Small-Medium Enterprise (SME) and to participate in the National Survey of Small Business Finance (NSSBF) used in empirical studies of trade credit such as Petersen and Rajan (1997) and Burkart, Ellingsen, and Giannetti (2011).

provide trade credit.

Second, the sample includes both public and private firms[12] as well as firms with and without public debt. Public firms or firms with public debt still borrow from their suppliers (payables to total assets ratio is 7.8% and 8.8% respectively). Firms with above median ratio of undrawn revolving credit to total assets, borrow on average 7.7% of their total assets from their suppliers. Sufi (2009) suggests that lack of access to lines of credit can be a measure of financial constrains that firms face, therefore firms that have large ratio of undrawn revolving credit might be considered as less financially constrained.

Finally, if trade credit was used only by financially constrained firms and provided only by firms with good access to finance then we would not observe positive correlation of 25%[13] between accounts receivable and accounts payable (normalized by total revenues) for the firms in the sample. When we normalize receivables and payables by total assets the correlation between provision and usage of trade credit is 44%. The strong positive correlation suggests that firms in the sample simultaneously borrow from their suppliers and lend to their customers.

The positive correlation between accounts receivable and accounts payable is a piece of evidence in favor of the moral hazard explanation of trade credit proposed by Kim and Shin (2012). In their model firms that have more accounts payable need to have more accounts receivable in order to have incentives to overcome the moral hazard problem. The alternative explanation for the positive relationship is that firms

[12] The private firms in the sample that have financial information include large firms, firms that were previously traded and firms that have privately traded debt.

[13] Statistically significant at 1% level.

might try to match maturities of assets and liabilities for risk management purposes (Banerjee, Dasgupta, and Kim 2004, Fabbri and Klapper 2008). Therefore the positive relationships between receivables and payables is explained by the fact that they have similar maturities. I address both alternatives in a cross-sectional analysis.

The empirical results of the cross-sectional analysis is presented in Table 3. In specification (1) the left hand side variable is accounts receivable divided by total revenues and the right hand side variables include the log of total assets and age, profitability, measures of inventory levels, leverage, undrawn revolving credit divided by total assets, indicator variables for incorporation in US, whether the firm is independent or a subsidiary, whether it is publicly traded, industry dummies [14] and an intercept. Only the public status indicator variable, which is assigned a value of 1 when the company is traded, has a positive and statistically significant coefficient in this specification. This result suggests that firms that are publicly traded have a better access to capital and extend more trade credit to their customers.

Specification (2) includes accounts payable divided by total revenues as an additional explanatory variable. The coefficient on this variable is positive, statistically and economically significant. One standard deviation change in the normalized accounts payable increases the level of normalized receivables by 5.5% (0.409*0.135).

To test the maturity matching hypothesis I use the fact that revolving credit lines have similar maturity to accounts payables and therefore should play a similar role in the determination of accounts receivable. I include revolving credit divided by total assets as an explanatory variable in specification (3) of Table 3. The coefficient on

[14] The industry dummies are defined at the six digits GICS level (22 industries).

revolving credit divided by total assets in this regression is positive and statistically significant at the 10% significant level. However, the coefficient is one order of magnitude smaller than the coefficient for payables in specification (2). One standard deviation change in revolving credit divided by total assets ratio increases receivables divided by total revenues by 0.56% (0.048*0.116). Specification (4) includes both payables and revolving credit line as explanatory variables. In this specification, the coefficient on payables is statistically and economically significant while the coefficient on revolving credit is marginally significant and economically insignificant.

The positive relationship between accounts receivable and accounts payable can be consistent with the maturity matching explanation if payables are preferred over revolving credit lines as a source of short-term finance. However, this hypothesis does not explain why would revolving credit be a more expensive source of finance relative to the trade credit and why would firms use the trade credit and revolving credit simultaneously. The implied interest rate on the trade credit contracts can be very high. Even though there is no explicit interest rate on trade credit suppliers sometimes offer early payment discount if customers pay for the supplied goods earlier. Ng, Smith, and Smith (1999) using a survey data of vendors estimate effective annual interest rate on trade credit of 40%. They document that large proportion of firms that forgo early payment discount: 38.6% occasionally, 22.8% half of the time, 27.9% frequently. In a recent study Klapper, Laeven, and Rajan (2012) document average effective interest rate of 54% in the sample of 29 thousand trade credit contracts between 56 large buyers of final goods and 24 thousand smaller suppliers. It is unlikely that firms needs to pay annual interest rate higher than 40-54% on the revolving credit. The recursive moral hazard explanation of trade credit suggests that firms would prefer to forgo the discount in order to provide the right incentives to their suppliers or we will not see discounts provided by suppliers. Klapper, Laeven, and Rajan (2012) find that only in 13% of all contracts a discount was offered to a customer. Moreover, the survey data of vendors reported by Ng, Smith, and Smith (1999) suggests that OEMs[15] are less likely to pay cash for the inputs and are less likely to be offered a trade credit contract with the early repayment discount option. It suggests that suppliers are not attempting to get early repayment that can decrease their incentives to exert effort.

Overall, the cross-sectional results and summary statistics presented in this section provide some evidence for the moral hazard explanation of trade credit. In order to get more power in tests of the moral hazard explanation of trade credit, I derive two types of structural equation from the optimal contract solution (Section 5). The first type relates the normalized level of incentives to the absolute vertical position of each firm in the supply chain. The second type relates the difference in the levels of incentives and the relative position of each pair of firms in the supply chain. The next section describes the methodology to construct the supply chains and to build the measures of absolute and relative position.

4 Construction of the Supply Chains

In order to measure the position of a firm in the production process, I need to identify all supplier-customer pairs among the 2,735 firms in the sample. To create these relationships, I match firms based on the list of suppliers of each firm. When I find a match, I define a pair of firms, where the first firm is the customer and the second firm is the supplier.

[15] Buyers who use the product as an intermediary input.

The matching procedure creates 4,168 pairs of firms {customer, supplier} among the 2,735 firms in the sample. The number of firms that have at least one supplier or customer is 1,418. I refer to this set of firms as the *connected set*.

In the initial sample there are 1,317 firms that have neither a single supplier nor customer among the other 2,734 firms. This can occur if their list of suppliers is empty or if it includes firms that have not met the selection criteria. The analysis presented in the paper focuses only on the connected set of firms.

In the connected set of 1,418 firms, the average (median) number of suppliers and customers is 2.94 (1)[16], The maximum number of suppliers is 95 and the maximum number of customers is 75. There are 482 firms that have no suppliers and 364 firms that have no customers among the firms in the connected set.

Next I present the methodology to create the measures of absolute and relative position and apply it to the firms in the sample.

4.1 Measures of Position in Supply Chain

In a perfectly vertical supply chain, the absolute position of each firm equals to the number of links that separate it from the producer of the final good and the relative position between any two firms equals to the difference in their absolute positions. The industrial structure observed in the data includes firms with more than one supplier or customer. Therefore I need to define absolute and relative positions measures for the more complex production chains.

[16]The average number of suppliers and customers is the same when I calculate the unconditional average. The average number of suppliers is 4.45 among firms that have at least one supplier and the average number of customers is 3.95 among firms that have at least one customer.

In order to define the *absolute position* of a firm I need to define a set of firms that produce a final good. All firms in this set are assigned position 0. All firms that supply goods to either of the firms in the set of firms with a position of 0 are assigned position of 1. All firms that supply goods to any of the firms at position 1 are assigned a position of 2 and so forth. I refer to this definition of absolute position as the *minimum measure* of absolute position. If all firms in the sample have no more than one supplier or customer then the minimum measure of absolute position equal the position assigned to each firm according to Kim and Shin (2012) model.[17]

Figure 1 illustrates an example of supplier-customer relationships between a subsample of 26 firms. The vertical position of each firm in the figure is calculated according to the minimum measure of absolute position. Firms that belong to the industry of producers of consumer electronics (3, 8, 17, 20, and 26) are at the bottom of the figure and are assigned position 0. The highest vertical position in this example is 3. Firms at position 3 (firms with numbers 22, 21, and 24) supply inputs to at least one firm at position 2 but don not supply inputs to any of the firms with a position smaller than 2 directly.

One limitation of the minimum measure is that it focuses only on the producer of final goods that is related to the firm via the smallest number of supplier-customer relationships. This measure disregards the position of each firm relative to other producers of final goods. I calculate an additional measure that takes into account the

[17] To calculate this measure given a directed network of supplier-customer relationships, we need to compute the shortest distance from any firm to each of the firms at layer 0. The minimum vertical position measure is the shortest chain connecting each firm to any firm at position 0. As a result of this procedure, we know not only the vertical position of each firm, but also what is exactly the shortest production chain that assigns this firm its vertical position, and what other firms belong to this chain.

position of each firm relative to other producers of final goods as well. To define this measure, first I calculate the shortest supply chain that connects each firm with each producer of final goods. Then I calculate the length of these supply chains by counting the number of supplier-customer links they include. The result of this analysis is a list of distances for each firm relative to all of the producers of final goods it is connected to. Finally, I obtain the median distance over all the distances and define it to be the *median measure* of position for the firm.

In the supply chains where firms have more than one supplier or customer, the *relative position* between a pair of firms is defined as the number of supplier-customer relationships across the shortest possible supply chain that connects them. In Figure 1, there are 91 pairs of firms that are connected. For example, among the set of firms number (5, 6, 16, 17, 20) the relative position of 5 with 6, 6 with 20, 6 with 17, and 16 with 17 is 1, while the relative position of 5 with 20 and 5 with 17 is 2.

Next I apply the definition of the absolute position measure to the firms in the connected set. Among 1,418 firms in this set, 190 firms belong to the consumer discretionary sector and are defined as producers of final goods. However, 425 firms in the connected set do not belong to the supply chains that include any of the 190 firms. Therefore, I need to exclude these 425 firms from the sample because it is not possible to calculate the absolute position for these firms. In addition, among the 190 firms that belong to consumer discretionary sector there are 3 firms that do not have suppliers among the firms in the connected set. Therefore, I calculate the measures of absolute position for the final set of 990 firms. The graphical representation of the minimum measure appears in Figure 2 and of the median measure in Figure 3. In these graphs the vertical position of each firm is calculated according to the minimum and median measures.

For the 990 firms in the final set, the *minimum measure* of position ranges from 0 to 7, the average of the measure is 2.1, the median of the measure is 2, and standard deviation of the measure is 1.5. The *median measure* of position ranges from 0 to 11, the average of the measure is 4.7, the median of the measure is 5, and standard deviation of the measure is 2.6. The correlation between the minimum measure and the median measure is 77%.

In the further empirical analysis I use the relative measure of position for 190,493 pairs of firms.[18] The *relative position* measure for these pairs of firms ranges from 1 to 19, the average of the measure is 5.5, the median of the measure is 5, and standard deviation of the measure is 2.6. The histogram of the relative position measure appears in Figure 4.

In the next section I provide an intuition for the Kim and Shin (2012) model and derive structural equations from their optimal contract solution.

5 Derivation of the Structural Equations

Kim and Shin (2012) model a perfectly vertical supply chain, where each firm (i) in the chain supplies inputs to the next firm in the chain ($i-1$), and the firm at the bottom ($i=0$) of the chain produces the final good. Each firm in the chain can exert high or low effort in the production of its output. For example, we can interpret low effort as hiring a suboptimal number of employees by some firm in the supply chain

[18] These pairs include 748 firms out of 990 firms because only for these firms the proxy for the incentives could be constructed.

relative to the first best number of employees. The suboptimal hiring decision can result in production of low quality intermediary input that affects the quality of the final product. The optimal contract needs to align the incentives of individual firms with the objectives of the entire supply chain because firm's effort is not observed by the next firm in the chain.

In their model, firms have two channels with which to align incentives and ensure that high effort is exerted by all firms in the chain. The first channel is via the firm's profitability. If firms are more profitable they will have less incentives to shirk and threaten their stream of profits. The second channel is via a firm's trade credit contracts. The authors argue that firms may not pay their suppliers immediately such that they hold a stake in the success of the final good. If the final good fails then all the chain is liquidated, the inventory has no value outside the supply chain and the trade credit is not repaid.

The assumption of the model is that each firm in the perfectly vertical supply chain requires one unit of time to produce its output. The cost of low effort is lower for firms that are further from the producer of the final good because it takes longer for their effort level to affect the probability that the final product becomes obsolete.[19] On the other hand, the benefits of low effort are unrelated to the position of the firm in the supply chain. The combination of lower costs and similar benefits from low effort levels imply that firms at higher vertical position need to have more incentives.

I start the derivation of the empirical specifications from the solution to the optimal

[19] I do not use production times in my tests because they are hard to measure. Moreover, even if the time to produce was small, firms at higher vertical positions would still have lower costs of shirking because it is less likely that a cascade of failures triggered by a failure of the producer of a final good will reach these firms, or at least it will take more time.

contract provided in equation (13) of Kim and Shin (2012):

$$a_i p_i = a_{i+1} p_{i+1} + b_i w_i - (p_i - p_{i+1} - w_i) \quad (1)$$

In Eq.(1), $a_i p_i$ ($a_{i+1} p_{i+1}$) is referred to an outstanding balance of accounts receivable (payable) of firm i, p_i denotes revenues of firm i, p_{i+1} is the cost of inputs paid by firm i to its supplier firm $i+1$, and w_i is the cost of production of firm i (cost of goods sold excluding the cost of inputs). The interpretation of Eq.(1) is that net accounts receivable ($a_i p_i - a_{i+1} p_{i+1}$) and profits ($p_i - p_{i+1} - w_i$) need to be large enough to ensure that firm i prefers to exert the first best effort rather than to shirk and get a one period benefit of bw_i. The definition of b_i is given by equation (5) in their paper:

$$b_i = b \frac{\pi^H}{(\pi^L - \pi^H)(1 - \pi^H)^i} \quad (2)$$

In Eq.(2), $b > 0$ is the per-period private benefit (as a percent of a firm's net costs) that a firm enjoys if it exerts low effort. The private benefits parameter b is assumed to be common to all firms. If all firms in the supply chain exert high effort, then the probability that the chain is liquidated is π^H, if any of the firms exerts low effort then the probability is $\pi^L > \pi^H$.

In the model, the output produced by firm i is sold as part of the final product in i periods because each firm requires one period to produce its output and there are i firms down the chain (firms at positions: $i-1$, ..., 0). Under this assumption the incentive compatibility constrain of firm i should include a term that accounts for the fact that the costs of shirking (increase in probability of liquidation of the chain) occur i periods after the benefits of shirking (bw_i). This difference is embedded in the $(1 - \pi^H)^i$ term in Eq.(2) which is similar to the compounded discount rate with i the number of periods of compounding.

However, firms might realize the benefits of shirking not exactly at the end of the production cycle. Some firms can save costs prior to producing the output, others might be able to realize the benefit of shirking only after the output is produced. These deviations from the assumption of the model justify an introduction of an error term $\epsilon \sim N(0, \sigma^2)$. The error term captures deviations in the realization of bw_i relative to the end of the period. Under that specification, the cost of shirking is realized $i + \epsilon$ periods after the realization of the benefit of shirking. I assume a non-zero spatial correlation between adjacent firms in a supply chain because timing of realization of the benefit can be related to the type of transaction or technology employed by the two firms involved in a supplier-customer relationship.[20]

To derive testable empirical specifications from the optimal contract solution, I rearrange Eq.(1), and leave only the b_i term on the right hand side while substituting it in Eq.(2):

$$\frac{a_i p_i - a_{i+1} p_{i+1} + (p_i - p_{i+1} - w_i)}{w_i} = b \frac{\pi^H}{(\pi^L - \pi^H)(1 - \pi^H)^{i+\epsilon}} \tag{3}$$

Equation (3) relates the normalized incentives of each firm to its absolute position in the supply chain. The normalized level of incentives are composed of profits and net receivables (accounts receivable - accounts payable) divided by net cost of production.

[20] The results are the same if I cluster firms by industry. See discussion in section 6.2.

To make the equation linear in i, I take logs of both sides of Eq.(3:

$$log(\frac{a_i p_i - a_{i+1}p_{i+1} + (p_i - p_{i+1} - w_i)}{w_i}) = log(\frac{b\pi^H}{\pi^L - \pi^H}) - log(1-\pi^H)i - log(1-\pi^H)\epsilon \tag{4}$$

Next I derive a structural equation that relates the relative levels of incentives and the relative position between any pair of firms. There is a number of benefits of the pair-wise specification. First, it increases the power of the tests as it uses much more information available in the structure of supplier-customer relationships. Second, the pair-wise approach overcomes the difficulties to measure the absolute position of a firm when each firm is involved in several supply chains. Third, it allows to estimate the model for any subset of firms that are connected with supplier-customer relationships and does not require to define producers of final goods. Last but not least, the firm-level regression captures two types of variation in the incentive levels. There is a "within" the supply chain variation that suggests that firms at higher vertical positions need to have more incentives and there is a "between" the supply chains variation that suggests that more incentives are required to make longer supply chains feasible[21]. The implied probability of obsolescence from the firm-level regression can be overstated because of the second type of variation in the incentive levels. For example, a firm with an absolute position of 2 can have smaller incentives than firm at position 5 either because it belongs to the same supply chain or because it belongs to the different supply chain of length 2 which is shorter and therefore requires less incentives to keep it feasible. The pair-wise regression focuses on the "within" variation in the incentive levels because it uses pairs of firms that belong to the same supply chain.

[21]For a given profitability of the final good the first-best effort can be implemented only for a limited length of the supply chain. The usage of trade credit relaxes the IC constrain and allows to implement the optimal effort for a longer supply chain.

To derive the implication for the relative position, consider two firms: firm i and firm $i+j$ such that $j>0$, that belong to the perfectly vertical supply chain described in the model. The parameter j defines the relative position between the two firms. Equation(4) is an equilibrium condition that should hold for firm i and for firm $i+j$. I create a difference equation where I subtract the Eq.(4) for firm i from that for firm $i+j$:

$$log(L_{i+j}) - log(L_i) = -log(1-\pi^H)j - log(1-\pi^H)(\epsilon_{i+j} - \epsilon_i) \tag{5}$$

where $L_k = \frac{a_k p_k - a_{k+1} p_{k+1} + (p_k - p_{k+1} - w_k)}{w_k}$.

The interpretation of Eq.(5) is that in the perfectly vertical supply chain the difference in the levels of normalized incentives should on average only depend on the relative position of the firms in the chain (j) and the probability that the final product will become obsolete (π^H).

For each of the derived specifications I construct the empirical counterpart that I estimate. In Eq.(6) I define the empirical specification based on the Eq.(4):

$$log(\frac{NetRec_j + EBITDA_j}{NetCost_j}) = \alpha + \beta Position_j + \eta_j \tag{6}$$

Similarly, based on the Eq.(5) I define the following empirical specification for all pairs of firms that belong to the same supply chain:

$$D_k = \alpha + \beta RelativePosition_k + \zeta_k \tag{7}$$

where $D = log(\frac{NetRec_{i+j} + EBITDA_{i+j}}{NetCost_{i+j}}) - log(\frac{NetRec_i + EBITDA_i}{NetCost_i})$.

The table below provides the mapping between the theoretical parameters and the empirical proxies used in Eq.(6) and Eq.(7).

Variable	Full Name	Short Name
$a_i p_i$	Accounts Receivable per period	Rec
$a_{i+1} p_{i+1}$	Accounts Payable per period	Pay
$a_i p_i - a_{i+1} p_{i+1}$	Net Accounts Receivable	NetRec
w_i	Cost of Goods Sold minus Cost of Inputs	NetCost
$p_i - p_{i+1} - w_i$	Revenues - Cost	EBITDA
i	Absolute vertical position	Position
j	Relative vertical position	RelativePosition
$log(\frac{b\pi^H}{\pi^L - \pi^H})$	Constant term in Eq.(6)	α
$-log(1-\pi^H)$	The slope in Eq.(6) and Eq.(7)	β
$-log(1-\pi^H)\epsilon$	The error term in Eq.(6)	η
$-log(1-\pi^H)(\epsilon_{i+j} - \epsilon_i)$	The error term in Eq.(7)	ζ

I use the minimum and median measures of position as proxies for the $Position$ and the relative position measure as a proxy for the $RelativePosition$.

The $NetCost$ parameter refers to the cost of production excluding the cost of inputs. It is hard to measure what fraction of cost of goods sold (COGS) arises from the firm's activity as opposed to the inputs bought from suppliers, because this information is not available from financial reports. I use cost of goods sold (COGS) as a proxy for $NetCost$. Moreover, in many cases, the customer firm is unable to observe the quality of inputs used by its supplier. Therefore, when firms can choose between several suppliers, they can save costs of production by purchasing less expensive inputs with lower quality. As a result, the use of cost of goods sold (COGS) which includes the cost of inputs can be a more reasonable proxy for $NetCosts$. For robustness check, I use number of employees as a proxy for $NetCost$ assuming that using a suboptimal number of employees can be one of the ways for firms to shirk[22].

By estimating Eq.(6), we can use the estimate of beta to derive estimates of π^H in the following way: $\widehat{\pi^H} = 1 - exp(-\widehat{\beta})$. Using the delta method we can also derive the standard error of the estimate of π^H which is equal to $exp(-\widehat{\beta}) * se(\widehat{\beta})$. The other two parameters b and π^L are included in the intercept α and can not be identified separately.

The spatial correlation structure of the errors in Eq(6) and in Eq(7) is important for the inference. For the specification in Eq.(6), I assume that error terms of two firms are non-independent whenever these firms are adjacent in the supply chain (one firm supplies to the other firm). An alternative assumption that I use in the robustness checks is that all firms that belong to the same industry have non-independent error terms[23]. For the specification in Eq.(7) where the unit of observation is a pair of firms, I assume that error terms of two pairs are non-independent whenever the two pairs of firms share a common firm.

The empirical specification in Eq.(6) includes an error term that is not part of the model. This error term is independent of the measures of the vertical position. For example, this error term can capture shocks to net receivables due to liquidity shocks.

I the next section, I estimate Eq.(6) and Eq.(7) and test whether the implied estimate of π^H is positive, and whether the intercept in specification Eq.(7) is indistin-

[22] Ideally I would use cost of labor but it is unavailable in Capital IQ.

[23] There are 22 industries defined at the six digits GIC code level.

guishable from zero. In addition, I try to assess how reasonable the implied probability of obsolescence that I estimate.

6 Estimation Results

Table 4 presents the results from the estimation of Eq.(6). In specifications (1) and (2), the dependent variable is the log of the sum of EBITDA and net receivables divided by the cost of goods sold or the number of employees respectively. The slope in these specifications, $\beta = -log(1 - \pi^H)$, is expected to be positive.

We can learn from the results of the estimation that both the minimum and median measures of position have coefficients that are positive and statistically different from zero.[24] The results of the estimation suggest that among firms with positive incentive levels[25], there is a positive relationship between the measures of position and the measure of normalized incentives. The result is consistent with the derived predictions.

The estimation results for the pair-wise specification Eq(7) are reported in Table 5. The first specification uses all pairs of firms that belong to the same production chain. The second specification excludes duplications when one firm is a direct or indirect supplier to another firm in one observation and the opposite is true in another observation. It happens because there are loops in production chains composed of supplier-customer relationships. I assume that the true production chain is the one where the distance

[24] In unreported results I used average distance and maximum distance as alternative proxies for the vertical position of each firm in a production chain. For both proxies the slope in all six specifications is positive and statistically different from zero.

[25] Eq.(6) can not be estimated for observations with negative incentive levels because the theoretical model is developed under the assumption of stationarity. Specifically, the model assumes that given that the supply chain is not liquidated, each period is identical. This condition limits the sample to firms with positive values for the sum of EBITDA and net receivables.

between the two firms is the shortest. In the third specification I further exclude all pairs that have loops, potentially eliminating relationships along the true production chains. The results in all three specifications show that the coefficient on the relative position measure is positive and statistically significant. The results of the estimation suggest that there is a positive relationship between the relative measure of the normalized incentives and the relative position measure[26]. In addition, the constant in this regression is positive but statistically indistinguishable from 0. The pair-wise regression has more power to reject the model relative to the firm-level regression because there are thousands of observations and because of the additional empirical prediction about the intercept. In addition, while the firm-level regression imposes the same intercept for all firms, effectively assuming the same moral hazard problem for all production chains, the pair-wise regression does not require this assumption, it allows us to test whether the moral hazard problem is the same for firms that belong to the same production chain as it is suggested by the recursive moral hazard model. The statistical significance of the slope in the pair-wise regression is higher in the second specification, suggesting that accounting for the "loops" improves the fit of the model. The results in the third specification suggest that by eliminating both observations that constitute a loop and not only the one with the highest distance as in the second specification we eliminate true production chains and decrease the fit of the model. Overall, the estimation results provide a strong evidence in favor of the model.

The model suggests that both profits and net receivables play a role of incentives. It is important to understand whether trade credit in particular plays any role as an incentive device. I estimate specifications (3) and (4) in Table 4 which include only trade credit as incentives device. The coefficients on the absolute position (both the

[26]In this specification the measure of normalized incentives is the log of the sum of profits and net receivables divided by COGS.

minimum measure and the median measure) for both specifications are positive and statistically significant at the 1% level. I also exclude net receivables from equation (6) and estimate it using only measures of EBITDA. The results of this estimation are reported in specifications (5) and (6) of Table 4. The coefficients on the absolute position (both the minimum measure and the median measure) for both specifications are positive and statistically significant at the 1% level. The results suggest that not only is the total amount of incentives is positively related to the vertical position but also, that each one of the incentives is separately related (positively) to the absolute position as well. This result supports the hypothesis that trade credit is used as an incentives device in the supply chains.

6.1 Quantitative Assessment of the Model

The structural approach allows not only to test the model qualitatively but also to assess whether the implied estimates are reasonable. The goal of the quantitative assessment is to understand whether the estimation provides the right order of magnitude for the parameters of the model. It is not reasonable to expect more than that because the model is very stylized. It abstracts on purpose from additional forces that affect the probability of firm's liquidation, such as competition, demand volatility, leverage, inventory and more. Nevertheless, the quantitative assessment implies slightly high, but reasonable, implied rate of return on assets for an average firm in the same. To present this result, first, I will argue that quantitative estimates of the pair-wise regression are more appropriate relative to the firm-level regression. Second, I will calculate the implied probability of obsolescence. Then I will present a way to translate this probability into a discount rate. Finally, I will proxy for the length of the average transaction period and will translate the implied discount rate into an annual expected rate of return on assets.

The firm-level regression captures two types of variation in the incentive levels. There is a "within" the supply chain variation that suggests that firms at higher vertical positions need to have more incentives and there is a "between" the supply chains variation that suggests that more incentives are required to make longer supply chains feasible[27]. The implied probability of obsolescence from the firm-level regression can be overstated because of the second type of variation in the incentive levels. For example, a firm with an absolute position of 2 can have smaller incentives than firm at position 5 either because it belongs to the same supply chain or because it belongs to the different supply chain of length 2 which is shorter and therefore requires less incentives to keep it feasible. Therefore, positive estimated β in the firm-level regression is an evidence in favor of the model[28] but it can not be used for the quantitative assessment of the model. The pair-wise regression focuses on the "within" variation in the incentive levels because it uses pairs of firms that belong to the same supply chain.

Based on the estimate of β, the implied estimate of π^H in the pair-wise regression is 4% (std. error 1.8%). In order to get some intuition for the value of π^H, we need to understand its role in the theoretical model. The present value calculation in the model multiplies the cash flow received at time t by $(1-\pi^H)^t$ which is the probability that the final good is not liquidated after t periods. Therefore, this parameter ensures that even when all firms in the supply chain exert high effort, their cash flow is still uncertain. We can also define a discount rate r such that the cash flow received on

[27]For a given profitability of the final good the first-best effort can be implemented only for a limited length of the supply chain. The usage of trade credit relaxes the incentive compatibility (IC) constrain and allows implementation of the optimal effort for a longer supply chain.

[28]Both "within" and "between" variations in incentives are a direct implication of the model that are not predicted by other models.

date t is multiplied by $(\frac{1}{1+r})^t$ when computing its present value. There is a positive relationship between the level of π^H and the level of r. In the model, the probability of obsolescence increases from π^H to π^L when one of the firms in the supply chain shirks. Therefore, the interpretation of low effort by any of the firms in the supply chain is equivalent to increasing the expected return on assets. We can use a simple formula to define the discount rate consistent with the probability of obsolescence described in the model: $r = \frac{\pi^H}{1-\pi^H}$. Using the delta method, we can derive the standard error for the discount rate estimate as $se(\widehat{r}) = exp(\beta) * se(\widehat{\beta})$.

Based on the estimate of β, the implied estimate of π^H in the pair-wise regression is 5.45% ($\pi^H = 1 - exp(-\beta)$).[29] In order to get some intuition for the value of π^H, we need to understand its role in the theoretical model. The present value calculation in the model multiplies the cash flow received at time t by $(1 - \pi^H)^t$ which is the probability that the final good is not liquidated after t periods. Therefore, this parameter ensures that even when all firms in the supply chain exert high effort, their cash flow is still uncertain. We can also define a discount rate r such that the cash flow received on date t is multiplied by $(\frac{1}{1+r})^t$ when computing its present value. There is a positive relationship between the level of π^H and the level of r. In the model, the probability of obsolescence increases from π^H to π^L when one of the firms in the supply chain shirks. Therefore, the interpretation of low effort by any of the firms in the supply chain is equivalent to increasing the expected return on assets. We can use a simple formula to define the discount rate consistent with the probability of obsolescence described in the model: $r = \frac{\pi^H}{1-\pi^H}$. Using the delta method, we can derive the standard error for the discount rate estimate as $se(\widehat{r}) = exp(\beta) * se(\widehat{\beta})$.

[29] I use the estimate of beta (0.056) from the second specification in Table 5 because it adjusts for loops in the production chains.

The implied estimate of the expected rate of return on assets from the pair-wise regression is 5.76% (std. error 1.84%). However, we need to know what the relevant time period is for the discount rate. The model assumes that it takes one unit of time for each firm to deliver its output to the next firm in the chain. It also takes the same unit of time for the firm to repay its current payable balance. The probability of obsolescence in the model is defined over the same period of time and consequently the discount rate refers to this period as well.

There are two potential ways to back out the average transaction period in the sample. First, we can use the information about inventory levels. In the sample, the average number of days it takes for the firm to sell its inventory is around 100 days (inventory/cost of goods sold * 365). Second, we can use information on the average turnover rate of trade credit. Based on the average ratio of receivables to total revenues (16.5%) for firms in the sample, the average number of days receivables is approximately 60 days (receivables / total revenues * 365)[30].

Using the estimates of the transaction period (60-100 days), the 5.76% interest rate for the transaction period implies an annual discount rate of 23-41%[31]. This estimate is within two-standard deviations from a reasonable number for the average expected return on assets for a large sample of firms. Klapper, Laeven, and Rajan (2012) document average effective interest rate of 54% on trade credit. Compared to their result, the quantitative estimates are not high. The model uses a number of assumptions that could potentially affect the estimated parameter. For example, it assumes no liquidation value for the inventory, no growth rate or capital expenditures. Also the use of EBITDA as a proxy for profits and COGS as a proxy for production costs could affect

[30] This estimate may be downward biased because I use receivables after allowances for bad debt.

[31] $(1 + r_t)^{365/t}$ where t is the number of days. The standard error of the annual estimate is 8-15%.

the estimate. It is also not possible to evaluate the estimate too rigorously because the transaction period range (60-100 days) is not estimated from the model. Given all this considerations, I believe that the estimation results in a plausible quantitative estimate of the parameter in the model.

6.2 Robustness Checks and Extensions

While the recursive moral hazard model for trade credit is not rejected based on the structural estimation results, it is important to rule out alternative explanations for the positive relationship between the incentive measures and the vertical position. In this section I test alternative explanations.

One alternative explanation is that firms at the top of the production chains have higher net trade credit mechanically. They provide trade credit but do not receive trade credit because they do not have suppliers. This alternative explanation does not explain why profit margins are also higher for firms at the top of the chains. That might be the case if competition is weaker at the top of the chains. I test this alternative explanation by including log number of suppliers and other controls in the regression of incentives on the vertical position. Table 6 reports the results in column 3. The number of suppliers is not significant in this regression, but the vertical position is still significant at 10% level. In addition, I run the basic specification for a all layers of production besides top two layers. The monotonic relationship between incentives and vertical position holds even when top layers of production are excluded.[32]. The claim that the positive relationship between the profit margins and vertical position are driven purely by the variation in the competition levels across different vertical

[32]Results are available upon request.

positions (less competition in the top than in the bottom of the institutional structure of production) is addressed in Table 6 column 2. In this specification, I include the number of competitors of each firm as a proxy for competition.[33] The coefficient on the vertical position is positive and statistically significant. The coefficient on the log number of competitors is negative and statistically significant. It means that while the proxy for competition is valid, the results are not driven by the variation in the competition across different layers of production.

Another alternative explanation is that the results are driven by the bottom layer in a production chain. Firms that produce final goods might operate at high volume and low margins like Walmart and they do not provide trade credit to retail investors. I exclude firms with absolute measure of 0 in the robustness test regression presented in Table 7 specifications (1) and (2). The positive relationship between the measures of total normalized incentives and the measures of absolute position holds in the subsample of firms that excludes firms in the consumer discretionary sector. Moreover, the specification in Table 6 column 3 suggests that the positive relationship holds even after controlling for the number of customers of each firm. It captures the idea that firms at the lower layers might have less corporate customers and therefore have smaller net receivables.

Moreover, even without the robustness checks reported above we can know that the result is not driven by any particular layer of production or proxy for the absolute vertical position, because of the strong evidence in the pair-wise regression. The pair-wise regression compares relative levels of incentives for more than 190,000 pairs of firms. Any alternative explanation should not only explain why the absolute vertical position

[33] The number of competitors is reported by Capital IQ.

is positively related to the incentive levels, but also explain when the relative vertical position matters for the difference in profit margins and net trade credit between firms that belong to the same production chain. The alternative theory should not only explain why the slope is positive and statistically significant in the pair-wise regression, but also why the intercept is zero. Both of these results are predicted by the recursive moral hazard theory.

A less formal explanation of trade credit is that it is an industry standard to provide trade credit of a given length. According to this explanation, firms provide trade credit because their competitors do. If a firm stops providing trade credit, it will lose customers. This explanation does not explain though why there is a variation in trade credit terms across industries. The recursive moral hazard theory predicts that vertical position matters for incentives, but if industry is a proxy for the vertical position then we should not see any statistically significant relationship between the vertical positions and incentives. That is indeed the case. In Table 6, column 4, the regression includes industry dummies in addition to other controls. The positive relationship between incentives and vertical position within industries is small and not statistically significant. It means that industries are imperfect proxies for the vertical position. Antràs, Chor, Fally, and Hillberry (2012) construct a measure of vertical position for more than 400 industries in the US. The average vertical position in their sample is 2.1 (min 1, max 4.65). They assign the first layer to have a vertical position of 1, so to compare to my measures we need to subtract one from their measure because my measure starts with layer 0. If the vertical position ranges from 0 to 3.65, most of the industries should include one or two layers of production, otherwise the firm-level vertical position cannot have an average of 2.1 and a maximum of 7. Therefore, I conclude that the reason that the vertical position is not statistically significant in the regression with industry dummies, is because industries represent vertical position as well.

Another concern is about the proxies used in the empirical tests of the model. Specifically, I am concerned whether the results are sensitive to the profitability measure used in the main specification. To ensure that this is not the case, I use Earnings Before Interest and Taxes (EBIT) and Net Income (NI) as two alternative proxies for profits in the estimation of Eq(6). The estimates of β regressions are positive and statistically significant as predicted by the model (Table 7 specifications (3)-(6)), meaning that the results are robust for the choice of profitability measures and are not driven by depreciation, interest expenses or taxes.

The statistical significance of the results depends on the way observations are clustered in the regressions. It is especially true for the spacial regressions used in this paper because accounts payable of the customers are accounts receivable of the suppliers. In calculating standard errors of the coefficients reported in Table 4, I assume that two observations have non independent error terms if they correspond to firms that are involved in supplier-customer relationship (one firm is a direct supplier to another firm). Potentially there may be industry level shocks to the firms in the sample. As a robustness check, I cluster firms by industry. All estimates of β in specifications of Table 4 are statistically significant at least at the 5% level, except for the estimate of β in specification (3) that is significant at the 10% level.

7 Conclusion

In this paper I test theories of trade credit. I find that simple summary statistics and cross-sectional tests suggest that trade credit cannot be explained by theories that assume a two-layers market structure with financially strong suppliers and financially constrained customers. Instead I find that production chains are complex and to understand why firms use and provide trade credit we need to account for the market structure. From a number of theories considered, the recursive moral hazard theory of trade credit by Kim and Shin (2012) was consistent with the reduced-form regressions and required further investigation by estimating it using a structural approach. To test this theory one needs to observe not only direct relationships between suppliers and customers but to construct the entire structure of the production chains. I use a novel database to identify supplier-customer relationships and develop a methodology to measure vertical and relative position for a large sample of firms. I use the measures of position to estimate two structural equations derived from the optimal contract solution proposed by the theoretical model.

I document several results that support the model. First, there is a positive relationship between the vertical position of the firm and the measures of incentives that it has. Second, there is a positive relationship between the relative position of a pair of firms in the supply chain and the difference in their incentives. Third, I use the pair-wise regression to test for the intercept which according to the structural equation should be indistinguishable from zero. The estimation results don't allow me to reject the model based on this test.

Any alternative theory that attempts to explain the empirical results presented in this paper should both explain the strong positive relationship between the vertical position and profit margins, as well as net receivables. It should also explain a strong positive correlation between receivables and payables. Finally, it should explain why the relative position between any two firms in a supply chain is positively related to the difference in profitability and net receivables, and why the intercept is zero in this regression. While it is possible to consider alternatives explanations for some of the results, such as the maturity matching hypothesis, it is difficult to think about one alternative theory that explains them all. I conducted a range of robustness tests to verify that the results are not driven by specific measures of profitability, any particular layer of production, and are robust with respect to different measures of an absolute vertical position.

Besides empirical tests of trade credit theories, the paper provides the first evidence about the structure of production chains in a large sample of US economy. It develops an algorithm to compute vertical position of firms in the economy. This methodology can be applied even when we observe existence of a supplier-customer relationship but don't know the strength of the relationship.[34] I find that in the sample of 990 firms we can observe between 7 and 11 layers of production. Ability to measure vertical position of individual firms in the economy allows us to test existing theoretical models as well as inspires new theoretical models that utilize empirical facts about the institutional structure of production presented in this paper.

[34] Antràs, Chor, Fally, and Hillberry (2012) use input-output tables to construct a measure of upstreamness of different industries but not individual firms.

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Table 1: Summary Statistics for the Whole Sample

Variable	**Mean**	**Median**	**Min**	**Max**	**Std. dev.**	**Obs.**
Total Assets ($mm) [TA]	2,313	191	0.0005	279,264	12,063	2,430
Total Revenue ($mm) [TR]	2,240	160	0.0002	361,706	13,337	2,394
Num Employees	4,925	563	1	386,558	16,946	2,142
Age	36.7	24	1	234	35.7	2,461
Receivables / TA	15.5%	12.9%	0.1%	61.4%	12.7%	2,372
Payables / TA	10.9%	7.7%	0.3%	64.9%	11.0%	2,382
Receivables / TR	16.5%	14.9%	0.6%	64.3%	10.3%	2,332
Payables / TR	12.6%	8.4%	0.7%	79.7%	13.5%	2,252
Net Rec / TA	4.6%	4.3%	-46.1%	40.4%	12.1%	2,337
Total Debt /TA	23.1%	18.4%	0.0%	87.0%	22.4%	2,291
Bank Debt / TA	15.7%	10.1%	0.0%	78.1%	17.0%	1,527
ST. Debt / TA	10.7%	3.5%	0.0%	83.8%	16.9%	865
Revolving Credit / TA	9.3%	5.0%	0.0%	53.9%	11.6%	1,164
Und. Rev. Cred. / TA	14.5%	10.7%	0.0%	129.4%	17.1%	1,456
EBITDA / TR	9.1%	10.0%	-81.0%	74.7%	24.3%	2,089
EBIT / TR	3.0%	6.2%	-82.7%	54.9%	22.2%	2,078
Net Income / TR	-0.5%	3.3%	-88.2%	53.8%	22.3%	2,047

This table presents summary statistics for the whole sample of firms. Financial data is for Fiscal Year 2007. Age of companies is defined as a difference between 2008 and year of foundation. 'TR' stands for Total Revenue. 'TA' stands for Total Assets. 'Und. Rev. Cred.' is Undrawn Revolving Credit. EBIT is earnings before interest and taxes. EBITDA is earnings before interest, taxes, amortization and depreciation. Source of the data: Capital IQ.

Table 2: Trade Credit Summary

	Mean Rec / TA	Median Rec / TA	Obs.	Mean Pay / TA	Median Pay / TA	Obs.
Company Type:						
Private	0.155	0.120	273	0.095	0.074	272
Public	0.155	0.130	2,099	0.111	0.078	2,110
Public Debt Dummy						
No Public Debt	0.184	0.163	285	0.115	0.084	284
Public Debt	0.162	0.141	1,213	0.117	0.088	1,207
1 if Undrawn Revolving Credit to TA <= median (10.7%), 0 otherwise						
0	0.178	0.163	706	0.103	0.083	706
1	0.157	0.134	725	0.100	0.077	726
Headquarters:						
Non-US	0.178	0.154	113	0.120	0.097	113
US	0.154	0.128	2,259	0.109	0.076	2,269
Company Status:						
Subsidiery	0.150	0.120	201	0.095	0.072	204
Independent	0.155	0.130	2,171	0.111	0.077	2,178
Num. Employees						
less or equal 500	0.144	0.102	998	0.121	0.078	1,002
more than 500	0.166	0.148	1,101	0.096	0.076	1,105
1 if Total Assets above median (191 $mm), 0 otherwise						
0	0.163	0.129	1,161	0.129	0.087	1,168
1	0.147	0.130	1,211	0.090	0.071	1,214
Primary Sector						
Consumer Discretionary	0.171	0.164	351	0.123	0.095	351
Energy	0.092	0.054	485	0.086	0.053	495
Industrials	0.198	0.179	486	0.123	0.095	485
Information Technology	0.169	0.139	707	0.111	0.069	700
Materials	0.134	0.127	343	0.105	0.082	351
Whole Sample	0.155	0.129	2,372	0.109	0.077	2,382

This table presents average and median levels of accounts receivable and accounts payable to total assets ('Rec / TA' and 'Pay / TA' respectively) for different subsamples and for the whole sample. Source: Capital IQ, Fiscal Year 2007.

Table 3: Joint Determination of Receivables and Payables

VARIABLES	Receivables / Total Revenues (1)	(2)	(3)	(4)
Payables / Total Revenue		0.409***		0.369***
		(0.049)		(0.062)
Log TotalAssets (TA)	-0.000	-0.002	-0.001	-0.002
	(0.001)	(0.001)	(0.001)	(0.002)
Log_Age	-0.001	0.001	0.002	0.003
	(0.003)	(0.003)	(0.003)	(0.003)
US_Dummy	-0.027	-0.014	-0.019	-0.004
	(0.020)	(0.019)	(0.019)	(0.018)
Operating_Dummy	-0.008	-0.009	-0.012	-0.016**
	(0.008)	(0.006)	(0.009)	(0.006)
Public_Dummy	0.019***	0.015***	0.020***	0.015**
	(0.004)	(0.005)	(0.006)	(0.006)
EBITDA / Total Revenues	0.008	0.051***	0.028	0.065***
	(0.015)	(0.018)	(0.016)	(0.017)
Inventory / Total Revenues	0.016	0.025	0.013	0.021
	(0.033)	(0.029)	(0.033)	(0.031)
Total Debt / Total Assets	-0.016	-0.021	-0.033	-0.035*
	(0.017)	(0.016)	(0.019)	(0.019)
Undrawn Revolving Credit / TA	0.001	0.013	-0.030**	-0.009
	(0.015)	(0.010)	(0.014)	(0.011)
Revolving Credit / TA			0.048*	0.045*
			(0.025)	(0.026)
Industry Dummies	Yes	Yes	Yes	Yes
Observations	1162	1162	783	783
Adjusted R^2	0.185	0.308	0.215	0.322

*** p<0.01, ** p<0.05, * p<0.1

The dependent variable is accounts receivable to total revenues (TR). The coefficients are estimated using ordinary least squares. Each regression has a constant and industry dummies whose coefficients is not reported. Standard errors are White-corrected for heteroscedasticity and clustered at the industry level (22 clusters). All financial ratios in the regressions were winsorized at 1% and 99% levels. Financial data is for Fiscal Year 2007. Log_Age is a natural logarithm of firm's age defined as a difference between year 2008 and year of firm's foundation, Operating_Dummy gets a value of 0 if the company is a subsidiary, US_Dummy gets value of 1 if the company is incorporated in US, Public_Dummy gets a value of 1 if the company is publicly traded. Source of the data: Capital IQ.

Table 4: Estimation of Eq.(6)

$log(\frac{NetRec_j+EBITDA_j}{COGS_j}) = \alpha + \beta Position_j + \epsilon_j$	(1)	(2)	(3)	(4)	(5)	(6)
Minimum Distance Measure of Absolute Position						
beta	0.247	0.328	0.111	0.202	0.302	0.379
t-stat	7.42	6.76	3.39	5.70	7.24	7.02
alpha	-1.74	-3.47	-2.40	-4.27	-2.26	-3.96
t-stat	-25.46	-49.09	-34.48	-55.20	-30.15	-55.93
Observations	748	703	719	685	717	672
R^2	0.110	0.168	0.021	0.066	0.142	0.182
Median Distance Measure of Absolute Position						
beta	0.132	0.182	0.060	0.102	0.170	0.217
t-stat	7.01	6.66	2.98	4.87	7.69	7.11
alpha	-1.85	-3.65	-2.46	-4.34	-2.44	-4.20
t-stat	-18.97	-33.48	-24.57	-40.98	-24.63	-39.94
Observations	748	703	719	685	717	672
R^2	0.093	0.154	0.018	0.051	0.132	0.178

This table presents estimation with OLS of six specifications:

(1): $log(\frac{NetRec_j+EBITDA_j}{COGS_j}) = \alpha + \beta Position_j + \epsilon_j$

(2): $log(\frac{NetRec_j+EBITDA_j}{Num.Emp._j}) = \alpha + \beta Position_j + \epsilon_j$

(3): $log(\frac{NetRec_j}{COGS_j}) = \alpha + \beta Position_j + \epsilon_j$

(4): $log(\frac{NetRec_j}{Num.Emp._j}) = \alpha + \beta Position_j + \epsilon_j$

(5): $log(\frac{EBITDA_j}{COGS_j}) = \alpha + \beta Position_j + \epsilon_j$

(6): $log(\frac{EBITDA_j}{Num.Emp._j}) = \alpha + \beta Position_j + \epsilon_j$

Standard errors are White-corrected for heteroscedasticity and residuals are assumed to be non-independent for any two firms that are involved in supplier-customer relationship. 'NetRec' is accounts receivable minus accounts payable, EBITDA is earnings before interest, taxes, depreciation and amortization, COGS is cost of goods sold, Num. Emp. is number of employees, Position measure is calculated according to minimum or median measures of the absolute position defined in Section 4.1.

Table 5: Estimation of Eq.(7): Pair-wise Regression

$$D_k = \alpha + \beta RelativePosition_k + \zeta_k$$

	(1)	(2)	(3)
beta	0.041**	0.056***	0.049***
t-stat	2.158	3.135	2.43
alpha	0.043	0.056	0.165
t-stat	0.377	0.455	1.105
Observations	190,493	144,349	112,885
R^2	0.004	0.008	0.006

*** p<0.01, ** p<0.05, * p<0.1

This table presents estimation of equation (7) using OLS. The left hand side variable is log of net receivables (accounts receivable minus accounts payable) plus earnings before interest, taxes, depreciation and amortization (EBITDA) to cost of goods sold (COGS) of firm $i + j$ minus the same variable for firm i. The right hand side variable is j which is the relative position between the two firms. If firm a supplies to firm b then the relative position between them is 1. If firm a supplies to firm b and firm b supplies to firm c then the relative position between firm a and the firm c is 2. Specification (1) is for all pairs of firms that belong to the same production chain. Specification (2) eliminates possible "loop": if both A is a supplier to B and B is a supplier to A then I use this pair of firms only once where I assume that the shortest distance between the two firms is the relevant production chain and the reverse relationship is noise (I exclude pairs if the distance from A to B is the same as from B to A.) Specification (3) excludes all observations with "loops": A is a direct or indirect supplier to B, but B is not direct or indirect supplier to A. Standard errors are White-corrected for heteroscedasticity. Residuals are assumed to be non-independent between two observations that share the same firm. Specifically, when one observation is difference between firms a and b and another observation is a difference between firms a and c or b and c then these two observations share firm a or firm b and therefore are assumed to be non-independent.

Table 6: Firm-level Regression with Controls

Dependent Variable:	$log(\frac{NetRec_i+EBITDA_i}{COGS_i})$			
	(1)	(2)	(3)	(4)
Minimum Measure of Position	0.127**	0.136***	0.079*	0.015
	(0.052)	(0.038)	(0.039)	(0.070)
Inventory / Total Assets[TA]	-3.002***		-1.190	-1.129
	(0.721)		(0.700)	(0.779)
Sales / TA		-0.862***	-0.772***	-0.764***
		(0.114)	(0.166)	(0.199)
Log(Competitors +1)		-0.131***	-0.105**	-0.096*
		(0.039)	(0.047)	(0.050)
Log(Customers +1)			-0.069	-0.054
			(0.066)	(0.053)
Log(Suppliers +1)			-0.044	0.002
			(0.063)	(0.062)
Log(Total Assets)			0.031	0.018
			(0.039)	(0.044)
Total Debt / TA			-0.824***	-0.859***
			(0.126)	(0.165)
Constant	-1.173***	-0.297	-0.163	-0.235
	(0.146)	(0.203)	(0.287)	(0.275)
Industry Dummies	No	No	No	Yes
Observations	689	748	684	684
Adjusted R^2	0.162	0.313	0.325	0.348

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

The coefficients are estimated using ordinary least squares. Standard errors are White-corrected for heteroscedasticity and clustered at the industry level (22 clusters). All financial ratios in the regressions were winsorized at 1% and 99% levels. Financial data is for Fiscal Year 2007. Data source: Capital IQ.

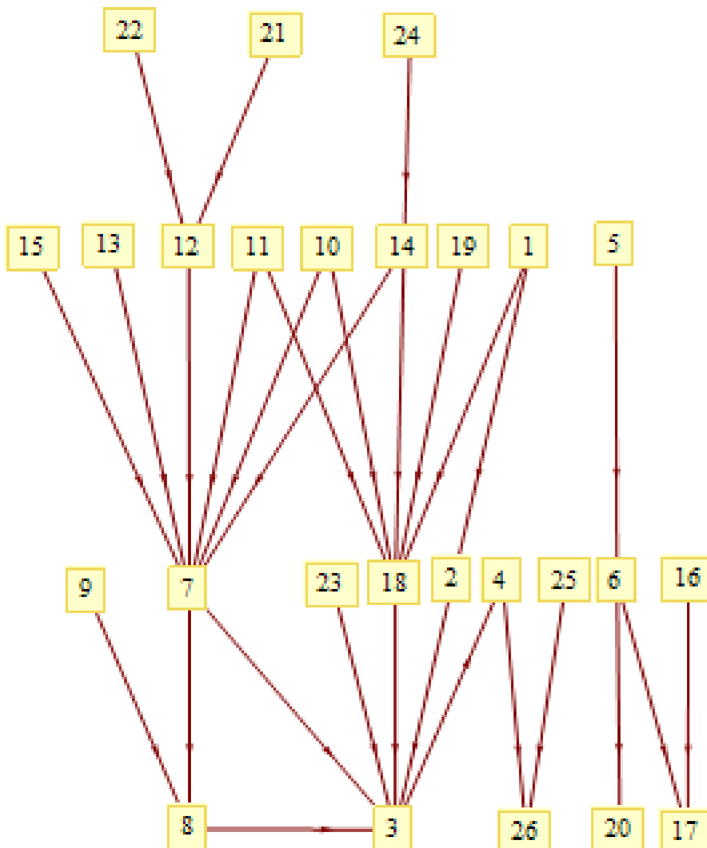
Table 7: Estimation of Equation (6): Robustness Tests

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Minimum Measure	0.232**		0.212***		0.206***	
	(0.106)		(0.058)		(0.036)	
Median Measure		0.142***		0.114***		0.108***
		(0.045)		(0.034)		(0.026)
Constant	-1.687***	-1.910***	-1.916***	-2.015***	-2.009***	-2.089***
	(0.221)	(0.202)	(0.138)	(0.162)	(0.138)	(0.162)
Observations	597	671	699	699	657	657
R^2	0.068	0.078	0.078	0.066	0.075	0.060

*** p<0.01, ** p<0.05, * p<0.1

This table presents estimation of equation (6) using OLS. Each specification uses a different proxy for the absolute position of a firm in a supply chain. Standard errors are White-corrected for heteroscedasticity and clusters at the industry level. In specifications (1) and (2), the left hand side variable is log of net receivables plus EBITDA to COGS. Firms with measures of absolute position equal to 0 are excluded from the sample.
In specifications (3) and (4), the left hand side variable is log of net receivables plus EBIT to COGS. In specifications (5) and (6), the left hand side variable is log of net receivables plus Net Income to COGS.

Figure 1: An Example of the Industrial Structure of Firms



The graph illustrates an example of the structure of supply chains composed of 26 firms. Firms at the bottom of the graph belong to the consumer electronics industry. Each firm appears as a node on the graph. Arrows start from the supplier and point to the customer. The vertical position of each firm is according to the minimum measure of absolute position. The horizontal position has no meaning.

Figure 2: Industrial Structure of Firms in the Sample: Minimum Measure of Position

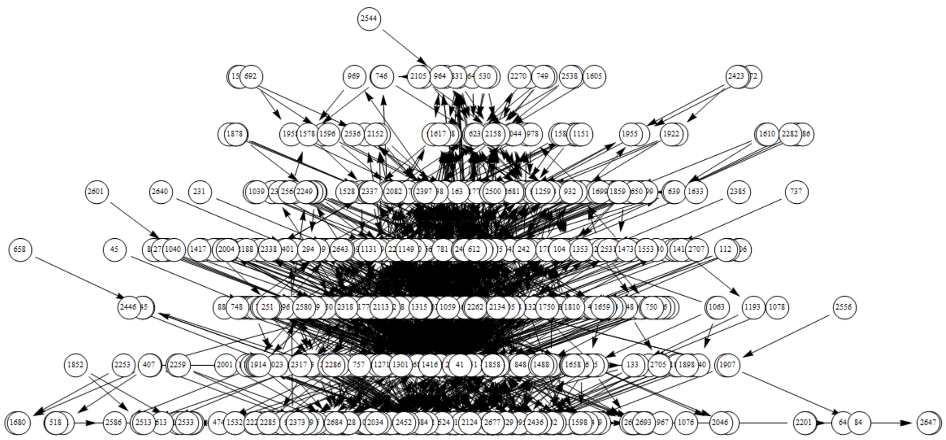
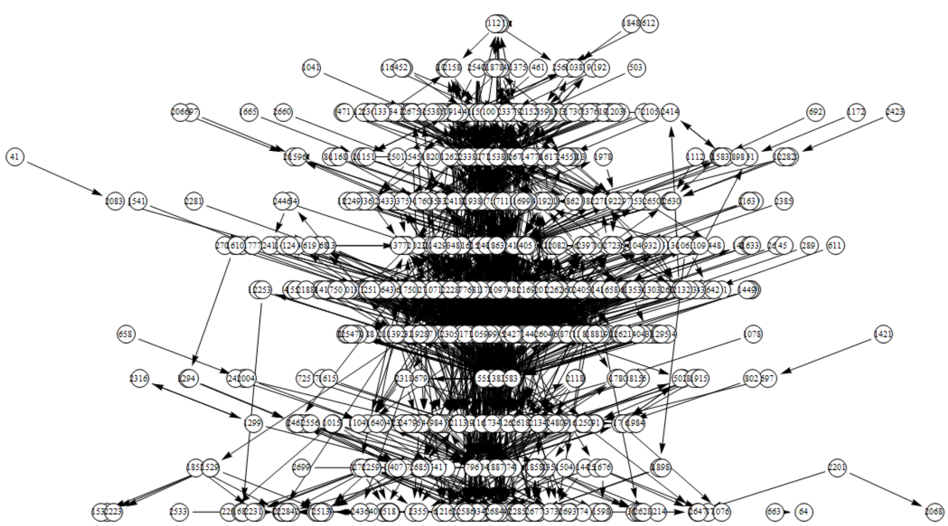
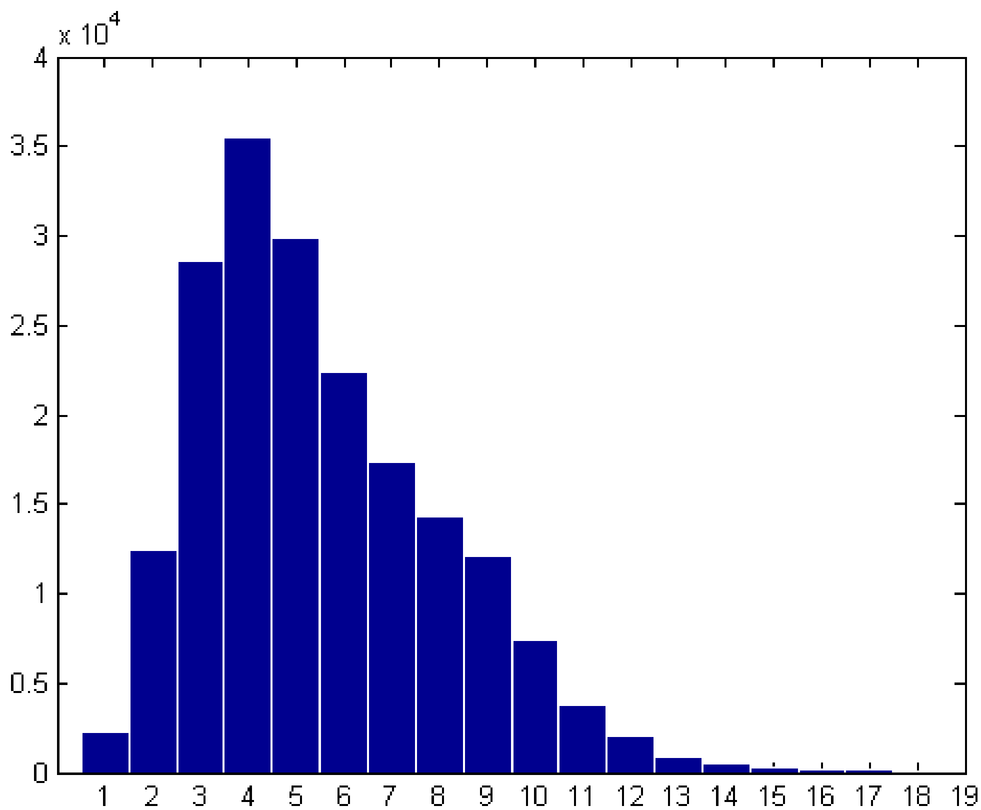


Figure 3: Industrial Structure of Firms in the Sample: Median Measure of Position



The graphs present the structure of supply chains composed of 990 firms. Each firm appears as a node on the graph. Arrows start from the supplier and point to the customer. The vertical position of each firm is according to the minimum measure of absolute position (top graph) or the median measure of absolute position (bottom graph) as defined in Section 4.1. The horizontal position has no meaning in these graphs.

Figure 4: Histogram of the Relative Position Measure



The figure presents the histogram of the relative position measure defined for 190,493 pairs of firms. The definition of the measure appears in Section 4.1. The measure is used in the estimation of Eq(7) and the results of the estimation are reported in Table 5.