Take the Goods and Run: Contracting Frictions and Market Power in Supply Chains*

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Abstract

This paper studies the efficiency of self-enforced relational agreements, a common solution to contracting frictions, when sellers have market power and contracts cannot be externally enforced. To this end, I develop a dynamic contracting model with limited enforcement in which buyers can default on their trade-credit debt and estimate it using a novel dataset from the Ecuadorian manufacturing supply-chain. The key empirical finding is that bilateral trade is inefficiently low in early periods of the relationship, but converges toward efficiency over time, despite sellers' market power. Counterfactual simulations imply that both market power and enforcement contribute to inefficiencies in trade.

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When courts cannot enforce contracts, trading partners often resort to long-term relational contracts, sustained through repeated interactions, to ease frictions and constrain opportunistic behavior (Johnson et al., 2002). As weak contract enforcement is a common feature of developing economies, relational agreements are highly relevant inter-firm organizational structures. Understanding the efficiency of these informal agreements is essential for policy-makers in developing countries, as they frequently have to make trade-offs regarding where to focus their reform efforts.

The traditional view sees contracting frictions as a hindrance that distorts productive decisions (La Porta et al., 1997; Nunn, 2007), implying that, as a standard solution, relational contracts may be inefficient. However, it is noteworthy that the same economies where enforcement constraints are likely to be a significant factor may also encounter additional frictions, such as high market concentration, making them second-best environments (Rodrik, 2008). In the presence of seller market power, weak enforcement may increase the buyer's relative bargaining power, thereby limiting downstream distortions while improving the efficiency of a relationship as opposed to a perfect enforcement world (Genicot and Ray, 2006).[1] Thus, the efficiency of relational agreements remains unclear.

This paper uses theory and data to quantify the static (period-by-period) efficiency of self-enforced long-term relationships in the presence of seller market power and limited external enforcement of contracts. I develop a novel long-term contracting model where 1) the seller can price discriminate across buyers and time, and 2) the buyer can act opportunistically and simply *take the goods and run* whenever the delivery of the goods occurs before payment. Without access to external enforcement, the seller uses the value of the relationship itself to discipline the buyer's behavior. The modeling framework is applied to examine self-enforced relationships in the manufacturing supply chain in Ecuador, a middle-income country with slow commercial courts and concentrated sectors.

The paper has two novel empirical contributions. First, by utilizing a structural econometric model, it provides the first empirical evidence regarding the efficiency evolution of long-term trade relationships. The findings demonstrate that relationships tend to be highly inefficient at the early stages, but over time, such inefficiencies diminish, indicating the crucial role of repeated informal agreements in creating surplus. Second, the study examines the counterfactual scenario of implementing best-practice institutions (e.g., eliminating contracting frictions) and

[1] Throughout the paper, the working definition of **seller market power** is the *seller's ability to price discriminate with prices above marginal costs*. This definition encapsulates the common one referring to the ability of sellers to price above marginal costs often used in the economics literature (e.g., De Loecker et al., 2020) and in economic law (e.g., Kaplow, 2016). Moreover, the common definition of market power is seen as a necessary condition for price discrimination (Varian, 1989; Stole, 2007). I do note, however, that in general price discrimination, relative to profit-maximizing uniform pricing, can be welfare-enhancing or welfare-decreasing (Varian, 1989). In the specific case of third-degree price discrimination (non-linear pricing or wholesale quantity discounts), price discrimination can be also welfare-increasing or welfare-decreasing relative to profit-maximizing uniform pricing (Katz, 1984; Varian, 1985). Furthermore, except the case of perfect price discrimination, market power (both in uniform prices or with price discrimination) generates quantity distortions relative to a competitive benchmark.

finds an intertemporal trade-off. In the short term, the implementation of best-practice institutions leads to an increase in welfare. However, in the medium and long term, such institutional changes are found to result in welfare losses when compared to the observed second-best equilibrium. In contrast, efficiency improves when all modeled frictions are addressed simultaneously.

I start by documenting six fundamental patterns that provide the basis for the key elements of the model. First, it is observed that most trade takes place through repeated relationships. Second, the vendor finances a substantial share of transactions using trade-credit, even in new relationships, indicating that the seller bears the risk of the transaction. Third, as relationships age, they exhibit growth in both quantity and value. Fourth, sellers offer considerable quantity discounts, with a 10% increase in quantity corresponding to a 2% decrease in unit price. Fifth, accounting for quantity discounts, older buyers receive up to a 3% discount compared to new buyers as the relationship matures. These discounts are observed only in cases where buyers use trade-credit as opposed to paying the full order amount upfront. Finally, the survival probability of relationships is observed to increase in quantity and as relationships mature. These patterns provide valuable insights into the nature of long-term relationships in the manufacturing supply chain in Ecuador, which are used to build the theoretical model and to inform the empirical analysis.

Standard models in the literature (such as efficiency gains, learning, demand assurance, or supply-side enforcement issues) are not able to capture all of these patterns under realistic assumptions. For that reason, to account for these patterns and assess the efficiency of relationships over time, I develop a novel dynamic contracting model by embedding a non-linear pricing model with heterogeneous participation constraints (Jullien, 2000; Attanasio and Pastorino, 2020) into an infinitely repeated game with limited enforcement (Martimort et al., 2017; Pavoni et al., 2018; Marcet and Marimon, 2019). In the model, sellers and buyers with private heterogeneous demand meet randomly and have the opportunity to engage in repeated trade. The seller has all the bargaining power and proposes a dynamic contract of prices and quantities, for which they have commitment. Consistent with the data, the seller in the model finances all the transactions using trade-credit. Buyer heterogeneity provides incentives to price discriminate, so the seller offers menus of quantities and prices that satisfy *incentive compatibility* and induce revelation of the buyer asymmetric information.

Crucially, the buyer cannot commit to paying their debts and is subject to forward-looking *limited enforcement* constraints. The future stream of benefits created by the relationship for the buyer must be large enough to secure the payment. To prevent a *take the goods and run* scenario, the seller must share a greater amount of surplus, through greater levels of future net returns, than otherwise. Thus, enforcement constraints could dynamically act against the seller's profit-maximizing incentives to distort trade downward through inefficiently low quantities. Matching the empirical picture described above, the optimal dynamic menu of quantities and prices in a setting with limited enforcement features *backloading*: both the total surplus generated by the relationship and the net return enjoyed by the buyer increase over time.

To determine the optimal quantity allocations in this setting, I use a recursive Lagrangian approach (Pavoni et al., 2018; Marcet and Marimon, 2019), which characterizes the optimal dynamic contract in terms of *past* and *present* limited enforcement Lagrange multipliers (LE multipliers). The present LE multipliers capture the current limited enforcement constraints, while past LE multipliers account for promises made in the past to prevent default and serve as promise-keeping constraints. In equilibrium, the optimal quantity allocations are then determined by a *modified virtual surplus*, which takes into account the standard informational rents due to incentive compatibility, as well as the shadow costs of binding enforcement constraints.

The paper proposes an econometric model that is directly derived from the theoretical model and shows that the parameters of the model can be identified using cross-sectional data on prices, quantities, age of relationships, and marginal costs for one seller. The model relies on the seller's optimality conditions and the buyer's dynamic first-order conditions for incentive compatibility (as in the static results of Luo et al., 2018 and Attanasio and Pastorino, 2020) to identify the dynamic effects of limited enforcement on trade. The identification intuition is twofold. First, the seller offers prices and quantities that induce the revelaxtion of information about buyers' types and discriminate across them. This implies that price and quantity variation across buyers is a signal of their underlying types. Second, the degree of trade distortion in quantities relative to the efficient outcome provides information on whether current or past enforcement concerns are constraining the trade relationship. By examining the difference between marginal prices and marginal costs, which indicates the presence of downward and upward distortions, we can identify the extent of additional distortions due to limited enforcement.

I estimate the model using three administrative databases collected by the Ecuadorian government for tax purposes that provide empirical analogs to the objects in the theoretical model. I obtain pair-specific unit prices and quantities using a new electronic invoice database that contains all domestic sales for 49 manufacturing firms in the textile, pharmaceutical, and cement-product sectors for 2016-2017, each with a large number of buyers each year (median of 600). The age of relationships is inferred through the universe of firm-to-firm VAT database, which tracks the total volume of bilateral trade from 2008-2015. Lastly, a measure of seller's costs comes from information on total variable costs (i.e., intermediate inputs expenditure and labor wages) contained in usual financial statements reported to the tax authority.

The estimated model fits the data well, and the estimation results reveals that enforcement concerns are relevant throughout the life-cycle of a relationship. Specifically, almost all new relationships have binding enforcement constraints, meaning that if the seller where to increase current prices without a corresponding future decrease in prices or increase in quantities, the buyer would default and exit the relationship. As relationships age, these constraints are relaxed, reflecting the increase in quantities coming from past promises made by the seller.

Using the estimated model parameters, I evaluate the efficiency of transactions at any given point and examine the division of surplus. My findings indicate that new relationships operate at approximately 30% of the optimal (i.e., frictionless) level, but efficiency increases as relationships age. Relationships lasting five years or more can achieve efficiencies upwards of 80%. In the aggregate, my analysis reveals that sellers heavily distort quantities early on. Specifically, only 5% of suppliers achieve levels of aggregate output that are indistinguishable from efficient output when dealing with new buyers, whereas 84% of sellers achieve long-term aggregate output levels that cannot be distinguished from efficient levels. Remarkably, these patterns hold for each industry studied, talking to the generality of the result. As for the division of surplus, I find that sellers capture the majority (around 80%) of the generated surplus, although some buyers may capture up to 30% of the total surplus.

The paper proceeds to investigate counterfactual scenarios that have surprising implications. First, the analysis shows that addressing enforcement constraints alone, without addressing market power, can lead to higher surplus in the short term, but result in a lower total surplus in the medium and long term. Similarly, only addressing market power leads to substantial welfare losses across different types and time periods. These findings are consistent with the *theory of second-best* (Lipsey and Lancaster, 1956), which suggests that in the presence of one friction, the effect on welfare of removing one friction alone is uncertain. In this particular case, each friction serves to counterbalance the other. Second, the paper explores the effects of addressing both frictions simultaneously. The results indicate that most relationships achieve a higher total surplus and lower surplus for the seller when both frictions are addressed together. Overall, these counterfactual analyses underscore the significance of recognizing the interplay between various frictions in markets. Simply addressing one friction in isolation may not produce the desired outcome and could result in unintended consequences.

This paper contributes to several strands of the theoretical and empirical literatures. First, I contribute to a vast and diverse theoretical literature on imperfect lending and contracting (Bull, 1987; MacLeod and Malcomson, 1989; Thomas and Worrall, 1994; Watson, 2002; Ray, 2002; Levin, 2003; Albuquerque and Hopenhayn, 2004; Board, 2011; Halac, 2012; Andrews and Barron, 2016; Martimort et al., 2017; Troya-Martinez, 2017). The closest theoretical paper to mine is Martimort et al. (2017), which provides a theory of a two-sided limited enforcement problem in which buyers can default on debts and sellers can cheat on quality. In their setting, the buyer is the principal and increasingly shares a greater amount of surplus with the seller, implying dynamics where quantities *and* prices both increase. These dynamics do not match those observed in the setting I study, which has frictions that are common in many parts of the developing world. In contrast, I consider a model where, besides the incentives to default, the buyer has private information about the value of the relationship and the seller has the bargaining power.

Second, I contribute to the empirical literature on imperfect lending and contracting (McMillan and Woodruff, 1999; Banerjee and Duflo, 2000; Karaivanov and Townsend, 2014; Antras and Foley, 2015; Macchiavello and Morjaria, 2015; Boehm and Oberfield, 2020; Startz, 2024; Blouin and Macchiavello, 2019; Heise, 2024; Ghani and Reed, 2020; Ryan, 2020; Harris and Nguyen, 2022). Several papers, including Blouin and Macchiavello (2019), Ryan (2020), Startz (2024), and Harris and Nguyen (2022) have previously estimated the efficiency losses arising from imperfect contracting. In particular, Blouin and Macchiavello (2019) analyze strategic default on forward-contracts by sellers in the international coffee market, Ryan (2020) focuses on contract renegotiation in public procurement, Startz (2024) studies weak contract enforcement concerning seller opportunism and the presence of search frictions, and Harris and Nguyen (2022) studies the interaction of relational contracts with the thickness of a spot market. To my knowledge, my paper is the first empirical study to quantify the evolution of efficiency in relationships over time and find that dynamics matter significantly. Moreover, relative to these papers, my contribution is to quantify the inefficiencies from buyer opportunism in conjunction with seller market power. As the use of trade-credit is highly common in developing and high-income countries (Murfin and Njoroge, 2015; Giannetti et al., 2021; Burstein et al., 2024), and trade-credit reliance appears to increase with seller market power (Giannetti et al., 2011; Garcia-Marin et al., 2023) my findings and methodology have a wide-scope applicability.

Within the same body of work, this study relates to an extensive literature on formal and informal contracts in agricultural supply chains (Jacoby et al., 2004; Barrett et al., 2012; Michelson, 2013; Bubb et al., 2016; Macchiavello and Miquel-Florensa, 2017, 2019; Michler and Wu, 2020).[2] The literature supports the notion that formal contracting positively impacts welfare levels through real effects on income (Barrett et al., 2012; Michelson, 2013; Macchiavello and Miquel-Florensa, 2019), and that relational contracts can generate efficiency gains in the presence of contracting frictions (Jacoby et al., 2004; Macchiavello and Miquel-Florensa, 2017; Banerji et al., 2012). While Banerji et al. (2012) finds that relational contracts achieve constrained-efficiency under external output distortions, these gains from relational contracting may be limited in the presence of monopoly power (Jacoby et al., 2004), perform worse than vertical integration (Macchiavello and Miquel-Florensa, 2017), or may even be non-existent in certain contexts (Bubb et al., 2016). My contribution lies in providing a further analysis of the interaction between seller market power and relational contracts, empirically demonstrating that in the Ecuadorian context, the influence of relational contracts drives contracts towards unconstrained efficiency in the medium and long term.

Third, this paper relates to the literature examining the effects of market power in developing settings. Some studies have found that low market competition negatively impacts welfare,

[2]The paper is also linked to the literature testing communal risk-sharing in villages, which constitute a form of relational agreement (Townsend, 1994; Udry, 1994; De Weerdt and Dercon, 2006; Mazzocco and Saini, 2012; Chiappori et al., 2014). This literature indicates that while full village insurance is often rejected, certain networks among households (e.g., caste) do share risk efficiently, aligning with my finding that informal agreements can be near-optimal in some settings.

as firms distort total output and do not pass on cost savings to consumers (Fisman and Raturi, 2004; Atkin and Donaldson, 2015; De Loecker et al., 2016; Bergquist and Dinerstein, 2020; Casaburi and Reed, 2022; Grant and Startz, 2022; Reed et al., 2022; Chatterjee, 2023; Brugués and De Simone, 2024). However, some of the literature has demonstrated that monopoly power can enhance welfare in the presence of additional frictions. Such manifestations of the *theory of second-best* suggest that market power enables suppliers to offer credit (McMillan and Woodruff, 1999; Emran et al., 2021) and generate sufficient surplus for sustaining repeated relationships (Macchiavello and Morjaria, 2021; Boudreau et al., 2023).[3] In a similar vein, my paper finds that market power, manifested in the seller's ability to price discriminate flexibly, allows them to offer contracts that overcome each buyer's specific contracting frictions and achieve trade levels that would otherwise be unattainable.

Fourth, this work also follows the theoretical and empirical literature related to price discrimination (Maskin and Riley, 1984; Jullien, 2000; Villas-Boas, 2004; Grennan, 2013; Luo et al., 2018; Attanasio and Pastorino, 2020; Marshall, 2020). The works by Luo et al. (2018) and Attanasio and Pastorino (2020) provide estimation methodology and identification results for static non-linear pricing problems, with and without binding participation constraints, respectively. This paper generalizes their models and estimation methods to a multi-period setting by the relying on the recursive Lagrangian approach, a tool typically used in sovereign-debt macroeconomic models (Aguiar and Amador, 2014). Furthermore, while Attanasio and Pastorino (2020) provide identification results for non-linear pricing models with participation constraints under constant participation multipliers, I extend their findings by showing that, for non-constant multipliers, these models are identified under a parametric assumption.

The paper is organized as follows. Section 1 provides a description of the context and data. Section 2 offers the motivating facts that the model needs to match. Section 3 presents the model. Section 4 discusses identification and Section 5 the estimation procedure. Section 6 presents the estimated results and model fit. Section 7 discusses welfare and three counterfactual exercises. Finally, Section 8 concludes the paper.

[3] Theoretical studies in the theory of second best include Petersen and Rajan (1995), who demonstrate that increasing competition in bank lending can harm buyers by reducing the overall volume of lending when buyers have limited commitment to repaying their debts. This paper contributes to this literature by empirically showing that addressing only one market friction can result in welfare losses, and that addressing both enforcement and seller market power simultaneously could increase welfare. Additionally, my counterfactual results align with the theoretical findings of Genicot and Ray (2006), who show that improving enforcement reduces the buyer's expected payoff when the seller has bargaining power, and of Troya-Martinez (2017), who find that total welfare decreases as enforcement quality increases beyond a certain level.

1 Context, Interviews, and Data

Ecuador is an upper-middle-income country with weak enforcement of contracts and concentrated manufacturing markets. According to the World Bank Doing Business survey, Ecuador ranks as a median country in terms of Contract Enforcement, measuring the efficiency of courts in resolving commercial disputes, and one of the worst in terms of Insolvency measures, reflecting the inefficiency of courts in dealing with debt defaults due to bankruptcy (Online Appendix Figure OA-2). Additionally, the country's manufacturing sectors exhibit high levels of concentration, with average Herfindahl-Hirschman Indices of 0.6 for 6-digit economic codes (Online Appendix Figure OA-3), which are significantly higher than the concentration threshold of 0.25 used by the US Justice Department to identify highly concentrated markets.

1.1 Interviews

To gain a deeper understanding of the relationship management practices of manufacturing firms in Ecuador, I conducted hour-long interviews with high-ranking managers from 10 *manufacturing* firms in my studied industries in the spring of 2019. The following are the key findings from these interviews, from the perspective of the seller:

- Relationships among firms are not primarily based on written contracts but rather on informal agreements. Although transactions are documented, they are usually managed without the involvement of third-party enforcement, as formal enforcement is seen as costly and inefficient.[4]
- Quality issues from upstream suppliers are not a major concern, as the inputs used are highly standardized.[5]
- Enforcing payment for trade-credit transactions requires some investment in terms of time and personnel to pressure buyers to pay their debts.
- Most firms are aware that cash transactions offer discounts compared to trade-credit, but they often resort to trade-credit due to a lack of short-term liquidity.

This paper will not attempt to explain the underlying causes of these features but instead will focus on how they shape ongoing relationships.

[4]The Judicial Magazine of the Ecuadorian Government, available here, provides further evidence of the inefficiency of the court system. Two recent cases of buyer default were found, one taking 6 years to resolve and the other 4 years. A 2016 reform was made to the *Código Orgánico General de Procesos* to speed up debt collection, but in practice, this route is used as a last resort and takes around 2 years to enforce payment, according to personal estimates from 7,000 cases in the Civil Court in Quito in 2017.

[5]For textiles, their main supplies include raw textiles, which in the case of the manufacturing firms in my sample, are often imported (Online Appendix Table OA-8). For pharmaceuticals, variable inputs include active components, again often imported (Online Appendix Table OA-8). For cement-products, the main components include gravel and cement.

1.2 Administrative Data

The data used in this paper come from various administrative databases collected by Ecuador's Servicio of Rentas Internas (IRS) for tax purposes.

VAT database. By law, since 2008, firms are required to report all of their firm-to-firm inputs and purchases with information on the identity of the buyer and seller through the business-to-business (B2B) VAT system. I use the universe of B2b VAT database for 2008-2015 to measure the lengths of relationships. In particular, I define *age of relationship* as the total number of years that the seller has sold some positive value to the buyer in the past. Given the first year of observation is 2008, the age of the relationship is censored at +9.

Electronic Invoicing. The primary data source for the analysis is the electronic invoicing (EI) system. In 2014, Ecuador started rolling out a new EI system to collect VAT information more consistently, requiring large firms to implement this new technology. By 2015, the largest 5,000 firms were required to use the EI system for all sales. This system would send a copy of the transaction information to the buyer and government immediately after the transaction occurs. For each sale done by a firm in the system, the EI collects product-level information, including a bar-code identifier, product description, listed unit price, quantities, and discounts relative to listed prices, as well as transaction-level information, such as the buyer's unique national identifier and method of payment.[6] Method of payment can be cash, check, credit card, trade-credit offered by the seller with trade-credit payment terms, among others.

The data collected for this study is drawn from the EI system and pertains to 49 manufacturing firms operating in the textiles, pharmaceuticals, and cement sectors for the years 2016-2017. These firms are large, with an average (median) of 8,000 buyers (600) and a market share of 24% in their 6-digit sector at the national level and 50% in their sector at the provincial level. The database coverage is considered to be good, with the average selling firm in the sample having more than 90% of its reported sales captured by the EI system. Managerial interviews also revealed that most of these firms use the invoices received and sent for internal accounting purposes.

Because the manufacturing firms in this study produce multiple products, I use two approaches to measure quantities and prices. First, when presenting the stylized facts in Section 2, I focus on quality-adjusted prices and quantities. Specifically, I standardize prices and quantities by netting out product-seller-year fixed effects in transaction-level regressions of log unit prices or log quantities and I aggregate them to average standardized units at the buyer-seller-year level. Second, for the structural model estimation in Section 5, I rely on total quantities aggregated across all products for each buyer-seller-year and on average unit prices computed by dividing the total value of transactions by total quantities. Further details on the construction

[6] Listed prices may differ across buyers within a particular week, so listed discounts are not the only source of price variation.

of these variables are provided in the Online Appendix Section OA-1.1.

Financial Statements. I complement this information with yearly data on expenditures and wage bill from financial statements for all sellers for 2016-2017, which will be used to obtain firm-level variable costs.

1.3 Overview of the data

Online Appendix Section OA-1.2 provides detailed descriptive statistics for the datasets used. These statistics show that the sellers in the sample are large, well-established firms that make extensive use of imported inputs and channel most of their sales domestically, whereas buyers tend to be smaller, younger, less capital-intensive, and less exposed to international trade. Sellers outside the sample but in the same industries are typically even smaller—often micro-entrepreneurs with minimal reliance on imported inputs. Industry-specific breakdowns across textiles, pharmaceuticals, and cement-products indicate that, in each selling sector, a sizable share of buyers operate in wholesale and retail trade, suggesting relatively linear input needs. The electronic invoice data reveal that sellers transact with numerous buyers, with a median (average) bill of around \$USD 9,000 (\$USD 44,000). Illustrative product-level information highlights substantial variation in prices and costs within industries—potentially reflecting local market power or product differentiation—and indicates that product units within a firm's portfolio are comparable.

2 Motivating Evidence

This section presents evidence on how buyer-seller relationships work in the Ecuadorian supply chain.[7] Based on the data analyzed, there are three key findings: i) Trade heavily relies on past relationships and trade-credit arrangements. ii) As relationships mature, the quantity of goods exchanged increases, while prices decrease. iii) At any given time, larger purchases are associated with lower prices. In Section 3, a long-term contract model is proposed to capture these dynamics. The model allows the seller to use price discrimination across buyers and time, and enables buyers to default on trade-credit debts without facing legal consequences.

Fact 1: Large amount of trade occurs via repeated relationships. Figure 1a demonstrates the significance of repeated relationships for the sellers included in this study. The blue bars represent the average proportion of clients by length of relationship, while the green bars indicate the average proportion of the total quantity sold. The results reveal that although roughly

[7] Some of these relationship patterns have been previously documented in the literature. Heise (2024) and, partially, Monarch and Schmidt-Eisenlohr (2023) have previously documented the fact of relationship dynamics in quantities and prices for international trade, and Burstein et al. (2024) for intra-national trade in Chile. The persistence of intra-national links has been documented by Huneeus (2018) for Chile. Price discrimination in the context of medical devices and wholesale food has been documented by Grennan (2013) and Marshall (2020), respectively. Similarly, Antras and Foley (2015), Garcia-Marin et al. (2023), Amberg et al. (2020), and Burstein et al. (2024) have documented similar patterns of trade-credit issuance.

35% of all buyer-seller pairs consist of new buyers, only about 10% of the total trade is conducted through these fresh relationships. In contrast, relationships that have endured for at least nine years constitute less than 10% of all pairs but contribute to over 30% of the total trade.

Fact 2: Large share of transactions occur via trade-credit. The EI database includes payment method information, specifying whether the seller financed the transaction and the credit terms in days. For this analysis, I only consider whether the buyer was offered trade-credit, irrespective of the terms of the agreement.[8] Figure 1b displays the average share of purchases by buyer, across sellers, of relationships of a certain age that involved trade-credit. The data shows that the use of trade-credit is widespread, with approximately 65% of all purchases conducted via trade-credit in the first year of contact. For older relationships, around 70 to 75% of the volume of purchases are conducted via trade-credit.[9,10]

This fact has two important implications. Firstly, the seller bears a substantial portion of the risks associated with the transaction. In the absence of a strong legal enforcement framework, any opportunistic action taken by the buyer would result in the direct costs being absorbed by the seller. Secondly, the seller's opportunistic actions, such as cheating in quality or quantity, are likely to be limited (Smith, 1987; Klapper et al., 2012; Antras and Foley, 2015). Post-delivery, the buyer may retain the value of the transaction as a guarantee of quality. Therefore, when the seller finances transactions, the risk in trade tends to favor the buyer.

Fact 3: Quantities increase as relationships age. Figure 1c plots empirical evidence on the life cycle of quantities in buyer-seller relationships. The figure shows a binscatter regression of standardized log quantities on dummies for different ages of relationships in the cross-section. I find that older relationships tend to purchase more of a given product within a given year than younger relationships. These patterns also hold within a relationship, using total quantity purchased while controlling for pair fixed effects (Online Appendix Figure OA-4a).

Fact 4: Quantity discounts for a given age of relationship. Next, I examine the link between prices and quantities, focusing on *quantity discounts*, a common term in the literature for non-linear quantity-dependent decreasing price schedules (Maskin and Riley, 1984; Katz, 1984).[11]

Given the differences in the quantities sold by different manufacturers, I present quantities as quantiles, calculated within each seller and across the following relationship categories: i)

[8] On average, trade-credit agreements have a maturity of 40 days in textiles, 55 days in pharmaceuticals, and 40 days in cement products (Online Appendix Figure OA-9).

[9] These estimates are close in magnitude to inter- and intra-national figures from Chile, as reported by Garcia-Marin et al. (2023) and Burstein et al. (2024), respectively.

[10] It is possible that this empirical pattern for financing is valid for the sample of large manufacturing firms in my sector, but may not hold for smaller or informal firms. Reassuringly, using data from the World Bank, World Enterprise 2017 Survey for Ecuador, I find that 63% of retail firms and 77% of manufacturing firms use supplier or customer credit to finance working capital.

[11] The literature does not differentiate whether discounts come from a posted schedule or negotiated discounts. In this paper, I consider both sources by focusing on the effective price, which includes product-specific discounts as well as potential differences in posted prices across buyers. Also note, the term *quantity discounts* can also be seen in the literature as wholesale discounts.

Figure 1: **Motivating Facts**

(a) Share of Clients and Trade (b) Trade-credit (c) Quantity over Time

(d) Quantity Discounts (e) Prices over Time (f) Survival Rates

Notes: Subfigure (a) displays the distribution of the average of the share of clients and quantity sold by relationship age, calculated across all sellers in 2016. Sub-figure (b) displays the average of the share of purchases channeled through trade-credit, along with a 90% confidence interval, calculated across all sellers. Subfigure (c) displays the evolution of standardized log quantities, with their corresponding 90% confidence intervals, calculated across all sellers. The standardized log quantity is obtained by taking the average quantity sold in a given year for each seller-product and subtracting the log average quantity for that year. The standard errors are calculated at the seller-year level. Subfigure (d) shows the relationship between quantity purchased and standardized log unit price through a binscatter plot that displays the measure of unit price against the quantity sold, based on relationship age. The standardized log unit price is obtained netting out average log unit price for that year for each seller-product. The quantiles of quantity are calculated for each seller-relationship age combination. Subfigure (e) presents a binscatter plot of standardized log unit prices against years of relationship, controlling for a flexible spline of standardized log quantities. The standard errors are calculated at the seller-year level. Subfigure (f) displays a binsscatter plot of the average survival rate of pairs at different ages and quantiles of quantity. The quantiles of quantities are calculated for each seller-age combination, and the error bars represent a 90% level of variation across all sellers.

new relationships, ii) relationships aged 1-3 years, iii) relationships aged 4 or more years. To compare quality-adjusted prices, the standardized unit price by quantiles of quantity is displayed as a binscatter plot in Figure 1d. The results demonstrate that, regardless of the relationship's age, larger quantities obtain lower quality-adjusted prices. This finding also holds true when considering average unit prices (Online Appendix Figure OA-4b). In terms of magnitude, a 10% increase in total quantity purchased is associated with an average price decrease of 2% (Online Appendix Table OA-5).

Fact 5: For a given quantity, older relationships pay lower unit prices. Figure 1e presents the relationship between unit prices and the age of the relationship. Using a binscatter regression of standardized log prices on age-of-relationship dummies, while controlling for a flexible spline of standardized quantities to account for potential quantity discounts, the figure reveals that older relationships receive up to 3% more quality-adjusted discounts compared to new relationships. These effects in standardized prices are comparable to those of moving from the median to the top percentile in quantity.

These dynamic discounts over time remain robust even after controlling for pair fixed effects in a regression of log average prices on relationship age (Online Appendix Figure OA-4c), indicating that the results are not driven by composition nor short-term fixed characteristics of the firm. Moreover, the results are robust and stable after including additional buyer and relationship-level controls, e.g., buyer's size or relationship demand and supply shares (Online Appendix Table OA-6). Interestingly, the discounts are only observed in trade-credit transactions and not in pay-in-advance ones (Online Appendix Table OA-9), supporting the interpretation of limited contract enforcement as the underlying mechanism for the observed price and quantity dynamics (over alternatives such as efficiency gains or demand assurance).

Fact 6: Relationships that trade more are more likely to survive. Figure 1f plots the share of relationships that survive from 2016 until 2017 by quantile of quantity in 2016 and age of relationship. The figure shows the survival rates of new links in red, links aged 1-3 years in blue, and links aged 4 years or more in green. I find that approximately 40 percent of new relationships survive at least one more year, 60 percent of relationships aged 1-3 years survive, and more than 75 percent of relationships aged 4 years or more survive. Moreover, within each relationship age category, pairs that trade higher volumes are more likely to survive from year to year.

While this paper does not focus on institutional differences among the sectors studied, it is important to highlight that the observed stylized facts (Facts 1 through 6) are consistent across all three industries analyzed (Online Appendix Section OA-3). Consequently, although specific primitives may vary by industry and seller, the underlying forces remain universally operative.

3 An Empirical Dynamic Contracting Model

This section introduces an empirical model of dynamic contracting with limited enforcement and seller market power from the perspective of a single seller. Through the first-order, necessary conditions for optimality of the seller and the buyers, I derive the key empirical equation.

3.1 Preliminaries

Setting. Consider an infinitely repeated relationship between a seller (the principal) and a buyer (the agent). Time is indexed by $\tau \geq 0$, and both parties discount future payoffs at a common factor $\delta < 1$. The buyer's preferences depend on a private type θ, which is drawn once at the outset from a continuous distribution with support $[\underline{\theta}, \overline{\theta}]$, where $\underline{\theta} = 1$ and $\overline{\theta} < \infty$, with cumulative distribution function $F(\theta)$ and density $f(\theta)$.[12] Although the type is privately observed, the distribution $F(\cdot)$ is common knowledge.

In addition to potential endogenous terminations of a relationship, relationships end exogenously every period from shocks that occur with common knowledge probability $X(\theta)$. As a result, the distribution of types evolves over time. Specifically, define the time-τ density as $f_\tau(\theta) = f(\theta)(1-X(\theta))^\tau / \int (f(m)(1-X(m))^\tau) dm$, with the associated cumulative distribution function $F_\tau(\theta)$.

A trade profile is defined by an infinite sequence of tariffs $\{t_\tau\}_{\tau=0}^\infty$ and quantities $\{q_\tau\}_{\tau=0}^\infty$. This profile delivers a discounted payoff to the seller of

$$\sum_{\tau=0}^{\infty} \delta^\tau \left(t_\tau - c_\tau q_\tau\right) \tag{1}$$

and to a buyer of type θ of

$$\sum_{\tau=0}^{\infty} \delta(\theta)^\tau \left(\theta\, v(q_\tau) - t_\tau\right), \tag{2}$$

where $v(\cdot)$ is a strictly increasing and strictly concave return function, $\delta(\theta) \equiv \delta(1-X(\theta))$, and c_τ denotes the constant marginal cost in period τ.[13]

Empirical evidence in Section 2 suggests that trade-credit is prevalent. Hence, I assume that the seller delivers goods before receiving payment, effectively extending trade-credit in every transaction. This assumption, while strong, streamlines the analysis by eliminating an additional choice variable, i.e., the choice to offer and accept trade-credit.

In line with the dynamic mechanism design literature (Pavan et al., 2014; Garrett et al., 2018), I assume that the seller can fully commit to a long-term contract. In particular, the seller does not alter the terms of the trade profile over time. This assumption is made for technical convenience, allowing me to concentrate on direct mechanisms thanks to the revelation principle, where the direct mechanism $C(\theta) = \{q_\tau(\theta), t_\tau(\theta)\}_{\tau=0}^\infty$ stipulates quantities and post-delivery tariffs in each period for agent reporting type θ.

Notably, while the seller has long-term commitment over the mechanism, the buyer can act opportunistically in the short-term, within each period. Namely, they can neglect payment and simply *take the goods and run*.

[12] The normalization $\underline{\theta} = 1$ is made without loss of generality.

[13] The concavity of the buyer's return function can be micro-founded by using diminishing returns in production for one input, keeping at least one other input fixed. This assumption is common in the literature. For instance, standard production function estimation generally assumes that capital is set one year in advance (e.g., Levinsohn and Petrin, 2003).

Timing. The contracting game unfolds as follows:

1. **Pre-trade (at $\tau = 0$):** The buyer observes their persistent private type θ. The seller offers the mechanisms menu $\{C(\theta)\}_{\underline{\theta}}^{\overline{\theta}}$, for which they have commitment. The buyer then either accepts or rejects the offer. Upon acceptance, the buyer reports a type $\widehat{\theta}$. If the buyer rejects the offer, both parties obtain their outside options, each normalized to zero.[14]
2. **Within each trading period $\tau \geq 0$:**
   - The seller first produces and delivers $q_\tau(\widehat{\theta})$.
   - The post-delivery payment $t_\tau(\widehat{\theta})$ is paid by the buyer, or the contract is breached.
   - When payment is made, the stage payoffs are $u_\tau(\theta, \widehat{\theta}) = \theta\, v(q_\tau(\widehat{\theta})) - t_\tau(\widehat{\theta})$ for the buyer and $\pi_\tau(\widehat{\theta}) = t_\tau(\widehat{\theta}) - c_\tau q_\tau(\widehat{\theta})$ for the seller.
   - In case of a breach, stage payoffs are $\theta v(q_\tau(\widehat{\theta}))$ for the buyer and $-c_\tau q_\tau(\widehat{\theta})$ for the seller.
3. **Between trading periods:**
   - If payment is made, the relationship may still be terminated exogenously with probability $X(\theta)$, in which case both parties revert to their outside options; otherwise, the relationship continues to the next period with probability $1 - X(\theta)$.
   - If a breach occurs, the seller terminates the contract and both parties receive their outside options in all subsequent periods.[15]

Equilibrium. The solution concept for this principal–agent game is a Perfect Bayesian Equilibrium in pure strategies. Under this equilibrium, the seller's contract $\{C(\theta)\}_{\underline{\theta}}^{\overline{\theta}}$ at $\tau = 0$ is profit-maximizing—subject to the relevant constraints—given their beliefs about the buyer's privately known type and the buyer's anticipated default decisions. In turn, the buyer's initial announcement and subsequent default or payment decisions each trading period form a subgame-perfect best response to the specified trade profiles, as well as the threat of termination in the event of default. Because the seller fully commits to the contract at $\tau = 0$, no further beliefs or actions on their part are required once the contract is in place.

3.2 Constraints

As usual, the set of constraints of the seller's problem contains the traditional individual rationality and incentive compatibility constraints of adverse selection problems.[16] However, this setting's novelty is to include additional enforcement constraints in each trading period, which

[14]For the buyer, this normalization is nonrestrictive under standard production function assumptions (e.g., linearity in variable inputs) or in a monopolistic supplier setting. Similarly, for the seller, constant returns to scale justify this normalization.

[15]Because enforcement constraints ensure that breaches never occur in equilibrium, there is no loss of generality in assuming termination as punishment. This *worst outcome* approach was introduced by Abreu (1988) and is standard in the relational contracting literature (Levin, 2003; Halac, 2012; Martimort et al., 2017).

[16]To make non-trivial theoretical predictions about the dynamics in the relational contract, one should add *interim* individual rationality constraint, $u_\tau(\theta) \geq \underline{u}$, for some lower bound $\underline{u}$. For the empirical estimating framework presented here, this additional assumption is not needed, as it enters into the limited enforcement multipliers used to satisfy the enforcement constraints.

act as endogenously determined participation constraints. Each of the enforcement constraints will ensure the buyer will not endogenously default in the specific time period.

Buyer's Incentive Compatibility. Under the assumption of perfectly persistent types, incentive compatibility requires that the agent evaluates their lifetime return:

$$\underbrace{\textstyle\sum_{\tau=0}^{\infty} \delta(\theta)^{\tau} u_{\tau}(\theta)}_{\text{Lifetime truthful returns}} \geq \underbrace{\textstyle\sum_{\tau=0}^{\infty} \delta(\theta)^{\tau} u_{\tau}(\theta, \widehat{\theta})}_{\text{Lifetime deviation returns}} \quad \forall \theta, \widehat{\theta}, \tag{IC-B}$$

where their period's net return is $u_{\tau}(\theta) \equiv u_{\tau}(\theta, \theta) = \theta v(q_{\tau}(\theta)) - t_{\tau}(\theta)$.

Buyer's Limited Enforcement Constraint. The novel friction in the model is the limited enforcement of the trade-credit contracts, which allows for the possibility of buyer's default. Under the assumption of contracting termination following a breach and the normalization of the buyer's outside option to zero, a *default-free* menu satisfies the limited enforcement constraint of the buyer:

$$\underbrace{t_{\tau}(\theta)}_{\substack{\text{Post-delivery} \\ \text{payment}}} \leq \underbrace{\textstyle\sum_{s=1}^{\infty} \delta(\theta)^{s} u_{\tau+s}(\theta)}_{\substack{\text{Discounted future} \\ \text{truthful returns}}} \quad \forall \theta, \tau. \tag{LE-B}$$

The condition requires that the costs of breaking the relationship, in terms of the forgone opportunities of trade, have to be greater than the benefits from breaching the contract.

The buyer's LE-B constraint at $\tau = 0$ implies the individual rationality constraint required for buyer participation in trade.[17] From this, it follows that ex-ante trade under limited enforcement should leave participating buyers weakly better than under perfect enforcement whenever the seller has the bargaining power.

Buyer's Double-Deviation Constraint. The buyer could do a *double-deviation*, in which they announce type $\widehat{\theta}$ and default at some period τ. To prevent that, the truthful revelation menu must be appealing enough and satisfy

$$\underbrace{\textstyle\sum_{\tau=0}^{\infty} \delta(\theta)^{\tau} u_{\tau}(\theta)}_{\text{Lifetime truthful returns}} \geq \underbrace{\delta(\theta)^{\tau} \theta v(q_{\tau}(\widehat{\theta}))}_{\substack{\text{Deviation + breach} \\ \text{stage return at } \tau}} + \underbrace{\textstyle\sum_{s=0}^{\tau-1} \delta(\theta)^{s} u_{s}(\theta, \widehat{\theta})}_{\text{Deviation returns up to } \tau-1} \quad \forall \theta, \widehat{\theta}, \tau \tag{DD-B}$$

As the constraints IC-B and LE-B are necessary conditions for constraint DD-B, I concentrate on the relaxed problem and omit DD-B.[18]

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[17] A mechanism C is individually rational if the participation constraint at $\tau = 0$ holds: $\sum_{\tau=0}^{\infty} \delta(\theta)^{\tau}(u_{\tau}(\theta)) \geq 0 \;\; \forall \theta$. To see how LE-B implies this, add $u_0(\theta)$ on both sides and note that $u_{\tau}(\theta) + t_{\tau}(\theta) = \theta v(q_{\tau}(\theta)) \geq 0$.

[18] For IC-B, simply consider $\tau \to \infty$ in DD-B. For LE-B, simply set $\widehat{\theta} = \theta$ in DD-B. Moreover, note that, for any $\widehat{\theta}$ such that $\delta(\theta)^{\tau} \theta v(q_{\tau}(\widehat{\theta})) + \sum_{s=0}^{\tau-1} \delta(\theta)^{s} [\theta v(q_s(\widehat{\theta})) - t_s(\widehat{\theta})] < \delta(\theta)^{\tau} \theta v(q_{\tau}(\theta)) + \sum_{s=0}^{\tau-1} \delta(\theta)^{s} u_s(\theta)$, condition LE-B implies DD-B, so for such $\widehat{\theta}$ the condition DD-B is irrelevant. For all other $\widehat{\theta}$, the condition is LE-B is a necessary condition for DD-B to hold. In particular, if DD-B holds, then $\delta(\theta)^{\tau} t_{\tau}(\theta) \leq \sum_{s=\tau+1}^{\infty} \delta(\theta)^{s} u_s(\theta) - \Big(\sum_{s=0}^{\tau-1} \delta(\widehat{\theta})^{s} [\theta v(q_s(\widehat{\theta})) - t_s(\widehat{\theta})] - \sum_{s=0}^{\tau-1} \delta(\theta)^{s} [\theta v(q_s(\theta)) - t_s(\theta)]\Big) \;\; \forall \theta, \widehat{\theta}, \tau$. As the term in the brackets is positive by assumption, LE-B holds.

3.3 The Firm's Problem

Denote total surplus as $s(\theta,q,c) = \theta v(q) - cq$. The principal's problem is to maximize their lifetime profits. As the buyer's type θ is unknown, their problem is set in expectation. The seller therefore chooses a direct mechanism that maximizes their expected lifetime profits:

$$\max_{\{u_\tau(\theta),q_\tau(\theta)\}} \sum_{\tau=0}^{\infty} \delta^\tau \int_{\underline{\theta}}^{\overline{\theta}} [s(\theta,q_\tau(\theta),c_\tau) - u_\tau(\theta)] f_\tau(\theta) d\theta, \tag{SP}$$

such that IC-B, LE-B, and DD-B are satisfied. That is, the objective of the seller is to maximize total surplus while reducing the share of surplus given to the buyer as much as possible without breaching the constraints.

3.4 Necessary First-Order Conditions

The next proposition provides the necessary conditions for the profit-maximization problem of the firm.

Proposition 1. *Suppose that the contract $C^*(\theta) = \{q_\tau^*(\theta), t_\tau^*(\theta)\}_{\tau=0}^{\infty}$ maximizes the lifetime profits of the firm subject to IC-B, LE-B, and DD-B. Then, it must be that the contract satisfies the first-order conditions of the seller's problem SP:*

$$\theta v'(q_\tau^*(\theta)) - c_\tau = \frac{\Gamma_\tau(\theta) - F_\tau(\theta) - \sum_{s=0}^{\tau-1}(1-\Gamma_s^\tau(\theta))\tilde{\Gamma}_s^\tau(\overline{\theta}) + \theta\gamma_\tau(\theta)}{f_\tau(\theta)} v'(q_\tau^*(\theta)), \tag{SFOC}$$

for each τ and θ, such that $\gamma_\tau(\theta)$ is the corresponding Lagrange multiplier for type's θ LE-B constraint at time for type θ; $\Gamma_\tau = \int_{\underline{\theta}}^{\theta} \gamma_\tau(x)dx$ is the cumulative multiplier on the constraint from $\underline{\theta}$ to θ, such that $\Gamma_\tau(\overline{\theta}) = 1$; $\Gamma_s^\tau(\theta)$ is the conditional cumulative multiplier $\tau - s$ periods ago from $\underline{\theta}$ to θ; and $\tilde{\Gamma}_s^\tau(\overline{\theta})$ the discounted cumulative multiplier $\tau - s$ periods ago from $\underline{\theta}$ to $\overline{\theta}$. Moreover, the tariffs satisfy the following local incentive compatibility condition:

$$t_\tau^{*'}(\theta) = \theta v'(q_\tau^*(\theta)) q_\tau^{*'}(\theta). \tag{t-RULE}$$

For a full derivation, refer to Appendix A.

The allocation equation SFOC responds to intuitive forces. For clarity, assume momentarily that $v(q) = kq^\beta$ and the breakup probability is zero for all types, i.e., $X(\theta) = 0$ for all θ. Under these assumptions, $\Gamma_s^\tau(\theta) = \Gamma_s(\theta)$, $\tilde{\Gamma}_s^\tau(\overline{\theta}) = 1$, $F_\tau(\theta) = F(\theta)$, and $f_\tau(\theta) = f(\theta)$. The equation SFOC simplifies to:

$$q_\tau(\theta)^{1-\beta} = \overbrace{\frac{k\beta}{c_\tau}}^{\text{Inv. }\mu} \left[\overbrace{\theta - \frac{1-F(\theta)}{f(\theta)}}^{\text{Virtual Surplus}} - \overbrace{\frac{\theta\gamma_\tau(\theta)}{f(\theta)}}^{\text{LE}} + \overbrace{\frac{(1-\Gamma_\tau(\theta))}{f(\theta)}}^{\text{LE+IC}} + \overbrace{\frac{\sum_{s=0}^{\tau-1}(1-\Gamma_s(\theta))}{f(\theta)}}^{\text{Past LE + IC}} \right] \tag{3}$$

which resembles the typical solution to an adverse selection problem. In this solution, the allocation is determined by an inverse markup (μ) rule adjusted by the *modified virtual surplus*, which accounts for necessary rents due to incentive compatibility and the limited enforcement constraint.

First, as is typical, the amount of allocated quantities decreases as the inverse markup that a seller would charge under linear monopolist pricing (μ) increases.

Second, through the virtual surplus, higher types (θ) receive greater quantities, while the incentive compatibility constraint forces the seller to distort trade downward for lower types $(1-F(\theta))$, thus granting higher types informational rents. These are the common forces at play in non-linear pricing contracts (Maskin and Riley, 1984).

Third, when the current limited enforcement constraint is binding ($\gamma_\tau(\theta) > 0$), it restricts the volume of trade. Keeping the future stream of quantities constant, if the buyer is on the verge of defaulting, the seller needs to reduce tariffs immediately. However, to maximize profits by reducing total costs per dollar of revenue, the seller must also decrease quantities. Therefore, enforcement concerns lead to a reduction in contemporaneous quantities.

Fourth, a countervailing force exists: to maintain incentive compatibility and prevent low types from mimicking higher types, quantities are uniformly shifted upwards by $1-\Gamma_\tau(\theta)$. This countervailing force is also present in the static allocation equations in Jullien (2000) and Attanasio and Pastorino (2020).

Fifth, dynamic promises aimed at increasing future trade to incentivize the payment of debts are captured by the inclusion of past cumulative multipliers ($\sum_{s=0}^{\tau-1}(1-\Gamma_s(\theta))$). These multipliers generate the backloading of quantities, acting as a promise-keeping constraint where types whose limited enforcement constraint was binding in the past receive higher quantities in the present.

The equilibrium combination of $\Gamma_\tau(\theta)$, $\Gamma_s(\theta)$, and $\theta\gamma_\tau(\theta)$ determines whether the allocated quantity is greater or lower than it would be under full enforcement.

Returning to the general equation SFOC, it is worth highlighting the role of selection implied by the exit probability $X(\theta)$ in the allocation of quantities, as it generates two opposing forces.

On the one hand, the selection functions exert downward pressure on quantities through the virtual surplus and the cumulative multipliers. In the virtual surplus, positive selection ($X'(\theta) < 0$) implies lower quantities over time, all else being equal. This occurs as the selection pattern concentrates the distribution towards higher types over time, forcing the seller to decrease future quantities for middle types to maintain incentive compatibility. Moreover, selection also influences the promises captured through past cumulative multipliers. Ceteris paribus, if the selection function $X(\theta)$ implies first-order stochastic dominance over another selection function $\tilde{X}(\theta)$, i.e., $F_\tau(\theta) \leq \tilde{F}_\tau(\theta)$, the past cumulative multipliers move closer to one for each type. This shift reduces the upward push that past promises would normally provide.

On the other hand, the heterogeneity in exit rates implies relatively less discounting of past multipliers for middle and upper types. This means that as their past multipliers are discounted less, the impact of earlier promises is stronger for them. Consequently, compared to low types, the selection mechanism leads to more significant backloading of quantities for middle or high types.

3.5 Model Properties

Next, I discuss how the model rationalizes the stylized facts in Section 2. Formal proofs for the statements in this subsection and a two-type solved example appear in Online Appendix Section OA-4. That appendix also examines equilibrium contracts under individual relaxations of the model's constraints, showing that only the complete framework—incorporating both limited enforcement and asymmetric information—can fully explain the stylized facts.

Non-Stationarity. The optimal contract must be non-stationary, driven by the forces implied by the limited enforcement constraints (Proposition 3). In particular, these constraints create a dynamic asymmetry in incentives between buyer and seller. The buyer evaluates current tariffs relative to future net returns, which, all else being equal, incentivizes the seller to reduce current quantities while keeping current tariffs constant, thereby increasing current profits and still satisfying the enforcement constraint. Relative to the optimal stationary contract, it is possible to construct non-stationary deviations that increase initial profits, even in the presence of the incentive compatibility constraint stemming from asymmetric information.

Quantity Discounts. At each relationship age, the seller offers quantity discounts to maintain incentive compatibility (Proposition 4). The conditions needed to support such discounts are strengthened forms of the usual assumptions in non-linear pricing models (e.g., Maskin and Riley, 1984). Specifically, the evolution of distribution types $F_\tau(\theta)$ must preserve log-concavity and satisfy a modified monotone hazard condition, in addition to the standard requirement that quantities be strictly increasing in the buyer's type for each relationship age ($q'_\tau(\theta) > 0$).

Backloading of Quantities. The model rationalizes increases in quantity over time ($q_\tau(\theta) \leq q_{\tau+1}(\theta)$) if and only if enforcement constraints are relaxed ($\gamma_\tau(\theta) \leq \gamma_{\tau+1}(\theta)$) (Proposition 5, i.). Thus, the model permits quantity dynamics.

Moreover, absent selection patterns, the model explicitly predicts backloading of quantities. (Proposition 5, ii.) There exists a finite time period τ^* such that enforcement constraints are no longer binding for any type θ, causing the contract to converge to a long-term stationary equilibrium. In this equilibrium, quantities reach their highest levels for each type ($q_{\tau^*}(\theta) \geq q_\tau(\theta)$ for $\tau^* \geq \tau$).

Backloading of Prices. The model accommodates backloading of prices (Proposition 6). In particular, if the quantity schedule (weakly) increases over time for all buyers (and strictly for the lowest type), then the resulting increase in quantities forces a global decrease in prices to preserve local incentive compatibility.

3.6 Discussion of Modeling Assumptions

Although standard in the literature (Pavan et al., 2014; Garrett et al., 2018), the assumption that the seller can commit to the mechanism might be unrealistic in a setting where the buyer can defect and default. Despite this limitation, I adopt the commitment assumption as it allows me to focus on direct mechanisms through the standard revelation principle approach.

Another assumption is that the seller does not cheat on quality. This issue, combined with the lack of enforcement on the buyer's side, has been theoretically explored for two seller types by Martimort et al. (2017). While their framework could technically be applied, I do not follow it for several reasons. First, a model featuring seller opportunism would generate front-loaded prices, which is inconsistent with the data. Second, because a large share of trade is conducted via trade-credit, buyers can withhold payment if quality is subpar, reducing the scope for seller cheating (Smith, 1987; Klapper et al., 2012; Antras and Foley, 2015). Finally, the sellers in this study are larger, more capital-intensive, and more directly involved in input sourcing than the average manufacturing firm, reducing the likelihood of quality issues arising from production errors.

Buyer types are assumed fully persistent due to data limitations. While the model can accommodate Markov types, empirical implementation would require tracking new buyer transactions over time, which is infeasible with the two years of data available.

4 Identification

In this section, I discuss the identification of the model primitives θ and $v(\cdot)$ and the auxiliary functions $\Gamma_\tau(\cdot)$ and $\gamma_\tau(\cdot)$. Each of these primitives and auxiliary functions are seller-year-specific. The results presented here build on the identification work of Luo et al. (2018) and Attanasio and Pastorino (2020), but extend the analysis to a multi-period framework rather than a single-period problem. To derive a key identifying equation that maps data into primitives, I rely on the necessary conditions for the seller and the buyer as outlined in Proposition 1.

4.1 Observables and Known Objects

For each seller in a given year, the observables are unit prices $p_\tau(q)$ (or tariffs $T_\tau(q)$) and quantities q_τ for different buyers with relationship age τ, as well as marginal costs c.[19] Throughout this section, I abstract from the possibility of exogenous breakups; the possibility of breakups will be reintroduced in estimation.[20]

[19] The price schedule $T_\tau(\cdot)$ and its derivatives are nonparametrically identified from information on prices and quantities alone (Perrigne and Vuong, 2011), so in this section, I treat them as known. Moreover, I treat c as known, as I can backout average cost (across all product varieties) using information on total variable costs and total seller output.

[20] As exogenous breakups can be directly estimated from the data, they are treated as known during identification. Their inclusion would only complicate the notation without providing substantial insights regarding identification.

4.2 Identification Assumptions

I now begin by stating the identification assumptions (IA).

Identification Assumption 1. *Each seller offers a unique menu of dynamic contracts to all buyers, and such menu satisfies equations SFOC and t-RULE for all θ and τ.*

Identification Assumption 2. *Within each period, quantity increases strictly monotonically with type θ: $q'_\tau(\theta) > 0$.*

Identification Assumption 3. *The return function is of the form $v(q) = kq^\beta$, for $k > 0$ and $\beta \in (0,1)$.*

IA 1 guarantees the existence and uniqueness of the contract.[21] Moreover, instead of relying on forward iteration to solve the problem, IA 1 allows me to collapse all information about future unobserved quantities and tariffs into the limited enforcement multipliers.

IA 2 directly links observed quantities with underlying unobserved types, allowing us to infer that buyers purchasing higher quantities have higher types. IA 2 may fail under certain conditions, leading to quantities bunching over different types: (1) If the distribution of types $F_\tau(\theta)$ is non-continuous, presenting masses (jumps) at some type θ. (2) If the exit probability $X(\theta)$ is not smooth, implying jumps in future distribution of types. (3) If the exit probability $X(\theta)$ implies that the distribution $F_\tau(\theta)$ becomes log-convex.[22] (4) If the return function $v(\cdot)$ is too inelastic, making it difficult to implement incentive compatibility without significantly changing quantities. In such cases, bunching may be desirable to reduce losses from informational rents while preserving incentive compatibility.

Finally, through IA 3, I consider constant-elasticity parametrization for the return function $v(q)$, which will be essential for point identification of the primitives and auxiliary functions by restricting the number of parameters that need to be identified.

4.3 Deriving the Key Identification Equation

Exploiting the fact that the mapping from agent type θ to quantity q_τ is strictly monotone (IA 2), one can write the seller's first-order condition SFOC in terms of quantiles α:

$$k\beta\theta_\tau(\alpha)q_\tau(\alpha)^{\beta-1} - c = \left[\Gamma_\tau(\alpha) - \alpha - \sum_{s=0}^{\tau-1}(1-\Gamma_s(\alpha)) + \frac{\theta_\tau(\alpha)}{\theta'_\tau(\alpha)}\gamma_\tau(\alpha)\right] k\beta\theta_\tau(\alpha)q_\tau(\alpha)^{\beta-1}\frac{\theta'_\tau(\alpha)}{\theta_\tau(\alpha)}, \tag{I-Q}$$

[21] Although uniqueness assumptions are strong, they are often used in the identification of dynamic games, as these types of games may have multiple equilibria (Aguirregabiria and Nevo, 2013).

[22] In simulations, negative selection patterns ($X'(\theta) > 0$), which are not consistent with the data but a theoretical possibility nonetheless, lead to this.

as well as the derivative of the buyer's tariff rule t-RULE:

$$T'_\tau(q_\tau(\alpha)) = k\beta\theta_\tau(\alpha)q_\tau(\alpha)^{\beta-1}, \tag{I-T}$$

where $\alpha \in [0,1]$, $\theta_\tau(\alpha)$ and $q_\tau(\alpha)$ are the α-quantiles of the agent's type and quantity at tenure τ, respectively, and I used the fact that the observed tariff schedule can be mapped to the model tariff schedule by $T_\tau(q_\tau(\theta(\alpha))) = t_\tau(\theta(\alpha))$. Notice as well that I have linked past multipliers $\Gamma_s(\alpha)$ with the buyer's current quantile α, as types are fully persistent and quantiles are held fixed across tenures, and used the following relationships derived from IA 2: (i) $F_\tau(\theta(\alpha)) = \alpha$, (ii) $f_\tau(\theta(\alpha)) = 1/\theta'_\tau(\alpha)$, (iii) $\Gamma_\tau(\theta_\tau(\alpha)) = \Gamma_\tau(\alpha)$, and (iv) $\gamma_\tau(\theta(\alpha))\theta'_\tau(\alpha) = \gamma_\tau(\alpha)$.

By relying on I-T and the parametrization in IA 3, one can obtain the following expression for the ratio $\theta'_\tau(\alpha)/\theta_\tau(\alpha)$ in I-Q:

$$\frac{\theta'(\alpha)}{\theta(\alpha)} = q'_\tau(\alpha)\Big[\frac{T''(q(\alpha))}{T'(q(\alpha))} + \frac{1-\beta}{q_\tau(\alpha)}\Big], \tag{4}$$

which depends on functions of tariffs and quantities, and only one unknown elasticity parameter β.

Substituting I-T into I-Q, the key identification equation becomes:

$$\frac{T'_\tau(q_\tau(\alpha)) - c}{T'_\tau(q_\tau(\alpha))} = \frac{\theta'_\tau(\alpha)}{\theta_\tau(\alpha)}\Big[\Gamma_\tau(\alpha) - \alpha - \sum_{s=0}^{\tau-1}(1-\Gamma_s(\alpha))\Big] + \gamma_\tau(\alpha), \tag{I-EQ}$$

where $\Gamma_\tau(\cdot)$ and $\gamma_\tau(\cdot)$ are unknown, and the ratio $\theta'_\tau(\alpha)/\theta_\tau(\alpha)$ is given in 4 under IA 3. This equation will be the base for the identification of all unknown functions and parameters. Note that the full persistency of types, combined with IA 1, implies that the dynamic contract is identified using cross-sectional variation within cohorts for a given seller-year.

4.4 Identification Results

I now present point identification results.

Proposition 2. *Under IA 1, 2, and 3, the auxiliary functions $\Gamma_\tau(\cdot)$ and $\gamma_\tau(\cdot)$, and the elasticity parameter β are identified from cross-sectional data on prices, quantities and marginal costs from one seller. Moreover, the functions for types $\theta_\tau(\cdot)$ and $\theta'_\tau(\cdot)$ are identified over $\alpha \in [0,1]$ and the return function scale parameter k is identified.*

The proof is relegated to Appendix B. The argument involves the following four steps: (1) For the highest types $\alpha \approx 1$ at $\tau = 0$, the identification equation I-EQ is shown to depend solely on one unknown elasticity parameter β. This is because the cumulative multiplier can be unconditionally shown to be $\Gamma_0(1) = 1$, which in turn implies that the observed difference in marginal prices $T'(1)$ and marginal costs c directly reveals $\gamma_0(1)$. To a first-oder approximation, the equation I-EQ is known for each $\alpha \approx 1$ up to the unknown parameter β. Therefore, pooling the equations across the highest types, the cross-sectional variation in prices identifies β. (2) Once β is identified, the functions $\Gamma_0(\alpha)$ and $\gamma_0(\alpha)$ can be recovered for all types. They are determined as the unique solutions to an ordinary differential equation whose other components are known, which implies that the multipliers are point-identified. (3) With β and the multipliers for tenures $s < \tau$ already identified, the multipliers at tenure τ are recovered as the unique solutions to the corresponding ordinary differential equation. (4) Finally, having identified all multipliers, simply apply the identification argument in Luo et al. (2018) for static non-linear pricing problems to identify the distribution of types $\theta_\tau(\alpha)$. The scale parameter k is then recovered using known elements via equation I-T.

Although parametrizing $v(\cdot)$ via IA 3 yields point identification, in the estimation procedure I choose to parametrize $\Gamma_\tau(\cdot)$ as a flexible function of q_τ, rather than imposing a parametric form on $v(\cdot)$. This approach simplifies solving the differential equations for $\Gamma_\tau(\cdot)$ and $\gamma_\tau(\cdot)$, as it confines them to a known family of functions. As shown below, the return function $v(\cdot)$ is recovered semi-parametrically, in a manner consistent with the chosen parametrization of the multiplier functions.

4.5 Discussion of Limitations in Identification

In my methodology, I leverage the fact that the seller knows the optimal contract solution, which must satisfy the first-order conditions of both the seller and the buyer. Besides the benefits of allowing estimation without solving the full model through forward iteration, this assumption also proves useful if the model is misspecified. Specifically, it allows the buyer to have outside options that the econometrician does not observe, provided the seller is aware of these outside options. They are then incorporated into the enforcement constraints. Although the econometrician may not distinguish outside options from future promises, these factors do not create identification issues for the welfare analysis primitives.[23]

A key limitation of this approach is that it cannot handle counterfactuals involving dynamic quantities. Solving for those would require forward iteration solution methods. Nevertheless, this methodology yields valuable insights into the efficiency of *actual* trade, which is the paper's main focus.[24]

Finally, my identification results rely on observing (or using proxies for) marginal costs. The gap between prices and marginal costs indicates whether trade for the highest type is distorted by enforcement constraints. Previous work by Attanasio and Pastorino (2020) infers unobserved

[23]Mispecification of the model will affect the equilibrium tariff solution. For example, if buyers have a constant outside option, the equilibrium tariffs will be lower by the value of the outside option. However, this does not affect marginal prices or the primitives (such as the base marginal return or the type) identified from them.

[24]Model mispecification regarding outside options also affects counterfactuals under different enforcement or pricing regimes. If the outside options are constant, the counterfactual outcomes remain correct in terms of efficiency, though surplus division is biased in favor of the seller. When outside options are heterogeneous, the counterfactual efficiency may also be affected; the direction of this bias is uncertain *ex-ante* and depends on the distribution of types and the curvature of the return function.

costs via the parametrization of the multipliers, thereby jointly identifying costs consistent with those multipliers. In the same vein, Luo et al. (2018) identifies costs by assuming that, in the absence of enforcement constraints, trade for the highest type is efficient, with marginal prices equating marginal costs. By drawing on production-cost data for sellers, I can relax these assumptions.

5 Estimation

In this section, I first describe the estimation sample and define relationship tenure used in estimation. Then, I present the Intermediate Steps used to estimate the objects that are assumed to be known for identification purposes but need to be estimated from finite data. Lastly, I describe the Main Steps in the estimation process to recover the primivities and auxiliary functions, which rely on a cross-sectional approach using the main identification equation with the available data for each seller-year separately.

5.1 Definitions of Relationship Tenure and Estimation Sample

To facilitate estimation and reduce measurement error in relationship ages, I impose two restrictions. First, I require that buyers have at least one previous relationship with some seller (not necessarily those in my sample) prior to 2016.[25] Second, I pool relationship ages using the following classification method and define *relationship tenure* between seller i and buyer j at year t as:

$$tenure_{ijt} = \begin{cases} \text{pair-age}_{ijt} & \text{if pair-age}_{ijt} < 5, \\ 5 & \text{if pair-age}_{ijt} \geq 5. \end{cases}$$

I bunch all older relationships together to ensure a sample large enough for estimation.[26]

The final sample with the estimated structural model consists of 24 sellers with information for both 2016 and 2017, and 25 sellers with information for either 2016 or 2017. I consider these 73 seller-year observations on their own, but use sellers that appear in multiple years to validate the fit over time.

5.2 Estimation of Objects Assumed as Known in Identification

Before reaching the key estimating equation, there are three intermediate steps to recover the objects assumed as known in identification. Namely, I detail the steps to recover the 1) tariff function, 2) the heterogeneous exit/survival rates, and 3) the marginal costs.

[25] I verify that this restriction is not driving the results by estimating the model with *all* available buyers, despite the possible measurement error in the age of the relationship. Overall, results are very consistent with those presented here. Results of this robustness check are available upon request.

[26] The threshold at $+5$ is not driving the results, as results are robust to using higher threshold values.

Intermediate Step 1: Tariff Function. For identification, I treated the tariff function $T_\tau(\cdot)$ as given. However, I observe only pairs of payments and quantities $(t_{i\tau}, q_{i\tau})$ for $i = 1, 2, ..., N_\tau$ for each tenure. The pricing model discussed in Section 3 implies that observed tariffs lie on the curve $t_{i\tau} = T_\tau(q_\tau(\theta_i \tau))$, as they are both functions of the type $\theta_{i\tau}$ in a given tenure. However, observed prices and quantities may not lie on the curve, if there is measurement error or further unobserved heterogeneity beyond quantity and relationship age, introducing additional randomness beyond $\theta_{i\tau}$.

To deal with this additional randomness, I follow Perrigne and Vuong (2011), who show that the tariff function is nonparametrically identified under the assumption that observed tariffs differ from optimal tariffs due to random measurement error. In particular, observed tariffs are a function of optimal tariffs $t_{i\tau} = T_\tau(q_{i\tau})e^{\upsilon_{i\tau}}$, such that $\upsilon_{i\tau}$ is independent of $q_{i\tau}$.

I consider a parametric version of the model, in which $T_\tau(q) = e^{\rho_{0\tau}} q^{\rho_{1\tau}}$. This leads to the estimation model with measurement error:

$$ln(t_{i\tau}) = \rho_{0\tau} + \rho_{1\tau} ln(q_{i\tau}) + \upsilon_{i\tau}, \tag{5}$$

where $t_{i\tau}$ is the observed tariff and $q_{i\tau}$ is the observed quantities for buyer i with tenure τ. Under the given assumption of independence, the tariff schedule can be estimated via ordinary least squares. The estimated tariff schedule linking observed quantities is $\widehat{T}_\tau(q_{i\tau}) = e^{\hat{\rho}_{0\tau}} q_{i\tau}^{\hat{\rho}_{1\tau}}$, while the marginal tariff is $\widehat{T}'_\tau(q_{i\tau}) = \hat{\rho}_{1\tau} t_{i\tau}/q_{i\tau}$. Note that I allow for differences in tariff schedules across τ, responding to the dynamic treatment of the problem, i.e., the same level of quantity q may have different associated tariffs if the buyer-seller relationship is new or has been sustained for some years.

Intermediate Step 2: Heterogeneous Survival Rates. I estimate heterogeneous survival rates $S(\cdot)$, i.e., $(1 - X(\cdot))$, at the percentile-tenure level. In particular, I rank buyers in percentiles of quantity for each tenure in 2016. I then calculate the share of buyers in each percentile that survived until 2017. To reduce noise and preserve monotonicity and smoothness of the survival rate, I then approximate the estimated nonparametric survival rates as a logistic function of percentiles:

$$S_\tau(r) = \frac{\exp(a_\tau + b_\tau r)}{1 + \exp(a_\tau + b_\tau r)} + \varepsilon^s_\tau(r), \tag{6}$$

where $S_\tau(r)$ is the share of buyers surviving from 2016 until 2017 in percentile rank r for tenure τ and $\varepsilon^s_\tau(r)$ is Gaussian noise orthogonal to r.

Intermediate Step 3: Marginal Cost. Marginal cost is estimated directly from the data under the assumption of constant marginal cost, which implies marginal cost is equal to average variable cost. I present validating exercises for this assumption in my setting in Online Appendix Section OA-7.[27] Therefore, I recover average variable cost by dividing the sum of total expenditures and total wages by the total quantity sold for each seller-year.

5.3 Estimation of the Primitives and Auxiliary Functions

Now, I detail how to recover the auxiliary functions $\Gamma_\tau(\cdot)$ and the primitives θ and $v(\cdot)$, as well as their derivatives, by relying on the key identification equation I-EQ.

Main Step 1: Auxiliary Functions $\Gamma_\tau(\cdot)$ and $\gamma_\tau(\cdot)$. First, to recover the auxiliary functions $\Gamma_\tau(\cdot)$ and $\gamma_\tau(\cdot)$, I rely on an iterative approach, starting at $\tau = 0$, assuming that an estimate for $\Gamma_s(\cdot)$ for $\tau > s$ is already available from previous iterations.[28]

With the survival rates, marginal costs, and tariff functions in hand, the empirical analog of the key identifying equation I-EQ is given by:

$$\frac{\widehat{T}'_\tau(q_{i\tau}) - \widehat{c}}{\widehat{T}'_\tau(q_{i\tau})} = \frac{\theta'_\tau(\alpha)}{\theta_\tau(\alpha)}\left[\Gamma_\tau(\alpha) - \alpha - \sum_{s=0}^{\tau-1}(1 - \widehat{\Gamma}^\tau_s(\alpha))\right] + \gamma_\tau(\alpha), \tag{7}$$

where the past conditional cumulative multiplier estimates $\widehat{\Gamma}^\tau_s(\alpha)$ for $s < \tau$ are obtained via numerical integration.[29]

Equation 7 contains multiple unknown functions. Above, I demonstrated that parametrizing $v(\cdot)$ (IA 3) is sufficient for nonparametrically identifying the auxiliary functions. However, instead of relying on the parametrization of the return function $v(\cdot)$, I leverage the fact that the LE multiplier $\Gamma_\tau(\alpha)$ possesses the properties of a cumulative distribution function.[30] Thus, I parametrize the multiplier as a logistic distribution:

$$\Gamma_\tau(\alpha) = \frac{exp(\phi_\tau(q_\tau(\alpha)))}{1 + exp(\phi_\tau(q_\tau(\alpha)))}, \tag{8}$$

where $\phi_\tau(q_\tau(\alpha))$ is a linear polynomial.[31] Under this parametrization, the derivative of the multiplier is $\gamma_\tau(\alpha) = \phi'_\tau(q_\tau(\alpha))\Gamma_\tau(\alpha)(1 - \Gamma_\tau(\alpha))$. As mentioned above, the parametrization over $\Gamma_\tau(\cdot)$ simplifies the estimation approach, as the solution to the differential equations for $\Gamma_\tau(\cdot)$ and $\gamma_\tau(\cdot)$ are restricted to depend on the same parameters.

[27] In particular, I show that average variable costs are highly serially correlated within a given seller and that a test for constancy of marginal costs relying on demand-side instruments fails to reject constancy.

[28] Although the iterative approach may introduce propagation errors from earlier stages, joint estimation is infeasible because it requires numerically integrating past cumulative multipliers as an extra step during the parameter search. Joint estimation is viable if hazard rates are homogeneous or if relationships never terminate.

[29] Specifically, I numerically integrate the function $\left(\widehat{S}_\tau(\alpha)\right)^{\tau-s}\widehat{\gamma}^\tau_s(\alpha)$ using inverse transform sampling for each quantile α. Here, $\widehat{S}_\tau(\alpha)$ is the estimated survival rate from *Intermediate Step 2*, and $\widehat{\gamma}^\tau_s(\alpha)$ is the derivative of the cumulative multiplier at period s that corresponds to a buyer in quantile α during period τ. To match multipliers s periods ago, I rely on the estimated survival rates to generate a percentile-percentile transition matrix. This matrix allows me to align percentiles α_s for $s < \tau$ with percentiles α_τ.

[30] See Appendix A, which shows $\Gamma_\tau(\cdot)$ is non-negative, non-decreasing, and with boundary $\Gamma_\tau(1) = 1$.

[31] The multiplier function is the solution to a differential equation. As shown in Online Appendix Section OA-4.1.2, it is a function of the cumulative distribution of types θ, the marginal cost, and the expected base marginal return (i.e., depends on the curvature of the return function).

To compensate for the restrictions on the LE multipliers, I consider instead a flexible function for $\theta'(\alpha)/\theta(\alpha)$, specifically as an inverse quadratic function of quantity:

$$\frac{\theta'(\alpha)}{\theta(\alpha)} = \frac{1}{d_0 + d_1 q_\tau(\alpha) + d_2 q_\tau(\alpha)^2}. \tag{9}$$

All together, the key identification equation I-EQ is translated into the following estimating equation:

$$\begin{aligned}\frac{\hat{\rho}_{1\tau} p_\tau(\alpha) - \widehat{c}}{\hat{\rho}_{1\tau} p_\tau(\alpha)} = & \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad \text{(Main Est. Eq.)}\\ & \frac{1}{d_0 + d_1 q_\tau(\alpha) + d_2 q_\tau(\alpha)^2}\Big[\frac{exp(\phi_\tau(q_\tau(\alpha)))}{1+exp(\phi_\tau(q_\tau(\alpha)))} - \alpha - \widehat{M}_\tau(\alpha)\Big] \\ & + \phi'_\tau(q_\tau(\alpha))\frac{exp(\phi_\tau(q_\tau(\alpha)))}{1+exp(\phi_\tau(q_\tau(\alpha)))}\Big(1 - \frac{exp(\phi_\tau(q_\tau(\alpha)))}{1+exp(\phi_\tau(q_\tau(\alpha)))}\Big) + \varepsilon^g_\tau(\alpha),\end{aligned}$$

where I have used $p_{i\tau} = t_{i\tau}/q_{i\tau}$ and where ε^g is measurement error arising from the mispecification in the functional forms used in estimation. Moreover, past multipliers are captured by $\widehat{M}_\tau(\alpha) \equiv \sum_{s=0}^{\tau-1}(1 - \widehat{\Gamma}^\tau_s(\alpha))$ for $s < \tau$ estimated in earlier stages and taken in τ as given. The equation is estimated via maximum likelihood under the assumption that ε^g is drawn from a Gaussian with parameters $(0, \sigma^{\varepsilon^g})$. This step in the estimation process recovers the parameters $\{\phi_\tau, d_0, d_1, d_2, \sigma^{\varepsilon^g}\}$.

Main Step 2: Buyer Types θ. Once $\Gamma_\tau(\cdot)$ and $\gamma_\tau(\cdot)$ are estimated, the consumer type $\theta_\tau(\alpha)$ is obtained from

$$ln(\widehat{\theta}_\tau(\alpha)) = \frac{1}{N_\tau}\sum_{k=1}^{N_\tau}\frac{1\{\alpha \geq k/N_\tau\}}{\widehat{\Gamma}_\tau(k/N_\tau) - k/N_\tau - \widehat{M}_\tau(k/N_\tau)}\Big[1 - \frac{\widehat{c}}{\hat{\rho}_{1\tau} p_\tau(k/N_\tau)} - \widehat{\gamma}_\tau(k/N_\tau)\Big], \tag{10}$$

for $\alpha \in [0, (N_\tau - 1)/N_\tau]$ and where N_τ is the total count of buyers of tenure τ. The estimator for $\theta'_\tau(\alpha)$ is

$$\widehat{\theta'}_\tau(\alpha) = \frac{\widehat{\theta}_\tau(\alpha)}{\widehat{\Gamma}_\tau(\alpha) - \alpha - \widehat{M}_\tau(k/N_\tau)}\Big[1 - \frac{\widehat{c}}{\hat{\rho}_{1\tau} p_\tau(\alpha)} - \widehat{\gamma}_\tau(\alpha)\Big], \tag{11}$$

and corresponding density function $\widehat{f}_\tau(\theta(\alpha))$ is $1/\widehat{\theta'}_\tau(\alpha)$.

Main Step 3: Base Marginal Return $v'(\cdot)$ and Return Function $v(\cdot)$. The derivative of the tariff rule links the base marginal return with the marginal tariff and the consumer type: $v'(q_\tau(\alpha)) = T'_\tau(q_\tau(\alpha))/\theta_\tau(\alpha)$. Therefore, an estimator for the base marginal return is

$$v'\widehat{(q_\tau(\alpha))} = \frac{\hat{\rho}_{1\tau} p_\tau(\alpha)}{\widehat{\theta}_\tau(\alpha)} \tag{12}$$

and $v(\cdot)$ is estimated by

$$v(q_\tau(\alpha)) = \widehat{T}_\tau(q_\tau(0)) + \frac{1}{N_\tau}\sum_{k=1}^{N_\tau} v'(\widehat{q_\tau(k/N_\tau)})1\{\alpha \geq k/N_\tau\}. \tag{13}$$

These semi-parametric estimators for the return function are thus constructed to be consistent with the parametrization of the LE multipliers.

Parametrization of $v(\cdot)$ for Welfare and Counterfactual Analysis. To calculate pair-specific efficient (first-best) quantities, I require estimates of buyer types θ, baseline marginal returns $v'(\cdot)$, and seller marginal costs c. However, the range of optimal quantities may fall outside the range of realized quantities, potentially rendering baseline marginal returns undefined for certain values. To address this issue in the welfare and counterfactual analyses, I parametrize seller-specific marginal return functions, $v(\cdot)$, as $v(q) = kq^\beta$, where $k > 0$ and $\beta \in (0,1)$. These functions are then estimated for each seller-year using linear least squares with the estimated semi-parametric marginal returns, $\widehat{v'(\cdot)}$. Specifically, I estimate:

$$\ln(\widehat{v'}_{i\tau}) = \ln(k\beta) + (\beta - 1)\ln(q_{i\tau}) + \varepsilon_{i\tau},$$

using observations for buyer i and tenure τ and where $\varepsilon_{i\tau}$ is a Gaussian error term.

6 Estimation Results and Model Fit

In this section, present the estimates of primitives and auxiliary functions of the model, and show the data fit.[32] The results are shown pooling all sellers together but the estimation is conducted at the seller-year level. My model relies on the following seller-dependent ingredients: the initial distribution of private types θ, the base return function $v(\cdot)$, and the limited enforcement multipliers $\Gamma_\tau(\cdot)$ for tenure $\tau \in \{0, 1, \ldots, 4, 5\}$.

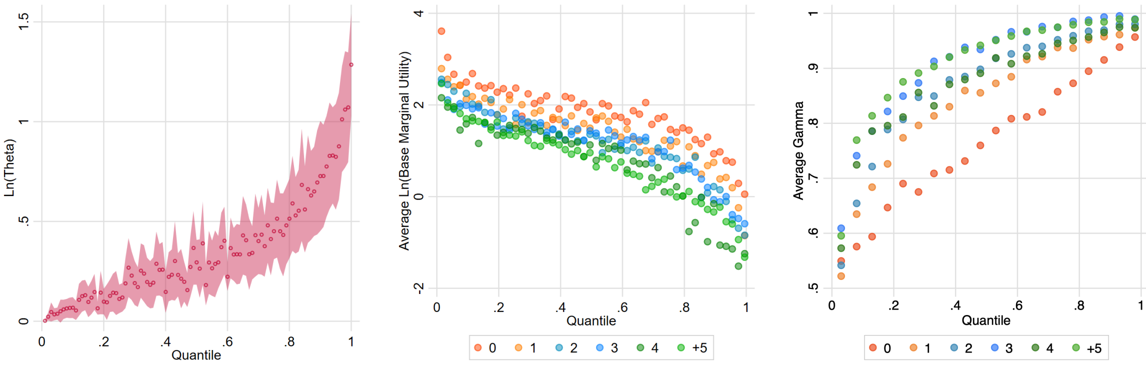
First, Figure 2a shows the average estimated log type θ by quantile of quantity for tenure 0, with error bars showing the dispersion across sellers for a given quantile.[33] The figure illustrates that, on average across sellers, types tend to increase with the quantity purchased, with a more significant increase in the top quantiles of quantities.

Next, Figure 2b plots the average estimated base marginal return $v'(\cdot)$ by quantity quantile and relationship tenure. Consistent with the model, the base marginal return function $v'(\cdot)$ decreases as quantity increases for all tenures. Additionally, the figure reveals that the functions $v'(\cdot)$ for older tenures shift downwards for many quantiles, reflecting the greater consumption levels as time goes by. These patterns suggest that the parametrization of the multiplier function

[32] Model fit of the tariff function is available in Online Appendix Section OA-8.0.1, while estimates of the survival functions by tenure in Online Appendix Section OA-8.1.

[33] For seller-year estimates of the distribution of types per seller-year, with confidence intervals constructed via bootstrap, refer to the Online Appendix Section OA-8.6.

Figure 2: **Estimated Primitives and Auxiliary Functions**



(a) Type (b) Base Marginal Return (c) Average Multiplier Γ_τ

Notes: Sub-figure (a) shows the average log type $ln(\theta)$ by quantile of quantity, across-sellers, with error bars representing the dispersion of ± 1.96 standard errors for each quantile across sellers. Sub-figure (b) displays the average base marginal returns, across-sellers, for different estimation tenure groups, by quantile of quantity. Sub-figure (c) presents the average estimated limited enforcement multiplier by tenure and quantile of quantity, across-sellers.

rather than the base return function provides sensible results. Moreover, the estimated values have a clear economic interpretation, as $v'(\cdot)$ represents the marginal revenue for the buyer of an extra unit of the good for a given type. For the median new buyer (respectively, tenure 5), spending one dollar on manufacturing the good generates 2.5 (1.25) dollars of revenue for the buyer (Online Appendix Figure OA-17), which suggests that inefficiencies are more prevalent in new relationships than in older ones.

Since the buyer is purchasing inputs using trade-credit, it is possible to translate the figures into the marginal product of capital (MPK) per dollar price of credit (interest rate). The MPK measures the return the buyer would receive if given an extra unit of the input at their transaction price. I find a wedge of 40% between MPK and the transaction price for the median new relationship and 34% for the median tenure 5 relationship. Although these wedges are smaller than the gaps of 80% estimated for Indian firms by Banerjee and Duflo (2014), they are larger than the average gaps of 6% calculated by Blouin and Macchiavello (2019) in the international coffee market.[34]

Finally, Figure 2c presents the average estimated limited enforcement multiplier $\Gamma_\tau(\cdot)$. The figure indicates that almost all new pairs are constrained, as the average multiplier $\Gamma_0(\cdot)$ equals only 1 for the top 1% of pairs, on average across sellers. However, as time goes by, the average multiplier approaches 1 for lower quantiles of trade, suggesting that the limited enforcement constraint becomes less restrictive over time.[35]

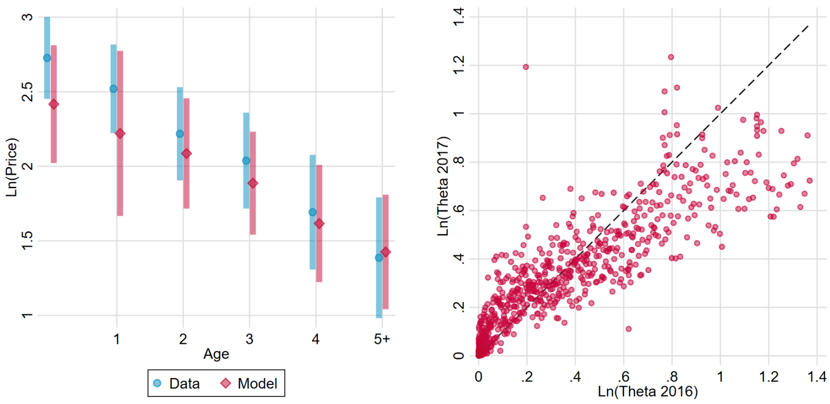
[34]It is important to note that the estimated gaps for micro-enterprises are even greater, ranging from 300% to 500% in Mexico (McKenzie and Woodruff, 2008). However, since the median buyer in my sample has total yearly sales of USD 200,000, they cannot be directly compared to micro-enterprises.

[35]The estimates for the multiplier allows us to test the model against the standard asymmetric information

6.1 Model Fit

I use five different measures to assess the fit of the model. First, the model has good statistical fit across tenures (Online Appendix Figure OA-18). While the fit does deteriorate over time and propagation bias is evident from a one-sided dispersion in the moment condition, it remains reasonable across tenures, with an average R-squared of 0.51 at tenure 0 and 0.42 at tenure 5. Second, I compare the observed quantities with model-predicted quantities. The predicted quantities, obtained using the closed-form solution of the seller's first-order condition under the parametrization of $v(\cdot)$, match well with the observed quantities across all tenures (Online Appendix Figure OA-19). Third, using the predicted quantities and the incentive-compatible tariff function (t-RULE), I generate predicted tariffs. The model-generated tariffs match the observed tariffs well across tenures (Online Appendix Figure OA-20).

Figure 3: **Non-targeted Moments**



(a) Price Discounts (b) Type in 2016 v. 2017

Notes: Sub-figure (a) presents a plot of unit prices by tenure over time using a binscatter plot, comparing prices in the data with model-generated prices. Model-generated unit prices are calculated by dividing model-generated tariffs by model-generated quantities. The error bars represent 95% confidence intervals, with standard errors clustered at the seller-year level. Sub-figure (b) shows the estimated types θ in 2017 plotted against those estimated in 2016, for buyer-seller pairs that appear in both years. These estimates were obtained through separate seller-specific estimations for each year using cross-sectional variation only. The dashed line represents the 45 degree line.

Fourth, I compare the non-targeted observed cross-sectional unit price discounts by tenure to those generated by the model in Figure 3a. The model replicates the observed discounts quite well.

To validate the model's within-pair dynamics, I consider a fifth validation exercise. I use the panel structure to verify that the primitives of the model are similar over time within pairs. Given that the model is estimated using cross-sectional information for each seller separately in 2016 and 2017, Figure 3b shows the value of estimated $\widehat{\theta}$ in 2017 against the value of estimated

model. Online Appendix Table OA-8.2 displays the distribution of t-statistics for the LE multiplier at tenure 0 (Γ_0) to test against the null hypothesis of a standard model. Based on the t-statistics, I reject the null that the standard non-linear pricing model applies in my setup for 86% of the markets (seller-years).

$\widehat{\theta}$ in 2016 for pairs that are active in both years. The figure illustrates a good correspondence between both estimated values, with the markers overlaying the diagonal in the graph. This result helps validate both the estimation procedure, as similar results are obtained via two independent estimation processes, and the persistency assumption for the types.

7 Welfare and Counterfactuals

In this section, I analyze the efficiency of relationships over time using the estimated model, while relying on the parametric estimates of $v(\cdot)$ (Online Appendix Table OA-13). Additionally, I evaluate the welfare performance of different pricing and enforcement schemes. I focus on three margins: (a) perfect enforcement with non-linear pricing, (b) limited enforcement with uniform pricing, and (c) perfect enforcement with uniform pricing.

7.1 Efficiency Relative to First-Best

Under the parametrization $v(q) = kq^{\beta}$, the first-best quantities for each pair are given by:

$$q^{fb}(\theta) = \left(\frac{k\beta\theta}{c}\right)^{1/(1-\beta)}. \tag{14}$$

Moreover, total surplus is a function of the buyer's type θ, quantity q, and seller's marginal cost c: $Surplus(\theta, q, c) = \theta k q^{\beta} - cq$. Hence, the static efficiency of allocation q for buyer type θ is defined as:

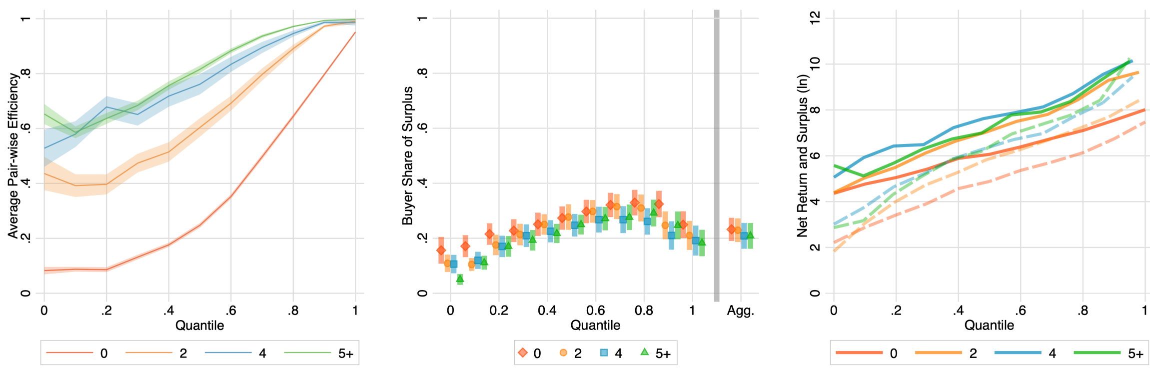
$$\text{Efficiency}(\theta, q, c) = \frac{Surplus(\theta, q, c)}{\max_q Surplus(\theta, q, c)}.$$

Figure 4a plots the average efficiency for each tenure across quantity deciles, averaging over all pairs, excluding tenure 1 and 3 for clearer visualization. The figure shows that new relationships are severely constrained, with the median buyer trading at only around 30% of their optimal level. However, as relationships age, efficiency increases. The median buyer trades at 60% of optimal levels at tenure 2, 75% at tenure 4, and over 80% at tenure 5. Additionally, the figure demonstrates significant heterogeneity in traded efficiency within relationship age: partners trading little experience greater distortions than partners trading more intensively.

While the general theoretical model does not yield precise estimates, the observed patterns of efficiency increasing with age and quantities can be explained by two key features of the model. First, to maintain incentive compatibility, higher types must receive higher quantities, resulting in lower distortions at the top compared to the bottom. Second, as trade is initially constrained and quantities are backloaded, increasing over time, efficiency is expected to increase.[36] However, the model does not mechanically imply an increase in efficiency over time.

[36] The backloading of prices and quantities is primarily concentrated among lower types, which helps explain the high efficiency of high types early on (Online Appendix Figure OA-5).

Figure 4: **Efficiency and Buyer Surplus**



(a) Efficiency (b) Buyer Surplus (c) Surplus & Net Return

Notes: Sub-figure (a) presents average efficiency by quantile of quantity and tenure across all buyer-seller pairs. Error bars show dispersion of ± 1.96 standard errors for each quantile across pairs. Sub-figure (b) shows average buyer share of surplus for quantile of quantity and tenure across all sellers. Error bars show ± 1.96 standard errors, clustered at the seller-year level. Sub-figure (c) plots average (log) surplus in solid lines and average (log) buyer net return in dashed lines by quantile of quantity and tenure, averaging across sellers.

If initial trade levels were close to or above efficient levels, higher quantities would lead to inefficient trade.

Of course, this characterization of efficiency might be too strict if the majority of trade is channeled through large buyers. To account for intensity-inclusive efficiency, I study the weighted average efficiency of all transactions per seller. This approach considers the potential efficiency losses and constructs weights using the share of total efficient quantities at a given tenure. Under this measure, the total output is inefficient early on but converges towards efficiency in the medium and long term. In Panel (a) of Table 1, I report the share of sellers trading at efficient levels, both in average total output and with the average buyer.[37] The results indicate that only 5% of sellers are trading efficiently with new buyers, but efficiency increases quickly, with 70% of sellers trading efficiently by tenure 2. In the long term, 84% of sellers transact with their buyers at efficient levels.

To better understand the long-term efficiency of relationships across different selling sectors, I present the share of sellers trading at aggregate efficient levels in Panel (b) of Table 1. While at the beginning of relationships almost no seller is trading efficiently, efficiency levels start to diverge at tenure 2. Starting at this point, Textiles shows slower growth in efficiency, while Pharmaceutical and Cement-Products continue to improve. By tenure 5, almost all Pharmaceutical and Cement-Products sellers are trading at aggregate efficient levels, while 70% of Textiles sellers do so. Despite this heterogeneity across sectors, the general takeaway is clear: even in different sectors, aggregate trade efficiency is high in the medium and long term.

[37] I test for seller-level efficiency via 30 bootstrap simulations and consider a seller's output efficient if the 95th percentile of weighted surplus is within 1% of efficiency.

Table 1: **% Share of Sellers with Efficient Trade**

	Tenure					
	0	1	2	3	4	5
Panel (a): All Sectors						
Weighted	5	41	70	79	75	84
Unweighted	5	23	32	37	38	30
Panel (b): Weighted, By Sector						
Textiles	6	45	59	64	64	68
Pharmaceutical	0	31	73	88	73	88
Cement-Products	13	50	75	87	87	95

Notes: This table reports the share of sellers that trade efficiently. Panel (a) presents results across all sectors. The first measure (Weighted) computes the share of sellers whose weighted average output cannot be rejected to be different from the efficient output at the 10% level. The weights are constructed over potential output for each seller-tenure. The second measures (Unweighted) computes the share of sellers for which the surplus created by the average buyer cannot be rejected to be different from efficient at the 10% level. Panel (b) presents results using the Weighted measure for each selling sector.

To provide a benchmark for the estimated inefficiencies due to imperfect contracting, it is helpful to compare these results to previous estimates in the literature. While the specific settings and frictions may vary, this comparison offers valuable insights. For instance, Blouin and Macchiavello (2019) find that strategic default reduces output by 16% for the mean relationship, with only 26% of relationships operating at first-best. Similarly, Ryan (2020) finds that weak contract enforcement reduces efficiency by 10% on average, while Startz (2024) finds that jointly contracting and search frictions reduce welfare by 9%. In contrast, the results presented in this paper offer a dire look at the relationship level, with average output at only 38% of first-best. However, when weighting for the size of relationships, the estimated inefficiencies are more moderate and in line with the literature, with a weighted average loss of 15%. It is worth highlighting that the previous studies only estimate efficiency for stationary relationships, whereas this paper offers efficiency estimates over the lifespan of a relationship. Additionally, these magnitudes of relationship-level inefficiencies may not be specific to developing countries, as contemporaneous work by Harris and Nguyen (2022) finds that the median relationship in the US trucking industry achieves only 44% of first-best output.

To analyze surplus division, I present Figure 4b. This figure displays the average share of surplus captured by buyers, across sellers, by bins over quantiles of quantity purchased at different tenures. The results show that sellers capture the majority of the surplus, with the median buyer in any tenure capturing around 25 percent of the generated surplus. The figure also reveals that, consistent with the non-linear pricing scheme, buyers who trade more intensively tend to capture a larger share of the surplus, up to 35 percent. However, the smallest buyers may capture less than 10 percent of the total surplus. In the aggregate, sellers capture an average of

80% of all surplus created, and this share is relatively constant over time. The combination of results showing that (1) sellers capture the majority of surplus and (2) sellers have the ability to extract different levels of surplus across different buyers can be seen as evidence that sellers indeed have market power in this setting.

The general flattening of the buyer share of surplus for the highest types does not reflect that middle types obtain greater net returns. Indeed, Figure 4c shows the net return of buyers in dashed lines as well as the total surplus in solid lines. Both total surplus and buyer's net return increase with quantile, with higher types obtaining higher net returns within tenure, in line with the requirements for incentive compatibility. Moreover, the total amount of net return captured by buyers grows over time. Instead, the non-linearity in the buyer share of surplus reflects the underlying distribution of types. In simulations not shown here, I find that extreme-valued distributions show the non-linear pattern in the buyer share of surplus, while for uniform distributions the buyer share of surplus increases monotonically with quantile. This is because the surplus at the highest types is growing faster than the amount of net return received.

A similar intuition helps explain why the aggregate buyer share of surplus is relatively constant over time. In particular, within a given type, if quantities increase relatively faster than prices decrease, the share of surplus can be kept constant or even decrease.

7.2 Counterfactuals

Next, I use the estimated model to explore the implications of improving the enforcement of trade-credit contracts and enforcing current Ecuadorian legislation that forbids price discrimination on identical transactions. I consider three counterfactual scenarios, explained below. Details on the computations of each counterfactual are provided in Online Appendix Section OA-9.1.

Counterfactual (a): Non-linear pricing with perfect enforcement. One natural question is to consider what the surplus would be in a world of perfect enforcement of contracts, mimicking a policy that improves court efficiency. This is implemented by allowing the seller to use non-linear pricing but forbidding the buyer to default.

Counterfactual (b): Uniform pricing with limited enforcement. Alternatively, one may address other frictions in the model. While asymmetric information is a friction generating distortions relative to the first-best (the seller distorts quantities for some buyers to incentivize the revelation of private information), another key friction is the ability of the seller to charge prices above marginal costs. Absent enforcement constraints, if the seller were not able to charge prices above marginal costs, trade would be efficient under incomplete information too. Thus, market power expressed as prices over marginal costs generates distortions. For a policymaker, policies addressing pricing power may be easier to design and enforce than policies addressing pair-specific information asymmetry.

Therefore, I consider a counterfactual policy aimed at addressing market power. Written law in Ecuador, the European Union, and the US forbids price discrimination that applies differential treatment to customers performing an otherwise equivalent transaction, including possibly preferential treatment due to tenure.[38] Under the model assumptions (constant marginal costs), any price discrimination would be unlawful and thus of interest to a policymaker as well. As such, this counterfactual studies the welfare effects of a policy that enforces uniform pricing but keeps the limited enforcement regime active.

Counterfactual (c): Uniform pricing with perfect enforcement. Lastly, I consider addressing both market power and enforcement.[39] The policy forbids price discrimination by enforcing uniform markups and forbids buyer default.

Discussion of Counterfactual Results. Table 2 shows the counterfactual results, displaying average surplus (as a percentage of the baseline) for each percentile group—formed by grouping quantiles of quantity—and tenure, and aggregate results weighted by observed quantities for each tenure.[40]

Counterfactual (a): Non-linear pricing with perfect enforcement. Panel (a) shows the results. The policy exercise generates an inter-temporal trade-off for middle and low types, as fixing enforcement generates massive gains for them in the early stages of the relationship. That is, weak enforcement forces the seller to create further downward distortions for low- and middle-types when buyers can default on trade. Fixing enforcement alone would increase surplus for 75% of the buyers in tenure 0 and 1. However, as relationships age, contract enforcement distortions become of second order. By tenure 3 and onward, limited enforcement contracts actually help discipline the downward distortions from non-linear pricing by the seller. Fixing enforcement would decrease the generated surplus in old relationships for essentially all buyers, as the seller increases quantities over time to incentivize debt repayment from the buyer side. In the long term, the threat of default is sufficient to overcome sellers' downward output distortions

[38]In Ecuador, Art. 9 of *Ley Orgánica de Regulación y Control del Poder de Mercado*. In the EU, Art. 102(c) of *Treaty on the Functioning of the European Union* (ex of Art. 82(c) of. *EC Treaty*). In the US, Section 2(a) of the *Robinson-Patman Act*. In practice, only the EU has enforced such a law in court. See, for instance, the cases *Hoffmann-La Roche v. Commission* and *Manufacture française des pneumatiques Michelin v Commission*. In the US, *some* variants of preferential pricing (such as loyalty discounts in multiproduct markets) have been upheld in court. See, for instance, cases *LePage's v 3M* and *SmithKline v Eli Lilly*. Moreover, in the US, discounts below cost are seen as anticompetitive (see *Eisai Inc. v. Sanofi-Aventis U.S., LLC*). In Ecuador, no cases have been brought to court regarding the specific Art 9.

[39]There are instances of real-world examples of policy reforms aimed at addressing payment enforcement and market power jointly or concurrently. For instance, the U.K. demonstrates concurrent independent reforms. The Late Payment of Commercial Debts (Interest) Act (1998, Amended 2013) addresses late payments by imposing penalties and establishing enforcement mechanisms. Separately, Section 18 of the Competition Act 1998 prohibits unequal treatment of equivalent transactions, targeting market power abuse. Conversely, the U.S. exemplifies joint reforms. The Packers and Stockyards Act of 1921 encompasses both payment enforcement and competition concerns. It mandates prompt payment for livestock sellers, prohibits unfair pricing practices that favor certain trading partners, and empowers the Department of Agriculture to enforce these provisions.

[40]Additional results for the three counterfactual exercises related to buyer net return, profits, and prices are presented in Online Appendix Section OA-9.2, where the table reports the percentage of observations in the baseline with a greater value in the specific category (e.g., prices) relative to the counterfactual.

Table 2: **Average Surplus as % of Baseline**

	10%	25%	50%	75%	100%	Agg.	10%	25%	50%	75%	100%	Agg.
	Panel (a): Non-linear + Perfect Enforcement						*Panel (c): Uniform + Perfect Enforcement*					
Tenure 0	1,508.4	1,419.0	628.0	150.3	56.5	67.9	46,633.7	42,233.1	8,487.5	1,083.0	64.0	192.6
Tenure 1	430.3	430.6	256.0	112.0	49.8	64.7	13,887.9	12,003.0	8,472.0	649.7	49.4	337.1
Tenure 2	164.8	139.9	102.6	59.7	44.2	46.7	5,399.0	4,161.9	1,531.8	97.7	35.9	75.3
Tenure 3	80.5	82.7	68.6	53.4	43.2	44.9	1,816.5	1,198.1	417.5	63.3	33.5	51.0
Tenure 4	72.4	72.7	67.9	54.0	45.2	47.9	745.0	624.2	294.0	60.8	35.1	53.5
Tenure 5	60.7	66.4	60.2	53.9	47.0	48.7	224.6	195.7	112.2	49.9	36.8	42.7
	Panel (b): Uniform + Limited Enforcement						*% Excluded*					
Tenure 0	1.0	1.3	1.5	2.1	3.2	3.1	97.3	96.4	95.8	94.1	90.5	90.9
Tenure 1	2.8	4.0	5.8	5.7	5.3	5.4	93.4	91.9	88.6	87.3	85.8	86.1
Tenure 2	12.2	14.1	18.4	16.7	15.4	15.5	81.5	77.8	70.1	65.7	61.3	61.9
Tenure 3	16.9	19.4	26.6	23.0	19.4	19.9	76.9	69.0	59.5	51.5	50.0	50.4
Tenure 4	17.7	25.3	33.4	28.9	24.6	23.6	66.8	58.1	47.5	44.7	43.5	50.0
Tenure 5	28.6	37.9	43.5	34.0	29.2	30.4	65.3	58.8	37.5	29.8	25.4	26.7

Notes: This table presents average efficiency measures as % of baseline (non-linear price with limited enforcement) of different pricing and enforcement regimes by percentile groups of quantity and tenure. Percentile groups are defined based on quantiles as follows: the 10% group includes all buyers within seller-year-tenure quantiles from 0 to 10% (non-inclusive), the 25% group includes buyers within quantiles from 10% to 25% (non-inclusive), and this pattern continues for all other percentile groups. Panel (a) reports results for non-linear pricing with perfect enforcement. Panel (b) reports optimal monopolistic uniform price with limited enforcement, with the subpanel reporting the share of excluded buyers in this counterfactual. Panel (c) reports results for optimal monopolistic uniform price with perfect enforcement. No buyer is excluded in Panels (a) and (c).

from prices above marginal costs.

For higher types, however, the policy is always welfare-reducing. To see why, consider equation 3 and the estimates for the multiplier $\Gamma_\tau(\cdot)$, which are less than 1 except for the highest type. Shutting down enforcement constraints sets $\Gamma_\tau(\cdot) = 1$ for all buyers. Thus, for any type such that $\Gamma_\tau(\theta) < 1$, total trade would tend to decrease. Furthermore, any past promise to increase trade, captured in past multipliers, would also disappear.

As a result, given that higher types trade efficiently across the board, the policy has an aggregate negative welfare effect, though the welfare losses are smaller for earlier periods, partially reflecting the inter-temporal trade-off of lower and middle types.

Counterfactual (b): Uniform pricing with limited enforcement. Panel (b) presents the results. The surplus ranges from 0 to 40 percent of the baseline surplus across time and types. The surprisingly low performance of this alternative regime is explained by the large share of buyers that would be excluded from trade, as some buyers cannot credibly commit to repaying their debts and the seller cannot use dynamic incentives to discipline their behavior. Thus, in the presence of limited enforcement, the seller's ability to price discriminate actually improves the situation for both buyers and sellers by increasing the share of buyers that can be credibly incentivized not to default. In the aggregate, results are similar: efficiency is extremely low but it increases over time, reflecting the positive selection of types.

These results on inefficiency hold even if prices are identical to marginal costs. The seller's ability to target each individual buyer's enforcement constraint through differentiated prices and quantities allows them to prevent default.

Counterfactual (c): Uniform pricing with perfect enforcement. Panel (c) reports the results.

The table shows that surplus increases relative to the baseline, except for the highest types. Welfare gains are concentrated among the lowest types (who see gains of up to 46,000%), although even median types also see large increases (from 12% up to 8,000%). Higher types, however, are negatively affected by the policy. Under a uniform markup, prices tend to be higher than in the baseline (Appendix Table OA-14), and consumption is now determined solely by prices, decreasing the quantity consumed by higher types and thus reducing the generated surplus relative to the baseline. This is reflected in aggregate surplus: as the policy does not improve efficiency for higher types, aggregate surplus under the policy is higher than under the baseline in the early stages of the relationships but lower in the medium and long term. The intuition for this result is simple: higher types face greater distortions under the constant monopolist markup than otherwise.

Given the large inter-temporal trade-off, the macro effect of this policy depends significantly on the weights assigned to each tenure. If the weights are based on the number of buyers, the policy improves welfare, with gains of approximately 40% relative to the baseline, as early tenures involve a larger number of buyers. Conversely, if the weights are derived from the quantities at baseline, the policy reduces welfare, resulting in a surplus of only 58% relative to the baseline, as older tenures carry greater importance.

Since this counterfactual allows the seller to set the monopolist's uniform price, a policy that addresses multiple frictions simultaneously would perform better with stronger measures to curb seller market power by further reducing markups.

8 Conclusion

This paper demonstrates that frictions in the manufacturing supply chain significantly affect long-term relationships. The novel theoretical model shows that limited enforcement constraints compel the seller to offer a larger net return to the buyer than under perfect enforcement, which in turn distorts trade inter-temporally by promising larger future quantities at lower prices to boost current profits. Using a unique intra-national trade database from Ecuador, I estimate a structural model of relational contracting with seller market power and quantify the efficiency of dynamic trade. The results reveal that although trade is initially inefficient, transacted quantities approach full efficiency in the long run despite the seller's market power, highlighting both the value and fragility of informal relational contracts. These findings suggest that unilateral reforms aimed at improving enforcement or modifying antitrust policies could inadvertently undermine long-term efficiency, whereas addressing multiple frictions simultaneously may yield significant welfare gains.

APPENDIX

A Proof of Proposition 1: *Model's First-Order Conditions*

Here, I walk through the characterization of the firm's problem subject to the constraints, deriving Proposition 1.

A.1 Relaxed Problem for Incentive-Compatibility

First, I focus on the relaxed problem, which replaces the global incentive compatibility constraints IC-B with a dynamic envelope formula. Specifically, any implementable dynamic incentive-compatible menu must satisfy (Theorem 1, Pavan et al., 2014):

$$\sum_{\tau=0}^{\infty} \delta(\theta)^{\tau} u_{\tau}'(\theta) = \sum_{\tau=0}^{\infty} \delta(\theta)^{\tau} v(q_{\tau}(\theta)), \tag{15}$$

for any arbitrary function $0 < \delta(\theta) < 1$ and $u_{\tau}'(\theta) \equiv du_{\tau}(\theta)/d\theta$. Substituting the envelope condition 15 with $\delta(\theta) = \delta$ into the seller's problem SP and integrating by parts yields:

$$\sum_{\tau=0}^{\infty} \delta^{\tau} \int_{\underline{\theta}}^{\overline{\theta}} \left[s(\theta, q_{\tau}(\theta), c_{\tau}) - \int_{\underline{\theta}}^{\theta} v(q_{\tau}(x))dx \right] f_{\tau}(\theta)d\theta - \sum_{\tau=0}^{\infty} \delta^{\tau} u_{\tau}(\underline{\theta}). \tag{16}$$

The return term of the buyer acknowledges the rents that must be given to higher types to preserve incentive compatibility.

It is well known that the solution to the full program might not match the solution to the relaxed program, as the dynamic envelope condition is only a necessary condition (Stantcheva, 2017). However, if the optimal contract is strictly monotonic (i.e., those with $q_{\tau}'(\theta) > 0$ for all θ and τ) for fully persistent types, then the contract is globally incentive compatible (Battaglini and Lamba, 2019).

A.2 Limited Enforcement Constraints in the Relaxed Problem

I write the problem in a Lagrangian-type form (in the spirit of the static problem in Jullien (2000)). For this formulation, the dynamic LE-B constraint for type θ at time τ is given by:

$$\left\{ \sum_{s=1}^{\infty} \delta^{s} (1 - X(\theta))^{s} u_{\tau+s}(\theta) - [\theta v(q_{\tau}(\theta)) - u_{\tau}(\theta)] \right\} \gamma_{\tau}(\theta) = 0, \tag{17}$$

where $\gamma_{\tau}(\theta)$ is the corresponding limited enforcement Lagrange (LE) multiplier for type θ's enforcement constraint at time τ. The LE multiplier is positive ($\gamma_{\tau}(\theta) > 0$) whenever the limited enforcement constraint binds, capturing the shadow value of the enforcement constraint for θ. To include the constraint across types, we integrate over all types to obtain:

$$\int_{\underline{\theta}}^{\overline{\theta}} \left\{ \sum_{s=1}^{\infty} \delta^{s} (1 - X(\theta))^{s} u_{\tau+s}(\theta) - [\theta v(q_{\tau}(\theta)) - u_{\tau}(\theta)] \right\} d\Gamma_{\tau}(\theta) = 0, \tag{Lagrangian-D-LE}$$

where $\Gamma_{\tau}(\theta) = \int_{\underline{\theta}}^{\theta} \gamma_{\tau}(x)dx$ is the *cumulative* LE multiplier with derivative $\gamma_{\tau}(\theta)$. The cumulative LE multiplier $\Gamma_{\tau}(\theta)$ captures the extent by which trade is distorted by limited enforcement. It represents the shadow value of relaxing the enforcement constraints uniformly from $\underline{\theta}$ to θ, capturing the amount of profits lost by the seller due to enforcement incentives.

The cumulative multiplier has the properties of a cumulative distribution function. Extending θ increases the set on which the enforcement constraint is relaxed, so Γ_τ is nonnegative and nondecreasing. By relaxing the constraints uniformly, the seller can reduce the buyers' net returns by keeping quantities unchanged, hence $\Gamma_\tau(\overline{\theta}) = 1$.[41]

After manipulating the limited enforcement constraints, one can obtain the full Lagrangian maximand:

$$\sum_{\tau=0}^{\infty} \delta^\tau \int_{\underline{\theta}}^{\overline{\theta}} \left[s(\theta, q_\tau(\theta), c_\tau) - v(q_\tau(\theta)) \frac{\Gamma_\tau(\theta) - F_\tau(\theta) - \sum_{s=0}^{\tau-1}(1-\Gamma_s^\tau(\theta))\tilde{\Gamma}_s^\tau(\overline{\theta}) + \theta\gamma_\tau(\theta)}{f_\tau(\theta)} \right] f_\tau(\theta) d\theta, \tag{18}$$

with the corresponding slackness condition Lagrangian-D-LE where $\Gamma_s^\tau(\theta)$ is the conditional cumulative LE multiplier constraint defined by:

$$\Gamma_s^\tau(\theta) = \frac{\int_{\underline{\theta}}^{\theta}(1-X(x))^{\tau-s}\gamma_s(x)dx}{\tilde{\Gamma}_s^\tau(\overline{\theta})}, \tag{19}$$

for $\tilde{\Gamma}_s^\tau(\overline{\theta}) = \int (1-X(\theta))^{\tau-s}\gamma_s(\theta)d\theta$.[42] The conditional cumulative multiplier constraint adjusts for the likelihood that a given θ has survived $\tau - s$ periods, assigning lower weights to θs that are less likely to survive.

A.3 Relaxing the Double-Deviation Constraint

The problem is further relaxed by omitting the Double-Deviation Constraint DD-B. This is sensible as both IC-B and LE-B are necessary conditions for the constraint.

First, to see that DD-B implies IC-B, consider the limit as $\tau \to \infty$:

$$\begin{aligned}\sum_{\tau=0}^{\infty} \delta(\theta)^\tau u_\tau(\theta) &\geq \lim_{\tau\to\infty} \left\{ \delta(\theta)^\tau \theta v(q_\tau(\widehat{\theta})) + \sum_{s=0}^{\tau-1} \delta(\theta)^s \left[\theta v(q_s(\widehat{\theta})) - t_s(\widehat{\theta}) \right] \right\} \forall \theta, \widehat{\theta}, \\ &\geq \sum_{s=0}^{\infty} \delta(\theta)^s \left[\theta v(q_s(\widehat{\theta})) - t_s(\widehat{\theta}) \right] \forall \theta, \widehat{\theta},\end{aligned} \tag{21}$$

thus IC-B is a necessary condition for DD-B.

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[41] In Online Appendix Section OA-5, I show formally that $\Gamma_\tau(\overline{\theta}) = 1$.

[42] Pre-multiply each constraint by δ^τ and sum over τ. Reorder internal summations, substitute in the dynamic envelope condition, and eliminate constant terms to obtain:

$$\begin{aligned}&\sum_{\tau=0}^{\infty} \delta^\tau \int_{\underline{\theta}}^{\overline{\theta}} \int_{\underline{\theta}}^{\theta} v(q_\tau(x))dx \sum_{s=0}^{\tau-1}(1-X(\theta))^{\tau-s} d\Gamma_s(\theta) \\ &- \sum_{\tau=0}^{\infty} \delta^\tau \int_{\underline{\theta}}^{\overline{\theta}} \left[\theta v(q_\tau(\theta)) - \int_{\underline{\theta}}^{\theta} v(q_\tau(x))dx \right] d\Gamma_\tau(\theta).\end{aligned} \tag{20}$$

Then integrate by parts.

Second, to see that DD-B implies LE-B, simply set $\widehat{\theta} = \theta$:

$$\sum_{\tau=0}^{\infty} \delta(\theta)^{\tau} u_{\tau}(\theta) \geq \delta(\theta)^{\tau} \theta v(q_{\tau}(\theta)) + \sum_{s=0}^{\tau-1} \delta(\theta)^{s} \left[\theta v(q_s(\theta)) - t_s(\theta)\right] \forall \theta, \tau \Leftrightarrow \tag{22}$$

$$\sum_{s=\tau+1}^{\infty} \delta(\theta)^{s} u_s(\theta) + \delta(\theta)^{\tau} u_{\tau}(\theta) \geq \delta(\theta)^{\tau} \theta v(q_{\tau}(\theta)) \forall \theta, \tau \Leftrightarrow \tag{23}$$

$$\sum_{s=1}^{\infty} \delta(\theta)^{s} u_{\tau+s}(\theta) \geq t_{\tau}(\theta) \forall \theta, \tau. \tag{24}$$

Therefore, LE-B is a necessary condition for DD-B.

Furthermore, for any $\widehat{\theta}$ such that:

$$\delta(\theta)^{\tau} \theta v(q_{\tau}(\widehat{\theta})) + \sum_{s=0}^{\tau-1} \delta(\theta)^{s} \left[\theta v(q_s(\widehat{\theta})) - t_s(\widehat{\theta})\right] < \delta(\theta)^{\tau} \theta v(q_{\tau}(\theta)) + \sum_{s=0}^{\tau-1} \delta(\theta)^{s} u_s(\theta), \tag{25}$$

condition LE-B implies DD-B, so for such $\widehat{\theta}$ the condition DD-B is irrelevant.

For all other $\widehat{\theta}$, the condition LE-B is necessary for DD-B to hold. In particular, if DD-B holds, then:

$$\delta(\theta)^{\tau} t_{\tau}(\theta) \leq \sum_{s=\tau+1}^{\infty} \delta(\theta)^{s} u_s(\theta) - \left(\sum_{s=0}^{\tau-1} \delta(\widehat{\theta})^{s} \left[\theta v(q_s(\widehat{\theta})) - t_s(\widehat{\theta})\right] - \sum_{s=0}^{\tau-1} \delta(\theta)^{s} \left[\theta v(q_s(\theta)) - t_s(\theta)\right] \right) \forall \theta, \widehat{\theta}, \tau. \tag{26}$$

As the term in the brackets is positive by assumption, LE-B holds.

A.4 The Seller's First-Order Condition

All in all, the corresponding seller's first-order condition for the relaxed problem determining the allocation rule at any relationship tenure τ is:

$$\theta v'(q_{\tau}(\theta)) - c = \frac{\Gamma_{\tau}(\theta) - F_{\tau}(\theta) - \sum_{s=0}^{\tau-1} (1 - \Gamma_s^{\tau}(\theta)) \tilde{\Gamma}_s^{\tau}(\overline{\theta}) + \theta \gamma_{\tau}(\theta)}{f_{\tau}(\theta)} v'(q_{\tau}(\theta)). \tag{SFOC}$$

Therefore, if the quantity profile $\{q_{\tau}^{*}(\theta)\}$ maximizes lifetime profits for the firm subject to IC-B, LE-B, and DD-B, it must also satisfy SFOC.

A.5 Tariffs

Tariffs are then constructed to satisfy the dynamic envelope formula 15 for the optimal quantity profile $\{q_{\tau}^{*}(\theta)\}$ solving the seller's problem:

$$t_{\tau}'^{*}(\theta) = \theta v(q_{\tau}^{*}(\theta)) q_{\tau}'^{*}(\theta). \tag{t-RULE}$$

B Proof of Proposition 2: *Point Identification*

In this section, I detail how $\Gamma_{\tau}(\cdot)$ is point identified with observations of prices, quantities, and marginal cost for one seller under the parametrization of $v(q) = kq^{\beta}$ for $k > 0$ and $\beta \in (0,1)$.

As a preliminary step, I state the following lemma.

Lemma 1. $\Gamma_{\tau}(\overline{\theta}) = 1, \forall \tau$.

The proof is relegated to Online Appendix Section OA-5. The intuition is that marginal uniform relaxation of the enforcement constraint does not optimally affect quantities across buyers but rather simply shifts the tariffs upward by the same amount. Thus, the shadow cost of a marginal uniform relaxation of the enforcement constraints is exactly the marginal uniform relaxation.

B.1 Step 1: Show β is identified

We first show that β is identified from observations on prices, quantities, and marginal cost for $\tau = 0$. In this step, we omit subscripts $\tau = 0$.

Consider $\rho(\alpha) = \partial \ln(\theta(\alpha))/\partial\alpha = \theta'(\alpha)/\theta(\alpha)$. Substituting in, the key identification equation I-EQ becomes

$$\frac{T'(q(\alpha)) - c}{T'(q(\alpha))} = \rho(\alpha)\Big[\Gamma(\alpha) - \alpha\Big] + \gamma(\alpha). \tag{27}$$

Evaluating at $\alpha = 1$ and using the fact that $\Gamma(1) = 1$ (Lemma 1), yields

$$\gamma(1) = \frac{T'(q(1)) - c}{T'(q(1))}. \tag{28}$$

Therefore, all parameters, except $\rho(\alpha)$, are known at the boundary $\alpha = 1$.

As an auxiliary result, note that:

$$\gamma'(1) = \frac{cT''(q(1))}{\Big((T'(q(1))\Big)^2}, \tag{29}$$

which is known.

Then consider the first-order condition at $\alpha = 1 - \varepsilon$ using Taylor approximations for the enforcement multipliers:

$$\frac{T'(q(1-\varepsilon)) - c}{T'(q(1-\varepsilon))} \approx \rho(1-\varepsilon)\Big[\Gamma(1) - \gamma(1)\varepsilon - 1 + \varepsilon\Big] + \gamma(1) - \gamma'(1)\varepsilon, \tag{30}$$

under the assumption that Γ is regular and second-order differentiable as it approaches $\alpha = 1$. From this equation, the value for $\rho(1-\varepsilon)$ is identified.

Using the derivative of the tariff rule I-T, obtain

$$\rho(\alpha) = \theta'(\alpha)/\theta(\alpha) = q'(\alpha)[T''(q(\alpha))/T'(q(\alpha)) + A(q(\alpha))], \tag{31}$$

where $A(q(\alpha)) = -v''(q(\alpha))/v'(q(\alpha))$. The assumed parametrization in IA 3 implies $A(q) = (1-\beta)/q$. As $T'(\cdot)$, $T''(\cdot)$, $q(\cdot)$, and $q'(\cdot)$ are known, $\rho(\cdot)$ depends on only one unknown parameter β, which is identified from the value of $\rho(1-\varepsilon)$ above.

B.2 Step 2: Show Γ_0 is identified from β

Consider equation 27 and use the parametrized version of $\rho_0(\alpha)$ for 31:

$$\Gamma_0(\alpha)+\gamma_0(\alpha)\left[q_0'(\alpha)\left(\frac{T_0''(q_0(\alpha))}{T_0'(q_0(\alpha))}+\frac{1-\beta}{q_0(\alpha)}\right)\right]^{-1}= \tag{32}$$
$$\alpha+\frac{T_0'(q_0(\alpha))-c}{T_0'(q_0(\alpha))}\left[q_0'(\alpha)\left(\frac{T_0''(q_0(\alpha))}{T_0'(q_0(\alpha))}+\frac{1-\beta}{q_0(\alpha)}\right)\right]^{-1}.$$

The LE multiplier $\Gamma_0(\alpha)$ is identified from the solution to the differential equation above using the boundary condition $\Gamma_0(1)=1$ (Lemma 1), and the fact that $T_0''(\cdot)$, $T_0'(\cdot)$, $q_0(\cdot)$, $q_0'(\cdot)$, and β are known or identified.

B.3 Step 3: Show Γ_τ is identified from β and Γ_s for $s<\tau$

To identify $\Gamma_\tau(\alpha)$, we start recursively from $\tau=1$. With knowledge of $\Gamma_s(\cdot)$ for $s<\tau$ and β, we note that from:

$$\Gamma_\tau(\alpha)+\gamma_\tau(\alpha)\left[q_\tau'(\alpha)\left(\frac{T_\tau''(q_\tau(\alpha))}{T_\tau'(q_\tau(\alpha))}+\frac{1-\beta}{q_\tau(\alpha)}\right)\right]^{-1}= \tag{33}$$
$$\alpha+\sum_{s=0}^{\tau-1}(1-\Gamma_s(\alpha))+\frac{T_\tau'(q_\tau(\alpha))-c}{T_\tau'(q_\tau(\alpha))}\left[q_\tau'(\alpha)\left(\frac{T_\tau''(q_\tau(\alpha))}{T_\tau'(q_\tau(\alpha))}+\frac{1-\beta}{q_\tau(\alpha)}\right)\right]^{-1},$$

$\Gamma_\tau(\alpha)$ is identified from the solution to the differential equations above with the boundary condition $\Gamma_\tau(1)=1$ and the fact that $\Gamma_s(\cdot)$, c, $T_\tau'(\cdot)$, $T_\tau''(\cdot)$, $q_\tau(\cdot)$, $q_\tau'(\cdot)$, and β are known or identified.

B.4 Step 4: Show $\theta_\tau(\cdot)$, $\theta_\tau'(\cdot)$, and k are identified

With known multipliers and separately by tenure, I-EQ is equivalent to the non-linear pricing problem in Luo et al. (2018). Therefore, their results imply that the distribution of types is identified. The intuition for the identification result is that the incentive compatibility constraints for truthful revelation imply a monotonic relationship between quantities and types, which means the underlying distribution of unknown types can be recovered from the observed distribution of quantities.

Finally, the scale parameter k is identified I-T, as all elements are now identified or observed.

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