

Pirates of the Mediterranean: An Empirical Investigation of Bargaining with Asymmetric Information

By ATTILA AMBRUS, ERIC CHANEY AND IGOR SALITSKIY *

Draft: April 7, 2015

We investigate the effect of delay on prices in bargaining situations using a data set containing thousands of captives ransomed from Barbary pirates between 1575 and 1692. Plausibly exogenous variation in the delay in ransoming provides evidence that negotiating delays decreased the size of ransom payments, and that most of the effect stems from the signaling value of strategic delay, in accordance with theoretical predictions. We also structurally estimate a version of the screening type bargaining model, adjusted to our context, and find that the model fits both the observed prices and acceptance probabilities well.

Throughout history individuals and governments have negotiated and paid ransoms to secure the release of prisoners and property. These negotiations have often been prolonged, imposing significant costs on the involved parties. Ransom negotiations for the release of individuals captured by Somali pirates provide one recent example of this phenomenon. Although delayed negotiations expose captives to greater mistreatment, such delays have been common, with the average duration in captivity climbing to eight months in 2011 (One Earth Future, 2012).

* Ambrus: Duke University and NBER. Chaney: Harvard University. Salitsky: Vienna University of Economics and Business. We thank Ran Abramitzky, Mauricio Drelichman, Avner Greif, Nathan Nunn, Robert Powell, Gillian Weiss and seminar participants at AALIMS-Princeton, Berkeley, Duke, Northwestern, NYU Abu Dhabi, Stanford and the 2014 SITE meeting on the Dynamics of Collective Decision Making for helpful comments and discussions. The library staff at the *Biblioteca Nacional de Madrid* and the *Archivo Histórico Nacional* facilitated the data collection. Judith Gallego provided outstanding research assistance. Any remaining errors are ours.

Why are negotiating delays common in ransoming and other bargaining environments? The theoretical bargaining literature suggests the role of asymmetric information (Sobel and Takahashi, 1983; Fudenberg, Levine and Tirole, 1985; Gul and Wilson, 1986; Admati and Perry, 1987). The central idea is that the same amount of delay is more costly for buyers with a higher evaluation, hence delay can credibly signal to the seller that the buyer’s evaluation is low. While this explanation is intuitively appealing, it has been difficult to empirically substantiate that negotiating delays lead to lower prices (e.g. Kennan and Wilson, 1989).

In this paper we use a historical data set on thousands of captives ransomed by Spanish ransoming teams from North-African-based pirates to investigate the empirical relevance of dynamic bargaining models with asymmetric information in ransoming situations. Based on historical evidence, we think about negotiations for the release of different captives as a dynamic bargaining game with asymmetric information. In particular, we assume that the relevant uncertainty is one-sided, regarding the exact value of each captive for the rescuers.

Formally, we investigate a “screening” type dynamic bargaining game (Sobel and Takahashi, 1983; Fudenberg, Levine and Tirole, 1985) in which only the uninformed player (in our case, the seller) makes offers. We extend the most basic specification of the screening bargaining model in various dimensions, in order to fit it better to our setting. These are: (i) we assume that the time between bargaining rounds (corresponding to Spanish rescue missions) is random, according to a Poisson arrival process; (ii) we allow for a positive reservation value for the seller; (iii) we consider physical depreciation of captives, on top of standard discounting; and (iv) we allow for a positive probability that funds for rescuing a captive do not arrive in time for the first bargaining opportunity after the person was captured. These extensions do not change the qualitative implications of the screening bargaining model. In particular, as long as there is a gap between the smallest buyer valuation and the seller’s reservation value,

there is a unique sequential equilibrium, in which the seller proposes a decreasing sequence of prices. Moreover, negotiations end in a finite number of rounds (that depends on the parameters of the model), with the last price offer being equal to the lowest buyer valuation.

Our empirical investigation is twofold. In the first part, we focus on establishing that negotiating delays caused a decrease in equilibrium prices. We do this for two reasons. First, this prediction is common to all rational models of bargaining when the relevant private information is on the buyer's side, not only the specific model we propose. Second, our historic data set allows us to exploit the poor communications of the day to derive a plausibly exogenous source of delay. Specifications using this variation help address endogeneity issues that are thought to have biased estimates of the relationship between delay and prices in previous studies.

Using data on thousands of captives ransomed in Algiers, Algeria we find that on average the Spanish paid less for a captive the longer he had been in captivity (which is one of our two proxies for negotiating delay). Although this correlation is consistent with the claim that delay led to lower prices through signaling low buyer evaluation, there are clearly other possible explanations for this result. One of these is that there were multiple types of captives that the pirates could tell apart, and negotiations for types of captives with a higher value lasted a significantly different amount of time than negotiations for types with a lower value.

To address such concerns we use an instrument for delay that is rooted in the slow speed of travel in pre-industrial Spain. The family and friends of captives whose home towns were closer to the cities where the bargaining teams were based were likely to learn about an individual's captivity with less delay -and to remit the necessary ransom funds sooner- than those whose home towns were farther afield. A similar relationship held for individuals closer to ports commonly used to sail to Algiers. Thus, the funds to rescue a given individual were likely to

reach Algiers more quickly the closer the individual's home was to these cities. We argue that the pirates could not distinguish between this distance-induced delay and strategic delay.

We use the relevant distances to construct an instrument for delay and find that a year's increase in captivity was associated with roughly an 8% decrease in a captive's ransom price. As opposed to this, we find that a year's increase in the age of a captive at the time of captivity is associated with about a 1% decrease in ransom price. Since qualitative sources suggest that the pirates were careful to preserve the value of captives they hoped to ransom, this suggests that most of the decrease in ransom price over time was due to the signaling value of delay on the part of the buyer.

The available data are consistent with the validity of the exclusion restriction underlying the IV regressions. In particular, in a subsample of the data we observe one component of the buyer's evaluation directly: the amount of earmarked money that the captive's friends and relatives collected for rescuing the captive. Results on this subsample are similar to those in the broader sample, suggesting that systematic differences in unobserved valuations are not driving our results. Our empirical use of information that only one of the parties possessed adds to a growing empirical literature on adverse selection that aims to collect and utilize such information (Finkelstein and McGarry, 2006; Finkelstein and Poterba, 2006; Abramitzky, 2009). To our knowledge, ours is the first paper to empirically use such information in the context of bargaining under asymmetric information.

In the second part of the empirical analysis, we structurally estimate the dynamic bargaining model we propose. In particular, we search for the parameters of the screening model that maximize the likelihood of observing the prices in our data and the number of ransoming trips before captives had been ransomed. This approach has two advantages. First, it uses more information to identify parameters than the reduced form approach. In particular, it directly uses the information on the distribution of the number of negotiation rounds. Second, it

yields estimated structural parameters, which we use to analyze the distribution of the trade surplus and to evaluate alternative trade mechanisms.

The results show that our screening model can match well both the observed prices and the distribution of missed ransoming trips. The estimated parameters indicate that there was substantial information asymmetry between the Spaniards and pirates, and that the first offer price was significantly lower than the median valuation. We also find that for a high share of captives (31%) ransom money were not available during the first trip, and that pirates' reservation value of captives was much lower than the Spaniards' median valuation. Computed allocation of the trade surplus shows that the Spaniards were able to capture the bulk of the surplus (54% of the total), pirates enjoyed only 32% of the surplus and 14% of the surplus was lost due to delay in bargaining. This indicates a relative efficiency of the bargaining process.

Using the estimated parameters, we also compute the surplus allocation had the pirates sold captives in bundles of ten or committed to a take-it-or-leave-it offer (which would have required coordination among different slave holders). The result shows that selling captives in bundles would have resulted in higher surplus allocation to pirates and lower delay costs. Committing to a single offer would have resulted in higher surplus allocation to pirates, but it would have implied significantly higher delay/termination costs. Given that the majority of captives in our data were not ransomed during the first ransoming trip, we interpret this result as an indication of pirates inability to commit to a single offer.

The remainder of the paper proceeds as follows. Section I discusses the related literature. Section II provides an historical overview, while Section III introduces the theoretical model. Section IV describes the data and presents our reduced form empirical results, while in Section V we structurally estimate the proposed bargaining model. A final section concludes.

I. Related Literature

Our results are most closely related to the empirical literature on bargaining under asymmetric information. Much of this literature has relied on experiments (Neelin and Spiegel, 1988; Ochs and Roth, 1989; Mitzkewitz and Nagel, 1993; Straub and Murnighan, 1995; Croson, 1996; Guth, Huck and Muller, 1996; Rapoport, Sundali and Seale, 1996; Schmitt, 2004) and generally finds that play strays from equilibrium predictions. These papers compellingly argue that the main reason for this is that many subjects exhibit other-regarding preferences, and in particular reject offers that would give them less than what they regard as a fair share of the surplus. One important advantage of our setting is that it is reasonable to assume that the professional bargaining teams on the Spanish side, and private slave holders on the Algerian side, only cared about their own physical payoffs.

The non-experimental empirical literature has also faced challenges. In particular, existing studies have struggled to establish a negative relationship between the length of negotiations and prices. For example, Card (1990) found virtually no relationship between agreed upon wage and the length of negotiations analyzing Canadian employment contract data for the period 1964-1985. Although McConnell (1989) finds a statistically significant negative relationship between average wage settlements and average strike duration using US contract data for the period 1970-1981 this relationship is sensitive to model specification. Our results robustly suggest that delay had a causal effect on prices, thus providing evidence consistent with one of the central predictions of the theoretical literature.

Our work also contributes to a recent string of papers structurally estimating dynamic bargaining models with asymmetric information: Sieg (2000), Keniston (2011) and Larsen (2014).¹ Similarly to our paper, Sieg (2000) investigates

¹Less related are the works of Watanabe (2009) and Tang and Merlo (2010), that estimate complete information bargaining games. There is also an earlier literature computing point estimates of parameters

a situation with one-sided private information, but in a setting in which the uninformed party can only make one offer, and rejection leads to a court case decided by a jury. Keniston (2011) and Larsen (2014) investigate situations with two-sided private information. Because of the complexity of dynamic bargaining games with two-sided asymmetric information, these papers do not estimate equilibrium strategies, instead they try to recover the basic parameters of the bargaining games in more indirect ways.

More distantly, our work is related to studies of the determinants of bribes and extortion payments (Hsieh and Moretti, 2006; Olken and Barron, 2009; Rose-Ackerman, 2010). Although ransom payments are believed to stimulate predation in weakly-institutionalized polities with significant welfare impacts (Besley, Fetzer and Mueller, 2012) their determinants are poorly understood. The evidence presented in this paper suggests the relevance of bargaining theory in explaining ransoming outcomes.²

II. Historical Background

Between the 16th and 19th centuries, the Barbary pirates preyed on commerce and coastal populations in the Mediterranean and Atlantic. These pirates derived important revenues from the sale of captured cargoes and captives, affecting both trade and coastal settlement patterns for centuries (Tenenti, 1967; North, 1968; Friedman, 1983). Recent scholarship estimates that the pirates captured and enslaved over one million individuals between 1530 and 1780 (Davis, 2001, 2003).³

The city of Algiers (in modern-day Algeria) was an important center of pirate

of dynamic bargaining models based on US data on wage negotiations: see Fudenberg, Levine and Ruud (1985) and Kennan and Wilson (1993). See also Merlo, Ortalo-Magne and Rust (2013) who estimate a dynamic model with asymmetric information adopting a reduced-form assumption about bargaining behavior.

²In a broader sense our results speak to a growing literature investigating piracy from an economic standpoint (Leeson, 2007, 2009; Hillmann and Gathmann, 2011). Like these studies, our paper suggests the relevance of economic theory in explaining the actions of pirates.

³Since the Barbary pirates operated with the support of their local governments we should technically refer to these pirates as corsairs. For expositional simplicity, however, we follow popular convention and use the term pirates. For a detailed treatment of the history of the Barbary pirates see Julien (1970), Abun-Nasr (1977), Bono (1998), Davis (2003), Panzac (2005) and Weiss (2011).

activity on the North African coast. Following its establishment as a center of piracy in the early 16th century, it was home to thousands of individuals who had been captured by pirates and subsequently sold into slavery.

Two primary factors determined the price of captured individuals in the Algerian slave market. The first of these was related to the present value of a captive's marginal product. Older captives were valued less and captives with special skills (such as carpentry) commanded higher prices. The second factor was a slave's potential for ransom. As this potential increased with a slave's social status, slave traders and potential buyers examined both the possessions and bodies of the captives in detail in an attempt to ascertain their social status. The Algerians also provided incentives to fellow captives to correctly identify high-ranking captives.

Once a captive had been sold into slavery, his captors encouraged him -or a fellow captive on his behalf if he was illiterate- to write home to secure ransom payments. Merchants, ransomed captives and returning Spanish ransoming expeditions carried these letters to Spain (Hershenzon, 2011, pp. 64, 65).

How long did it take for this information to reach a captive's home? Although it is impossible to exactly measure, delay increased with the distance from the captive's home to what we refer to as the "bargaining bases." These cities were the three ports commonly used to travel from Spain to Algiers (Alicante, Cartagena and Valencia) and the two cities (Madrid and Seville) in which the Spanish bargaining teams were based (Martínez Torres, 2004, p. 107). The distance-induced delay in the arrival of news of a loved one's capture could be significant. For example, even if the bearer of the letter went directly from the bargaining base to a captive's home by land, he would have on average covered about 13 kilometers per day (Grafe, 2012, p. 110). In practice, this speed is likely an upper bound on the speed with which the news of an individual's capture traveled.⁴

⁴For example, it is probable that distance also increased the likelihood of a letter being lost. The loss of letters also contributed to overall delay as captives routinely had to write many times before letters reached their destination (Hershenzon, 2011, pp. 63-64)

Once the news of an individual's capture had reached home, the local community had various means to raise ransom funds. For the most part, the brunt of the financial burden for an individual's ransom lay with his family. To raise the necessary funds, family members resorted to a variety of strategies such as selling property, taking out loans or using the dowries of unwed daughters. Those who were unable to raise the necessary funds could beg or directly petition the government for aid.⁵

Most families entrusted their ransom funds to one of the two Catholic religious orders who transported these funds to Algiers and negotiated the ransom payments on a family's behalf (Martínez Torres, 2004, p. 79). As with the news of an individual's capture, the time required to transport ransom funds to these religious orders seems to have increased with the distance of a captive's home from the bargaining bases (e.g. Anaya Hernández, 2001).

In sum, after a captive had been captured and sold in the Algerian slave market, the distance to the bargaining bases affected the delay with which his ransom money reached Algiers in two ways. First, it increased the delay with which his family learned of his captivity. Second, it increased the time necessary to transfer funds to the religious orders that negotiated ransoms in North Africa.

A. *Negotiations in Algiers*

After arriving in Algiers, the Spanish ransoming teams focused on ransoming two groups of individuals. The first group included those "earmarked captives" whose families and friends had raised funds for their ransom. Funds for the ransom of these captives on average accounted for 40% of all ransom funds (Friedman, 1983, p. 115). The second group of captives were ransomed using the remaining funds which came from alms and bequests. Some of these funds could be used at the discretion of the religious orders although a portion were to be used for the ransom of specific types of captives such as women, children, clerics or soldiers.

⁵The "government" in this case was primarily the *consejo de cruzada* which was centered in Madrid.

Before the ransom negotiations began, the ransoming team was instructed to “visit the dungeons where the miserable captives live [...] and identify all the Christian vassals of the King [of Spain...] their home towns, names [and] the names of their parents” (mss 2974, f.4) and to note those captives they wished to ransom.⁶ The Spanish seem to have done this for every captive possible, in part to obscure the identity of the captives they wanted to ransom.⁷

At the start of the negotiations the Algerian government required the Spanish to ransom some of its slaves at inflated prices. After this, the Spanish were generally free to negotiate ransoms with private Algerian slave owners. When an agreement was reached, the Spanish recorded the relevant information in a book and gave the slave owner a signed piece of paper. At the end of the negotiations, the Spanish paid the slave owners and the ransomed slaves returned with the negotiating team to Spain (mss 2974, f. 6).

Although the Algerians knew that the Spanish preferred to ransom certain types of captives and could often identify the highest-ranking individuals (Friedman, 1983, p. 151), there is evidence that they faced uncertainty regarding which captives the Spanish wanted to ransom and how much the Spanish were willing to pay. For example, surviving instructions to the ransoming teams consistently advise the negotiators to “delay the ransom [...] and pretend to not be interested in the captives that they most want to rescue [...since the Algerians after this delay] will often sell their slaves for less than they thought they were worth” (mss 2974, f. 5). These instructions seem to have been followed in practice as evidence has survived of the ransoming teams leaving captives in captivity for longer to obtain lower prices. For example, in the record of one ransoming mission from the end of the 16th century, the scribe notes that some earmarked captives were not ransomed in that trip because their prices were “too high” (l. 122, f. 159r).

⁶Throughout, archival entries prefaced with l are from the *Archivo Histórico Nacional, códices*. The number after l details the legajo. Archive entries prefaced with mss are from the *Biblioteca Nacional de Madrid*. The number after mss gives the manuscript number. See the Supplementary Appendix for details.

⁷Lists with the physical descriptions of earmarked captives further helped the negotiating team correctly identify these captives (Martínez Torres, 2004, p. 41).

III. The Theoretical Model

We model ransom negotiations between Spanish rescue teams and captive holders as dynamic bargaining games with asymmetric information. In particular, the relevant private information is the exact value of a given captive for the rescuers. Our motivation here is that the value of a particular captive for the Spaniards always had a component not known by the slave owners: the amount of earmarked money that was collected for a given captive. Over time, the captors could learn the distribution of this private value conditional on observables of a captive, but not the exact value for individual captives. In contrast, other important parameters of the bargaining process, such as the parties' time preferences and transaction costs, or reservation values of different types of captives for the holders, could either be observed by the parties through public information (such as interest rates charged by money lenders, or the price that a certain type of captive could be sold for at slave markets) or learned over time.⁸

For now, we also assume that the negotiation for every captive is a separate game, and independent of all other negotiations. This is motivated by the fact that the captives in our data set were held by many different slave owners, who negotiated with the rescuers separately. In Section V, where we structurally estimate the model, we investigate how much slave owners could gain by bundling their captives and negotiating for their collective release.

To keep the analysis tractable, we consider the simplest modeling framework for dynamic bargaining with one-sided asymmetric information, in which only the player with no private information (the seller) makes offers, standardly referred to as a screening type bargaining model.⁹ Accepting an offer ends the game,

⁸Captive-holders might have privately known individual-specific evaluation for a certain type of captive, exceeding market price. However, for common type captives, the thickness of the market implies that they could purchase additional captives of the same kind until the marginal benefit became equal to the market price.

⁹Sobel and Takahashi (1983) introduced a finite version of the model, while Fudenberg, Levine and Tirole (1985) and Gul and Wilson (1986) extended the analysis to infinite horizon. These models are incomplete-information extensions of the dynamic bargaining models

while rejection implies that the game moves to the next period, where periods represent ransoming trips. We note that the negative relationship between the length of the negotiations and the agreed upon price, which we focus on testing in the reduced form analysis of Section IV, is an implication of not only the model described here, but of any rational model of dynamic bargaining with one-sided private information on the buyer side.¹⁰

Motivated by specific features of the bargaining environment we investigate, and to facilitate structural empirical investigation, we extend/modify the most basic specification of the screening model, described for example in 5.1 of Kennan and Wilson (1993), in four directions. First, instead of a fixed time lapse between bargaining periods, we assume that bargaining opportunities come stochastically, according to a Poisson arrival process. Second, we allow the seller's outside option to be strictly positive. Third, we allow for physical depreciation of the captives over time (besides standard discounting). Lastly, we allow for the possibility of a liquidity constraint in that the funds for rescuing a captive arrive after a delay, in which case the buyer cannot accept any first period proposal. Here we assume that the arrival of funds is private information; hence the seller does not know whether rejection of a first period offer is due to a temporary lack of funds or a low valuation for the captive. The first extension essentially does not affect the analysis, as a game with random bargaining opportunities can be translated to an expected payoff-equivalent standard deterministic discrete-time bargaining game. In fact in the theoretical analysis we work with the notationally simpler discrete-time version of the model, but in the structural analysis we use stochastic bargaining opportunities, as the time between bargaining trips varied and was influenced by random events. The second and third extensions are standard, and given the parameter restrictions below, they do not affect the qualitative predictions of the model. However, they are important for the validity of the

proposed by Stahl (1972) and Rubinstein (1982).

¹⁰For discussions of this point, see for example Card (1990) and Kennan and Wilson (1993).

structural estimations, and for the resulting welfare analysis. The extension to the possibility of a liquidity constraint complicates the calculation of the initial offer of the seller in equilibrium, but continuation games after the first bargaining period are equivalent to bargaining games with no liquidity constraint (with an appropriately updated distribution of types).

Formally, our general model is a continuous-time bargaining game, starting with a bargaining opportunity at time 0 (time is normalized to 0 at the first bargaining opportunity). Subsequent bargaining opportunities arise randomly, according to a Poisson arrival process with arrival rate λ . If at time s there is a bargaining opportunity, the seller makes a price offer y_s , immediately followed by an acceptance or rejection response by the buyer. Let $v \geq 0$ be the seller's flow reservation utility, $r > 0$ be the common discount rate, $x \geq 0$ be the common depreciation rate, and b denote the buyer's privately known time-zero valuation. We assume that b is distributed according to a cumulative distribution function $F(\cdot)$ with support $[\underline{b}, \bar{b}]$, where $f(b) = F'(b)$ is the associated probability density function. We impose $v/(r+x) < \underline{b}$, implying that the buyer's valuation always strictly exceeds the seller's outside option.¹¹ Finally, we assume that the buyer is liquidity constrained and unable to accept the offer at time 0 with some probability $\pi \in [0, 1]$.

This continuous-time game can be mapped into a discrete-time game with equivalent expected payoffs, in which bargaining opportunities arise deterministically, at $t = 0, 1, 2, \dots$, with common discount factor $\delta = \frac{\lambda}{\lambda+r}$ and depreciation factor $\beta = \frac{\lambda}{\lambda+x}$. For ease of exposition, and given the payoff equivalence, below we focus on this discrete-time representation.

The game has a unique sequential equilibrium, analogous to a similar result in Gul and Wilson (1986).¹² The equilibrium has the feature that negotiations

¹¹This assumption makes the analysis simpler, and it is also plausible for the type of captives we focus on in the empirical analysis.

¹²Our assumptions correspond to what they label as the "gap case" in their paper. Note that while the basic model of Gul and Wilson (1986) analyzes subgame perfect Nash equilibria of a game in which a durable goods monopolist is selling its product to a continuum of consumers, as discussed on p. 170 of

end at some finite period T , determined endogenously by the parameters of the model. In periods $1, \dots, T$ the seller proposes a strictly decreasing sequence of prices p_1, \dots, p_T , such that p_T is exactly equal to the lowest buyer valuation at time T . Buyers are partitioned into T intervals, where the k th highest interval corresponds to buyers who accept the seller's offer in the k th period. Relative to a basic screening model, the extensions we introduce do not change the qualitative conclusions of the model.¹³ The possibility of a liquidity constraint on the buyer side changes the initial price offer of the seller, and hence all subsequent offers, but in a way that corresponds to strategies in an out-of-equilibrium continuation game in the unique sequential equilibrium of the game with no liquidity constraint.

Below we demonstrate the above results by analytically solving for the unique sequential equilibrium when $\beta = 1$ (no depreciation) and the buyer's valuation uniformly distributed on $[\underline{b}, \bar{b}]$. For a general characterization of sequential equilibrium, with positive depreciation and a general distribution of buyer valuations, see the Supplementary Appendix.

First consider the case of $\pi = 0$ (no liquidity constraint). Since $p = \underline{b}$ in the final bargaining period, we can compute the upper bound on the remaining types such that $p = \underline{b}$ is optimal for the seller. Since the optimal p in the final period satisfies:

$$(1) \quad p = \delta \underline{b} + \frac{1}{2}(v + (1 - \delta)X),$$

the upper bound on remaining types before the final round is $X = 2\underline{b} - \frac{v}{1-\delta}$.

Let b_t^* denote the threshold valuation such that the buyer is indifferent between accepting and rejecting in period t . The price in the next-to-last period, p_{T-1} must be such that b_{T-1}^* is indifferent between accepting this price in period $T-1$ and waiting until the last period, which leads to $p_{T-1} = (1 - \delta)b_{T-1}^* + \delta \underline{b}$.

their paper, the same analysis applies to sequential equilibria of a bilateral bargaining game between a buyer and a seller, where the buyer's evaluation is private information.

¹³In particular, the proof of Theorem 1 in Gul and Wilson (1986) can be extended to our setting. Since the steps of the proof are completely analogous to those in the original proof, they are omitted.

Continuing in a similar fashion, types b_2^*, \dots, b_{T-1}^* and prices p_1, \dots, p_{T-2} can be determined recursively:

$$(2) \quad b_{t+1}^* = \frac{1}{2} \left(b_t^* + \frac{v}{1-\delta} \right) \quad t = 1, 2, \dots, T-2,$$

$$(3) \quad p_t = b_t^*(1-\delta) + \delta p_{t+1} \quad t = 1, 2, \dots, T-1.$$

Now consider $\pi \in (0, 1]$. In this case, the posterior in the second period is the prior up to the cutoff for acceptance in the potentially constrained period (where there is a kink), and a ‘flattened’ version of the prior from the kink to \bar{b} . Suppose now that there is a cutoff of \tilde{b}_1 in the first period in the original liquidity-unconstrained problem, such that the posterior with \tilde{b}_1 is the same as in the liquidity-constrained problem with b_1^* for all $b \in [b, b_1^*]$ (i.e., for any valuation below the kink). Since the marginal return below the kink is the same in the two problems, the optimum b_2^* is that which corresponds to \tilde{b}_1 (and will be below the kink). Therefore, since the game will resemble the original case from $t = 2$ on, we can express the future prices and cutoffs as:

$$b_t^* = \frac{1}{2^{t-1}} \tilde{b}_1 + \left(1 - \frac{1}{2^{t-1}} \right) \frac{v}{1-\delta},$$

$$p_t = \delta^{T-t} \underline{b} + \frac{(1-\delta)(1-(\delta/2)^{T-t})}{2^{t-1}(1-\delta/2)} \tilde{b}_1 + \left(\frac{1-\delta^{T-t}}{1-\delta} - \frac{1-(\delta/2)^{T-t}}{2^{t-1}(1-\delta/2)} \right) v,$$

where the ‘effective’ cutoff in period 1 is:

$$\tilde{b}_1 \equiv (\pi \bar{b} + (1-\pi)b_1^*) = \pi \bar{b} + \frac{1-\pi}{1-\delta} (p_1 - \delta p_2).$$

The seller’s payoff if the game ends in t is $(1-\delta^{t-1}) \frac{v}{1-\delta} + \delta^{t-1} p_t$, so the objective function can be given as

$$\max_{b_1^* \in [\frac{1}{2}(\bar{b} + \frac{v}{1-\delta}), \bar{b}]} \left\{ (1 - \pi)(\bar{b} - b_1^*)p_1 + \sum_{t=2}^{T-1} \frac{\tilde{b}_1 - \frac{v}{1-\delta}}{2^{t-1}} \left[\frac{(1 - \delta^{t-1})v}{1 - \delta} + \delta^{t-1}p_t \right] \right. \\ \left. + \left[\frac{\tilde{b}_1 - \frac{(1-2^{T-2})v}{1-\delta}}{2^{T-2}} - \underline{b} \right] \left(\frac{(1 - \delta^{T-1})v}{1 - \delta} + \delta^{T-1}\underline{b} \right) \right\}.$$

The optimal choice of b_1^* can be derived by taking the first order condition and algebraically manipulating it (we omit these steps here, to save space). With b_1^* known, the remaining b_2^*, \dots, b_{T-1}^* can be calculated as in the case without the liquidity constraint from (2), and the prices $\underline{b} = p_T, p_{T-1}, \dots, p_2$ can likewise be calculated as before, from (3). Then, the initial price offer can be computed from $p_1 = (1 - \delta)b_1^* + \delta p_2$.¹⁴

Lastly, the above solution is only valid if the correct T is used. Hence, the full solution is that which simultaneously satisfies the expressions above, as well as

$$T = \arg_t b_{t-1}^* \in (\underline{b}, 2\underline{b} - \frac{v}{1-\delta}),$$

for the computed b_{t-1}^* given T .

IV. Reduced-Form Estimates

Our data come from surviving records of the notaries that accompanied 22 ransoming missions to Algiers between 1575 and 1692.¹⁵ The Spanish crown appointed this notary who was responsible for keeping detailed records of all financial transactions and verifying their accuracy. These records are believed to be accurate and have been described as “extremely thorough” (Friedman, 1983, p. 107).

The ransom record of Juan Antonio Sandier from the year 1667 is a

¹⁴In the Supplementary Appendix we also show that this price sequence is decreasing.

¹⁵We omit ransoming missions after 1700 because after this date the ransoming missions are thought to have had different procedures, expenditures and goals than those prior to this date (Martínez Torres, 2004, p. 34). These changes may have been related to a decline in the military power of the pirates towards the end of the 17th century as explained in Chaney (Forthcoming).

representative ransom entry. It reads: “Juan Antonio Sandier son of Juan de la Peña and of Luisa Rodriguez from Valladolid of 41 years of age and 15 months of captivity [...] his ransom cost 160 pesos of which 50 pesos came from earmarked money [...] the remainder came from the alms of the holy cathedral of Valladolid” (mss 3586, f. 62). In this entry we learn that Juan Antonio Sandier was ransomed after 15 months of captivity for the price of 160 pesos.¹⁶ In addition, his family (or friends) had sent 50 pesos for his ransom. The remaining funds came from alms collected in the cathedral of his home town of Valladolid.

Using thousands of similar entries we have identified 4680 individuals ransomed in 22 ransoming expeditions. The Supplementary Appendix provides a detailed description of the data construction along with a list of summary statistics and correlations.

To investigate the effect of delay on ransom prices, we estimate an equation of the form:

$$(4) \quad \ln(\text{ransom}_{ib}) = \alpha_b + \beta \text{timecaptive}_{ib} + \gamma' \mathbf{x}_{ib} + \varepsilon_{ib}$$

where i indexes individuals and b ransoming trips. The variable $\ln(\text{ransom})_{ib}$ denotes the natural logarithm of a captive’s ransom price. α_b denotes ransoming trip dummies which we include to account for trip-specific unobservables such as the possibility that some negotiating teams were more skilled than others. The variable timecaptive_{ib} is the time an individual spent in captivity before he was ransomed and is the proxy for negotiating delay that is used in this section.¹⁷ The vector \mathbf{x}_{ib} contains a set of individual-level covariates, including profession dummies and a dummy variable for females and children. These variables are

¹⁶The silver peso (also known as the *real de a ocho*, piece of eight or Spanish dollar) was a currency unit in the Spanish Empire.

¹⁷ We use this metric instead of the number of missed ransoming trips in this section to directly test the hypothesis that the coefficient on time in captivity is distinct from the affect of aging. Results are qualitatively similar, however, if the missed trips metrics is used.

explained in the appendix.

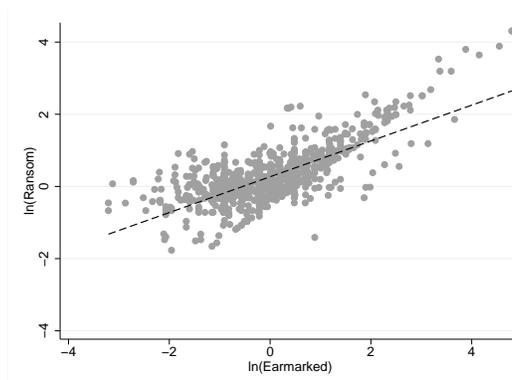
We begin our regression analysis in panel A of Table 1 by comparing ransomed captives within trips. Throughout this section coefficients in Equation 4 are multiplied by 100 for ease of exposition. In column 1, we present results from a regression that omits all covariates with the exception of an individual's age at capture and trip dummies.¹⁸ The point estimate implies that a year increase in captivity is associated with a 1.18% decrease in the ransom prices. This is significantly different from the coefficient on age at capture which implies that a year increase in an individual's age is associated with a .63% decrease in that individual's ransom. In column 2 we add the vector of controls and note that the results are qualitatively similar. Throughout, we report standard errors clustered by year of capture.¹⁹

While these results provide evidence of a negative correlation between time in captivity and the size of the ransom, there are many reasons to doubt this correlation is causal. Perhaps the most obvious possibility is that the Spanish simply waited longer to ransom less valuable captives. Fortunately, we have been able to identify the amount of money sent from Spain for 915 captives. Although historical evidence suggests that this represents roughly half of all the earmarked captives, the subsample of captives that we have identified as earmarked provides a useful check on the general results for at least two reasons. First, inasmuch as the omission of earmarked money in the sources was random, these results will be representative of the entire earmarked subpopulation. Second, in this earmarked sample we are able to directly control for the quantity of money sent to ransom each earmarked individual. This information was only held by the Spanish, and although the ransoming team often supplemented these earmarked funds to secure

¹⁸In addition, we omit individuals who have missing distances to the bargaining bases for comparability between the IV and OLS estimates.

¹⁹Given that we always include trip fixed effects we are most worried about within-year correlations as many individuals caught in the exact same circumstances were ransomed in different trips. However, we have also experimented with double-clustering by both this dimension and at the trip level (Cameron, Gelbach and Miller, 2011). A drawback of this approach is that we only have 22 trip clusters and we are not aware of work addressing situations in which there is multi-way clustering and few clusters.

Figure 1. : Observed Ransoms and Earmarked Funds



Note: The dashed line provides the fitted values of the regression of ransom prices on earmarked funds which implies that a 1% increase in earmarked funds is associated with a 0.5% increase in ransom price.

the release of a captive, there were limits on how much the Spanish could pay above and beyond these earmarked funds.

In Figure 1, we provide evidence that the earmarked funds provide a reasonable proxy for the ransoming teams private valuations by plotting the logarithm of ransom prices against the amount of money sent for each of these captives (we have partialled out trip fixed effects for both variables). As the figure shows, a 1% increase in earmarked money on average increased ransom price by 0.5 %, increasing the relative share of the surplus that the Spanish could keep.

In column 3 we restrict the sample to these earmarked captives and control for a quadratic function of the logarithm of earmarked funds (as the relationship between the two appears to be approximately quadratic). When we do this the standard errors increase. In columns 4-6 we restrict the sample to individuals from within mainland Castile as a robustness check given that the ransoming missions were told to concentrate on freeing Castilian captives.²⁰ Here we simply note that these results are qualitatively similar to those in columns 1-3. Thus, the results in panel A of Table 1 provide evidence of a negative correlation between

²⁰The mainland of the former Kingdom of Castile is located in the Western two-thirds of modern-day mainland Spain. In the Supplementary Appendix we provide a map with the exact location of the Kingdom.

time in captivity and ransom prices, although in some specifications we cannot reject the null hypothesis that this correlation is simply due to the effects of aging.

Despite our ability to control for the ransoming team's private valuations in the earmarked sample, there are still reasons to doubt that the results reflect the causal effect of negotiating delay on ransom prices. First, there is the obvious issue of measurement error. We are using time in captivity as a proxy for bargaining delay, when in reality many captives who were ransomed after longer delays were sent to regions where the ransoming teams did not travel and were only ransomed when they were sold to owners in Algiers (Friedman, 1983, p. 45). Inasmuch as this noise is random, it will attenuate the coefficient on time in captivity. Second, there is the issue of reverse causality. Our prior is that this simultaneity bias is likely to bias the results upward as conditional on the ransom team's valuations of individuals whom the pirates initially over-valued should be ransomed later than those whom they did not over-value.²¹

To address these concerns, we develop an instrumental variables strategy rooted in the poor communications of the pre-industrial world. This strategy relies on historical evidence that both the information regarding a captive's capture and the time required to remit the funds to Algiers increased for earmarked captives whose homes were further from the bargaining bases. Our identifying assumption is that -conditional on covariates- the Algerians could not distinguish this distance-induced delay from strategic negotiating delay. In other words, we assume that the only reason that captives from further afield were ransomed for less was because they had been left in captivity for longer. The Algerians, in turn, interpreted this delay as a credible signal that the Spanish valued these captives less.

We faced two practical difficulties implementing this IV strategy. First, note that our distance metric should only affect the delay with which earmarked

²¹To see this most easily, suppose that there are two types of captives with identical amount of earmarked funds sent and that the pirates undervalue one group and make the initial ransom offer R which is immediately accepted. The other group, they initially overvalue and is only ransomed after some delay for the price $R+g$ where $g>0$. If we plotted observed ransoms against time in captivity in this case we would find a positive slope even if the "ransom price schedules" are declining in time in captivity for both groups of captives.

captives are ransomed.²² Consequently, in the ideal world we would separate the sample by earmarked and non-earmarked captives. As noted above, unfortunately we are unable to identify all of the earmarked captives. However, since only earmarked captives will be “compliers” we expect the IV results in the entire sample to be similar to those in the complete (unobserved) earmarked subsample.

Second, the historical evidence suggests the distance from the bargaining bases affected the delay with which ransom funds reached in Algiers in two steps. In the first step, this distance increased the time it took news of a captive’s ransom to reach his home. In the second, the distance increased the time it took to transport the ransom funds to the negotiating orders. We would have liked to exactly construct the delays induced by each step for each home town. Unfortunately, the information necessary to do this is not available. As a proxy for this quantity we use the minimum great circle distance of the captive’s home town to the bargaining bases.²³ Throughout we use one plus the natural logarithm of this distance as it ensures that captives from distant locations such as the Americas do not play a disproportionate role.²⁴

In panel B of Table 1 we present the IV coefficients whereas in panel C we present the first-stage. The samples and control vector included are the same as in the corresponding columns of panel A. Below the IV coefficients we present 95% confidence intervals that are robust to both weak instruments and arbitrary correlations within year of capture (Finlay and Magnusson, 2009).

Columns 1-3 show that there is a reasonably strong first stage in the entire sample (implying that a 1% increase in distance increases a captive’s time in captivity by roughly 1 day), and the corresponding IV coefficients imply that a

²²This is because non-earmarked captives were ransomed with general funds and thus the distance of their home to the bargaining bases did not affect the delay with which these general funds were available.

²³It is worth noting here that prior to the ransoming expedition the bargaining teams often traveled to collect ransom funds. As we usually do not observe the exact places they went, we ignore this fact and note that these places seem to have been in relatively close proximity to the bargaining bases.

²⁴It is useful to note that in two stage least squares “consistency of the second-stage estimates does not turn on getting the first-stage functional form right” (Angrist and Krueger, 2001, p. 80). Thus we generally find very similar results to those presented when we use our distance metric untransformed and drop a handful of captives from distant locations.

year in captivity resulted in a decrease in the ransom price of between roughly 6 and 8%. These point estimates are generally larger in columns 4-6 but are approximately similar in magnitude, especially in the specification which holds constant the amount of earmarked funds sent for a captive. In column 7 we provide evidence that the bargaining bases are not driving the results by including in the specification of column 5 a dummy equal to one if the captive's home was within 50 km of the bargaining bases.²⁵

If our instrument is valid, it implies that the Algerians were systematically ransoming captives from further afield for less because they mistook distance-induced delay for negotiating delay. In our view, this is a plausible assumption. First, even if the Algerians perfectly observed the distance-induced component of delay it is not clear how they should have shifted their "ransoming schedule" given that there was uncertainty regarding which captives were earmarked. This is because the effect of distance on delay was asymmetric: it only affected captives who were to be ransomed with earmarked funds. For non-earmarked captives, the optimal ransoming schedule (i.e. the rate at which the pirate's ransom offer changed as time in captivity increased) was the same regardless of the distance of a captive's town to the bargaining bases. If the pirates knew that a captive was from further afield, it would have been optimal to shift the ransoming schedule outwards for that captive. However, given the uncertainty regarding which captives were earmarked this outward shift should have at least been reduced to reflect the probability a captive was earmarked. This strategy, however, would not have been costless as non-earmarked captives would have remained in captivity for longer with no effect on their ransoms. Recall that these captives were the majority of ransomed captives (and even a larger majority of all potentially ransomable captives). Thus even if the pirates had perfectly observed the relevant distances they might have found it optimal to treat all captives

²⁵We have also experimented with restricting the geographic region within mainland Castile. While the point estimates generally remain similar, we lose statistical power as we drop observations making these regressions less informative.

similarly regardless of the distance to their homes.²⁶

To further investigate the extent to which the Algerians observed the relevant distances, we investigate both the first stage and the reduced form calculated using the “placebo instrument” measuring the distance of a captive’s hometown to Algiers. We do this because it seems likely that the Algerians could have approximately calculated these distances. As we show in columns 1-4 of table 2 there is no relationship between distance from Algiers and time in captivity or ransom prices. This result shows that the relevant part of the distance from the bargaining bases was more difficult to observe than simply noting that certain towns were further from Algiers than others.

Perhaps the most convincing evidence in support of our instrument, however, comes from the regression of earmarked funds on distance to the bargaining bases which are presented in columns 5 and 6 of Table 2. These results show that among the earmarked sample, there is no relationship between the amount of earmarked money sent for a captive and the instrument. Thus, we find no evidence that our instrument is correlated with the ransoming team’s valuation which to our minds is the most worrying potential threat to our identification strategy.

V. Structural Estimation

While the reduced-form section provides evidence that negotiating delay had a causal effect on ransom prices, this analysis is limited in its ability to address other relevant dimensions of the negotiations. In this section we provide a structural estimation of the bargaining model described in Section II. The goal of this estimation is to evaluate how well the model fits our data, discuss the estimated structural parameters, and evaluate the distribution of the surplus between buyers and sellers. To introduce our structural estimation, we provide a mapping between

²⁶We have calculated the area between the reduced form line and the reduced form constrained to have slope zero to get a sense of how much this strategy would have cost under the null of instrument exogeneity. We find that the cost was approximately 10% of the ransom costs which doesn’t seem unreasonable, particularly when weighed against the expected costs under the alternative strategy of holding the non-earmarked slaves in captivity for longer (many of those ransomed did not work while in captivity).

the dataset and the theoretical model, and a parametrization of the model. The buyer in our model is a Spanish team that was sent to ransom captives from slave owners in North Africa, while slave owners are the sellers.

We assume that the buyer's valuation of captive i with time in captivity t has the following form:

$$(5) \quad v_{it}^b(t) = e^{\mu_i - rt_i - xt_i} e^{\sigma Z_i},$$

where $\mu_i = \alpha \mathbf{X}_i$ is a commonly known component of the valuation, and assumed to be a linear function of observed personal characteristics \mathbf{X}_i (same as the ones we used as control variables in our reduced-form estimations); r is the common real interest rate; σ is a measure of information asymmetry and Z_i is a valuation component privately known by the buyer. We assume that the seller knows the distribution of Z_i , which is assumed to be truncated normal. The truncation level Z_{min} determines the minimal buyer's valuation (for $\mu_i = 0$ and $t = 0$):

$$(6) \quad v_{min} = e^{\sigma Z_{min}} > 0.$$

This specification implies that the minimal buyer valuation is strictly positive. Given that $e^{\sigma Z_i} \approx 1 + \sigma Z_i$, $\sigma Z_i * 100$ is as a percent deviation from the median valuation. For example, $\sigma Z_i = 0.3$ means that the buyer's valuation is 30% higher than the median valuation.

The seller's valuation has a similar structure:

$$(7) \quad v_{it}^s(t) = e^{\mu_i - rt_i - xt_i} v_{res},$$

where $v_{res} < v_{min}$ to make the trade always efficient.

As the duration of the rescue trips was a small fraction of the time elapsing between trips, for simplicity we assume that slave owners were able to make one offer each time the Spaniards visited their market. We assume the timing of the

rescuing trips are distributed Poisson with intensity parameter λ . We estimate this parameter from the data. On the interval [1575, 1692] we have found evidence of 40 trips suggesting that the average time between trips is 2.95 years.²⁷ As one can easily verify, the maximum likelihood estimate of lambda is the inverse of the average time between the trips $\overline{\Delta t}$,

$$(8) \quad \hat{\lambda} = (\overline{\Delta t})^{-1}.$$

This corresponds to $\hat{\lambda} = 0.34$ in our sample, which we use as our estimate of λ throughout this section.

As we argued in the previous section, the relevant information had not reached the friends and family of many captives prior to the departure of the first ransoming trip to Algiers following their capture. For some of these captives, this would result in the rejection of the first offer simply because the relevant earmarked funds were not yet available. We incorporate this into our estimation by assuming that with probability π the first offer was rejected for exogenous reasons and estimate this parameter with the others.

Using the equilibrium of the screening model described in the previous section, for any set of parameter values we can compute the equilibrium price $p(i, n, t)$, where n is the number of the offer. For example, $p(i, 3, 6)$ would be the equilibrium price in the third offer for captive i who spent six years in captivity. For the functional forms of the buyer's and seller's valuations the equilibrium price has a convenient multiplicative form:

$$(9) \quad p(i, n, t) = p_n e^{\alpha X_i - \lambda t_i},$$

where p_n is just a function of the offer number.

The actual offer price could be different from the computed equilibrium price for many reasons (such as our model not being a perfect description of reality,

²⁷See the Supplementary Appendix for the sources we used to identify ransoming trips.

measurement errors, etc.). To incorporate these errors, we assume that the actual offer prices differed from the equilibrium prices by an independent multiplicative error term:

$$(10) \quad \log P(i, n, t) = \log p(i, n, t) + \varepsilon_i,$$

where $\varepsilon_i \sim N(0, \theta)$ and iid.

We estimate the parameters of our model by Maximum Likelihood (ML). For our model the log-likelihood function can be expressed in the following way:²⁸

$$(11) \quad (\hat{\boldsymbol{\alpha}}, \hat{r}, \hat{x}, \hat{\sigma}, \hat{\pi}, \hat{v}_{res}, \hat{v}_{min}) = \arg \max_{\boldsymbol{\alpha}, r, x, \sigma, \pi, v_{res}, v_{min}} [\log L],$$

$$(12) \quad \log L = -\frac{N}{2} \log\left(\frac{1}{N} \sum_i (\log P(i, n_i, t_i) + xt_i - \boldsymbol{\alpha} \mathbf{X}_i - \log p_{n_i})^2\right) + \sum_i \log \text{Prob}[n_i],$$

where N is the number of observations, n_i is the number of missed trips plus one or our proxy for the number of rejected offers and t_i is the time in captivity of captive i and $\text{Prob}[n_i]$ is the predicted probability that offer n_i will be accepted. Intuitively, the likelihood of each observation consists of two parts. The first part is the likelihood of the observed price; the second part is the likelihood of observing the corresponding number of missed trips before the captive had been ransomed. Thus, in our structural estimation we match both observed prices and observed numbers of missed trips (unlike the reduced form estimations where we only match prices).

The functional form of the log-likelihood function allows us to perform maximization in two steps²⁹. In the first step for each parameter values (r , x , σ ,

²⁸This concentrated likelihood function can be derived from the original likelihood function by solving for and substituting in the variance of the error term, θ . The details of the derivation of the likelihood function are provided in the Supplementary Appendix.

²⁹We can maximize in two steps due to the fact that $\log p_{n_i}$ and $\log \text{Prob}[n_i]$ do not depend on $\boldsymbol{\alpha}$.

π, v_{res}, v_{min}) we minimize the sum of squared errors $\sum_i (\log P(i, n_i, t_i) + xt_i - \alpha \mathbf{X}_i - \log p_{n_i})^2$. This can be simply done by regressing $\log P(i, n_i, t_i)$ on t_i, \mathbf{X}_i , and $\log p_{n_i}$. The residual sum of squared errors in this regression is denoted RSS_{OLS} . Substituting the resulting RSS_{OLS} in the original likelihood function yields the following simplified expression:

$$(13) \quad \log L = -\frac{N}{2} \log\left(\frac{1}{N} RSS_{OLS}\right) + \sum_i \log \text{Prob}[n_i].$$

In the second step we maximize the expression above with respect to the non-linear parameters $(r, x, \sigma, \pi, v_{res}, v_{min}/v_{res})$. Estimating the vector parameter α in a separate step is necessary because this vector has more than ten elements (personal characteristics, trip fixed effects), which would make a one-step procedure very challenging.

The sample and the set of captive characteristics \mathbf{X}_i used in our estimation coincide almost exactly with those used in the reduced-form analysis. Hence, we do not describe them here. The only difference between the samples is that in this section we drop outliers in the number of missed trips³⁰. The estimated parameters are reported in Table 3. The estimate of $\sigma = 0.35$ implies that 95% of captives had values from 50% to 200% of the median value (controlling for personal characteristics); $v_{res} = 0.26$ means that the reservation value of the slave owners was about 26% of the median valuation by the Spaniards. The depreciation rate of $x = 0.02$ means that each year in captivity decreases the value of captives by 2%; $\pi = 0.32$ indicates that the Spaniards did not have money for 32% of captives when these captives' first ransoming mission following their capture arrived in Algiers; $v_{min}/v_{res} = 1.6$ implies that the minimal buyer's valuation was 42% of the median valuation. Most parameter

³⁰Outliers can affect our structural estimation significantly because we do not allow for errors in the number rejected offers and our structural model would have to rationalize existence of negotiations with many rejected offers. We report results where we drop negotiations with the number of rejected offers exceeding five. However, results do not change significantly if we drop only negotiations with the number of rejected offers exceeding ten.

values are significantly different from zero.³¹

Using the estimated parameters we first analyze how well our model fits the data. To do so, we compute the normalized transaction prices removing the effects of personal characteristics and time in captivity:

$$(14) \quad \tilde{P}(n_i) = P(n_i, t_i) / e^{\hat{\alpha} \mathbf{X}_i - \hat{\alpha} t_i}.$$

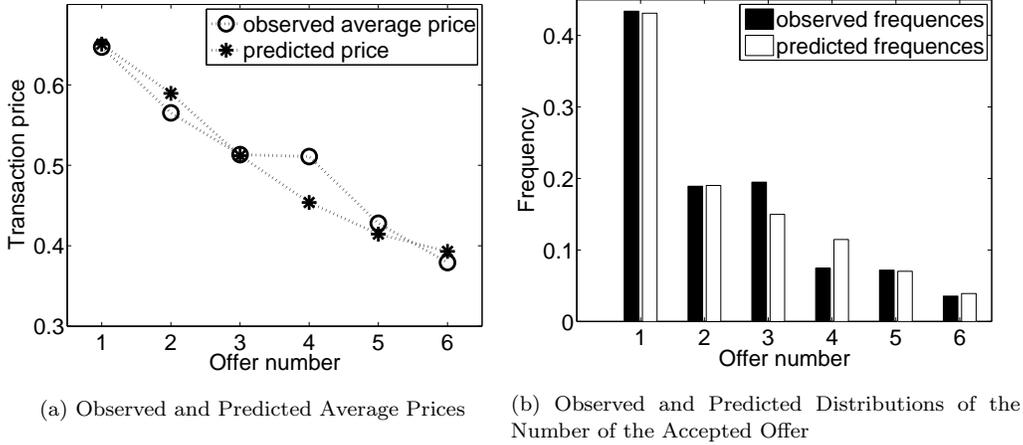
This normalization allows one see directly how the offer prices depend on the number of rejected offers. We compare these normalized observed prices with their predicted values p_{n_i} . Figure 2a plots the average of $\tilde{P}(n_i)$ for each n , and p_n as functions of n . This figure shows that overall the model matches the observed decline in the average price with the number of rejected offers well. Consistent with our screening model both functions are decreasing in n . The rate of decline is substantial. While the first offer is close to 65% of the median value, the third offer is about 50% of the median value. Thus, the estimated price drops by 15% after two offers had been rejected. The sixth offer price predicted by the model is 40% of the median valuation. Hence, our model predicts that all captives were eventually rescued by the Spaniards after six trips. This prediction matches the fact that in our data almost all captives were rescued after six trips.

The second dimension we examine is the probability of offer acceptance. To check how well the model performs in this dimension we plot the observed distribution of the number of accepted offer (distribution of n_i) with the predicted probability of offer acceptance ($\text{Prob}[n_i]$). Figure 2b shows the results. Overall, the model matches the data well in this dimension. The first offer is accepted with probability 0.43 and this probability declines as the number of offers increases.

Figures 2a and 2b reveal that even though the pirates started with a relatively low price, 65% of the median valuation, only in 43% of the cases was the offer accepted. Some of the offer rejections are explained by the first period liquidity

³¹Throughout, we bootstrap the standard errors.

Figure 2. : Model Fit



Note: The observed average price is the average price paid for a captive with the observed median valuation normalized to 1, as defined in equation (14). The predicted price p_n , is the optimal price offer for a captive with the median valuation 1, for whom $n - 1$ offers have been rejected. Both prices are computed based on the parameter estimates reported in Table 3. The observed distribution is the distribution of the number of missed trips plus one. The predicted distribution is the probability of offer number n being accepted. The predicted distribution is computed based on the parameter estimates reported in Table 3.

constraint. Our estimates show that only in 69% of the cases ($1-\pi$) the Spaniards would have accepted any first offer. Thus, out of the 69% that did not have the first period liquidity constraint, 26% decided to wait for a better price and 43% accepted the offer.

In our structural estimation above we assume that we measure the number of rejected offers perfectly. However, due to potential transfers of captives between different places, the number of missed trips may not coincide with the number of opportunities for the slave owners to make an offer to the Spaniards. This measurement error and that from other sources may bias our estimates. To analyze this bias, we note that assuming we observe all ransom trips to Algiers, the true number of offers can only be lower than the number of missed trips. This means that the true distribution of the offers is shifted to the left of the observed distribution of missed trips. Similarly, the true price schedule is steeper than the one reported in Figure 2a. Numerical simulations of our screening model

show that such effects are associated with higher depreciation, higher discount factors and more uncertainty about the value of the captives, σ . Hence, if the measurement error is severe, we expect our estimates of the interest rate, the discount factor and σ to be lower than their true values.

One of the benefits of our structural estimation is that we can use the estimated parameters to evaluate the distribution of trade surpluses and the delay costs. To introduce the notation for these surpluses, let $n(Z)$ denote the number of the accepted offer as a function of the private valuation parameter and $t(Z)$ the random acceptance time that corresponds to this equilibrium. We define the seller's surplus as the expected discounted price net of the reservation value:

$$(15) \quad V^s = E[(p_{n(Z)} - v_{res})e^{-t(Z)(x+r)}].$$

Respectively, the buyer's surplus is defined as the expected value of the captive minus the price paid, discounted for the interest rate and depreciation:

$$(16) \quad V^b = E[(v(Z) - p_{n(Z)})e^{-t(Z)(x+r)}].$$

The total trade surplus is defined as the expected value of a captive minus the seller's reservation value of the captive:

$$(17) \quad V^{total} = E[v(Z)] - v_{res}.$$

Finally, since delay costs is the only source of inefficiency in our model, one can calculate these costs as the difference between the total surplus and the surpluses of the buyer and the seller:

$$(18) \quad C^{delay} = V^{total} - V^s - V^b.$$

The simulated surpluses are reported in the first column of Table 4. These

estimates show that the Spaniards were able to keep the bulk of the total surplus, 54%; the pirates' share is estimated at 32% of the total trade surplus. The estimated delay costs are relatively low, about 14% of the surplus.

In addition to the welfare analysis, we perform two counterfactual tests. The first assumes that instead of selling captives separately, the slave owners could bundle a number of captives together. By using this strategy the pirates could have reduced the amount of information asymmetry between themselves and the Spaniards. To show the effect of this strategy, we assume that a bundle the seller could offer consists of ten randomly picked captives. Keeping all other conditions of the trade the same, this would result in a significant redistribution of surplus from the buyer to the seller and would reduce the costs of delay. This result is reported in column two of Table 4, According to our estimation, about 10% of the total trade surplus would shift from the buyer to the pirates.

The second counterfactual experiment assumes that instead of screening, the seller could commit to make one take-it-or-leave-it offer to the buyer. In this case the values of the seller and the buyer and the total surplus can be computed using formulas (15)-(17), but instead of the delay costs, equation (18) defines the negotiation termination costs. Our results, reported in column three of Table 4, show that being able to commit to a take-it-or-leave-it offer could increase the seller's surplus by 14% relative to the no-commitment case and decrease the buyer's surplus by 18%. The resulting 4% difference is the difference between the termination and delay costs.

VI. Conclusion

Using a historical data set containing detailed information on thousands of captives ransomed from the Barbary pirates, we documented a robust negative relationship between negotiating delays (as proxied by time in captivity) and ransom prices. This result is both consistent with qualitative evidence from contemporary bargaining instructions and with the predictions of all rational

models of bargaining when the relevant private information is regarding the buyer's evaluation. To address potential endogeneity concerns we developed an instrumental variable strategy rooted in the slow speed of travel in pre-industrial Spain. We also performed a structural estimation of a dynamic screening type bargaining model, extended with features motivated by the historical setting. We showed that the model fits the observed prices and acceptance probabilities well. We used the estimated structural parameters to analyze the trade surplus distribution and compute how this distribution would have changed under different trading mechanisms.

In closing, we note that the historical response of many European powers to the Barbary pirates may provide insights into negotiating with Somali pirates (and possibly other criminal groups). For example, the historical preference for centralized ransoming organizations suggests that such institutions might aid negotiations with pirates today by both enabling negotiations for multiple cargoes at once and by reducing transaction costs (which, besides saving costs directly, improves the bargaining power of the negotiating team).

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Table 1—: Time in Captivity, Distance to Bargaining Bases and Ransom Prices

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|------------------------|-------------------------|------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| Panel A: OLS | | | | | | | |
| Years Captive | -1.18 (0.14) | -1.05 (0.13) | -0.93 (0.37) | -1.22 (0.17) | -1.06 (0.18) | -0.81 (0.47) | -1.04 (0.18) |
| Age at Capture | -0.63 (0.08) | -0.59 (0.07) | -0.54 (0.12) | -0.79 (0.09) | -0.71 (0.09) | -0.59 (0.14) | -0.71 (0.10) |
| $\ln(Earrmarked)$ | | | -94.33 (20.06) | | | -99.78 (19.65) | |
| $\ln^2(Earrmarked)$ | | | 9.59 (1.48) | | | 10.02 (1.44) | |
| p-value | [0.00] | [0.00] | [0.29] | [0.03] | [0.07] | [0.65] | [0.08] |
| Panel B: IV | | | | | | | |
| Years Captive | -7.45 (2.39) | -6.67 (1.91) | -7.87 (2.39) | -16.34 (6.69) | -10.73 (4.86) | -7.84 (4.33) | -9.84 (5.11) |
| Age at Capture | -0.91 [-14.17,-3.57] | -0.95 [-9.48,-2.66] | -0.85 [-14.22,-3.03] | -1.39 [-42.57,-7.07] | -1.20 [-14.77,-1.68] | -0.83 [-17.62,-9.13] | -1.16 [-28.27,-0.32] |
| $\ln(Earrmarked)$ | | | -93.57 (18.70) | | | -102.07 (18.75) | |
| $\ln^2(Earrmarked)$ | | | 9.46 (1.35) | | | 10.09 (1.35) | |
| p-value | [0.00] | [0.00] | [0.00] | [0.02] | [0.04] | [0.09] | [0.08] |
| Panel C: First Stage | | | | | | | |
| $\ln(\text{Distance})$ | 0.25 (0.06) | 0.31 (0.06) | 0.34 (0.07) | 0.16 (0.05) | 0.18 (0.05) | 0.22 (0.08) | 0.29 (0.13) |
| N | 4220 | 4220 | 876 | 2496 | 2496 | 567 | 2496 |
| Clusters | 127 | 127 | 100 | 120 | 120 | 78 | 120 |
| Controls? | No | Yes | Yes | No | Yes | Yes | Yes, Cities |
| Sample | All | All | All | Castile | Castile | Castile | Castile |

Notes: the dependent variable in panels A and B is the logarithm of captive's ransom whereas that in panel C is years in captivity before ransom. The row p-value in panels A and B presents the p-value for the null hypothesis that the coefficient on years in captivity is the same as that on age at capture. $\ln(\text{Distance})$ is the logarithm of one plus the minimum distance the captive's home to the bargaining bases. Standard errors are clustered by year of capture. Coefficients in panels A and B are multiplied by 100 for ease of exposition.

Table 2—: Distance to Algiers and Earmarked Funds

| | (1) | (2) | (3) | (4) | (5) | (6) |
|--------------|------------------|-----------------|----------------|----------------|----------------------|-----------------|
| | <u>ln(Price)</u> | | <u>Captive</u> | | <u>ln(Earmarked)</u> | |
| ln(DistAlg) | 0.53 (1.54) | -3.30 (3.70) | 0.16 (0.12) | 0.53 (0.45) | | |
| ln(Distance) | | | | | 1.17 (1.87) | -2.14 (2.70) |
| N | 4220 | 2496 | 4220 | 2496 | 876 | 567 |
| Clusters | 127 | 120 | 127 | 120 | 100 | 78 |
| Sample | All | Castile | All | Castile | All | Castile |
| Controls? | Yes | Yes | Yes | Yes | Yes | Yes |

Notes: the dependent variable in columns 1 and 2 is the logarithm of a captive’s ransom. The dependent variable in columns 3 and 4 is the time a captive was in captivity prior to ransom while in columns 5 and 6 the dependent variable is the logarithm of earmarked funds. ln(DistAlg) is the logarithm of one plus the distance of a captive’s home to Algiers. ln(Distance) is the logarithm of one plus the minimum distance the captive’s home to the bargaining bases. Controls include age at capture and profession, child and female dummies. Standard errors are clustered by year of capture. Coefficients in columns 1,2, 5 and 6 are multiplied by 100 for ease of exposition.

Table 3—: Structural Parameters of the Screening Model

| Structural Parameters | Linear Parameters |
|-----------------------|---------------------------------------|
| σ | Age when captured -0.0056 (0.0398) |
| v_{res} | Female 0.1145 (0.2760) |
| x | Child 0.0199 (0.0035) |
| r | Profession controls Yes (0.0071) |
| π | Trip fixed effects Yes (0.0478) |
| v_{min}/v_{res} | N_{obs} 3885 (0.2822) |

Notes: This table presents maximum likelihood estimates of the structural parameters of the screening model. The structural parameters are: σ - a measure of information asymmetry, v_{res} - seller’s reservation value, x - depreciation rate of a captive, r - the same interest rate for pirates and Spaniards, π - the probability of the funds arriving only with the second ransom team, v_{min}/v_{res} - minimal valuation by the buyer over the seller’s reservation value. Standard errors are in parentheses.

Table 4—: Estimated Distribution of Trade Surplus

| | Screening | Bundles of 10 | Take-it-or-leave-it |
|-------------------|------------------|------------------|---------------------|
| | Percent of total | Percent of total | Percent of total |
| Seller's surplus | 31.5 | 43.4 | 45.1 |
| Buyer's surplus | 54.3 | 47.0 | 36.3 |
| Delay/termination | 14.2 | 9.6 | 18.6 |
| Total surplus | 100.0 | 100.0 | 100.0 |

Note: This table shows the expected trade surpluses for the parameter estimates reported in Table 3. The seller's surplus is the expected discounted price minus the reservation value. The buyer's surplus is the expected discounted valuation minus the price paid to the seller. The delay costs is the expected depreciation of a captive during the negotiation process net of the services he produces to the seller. The total surplus is the difference between the expected valuation by the buyer and the seller's reservation value. The termination costs are applicable to the take-it-or-leave-it strategy and are defined as the difference between the total surplus and the surpluses of the agents. The first column shows the distribution of surpluses if the original trading mechanism is used. The second column shows the distribution of surpluses if 10 random captives with the same observable characteristics are sold as a bundle. The last column shows the distribution of expected gains from trade if the seller can commit to make only one offer.