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

Felipe Brugués†

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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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†The Business School, Instituto Tecnológico Autónomo de México. E-mail: felipe.brugues@itam.mx

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,[1] 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). 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. Firstly, 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. Secondly, the study examines the counterfactual scenario of implementing best-practice institutions

[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.

(e.g., eliminating contracting frictions) and 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 revelation 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. Given the large number of trading partners, I explore the heterogeneity of enforcement constraints and find they differ significantly by buyers' and sellers' characteristics. For example, they are more likely to bind when the seller and buyer's headquarters are far away.

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. Firstly, 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. Secondly, 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, Forthcoming; 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

[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.

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, 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).[4] 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,

[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.

[4] This paper is related to the literature studying the durable/storable-goods monopolist (e.g. Coase, 1972; Bulow, 1982; Dudine et al., 2006; Hendel and Nevo, 2013; Hendel et al., 2014). However, it differs from it, as this paper treats inputs as non-durable and non-storable by assuming the buyer's production opportunity is time-specific.

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.

Lastly, the empirical facts presented in Section 2 have been individually documented by previous and contemporaneous work. For instance, Heise (Forthcoming) and, partially, Monarch and Schmidt-Eisenlohr (Forthcoming) 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. However, to the best of my knowledge, this paper is the first to document relationship dynamics regarding prices and quantities intra-nationally and to present all of these facts in the same setting.

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

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-1). 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-2), 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.[5]
- Quality issues from upstream suppliers are not a major concern, as the inputs used are highly standardized.[6]
- 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.

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-

[5]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.

[6]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-3). For pharmaceuticals, variable inputs include active components, again often imported (Online Appendix Table OA-3). For cement-products, the main components include gravel and cement.

level information, such as the buyer's unique national identifier and method of payment.[7] 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.

The study defines a *product* as a bar-code identifier and description combination. While discounts are observed at the product level, I allocate the discounts offered in a transaction equally across all the products purchased in that transaction by adjusting the listed product unit prices. For example, if a 5% discount is offered on the total bill, the reported unit prices of all the products are adjusted by 5%. I do this, rather than performing analysis with observed discounts to average out managerial mistakes, such as assigning all discounts to a single product, while in principle the agreed discounts were on the total bill.[8]

Let p^l_{ijgry} be the listed unit price and q_{ijgry} be the reported quantity for buyer i from seller j for good g in transaction r during year y, and d_{ijry} be the total discount share in the transaction. Then, the effective unit price is defined as $p_{ijgry} = (1 - d_{ijry}) \times p^l_{ijgry}$. Following DellaVigna and Gentzkow (2019), I define standardized unit prices at the transaction-product level $\tilde{p}_{ijgry}$ as:

$$\tilde{p}_{ijgry} = ln(p_{ijgry}) - \overline{ln(p_{jgy})}, \tag{1}$$

where $\overline{ln(p_{jgy})}$ is the average log effective unit price for the good g of seller j in year y. The standardized unit price captures the percentage price difference for a given product in a transaction relative to its average yearly price. I define standardized quantity at the transaction-product level $\tilde{q}_{ijgry}$ in an analogous manner:

$$\tilde{q}_{ijgry} = ln(q_{ijgry}) - \overline{ln(q_{jgy})}, \tag{2}$$

where $\overline{ln(q_{jgy})}$ is the average log quantity for the good g of seller j in year y. As with prices, standardized quantities measure the percentage quantity difference for a given

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

[8] An alternative method would be to use observed discount shares at the product level and adjust listed prices by the product-specific discount share. In practice, the reduced-form facts hold using either method. See, for instance, Online Appendix Table OA-2 for a robustness exercise using product-level vs bill-level allocation of discounts.

product in a transaction relative to its average quantity sold in the year. Note that these definitions for standardized units are equivalent to netting out product-seller-year fixed effects in a regression of log effective unit prices or log quantities.

To obtain pair-year-level values of the standardized prices and quantities, I aggregate them by the respective share of total expenditures, which provides a common weight for prices and quantities. Define V_{ijy} as the total value of transactions between buyer i and seller j in year y. Let $s_{ijgry} = v_{ijgry}/V_{ijy}$ be the share of expenditure that good g in transaction r represents for the pair and $v_{ijgry} = p_{ijgry} * q_{ijgry}$ be the transaction value.[9] Then, define pair-year level equivalents for the standardized prices and quantities as:

$$\tilde{p}_{ijy} = \sum_{r \in R_{ijy}} \sum_{g \in G_{ijry}} s_{ijgry} * \tilde{p}_{ijgry}, \tag{3}$$
$$\tilde{q}_{ijy} = \sum_{r \in R_{ijy}} \sum_{g \in G_{ijry}} s_{ijgry} * \tilde{q}_{ijgry},$$

where R_{ijy} is the set of all the transactions between i and j in year y and G_{ijry} is the set of all goods in transaction r. The pair-level standardized price then captures the average relative price a buyer has in a given year. For instance, if $\tilde{p}_{ijy} = 0.1$, then the buyer pays on average 10% on their products than other buyers. The pair-level quantities capture the average relative quantity a buyer purchases in a given year. Thus, if $\tilde{p}_{ijy} = 0.1$, then the buyer purchases 10% more in quantity than other buyers.

To address the potential concern that cross-sectional differences in prices and quantities could be driven by variations in the bundles of goods purchased by buyers and over time, I report the main stylized facts on the patterns and dynamics of prices and quantities using standardized measures. The use of these measures indicates that differences in the products purchased by buyers do not influence the results.

For estimation purposes, however, I use the following definitions of prices and quantities, as they are better suited to the structure of the model. For total quantity q_{ijy}, I sum over all reported quantities over all goods and all transactions:

$$q_{ijy} = \sum_{r \in R_{ijry}} \sum_{g \in G_{ijry}} q_{ijgry}. \tag{4}$$

As discussed below in this Section, aggregation across products is not extremely problematic, as firms tend to produce either items or packages that can be summed over in a relatively consistent way.

For prices, I obtain the average unit price by dividing the total value of transactions by the total quantity:

$$p_{ijy} = V_{ijy}/q_{ijy}. \tag{5}$$

This definition of prices is consistent with the weighted average of product-level effective

[9] Again, reduced-form results are robust to relying on quantities as weights, rather than values (Online Appendix Table OA-2).

prices, as demonstrated in Online Appendix Figure OA-6, which presents the fit between average unit prices and weighted effective unit prices.[10] The figure shows a strong fit between the two measures, with a correlation of 0.58 at the buyer-seller-year level.

The aggregate quantity produced by seller j in year y is given by $Q_{jy} = \sum_{i \in I_{jy}} q_{ijy}$, where I_{jy} is the set of all buyers that transacted with the seller in the year. While the measures of quantities differ between the model and the motivating evidence, all motivating facts hold when using total quantities, both in the cross-section and in the short panel structure (controlling for buyer-seller pair fixed effects). Robustness results using average unit prices and total quantity are also discussed below.

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.[11]

1.3 Overview of the data

Table 1 shows that the sellers in my sample are typically large and well-established, employ directly imported goods in their production, channel their sales through the local market rather than exporting. On the other hand, buyers are smaller, younger, and have limited direct contact with international trade. Moreover, buyers are less capital-intensive than sellers. At the same time, sellers in the same 6-digit industry but not in my sample are orders of magnitude smaller, younger, do not use imported inputs, and are much less capital-intensive than seller in sample.[12]

Table 1: **Summary Statistics - Sellers and Buyers in 2016**

	Sellers - Sample			***Buyers***			***Sellers - Not Sample***		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Total Sales (million USD)	14.95	8.26	24.33	2.35	0.20	24.33	0.10	0.00	3.04
Total Inputs (millon USD)	10.58	5.31	18.94	1.92	0.15	24.13	0.07	0.00	1.86
Age	30.47	29.00	19.16	15.18	14.00	9.75	9.24	7.00	8.88
Import Share (%)	24.47	21.38	22.96	3.82	0.00	13.49	0.30	0.00	3.91
Export Share (%)	5.81	0.00	19.11	1.06	0.00	8.87	0.10	0.00	2.81
Capital-Expenditures Ratio	0.27	0.30	0.18	0.16	0.05	0.23	0.02	0.00	0.10
Observations	49			28,138			28,424		

Notes: This table reports summary statistics about the size, age, capital intensity, and trade exposure of buyers and sellers in the sample for the year 2016. Monetary values are in U.S. dollars for 2016.

Table 2 shows the industrial composition of buyers by selling sector. The market segments of buyers for Textile products are mainly Wholesale and Retail, as well as Manufacturing. Most Pharmaceutical product buyers come from Wholesale and Retail

[10] Observed weighted prices are obtained by aggregating unit prices using the share of the total quantity of the goods sold as weights.

[11] In robustness exercises in Section 2, I also use sales, exports, imports, total assets, total debt, total receivables, and total uncollectibles for all buyers and sellers in the data for 2008-2017. This data is obtained from the financial statements. I also add information on 6-digit sector code, GPS location of headquarters' neighborhood, year founded, type of ownership (multinational, local, part of a business group), and whether the buyer and seller are vertically integrated. These variables are also used to explore the heterogeneity in estimated multipliers.

[12] The large number of sellers not in sample is driven primarily by thousands of micro-entrepreneurs in textiles. Online Table Appendix Table OA-3 presents the sample descriptive statistics by seller industry.

and the Human Health sector (such as hospitals and doctors). Finally, the market segments of buyers for Cement-Products are mainly Wholesale and Retail, Construction, and Professional Services (such as engineers and architects). This composition of buyers from different sectors is indicative that buyers, except for those from Construction and Professional Services for Cement-Products, are likely to have linear input needs.

Table 2: **Industrial Composition of Buyers by Selling Sector**

Seller Industry	Ranking	Buyer Industry	Average % Share Pairs
Textiles	1	Wholesale & Retail	40
Textiles	2	Manufacturing	15
Textiles	3	Professional Activities	8
Textiles	4	Agriculture	5
Textiles	5	Other	31
Pharmaceutical	1	Wholesale & Retail	46
Pharmaceutical	2	Human Health	17
Pharmaceutical	3	Manufacturing	10
Pharmaceutical	4	Construction	4
Pharmaceutical	5	Other	23
Cement-Products	1	Wholesale & Retail	25
Cement-Products	2	Construction	20
Cement-Products	3	Professional Activities	16
Cement-Products	4	Manufacturing	8
Cement-Products	5	Other	31

Notes: This table provides a breakdown of the industrial composition of buyers for each selling sector.

Table 3 presents summary statistics on quantities, values, and the number of buyers per seller obtained through the EI dataset.[13] Notice that the reporting threshold is smaller than in previous work (Bernard et al., 2022; Alfaro-Urena et al., 2022), implying a larger number of buyers. Despite the large number of buyers, the yearly bills are not small for the country, with median (average) bill of 9K USD (44K USD).[14]

Table 3: **Summary Statistics - Electronic Invoice Database**

	Mean	Median	SD
N. Buyers	8,028.41	613.50	25,078.11
Total Sales (million USD)	16.58	7.23	29.44
Total Q (million)	5.42	1.20	9.01
Q per Buyer	12,455.39	1,495.22	25,823.40
Bill per Buyer (USD)	43,490.37	9,067.65	105,840.28
Observations	49		

Notes: This table reports summary statistics of the electronic invoice database. N. buyers refers to the number of unique buyers each seller in the sample has on average over 2016 and 2017. Quantity is the sum of all quantities across products. Bill per buyer is the total value of the transactions between buyer and seller.

The median (average) buyer purchases around 1.5K (12.5K) units of product. What

[13] Product-level dispersion of standardized prices and quantities are presented in Online Appendix Figures OA-4 and OA-5. The statistics show that within a given month, cross-buyer differences on average product prices are 10% and on product quantities are close to 50%.

[14] At the same time, due to the staggered rollout of the policy, data is sourced from the largest firms in the economy. Indeed, the size in number of buyers and total sales of the median manufacturing firm in my sample corresponds to size of manufacturing firms between the top 5 and 10 percent in Costa Rica (Alfaro-Urena et al., 2022) and between the top 25 and 10 percent in Belgium (Bernard et al., 2022).

are these products? Table 4 provides information on a random sample of products, including their prices and average costs. The prices are obtained directly from invoices, while the average costs are imputed by dividing the total variable costs, including wages and intermediate inputs, by nthe aggregate output in units for each firm.

Table 4: **Example - Product Information, Prices, and Average Costs**

Industry	Firm-ID	Product Description	Observed Unit Price	Imputed Average Cost
Textiles	1	Teddy King, Size 55, Brim 7CM, Color-B02 [Panama Hat]	33.90	11.96
Textiles	2	Shirt, R:1931, Squares	19.34	9.85
Textiles	3	Tank Undershirt, Male, Size M, White	10.27	6.72
Textiles	4	Betty K246	19.44	16.94
Textiles	5	Bikini, Woman, 500306, Black, L	13.50	16.78
Textiles	6	Ribbon, Black, 30 mm X 700	26.62	1.86
Textiles	7	Skirt, Tropical Squares, Scottish	46.01	17.77
Textiles	8	Boots, LLN NG AM, Size 39	7.09	2.17
Textiles	9	Elastic Socks, Nylon and Cotton	16.56	8.48
Textiles	10	Jacket, Kids, Spiderman Print, Hoodie	18.30	7.11
Pharmaceutical	1	Nitazoxanida, 500mg X 6 tablets	5.27	4.83
Pharmaceutical	1	Clopidogrel Tarbis 75 mg film-coated tablets	12.90	6.57
Pharmaceutical	2	Losartan/Hydrochlorothiazide, 100mg X 28 tablets	5.04	0.78
Pharmaceutical	3	B Complex, Syrup 120 ml	2.32	0.81
Pharmaceutical	4	Sodium perborate, mint oil, saccharin	4.69	1.81
Pharmaceutical	5	Boldenone 50, Injectable, Bottle X 500 ml	123.12	3.01
Pharmaceutical	6	Pinaver, Film-coated, 100 mg X 20 tables	10.32	2.62
Pharmaceutical	7	Endobion X 60 tablets	14.83	5.49
Pharmaceutical	7	Prostageron X 60 capsules	14.75	7.04
Pharmaceutical	8	Oral rehydration solution, cherry, 500ml	2.67	1.80
Cement-Products	1	Gray French Pedestrian Paving Stone	11.28	18.11
Cement-Products	2	Corrugated Plate	23.73	9.56
Cement-Products	3	Polymer-modified adhesive mortar for ceramics, 25kg	6.31	2.99
Cement-Products	4	Polymer-modified adhesive mortar for ceramics, 25kg	6.94	12.36
Cement-Products	5	Polymer-modified adhesive mortar for ceramics, 25kg	6.65	3.45
Cement-Products	6	Straight Pole 21m x 1400kg, Reinforced Concrete	882.00	73.95
Cement-Products	6	Straight Pole 21m x 2400kg, Reinforced Concrete	1362.73	73.95
Cement-Products	7	Tile 50x50x2 cm (Color)	32.00	6.62
Cement-Products	8	MFC Concrete, 300, XXXXX XXXX-XXXX	94.00	50.34
Cement-Products	8	CFC Concrete, 240, XXXXX XXXX-XXXX	79.43	50.34

Notes: This table presents a sample of ten random products from each of the studied sectors (textiles, pharmaceutical, and cement-products), with product descriptions translated into English and sensitive information, such as brand names, removed to ensure confidentiality. The observed average unit prices reflect the listed prices reported by the firms, while the imputed average costs are estimated using the firms' total variable costs divided by total quantity.

In the textiles industry, products may include shirts, skirts, hats, and others, with different patterns or sizes also considered separate products. Aggregation is thus over individual clothing *items*. Instead, in the pharmaceutical sector, products are typically packages of tablets or bottles, with aggregation across products being over *packages*. Comparing product-level prices with firm-level average costs yields reasonable estimates in both cases. For example, a shirt is sold for 19 USD and costs 9.85 USD to manufacture, and Vitamin B Syrup is sold for 2.3 USD, but it costs only 81 cents to manufacture.

In the cement-products industry, products may include stones, mortar, concrete, and the like. While aggregating over these types of products can be more challenging, it should be noted that firms producing products such as mortar do not typically produce tiles, poles, or stones. Two other notes are in order. First, there are three different firms selling mortar at similar prices, despite being headquartered in different and distant cities. This suggests that despite the products being substitutes, sellers may still have local market power due to transportation costs. Second, one firm produces two types of pole products, sold at different prices but with the same cost of production. Another firm produces two types of concrete products, sold at different prices but with the same cost of production. As costs will enter into the dependent variable in my main estimation process, possible mistakes in costs would enter as measurement error in the econometric model.

2 Motivating Evidence

This section presents evidence on how buyer-seller relationships work in the Ecuadorian supply chain. 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 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.[15] 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.[16,17,18]

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

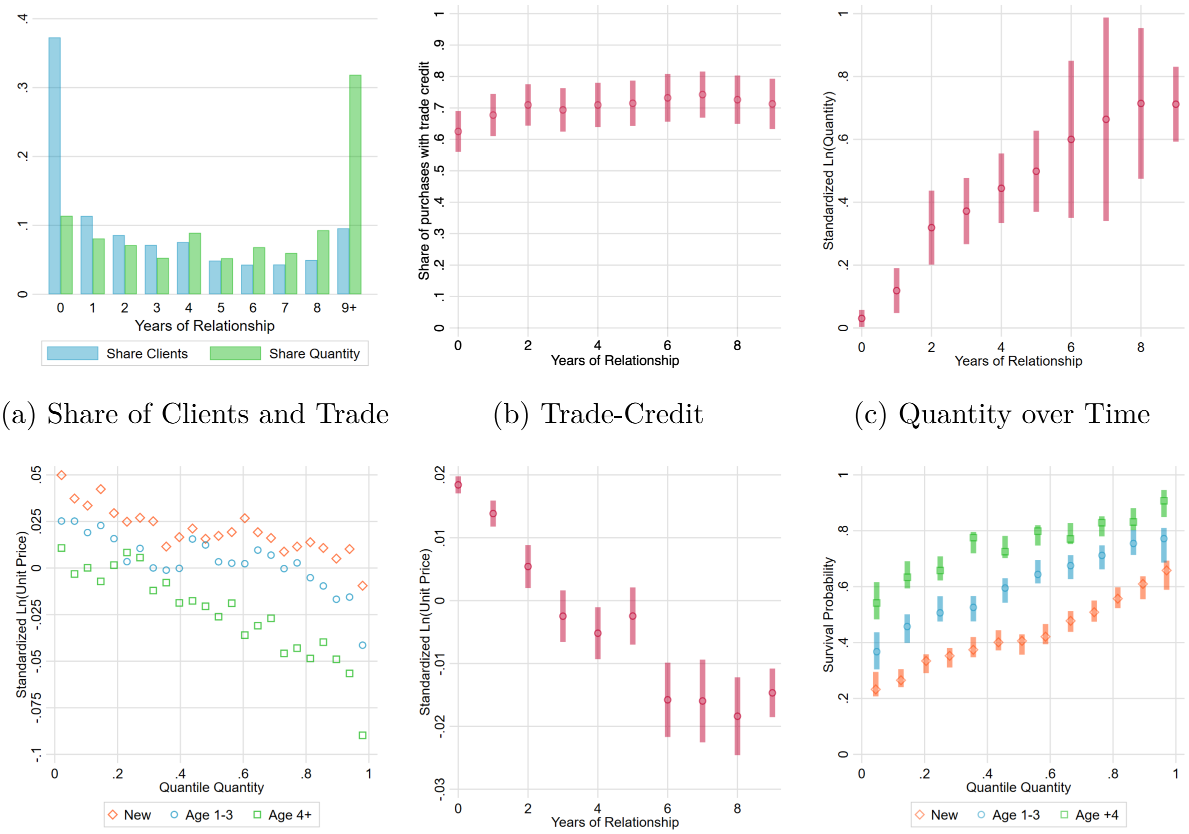
[15] On average, trade-credit agreements have a maturity of 40 days in textiles, 55 days in pharmaceuticals, and 40 days in cement products (Online Appendix Figure OA-12).

[16] In results not shown here, 85% of new relationships use *some* trade-credit, with close to 100% of older relationships using some trade-credit.

[17] 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.

[18] 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.

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.

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

I now present empirical evidence on the life cycle of quantities in buyer-seller relationships, depicted in Figure 1c. 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-7a).[19]

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).[20]

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) 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-7b). In terms of magnitude, a 10% increase in total quantity purchased is associated with an average price decrease of 2% (Online Appendix Table OA-1).

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.

[19]Note, however, that I observe at most two years per pair. For that reason, within-pair growth uses partial information to reconstruct the entire path of quantities. To verify that the partial panel of quantities correctly captures the growth of relationships, in Online Appendix Figure OA-7d, I plot the path of total value transacted in relationships using both the partial panel captured in the EI database and a longer panel using VAT data for the years 2008-2015. To correctly measure the age of a relationship in the VAT data, I drop relationships that start during the first year a seller appeared in the data. Moreover, to correct for partial-year effects in exit (Bernard et al., 2017), I drop the last observation available for each pair. The figure shows that under both databases, the value transacted within pairs increases as they age. Furthermore, the EI database's partial panel accurately captures the full growth path observed in the VAT data.

[20]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.

Importantly, 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-7c), indicating that the results are not driven by composition, nor by short-term fixed characteristics of the firm (such as location, managerial bargaining, size, etc.). Additionally, I replicate Figure 1e in Table 5 to assess the robustness of the results to additional buyer and relationship-level controls. Relative to the base specification presented in Column (1), I find that the effects of relationship age and quantity discounts remain relatively unchanged after accounting for various buyer and pair characteristics.

In Column (2), I control for buyer and pair characteristics such as age, distance between headquarters, size (measured by sales, number of employees, and assets), and whether the firm is a multinational, exporter, importer, or part of a business group. I also consider the importance of the relationship for both the buyer (in terms of supply share) and seller (in terms of demand share) to capture any potential asymmetries in bilateral bargaining power (Dhyne et al., 2022; Alviarez et al., 2023). In Column (3), I include further controls, such as buyer wages, expenditures, cash, fixed assets, debt, leverage, and export and import shares, as well as 6-digit sectoral fixed effects for buyers. The stability of the coefficients implies that buyer characteristics observed by the seller, but not accounted for in a model focusing solely on relationship and quantity variation, likely enter as measurement error rather than generating bias in the coefficients linking prices, quantities, and relationship age.

In Columns (4) and (5), I substitute the relationship age with its logarithmic form, rather than in levels, and again find robust results for both discounts over time and by quantity. Importantly, prices are most responsive to quantities and the age of the relationship. For instance, the coefficient for the (log) age of the relationship is 4 to 10 times larger than the coefficient for the (log) age of the buyer, and 15 to 20 times larger than the coefficient for the (log) sales of the buyer.

I also present heterogeneity in backloading in prices and quantities by quantile of quantity using pair-level variation between 2016 and 2017, over different relationship age groups (Online Appendix Figure OA-8). Backloading in prices and quantities tends to be weaker (or null) for higher types, and it slows down for older relationships.

Although this paper does not concentrate on the institutional differences across studied sectors, it is important to highlight that the observed facts are consistent across all three industries analyzed, as discussed in Online Appendix Section OA-3. Thus, although the specific primitives may differ by industry and seller, the general underlying forces are at play.

To further support 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), I explore the effect of payment modality on these patterns in Online Appendix Table OA-4, which shows price dynamics by payment

Table 5: **Standardized Log Price - Robustness to Additional Controls**

VARIABLES	(1) Std. ln(Price)	(2) Stdz. ln(Price)	(3) Stdz. ln(Price)	(4) Stdz. ln(Price)	(5) Stdz. ln(Price)
Age of Relationship	-0.00554***	-0.00552***	-0.00480***		
	(0.00156)	(0.00146)	(0.00140)		
ln(Age of Relationship+1)				-0.0186***	-0.0161***
				(0.00500)	(0.00483)
Stdz. ln(Quantity)	-0.0472***	-0.0463***	-0.0420***	-0.0463***	-0.0420***
	(0.00780)	(0.00722)	(0.00414)	(0.00719)	(0.00414)
Supply Share		0.0262*	0.0183	0.0268	0.0184
		(0.0157)	(0.0137)	(0.0163)	(0.0148)
Demand Share		0.0119	0.0378	-0.00200	0.0250
		(0.0486)	(0.0400)	(0.0479)	(0.0388)
ln(Age Buyer)		-0.000836	-0.00368***	-0.00169	-0.00439***
		(0.00117)	(0.00117)	(0.00114)	(0.00124)
ln(Distance Km)		2.96e-05	0.000472	-2.77e-05	0.000424
		(0.00192)	(0.00194)	(0.00192)	(0.00194)
ln(Sales Buyer)		0.00108**	0.000774**	0.00110**	0.000804**
		(0.000469)	(0.000318)	(0.000477)	(0.000318)
ln(N. Employees Buyer)		0.000235	0.00161*	0.000256	0.00160*
		(0.000846)	(0.000932)	(0.000841)	(0.000936)
ln(Assets Buyer)		0.00131***	0.00228***	0.00132***	0.00230***
		(0.000318)	(0.000696)	(0.000319)	(0.000668)
ln(Wages Buyer)			-0.000472		-0.000471
			(0.000319)		(0.000322)
ln(Expenditures Buyer)			-0.000949**		-0.000926***
			(0.000377)		(0.000347)
ln(Cash Buyer)			0.000785**		0.000784**
			(0.000338)		(0.000335)
ln(Fixed Assets Buyer)			0.000507**		0.000501**
			(0.000253)		(0.000247)
ln(Debt Buyer)			-0.000456		-0.000453
			(0.000411)		(0.000410)
Leverage Buyer			0.000833		0.000835
			(0.00195)		(0.00194)
1{BG Buyer}		-0.00374	7.80e-05	-0.00383	-7.23e-06
		(0.00236)	(0.00207)	(0.00236)	(0.00207)
1{Multinational Buyer}		0.0194		0.0197*	
		(0.0120)		(0.0118)	
1{Exporter Buyer}		-0.00747	-0.0239**	-0.00721	-0.0239**
		(0.00566)	(0.00937)	(0.00553)	(0.00948)
Export Share Buyer			0.0321***		0.0314***
			(0.00793)		(0.00791)
1{Importer Buyer}		0.00369**	0.000511	0.00357*	-0.000107
		(0.00184)	(0.00440)	(0.00183)	(0.00442)
Import Share Buyer			0.0105*		0.0112*
			(0.00562)		(0.00579)
Observations	76,412	73,633	65,754	73,633	65,754
R-squared	0.075	0.082	0.048	0.083	0.048
Year FE	Yes	Yes	Yes	Yes	Yes
Buyer Sector FE	No	No	Yes	No	Yes

Notes: This table presents regressions regressions of standardized unit prices on age of relationship, standardized quantity, and different buyer characteristics. Standard errors are clustered at the seller-year level. *** p<0.01, ** p<0.05, * p<0.1

modality relying on the transaction-level data. Pooling all industries, we observe that for transactions conducted via trade-credit, quality-adjusted prices decrease as relationships age, accounting for plausible quantity discounts by controlling for a flexible spline in quantity. Conversely, when the transaction's modality is pay-in-advance, standardized prices increase as relationships age. The same pattern holds within each industry.

I interpret these findings, coupled with the phenomenon of backloading of quantities, as supporting a model with limited contract enforcement. Such a model can explain the observed price and quantity dynamics if the seller has a profit-maximizing incentive. By delaying the buyer's net return, the seller can motivate the buyer to act in a disciplined manner, leading to the maximization of expected profits.

Fact 6: Relationships that trade more are more likely to survive

Lastly, relationships are persistent. 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.

3 An Empirical Dynamic Contracting Model

This section introduces an empirical model of dynamic contracting with limited enforcement and seller market power. Through the first-order, necessary conditions for optimality of the seller and the buyer, 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 we denote by $\delta < 1$ the common discount factor. Buyers' preferences depend on a private information match attribute (or type) θ, continuously distributed with support $[\underline{\theta}, \bar{\theta}]$, $\underline{\theta} > 0$, cumulative distribution function $F(\theta)$ and probability density function $f(\theta)$. This match attribute is drawn at the beginning of the relationship and is kept constant over time. Although the parameter is private information, the distribution $F(\cdot)$ is common knowledge.

Relationships end due to exogenous shocks that happen at every period τ with probability $X(\theta)$.[21] The exit probability $X(\cdot)$ is also common knowledge. Due to this, the type's distribution evolves over time. Define $f_\tau(\theta) = f(\theta)(1-X(\theta))^\tau / \int (f(m)(1-X(m))^\tau) dm$ as the probability density function for time τ and $F_\tau(\theta)$ as its corresponding density function.

A trade profile stipulates an infinite array of transfers t_τ and quantities q_τ for each time period τ, $\{t_\tau, q_\tau\}_{\tau=0}^{\infty}$.[22] The trade profile gives the following discounted payoff to the principal

$$\sum_{\tau=0}^{\infty} \delta^\tau (t_\tau - c_\tau q_\tau) \tag{6}$$

and to the buyer type θ:

$$\sum_{\tau=0}^{\infty} \delta(\theta)^\tau (\theta v(q_\tau) - t_\tau), \tag{7}$$

where $v(\cdot)$ is the base return function, $\delta(\theta) \equiv \delta(1 - X(\theta))$, and c_τ is the within-period constant marginal cost of production. I consider $v(\cdot)$ strictly increasing and strictly concave.[23]

In line with the empirical evidence in Section 2, which shows trade-credit is common, I assume the seller first delivers the goods and has to wait for the buyer to transfer the

[21] The model can accommodate for dynamic hazard rates $X_\tau(\theta)$.

[22] Throughout the next sections, I will use the terms transfers and tariffs interchangeably.

[23] This property 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).

promised amount before the end of the period, effectively offering trade-credit to the buyer in every transaction. While this assumption is strong, it reduces the complexity of the problem by shutting down one additional choice variable.

As it is standard in the literature on dynamic mechanism design (Pavan et al., 2014; Garrett et al., 2018), I assume the seller can commit fully to the long-term contract, meaning they will not change the terms of the trade profile at any point in the future. 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 transfers in each period for agent reporting type θ.

Lastly, 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.*

Timing. The contracting game takes places in the following order:

1. Prior to trade, at $\tau = 0$, the buyer observes their private type θ. The seller offers the mechanisms menu $\{C(\theta)\}_{\underline{\theta}}^{\bar{\theta}}$. The buyer either accepts or rejects the offer. If the buyer accepts, they report type $\widehat{\theta}$. If they reject, both the seller and buyer receive their outside options, normalized to 0.[24]
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.
    - Following a breach on the buyer's side, the contract is terminated by the seller.

As it will made clear below, the contract considered is default-free, thanks to the use of enforcement constraints, and features no renegotiation. Since default never occurs in equilibrium, there is no loss in assuming that the seller terminates trade following a breach (Abreu, 1988; Levin, 2003).

Summary of Environment. The next assumption summarizes the environment of the problem.

Model Assumption 1. *a. Buyers privately observe their fully persistent match-type θ prior to trade. The type is drawn from a commonly known distribution function $F(\theta)$ with probability distribution $f(\theta)$.*

b. Relationships exogenously break down each period with known probability $X(\theta)$, implying that the distribution of types $F_\tau(\theta)$ evolves over time.

c. There is a common discount factor δ, which together with the exit probability implies buyer's effective discount factor $\delta(\theta)$.

[24]For the buyer, this normalization is not restrictive if they use a production function that mixes variable inputs linearly or if the supplier is a true monopolist. As shown in 1, buyers tend to be wholesalers or retailers, which plausibly use inputs linearly. For the seller, the normalization is not restrictive if there production function features constant returns to scale.

d. The seller proposes a direct mechanism $C(\theta)$, for which they have commitment. Buyers announce type $\widehat{\theta}$, pay for goods after receiving them, and can act opportunistically and default on their debt $t_\tau(\widehat{\theta})$ if they wish. If they do, the relationship is terminated.

e. Each period τ, buyers' net return is given by $\theta v(q_\tau(\widehat{\theta})) - t_\tau(\widehat{\theta})$, for $v(\cdot)$ strictly increasing and strictly concave, while seller's net profit is given by $t_\tau(\widehat{\theta}) - c_\tau q_\tau(\widehat{\theta})$, for constant marginal cost c_τ.

3.2 Constraints

As usual, the set of constraints of the seller's problem contains the usual individual rationality and incentive compatibility constraints of adverse selection problems.[25] However, this setting's novelty is to include additional enforcement constraints in each trading period, which 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, similar to Martimort et al. (2017), incentive compatibility requires that the agent evaluates their lifetime return:

$$\sum_{\tau=0}^{\infty} \delta(\theta)^\tau u_\tau(\theta) \geq \sum_{\tau=0}^{\infty} \delta(\theta)^\tau [\theta v(q_\tau(\widehat{\theta})) - t_\tau(\widehat{\theta})] \quad \forall \theta, \widehat{\theta}, \tag{IC-B}$$

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

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:

$$t_\tau(\theta) \leq \sum_{s=1}^{\infty} \delta(\theta)^s u_s(\theta) \quad \forall \theta, \tau. \tag{LE-B}$$

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.[26] From this, it follows that ex-ante trade under limited enforcement should leave participating buyers weakly better than under perfect

[25] To make non-trivial theoretical predictions about the dynamics in the relational contract, one should add *interim* individual rationality constraint, $u_\tau(\theta) \geq \underline{\mathrm{u}}$, for some lower bound $\underline{\mathrm{u}}$. 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. In describing theoretical predictions, I will highlight when this assumption is used.

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

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

$$\sum_{\tau=0}^{\infty} \delta(\theta)^{\tau} u_{\tau}(\theta) \geq \delta(\theta)^{\tau} \theta v(q_{\tau}(\widehat{\theta})) + \sum_{s=0}^{\tau-1} \delta(\theta)^{s} [\theta v(q_s(\widehat{\theta})) - t_s(\widehat{\theta})] \quad \forall \theta, \widehat{\theta}, \tau \tag{DD-B}$$

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.[27]

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. *Consider a problem that satisfies Model Assumption 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

[27] 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 $\delta(\theta)^{\tau} t_{\tau}(\theta) \leq \sum_{s=\tau+1}^{\infty} \delta(\theta)^s u_s(\theta) - \left(\sum_{s=0}^{\tau-1} \delta(\widehat{\theta})^s [\theta v(q_s(\widehat{\theta})) - t_s(\widehat{\theta})] - \sum_{s=0}^{\tau-1} \delta(\theta)^s [\theta v(q_s(\theta)) - t_s(\theta)] \right) \; \forall \theta, \widehat{\theta}, \tau$. As the term in the brackets is positive by assumption, LE-B holds.

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:

$$q_\tau(\theta)^{1-\beta} = \overbrace{\frac{k\beta}{c_\tau}}^{\text{Inv. } \mu} \left[\overbrace{\theta - \frac{1-F(\theta)}{f(\theta)}}^{\text{Virtual Surplus}} - \overbrace{\frac{\theta\gamma_\tau(\theta)}{f(\theta)}}^{\text{LE}} + \overbrace{\frac{(1-\Gamma_\tau(\theta))}{f(\theta)}}^{\text{LE+IC}} + \overbrace{\frac{\sum_{s=0}^{\tau-1}(1-\Gamma_s(\theta))}{f(\theta)}}^{\text{Past LE + IC}} \right] \tag{8}$$

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 typical 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 allocation equations in Jullien (2000) and Attanasio and Pastorino (2020).

Fifth, contrasting the solutions of Jullien (2000) and Attanasio and Pastorino (2020), 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. A similar result is presented in Martimort et al. (2017) for a discrete number of types.

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 countervailing forces. On the one hand, the selection functions exert downward pressure on quantities through the virtual surplus and the cumulative multipliers. Firstly, for the virtual surplus, positive selection ($X'(\theta) < 0$) implies lower quantities over time, all else being equal. As the selection pattern concentrates the distribution towards higher types over time, the seller must decrease future quantities for middle types to maintain incentive compatibility. Secondly, selection also influences the promises captured in the past through the cumulative multipliers. Ceteris paribus, if the selection function $X(\theta)$ implies first-order stochastic dominance over another selection function $\tilde{X}(\theta)$, i.e., $F_\tau(\theta) \leq \tilde{F}_\tau(\theta)$, then increases from past promises will diminish in value over time. For example, in contrast to a scenario where relationships are perpetual, promises made in the distant past carry less weight when exogenous exits occur ($X(\cdot) > 0$). Consequently, all else being equal, backloading forces are weaker in the presence of exogenous exits. However, in the absence of relationship termination, promises made in the past will perpetually affect trade levels, as demonstrated by Marcet and Marimon (1992).

On the other hand, the discounting of past promises is lower for middle and upper types due to their lower exit rates. Thus, relative to lower types, the selection function implies greater backloading in quantities for middle types. Moreover, in comparison to higher types, backloading will also be more pronounced for middle types, as the influence of past cumulative multipliers ($\sum_{s=0}^{\tau-1}(1-\Gamma_s(\theta))$) is greater for middle than higher types.

Lastly, if a tariff schedule satisfies t-RULE, then it preserves local incentive compatibility constraints. Together, equations SFOC and t-RULE will serve as the identifying and estimating equations for the paper.

3.5 Model Implications

Next, I offer a discussion on how the model is able to rationalize the stylized facts in Section 2. For this, it is useful to explore the optimal contract after relaxing the different constraints.

3.5.1 *Perfect Enforcement and Complete Information*

Under complete information and full enforcement, the seller acts as a monopolist practicing first-degree price discrimination with a stationary contract $(t^{1d}(\theta), q^{1d}(\theta))$, defined as

$$\theta v'(q^{1d}(\theta)) = c \quad \text{and} \quad t^{1d}(\theta) = \theta v(q^{1d}(\theta)). \tag{1D-Q \& 1D-T}$$

The seller offers first-best quantities but extracts all the rents from the buyer (subject to an interim individual rationality constraint, $u_\tau(\theta) \geq 0$). This allocation is infinitely repeated over time. In this model, quantities and prices are constant over time, hence there are no dynamics. Moreover, while quantities increase by type, prices may be constant under some parametrizations of $v(\cdot)$.

3.5.2 *Perfect Enforcement and Incomplete Information*

This setting is similar to the canonical repeated adverse selection problem (Baron and Besanko, 1984; Sugaya and Wolitzky, 2021). As the seller has commitment, there is no loss of generality in restricting the study to an infinite sequence menu $\{t_\tau(\theta), q_\tau(\theta)\}_{\underline{\theta},\bar{\theta}}$ that induces the agent to report their true type. The problem of the seller is maximizing profits subject to IC-B and interim individual rationality constraints ($u_\tau(\theta) \geq 0$).

The theoretical insights from Baron and Besanko (1984) apply in this setup.[28] The optimal dynamic contract with full enforcement is equal to repeated Baron-Myerson static contracts with quantities determined by:

$$\theta v'(q_\tau^{pe}) = c_\tau - \frac{1 - F_\tau(\theta)}{f_\tau(\theta)} v(q_\tau^{pe}(\theta)), \tag{PE-Q}$$

and tariffs such that

$$t_\tau^{pe}(\theta) = \theta v(q_\tau^{pe}(\theta)) - \int_{\underline{\theta}}^{\theta} v(q_\tau^{pe}(x))dx. \tag{PE-T}$$

To preserve incentive compatibility of the buyer, the seller offers higher quantities to higher types within a given period. Moreover, the price schedule is shown to feature quantity discounts under common classes of assumptions on the curvature of demand and the distribution of types (Maskin and Riley, 1984) .

Under positive selection (i.e., $X'(\theta) < 0, \forall\theta$), average and type-specific quantities *decrease* over time. Similarly, average and type-specific unit prices *increase*.[29] Instead, without selection patterns (i.e., $X'(\theta) = 0, \forall\theta$), the optimal full enforcement contract with asymmetric information is stationary.

Therefore, while asymmetric information is able to rationalize the observed quantities discounts, on its own, it is not able to rationalize the dynamics of quantities and prices under observed selection patterns.

3.5.3 *Limited Enforcement and Complete Information*

Next, consider a model without adverse selection, where the buyer can default on trade-credit at any time. In this context, the seller selects trade profiles $\{t_\tau(\theta), q_\tau(\theta)\}_{\underline{\theta},\bar{\theta}}$ that maximize lifetime profits, subject only to the limited enforcement constraint (equation LE-B). This model is reminiscent of the models in Thomas and Worrall (1994), Ray (2002),

[28] Theorem 4' offers the results for fully persistent types in an infinite horizon model.

[29] With positive selection, informational rents given to middle-types decrease, as the distribution is shifting towards higher-types $F_\tau(\theta) > F_{\tau+1}(\theta)$. In order to incentivize the highest types still active, middle-types will be distorted downwards in the future. Marginal unit prices are given by $p(q(\theta)) = c + (1 - F_\tau(\theta)/f_\tau(\theta)$ (Armstrong, 2016), which will be generally larger for each θ, and as such, average price will be larger at each q.

and Albuquerque and Hopenhayn (2004), which feature quantity and price backloading, as those described in the reduced form section.

In particular, the optimal contract quantities are determined by the following equation:

$$\theta v'(q_\tau^{le}) = \frac{c_\tau}{1-\gamma_\tau(\theta)}, \tag{LE-Q}$$

where $\gamma_\tau(\theta)$ is the Lagrange multiplier on the limited enforcement constraint.

Without the need of an interim individual rationality constraint, the limited enforcement constraint generates dynamics, features an *initial phase*, in which quantities are set to zero for all types, for which $\gamma_0(\theta) = 1$, and a stationary *mature phase*, in which $\gamma_\tau(\theta) = X(\theta)$. More patient buyers, those with smaller $X(\theta)$, are closer to their first-best. Additionally, all else equal, higher types receive higher quantities.

The enforcement constraints are always binding, and the optimal tariffs are set as follows:

$$t_\tau^{le}(\theta) = \delta(\theta)\theta v(q_{\tau+1}^{le}), \tag{LE-T}$$

so tariffs are constant over time, but prices decrease between the *initial* and *mature* phase. Prices may vary by type, but in a simple CES model, prices are constant across types.

Therefore, limited enforcement generates backloading. This backloading is not a result of unequal discount rates, as it also appears in cases without exit. The intuition is that limited enforcement constraints create an asymmetry: the buyer compares current tariffs to future returns, so *ceteris paribus*, there is an incentive to minimize current quantities to maximize current profits. However, trade converges to the mature phase almost immediately, by the second interaction.

By making the additional interim individual rationality constraint ($u_\tau(\theta) \geq 0$), the initial phase lengthens. The reason is that the additional limited liability constraint forces quantity changes between periods to be smaller. The length of the initial path is dependent on the parameters for the buyer's return function and the discount factor. The higher the common discount factor or the lower the exit rate (the more patient the buyer), the longer the path before the mature phase. Similarly, the more responsive the return function, the longer the path. Though the path to convergence is longer, under a CES model, prices are constant across types within a given period.

3.5.4 *Full Model: Limited Enforcement and Incomplete Information*

As demonstrated, incomplete information independently rationalizes quantity discounts, while limited enforcement independently rationalizes the backloading of quantities and prices. Now, I will explore the properties of a model that incorporates both limited enforcement and incomplete information. Given the complexity of this combined model and its main purpose as an empirical framework, I will present general results rather than fully characterizing the optimal dynamic contract.

Non-Stationarity. As in the results above, the optimal contract must be non-stationary. To see this, first note that the problem does have a unique stationary equilibrium. However, a non-stationary deviation exists that dominates the stationary equilibrium. In particular, consider a uniform deviation to the stationary contract, in which all types are extracted an additional uniform ε by adjusting their initial period quantities downwards. As initial tariffs and the remainder of the contract are unchanged, the limited enforcement constraints are still satisfied. Moreover, as all types are extracted the same uniform ε, the incentive compatibility constraints are unchanged. This deviation offers higher profits and still satisfies the constraints. Therefore, if a globally optimal contract exists, it must be non-stationary.[30]

Model Properties.[31] The model is able to rationalize the empirical facts presented in Section 2. First, within any relationship age, the seller offers quantity discounts (Proposition 3). The conditions for quantity discounts to hold are strengthened versions of the usual assumptions of non-linear pricing models (e.g., Maskin and Riley, 1984). In particular, the evolution of distribution types $F_\tau(\theta)$ must preserve log-concavity and hold under modified monotone hazard condition, together with the standard requirement of monotonicity of quantities for every relationship age ($q'_\tau(\theta) > 0$).

Second, 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 4, i.). Thus, the model permits quantity dynamics. Furthermore, absent selection patterns, the model explicitly predicts backloading of quantities. (Proposition 4, ii.) In particular, there is a time period τ^* such that enforcement constraints are no longer binding for any type θ, so the contract converges to a long-term stationary equilibrium. In such equilibrium, quantities are at their highest for each type ($q_{\tau^*}(\theta) \geq q_\tau(\theta)$). Such long-term equilibrium maybe potentially be efficient or inefficient (Proposition 4, iii.), featuring under- or over-consumption. This means that the model does not necessarily imply long-term efficiency.

Third, the model accommodates backloading of prices (Proposition 5). In particular, if the quantity schedule (weakly) features backloading for all buyers (and strictly so for the lowest type), then an increase in quantities forces a global decrease in prices to preserve local incentive compatibility.

The intuition as to why the model with limited enforcement and asymmetric information rationalizes the observed dynamics is the following.[32] First, the enforcement constraint generates an incentive to decrease quantities now, keeping all future trade profiles constant. Thus, the enforcement constraint generates the backloading of prices and

[30] I outline the formal argument for this in Online Appendix OA-4 through two steps: 1) showing existence of an stationary equilibrium and 2) showing the non-stationary deviation dominates the stationary equilibrium.

[31] Refer to Online Appendix OA-7 for proofs to the referenced propositions and to see a solved two-type example, please refer to Online Appendix OA-6.

[32] Online Appendix Section OA-6 presents a solved two-type example that provides intuition as to how the optimal dynamic contract works.

quantities. Second, the length of the initial phase will be determined by the interim individual rationality constraints, which prevent quantities change too much between periods, to stop the net returns of the buyer from crossing a specific threshold. Third, to preserve incentive compatibility, quantities are distorted downward for lower types and price discounts are offered to higher types. Finally, dynamically, quantities increase and prices decrease for all types, as promised were made to prevent default. Interestingly, even though higher types tend to be less distorted in quantities and see less quantity dynamics over time, the seller can extract higher profits from them at the beginning of the relationship because trade profiles for lower types were unattractive due to low quantities and high prices. And therefore, the seller can extract higher profits from all types at the beginning of the relationship, more so than they could under perfect enforcement.

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 and to measure the effects of lack of enforcement. While advances have been made in solving infinitely repeated games with a continuum of buyers when the principal lacks commitment (Doval and Skreta, 2022), such methods would require longer data panels to separately identify the enforcement constraints on the buyer's side from the dynamic belief formation on the seller's side.

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). One can address the limited enforcement issues for both parties through a pooling enforcement constraint, which reduces both conditions to a single Lagrange multiplier per period. While technically feasible to apply here, I do not follow this approach for several reasons. A model with seller opportunism features front-loading of prices, counter to what we observe. Moreover, since a large share of trade occurs via trade-credit, seller opportunism is mitigated by allowing the buyer to withhold payment if quality is subpar (Smith, 1987; Klapper et al., 2012; Antras and Foley, 2015). Lastly, compared to the average manufacturing firm, sellers in my study are larger, more capital-intensive, and import more inputs directly, making quality issues from production errors less likely.

On the buyer's side, I assume their types are fully persistent due to data limitations. The model can easily accommodate Markov types, but to bring it to the data, the researcher would need to track the transactions of new buyers over time. As I only observe two years of data, I must rely on a full persistence assumption.

4 Identification and Estimation of Dynamic Contracts

In this section, I discuss the identification and estimation of the model primitives θ and $v(\cdot)$, and the auxiliary functions $\Gamma_\tau(\cdot)$ and $\gamma_\tau(\cdot)$. 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. I present additional assumptions required to derive the identifying equation and provide a detailed discussion regarding the identification assumptions. Furthermore, I offer guidance on how model misspecification may affect the results. Finally, I describe a cross-sectional estimation procedure that utilizes the main identification equation to recover the model primitives from the available data.

4.1 Identification

For each seller in a given year, the observables are unit prices $p_\tau(q)$ (or transfers $t_\tau(q)$) and quantities q_τ for different buyers with relationship age τ, as well as marginal costs c.[33] Throughout this section, I abstract from the possibility of exogenous breakups; the possibility of breakups will be reintroduced in estimation.[34] 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.

I now begin by stating the identification assumptions (IA). As demonstrated in Section 3, the dynamic contract is a complex object. Instead of deriving the full equilibrium contract through forward-iteration, I rely on the following assumption.

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.*

Under IA 1, I can collapse all information about future unobserved quantities and transfers into the limited enforcement multipliers. The seller is aware of the solution and the future promises —the first order conditions are consistent with them— and I exploit this knowledge to learn about enforcement distortions. Although the assumption is strong, it is often used in the identification of dynamic games, as these types of games may have multiple equilibria (Aguirregabiria and Nevo, 2013).

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

IA 2 directly links observed quantities with underlying unobserved types, allowing us to infer that buyers purchasing higher quantities have better match-quality with the seller.

[33] 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.

[34] 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.

Furthermore, we can deduce the distribution of types from the distribution of quantities, $F_\tau(\theta(\alpha)) = \alpha$, for quantile α. This also implies $f_\tau(\theta(\alpha)) = 1/\theta'_\tau(\alpha)$ through the chain rule. Lastly, we derive the relationships $\Gamma_\tau(\theta_\tau(\alpha)) = \Gamma_\tau(\alpha)$ and $\gamma_\tau(\theta(\alpha))\theta'_\tau(\alpha) = \gamma_\tau(\alpha)$.

This assumption 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.[35] (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.

Identification Assumption 3. *Types θ are fully persistent.*

IA 3 allows us to link past estimated multipliers $\Gamma_s(\theta)$ for $s < \tau$ over time. Specifically, this assumption, in conjunction with IA 2, implies that buyers at the quantity quantile α at time τ correspond to the multipliers of buyers at the quantity quantile α at time s, $\Gamma_s(\alpha)$.[36]

Identification Assumption 4. *The return function is of the form $v(q) = kq^\beta$, for $k > 0$ and $\beta \in (0, 1)$.*

I assume a constant-elasticity parametrization for the return function $v(q)$, which will be essential for point identification of the primitives. The parametrization is consistent with the assumption of increasing but diminishing returns on the input for the buyer, i.e., $v'(\cdot) > 0$ and $v''(\cdot) < 0$.

Identification Assumption 5. $\underline{\theta}_\tau = 1$.

Finally, without loss of generality, I make a common normalization assumption on the lowest type. As Luo et al. (2018) show, $\underline{\theta} = 1$ is a valid normalization for a general function $v(\cdot)$. Under IA 4, $\underline{\theta} = 1$ also serves as a normalization, as it suffices to multiply k by the normalization constant to obtain an observationally equivalent problem structure.

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 and the derivative of the buyer's transfer rule t-RULE in terms of

[35] In simulations, negative selection patterns ($X'(\theta) > 0$) lead to this.

[36] Access to a long-term panel would enable the relaxation of this assumption, as the econometrician could track, for each buyer b, past estimated multipliers $\Gamma_s(\theta_{s,b})$, even when the types change over time ($\theta_{s,b} \neq \theta_{\tau,b}$). Unfortunately, my short panel of two years only permits the tracking of multipliers for one year in the past, and only for buyers who have just begun trading, rather than buyers in long-term relationships.

quantiles α (Luo et al., 2018; Luo, 2018):

$$k\beta\theta_\tau(\alpha)q_\tau(\alpha)^{\beta-1} - c =$$
$$\left[\Gamma_\tau(\alpha) - \alpha - \sum_{s=0}^{\tau-1}(1-\Gamma_s(\alpha)) + \frac{\theta_\tau(\alpha)}{\theta'_\tau(\alpha)}\gamma_\tau(\alpha)\right] k\beta\theta_\tau(\alpha)q_\tau(\alpha)^{\beta-1}\frac{\theta'_\tau(\alpha)}{\theta_\tau(\alpha)},$$
$$T'_\tau(q_\tau(\alpha)) = k\beta\theta_\tau(\alpha)q_\tau(\alpha)^{\beta-1},$$

where $\alpha \in [0,1]$, and I used the fact that the observed price schedule can be mapped to the model transfer schedule by $T_\tau(q_\tau(\theta(\alpha))) = t_\tau(\theta(\alpha))$. Moreover, $\theta_\tau(\alpha)$ and $q_\tau(\alpha)$ are the α-quantiles of the agent's type and quantity at tenure τ, respectively. Notice as well that I have used $f_\tau(\theta(\alpha)) = 1/\theta'_\tau(\alpha)$ and $\gamma_\tau(\theta_\tau(\alpha)) = \gamma_\tau(\alpha)/\theta'_\tau(\alpha)$ (IA 2) and linked multipliers $\Gamma_s(\alpha)$ with the buyer's current quantile α (IA 3).

Together, the key identification equation becomes:

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

where $\theta_\tau(\cdot)$, $\theta'_\tau(\cdot)$, $\Gamma_\tau(\cdot)$, and $\gamma_\tau(\cdot)$ are unknown. This equation will be the base for the identification of all unknown functions and parameters. Besides the discussion above, it is worth clarifying that IA 1 and 3 imply the dynamic contract is identified using *cross-sectional* variation across cohorts within a given seller-year.

Identification Results. I now present point identification results.[37]

Proposition 2. *Under IA 1, 2, 3, and 4, 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. Additionally with IA 5, 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 identification intuition is the following, highlighting why IA 4 is the key for point identification.

Generally speaking, the identifying equation I-EQ is nonparametrically unidentified because both the ratio $\theta'_\tau(\alpha)/\theta_\tau(\alpha)$ and the multipliers $\Gamma_\tau(\alpha)$ are unknown. However, even without parametrizing $v(\cdot)$, it can be shown that $\theta'(\alpha)/\theta(\alpha) = T''(q(\alpha))/T'(q(\alpha)) - v''(q(\alpha))/v'(q(\alpha))$ since tariffs must satisfy incentive compatibility. Consequently, from the identifying equation I-EQ, $\Gamma_\tau(\alpha)$ is point identified up to $-v''(q(\alpha))/v'(q(\alpha))$. By providing additional structure on the curvature of the return function, the identification equation simplifies. Specifically, by parametrizing $v(q)$ under IA 4, the ratio $-v''(q(\alpha))/v'(q(\alpha))$ becomes $(1-\beta)/q$, which depends only on a single parameter.

[37] Luo (2018) studies the nonparametric identification of this model and of $\Gamma_\tau(\alpha)$ in particular with observations on prices and quantities alone. They find that this model is nonparametrically identified if one can find an alternative efficient market, for which $\Gamma_\tau(\alpha) = 1$ for all α, in order to learn about $\theta'_\tau(\alpha)/\theta_\tau(\alpha)$. With information on $\theta'_\tau(\alpha)/\theta_\tau(\alpha)$ in hand, $\Gamma_\tau(\alpha)$ is nonparametrically identified from information on transfers and prices alone. This approach is not feasible in my setting as each seller is considered a market, and it is impossible to find something that could be regarded as an alternative efficient market for each seller.

The proposition shows that this simplification is sufficient to provide point identification of the auxiliary functions $\Gamma_\tau(\cdot)$ and $\gamma_\tau(\cdot)$. This is based on the fact that the multipliers are identified for the highest type $\overline{\theta}$ in tenure $\tau = 0$ without any additional assumptions. In particular, any distortions to the consumption of the highest type reflect only enforcement constraints. If such constraints were absent, the consumption of the highest type would be efficient, as in the usual Baron-Myerson problem. Therefore, any gap in marginal revenue and marginal cost for the highest type ($T_0'(q_0(1)) - c$) *directly* identifies the enforcement multiplier $\gamma_0(1)$ for $\tau = 0$ and $\alpha = 1$.[38]

The knowledge of enforcement multipliers $\Gamma_0(1)$ and $\gamma_0(1)$ at $\alpha = 1$ allows for an approximation of the identification equation for an arbitrary quantile $1-\varepsilon$, for a small enough ε, through a Taylor expansion. As a result, the identification equation for such a quantile $1-\varepsilon$ will have only one unknown, β, which is now identified based on observations of quantities, prices, and marginal costs. Therefore, the difference in marginal prices $T_0'(1)$ and $T_0'(1-\varepsilon)$ will provide information about the degree of dispersion required to satisfy incentive compatibility due to changes in the marginal return for the buyer, thus providing information about the curvature of the return function β.

These results extend the identification approach of Attanasio and Pastorino (2020) by making a novel contribution. Namely, I offer point identification results through a parametrization, even in cases where the multipliers may vary. In contrast, Attanasio and Pastorino (2020) only provide point identification results for the case of constant multipliers, and address identification concerns by using a parametrized multiplier function.

For estimation, nonetheless, I follow the approach of Attanasio and Pastorino (2020), which consider a parametrization of $\Gamma_\tau(\cdot)$ as a flexible function of q_τ rather than parametrizing the return function $v(\cdot)$. This simplifies the search for the solution to the differential equation $\Gamma_\tau(\cdot)$ and $\gamma_\tau(\cdot)$, as it known restricts them to be part of an known family of functions.

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. Observable quantity distortions relative to an unconstrained world are then used to infer informational and enforcement rents. This approach offers several benefits, as it allows me to identify and estimate the model without needing to solve it fully. A full-solution approach would require repetitive forward iteration of the model for each specific type, which could become computationally burdensome and limit the dimension of the type-space.

This assumption also proves useful in cases of model mispecification. Specifically, it permits the buyer to have outside options that the econometrician cannot observe, as

[38] As an auxiliary lemma in Appendix B, the cumulative multiplier at the highest type is shown to be equal to 1 for all periods τ, i.e., $\Gamma_\tau(1) = 1$.

long as the seller is aware of them, and these outside options will be accounted for in the enforcement constraints. Although the econometrician may not be able to distinguish the effects of outside options from those of future promises, this does not create any identification issues for the welfare analysis primitives.[39]

One important limitation of this approach is that it cannot address counterfactuals involving dynamic quantities, since solving for such quantities would require iterative solution methods. Nevertheless, this methodology provides valuable insights for understanding the efficiency of *actual* trade, which is the focus of this paper.[40]

My identification results rely on observing (or using proxies for) marginal costs. The gap between prices and marginal costs indicates whether trade is distorted by enforcement constraints for the highest type. Previous work by Attanasio and Pastorino (2020) identifies unobserved costs through the parametrization of the multipliers, jointly identifying costs consistent with those multipliers. Similarly, Luo et al. (2018) identifies costs by assuming that, in the absence of enforcement constraints, trade for the highest type is efficient, making marginal prices equal to marginal costs. By using data on production costs for the sellers, I can relax these past assumptions.

4.2 Estimation

I now present the estimation approach, which relies on the identification equation I-EQ.[41] The equation is estimated separately for each seller-year j and tenure τ, using $N_{j\tau}$ observations of quantities $q_{ij\tau}$ and transfers $t_{ij\tau}$ for each buyer i. Exogenous hazard rates $X_{ij\tau}$ are now reintroduced. Given that estimation is done separately for each seller-year, I drop the subscript j in the remainder of the section.

Before reaching the key estimating equation, there are three intermediate steps to obtain all required components

4.2.1 *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 transfers 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. As noted by Luo et al. (2018), however, observed prices and quantities may not lie on the curve,

[39] Mispecification of the model will impact the equilibrium transfer solution. For example, if buyers have a constant outside option, equilibrium transfers will be lower by the value of the outside option. However, this will not affect the marginal prices and thus the primitives identified from them, including the base marginal return and the type, remain unaffected as well.

[40] Model mispecification in terms of outside options also affects the counterfactuals of different enforcement or pricing regimes. If the outside options are constant, the counterfactuals will be correct in terms of efficiency. Surplus division will be biased towards the seller. If outside options are heterogeneous, the counterfactual efficiency will also be affected. Yet, the direction of the bias is uncertain ex-ante, as it depends on the distribution of types and the curvature of the return function.

[41] Online Appendix Section OA-8 provides Monte Carlo simulations demonstrating the accuracy of the estimation method for a two-period dynamic contract.

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:

$$ln(t_{i\tau}) = \rho_{0\tau} + \rho_{1\tau} ln(q_{i\tau}) + \upsilon_{i\tau}, \tag{9}$$

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.

4.2.2 *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 hazard rates as a logistic function of percentiles:

$$S_\tau(r) = \frac{\exp(a_\tau + b_\tau r)}{1 + \exp(a_\tau + b_\tau r)} + \varepsilon^s_\tau(r), \tag{10}$$

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.

4.2.3 *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. As described in Section 1, average variable cost is defined as total expenditures and total wages divided by total quantity sold. While the assumption of constant marginal costs is standard in the non-linear pricing literature (Luo et al., 2018; Attanasio and Pastorino, 2020),[42] I

[42] The past literature does not have a direct measure of costs and therefore identifies/estimates the constant coefficient using threshold rules (Luo et al., 2018) or by showing that a parametrization on the multiplier helps reduce identification issues for the cost coefficient (Attanasio and Pastorino, 2020). As I do observe cost information for the sellers, I can rely on a single parametric assumption and offer semi-parametric identification of all other relevant objects.

present validating exercises for this assumption in my setting. 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 (Online Appendix Section OA-9).

4.2.4 *Main Step 1: Auxiliary Functions* $\Gamma_\tau(\cdot)$ *and* $\gamma_\tau(\cdot)$

Now, I move to the main estimating steps relying on the key identification equation I-EQ.

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.

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

$$\frac{\widehat{T}'_\tau(q_{i\tau}) - \widehat{c}}{\widehat{T}'_\tau(q_{i\tau})} = \frac{\theta'_\tau(\alpha)}{\theta_\tau(\alpha)}\left[\Gamma_\tau(\alpha) - \alpha - \sum_{s=0}^{\tau-1}(1 - \widehat{\Gamma}^\tau_s(\alpha))\right] + \gamma_\tau(\alpha), \tag{11}$$

where the conditional cumulative multiplier constraint for $s < \tau$ is obtained through numerical integration by Inverse Transform Sampling of $(\widehat{S}_\tau(\alpha))^{\tau-s}\widehat{\gamma}^\tau_s(\alpha)$ for each quantile α, and $\widehat{\gamma}^\tau_s(\alpha)$ is the estimate for the derivative of the cumulative multiplier at time s, which would correspond to a quantile α in time τ, accounting for the selection patterns.

Equation 11 contains multiple unknown functions. Above, I demonstrated that parametrizing $v(\cdot)$ (IA 4) 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.[43] Thus, I parametrize the multiplier as a logistic distribution:[44]

$$\Gamma_\tau(\alpha) = \frac{exp(\phi_\tau(q_\tau(\alpha)))}{1 + exp(\phi_\tau(q_\tau(\alpha)))}, \tag{12}$$

where $\phi_\tau(q_\tau(\alpha))$ is a linear polynomial. 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.

To compensate for the restrictions on the LE multipliers,[45] I consider instead a flexible function for $\theta'(\alpha)/\theta(\alpha)$, specifically as an inverse quadratic function of quantity:

$$\frac{\theta'(\alpha)}{\theta(\alpha)} = \frac{1}{d_0 + d_1 q_\tau(\alpha) + d_2 q_\tau(\alpha)^2}. \tag{13}$$

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

[44]The multiplier function is the solution to a differential equation. As shown in Online Appendix Section OA-4.1.1, 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).

[45]An alternative would be to parameterize the return function and consider the LE multipliers as a flexible differential equation.

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

$$\frac{\hat{\rho}_{1\tau} p_\tau(\alpha) - \widehat{c}}{\hat{\rho}_{1\tau} p_\tau(\alpha)} = \tag{Main Est. Eq.}$$

$$\frac{1}{d_0 + d_1 q_\tau(\alpha) + d_2 q_\tau(\alpha)^2}\Big[\frac{exp(\phi_\tau(q_\tau(\alpha)))}{1 + exp(\phi_\tau(q_\tau(\alpha)))} - \alpha - \widehat{M}_\tau(\alpha)\Big]$$
$$+ \phi'_\tau(q_\tau(\alpha))\frac{exp(\phi_\tau(q_\tau(\alpha)))}{1 + exp(\phi_\tau(q_\tau(\alpha)))}\Big(1 - \frac{exp(\phi_\tau(q_\tau(\alpha)))}{1 + exp(\phi_\tau(q_\tau(\alpha)))}\Big) + \varepsilon^g_\tau(\alpha),$$

where I have used $p_{i\tau} = t_{i\tau}/q_{i\tau}$ and where ε^g is measurement error coming from the mispecification of Γ, the tariff function, or the marginal cost. 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 $\{\phi_\tau, d_0, d_1, d_2, \sigma^{\varepsilon^g}\}$.

To match previously estimated LE multipliers $\Gamma_s(\theta)$ to $\theta(\alpha)$ at tenure τ, I use 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. Additionally, I use the estimated survival rates for τ corresponding to α to properly discount past promises captured in past multipliers.

While this iterative approach may introduce potential propagation errors from previous stages, joint estimation of all tenures together is not readily feasible with my method. The main complication arises from the need to adjust past cumulative multipliers for the evolution of the distribution of types, which is influenced by heterogeneous hazard rates. To obtain the adjusted cumulative multipliers, one must numerically integrate over the evolving distribution of types. This introduces an additional step that would need to be accounted for during the parameter search process of the joint moments. For these reasons, I opt for the iterative approach. Note that if hazard rates are homogeneous or relationships never end, joint estimation is feasible by adding all the likelihood moments linearly in a single likelihood maximization process.

4.2.5 *Main Step 2: Buyer Types and Type Distribution*

Once $\Gamma_\tau(\cdot)$ and $\gamma_\tau(\cdot)$ are estimated, the consumer type $\theta_\tau(\alpha)$ is obtained from

$$ln(\widehat{\theta}_\tau(\alpha)) =$$
$$\frac{1}{N_\tau}\sum_{k=1}^{N_\tau}\frac{1\{\alpha \geq k/N_\tau\}}{\widehat{\Gamma}_\tau(k/N_\tau) - k/N_\tau - \widehat{M}_\tau(k/N_\tau)}\Big[1 - \frac{\widehat{c}}{\hat{\rho}_{1\tau} p_\tau(k/N_\tau)} - \widehat{\gamma}_\tau(k/N_\tau)\Big], \tag{14}$$

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

$$\widehat{\theta'}_\tau(\alpha) = \frac{\widehat{\theta}_\tau(\alpha)}{\widehat{\Gamma}_\tau(\alpha) - \alpha - \widehat{M}_\tau(k/N_\tau)} \Big[1 - \frac{\widehat{c}}{\hat{\rho}_{1\tau} p_\tau(\alpha)} - \widehat{\gamma}_\tau(\alpha)\Big], \tag{15}$$

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

4.2.6 *Main Step 3: Base Marginal Return and Return Function*

The derivative of the transfer 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

$$\widehat{v'(q_\tau(\alpha))} = \frac{\hat{\rho}_{1\tau} p_\tau(\alpha)}{\widehat{\theta}_\tau(\alpha)} \tag{16}$$

and $v(\cdot)$ is estimated by

$$v(q_\tau(\alpha)) = \widehat{T}_\tau(q_\tau(0)) + \frac{1}{N_\tau} \sum_{k=1}^{N_\tau} v'(\widehat{q_\tau(k/N_\tau)}) 1\{\alpha \geq k/N_\tau\}. \tag{17}$$

4.2.7 *Parametrization of $v(\cdot)$ for Counterfactual Analysis*

To calculate pair-specific efficient (first-best) quantities, I require the estimated buyer types θ, base marginal returns $v'(\cdot)$, and seller marginal costs c. The range of optimal quantities may not be covered by the range of realized quantities, and thus, base marginal returns may be undefined for some quantities. To address this, during counterfactual analysis, I parametrize the seller-specific marginal return functions $v(\cdot)$ as $v(q) = kq^\beta$, for $k > 0$ and $\beta \in (0, 1)$. I then estimate these functions for each seller using linear least squares and the values of estimated semi-parametric marginal returns $\widehat{v'(\cdot)}$.

5 Empirical Results

In this section, I first explain the definition of relationship tenure, then discuss the estimates of primitives and auxiliary functions of the model, and show the data fit (both quantitatively and qualitatively). I present the results pooling all sellers together but conduct estimation at the seller-year level.[46]

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.[47] Second, I pool relation-

[46] I show estimates of model fit of the tariff function in Online Appendix Setion OA-10.0.1 and for the survival functions by tenure in Online Appendix Section OA-10.1.

[47] 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.

ship 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.[48]

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 Results

5.2.1 *Primitives and Auxiliary Functions*

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.[49] Recall that for identification, I normalized the lowest type $\underline{\theta}$ to 1. 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.[50] 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 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-20), 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).

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

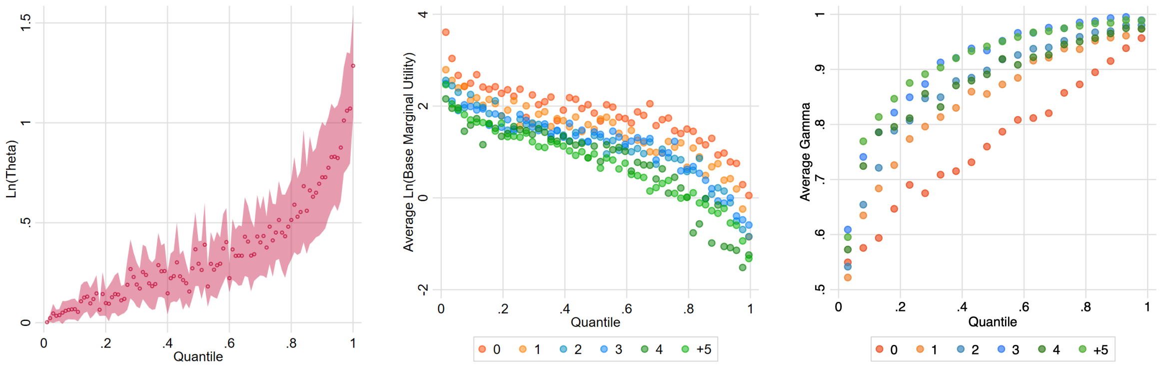
[49] For seller-year estimates of the distribution of types per seller-year, with confidence intervals constructed via bootstrap, refer to the Online Appendix Section OA-10.6.

[50] The semi-parametric estimates for the base marginal return function $v'(\cdot)$ are obtained from equation (16). For counterfactuals, I rely on the parametric estimates of $v(\cdot)$, reported in Online Appendix Table OA-8.

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.[51]

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.[52]

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.

5.3 Model Fit

I use four different measures to assess the fit of the model. First, the model has good statistical fit across tenures (Online Appendix Figure OA-21). 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

[51]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.

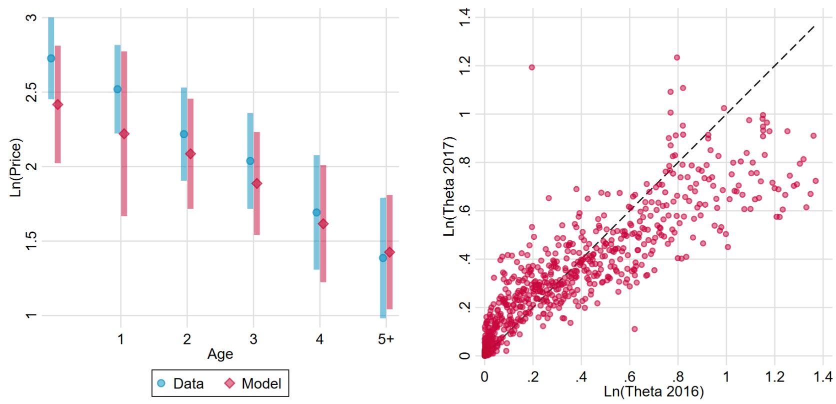
[52]The estimates for the multiplier allows us to test the model against the standard asymmetric information model. Online Appendix Table OA-10.2 displays the distribution of t-statistics for the LE multiplier at tenure 0 (Γ_0) to test against the null hypothesis of a standard model. Based on the significance of the parameters of estimated $\widehat{\Gamma}_0(\underline{\theta})$, I reject the null that the standard non-linear pricing model applies in my setup for 86% of the markets (seller-years).

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-22). 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-23).

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 $\widehat{\theta}$ 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.

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.

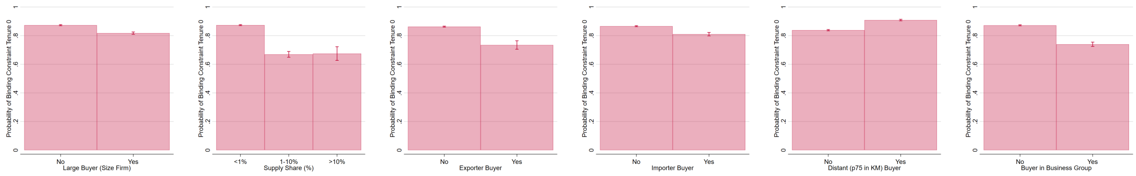
5.4 Qualitative Results

To further explore the implications of the estimated model, I investigate heterogeneity in limited enforcement constraints by seller and buyer characteristics. Although these exercises are outside the scope of the model, they serve to provide interpretation for the enforcement parameter.

Recall that $\gamma_0(\cdot) > 0$ implies that the buyer's limited enforcement constraint is binding. Figure 4 shows the probability that the constraint is binding at tenure 0 by different buyer characteristics, which offers qualitative differences consistent with previous literature on enforcement constraints. For example, larger firms, exporters, importers, or firms in business groups are less likely to have a binding constraint, as these would generally be more reliable buyers. Moreover, buyers that might find it hard to locate an alternative supplier, such as those that depend heavily on the seller (measured by their supply share), are also less likely to have a binding constraint (McMillan and Woodruff, 1999). Lastly, distant buyers, who plausibly impose higher enforcement costs for the seller, are more likely to experience binding enforcement constraints (Antras and Foley, 2015).

To better understand the factors affecting limited enforcement constraints from the sellers' perspective, Figure 5 displays the coefficients from regressions of the share of constrained buyers at tenure 0 on various seller characteristics. The results show that larger sellers, measured by total sales, total assets, or cash holdings, tend to have a lower share of constrained buyers. Similarly, sellers that export or import also have a lower share of constrained buyers. These findings suggest that such sellers may be of higher quality and thus generate larger surpluses for their clients at any level of quantity, making buyers less likely to default. On the other hand, higher levels of seller leverage, which may signal financial distress or uncertainty, are associated with a higher share of constrained buyers, indicating that buyers may be more cautious and less willing to consider long-term future relationships with these sellers. Overall, these results suggest that the quality and financial stability of sellers play an important role in determining the level of limited enforcement constraints in the market.

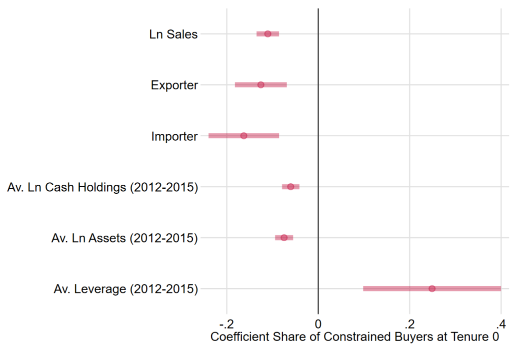
Figure 4: **Enforcement Constraints and Buyer Characteristics**



(a) Size (b) Supply Share (c) Exporter (d) Importer (e) Distance (f) B. Group

Notes: These figures present heterogeneity of estimated limited enforcement multipliers by buyer's characteristics. The figures shows the share of buyers in each group with positive enforcement constraint $\gamma_0(\cdot)$ in tenure 0. A firm is large if they are in the top 25 of sales from the set of buyers. Buyer is classified as exporter if they report at least $5,000 USD of exports and importer if they report at least $5,000 USD of imports. Distance between headquarters is calculated as KM. between neighborhoods as the crow flies. I classify a buyer as part of a business group if they have at least link with another firm in the economy through an shareholder that owns at least 1% shares in each firm. The error bars show the 95% confidence intervals across all buyers.

Figure 5: **Correlation Seller Characteristics and Share of Constrained Buyers**



Notes: This figure plots the estimated coefficients of a regression of the share of constrained buyers for each seller-year on different seller's characteristics. Sales refer to total sales. I classify a seller as an exporter if they report exports of at least $5,000 USD and as an importer if they report imports of at least $5,000 USD. Cash holdings, total debt, and total assets are obtained through the financial statements. Leverage is estimated as total debt over total assets.

6 Welfare and Counterfactuals

In this section, I analyze the efficiency of relationships over time using the estimated model.[53] Additionally, I evaluate the welfare performance of different pricing and enforcement schemes. I focus on three margins: (i) perfect enforcement with non-linear pricing, (ii) limited enforcement with uniform pricing, and (iii) perfect enforcement with uniform pricing.

6.1 Efficiency Relative to First-Best

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

$$q^{fb}(\theta) = \left(\frac{k\beta\theta}{c}\right)^{1/(1-\beta)}. \tag{18}$$

Moreover, total surplus is a function of the buyer's type θ, quantity q, and seller's marginal cost c: $Surplus(\theta, q, c) = \theta kq^{\beta} - cq$. 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 6a 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.

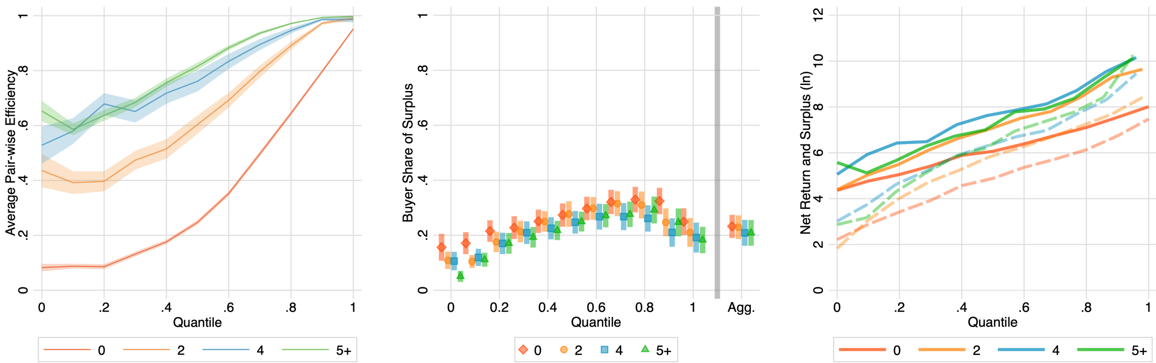
While the general theoretical model does not yield precise estimates, the observed patterns of efficiency increasing with age and quantities can be explained by two key features of the model. First, to maintain incentive compatibility, higher types must receive higher quantities, resulting in lower distortions 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.[54] However, the model does not mechanically imply an increase in efficiency over time. 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

[53] I now rely on the parametric estimates of $v'(\cdot)$, reported in Online Appendix Table OA-8.

[54] As discussed in the motivating section, 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-8).

Figure 6: **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 over all sellers. Error bars show dispersion of ±1.96 standard errors for each quantile across sellers. Sub-figure b) shows buyer share of surplus for quantile of quantity and tenure. Error bars show ±1.96 standard errors, clustered at the seller-year level. Sub-figure c)

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 6, I report the share of sellers trading at efficient levels, both in average total output and with the average buyer.[55] 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 6. 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.

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.

[55] 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 6: **% 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.

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 6b. 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 6c 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.

6.2 Counterfactuals

In this section, 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: (1) Maintaining price discrimination but improving contract enforcement; (2) Maintaining limited enforcement but eliminating price discrimination; (3) Eliminating both limited enforcement and price discrimination.

Counterfactual 1: *Perfect Enforcement + Price Discrimination*

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. To answer this question, I use the distribution of types at different tenures and equation 8 with $\Gamma_\tau(\cdot)$ set to 1 and $\gamma_\tau(\cdot)$ set to 0. I also set $\Gamma_s(\cdot)$ to 1 for $s < \tau$.

Counterfactual 2: *Limited Enforcement + Uniform Pricing*

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.[56] 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.

Under the assumed base return function, the optimal uniform price is $p^l = c/\beta$ for any quantity. The corresponding type θ's demand is given by $q^l(\theta) = (k\beta\theta/p^l)^{1/(1-\beta)}$. This stationary menu will be insufficient for some enforcement constraints. Given exogenous hazard rates $X(\theta)$, the stationary enforcement constraint will be given by:

$$\delta(1 - X(\theta)) \geq \beta, \tag{U-LE}$$

which indicates that the rate of return captured by β has to be smaller than the buyer-specific discount rate. Notice that this limited enforcement constraint will hold for any other uniform price, so buyers who are willing to default at the optimal uniform price p^l will also be willing to default at any other alternative uniform price p^l_a, including $p^l_a = c$, which would generally imply an efficient allocation.

Under a monotonicity assumption on $X(\theta)$,[57] the seller will set a minimum quantity $\underline{q}^l$ that the buyer needs to announce in order to be served. In particular, it will only serve $q(\theta) \geq \underline{q}^l$, where $\underline{q}^l = min\{q^l(\theta)|\delta(1 - X(\theta)) \geq \beta\}$. In the counterfactual exercise, I set their quantities to zero to those θ with $q^l(\theta) < \underline{q}^l$.[58]

Counterfactual 3: *Perfect Enforcement + Uniform Pricing*

Lastly, I consider addressing both market power and enforcement. I use quantities and prices as in counterfactual 2 above. However, as buyers are precluded from the possibility of default, the seller serves all buyers. Thus, no quantity is set to zero.

6.2.1 *Discussion of Counterfactual Results*

Table 7 displays the results of the counterfactual exercises. The table shows the average surplus as a percentage of the baseline for each percentile group in quantity and tenure,

[56] 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.

[57] The monotonicity on the hazard rate $X'(\theta) < 0$ is observed in the data.

[58] In this counterfactual exercise, I use an additional assumption: buyers demand truthfully the optimal level of quantity that is consistent with prices and full enforcement.

as well as aggregate results (weighted by observed quantities) by tenure.[59]

Counterfactual 1: *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 from prices above marginal costs.

For higher types, however, the policy is always welfare-reducing. To see why, consider equation 8 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 2: *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.[60] 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

[59] Additional results for the three counterfactual exercises related to buyer net return, profits, and prices are presented in Online Appendix Section OA-11, where the table reports the percentage of observations in the baseline with a greater value in the specific category (i.e., prices) relative to the counterfactual.

[60] In results not presented here, I consider an additional counterfactual regarding uniform pricing. Specifically, I consider a pooling contract that offers only a unique price and quantity mix for all buyers. The seller picks the mix to prevent the default of all buyers above a targeted threshold. Hence, the seller picks the profit margin and the share of defaults. In such a counterfactual, I obtain, again, a much lower surplus than in the baseline.

Table 7: **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. For instance, 10% collects all buyers between percentiles 0 and 10%. Panel A reports results for non-linear pricing with perfect enforcement. Panel B reports optimal monopolistic uniform price with limited enforcement. Subpanel reports 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 Panel A and C.

seller's ability to target each individual buyer's enforcement constraint through differentiated prices and quantities allows them to prevent default.

Counterfactual 3: *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-9), 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.

Nevertheless, given that this counterfactual allows the seller to choose the profit-maximizing uniform price, performance would improve the better the efforts to reduce seller market power by further reducing the average markup, while contemporaneously addressing enforcement.

Discussion. The counterintuitive results that solving only one friction at a time may lead to welfare losses is a direct manifestation of the *theory of second best* (Lipsey and Lancaster, 1956). In the presence of multiple market frictions, eliminating one friction will not necessarily lead to higher welfare. In fact, in the presence of one market friction, an additional friction might be necessary to reach the second-best outcome.

7 Conclusion

This paper examines how frictions in the manufacturing supply chain impact long-term relationships. Using a novel theoretical model, the study shows that allocating bargaining power to the seller while allowing the buyer to *take the goods and run* has significant implications for surplus, price, and quantity dynamics. The paper demonstrates that limited enforcement constraints, which prevent buyer defaults, require the seller to offer larger amounts of net return to the buyer than perfect enforcement would require. This creates an incentive for the seller to distort trade inter-temporally by promising larger quantities and lower prices in the future to reap larger profits now.

The study employs a unique intra-national trade database from Ecuador to estimate the structural model of relational contracting with seller market power, with the main contribution being the quantification of the efficiency of dynamic trade. The results suggest that trade is highly inefficient at the start of relationships, but transacted quantities approach full efficiency in the long term despite the seller's market power. These findings highlight the significant value created by informal agreements between buyers and sellers, but also demonstrate the fragility of these agreements. Unilateral reforms aimed at improving enforcement or applying Ecuadorian antitrust policy may undermine the long-term efficiency of relational contracts. However, addressing multiple frictions simultaneously could lead to 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):

$$\sum_{\tau=0}^{\infty} \delta(\theta)^{\tau} u'_{\tau}(\theta) = \sum_{\tau=0}^{\infty} \delta(\theta)^{\tau} v(q_{\tau}(\theta)), \tag{19}$$

for any arbitrary function $0 < \delta(\theta) < 1$ and $u'_{\tau}(\theta) \equiv du_{\tau}(\theta)/d\theta$. Substituting the envelope condition 19 with $\delta(\theta) = \delta$ into the seller's problem SP and integrating by parts yields:

$$\sum_{\tau=0}^{\infty} \delta^{\tau} \int_{\underline{\theta}}^{\overline{\theta}} \left[s(\theta, q_{\tau}(\theta), c_{\tau}) - \int_{\underline{\theta}}^{\theta} v(q_{\tau}(x))dx \right] f_{\tau}(\theta) d\theta - \sum_{\tau=0}^{\infty} \delta^{\tau} u_{\tau}(\underline{\theta}). \tag{20}$$

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:

$$\left\{\sum_{s=1}^{\infty}\delta^s(1-X(\theta))^s u_{\tau+s}(\theta) - [\theta v(q_\tau(\theta)) - u_\tau(\theta)]\right\}\gamma_\tau(\theta) = 0, \tag{21}$$

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 $\Gamma_\tau(\overline{\theta}) = 1$.[61]

After manipulating the limited enforcement constraints,[62] one can obtain the full Lagrangian maximand:

$$\sum_{\tau=0}^{\infty}\delta^\tau\int_{\underline{\theta}}^{\overline{\theta}}\left[s(\theta, q_\tau(\theta), c_\tau) - v(q_\tau(\theta))\frac{\Gamma_\tau(\theta) - F_\tau(\theta) - \sum_{s=0}^{\tau-1}(1-\Gamma_s^\tau(\theta))\tilde{\Gamma}_s^\tau(\overline{\theta}) + \theta\gamma_\tau(\theta)}{f_\tau(\theta)}\right]f_\tau(\theta)d\theta, \tag{23}$$

with the corresponding slackness condition Lagrangian-D-LE where $\Gamma_s^\tau(\theta)$ is the condi-

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

[62] 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:

$$\sum_{\tau=0}^{\infty}\delta^\tau\int_{\underline{\theta}}^{\overline{\theta}}\int_{\underline{\theta}}^{\theta}v(q_\tau(x))dx\sum_{s=0}^{\tau-1}(1-X(\theta))^{\tau-s}d\Gamma_s(\theta)$$
$$-\sum_{\tau=0}^{\infty}\delta^\tau\int_{\underline{\theta}}^{\overline{\theta}}\left[\theta v(q_\tau(\theta)) - \int_{\underline{\theta}}^{\theta}v(q_\tau(x))dx\right]d\Gamma_\tau(\theta). \tag{22}$$

Then integrate by parts.

tional cumulative LE multiplier constraint defined by:

$$\Gamma_s^\tau(\theta) = \frac{\int_{\underline{\theta}}^{\theta}(1-X(x))^{\tau-s}\gamma_s(x)dx}{\tilde{\Gamma}_s^\tau(\overline{\theta})}, \tag{24}$$

for $\tilde{\Gamma}_s^\tau(\overline{\theta}) = \int(1-X(\theta))^{\tau-s}\gamma_s(\theta)d\theta$. 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 $\tau \to \infty$:

$$\sum_{\tau=0}^{\infty}\delta(\theta)^\tau u_\tau(\theta) \geq \lim_{\tau\to\infty}\left\{\delta(\theta)^\tau\theta v(q_\tau(\widehat{\theta})) + \sum_{s=0}^{\tau-1}\delta(\theta)^s\left[\theta v(q_s(\widehat{\theta})) - t_s(\widehat{\theta})\right]\right\}\forall\theta,\widehat{\theta}, \tag{25}$$
$$\geq \sum_{s=0}^{\infty}\delta(\theta)^s\left[\theta v(q_s(\widehat{\theta})) - t_s(\widehat{\theta})\right]\forall\theta,\widehat{\theta},$$

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

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

$$\sum_{\tau=0}^{\infty}\delta(\theta)^\tau u_\tau(\theta) \geq \delta(\theta)^\tau\theta v(q_\tau(\theta)) + \sum_{s=0}^{\tau-1}\delta(\theta)^s\left[\theta v(q_s(\theta)) - t_s(\theta)\right]\forall\theta,\tau \Leftrightarrow \tag{26}$$
$$\sum_{s=\tau+1}^{\infty}\delta(\theta)^s u_s(\theta) + \delta(\theta)^\tau u_\tau(\theta) \geq \delta(\theta)^\tau\theta v(q_\tau(\theta))\forall\theta,\tau \Leftrightarrow \tag{27}$$
$$\sum_{s=1}^{\infty}\delta(\theta)^s u_{\tau+s}(\theta) \geq t_\tau(\theta)\forall\theta,\tau. \tag{28}$$

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

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

$$\delta(\theta)^\tau\theta v(q_\tau(\widehat{\theta})) + \sum_{s=0}^{\tau-1}\delta(\theta)^s\left[\theta v(q_s(\widehat{\theta})) - t_s(\widehat{\theta})\right] < \delta(\theta)^\tau\theta v(q_\tau(\theta)) + \sum_{s=0}^{\tau-1}\delta(\theta)^s u_s(\theta), \tag{29}$$

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:

$$\delta(\theta)^\tau t_\tau(\theta) \leq \sum_{s=\tau+1}^{\infty}\delta(\theta)^s u_s(\theta) - \left(\sum_{s=0}^{\tau-1}\delta(\widehat{\theta})^s\left[\theta v(q_s(\widehat{\theta})) - t_s(\widehat{\theta})\right] - \sum_{s=0}^{\tau-1}\delta(\theta)^s\left[\theta v(q_s(\theta)) - t_s(\theta)\right]\right)\forall\theta,\widehat{\theta},\tau. \tag{30}$$

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 19 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. $\Gamma_\tau(\bar{\theta}) = 1, \forall \tau$.

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

$$\frac{T'(q(\alpha)) - c}{T'(q(\alpha))} = \rho(\alpha)\Big[\Gamma(\alpha) - \alpha\Big] + \gamma(\alpha). \tag{31}$$

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

$$\gamma(1) = \frac{T'(q(1)) - c}{T'(q(1))}. \tag{32}$$

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

As an auxiliary result, note that:

$$\gamma'(1) = \frac{cT''(q(1))}{T'(q(1))}, \tag{33}$$

which is known.

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

$$\frac{T'(q(1-\varepsilon)) - c}{T'(q(1-\varepsilon))} \approx \rho(1-\varepsilon)\Big[\Gamma(1) - \gamma(1)\varepsilon - 1 + \varepsilon\Big] + \gamma(1) - \gamma'(1)\varepsilon, \tag{34}$$

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 transfer rule, obtain

$$\rho(\alpha) = \theta'(\alpha)/\theta(\alpha) = T''(q(\alpha))/T'(q(\alpha)) + A(q(\alpha)), \tag{35}$$

where $A(q(\alpha)) = -v''(q(\alpha))/v'(q(\alpha))$. The assumed parametrization implies $A(q) = (1-\beta)/q$. As $T'_\tau(\cdot)$, $T''_\tau(\cdot)$, and $q_\tau(\cdot)$ 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 31 and use the parametrized version of $\rho_0(\alpha)$ for 35:

$$\Gamma_0(\alpha)+\gamma_0(\alpha)\left[\frac{T''_0(q_0(\alpha))}{T'_0(q_0(\alpha))} + \frac{1-\beta}{q_0(\alpha)}\right]^{-1} = \tag{36}$$
$$\alpha + \frac{T'_0(q_0(\alpha)) - c}{T'_0(q_0(\alpha))}\left[\frac{T''_0(q_0(\alpha))}{T'_0(q_0(\alpha))} + \frac{1-\beta}{q_0(\alpha)}\right]^{-1}.$$

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 $T''_0(\cdot)$, $T'_0(\cdot)$, $q_0(\cdot)$, 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:

$$\Gamma_\tau(\alpha)+\gamma_\tau(\alpha)\left[\frac{T''_\tau(q_\tau(\alpha))}{T'_\tau(q_\tau(\alpha))} + \frac{1-\beta}{q_\tau(\alpha)}\right]^{-1} = \tag{37}$$
$$\alpha + \sum_{s=0}^{\tau-1}(1-\Gamma_s(\alpha)) + \frac{T'_\tau(q_\tau(\alpha)) - c}{T'_\tau(q_\tau(\alpha))}\left[\frac{T''_\tau(q_\tau(\alpha))}{T'_\tau(q_\tau(\alpha))} + \frac{1-\beta}{q_\tau(\alpha)}\right]^{-1},$$

$\Gamma_\tau(\alpha)$ 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, $T'_\tau(\cdot)$, $T''_\tau(\cdot)$, $q_\tau(\cdot)$, and β are known or identified.

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