

# Late Payments in Procurement: A Theoretical and Experimental Investigation

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## Abstract

Late payments to suppliers pervade global supply chains. We investigate how uncertainty about the payment timetable affects suppliers' pricing decisions in business-to-business transactions. Based on regulatory reporting data, we construct a game-theoretic model in which the buyer offers a non-binding payment term to potential suppliers, and the suppliers compete on price for the contract. We first show how payment delays generate a cost to the buyer in the form of reduced supplier competition. We then consider a regulatory penalty for involuntary payment delays, i.e., the buyer voluntarily chooses to pay late. Setting the highest penalty for a late payment leads to the highest buyer profit through its effect on supplier competition. However, a welfare loss arises with an improperly set penalty because it fails to align incentives correctly for a subset of buyers. We provide experimental evidence that supports the model's predictions as to the qualitative market effect of uncertainty about the payment timetable, including free-riding effects from improperly set penalties. The results suggest that procurement managers and regulators can make a case for shorter payment terms – enforced by appropriate regulatory penalties – based on suppliers' strategic behaviours.

**Keywords:** Late Payment, Procurement, Entry, Signaling Game, Experiment

## 1. Introduction

Late payments to suppliers are endemic in global supply chains. More than one in ten invoices issued by small and medium-sized enterprises (SMEs) are paid with delay, ranging from 8% in Brazil, to 12.5% in the US, and 18% in the UK and Singapore; this translates to over one trillion US dollars in payments made outside of the agreed term globally (Miller and Wongsaroj 2017). Late payments on large invoices are equally likely as those on small invoices, and so from a managerial perspective pose a significant business risk. Research released by the British Federation of Small Businesses revealed that the failure of clients to pay on-time was perceived as the single greatest risk faced by suppliers (FSB 2018).<sup>1</sup> A representative survey of financial decision-makers found that 89% continue to pay suppliers late (Bottomline 2020). The strategic choice of firms to negotiate longer payment terms has been further accentuated by the coronavirus pandemic (see Broughton 2021).

Involuntary payment delays on accounts receivable have a negative effect on supplier cash flows. There is a disproportionate impact on SMEs; the propensity of firms to pay late is positively related to their market power (Wu et al. 2020).<sup>2</sup> The aggregate impact of late payments is stark. Late payments were estimated to be responsible for the closure of 50,000 companies in the UK during a single year, undermining investment and hiring (FSB 2016). They have been associated with a withholding of supplies and a counter-productive increase in procurement costs for buyers (Howorth and Reber 2003). Commentators routinely claim that late payments inflate market prices.<sup>3</sup> In EU member states, there is a significant statistical relationship between the timeliness of business-to-business payments and firm survival rates (Connell 2014, Conti et al. 2020).

A significant challenge in inferring a robust causal relationship from secondary data as to the directional impact of late payments on prices is simultaneity. It may be that higher procurement costs increase the probability of a late payment, rather than residual uncertainty over the payment timing causing suppliers to adjust their entry and pricing decisions. Thus, it is difficult to separate the horizontal market effects from broader strategic considerations. In this paper, we use theory to generate clear comparative static predictions and lab experiments to isolate the

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<sup>1</sup> In the FSB survey, more than 80% of businesses reported experience of receiving payments beyond the due date. This practice spanned multiple business sectors, from construction to retail, with one in five suppliers to the public sector also affected. As of January 2021, £23.4 billion worth of late invoices are owed to businesses in Britain alone (Small Business Commissioner 2021).

<sup>2</sup> A culture of poor payment practices extends beyond missed invoice dates. For example, evidence submitted to a British parliamentary select committee in 2018 suggests that Carillion – the collapsed facilities management and construction group – were “notorious late payers” and had requested a discount from suppliers for use of an early repayment facility. In fact, Carillion had doubled its payment term and used suppliers as a line of credit (“Committees publish correspondence” 2018).

<sup>3</sup> For example, in *The New York Times*: “The additional financing costs that suppliers incur because they aren’t being paid promptly work their way back into higher prices for consumers” (Strom 2015).

qualitative effect through which uncertainty about the payment timetable influences suppliers' pricing decisions while controlling the entry channel. By identifying the direction - rather than precise magnitude - of the effect in a controlled laboratory setting that secures internal validity, we can increase our understanding of how to design regulatory interventions in the field (Kessler and Vesterlund 2015).

Building on insights from earlier industrial organization models of Bertrand competition with entry (Lang and Rosenthal 1991), we design a simple procurement game that captures the stylized features of procurement with payment uncertainty. In our setup, buyers offer a non-binding payment term to potential suppliers, and suppliers decide whether to incur a fixed and irreversible cost to compete on price for the contract. We consider two payment terms in our model: standard (e.g., 30 days) or extended (e.g., 60 days). There is a time value to keeping cash on hand which we implement as a lower effective price. We assume that some firms benefit more from this than others, which is private information. There are various possible sources of this asymmetric information, such as inventory and cash flow, bargaining power, or a supplier's probability of successful litigation for monies due. We remain agnostic as to the driver of a firm's residual value from stretching the payment timetable and focus on the horizontal market effects. Empirical evidence to support our modelling choices is presented in the next section.

We then consider aspects of the regulatory environment which influence a buyer's payment strategy. Specifically, we investigate the qualitative impact on submitted supplier bids of a third-party penalty (e.g., a regulatory fine) imposed on the buyer for reneging upon an agreement to pay in a standard term (i.e., for making payment late). The market effect of imposing a penalty for late payment is an active area of policy debate.<sup>4</sup> SMEs are increasingly demanding new legislative measures to tackle the problem of late payments via third-party enforcement, as concerns about loss of repeat business make direct enforcement by these suppliers difficult.<sup>5</sup> Our conversations with a supply chain manager at a Fortune 100 company suggest that even major multi-national corporations struggle to impose penalties (permitted by the contract) on other businesses that pay beyond the agreed payment term, for fear of losing them as a customer or supplier. The laboratory experiments which we report on in the second part of the paper contribute to this debate a "wind tunnel" test aimed at increasing our posterior belief as to the likely comparative static that will hold in the field (Schram 2005, p. 232).

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<sup>4</sup> In the UK, legislation enacted in 2016 established a mandate to crack down on the endemic culture of late payment; new powers proposed by the government include the ability to levy fines on firms that fail to meet their payment obligations (Small Business Commissioner 2021). Relatedly, the EU directive 2011/7/EU on combating late payment in commercial transactions [2011] sets out minimum rules specifying that public and private companies must pay their invoices within 30 and 60 days, respectively. In the event of late payment, statutory interest and compensation for recovery costs are due to the supplier.

<sup>5</sup> See, for example, Clarke (2020) on calls from small businesses in Australia for third-party enforcement.

In the main analysis, we assume that the penalty is collected by an independent third party. The model's insights are qualitatively unchanged, however, by assuming that the penalty is paid directly to the supplier as compensation. Contrary to what regulators may have intended in their legislation (e.g., the EU directive 2011/7/EU on combating late payment in commercial transactions [2011]), we find that if the penalty accrues to the supplier as interest on monies due, then its effectiveness may be diluted.

Our results provide qualitative insights for both procurement managers and regulators. First, uncertainty about the payment timetable is associated with higher prices and lower market efficiency. Second, buyers earn higher profits from imposition of the highest penalty for renegeing upon an agreed payment term through lower market prices. Third, a market separation on standard and extended terms is welfare-decreasing relative to an outcome in which payments are made within a standard term only. Fourth, a welfare loss may arise with an improperly set penalty because it introduces an incentive for buyers who benefit most from keeping cash on hand to pay late. Together, these results offer a welfare argument for adopting shorter payment terms and interventions to deter late payments. The results also sound a note of caution to regulators: setting an inadequate penalty may permit a subset of buyers to free ride on the payment behaviours of others in the market.

This study is related to research at the intersection between operations management and finance, in particular on trade credit. Operations models often assume that buyers are willing to pay a premium for the vertical operational role of trade credit, to deter moral hazard (Babich and Tang 2012, Rui and Lai 2015), share demand risk (Kouvelis and Zhao 2012, Yang and Birge 2018), or coordinate multi-echelon supply chains (Devalkar and Krishnan 2019). These benefits may, however, come with increased bankruptcy risk which disrupt the buyer (Esenduran, Gray and Tan 2022). Suppliers in turn make financing agreements available as a signal of quality (Long et al. 1993) or commitment to the supply chain relationship (Ng et al. 1999). Tunca and Zhu (2018) use a game-theoretic approach to analyse supplier-side financing constraints inherent in payment delays and demonstrate the effectiveness of buyer intermediation in lowering wholesale costs and improving channel efficiency; the theoretical model is validated empirically using a structural estimation based on data from a large online retailer.

Implications of trade credit at the market level are less well developed. Peura et al. (2017) use a Bertrand competition model with liquidity shocks to show how suppliers might benefit from the use of trade credit contracts because of a softening in horizontal price competition. Firms in a stronger financial position may be able to use trade credit to exclude their weaker competitors. These models assume contractually fulfilled payment terms and no strategic supplier reaction to late payment (for a discussion, see Seifert et al. 2013). Our study contributes to the literature by relaxing these assumptions and modelling the strategic incentives of both the buyer and suppliers

in a competitive setting. We introduce a signaling game which enables us to study how the choice of firms to delay payments to their suppliers affects price competition and the impact of regulatory interventions on bidding strategies.

Empirical studies using secondary data also investigated the relationship between voluntary trade credit offerings and market outcomes, with conflicting results on the underlying relationship (see, e.g., McMillan and Woodruff 1999, Fisman and Raturi 2004, Hyndman and Serio 2010). Fabbri and Klapper (2016) document that suppliers' bargaining power is an important determinant of trade credit extension. A competing explanation is that financially stronger firms extend trade credit to deter entry by their more liquidity-constrained rivals (Barrot 2016). Wu et al. (2020) harness detailed trade credit data to show that firms are strategic in their choice of payment term, which is positively related to a firm's market power and supports late payment as an ingrained part of business operations. To our knowledge, we are the first to use the methodology of lab experiments to establish a causal channel between the structure of payment terms and suppliers' pricing. This adds to a body of experimental research in operations that studies procurement auctions and the efficient functioning of buyer-supplier relationships in competitive bidding (see, e.g., Shachat and Tan 2015, Fugger et al. 2019).<sup>6</sup>

## **2. Empirical Evidence on Payment Practices**

A wide swathe of industry data and anecdotal evidence suggest the prevalence of long payment terms in multiple sectors (IACCM 2015). For example, Seligson (2011) points to a notable example in the technology sector, "Exhibit A is Cisco Systems, one of the largest technology companies in the world, which announced last year that it would wait a full 60 days to pay its small-business suppliers – mostly because it had found that that was what other big companies were doing." Strong (2015) notes a similar phenomenon among food processing companies: "Diageo, the European spirits company, now asks for 90 days to pay its bills. Mondelez, Mars and Kellogg seek 120 days. The list of companies doing the same reads like a grocery store version of Who's Who." Absent deterrent penalties, extending long payment terms allows buyers to maximise capital usage.<sup>7</sup> Even where deterrent regulation exists, such as the EU directive 2011/7/EU on combating late payment in commercial transactions (2011), there are exceptions for trade parties who "expressly agree" to longer payment periods (p. L 48/2).<sup>8</sup>

To provide concrete evidence on the prevalence of late payments and to motivate some of our later modeling choices, we extracted reports submitted by medium and large UK businesses on

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<sup>6</sup> Elmaghraby and Katok (2019) review this literature.

<sup>7</sup> This has even propagated a new business model. See: [www.bloomberg.com/news/articles/2019-08-16/how-late-payments-to-vendors-spawned-a-new-business-quicktake](http://www.bloomberg.com/news/articles/2019-08-16/how-late-payments-to-vendors-spawned-a-new-business-quicktake).

<sup>8</sup> Where exceptions do not apply, the enforcement of prompt payment terms is variable. See, for example, the recent judgment in the case of Commission v Italy (Directive combating late payment) (C-122/18).

their supplier payment practices from a database maintained by the Department for Business, Energy, & Industrial Strategy (2016), covering the period April 6, 2017 to May 28, 2021. Firms must report the average time to pay an invoice, the percentage of invoices paid within 30, 60 or more days and the fraction of invoices which are paid late. They may also report the length of their standard payment terms and any extended payment terms used.

In Table 1, we report payment statistics separately for all firms in the database and for a subset of firms who agree to abide by a voluntary payment code (e.g., the Prompt Payment Code which commits a firm to paying 95% of invoices within 60 days). As can be seen, the average time to pay an invoice is 37 days (interquartile range of 25 to 47 days). There is also variation in payment durations. Whereas nearly 55% of invoices are paid within 30 days, 31% are paid within 60 days and 14.4% are only paid after 60 days. Moreover, nearly 30% of invoices are paid after the agreed terms. The distribution of late payment rates is positively skewed, implying a long tail of companies that report even higher rates. Firms who voluntarily commit to abide by a payment code have shorter time to pay and are less likely to pay invoices late.<sup>9</sup>

**Observation 1.** Late payments are common, occurring in nearly 30% of invoices.

Table 1 – UK company payment reporting statistics.

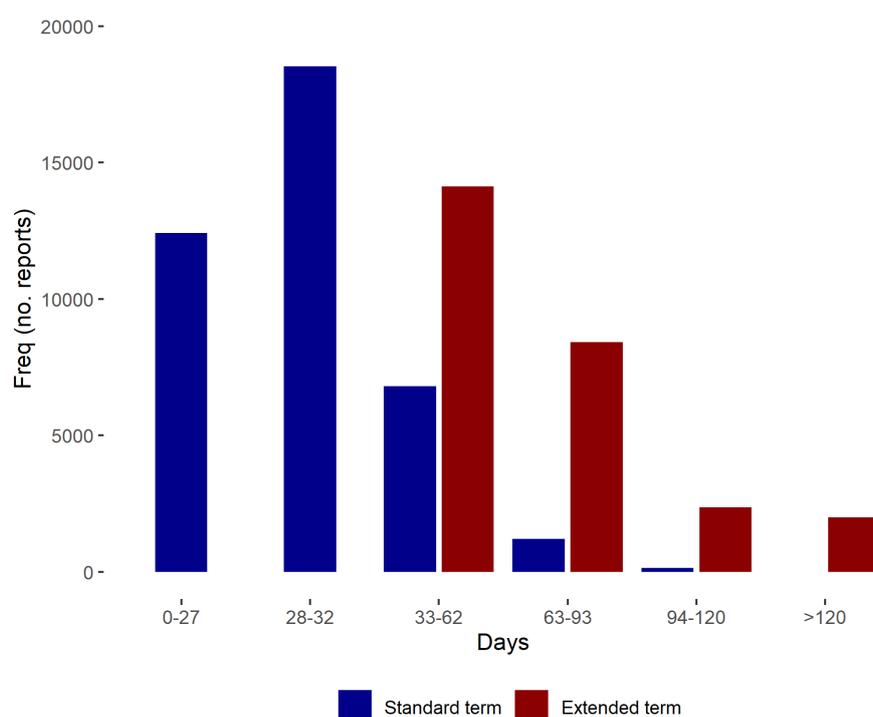
	N	Mean	Median	SD	IQR
<i>All firms</i>					
Time to pay (days)	39,806	37.00	34	20.28	[25, 47]
Pct. late	39,887	0.293	0.24	0.242	[0.10, 0.44]
Pct. ≤ 30 days	39,806	0.547	0.56	0.284	[0.30, 0.79]
Pct. 31 – 60 days	39,806	0.309	0.29	0.206	[0.14, 0.45]
Pct. > 60 days	39,806	0.144	0.08	0.169	[0.03, 0.19]
<i>Firms adhering to a voluntary payment code</i>					
Time to pay (days)	3,694	32.22	30	17.686	[22, 40]
Pct. late	3,701	0.224	0.17	0.198	[0.07, 0.31]
Pct. ≤ 30 days	3,694	0.639	0.70	0.267	[0.44, 0.87]
Pct. 31 – 60 days	3,694	0.270	0.22	0.211	[0.09, 0.41]
Pct. > 60 days	3,694	0.091	0.05	0.129	[0.02, 0.10]
Notes: Based on individual firm reports filed in the period 07-Nov-2017 to 28-May-2021 for financial years beginning on April 6th, 2017.					

<sup>9</sup> We make no claim that the payment code causes firms to pay on time. Indeed, there is a surely strong selection effect with firms who pay on time voluntarily committing to the code, presumably for some reputational benefit. Moreover, the consortium managing the prompt payment code has removed companies who violate the code too often ([www.smallbusinesscommissioner.gov.uk/ppc/](http://www.smallbusinesscommissioner.gov.uk/ppc/)). There have been recent changes to the requirements of the Prompt Payment Code. The sample data reported here cover the period before the changes to the code.

Using the submitted reports, we sought to categorize the standard payment terms into different buckets based on duration. We further sought to identify whether firms had extended payment terms beyond the standard terms and, if so, to categorize them into buckets. We were able to categorize 39,088 reports with standard payment terms. Of these, 26,894 (68.8%) also reported extended payment terms. In Figure 1 we plot the distribution of standard and extended payment terms according to the buckets that we categorized. There is a great deal of heterogeneity in both standard and extended payment terms. The most common standard payment term is between 28-32 days, whereas the most common extended term is between 33-62 days, although a non-negligible fraction of extended payment terms go beyond 94 days.<sup>10</sup>

**Observation 2.** More than two-thirds of reports indicate both standard and extended payment terms to suppliers.

Figure 1. Distribution of standard and extended payment terms among UK companies.



Notes: Based on 39,088 standard payment terms and 26,894 extended payment terms in the reporting dataset.

Together, the empirical observations underpin the payment strategies that we will consider in our model. In the Online Appendix, we provide a detailed description of the processing that we

<sup>10</sup> Caution should be taken in inferring exact frequencies from these categorizations due to measurement error. The objective of this analysis is simply to demonstrate that there is a great deal of variety in the terms that suppliers are offered.

undertook to generate the summary results presented in this section, and further analyse the reporting data. We observe that late payments and variable payment terms are a common occurrence across a wide swath of industries. Furthermore, although there have been some improvements in reducing the frequency of late payments since the reporting requirement was instituted in 2017, late payments and extended payment terms remain pervasive.

### 3. Model and Theory

We build from a one-shot Bertrand model with simultaneous entry and pricing (Lang and Rosenthal 1991). Suppose that there are two *ex-ante* identical potential suppliers, indexed by  $i$ . Each supplier can submit a bid  $b_i$  to deliver a contract to a single buyer at date 0. The buyer may choose to make payment at date 0, or delay payment until date 1. The supplier that submits the lowest bid wins the contract at a price equal to the winning bid, with ties broken at random; the losing supplier(s) earn zero. We will denote the winning supplier as the seller. Bids can be any number in the interval  $[0, R]$ , where  $R$  is large and constitutes the reserve price. Restricting entry and price competition to just two suppliers is without loss of generality.<sup>11</sup>

Before submitting a bid, each supplier must decide whether to incur a non-refundable entry cost  $E > 0$ . This is the cost of preparing a bid for tender, which is not imposed if a firm chooses not to enter in competition. Whether the rival supplier has entered is unobserved until after entry and pricing. Production costs are normalized to zero. If no bid is submitted, the contract is not completed. In that case, all parties earn zero.<sup>12</sup> We embed the Bertrand entry and pricing game into a signaling model. We summarize the stages of the model in Figure 2. In the Online Appendix, we provide a full representation of the extensive-form game of incomplete information.

*Stage 0.* The buyer learns her type, which is private information and directly influences her payment preferences (see below).

*Stage 1.* The buyer sends the potential suppliers a message,  $m \in \{0, 1\}$ , announcing an *ex-ante* payment term, where  $m = 0$  is an offer of a standard payment term (e.g., 30 days) and  $m = 1$  is an offer of an extended payment term (e.g., 60 days). This message is non-discriminatory, i.e., it does not depend on the identity of the seller.

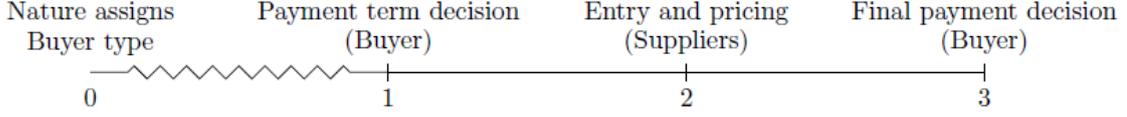
*Stage 2.* The potential suppliers observe the buyer's message  $m$  and make their entry and pricing decisions. Conditional on at least one entering supplier, the seller and the contract price  $p$  are determined as described above.

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<sup>11</sup> See Lang and Rosenthal (1991) for the general case of  $M$  potential suppliers.

<sup>12</sup> Specifying that entry and pricing be simultaneous, rather than sequential, is a modelling decision. Sequential entry and pricing generate counter-intuitive predictions when potential suppliers are asymmetric, due to the nature of mixed strategy equilibrium (Elberfeld and Wolfstetter 1999).

Figure 2. Timeline of the signaling model.



*Stage 3.* The buyer observes the bidding outcome and selects the final date  $\tau \in \{0,1\}$  to pay the seller, where  $\tau = 0$  denotes payment within a standard payment term, and  $\tau = 1$  denotes payment within an extended term (possibly late).

There is a benefit to keeping cash on hand and some firms benefit more from this than others. This insight is captured in the model by a buyer's payment preference over the final payment date,  $D(\tau)$ , which we operationalise as a lower effective price (discount factor). We assume that for all firms,  $D(0) = 1$  and  $D(1) < 1$ . A firm's type is thus defined on the discount factor at date 1,  $D(1)$ , which is given by  $\delta_B \in (0, 1)$ . The lower the discount factor, the stronger the buyer's preference for making payment at date 1. We endow the buyer with private information about her type, which is determined exogenously and observed prior to Stage 1. There are various possible sources of asymmetric information about a firm's value of delaying payment, such as inventory, cash flow, market power or a seller's probability of successful litigation for monies due. We do not take a stand on which of the underlying reasons applies here (all are plausible). Separate conversations with a public procurement practitioner in the UK and a manager at a global manufacturing company in the US indicate that there is uncertainty about whether payment will be received on-time or with delay, and that this uncertainty may be due to any one of the factors described, depending on the sector and locale.

For our purpose of generating clear predictions, it is sufficient to assume that there are two buyer types, either high,  $\delta_B = \delta_H$ , or low,  $\delta_B = \delta_L$ , where  $\delta_L < \delta_H$ . Therefore, the low type buyer (i.e., the buyer with the lower discount factor) has a stronger preference for making payment at date 1. The types are independently drawn from the same distribution. Potential suppliers hold the same prior belief concerning the buyer's type, described by a single number  $x \in (0, 1)$ . With probability  $x$ , the buyer is high type, and with probability  $1 - x$ , she is low type. There is but one seller type,  $\delta_S$ , which is common knowledge to all market participants.

We consider a fixed cost,  $c$ , which is levied as a penalty on the buyer for renegeing upon a standard payment term. This penalty accrues outside of the model; we relax this assumption later. Potential suppliers find themselves at one of two information sets in Stage 2, each containing two nodes. After receiving the buyer's message, they update their belief about the buyer's type using Bayes' Rule. Information about the type distribution is common knowledge. The buyer's profit is  $\pi_B = R - \delta_B^\tau p - \max\{\tau - m, 0\} \cdot c$  and the seller's is  $\pi_S = \delta_S^\tau p - E$ , where  $\delta_B^\tau = 1$  for  $\tau = 0$  and  $\delta_B^\tau = \delta_B$  for  $\tau = 1$ . The key assumption is that low types find renegeing less costly than high types.

In sum, the model is a signaling game à la Spence (1973), in which suppliers interpret the payment term as a signal of the buyer's preferences and adjust bids to compensate for expected differences in the final payment date. We assume throughout that firms are risk neutral. The buyer chooses the final payment date in Stage 3 to maximize own profit, considering the direct benefit of a late payment, as determined by her type, and the cost, as determined by the penalty.

### 3.1 Nash equilibrium of the entry and pricing stage

Let  $q$  be the potential suppliers' belief at the relevant information set in Stage 2 that payment will be received at  $\tau = 1$ . If  $q = 0$ , potential suppliers expect to receive payment at date 0 with probability one; if  $q = 1$ , potential suppliers expect to receive payment at date 1 with probability one. To gain insight, we first examine the second stage as a standalone entry and pricing game. No Nash equilibrium exists in pure strategies at parameter values of interest. To understand this, note that for all  $b_i \leq R$ , there exists an incentive for each supplier to undercut his competitor on price to increase profit. That is, competition among firms drives expected profits to zero. Once the payment value falls below the entry cost, each supplier would prefer not to bid for the contract. A unique symmetric equilibrium in mixed strategies does exist, however, consisting of an independent randomization by both players over their entry and bid decision for which there is no profitable unilateral deviation. This equilibrium is outlined in Lemma 1. The lemma uses Theorems 1 and 2 in Lang and Rosenthal (1991).

**Lemma 1.** *Suppose that potential suppliers are symmetric and  $\delta_S R > E$ . There is a unique symmetric Nash equilibrium of the entry and pricing stage characterized as follows: each supplier enters with probability  $\mu(q)$  and submits a bid according to the cumulative distribution function (c.d.f.)  $F(b, q)$ ,*

$$\mu(q) = 1 - \frac{E}{\gamma(q)R}, \quad \text{where } \gamma(q) = (1 - q + \delta_S q);$$

$$F(b, q) = \frac{1 - \frac{E}{\gamma(q)b}}{1 - \frac{E}{\gamma(q)R}} \text{ for } b \in \left[ \frac{E}{\gamma(q)}, R \right].$$

The conditional price c.d.f. is

$$G(b, q) = \frac{\alpha(b, q)}{\beta(q)}, \quad \text{where } \alpha(b, q) = 1 - \left( \frac{E}{\gamma(q)b} \right)^2, \beta(q) = 1 - \left( \frac{E}{\gamma(q)R} \right)^2.$$

Expected welfare is

$$W(q) = \beta(q) \cdot \pi_B, \quad \text{where } \pi_B = R - \delta_B^T p.$$

Lemma 1 states that, in equilibrium, potential suppliers randomize second stage entry with the same fixed probability  $\mu(q)$  and submit a bid according to the c.d.f.  $F(b, q)$ . Because the expected net profit of a potential supplier is zero, expected total welfare is determined by expected buyer surplus, given at least one entrant. The potential suppliers' symmetric equilibrium strategy depends on their belief  $q$  about the buyer's *ex-post* payment date. Entry is decreasing in  $q$ . The c.d.f. of the winning bid conditional on at least one bid being submitted is  $G(b, q)$ , with density function  $g(b, q)$ ; it follows that the expected market price is given by  $p(q) = \int_{E/Y(q)}^R b g(b, q) db$ , which is convex and increasing in  $q$ .<sup>13</sup> We obtain our first corollary directly.

**Corollary 1.** *Payment delays, either due to extended terms or late payments, are associated with higher prices and lower market welfare.*

Lemma 1 generalizes to the case of asymmetric suppliers. Conditional on the bid distribution, the supplier with the greatest payment value is most likely to compete and earn positive rents.

### 3.2 Perfect Bayesian equilibria of the signaling game

Now we consider the entry and pricing stage in the context of the wider extensive-form signaling game. The solution concept is perfect Bayesian Nash equilibrium (PBE). A PBE of the signaling game is defined on the buyer's payment term, which is the first component of the buyer's payment strategy  $[m, \tau]$ . In the continuation game associated with a standard payment term, the buyer may be deterred from paying with delay in the final subgame if the cost from renegeing upon her payment term is large enough. In the continuation game associated with an extended payment term, the buyer has a dominant strategy to pay at  $\tau = 1$ .

We cast potential suppliers' posterior beliefs on the final payment date rather than on the buyer's type, as it is the final payment date that influences a supplier's payoff and there is a direct relationship between a buyer's type and payment preferences. Let  $y$  and  $z$  denote the potential suppliers' posterior beliefs about receiving payment at  $\tau = 1$  at the information sets associated with a standard and an extended payment term, respectively. The suppliers' belief about the final payment date is equal to zero or one in any equilibrium where the two buyer types choose the same final payment date. Because  $\delta_L < \delta_H$ , no equilibrium exists in which the high type buyer pays at  $\tau = 1$  and the low type buyer pays at  $\tau = 0$ . Thus, on the equilibrium path, the unique interior posterior of interest is the probability of a low type buyer,  $1 - x$ .

We apply the Intuitive Criterion refinement (Cho and Kreps 1987), which rules out beliefs off the equilibrium path that place non-zero probability on equilibrium-dominated strategies. The key mechanism in the analysis concerns the threshold at which the penalty for renegeing upon a

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<sup>13</sup> The conditional c.d.f. is typically the observed distribution in naturally occurring markets.

standard payment term exceeds the buyer's benefit from paying late. This threshold depends on the suppliers' bidding strategy at the relevant information set, is strictly greater for low type than for high type buyers and is increasing in the expected market price. All proofs and a formal characterization of the equilibria in this section are presented in the Online Appendix.

**Proposition 1.**

If  $\delta_H < \max \left\{ 1 - \frac{c}{p(0)}, \frac{\beta(0) \cdot p(0) - R(\beta(0) - \beta(1))}{\beta(1) \cdot p(1)} \right\}$ , then the unique PBE is pooling on an extended term payment strategy  $[1,1]$ ; each supplier enters with probability  $\mu(1)$  and bids according to  $F(b, 1)$ . Expected welfare is  $W^a = \beta(1) \cdot (R - (x\delta_H + (1-x)\delta_L)) \cdot p(1)$ .

Proposition 1 states that, if the penalty is not large enough to deter a high type buyer from reneging upon a standard term at the expected market price associated with  $q = 0$ , then there is no set of posterior beliefs that can support an equilibrium with final payment at  $\tau = 0$ . Extended payment terms will obtain with a higher penalty if the buyer has a strong enough preference for delaying payment, i.e., if  $\delta_L$  is low enough. The suppliers' best response, independent of their posterior belief, is to follow a bidding strategy  $\mu(1)$  and  $F(b, 1)$ . As there is a benefit to keeping cash on hand, both buyer types prefer to pool on extended payment terms and pay at  $\tau = 1$ .<sup>14</sup>

To illustrate this equilibrium, in Figure 3 we graph the expected market price curve as a function of the suppliers' posterior belief  $q$ . The graphical statement of our assumption that low type buyers find reneging upon a standard term less costly than do high type buyers is depicted by the steeper isoprofit line for low type buyers ( $I_L$ ) than for high type buyers ( $I_H$ ). The isoprofit lines, for this and subsequent figures, factor in the equilibrium entry probabilities associated with  $q$ . The left endpoint of the isoprofit line represents the buyer's choice to pay at  $\tau = 0$  given  $m = 0$ ; the interior line segment represents the buyer's choice to pay at  $\tau = 1$  given  $m = 0$  (net of the penalty); and the right endpoint represents the buyer's choice to pay at  $\tau = 1$  given  $m = 1$ . If the conditions in Proposition 1 are satisfied, then the isoprofit lines lie above the market price curve. That is, both types are willing to pay more than  $p(1)$  to compensate for the benefit of holding cash in hand and so strictly prefer an extended payment term to a standard term.

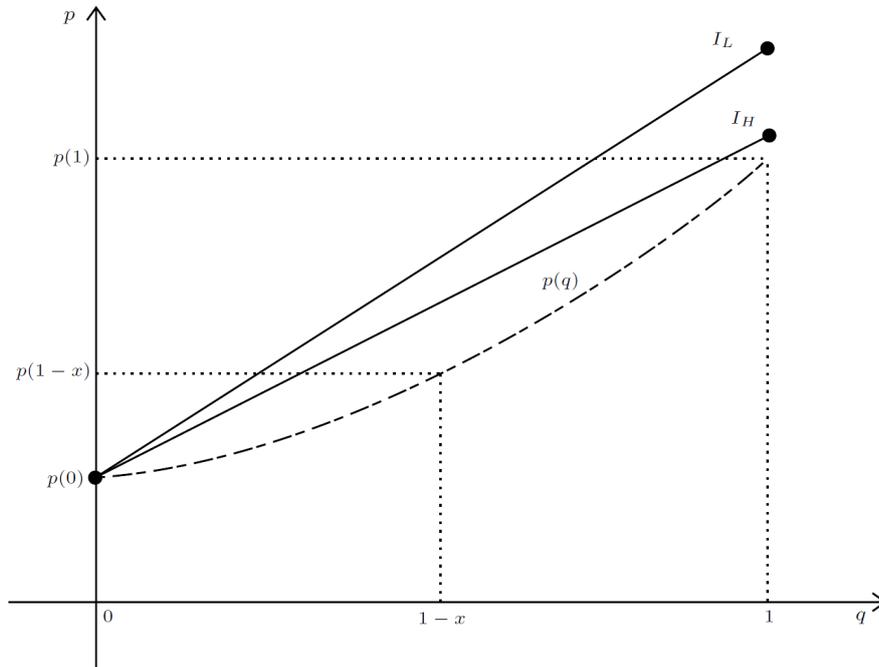
**Proposition 2.**

If  $\delta_L \geq \max \left\{ 1 - \frac{c}{p(1-x)}, \frac{\beta(1-x) \cdot p(1-x) - R(\beta(1-x) - \beta(1))}{\beta(1) \cdot p(1)} \right\}$ , then the unique PBE is pooling on a standard term payment strategy  $[0,0]$ ; each supplier enters with probability  $\mu(0)$  and bids according to  $F(b, 0)$ . Expected welfare is  $W^b = \beta(0) \cdot (R - p(0))$ .

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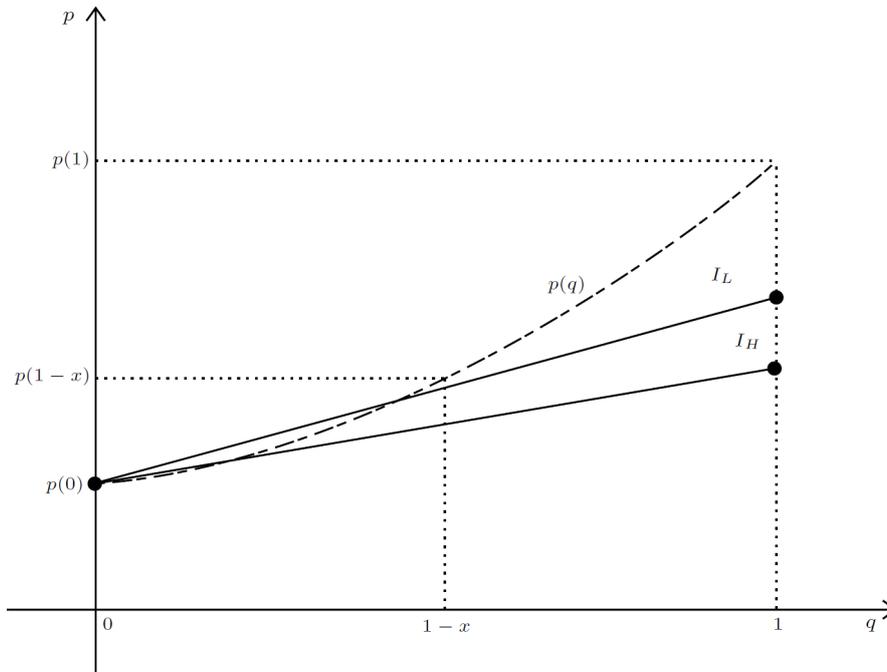
<sup>14</sup> Multiple off-the-path beliefs are possible; in the appendix, we provide a necessary condition for existence.

Figure 3. Pooling on extended payment terms with final payment at  $\tau = 1$ .



Notes: Isoprofit lines for low type ( $I_L$ ) and high type ( $I_H$ ). The dashed line expected market price curve  $p(q)$  is a function of the suppliers' belief about receiving final payment at  $\tau = 1$ . The left endpoint of the isoprofit line represents the buyer type's payment strategy  $[0,0]$ ; the interior line segment represents the buyer type's payment strategy  $[0,1]$ ; and the right endpoint represents the buyer type's payment strategy  $[1,1]$ . Both buyer types prefer an extended term because  $I_H(1) > p(1)$ .

Figure 4. Pooling on standard payment terms with final payment at  $\tau = 0$ .



Notes: Neither buyer type prefers to renege on a standard term because  $I_L(1-x) < p(1-x)$ .

Proposition 2 is the high penalty analogue to Proposition 1. There is maximal entry and price competition. We require both conditions on  $\delta_L$  to be met for uniqueness if both types are to prefer to pool on a standard payment term and pay at  $\tau = 0$  (see Figure 4). That is, we require the imposition of a penalty that can deter a low type buyer from reneging upon a standard payment term at the market price associated with  $q = 0$ . If the condition on  $\delta_L$  in Proposition 2 is satisfied, then neither type is willing to pay  $p(1)$  for the benefit of holding cash in hand on an extended term. The low type is unwilling to pay  $p(1 - x)$  for the benefit of paying late on a standard term.

**Corollary 2.** *Buyers benefit from the highest penalty through lower market prices,  $W^b > W^a$ .*

We now consider why both standard and extended payment terms are offered in the market.

**Proposition 3.**

*If  $\delta_H \geq \frac{\beta(0) \cdot p(0) - R(\beta(0) - \beta(1))}{\beta(1) \cdot p(1)}$  and  $1 - \frac{c}{p(1-x)} \leq \delta_L < \frac{\beta(0) \cdot p(0) - R(\beta(0) - \beta(1))}{\beta(1) \cdot p(1)}$ , then the unique PBE is separating: the high type buyer follows a standard term payment strategy  $[0,0]$ , and the low type buyer follows an extended term payment strategy  $[1,1]$ ; after observing a standard payment term, each supplier enters with probability  $\mu(0)$  and bid according to  $F(b, 0)$ ; after observing an extended payment term, each supplier enters with probability  $\mu(1)$  and bids according to  $F(b, 1)$ . Expected welfare is  $W^c = x \cdot \beta(0) \cdot (R - p(0)) + (1 - x) \cdot \beta(1) \cdot (R - \delta_L p(1))$ .*

For a unique separating equilibrium to exist in which the high type buyer offers a standard term and pays at  $\tau = 0$ , whereas the low type buyer offers an extended term and pays at  $\tau = 1$ , we require that the penalty be high enough to deter the high type from offering an extended term. If the conditions in Proposition 3 are satisfied, then the low type is willing to pay more than  $p(1)$  to compensate for the benefit of holding cash in hand (see Figure 5).

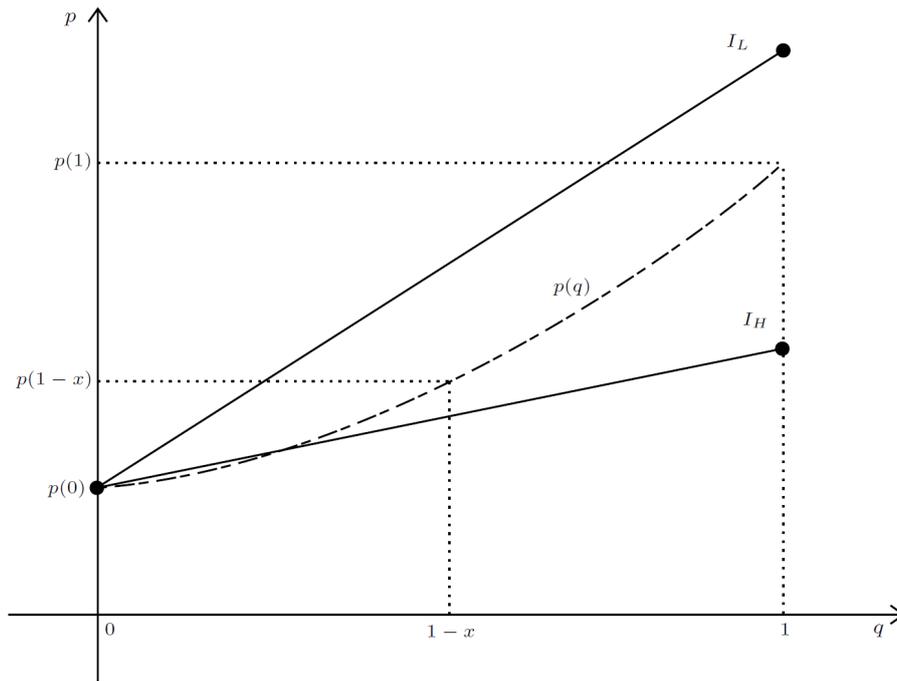
**Corollary 3.** *A market separation on standard and extended terms is welfare-decreasing,  $W^c < W^b$ .*

Proposition 3 provides support for Observation 2 and can rationalise the offering of both standard and extended payment terms in the market. Propositions 1 to 3 do not explain Observation 1: the prevalence of late payments beyond the agreed term. Our final proposition provides support for why we observe some buyers making payment late on a standard term.

**Proposition 4.**

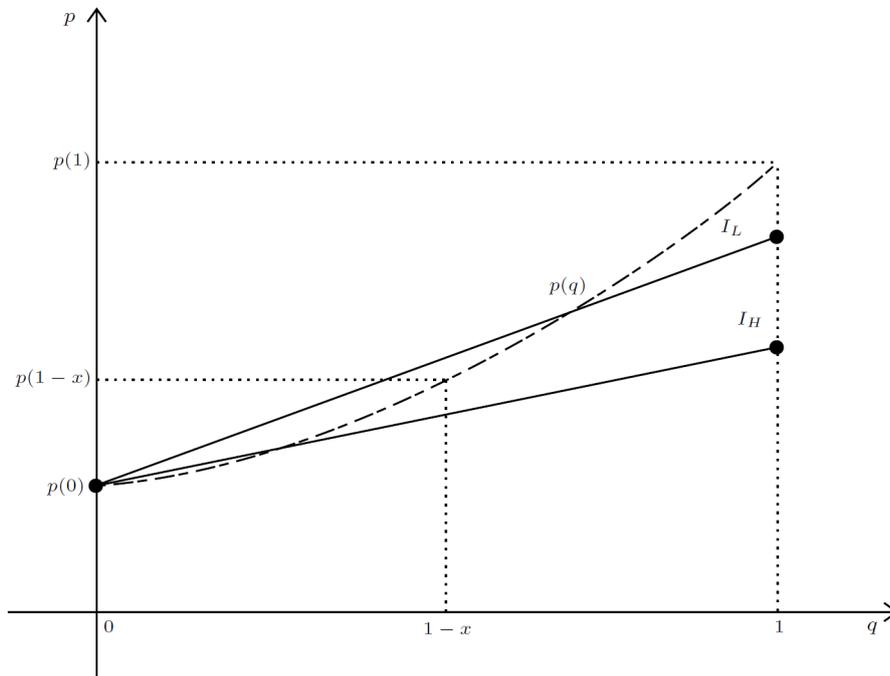
*If  $\delta_H \geq 1 - \frac{c}{p(1)}$  and  $\frac{\beta(1-x) \cdot p(1-x) - R(\beta(1-x) - \beta(1))}{\beta(1) \cdot p(1)} \leq \delta_L < 1 - \frac{c}{p(1-x)}$ , then the unique PBE is pooling on a standard term with final payment at  $\tau = 0$  by the high type buyer,  $[0,0]$ , and at  $\tau = 1$  by the low type buyer,  $[0,1]$ ; each supplier enters with probability  $\mu(1 - x)$  and bids according to  $F(b, 1 - x)$ . Expected welfare is  $W^d = \beta(1 - x) \cdot (R - (x + (1 - x)\delta_L) \cdot p(1 - x) - (1 - x) \cdot c)$ .*

Figure 5. Separating equilibrium with high (low) type paying on a standard (extended) term.



Notes: Low type buyer prefers an extended term because  $I_L(1) > p(1)$ . High type buyer prefers not to renege on a standard term because  $I_H(1-x) < p(1-x)$ .

Figure 6. Pooling on standard payment terms with late payment by low type buyers.



Notes: Low type buyer prefers to renege on a standard term because  $I_L(1-x) > p(1-x)$  and  $I_L(1) < p(1)$ . High type buyer prefers not to renege on a standard term because  $I_H(1-x) < p(1-x)$ .

Proposition 4 states that, if the penalty is set in an intermediate interval, and if the increase in supplier competition induced in response to the offer of a standard term is large enough, then low type buyers may “free ride” on high type buyers and profitably renege on a standard payment term. That is, low type buyers will mimic the offer of a standard term but end up paying at  $\tau = 1$ . If the conditions in Proposition 4 are satisfied, then only the low type buyer would be willing to pay more than  $p(1 - x)$  to compensate for the cost of making a late payment (see Figure 6).

**Corollary 4.** *Late payments beyond the agreed term are welfare-decreasing,  $W^d < W^b$ .*

#### 4. Experimental Design

We conduct an experiment to empirically test our model’s predictions. Subjects make decisions in either a buyer or seller role, which is determined randomly at the beginning of the experiment. Subjects are matched into groups of 1 buyer and 2 sellers across multiple procurement interactions in which the buyer could purchase one unit of a customized good from one of the sellers. The buyer’s valuation for the unit is 100. Either one of the sellers may be ineligible to customize the unit. Thus, a transaction is not guaranteed.

If a transaction takes place, then sellers compete on price for the contract. Subjects with a seller role are assigned the discount factor  $\delta_s = 0.50$  for the entire experiment. Subjects with a buyer role of type  $k$  are each randomly assigned a discount factor with equal probability from the set  $\delta_k \in \{0.75, 0.95\}$ . The two elements in this set correspond to the low and the high type buyers, respectively. We denote these as types 1 and 2 in the experiment. The buyer’s type remains private information and is drawn anew at the beginning of each market period. The sellers’ discount factor and the distribution of buyer discount factors is common knowledge. Thus, the sellers’ prior belief that their matched buyer is of high type is one-half.

We use a market frame for the experiment. Cooper and Kagel (2003) find that the meaningful context of a market experiment is well-suited to test the performance of equilibrium refinements in a signaling model and to better capture behaviour in field settings. Henceforth, when describing the experiment, we will use the language of the laboratory. Each period of the experiment consists of three stages. In the *pre-auction stage*, the buyer learns her type for the period and sends a message to the two sellers in her group. This message signals her intended payment method, either “upon delivery”, or “after delivery” (i.e., either a standard or extended payment term).

In the *auction stage*, the sellers observe the buyer’s message. Each seller submits a bid for which they would be willing to deliver the unit. This bid can be any integer from 25 to 100 (the reserve price). To enhance the internal validity of our experimental environment, we control for

the potential confound of seller over-entry by using a variant on the strategy method.<sup>15</sup> Specifically, subjects do not choose whether to enter the auction; instead, the software determines whether each seller is eligible to customize the unit, according to a pre-determined probability. It is not uncommon in market experiments to control certain aspects of behaviour to isolate the main channel of interest, in our case suppliers' pricing decisions.

The entry probability is set equal to the equilibrium mixed strategy entry randomization, given correct beliefs. Sellers are informed about their eligibility probability at the time of submitting a bid. Sellers are not informed about their own nor their competitor's eligibility realization until after submitting a bid. Any seller that is determined by the software to be ineligible can return his non-customized unit to the experimenter in exchange for 25 points (the entry cost). After both bids in a group have been submitted, the eligibility randomization is performed by the software, independently for each seller. If the software determines that both sellers are eligible, then the buyer purchases the unit from the seller that submitted the lower bid in the auction. Ties are broken at random. If the software determines that one seller is eligible, then the buyer purchases the unit from this seller. The price is the selected seller's bid.

In the *post-auction stage*, the buyer observes the transaction price (but not the identity) of the selected seller and selects a final payment method for the unit. If final payment is made upon delivery, then the buyer's payment cost and the seller's payment value equals the transaction price. If final payment is made after delivery, then the seller values payment at half of the transaction price; a low type buyer benefits from reduction in the payment cost to 75% of the transaction price; and a high type buyer benefits from reduction in the payment cost to 95% of the transaction price.<sup>16</sup> If the buyer reneges on an intention to make payment upon delivery, then a penalty is levied on the buyer. Subjects are informed that the penalty accrues to an independent third party outside of the experiment.

Based on our model, we design three treatments which vary the size of this penalty using a between-subjects design. In the first treatment, which we call *Low-Cost (LC)*, the penalty is set equal to 1. The penalty in this treatment is insufficient to deter either buyer type from renegeing upon an intention to make payment upon delivery and is a test of Proposition 1. In the second treatment, which we call *High-Cost (HC)*, the penalty is set equal to 16. The penalty in this

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<sup>15</sup> To investigate whether over-entry would arise in our environment, we conducted an additional experiment which permitted sellers to make both an entry and pricing decision at the auction stage. We replicate the over-entry result found in previous experiments with endogenous entry (e.g., Davis et al. 2014, Palfrey and Pevnitskaya 2008) and find that sellers' endogenous entry decisions may distort payment behaviours in the market (see the Online Appendix for details).

<sup>16</sup> To avoid any negative connotations, we do not refer to payment as "late" in the experiment. We make clear in the instructions that a buyer's intended payment method may not correspond with her final payment method: "*The final payment method selected can differ from the buyer's intended payment method*". Subjects must also answer a comprehension question related to this.

treatment is sufficient to fully deter renegeing upon an intention to pay upon delivery among buyers and is a test of Proposition 2. In the third treatment, which we call *Free-Rider (FR)*, the penalty is set equal to 8. This penalty is only sufficient to deter a high type buyer from renegeing upon an intention to pay upon delivery and is a test of Proposition 4, in which low type buyers are predicted to pay late. Note that it is not possible to test Proposition 3 using the same parameters but by changing the penalty only and so we do not test this proposition here.

#### 4.1 Hypotheses

Below, we present the experimental hypotheses (see also Table 2 for equilibrium predictions).

**Hypothesis 1.** (i) Buyers will signal an intention to pay after delivery more often in *LC* than *HC* or *FR*; and (ii) There will be no difference in intended payment decisions between low and high type buyers in any treatment.

The first part of Hypothesis 1 reflects that the buyer's cost of renegeing upon a standard payment term is too low in the *LC* treatment and so this signal is not credible. It is possible, however, that buyers will attempt to convince sellers of a (false) intention to pay upon delivery. The second part of Hypothesis 1 captures the nature of the predicted pooling equilibrium.

**Hypothesis 2.** (i) Buyers will make final payment after delivery more often in *LC* than *HC*; and (ii) low type buyers will make final payment after delivery more often than high type buyers in *FR*.

The first part of Hypothesis 2 states that, at low penalties for renegeing upon a standard payment term, the benefit of paying late dominates the associated cost for both buyer types, and vice-versa at high penalties. The second part of Hypothesis 2 states that if the penalty for renegeing upon a standard payment term is not set carefully, then low type buyers will have an incentive to free ride on high type buyers.

**Hypothesis 3.** (i) Bids will be independent of the buyer's signal in *LC*, but higher after receiving an intention to pay after delivery in *FR* and *HC*; (ii) Transaction prices will be rank ordered such that  $p_{LC} > p_{FR} > p_{HC}$ ; (iii) Buyer profit will be rank ordered such that  $\pi_{B,HC} > \pi_{B,FR} > \pi_{B,LC}$ ; and (iv) There will be no difference in seller profit among treatments.

Hypothesis 3 captures the negative welfare effect of late payments. In *LC*, the bid support is [50, 100] and the expected price is 66.67. High type buyers earn 27.5 and low type buyers earn 37.5. In *HC*, the bid support is [25, 100], sellers adjust their bids upwards in response to an offer of an extended payment term and the expected price is 40. Both buyer types earn 56.25. In *FR*, the bid support is [33, 100], sellers adjust their bids upwards in response to an offer of an

extended payment term and the expected price is 50. High type buyers earn 44.44 and low type buyers earn 48.44. In all treatments, the expected seller profit gross of the entry cost is 25.

Table 2 – Equilibrium predictions by treatment.

Treatment	<i>LC</i>	<i>HC</i>	<i>FR</i>
Intended payment	(AD, AD)	(UD, UD)	(UD, UD)
Final payment	(AD, AD)	(UD, UD)	(UD, AD)
Minimum bid	50	25	33.33
Average price	66.67	40	50
Buyer profit	(27.5, 37.5)	(56.25, 56.25)	(44.44, 48.44)
Seller profit	25	25	25

Notes: The first two rows indicate the buyer's intended and final payment decision for each type (high, low), where *UD* = *Upon Delivery* and *AD* = *After Delivery*. The third row indicates the minimum bid in the sellers' equilibrium support. The fourth row indicates the expected transaction price conditional on at least one seller being eligible to customize the unit. The fifth row indicates the expected buyer profit for each type. The final row indicates the expected seller profit gross of the entry cost.

#### 4.2 Procedure

The experiments were conducted in the fall of 2020, using oTree and Zoom (Chen et al. 2016, Zhao et al. 2020). As in a typical lab experiment, subjects attended sessions at a pre-specified date and time. All subjects were recruited from a lab database of predominantly graduate and undergraduate students at a large public university in the Southwestern United States. We recruited four independent cohorts of 9 subjects per treatment. In each cohort, we assigned one-third of subjects to the role of a buyer and two-thirds of subjects to the role of a seller. Within a cohort, subjects were randomly matched into new groups – consisting of one buyer and two sellers – in each period with minimal feedback between periods.<sup>17</sup> This was done to mitigate tacit collusion. Sessions lasted approximately 75 minutes. Average earnings were \$20.15 for buyers and \$15.17 for sellers. Before moving the experiment online due to the Covid-19 shutdown, we collected data for two cohorts of each treatment in the lab. The results are qualitatively unchanged by including this data. Further details of the experimental data, procedures and instructions are contained in the Online Appendix.

<sup>17</sup> Experimental instructions and further details of the procedure are contained in the Online Appendix.

## 5. Experimental Results

### 5.1 Summary Statistics

Table 3 reports aggregate data on observed intended and final payment decisions in the experiment and the relative frequencies with which the penalty for renegeing upon an intention to pay upon delivery was imposed on the buyer. We disaggregate this data by the buyer's type to examine how varying her benefit from making payment late influenced behaviour.

The probability that a buyer signals an intention to pay after delivery is higher in *LC* (62%) than in *HC* (39%) or *FR* (32%). These qualitative differences are observed for both low and high type buyers, consistent with the theoretical predictions. As a result, the number of eligible sellers is lower than expected in *HC* (actual 1.34 vs. expected 1.50) and *FR* (actual 1.21 vs. expected 1.33). Buyers in *LC* are the most likely to make final payment after delivery (89%) and this does not vary with the buyer's type. Only 36% of buyers in *HC* and 50% of buyers in *FR* make final payment after delivery. This latter finding corresponds with the aggregate frequency of late payments predicted by the theory and masks significant differences between types: low type buyers (74%) pay after delivery more often than high type buyers (22%). This is reflected in the penalty data: in *FR*, a penalty is imposed on 3% of high type transactions and 42% of low type transactions. Penalties are negligible in *HC* and observed on 28% of transactions in *LC*.

In Table 4, we present data on bids, transaction prices and buyer and seller profits. To examine whether sellers anticipated that the *ex-ante* signal would influence a buyer's *ex-post* payment date, bids are disaggregated by the intended payment decision. Consistent with the notion of a higher penalty acting as a deterrent mechanism, sellers only adjust their bids in response to a credible signal. In *LC*, sellers do not adjust their bids conditional on the intended payment method; in both *FR* and *HC* bids are lower when the buyer signals an intention to pay upon delivery. We observe average bids of 67.54 in *LC*, 60.83 in *FR* and 54.94 in *HC*. The transaction prices conditional on entry are lower (63.38, 56.83 and 50.19) and the theoretical ranking remains intact. Whereas in *LC* average transaction prices are close to the point prediction, in *HC* and *FR* they are higher than expected.

There is qualitative support for the expected ranking in buyer profits. On average, buyers earn the most in *HC* (47.52), the second-most in *FR* (39.30) and the least in *LC* (32.50). Aggregate seller profits are close to the entry cost in all three treatments. In *HC*, both buyer types pay on-time in equilibrium and so we expect no difference in profits. Low type buyers, however, earn a premium in this treatment of around four points (49.64 versus 45.55). They also earn more than high type buyers in *FR* (42.66 versus 36.08). Finally, in *LC* low type buyers are predicted to earn 10 more points than high type buyers and this is broadly consistent with the data (39.27 versus 28.78).

Table 3 – Payment date decisions (0 = Upon delivery; 1 = After delivery).

Treatment	<i>LC</i>		<i>HC</i>		<i>FR</i>	
	$H1(i) \checkmark$					
Intended payment	0.62	(0.15)	0.39	(0.11)	0.32	(0.12)
<i>Low type</i>	0.68	(0.15)	0.48	(0.31)	0.37	(0.18)
<i>High type</i>	0.52	(0.24)	0.30	(0.13)	0.26	(0.06)
	$H2(i) \checkmark$					
Final payment	0.89	(0.17)	0.36	(0.10)	0.50	(0.16)
<i>Low type</i>	0.89	(0.22)	0.49	(0.34)	0.74	(0.27)
<i>High type</i>	0.88	(0.12)	0.26	(0.14)	0.22	(0.07)
	$H2(ii) \checkmark$					

Notes: Mean (SD) values based on 4 independent cohorts per treatment. Horizontal braces correspond to the two-sample comparisons of interest and associated hypotheses. Vertical braces correspond to the one-sample comparisons of interest and associated hypotheses.  $\checkmark$  or  $\times$  indicate whether or not the hypothesis is supported based on the regression analysis in Table 5.

Table 4 – Bidding, prices and profits.

Treatment	<i>LC</i>		<i>HC</i>		<i>FR</i>	
Bid						
<i>Intended upon delivery</i>	66.76	(11.80)	52.46	(7.25)	57.55	(8.79)
<i>Intended after delivery</i>	67.82	(10.68)	61.42	(9.24)	68.23	(7.03)
	$H3(i) \checkmark$					
Price	63.38	(13.12)	50.19	(6.17)	56.83	(8.69)
	$H3(iii) \checkmark$ $H3(iv) \checkmark$					
Buyer profit	34.70	(5.92)	47.52	(5.83)	39.30	(4.72)
Low type	39.27	(6.20)	49.64	(6.96)	42.66	(6.39)
High type	28.78	(7.26)	45.55	(4.85)	36.08	(5.37)
Seller profit	25.30	(2.12)	26.04	(2.73)	27.28	(2.83)

Notes: Mean (SD) values based on 4 independent cohorts per treatment. Horizontal braces correspond to the two-sample comparisons of interest and associated hypotheses. Vertical braces correspond to the one-sample comparisons of interest and associated hypotheses.  $\checkmark$  or  $\times$  indicate whether or not the hypothesis is supported based on the regression analysis in Table 6.

## 5.2 Payment strategies

In Table 5, we estimate logistic regressions to examine determinants of the buyer's intended and final payment decisions in the experiment. In specifications (1) and (2), the dependent variable is a dummy variable for intended or final payment after delivery. In specification (3), the dependent variable is a dummy variable for whether a penalty is imposed on the transacting buyer. We include the treatment dummies as regressors and consider their full interaction with the buyer's type. All regression specifications include cohort fixed effects and a linear time trend. Marginal effects are presented next to the coefficient estimate, with robust standard errors based on clustering at the subject level. Unless stated, reported  $p$ -values are from two-sided Wald tests.

We find support for Hypothesis 1(i) in specification (1) of Table 5. Buyers in *FR* and *HC* are, respectively, 30% and 22% less likely to signal an intention to pay after delivery than buyers in *LC* ( $p = 0.014$  and  $p = 0.071$ ). There is no significant difference in signals between buyers in *HC* and *FR* ( $p = 0.307$ ). Hypothesis 1(ii) predicts that low type buyers will signal extended payment terms up-front no more often than high type buyers. However, we find that low type buyers are 16% more likely to signal payment after delivery in the pre-auction stage ( $p = 0.042$ ).

**Result 1.** Introducing a large enough penalty for reneging upon a standard payment term deters buyers from offering an extended payment term; it is less effective for low type buyers.

There is strong support for both parts of Hypothesis 2 in specifications (2) and (3) of Table 5. Consistent with Hypothesis 2(i), the probability of a late payment is 67% lower in *HC* than in *LC* ( $p < 0.01$ ) and there is no significant effect of the buyer's type in this treatment on the final payment decision. As predicted by Hypothesis 2(ii), low type buyers are significantly more likely to pay late than high type buyers in *FR* only ( $p = 0.026$ ). Low type buyers are thus significantly more likely to incur the penalty for late payment in this treatment ( $p < 0.01$ ).

**Result 2.** A high penalty deters late payments; if the penalty is not set carefully, then low type buyers can free-ride on the payment behaviours of high type buyers in the market.

In Figure 7, we plot the relative frequency of final payments after delivery in *FR* over time and according to the buyer's type. The figure provides strong interocular support for the divide in strategies between types: there is a clear separation between high type buyers who predominantly pay upon delivery and low type buyers who pay after delivery. This separation persists over time. Given that both types more often signal an intention to pay upon delivery (see Table 3), this trend is associated with low type buyers reneging upon a significant fraction of their payment terms offered.

Table 5 – Logit regression analysis of buyer payment decisions.

Dependent variable	<i>Intended payment AD</i> <sup>1</sup>		<i>Final payment AD</i>		<i>Penalty = 1</i>	
	$\hat{\beta}$	$dy/dx$	$\hat{\beta}$	$dy/dx$	$\hat{\beta}$	$dy/dx$
	(1)		(2)		(3)	
<i>HC</i>	-0.93*	-0.22*	-3.25***	-0.67***	-4.48***	-0.28***
	(0.52)	(0.12)	(0.95)	(0.13)	(1.07)	(0.08)
<i>FR</i>	-1.29**	-0.30**	-3.38***	-0.69***	-2.97***	-0.20***
	(0.53)	(0.12)	(0.89)	(0.12)	(1.08)	(0.07)
<i>Low type</i>	0.68**	0.16**	0.52	0.12	-0.52	-0.04
	(0.33)	(0.08)	(0.63)	(0.14)	(0.47)	(0.04)
<i>HC * Low type</i>			0.50	0.11	1.89	0.26
			(1.04)	(0.22)	(1.21)	(0.24)
<i>FR * Low type</i>			1.94**	0.35**	3.93***	0.65***
			(0.87)	(0.14)	(1.24)	(0.21)
<i>Period</i>	-0.02	-0.004	0.003	0.001	0.02	0.002
	(0.02)	(0.004)	(0.02)	(0.004)	(0.01)	(0.001)
<i>Constant</i>	0.17		2.31***		-0.28	
	(0.71)		(0.75)		(0.89)	
Observations	850		700		700	
Cohort fixed effects	Yes		Yes		Yes	
Log-likelihood	-533.40		-336.68		-251.27	
Wald test statistic	98.29***		274.96***		189.63***	

Notes: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . Coefficient estimates on the logit scale ( $\hat{\beta}$ ) and average marginal effects ( $dy/dx$ ), with robust standard errors in parentheses clustered at the subject level. The omitted experimental treatment is *LC*. The Wald test statistic is based on a Chi-squared test of joint regression significance.

<sup>1</sup>*AD = After Delivery*

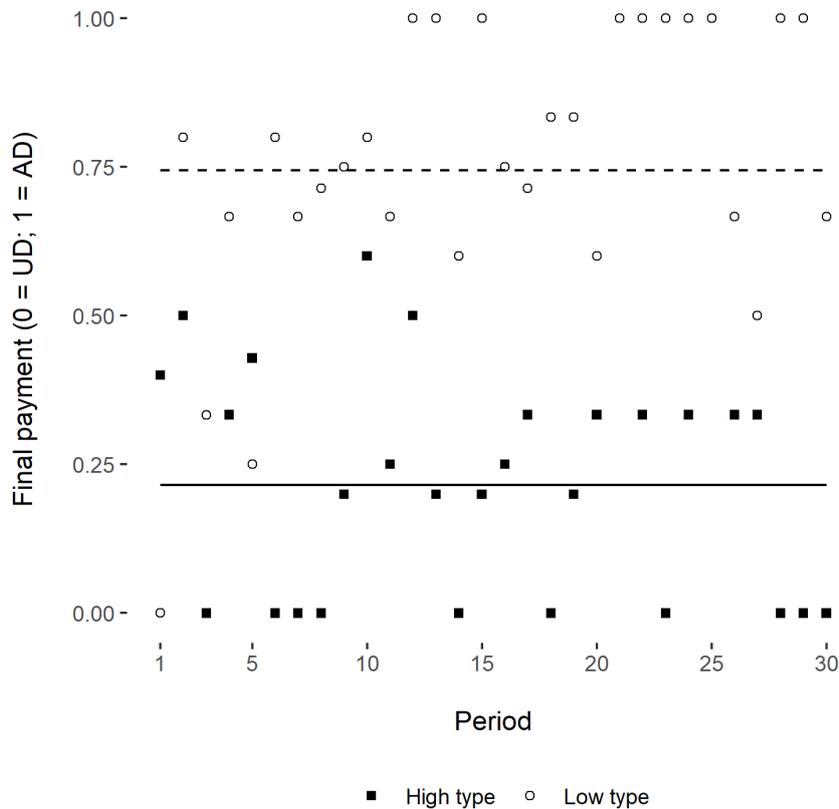
Our results are robust to including demographic controls and to focusing on the last half of the data only to address issues of learning that might arise because the buyer's type is redrawn in each period. In the Online Appendix, we further investigate payment strategies within-buyers. The equilibrium strategy is the modal one for each buyer type in every treatment. In *LC*, paying after the signalled term is also a commonly observed strategy, suggesting that buyers recognized the possibility of influencing seller prices via their choice of payment terms (even if it was not deemed credible in this treatment).

### 5.3 Seller bids, transaction prices and profits

We now turn to sellers' bidding behaviour in the auction stage of the experiment. In specifications (1) and (2) of Table 6, we regress seller bids and transaction prices on the treatment dummies and their full interaction with the buyer's intended payment decision.<sup>18</sup>

<sup>18</sup> All regressions are estimated using OLS, with robust standard errors calculated based on clustering at the subject level. The results are robust to using a random effects panel estimator. In the Online Appendix, we analyse the correspondence of individual-level bidding behaviour to the mixed strategy predictions.

Figure 7. Free-riding behaviour in the *FR* treatment.



Notes: *UD* = *Upon Delivery*, *AD* = *After Delivery*. The solid (dashed) line is the relative frequency of final payments after delivery in the *FR* treatment among high (low) type buyers.

Consistent with Hypothesis 3(i), potential sellers in *HC* and *FR* submit significantly higher bids after observing an intention to pay after delivery than upon delivery ( $p < 0.01$  for both interaction terms). The intended payment decision has no significant impact on bids in *LC*. That is, buyers' attempts in the *LC* treatment to influence bids through the signal are unsuccessful. This result provides empirical evidence to suggest that the use of extended payment terms can inflate procurement costs even when the institutional environment penalises buyers for paying late.

**Result 3a.** Sellers mark up their bids in response to extended payment terms if and only if the penalty for late payment is large enough.

Conditional on the buyer's intention, the average price is not significantly different from the equilibrium prediction of 40 in *HC*, 50 in *FR* and 66.67 in *LC* ( $p = 0.647$ ,  $p = 0.828$  and  $p = 0.132$ ). Bids and transaction prices are significantly lower in *HC* and in *FR* than in *LC* ( $p < 0.01$  for all four comparisons), and in *HC* relative to *FR* ( $p = 0.039$  and  $p = 0.032$ ). These findings support Hypothesis 3(ii), i.e., the anticipation of a late payment due to absence of deterrent regulation feeds into higher submitted prices.

Table 6 – OLS regression analysis of bids, transaction prices and profits.

Dependent variable	<i>Bid</i>	<i>Price</i>	<i>Buyer profit</i>	<i>Seller profit</i>
	(1)	(2)	(3)	(4)
<i>HC</i>	-17.85*** (3.69)	-20.15*** (4.21)	20.42*** (3.38)	1.35 (1.61)
<i>FR</i>	-10.42*** (3.34)	-12.41*** (3.91)	10.88*** (2.43)	3.13* (1.90)
<i>Intention AD</i> <sup>1</sup>	-0.35 (1.93)	-2.18 (3.27)	1.35 (1.79)	-3.92*** (1.21)
<i>HC * Intention AD</i>	11.95*** (4.06)	14.68*** (4.55)	-13.37*** (4.04)	0.78 (2.16)
<i>FR * Intention AD</i>	11.99*** (4.25)	17.71*** (4.19)	-14.19*** (3.58)	3.27* (1.68)
<i>Low type</i>			9.40*** (2.48)	0.51 (1.12)
<i>HC * Low type</i>			-2.54 (3.82)	-3.74** (1.82)
<i>FR * Low type</i>			-1.64 (3.39)	-6.81*** (2.18)
<i>Period</i>	0.68*** (0.10)	0.57*** (0.10)	-0.35*** (0.11)	0.07 (0.05)
<i>Constant</i>	62.81*** (2.80)	61.54*** (3.41)	30.61*** (2.36)	26.81*** (1.38)
Observations	1,650	682	850	1650
Cohort fixed effects	Yes	Yes	Yes	Yes
R-squared	0.22	0.27	0.13	0.03
Wald test statistic	50.02***	27.24***	10.86***	4.03***

Notes: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . Coefficient estimates are presented, with robust standard errors in parentheses clustered at the subject level. The omitted experimental treatment is *LC*. The models are estimated using OLS regression. The Wald test statistic is based on an F-test of joint regression significance.

<sup>1</sup> *AD* = *After Delivery*.

**Result 3b.** Bids and transaction prices are lower when the penalty for renegeing upon a standard payment term is higher.

In specifications (3) and (4) of Table 6, we analyse the determinants of buyer and seller profits. Buyers earn higher profits in *HC* and *FR* relative to *LC* ( $p < 0.01$  for both comparisons) due to the elevated rates of seller entry and lower transaction prices in these treatments.<sup>19</sup> Buyers also earn

<sup>19</sup> In *LC*, there is weak evidence that high type buyers earn more than the predicted 27.5 ( $p = 0.090$ ), but we fail to reject the hypothesis that low type buyers earn 37.5 ( $p = 0.191$ ). In *HC*, there is some evidence that high type buyers earn less than 56.25 ( $p = 0.056$ ) but we fail to reject the hypothesis that low type buyers earn this amount ( $p = 0.608$ ). In *FR*, we fail to reject either the hypothesis that high type buyers earn 44.44 ( $p = 0.354$ ) or that low type buyers earn 48.44 ( $p = 0.806$ ).

significantly more in *HC* than in *FR* ( $p < 0.01$ ), consistent with Hypothesis 3(iii). In *LC*, low type buyers end up significantly better off than high type buyers ( $p < 0.01$ ). The results in Table 6 also reinforce the profitability of offering a standard rather than extended payment term in *HC* and *FR* ( $p < 0.01$  for both interaction terms between the signal and treatment dummy).

**Result 3c.** The imposition of a deterrent penalty for renegeing upon a standard payment term increases buyer surplus; extended payment terms lower it.

Finally, we fail to reject the hypothesis that sellers earn break-even profits (= 25) on the equilibrium path when interacting with a low type buyer in any treatment ( $p > 0.1$  for each comparison). When interacting with a high type buyer, however, sellers' on-the-path profits are significantly above the break-even level in *HC* ( $p = 0.037$ ) and in *FR* ( $p < 0.01$ ), but not in *LC* ( $p = 0.142$ ). Sellers are also significantly better off when confronted with a high type buyer than a low type buyer in *HC* ( $p = 0.040$ ) and in *FR* ( $p < 0.01$ ), but not in *LC* ( $p = 0.645$ ). These findings reflect the deterrent nature of the penalty in mitigating late payments by high types in *HC* and *FR*, with positive effects on sellers' profits.

**Result 3d.** The imposition of a deterrent penalty for renegeing upon a standard payment term can increase the sellers' profits when confronted with a high type buyer.

#### 5.4 Summary of experimental results

In sum, the experimental results offer broad support for the qualitative insights of the model. Greater uncertainty about the payment timetable is associated with higher market prices and lower buyer profits. Buyers benefit from imposition of the highest penalty for a late payment through lower prices. If the penalty is not set high enough, then there is an incentive for low type buyers to exploit price spillover effects in the market and renege on a standard payment term. We also reiterate that all our results are robust to including demographic controls and accounting for learning.

### 6. Discussion: Penalty as Interest vs. a Lump-sum Penalty

A natural question is how our theoretical results depend on the form of the penalty for renegeing upon a standard payment term. We thus re-analyse the model under the assumption that the penalty is levied as interest on payment due. First, we consider a penalty that increases with payment size to demonstrate that our assumption of a lump-sum penalty is without loss of generality. Then, we assume that the penalty accrues to the seller. This has policy relevance. The EU directive 2011/7/EU entitles creditors to statutory interest on a late payment of at least eight percentage points above the European Central Bank's reference rate. We show that awarding the penalty to the creditor may have unintended consequences for payment behaviours.

(a) *Penalty as interest.* We previously considered a lump-sum fine  $c \geq 0$  on the buyer for reneging upon a standard payment term. Suppose instead that the buyer is penalised on any overdue invoice at a pre-defined interest rate  $r \leq (1 - \delta_S)$ . For now, we continue to assume that this penalty accrues to a third party outside of the model. Thus, the unique symmetric equilibrium in mixed strategies per Lemma 1 is unchanged and late payments continue to be associated with higher prices and lower welfare. The penalty is increasing proportionally in the payment size and so there are just three penalty intervals to consider in the equilibrium analysis.

If  $r < (1 - \delta_H)$ , then neither buyer type will pay at  $\tau = 0$  in the continuation game associated with a standard payment term and Proposition 1 applies. If  $r > (1 - \delta_L)$ , then both buyer types will pay at  $\tau = 0$  in the continuation game associated with a standard payment term and Proposition 2 applies. If  $(1 - \delta_L) < r < (1 - \delta_H)$ , then the two buyer types will diverge with their final payment decision in the continuation game associated with a standard payment term if  $\beta(1) \cdot \delta_L p(1) \geq \beta(1 - x) \cdot p(1 - x) - R(\beta(1 - x) - \beta(1))$  and so Proposition 4 applies.

(b) *Interest absorbed by the creditor.* Let the seller receive the accrued interest amount  $rp$  as compensation for any payment beyond an agreed standard term. Potential suppliers will incorporate the expectation of this interest payment into their second stage entry and pricing strategy. We redefine  $\gamma(q, r) = (1 - q + (\delta_S + (1 - m)r)q)$ , which is non-decreasing in  $r$ . With this substitution, Lemma 1 describes potential suppliers' entry and pricing strategy. The buyer's equilibrium payment behaviour is described above in (a). The penalty has no influence on the analysis in the continuation game associated with an extended payment term, nor in the continuation game associated with a standard payment term where the seller expects to receive payment at  $\tau = 0$  with probability one (i.e.,  $q = 0$ ). In the interval  $(1 - \delta_L) < r < (1 - \delta_H)$ , the lower bound threshold on  $\delta_L$  for Proposition 4 to apply is decreasing in  $r$ . Low type buyers are more likely to pay late because of the feedback effect on pricing decisions.

**Corollary 5.** *The effectiveness of the penalty at preventing a late payment by low type buyers is diluted when it accrues as interest to the creditor, relative to collection by a third party.*

## 7. Concluding Remarks

In this paper, we provide theoretical and experimental evidence that late payments feed into higher prices and lower market welfare. Late payments are a real liquidity risk in trading relationships and characterise a wide range of industries. Yet identifying the impact of such payment practices in the field confronts an endogeneity problem. For example, in the wake of the Covid-19 pandemic, firms faced unprecedented revenue shocks (Joseph et al. 2020). In the UK, more than half of sellers reported having unpaid invoices due as a direct result of the crisis (Office for National Statistics 2020) and 10% of all small businesses report that the pandemic has

lengthened payment terms (FSB 2020). In the US, defaults on invoice payments have risen significantly between 2019 and 2020 (Atradius 2020). The extent to which outstanding payments contribute to sellers increasing their prices or leaving the market is difficult to disentangle from wider financing constraints and demand shortfalls.

Existing operations research on the horizontal effects of late payment risk is underdeveloped. We show that the expectation of a longer time to pay induces sellers to compete less frequently and inflate their bids. Buyers face a counter-productive rise in procurement costs. Our analysis suggests that introducing a penalty on those buyers who renege on a standard payment term can improve welfare: as sellers become more confident in the payment terms received, they bid for contracts more often and compete more aggressively, leaving end consumers to benefit from lower prices. As the effectiveness of the penalty at deterring late payments may be diluted when accruing as interest to the creditor, regulators should consider introducing a fine levied by an independent third party. Implementing a penalty in this way would have the additional benefit of raising revenue and may mitigate power imbalances that discourage suppliers from demanding compensation for fear of losing repeat business – although that would still depend on anonymity in the reporting process. However, it is important to recognise that implementing a third-party penalty may not be feasible in all market settings, particularly if the cost of verifying payment performance is high. It may also be more difficult to set at the optimal level given firm heterogeneities. Our results suggest that buyers might be more likely to cooperate with such a regulatory scheme if they understand the horizontal price benefits from establishing a culture of prompt – rather than late – payments.

We provide experimental evidence to support our theoretical predictions and demonstrate that care should be taken in setting the level of any regulatory fine. If this fine is not set high enough, those firms who benefit most from paying late may “free ride” on the positive competition spillover effects generated by other firms who pay on-time. The experiments inform on why certain sectors may become stuck in an inefficient equilibrium characterised by extended payment terms and prolonged unpaid invoices: if sellers are unwilling to adjust their bids in response to an offer of a standard payment term for fear of the buyer renegeing, it is not in the buyer’s interest to change their payment practices. An empirically testable prediction of the model is that the relationship between average payment term and consumer price level will be more evident in regions or sectors where a late payment is penalised than where it is not.

A further implication of our analysis is that a regulatory penalty may be ineffective in times of economic stress - when the buyer may benefit more from paying with delay. An alternative would be to reward firms for prompt payment. It is not obvious, however, that this would be palatable for a regulator to implement – presumably, it would require some form of subsidy.

Discounts are often offered by sellers to consumers in voluntary trade credit agreements, as a reward for early payment.<sup>20</sup> Late payment is, by its very nature, an *involuntary* arrangement.

We acknowledge that the concept of welfare considered in this paper (expected buyer surplus) is narrow. This enabled us to focus on the horizontal effects of a late payment on entry and pricing, at the cost of abstracting from broader welfare implications that might arise in more complex market structures. For instance, one could examine the effects of late payment on sub-contractors in a multi-tier supply chain. Once the consequences of liquidity risk for downstream supplier competition are considered, the benefit of introducing a deterrent penalty may increase further. How payment terms and financial capacity interact between upstream and downstream suppliers is an interesting avenue for future work. Relatedly, we limit attention to a symmetric-information (among sellers) sealed-bid format in which preparing a bid is costly. Although this is reasonable for projects in which a cost estimate can be arrived at precisely (after some effort), in other situations these assumptions are restrictive. It would be interesting to examine the influence of the different selection rules on buyer-side and seller-side payment strategies.

Another limitation of our approach is that we consider only a one-shot interaction. In repeated interactions, reputational information may influence bidding strategies, change a buyer's incentive to pay late (e.g., due to a loss of trust and with it, future business), and lead to separating equilibria not captured by our model. Note that in a one-shot interaction, reputational information remains relevant if firms are required to report on payment practices in the public domain, as demonstrated by our regulatory reporting data.

The consequences of repeated interactions for the propensity of late payments are far from straightforward. Small firms, for example, may be reluctant to claim against larger clients for fear of losing repeat business. This was exactly the strategy of Carillion (cited earlier) before it collapsed. In the words of Rachel Reeves MP: "It's clear that Carillion were notorious late-payers, ruthlessly exploiting their position to bully their contractors in a desperate bid to prop up their precarious business model" ("Committees publish correspondence" 2018). Beyond the scope of the current paper, renegotiation of the payment date may alternatively be welfare-improving if it prevents a productive firm from going bankrupt after experiencing a financing shock during the invoice period. Incorporating external financing uncertainty into the model would further inform regulators as to the appropriate policies for mitigating late payments.

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<sup>20</sup> See, e.g., "2/10 Net 30", in which a company extends a 30-day invoice term to customers who pay on credit and a 2% discount on the purchase price if payment is made within 10 days.

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