RISK AND INFORMATION IN DISPUTE RESOLUTION: AN EMPIRICAL STUDY OF ARBITRATION

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Abstract. This paper studies arbitration, a widespread dispute resolution method. We develop an arbitration model where disputing parties choose strategic actions given asymmetric risk attitudes and learning by the arbitrator. We also model arbitration's effect on negotiated settlements. Upon establishing identification, we estimate the model using public sector wage disputes in New Jersey. Counterfactual simulations find that the more risk-averse party obtains superior outcomes in arbitration but inferior outcomes upon accounting for negotiated settlements. Simulations comparing two popular arbitration designs—final-offer and conventional—support the view that final-offer arbitration leads to less divergent offers and superior information revelation but higher-variance awards.

Keywords: Arbitration, Dispute Resolution, Strategic Communication, Cheap-Talk, Risk Attitudes, Bargaining

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1. Introduction

Arbitration is a private bilateral conflict resolution procedure in which a third party, the arbitrator, makes a binding decision on the dispute. Compared with formal litigation through a court system, arbitration is typically cheaper, faster and less formal. Moreover, arbitrators tend to be experts on the subject matter of the dispute, whereas judges assigned to court cases are usually generalists (Mnookin, 1998). Due to these advantages, arbitration has been extensively employed in the resolution of a variety of disputes including labor impasses, disagreements concerning commercial contracts, tort cases and tariff negotiations, among many others. In fact, Lipsky and Seeber (1998) surveyed the general counsels of the Fortune 1,000 companies in 1997, and found that 80 percent of the respondents had used arbitration at least once in the previous three years.

This paper combines theory and empirics to address two related sets of questions concerning arbitration. First, we investigate the role of risk aversion in arbitration, given disputing parties' uncertainty about the arbitrator's ruling. Specifically, we assess how imbalances between the risk-attitudes of the disputing parties affect arbitration outcomes. This question is related to an ongoing, more general debate on whether arbitration constitutes an uneven playing field for the parties involved. See, for example, Barr (2014) and Egan et al. (2018) and the New York Times article by Silver-Greenberg and Gebeloff (2015).[1]

Second, we compare the performance of two widely used arbitration designs—conventional and final-offer. In each of these designs, the disputing parties submit to the arbitrator one offer each. The key distinction is that in conventional arbitration the arbitrator is free to impose a ruling that differs from both offers, whereas in final-offer arbitration the arbitrator must select the offer of one side or the other. In either design, a rational arbitrator may attempt to learn from the offers any private information the parties have about the case in order to deliver a better-informed ruling. What is particularly interesting as a consequence of the different designs is that the offers in conventional arbitration are cheap-talk, whereas in final-offer arbitration they are not. Our analysis examines the differences between conventional

[1]Most existing analyses investigate the potential disparities arising in arbitration when one of the parties is more familiar with the process or has access to better resources. These concerns are common in consumer or employment disputes between individuals and large entities such as corporations. Here, instead, we focus on disputes between organizations with comparable experience in arbitration but that might present different risk-attitudes. In this context, we ask: does being more risk-averse put a party at a disadvantage in arbitration?

and final-offer arbitration when it comes to the behavior of the parties, the arbitrator's decisions and the amount of information revealed through the offers.

We answer these questions in the context of wage negotiations between local governments and police and fire officer unions in New Jersey. In that state, unions must renegotiate the officers' contracts with their employers roughly every two to three years. If the parties cannot reach an agreement, the state law requires the case to proceed to arbitration.[2] We exploit an empirical opportunity provided by the transition of the default arbitration method from final-offer to conventional in 1996. Our data contain the parties' offers and the arbitrator's ruling for every case decided through final-offer arbitration between 1978-1995 and through conventional arbitration between 1996-2000. We obtain the pre-1996 final-offer arbitration data from Ashenfelter and Dahl (2012), and, as far as we are aware, ours is the first study to systematically collect and investigate the post-1996 conventional arbitration data. We also collect a new sample of wage increases from 1978-1995 that were negotiated without triggering the default arbitration mechanism.

To analyze these data, we develop a theoretical model of arbitration that accounts for the strategic interaction between the two disputing parties—the union and the employer—and the arbitrator. The two parties are in a dispute over the wage increase, and, as in the model originally proposed by Farber (1980), we allow them to have asymmetric risk-attitudes. Additionally, motivated by evidence from the literature and following Gibbons (1988), our model accommodates learning by the arbitrator. More precisely, both the arbitrator and the disputing parties are uncertain about what constitutes the fair wage increase in a given case. After filing for arbitration, the disputing parties and the arbitrator privately receive noisy signals about the fair wage increase. Next, the parties submit their offers to the arbitrator. The arbitrator employs any information about the parties' signals conveyed by the offers to update her beliefs about the fair wage increase, and then makes a decision on the case. Irrespective of the arbitrator's eventual decision, the disputing parties pay costs to resolve the case by arbitration. We supplement the model with a pre-arbitration negotiation stage, in which the parties can settle the case without incurring these costs or dealing with the uncertainty surrounding the arbitrator's ruling.

[2]New Jersey is not unique in relying on arbitration to resolve disputes between local governments and their employees. As of the year 2000, around 30 states specified binding arbitration as the last-resort step in labor disputes for at least some categories of public employees (Slater, 2013). This procedure is especially important in negotiations involving essential workers, such as police and fire officers, who are forbidden to strike.

We bring the model to the data, initially focusing on final-offer arbitration. Specifically, we characterize the model equilibrium and formally establish identification of the model primitives under final-offer arbitration. We recover the parties' risk attitudes from the conditional odds that the arbitrator chooses the offers of one side versus the other. Intuitively, more risk-averse parties make less aggressive offers, which the arbitrator is more likely to select in equilibrium. Identification of the prior distribution of the fair wage increase and the parties' signal distribution is based on the observed joint distribution of final offers. We identify the distribution of arbitration costs from the arbitration rate, as well as from the comparison between each party's expected arbitration payoffs and the negotiated wage increases in cases settled pre-arbitration. Building upon the identification results, we propose a multi-step estimator, in which the arbitration stage model is estimated following our constructive identification argument and the negotiation stage model is estimated via maximum likelihood. We then implement the estimator using data from 1978-1995, when final-offer arbitration was the default arbitration procedure in our setting.

In our estimated model, we find the union to be risk-averse, while we let the employer be risk-neutral.[3] To investigate how this asymmetry in risk-attitudes affects dispute outcomes, we simulate a hypothetical scenario in which both parties are risk-neutral. The comparison between the baseline and counterfactual scenarios indicates that the union's risk aversion actually raises the expected salary increase for arbitrated cases, as it makes it more likely that the arbitrator chooses the union's offer. Nevertheless, due to the risk premium associated with the arbitrator's decision, the certainty-equivalent of going into arbitration is lower for the risk-averse union. As a consequence, when it is risk-averse, the union is willing to settle the case for a relatively low wage increase prior to arbitration. Averaging together the cases that settle and those that reach arbitration, we find that risk aversion by the union reduces the overall expected wage increase by 0.2 percentage points per year.

In a different counterfactual exercise, we analyze the differences between the final-offer and conventional arbitration designs by leveraging the 1996 change in the default arbitration method in New Jersey. We combine our model estimates with observed characteristics of cases decided by conventional arbitration post-96 to simulate hypothetical outcomes of these cases under final-offer arbitration. This approach allows us to compare the two dispute resolution methods without taking a stance on the equilibria being played in the cheap-talk game implied by conventional arbitration.

[3]We discuss the rationale for the risk-neutral employer in Section 3, footnote 12.

A number of differences stand out. First, our results indicate that the dispersion in arbitrated awards is higher for cases decided by final-offer, relative to conventional arbitration. But this difference in dispersion has a relatively minor impact on the union's certainty-equivalent of arbitration, so the effect of the choice of arbitration method on the settlement rate and on settlement amounts is smaller than traditionally conjectured (Stevens, 1966). Dispersion does, however, have negative consequences for an arbitration method's ability to deliver rulings that are close to the ideal or fair wage, as we discuss further below.

Second, we find that the expected gap between the offers made by the union and the employer more than doubles, i.e., the parties take more exaggerated positions, under conventional arbitration compared to the final-offer scenario. This result raises the question of whether the cheap-talk nature of conventional arbitration leads the parties to make offers that are not as informative to the arbitrator as those made under final-offer arbitration. To investigate this possibility, we develop a new metric for information transmission in arbitration. The key idea behind the metric is to compare the observed arbitration outcomes with a series of counterfactual benchmarks simulated under different degrees of information transmission, which we are able to compute given our estimated model primitives. Our results suggest that the parties in final-offer arbitration convey to the arbitrator information about the case that is roughly twice as precise as that transmitted in conventional arbitration; whether the game is a cheap-talk game or not is indeed consequential. There is a trade off, however, as the superior information transmission afforded by final-offer arbitration comes at the cost of its one-offer-or-the-other constraint on the arbitrator's ruling. On balance, we find that conventional arbitration does better in terms of delivering arbitration awards that are closer to the ideal or fair wage. By this criterion, in our empirical application, it is worth sacrificing the extra information of final-offer arbitration to free up the arbitrator's choice.

Our paper fits within a large literature on arbitration dating back to Stevens (1966). On the theoretical front, we contribute by characterizing the equilibrium of a final-offer arbitration model that brings together key elements from previous studies—namely, asymmetric risk-attitudes by the parties (Farber, 1980), learning by the arbitrator (Gibbons, 1988) and the possibility of settling the case prior to arbitration. Other theoretical studies of arbitration include Crawford (1979), Farber (1980), McCall (1990), Samuelson (1991), Farmer and Pecorino (1998), Olszewski (2011), Mylovanov and Zapechelnyuk (2013), and Çelen and Özgür (2018), among others.

Many studies explore the empirical implications of theoretical arbitration models. Notable examples include Farber and Bazerman (1986), Currie (1989), Ashenfelter et al. (1992), Marselli et al. (2015) and Egan et al. (2018). The specific setting that we study—contract renegotiations of police and fire officers in New Jersey—has also been the subject of the empirical analyses by Bloom (1981, 1986), Ashenfelter and Bloom (1984), Bloom and Cavanagh (1986), Ashenfelter (1987), Mas (2006) and Ashenfelter and Dahl (2012). Our paper differs from these in that we develop and implement a framework for the structural analysis of the data. The structural approach allows us to address questions related to risk and information that would not be accessible given a reduced-form strategy.[4] In that sense, our study relates to a broader literature devoted to the structural analysis of bargaining and dispute resolution models in settings other than arbitration. See, for example, Waldfogel (1995), Merlo (1997), Sieg (2000), Eraslan (2008), Watanabe et al. (2006), Merlo and Tang (2012, 2019a,b), Silveira (2017), Ambrus et al. (2018), Larsen (2020) and Bagwell et al. (2020).

By quantifying the strategic transmission of information in final-offer and conventional arbitration, our paper also contributes to the broad literature on communication. Recent empirical studies on costly signaling à la Spence (1973) include Kawai et al. (2020), Sahni and Nair (2020) and Sweeting et al. (2020), whereas Backus et al. (2019) document cheap-talk signaling. Previous research directly comparing the information transmission in costly signaling versus cheap-talk either is purely theoretical (Austen-Smith and Banks, 2000) or employs laboratory experiments (De Haan et al., 2015).[5] To the extent of our knowledge, our study is the first to undertake this type of comparison using field data.

The rest of the paper is organized as follows: Section 2 describes the wage negotiations for New Jersey police and fire officers and presents the data. Section 3 contains the theoretical model, and Section 4 presents our structural model and identification results. In Section 5, we describe our estimation procedure and report the estimation results. Section 6 contains the counterfactual analyses, and Section 7 concludes.

2. Institutions and Data

[4]To the extent of our knowledge, ours is the first structural analysis of an arbitration model. Egan et al. (2018) calibrate a model of arbitrator selection, without focusing on the strategic interaction between the parties during arbitration.

[5]De Haan et al. (2015) consider a setup closely related to the original model by Crawford and Sobel (1982), with one privately informed sender and one receiver. Although not directly comparable to ours, their results also indicate that costly signaling allows for more informative messages.

2.1. **Collective negotiations of police and fire officers in New Jersey.** In 1977, the New Jersey Fire and Police Arbitration Act established a system of arbitration to avoid impasse in public sector labor negotiations. If police and fire employee unions and their municipal employers did not reach an agreement 60 days before expiry of the current labor contract, the two parties were required to file for arbitration. Until 1996, the default arbitration procedure specified by the law was final-offer arbitration. On that year, a reform instituted conventional arbitration as the new default.

The New Jersey Public Employment Relations Commission (PERC) oversees each arbitration case. After the disputing parties file for arbitration, PERC provides a list of seven arbitrators randomly chosen from a panel of about 60 professionals. Each party then strikes up to three names from the list, and ranks the remaining four names in order of preference. PERC then assigns to the case the arbitrator with the highest preference in the combined rankings. This selection process favors arbitrators liked by both parties. It is thus not surprising that previous studies, including Ashenfelter and Bloom (1984), Ashenfelter (1987), and Ashenfelter and Dahl (2012), find evidence that arbitrators in New Jersey are impartial and exchangeable.

According to the New Jersey Statutes, the arbitrator is to make a decision based on a number of criteria, which include: the compensation currently received by the employees involved in the dispute; the wages, hours and working conditions of other employees that perform comparable services in the public and private sectors; the cost of living; the financial impact of the decision on the governing unit and its residents and taxpayers; and the interests and welfare of the public.[6]

2.2. **Data.** We study data from the New Jersey arbitration system, consisting of three major components. The first one is the universe of final-offer arbitration cases during 1978-1995, obtained from Ashenfelter and Dahl (2012). To be clear, these correspond to all wage negotiations in which the union and employer failed to reach agreement and thus resorted to final-offer arbitration as per the law. In the remainder of the paper, we refer to this data set as ARB_F. The second component is the universe of cases decided by conventional arbitration during 1996-2000, which we collected from the PERC website. We refer to this data set as ARB_C. Both the ARB_F and the ARB_C data sets contain, for each case, the offers made by the disputing parties, as well as the arbitrator's decision.

[6]New Jersey Statutes Title 34, Chapter 13A, Section 16.

The third major data component in our analysis consists of contracted wages for cases that settled without triggering the default arbitration proceedings during 1978-1995.[7] We obtained this information from contracts for police and fire officers on the PERC website. We refer to this data set as SET_F. Importantly, only a share of police and fire contracts from 1978-1995 are available on the PERC website, so the SET_F data constitute a sample of the wages settled in the period.

The structural analysis that we present beginning in Section 4 is based on a theoretical model of final-offer arbitration. Accordingly, the ARB_F and SET_F data sets constitute our estimation sample. We only use the ARB_C data set when we compare conventional and final-offer arbitration, in Section 6. In the interest of space, the current section presents only the estimation sample in more detail.

The ARB_F data consist of 586 cases and the SET_F data consist of 896 contracts after excluding observations with missing variables. Wages are reported as a percentage increase over the previous wage, rather than dollars. Table 1 provides basic summary statistics of the data. The typical observation involves a two-year contract for a municipal police department; fire contracts are fewer as many local fire departments are volunteer units. Union final offers always demand higher wages than offered by employer final offers, with an average difference of 1.7 percentage points and a maximum observed difference of 12 percentage points; Appendix Figure A1 provides a scatterplot of the final offers. At the same time, union and employer offers are positively correlated, with a correlation coefficient of 0.57.

Another statistic of interest is the arbitration rate—that is, the number of cases resolved by arbitration divided by the total number of cases. As previously explained, while the ARB_F data comprise the universe of final-offer arbitration cases in the 1978-1995 period, the SET_F data set consists of a random sample of settled cases. We do not directly observe the total number of contracts up for negotiation during our sample period. To assess the arbitration rate, we infer the total number of relevant cases as follows. In our data 458 unique employers appear at least once. As the sample period spans 18 years, we have a total of 8,244 potential employer-year pairs. Dividing this number by the average contract length in our data during 1978-1995, 2.43 years, we estimate the total number of contracts up for renegotiation to be 3,393.

[7]Resolving disputes by alternative forms of arbitration (such as conventional) prior to 1996 was possible upon the consensual agreement of the union and the employer. Our analysis treats these cases as settled, since they involve at least some degree of compromise by the disputing parties. This approach is consistent with the evidence in Lester (1984, 1989) that the majority of conventional arbitration awards up to 1987 in New Jersey were, in reality, mutually agreed upon by the parties.

Table 1. Summary Statistics: Arbitrated and Settled Cases, 1978-1995

	Arbitration		Settlement	
Sample size	586		896	
Job type (fraction)				
Police	0.90		0.81	
Fire	0.10		0.19	
	mean	sd	mean	sd
Num. years covered by contract	2.1	0.7	2.5	0.6
Wage increase (% points)	7.2	1.6	6.6	1.9
Union final offer (% points)	7.8	1.8	–	–
Employer final offer (% points)	6.1	1.6	–	–
Difference in final offers (% points)	1.7	1.6	–	–
Union win rate	0.63	–	–	–

Notes: Arbitrated cases are from the ARB_F data set (explained in the text), comprising all wage negotiations resolved by final-offer arbitration during 1978-1995. Settled cases are from the SET_F data set (explained in the text), which consists of a sample of wage increases for cases settled prior to arbitration from 1978-1995.

Dividing the total number of final-offer arbitration cases by this number, we obtain an arbitration rate of 26.4 percent.[8]

2.3. **Patterns in the Data and Literature.** We now present patterns in our data, as well as findings from previous empirical studies of arbitration, which motivate some of the modeling assumptions of the structural analysis we present in subsequent sections. First, we investigate the relationship between realized wage increases and covariates in Table 2. In light of the statutory guidance mentioning comparison to similar employees, we construct for each contract a variable *othermuni*, defined as the mean arbitrated salary increase of other municipalities in the same county during a time frame of up to two years preceding the contract year. We also include a dummy, denoted by *otherissues*, indicating whether the negotiations comprise any issue in addition to the workers' wages, including, for example, holiday schedules and uniform allowances.[9] By New Jersey law, the scope of negotiations excludes subjects

[8]We employ the total number of final-offer arbitration cases in our data (896) as the numerator, as opposed to the subsample of arbitrated cases without missing variables (586).

[9]The ARB_F data, which we obtain from Ashenfelter and Dahl (2012), only contain the *otherissues* dummy, and do not specify at the case level what issues other than wage increases were included in the negotiations. For the ARB_C data, we observe all the negotiated issues, and find that, among the items not directly related to compensation, vacation/holiday schedules and uniform allowances are the most frequent ones. The SET_F data set does not contain any information on whether non-wage issues were points of negotiation.

that would place substantial limits on the legislature's policy-making powers, such as pensions. To account for the financial impact on the governing unit and residents, we include the log of taxable property per capita ("tax base"), the quantile of median household income among New Jersey municipalities, and the credit rating assigned to municipal debt obligations by Moody's Investors' Service, as obtained from the New Jersey Data Book. To account for time effects such as changes in the cost of living, we include year fixed effects. Finally, we account for characteristics of the contract and bargaining units, including population as a proxy for size of the bargaining unit, job and employer type dummies, and contract length in years.

Column (1) regresses arbitrated wage increases in ARB_F on these covariates. Both *othermuni* and the log tax base have a positive, statistically significant relationship with arbitrated wages. This result is consistent with intuition that arbitrators are more likely to favor higher wages if comparable employees elsewhere receive high wages and if the tax base is larger. On the other hand, other covariates such as the Moody's ratings do not have a statistically significant effect. In particular, we do not find a significant effect for *otherissues*, indicating that the discussion of non-salary issues does not affect wage negotiations. This result is consistent with the view by Ashenfelter and Bloom (1984) that wage increases are the focus of the disputes in this setting. Column (2) uses a more concise set of covariates, also replacing year fixed effects with a smaller number of year-group fixed effects[10] and the 12-month percent change in the Consumer Price Index.[11] As expected, larger increases in the cost of living as reflected in the CPI are associated with larger wage increases. Though more concise, column (2) achieves an adjusted R^2 similar to that of column (1). Columns (3) and (4) repeat these regressions for settled wages in SET_F. Signs of the statistically significant coefficients remain the same as they were for arbitrated wages.

Next, we investigate how choosing a higher or lower final offer affects the union's and employer's probability of winning arbitration. As the arbitrator is constrained to impose one of the two final offers in final-offer arbitration, there exists a winner by definition. We first regress union and employer final offers, respectively, on all the covariates in Table 2, column (1). We then take the respective regression residuals as a measure of how high or low each final offer is relative to the expected offer conditional on covariates. Finally, we perform probit regressions with an indicator

[10]There are four year-groups, 1978-1986, 1987-1990, 1991-1992, 1993-1995, formed using tests of within-group equality of coefficients.

[11]Consumer Price Index for Urban Wage Earners and Clerical Workers in NY-NJ-PA, U.S. Bureau of Labor Statistics.

TABLE 2. Determinants of Wages, 1978-1995

	Arbitrated		Settled	
	(1)	(2)	(3)	(4)
Num yrs covered by contract	-0.021	0.045	-0.058	-0.036
	(0.110)	(0.101)	(0.091)	(0.089)
Othermuni	0.149	0.294	0.158	0.185
	(0.052)	(0.047)	(0.042)	(0.039)
Log tax base	0.324	0.284	0.069	0.005
	(0.116)	(0.094)	(0.117)	(0.087)
Income quantile	0.000		-0.003	
	(0.003)		(0.003)	
Log population	-0.069		-0.012	
	(0.059)		(0.067)	
Fire dummy	-0.041		-0.196	
	(0.202)		(0.156)	
County dummy	-0.086		-0.396	
	(0.287)		(0.352)	
Otherissues	-0.161			
	(0.160)			
CPI 12 mo pct change		0.045		0.165
		(0.025)		(0.028)
Year fixed effects	Y	N	Y	N
Year group fixed effects	N	Y	N	Y
Moody's rating fixed effects	Y	N	Y	N
Moody's rating joint test p-value	0.58	–	0.79	–
Observations	579	586	896	896
R^2	0.396	0.329	0.328	0.302
Adjusted R^2	0.356	0.321	0.299	0.296

Notes: Table reports OLS results. The unit of observation is a case. In all specifications, the dependent variable is the wage increase in percentage points. Standard errors are provided in parentheses. Arbitrated and settled cases are from the ARB_F and SET_F data sets, respectively. See text for further details.

for the employer winning as the dependent variable and these final offer residuals as the regressors. We find that the union is more likely to lose when it demands a higher wage, and the employer is more likely to win when it offers a higher wage.

In other words, a more aggressive (moderate) final offer decreases (increases) the probability of winning for both sides. Appendix Table A1 provides detailed results. These properties shed light on the strategic considerations at play in choosing final offers; each side must trade off the gain from having a more aggressive offer accepted against the reduced probability of a more aggressive offer being accepted.

As shown in Table 1, the union wins more often than the employer. This pattern is consistent with previous findings by Bloom (1981) and Ashenfelter and Bloom (1984) that the union behaves conservatively, both in an absolute sense and also relative to the employer. In light of this result, in our structural analysis, we consider a model that accommodates asymmetries between the risk attitudes of the two parties.

Finally, we collect evidence that the parties' offers influence the arbitrator. Clearly, in final-offer arbitration, the offers directly affect the arbitrator's decision, since the arbitrator is constrained to choosing one of them. But the previous literature has also provided evidence that the offers affect the arbitrator's beliefs about what the right decision should be—that is, the arbitrator learns about the case through the offers. Bazerman and Farber (1985) and Farber and Bazerman (1986) survey practicing arbitrators on hypothetical wage arbitration cases. They find that arbitrators' decisions place more weight on the parties' offers when they are of higher quality as measured by how close the two offers are. This suggests that arbitrators assess and additionally learn from the informational content in the parties' offers. The survey responses also reveal considerable variation in arbitrator rulings given identical arbitration cases, evidencing the existence of uncertainty in arbitration outcomes. In a similar vein, Bloom (1986) conducts a survey with practicing arbitrators, asking them about hypothetical cases based on actual police wage disputes decided in New Jersey—the exact same setting of our analysis. The paper finds evidence that the parties' offers influence arbitrators' decisions, even though the hypothetical cases presented to the respondents were of conventional arbitration—so decisions were not mechanically constrained by the offers. Taken together, these findings from the received literature motivate us to consider a model in which offers may convey information to the arbitrator.

3. Theoretical Model

We model two agents, a union and an employer, negotiating a wage increase, incorporating key features of the dispute resolution system described above. Henceforth, we collectively refer to the union and the employer as the *parties*. If the parties cannot reach an agreement, the case goes to final-offer arbitration. For ease of exposition, we begin the formal description of the model with the arbitration stage. Then we proceed backwards to explain the pre-arbitration negotiation process, which we call the negotiation stage.

3.1. **Arbitration Stage.** In final-offer arbitration, the union and the employer each submit an offer to the arbitrator regarding the wage increase. The arbitrator then imposes one of the two offers as the wage increase. This decision is binding.

3.1.1. *Setup.* Let s represent the ideal or objectively fair wage increase, and denote by y the increase actually set by the arbitrator. The arbitrator's utility function is $u_a(y, s) = -(y - s)^2$. The quadratic loss form is not important; what matters is that the arbitrator would like to set the arbitration award as close to the fair wage as possible. For tractability, we assume a CARA specification for the union's utility: $u_u(y) = [1 - \exp(-\rho y)] / \rho$, where the parameter ρ is common knowledge to all players. As for the employer, we assume risk-neutrality: $u_e(y) = -y$.[12]

Neither the arbitrator nor the parties are certain about the true value of s; as noted above, the literature finds considerable variation and uncertainty in arbitrator rulings. Instead, all players perceive s with noise; the arbitrator privately receives a signal $s_a = s + \varepsilon_a$, and the parties receive a signal $s_p = s + \varepsilon_p$. Following Gibbons (1988), the signal s_p is common knowledge between the union and the employer. New Jersey arbitration practitioners whom we surveyed confirm that, when the parties write their arbitration offers, there is no relevant information that only one side possesses, and each side is aware of what offer the other side will submit. Thus, the incomplete information of interest in arbitration is between the arbitrator and the parties; the parties do not observe s_a, so they are uncertain about the arbitrator's beliefs, and neither does the arbitrator observe s_p. We make the following assumptions about the information structure in the arbitration stage:

Assumption 1. *(i) The terms s, ε_a and ε_p are mutually independent; (ii) the distribution of s is normal with mean m and precision h (i.e., variance $1/h$); and (iii) the distributions of ε_a and ε_p are both normal with mean zero and precision h_ε (i.e., variance $1/h_\varepsilon$).*

The order of play in the arbitration stage is as follows: after the parties observe s_p and the arbitrator observes s_a, the union and the employer simultaneously make final

[12]Preliminary estimation allowing CARA utility for both parties yielded estimates for the employer's risk aversion parameter that were very close to zero. Therefore, we focus on the case of a risk-neutral employer, which substantially simplifies the notation.

offers y_u and y_e, respectively. The arbitrator then selects one of the two final offers as the actual wage increase.

3.1.2. *Equilibrium.* The relevant equilibrium concept is Perfect Bayesian Equilibrium. In equilibrium, the arbitrator updates her beliefs about the ideal wage increase s—based on the signal s_a, which she observes directly, and on any information about the signal s_p conveyed by the parties' final offers. Such updating by the arbitrator is consistent with the literature showing that arbitrators' opinions are influenced by final offers. She then selects the final offer that is closer to her updated expectation of s, denoted $y_a(s_a, y_u, y_e)$. That is, the arbitrator chooses the employer's offer if and only if $y_a(s_a, y_u, y_e) - y_e < y_u - y_a(s_a, y_u, y_e)$, or, equivalently,

$$y_a(s_a, y_u, y_e) < (y_u + y_e)/2 \equiv \bar{y}. \tag{1}$$

Then the union's and employer's problems in choosing final offers are, respectively,

$$\max_{y_u} u_u(y_e) \Pr[y_a(s_a, y_u, y_e) < \bar{y}|s_p] + u_u(y_u)\{1 - \Pr[y_a(s_a, y_u, y_e) < \bar{y}|s_p]\},$$

and

$$\max_{y_e} u_e(y_e) \underbrace{\Pr[y_a(s_a, y_u, y_e) < \bar{y}|s_p]}_{\Pr(\text{employer wins}|s_p)} + u_e(y_u) \underbrace{\{1 - \Pr[y_a(s_a, y_u, y_e) < \bar{y}|s_p]\}}_{\Pr(\text{union wins}|s_p)}.$$

The arbitrator's, union's and employer's equilibrium strategies—$y_a(s_a, y_u, y_e)$, $y_u(s_p)$ and $y_e(s_p)$, respectively—constitute a set of mutual best-responses. In particular, the final offer strategies of the union and the employer optimally balance a number of considerations: the gain from having a more aggressive offer accepted, the reduced probability of a more aggressive offer being accepted, and the opportunity to influence the arbitrator's beliefs through $y_a(\cdot,\cdot,\cdot)$. As we show below, the balance of these incentives endogenously generates divergence between the parties' positions.

By Assumption 1, Bayesian updating in this model is characterized by the normal learning model (DeGroot, 2005). Specifically, the parties' belief about the distribution of s, conditional on their signal s_p, is normal with mean

$$M_p(s_p) = \frac{hm + h_\varepsilon s_p}{h + h_\varepsilon}$$

and precision $h + h_\varepsilon$. Also, the parties' belief about the distribution of the arbitrator's signal s_a, conditional on s_p, is normal with mean $M_p(s_p)$ and precision $H \equiv [h_\varepsilon(h + h_\varepsilon)] / (h + 2h_\varepsilon)$. When both parties are risk-neutral, Gibbons (1988) proves the existence of a separating equilibrium in which $y_u(s_p) = M_p(s_p) + \delta$ and $y_e(s_p) = M_p(s_p) - \delta$, where δ is decreasing in the precision parameters h and h_ε but does not depend on the realization of s_p. That is, the union and employer strategically choose to depart from their conditional expectation of s, and the distance between their offers increases in the amount of uncertainty surrounding the case.

In Proposition 1, we show the existence of and characterize a separating equilibrium of our arbitration model, which allows for risk-averse or risk-loving utility and asymmetric risk attitudes between the two parties. Intuitively, final-offer arbitration has a built-in penalty for aggressive offers, as the arbitrator is less likely to choose them. This built-in penalty reins in the degree of aggressiveness and provides for a separating equilibrium, in which the arbitrator can infer s_p from the final offers. Extending Gibbons (1988), we show that each party's final offer departs from $M_p(s_p)$ by a distance that depends on the precision parameters h and h_ε and the risk aversion parameter ρ, but not on the realization of s_p. In Proposition 2, we show that the distance between final offers is strictly decreasing in h and h_ε and that the more risk-averse party makes a more conservative offer, choosing a distance from $M_p(s_p)$ that is smaller than that of the opponent. All proofs of the paper are in the Appendix.

Proposition 1. *Under Assumption 1, there exists a separating equilibrium of the arbitration stage in which the final offers by the union and the the employer have the form $y_u(s_p) = M_p(s_p) + \delta_u$ and $y_e(s_p) = M_p(s_p) - \delta_e$. The terms δ_u and δ_e are unique and do not depend on the signal s_p.*

Before stating Proposition 2, we elaborate on the arbitrator's equilibrium strategy. In the equilibrium of Proposition 1, the arbitrator knows that

$$[(y_u - \delta_u) + (y_e + \delta_e)]/2 = \bar{y} + (\delta_e - \delta_u)/2 = M_p(s_p),$$

where $\bar{y} \equiv (y_u + y_e)/2$. Therefore, the arbitrator can infer s_p by applying $M_p^{-1}(\cdot)$ to both sides of the equation above, yielding the inference rule

$$s_p(\bar{y}) = \frac{(h + h_\varepsilon)\,[\bar{y} + (\delta_e - \delta_u)/2] - hm}{h_\varepsilon}. \tag{2}$$

This expression characterizes the arbitrator's belief about s_p, conditional on the parties' final offers, both on and off the equilibrium path. Then, given s_a and $s_p(\bar{y})$, the arbitrator updates her beliefs about s. By Assumption 1 and the normal learning model, her updated expectation of the ideal wage increase is

$$y_a(s_a, y_u, y_e) = \frac{hm + h_\varepsilon s_p(\bar{y}) + h_\varepsilon s_a}{h + 2h_\varepsilon}.$$

Then, rearranging (1), we have that the arbitrator chooses y_e if and only if

$$s_a < \frac{h_\varepsilon \bar{y} + h(\bar{y} - m) + h_\varepsilon (\bar{y} - s_p(\bar{y}))}{h_\varepsilon} = \bar{y} - \left(\frac{h + h_\varepsilon}{h_\varepsilon}\right) \frac{\delta_e - \delta_u}{2} \equiv S(\bar{y}), \tag{3}$$

where the equality comes from (2).

As previously stated, the parties' belief about the distribution of the arbitrator's signal s_a, conditional on s_p, is normal with mean $M_p(s_p)$ and precision $H \equiv [h_\varepsilon(h + h_\varepsilon)] / (h + 2h_\varepsilon)$. Denote by $\Phi(\cdot)$ and $\phi(\cdot)$ the standard normal cumulative distribution and density functions, respectively. Then by (3), the probability of the employer winning conditional on s_p is equal to $\Phi([S(\bar{y}) - M_p(s_p)]\sqrt{H})$. Using this expression in the union's and employer's optimization problems above, the proof of Proposition 1 shows, after some algebra, that the following system of first-order conditions characterizes the equilibrium values of δ_u and δ_e:

$$\frac{\sqrt{H}}{2} \frac{\phi(\eta(\delta_u - \delta_e)/2)}{1 - \Phi(\eta(\delta_u - \delta_e)/2)} = \frac{\rho}{\exp(\rho(\delta_u + \delta_e)) - 1}, \tag{4}$$

$$\text{and} \qquad \frac{\sqrt{H}}{2} \frac{\phi(\eta(\delta_u - \delta_e)/2)}{\Phi(\eta(\delta_u - \delta_e)/2)} = \frac{1}{\delta_u + \delta_e}, \tag{5}$$

where $\eta \equiv \sqrt{H}(h + 2h_\varepsilon)/h_\varepsilon$. Since $M_p(s_p) = (\bar{y} + (\delta_e - \delta_u)/2)$ in equilibrium and by definition of $S(\bar{y})$ in (3), the probability of the employer winning is equal to

$$\Phi([S(\bar{y}) - M_p(s_p)]\sqrt{H}) = \Phi(\eta(\delta_u - \delta_e)/2) \tag{6}$$

in equilibrium. Also, taking a ratio of (4) over (5) yields

$$\frac{\Phi(\eta(\delta_u - \delta_e)/2)}{1 - \Phi(\eta(\delta_u - \delta_e)/2)} = \frac{\rho(\delta_u + \delta_e)}{\exp(\rho(\delta_u + \delta_e)) - 1}, \tag{7}$$

where the left-hand side equals the odds of the employer winning in equilibrium. We are now ready to state our next theoretical result.

PROPOSITION 2. *The equilibrium characterized in Proposition 1 is such that: (i) the distance between final offers $\delta_u + \delta_e$ is strictly decreasing in the precision parameters h and h_ε; and (ii) the more risk-averse party chooses a final offer that is less distant from $M_p(s_p)$—i.e., a smaller δ—and wins more often in expectation.*

The notion that the more risk-averse party wins more often in arbitration goes back to the seminal work of Farber (1980), who analyzes a simpler model in which there is no information communicated from the parties to the arbitrator. Our Proposition 2 generalizes this finding, showing that it continues to hold in an arbitration model with strategic communication.

3.2. **Negotiation Stage.**

3.2.1. *Setup.* We now model the effect on negotiated settlements of having arbitration as the disagreement outcome. Prior to arbitration, the union and the employer have the opportunity to settle the case. In the absence of a settlement, the case proceeds to the arbitration stage, which results in a wage increase of y. Such an increase depends on the signal realizations for the parties and the arbitrator, which are still unknown to the players at the negotiation stage. Therefore, from the perspective of the union and the employer at the negotiation stage, y is a random variable.

Irrespective of the wage increase to be decided in arbitration, the union and the employer incur arbitration costs c_u and c_e if they fail to settle. These costs are private information; only the union knows the realization of c_u, and only the employer knows the realization of c_e. Farber (1980) notes the role that such costs play in determining how much the parties are willing to concede during the negotiations that precede arbitration. These costs include not only the monetary costs of arbitration, such as arbitrator and lawyer fees, but also non-monetary costs, which may be more significant. Arbitration takes time—over seven months, on average, in 1982-1983 (Lester, 1984)—and often extends past the municipality's budget submission date. This delay in resolution of the dispute and establishment of the new employment contract hinders efficient budget-making and creates costs for all parties involved. Moreover, arbitration can lower employee morale (Mas (2006)), generate hard feelings,[13] and cost elected municipal leaders the police/fire union's political endorsement.[14] Meanwhile, arbitration costs, broadly defined, can also encompass negative components; Reilly (1963) notes that arbitration can actually be attractive to the negotiator because it allows him to give his client the impression of having fought to the end while shifting responsibility to the arbitrator. We interpret arbitration costs flexibly as a term encompassing these various components that affect the undesirability of arbitration.

For $j \in \{u, e\}$, the cost c_j follows a distribution F_{c_j} with support $[\underline{c}_j, \bar{c}_j]$. We assume that y, c_u and c_e are mutually independent. We also assume the following:

ASSUMPTION 2. *(i) For $j \in \{u, e\}$, F_{c_j} has an associated density function f_{c_j} such that $f_{c_j}(c) > 0$ for all $c \in [\underline{c}_j, \bar{c}_j]$; and (ii) the hazard function associated with the union's cost distribution, $f_{c_u}(c)/[1 - F_{c_u}(c)]$, is strictly increasing in c over $[\underline{c}_u, \bar{c}_u]$.*

[13]Major League Baseball is a well-known example where salary disputes are resolved by arbitration. Light (2016) quotes journalist Stephen Cannella regarding the non-monetary costs of arbitration: "Salary arbitration is the Major League equivalent of divorce court: Owners and players hate going there, and when a case ends, both sides leave with hard feelings."

[14]See, for example, the City of Houston's dispute with its fire department in Scherer (2019).

The monotonicity condition in Assumption 2.ii holds for, among others, the normal distribution and the Weibull distribution given a certain range of shape parameters.

The bargaining protocol at the negotiation stage is take-it-or-leave-it. Specifically, the order of play in the negotiation stage is as follows: the union and employer draw their respective costs c_u and c_e. The employer then offers to settle the case for a wage increase σ. If the union rejects the offer, the case proceeds to the arbitration stage.

3.2.2. *Equilibrium.* Solving the negotiation stage game by backward induction, the union rejects a settlement offer σ if its utility of the settlement is less than its expected utility of going to arbitration, or

$$u_u(\sigma) < \mathrm{E}\left[u_u\left(y - c_u\right)\right],$$

which simplifies to

$$\sigma < \tilde{y} - c_u, \tag{8}$$

where $\tilde{y} \equiv \frac{-1}{\rho} \log\left(\mathrm{E}\left[\exp\left(-\rho y\right)\right]\right)$ is the union's certainty equivalent to obtaining the random wage increase y.

The employer does not know the union's c_u. Therefore, the employer's problem is

$$\max_{\sigma} F_{c_u}\left(\tilde{y} - \sigma\right)\left(-\mathrm{E}\left[y\right] - c_e\right) + \left[1 - F_{c_u}\left(\tilde{y} - \sigma\right)\right]\left(-\sigma\right), \tag{9}$$

where $F_{c_u}\left(\tilde{y} - \sigma\right)$ is the probability, from the employer's perspective, that the union rejects settlement offer σ. Define a solution to this problem as *interior* if, given σ, there exists a value $c_u^* \in (\underline{c}_u, \bar{c}_u)$ such that, if $c_u = c_u^*$, the union is indifferent between settling the case and going to arbitration. The first-order condition associated with (9), considering an interior solution, is

$$\sigma + \frac{1 - F_{c_u}\left(\tilde{y} - \sigma\right)}{f_{c_u}\left(\tilde{y} - \sigma\right)} = \mathrm{E}\left[y\right] + c_e, \tag{10}$$

where, given 2.i, the ratio in the left-hand side is defined. The following lemma establishes properties of the equilibrium settlement offer.

LEMMA 1. *(i) In equilibrium, the employer never makes a settlement offer strictly greater than* $\tilde{y} - \underline{c}_u$*; and (ii) given Assumption 2, any equilibrium settlement offer that is interior is also unique and strictly increasing in* c_e*,* $\mathrm{E}\left[y\right]$ *and* $\tilde{y}$*.*

Our negotiation model is stylized, as bargaining in practice may not take a strict take-it-or-leave-it form.[15] Nonetheless, it is designed to tractably capture these key

[15]Though stylized, the take-it-or-leave-it solution is relevant. Perry (1986) shows that in an alternating-offer game with two-sided incomplete information where the cost of bargaining takes

properties of bargaining under the shadow of arbitration: (i) the parties may fail to settle even if there exist settlement values that both parties prefer to arbitration, (ii) the settlement offer increases in the union's and decreases in the employer's expected utility of arbitration, (iii) the settlement offer increases in the employer's arbitration cost, and (iv) the probability of reaching a settlement increases in both parties' arbitration costs. As will be evident in Section 6, the focus of this paper is the arbitration stage; our goal in also modeling negotiation is to provide direction on how arbitration affects negotiated outcomes, especially in light of asymmetric risk attitudes.

Finally, we note that the negotiation model is mathematically equivalent to some alternative models. For instance, consider a negotiation model in which the union and employer hold biased expectations of y, such that the union's perceived certainty equivalent of arbitration is shifted from $\tilde{y}$ to $\tilde{y} + \xi_u$, and the employer's expectation of the arbitrated wage is shifted from $\mathrm{E}[y]$ to $\mathrm{E}[y] + \xi_e$, with the bias terms $\xi_{j\in\{u,e\}}$ independently distributed as $\xi_j \sim F_{\xi_j}(\cdot)$. From (8) and (10), it is evident that the settlement offers and union rejection decisions generated by that model are equivalent to those generated by an unbiased model in which the union draws 'arbitration cost' $\tilde{c}_u$ from $\tilde{F}_{c_u}(\cdot)$, where $\tilde{F}_{c_u}(\cdot)$ is the distribution of $c_u - \xi_u$, and the employer draws 'arbitration cost' $\tilde{c}_e$ from $\tilde{F}_{c_e}(\cdot)$, where $\tilde{F}_{c_e}(\cdot)$ is the distribution of $c_e + \xi_u$. In this scenario, the 'arbitration costs' $\tilde{c}_j$ incorporate players' bias ξ_j as well as the actual arbitration costs c_j. Thus, our framework accommodates alternative negotiation models upon adjusting or broadening the interpretation of arbitration costs.

4. Structural Model

4.1. **Data Generating Process.** In our structural analysis, we consider every instance of wage negotiation between a union and an employer as a *case*, which we index by i. We treat the precision of the signals received by the parties and the arbitrator, $h_{\varepsilon,i}$, as a random variable, which has a distribution function $G_{h_\varepsilon}(\cdot)$ and is i.i.d. across cases. We assume that, for any case i, all players learn the realization of $h_{\varepsilon,i}$ at the beginning of the arbitration stage. In addition, we assume that the following random variables are i.i.d. across cases: the arbitration costs, $c_{u,i}$ and $c_{e,i}$; the ideal wage increase, s_i; and the noise terms $\varepsilon_{p,i}$ and $\varepsilon_{a,i}$, conditional on $h_{\varepsilon,i}$.

The model primitives are then: the union's risk aversion parameter, ρ; the parameters of the fair wage increase distribution, m and h; the distribution of signal precision, $G_{h_\varepsilon}(\cdot)$; and the distributions of arbitration costs for the union and the

the form of a fixed cost per period rather than discounting, the unique sequential equilibrium takes the form of a take-it-or-leave-it offer game.

employer, $F_{c_u}(\cdot)$ and $F_{c_e}(\cdot)$. We observe whether each case reaches the arbitration stage. For cases that settle before arbitration, we observe σ_i, the settlement amount. For cases that reach arbitration, we observe the final offers by the union and the employer—respectively $y_{u,i}$ and $y_{e,i}$—as well as y_i, the offer selected by the arbitrator.

Our empirical analysis allows the model primitives to vary with a vector of observable case characteristics, denoted by x_i. Section 5 explains in more detail the way we account for these observable characteristics in our estimation procedure. Moreover, our identification strategy relies on an observable case characteristic, denoted by z_i, that may affect the primitives ρ, m, h and $G_{h_\varepsilon}(\cdot)$—but not the distributions of arbitration costs, $F_{c_u}(\cdot)$ and $F_{c_e}(\cdot)$. For ease of notation, we do not explicitly condition the model primitives on x_i or z_i in our discussion of the identification strategy below, unless doing so is necessary to avoid confusion. Also to facilitate the notation, we omit the index i when we refer to a specific case.

4.2. **Identification.** We present our identification strategy in two parts, beginning with the arbitration stage and working backwards to the negotiation stage.

First, using only data on cases decided by arbitration, we identify the union's risk aversion parameter, the prior distribution of the fair wage increase, and the distribution of signal precision. Our proof is constructive. A high-level intuition for identification is that each $h_{\varepsilon,i}$ is identified from the observed distance between union and employer final offers based on the monotonicity established in Proposition 2(i); the distribution of final offers conditional on between-offer difference identifies the parameters m and h; and risk attitude ρ is identified from a conditional probability of the employer/union winning based on Proposition 2(ii). Formally,

PROPOSITION 3. *Under Assumption 1 and the equilibrium of Proposition 1, the model primitives ρ, m, h and nonparametric distribution $G_{h_\varepsilon}(\cdot)$ are identified from the joint distribution of final offers y_u and y_e and the arbitrator's decision y.*

The proof of Proposition 3 derives, among other things, the following relationship between prior precision h and the conditional variance of final offers, which we reference in the estimation section.

$$\frac{1}{H} = \left(\frac{1}{h\mathrm{Var}\left[y_u|y_u - y_e\right]} - 1\right)\left(\frac{1}{h} + \mathrm{Var}\left[y_u|y_u - y_e\right]\right). \tag{11}$$

Next, we address identification of the union's and employer's arbitration cost distributions, $F_{c_u}(\cdot)$ and $F_{c_e}(\cdot)$, respectively. For this, we expand the set of observables to include the probability of settlement and settlement amounts conditional on settlement. As the employer's settlement offer is an increasing function of c_e, the observed settlement amounts give us information about $F_{c_e}(\cdot)$. It is important to note, however, that we only observe settlement amounts *conditional* on settlement. As we derive in the proof of the next Proposition, the density of settlement offers conditional on settlement, $b^*(\cdot)$, relates to the primitive $f_{c_e}(\cdot)$ according to

$$b^*(\sigma) = \frac{[1 - F_{c_u}(\tilde{y} - \sigma)] f_{c_e}(\xi(\sigma))\xi'(\sigma)}{\int_{x=\underline{\sigma}}^{\bar{\sigma}} [1 - F_{c_u}(\tilde{y} - x)] f_{c_e}(\xi(x))\xi'(x)dx}, \tag{12}$$

where

$$\xi(\sigma) \equiv \sigma + \frac{1 - F_{c_u}(\tilde{y} - \sigma)}{f_{c_u}(\tilde{y} - \sigma)} - \mathrm{E}[y] \tag{13}$$

is the inverse settlement offer function, which maps settlement offer σ to the associated c_e. The denominator of (12) expresses the probability of settlement. We exploit the above relationship between $b^*(\cdot)$ and $f_{c_e}(\cdot)$ for identification.

In addition, our identification strategy employs an observable case characteristic, represented by the variable $z \in \mathcal{Z}$, that affects the model primitives ρ, m, h and $G_{h_\varepsilon}(\cdot)$. Through its effect on these model primitives, z affects the distribution of y, the arbitrated wage increase. We may thus write the union's certainty equivalent to obtaining y in arbitration as a function of z, denoted by $\tilde{y}(z)$. Similarly, denote the equilibrium settlement offer set by an employer, as a function of her arbitration costs c_e and the variable z, by $\sigma(c_e, z)$. We make the following assumptions regarding z:

Assumption 3. *(i) Given any $z_1, z_2 \in \mathcal{Z}$, we have $F_{c_j}(c|z = z_1) = F_{c_j}(c|z = z_2)$ for all $c \in [\underline{c}_j, \bar{c}_j]$, $j \in \{u, e\}$; (ii) $\forall c \in (\underline{c}_u, \bar{c}_u)$ there exists $z \in \mathcal{Z}$ such that $\tilde{y}(z) - \sigma(\bar{c}_e, z) = c$.*

Assumption 3(i) resembles an exclusion restriction for an instrumental variable—that is, changes in the wage shifter z do not affect the distribution of arbitration costs for the union or the employer. Assumption 3(ii) plays the role of a full support assumption establishing sufficient variation in $\tilde{y}$. Specifically, from the employer's negotiation stage first-order condition in (10), we see that a change in $\tilde{y}$ leads to a response in the employer's settlement offer that is mediated by $F_{c_u}(\cdot)$. As a result, changes in observed settlement offers caused by variation in $\tilde{y}$ give us information about the shape of $F_{c_u}(\cdot)$. This assumption guarantees that the amount of variation is sufficient to inform us about the shape of $F_{c_u}(\cdot)$ over its full support. Proposition 4 formally states the identification result. Our purpose in providing a nonparametric identification argument is to clarify the sources of identification. In empirical applications with finite samples, cost distributions may be estimated under weaker conditions by employing parametric specifications.

PROPOSITION 4. *Under Assumptions 2 and 3, the arbitration cost distributions for the union and employer, $F_{c_u}(\cdot)$ and $F_{c_e}(\cdot)$, are nonparametrically identified.*

5. ESTIMATION

Our estimation procedure closely follows the identification strategy presented in Section 4.2. It has two main steps. First, we estimate the union's risk aversion parameter, the mean and precision of the prior distribution of the fair wage and the distribution of signal precision. This first estimation step only employs the ARB_F data, on cases resolved by final-offer arbitration. Second, we estimate the distributions of arbitration costs for the union and the employer. This second step uses the SET_F data set, comprising cases that settled from 1978-1995, in addition to ARB_F.

We accommodate observed case heterogeneity by allowing the model primitives to vary with a vector of case characteristics, which we denote by x_i. This vector contains the following covariates from Table 2, column (2): the 12-month percent change in the Consumer Price Index; the log of taxable property per capita in the municipality (*log tax base*); the number of years covered by the contract; the mean arbitrated salary increase in other municipalities in the same county (*othermuni*); and year-group fixed effects. Section 2.3 provides a detailed description of each of these variables. As shown there, this set of covariates allows us to achieve explanatory power similar to that of the longer list of covariates we considered, while limiting the number of parameters to be estimated from our finite sample.

Regarding the model primitives that are distributions, Section 4.2 provides nonparametric identification arguments for the distribution of signal precision, $G_{h_\varepsilon}(\cdot)$, and the distributions of arbitration costs for the union and employer, $F_{c_u}(\cdot)$ and $F_{c_e}(\cdot)$. We estimate $G_{h_\varepsilon}(\cdot)$ nonparametrically following the identification argument. Meanwhile, we specify concise parametric distributions for $F_{c_u}(\cdot)$ and $F_{c_e}(\cdot)$ so that we do not rely on the full support assumption, Assumption 3(ii), required for nonparametric identification of the cost distributions. We then estimate the parameters of $F_{c_u}(\cdot)$ and $F_{c_e}(\cdot)$ via maximum likelihood. Readers wishing to skip the details of implementing the estimator may proceed to Section 6 for the post-estimation analysis.

5.1. **Risk attitude, moments of the fair wage, and signal precision.** Recall that, for every case i, we denote by $y_{u,i}$ and $y_{e,i}$ the final offers by the union and the employer, respectively. Also, define $d_{1,i} \equiv \delta_{u,i} + \delta_{e,i} = y_{u,i} - y_{e,i}$, the distance or gap between the union's and employer's final offers. Let the indicator a_i be equal to one if the arbitrator rules in favor of the employer in case i and zero otherwise, and define $p_i \equiv \mathrm{E}(a_i|d_{1,i})$, the probability the employer wins conditional on $d_{1,i}$.

We estimate ρ, the union's risk aversion parameter, following the argument of Proposition 3. As explained in the proof, Proposition 2(i) and (6) imply that $p_i = \Phi\left(\eta_i(\delta_{u,i} - \delta_{e,i})/2\right)$. Then, by (7),

$$\frac{p_i}{1-p_i} = \frac{\rho d_{1,i}}{\exp\left(\rho d_{1,i}\right) - 1}.$$

Based on this result, we propose the following estimator for ρ:

$$\hat{\rho} \equiv \arg\min_{\rho} \sum\nolimits_i \left[\frac{\hat{p}_i}{1-\hat{p}_i} - \frac{\rho d_{1,i}}{exp(\rho d_{1,i}) - 1}\right]^2,$$

where $\hat{p}_i$ is a preliminary estimate of p_i, which we obtain via a parametric logistic regression of a_i on $d_{1,i}$.

Next, we estimate the mean and precision of the prior distribution of the fair wage, together with the distribution of signal precision. We begin by rewriting the identifying equations in a form convenient for estimation. First, recall that, at the moment the parties formulate their final offers (that is, conditional on the parties' signal), their belief about the distribution of the arbitrator's signal has precision

$$H_i \equiv \frac{h_{\varepsilon,i}\left[h_i + h_{\varepsilon,i}\right]}{h_i + 2h_{\varepsilon,i}}. \tag{14}$$

Plugging $p_i = \Phi\left(\eta_i(\delta_{u,i} - \delta_{e,i})/2\right)$ in (5) and rearranging yields an expression for H_i in terms of observables,

$$H_i = \left[\frac{2p_i}{\phi\left[\Phi^{-1}\left(p_i\right)\right] d_{1,i}}\right]^2. \tag{15}$$

Second, rearranging (11), we obtain an expression for h_i in terms of H_i and a conditional variance of the final offers,

$$h_i = \left[\mathrm{Var}\left(y_{u,i}|d_{1,i}, x_i\right)\left(\frac{1}{H_i} + \mathrm{Var}\left(y_{u,i}|d_{1,i}, x_i\right)\right)\right]^{-\frac{1}{2}} \equiv \zeta_i. \tag{16}$$

Third, define $d_{2,i} \equiv \left(\delta_{u,i} - \delta_{e,i}\right)/2$. Using $\eta_i \equiv \sqrt{H_i}(h_i + 2h_{\varepsilon,i})/h_{\varepsilon,i}$ and rearranging $p_i = \Phi\left(\eta_i(\delta_{u,i} - \delta_{e,i})/2\right)$ yields an expression for $d_{2,i}$,

$$d_{2,i} = \frac{h_{\varepsilon,i}\Phi^{-1}\left(p_i\right)}{\sqrt{H_i}\left[h_i + 2h_{\varepsilon,i}\right]}. \tag{17}$$

Now we set up the estimation equations. For estimation, we let the mean and precision of the fair wage depend on the covariate vector x_i according to $m_i = m(x_i; \theta_m)$

and $h_i = h(x_i;\theta_h)$, respectively, adopting the specifications

$$m(x_i;\theta_m) = x_i\theta_m \text{ and } h(x_i;\theta_h) = 1/\exp(x_i\theta_h).$$

The latter specification constrains h to be non-negative since precision is the inverse of the variance. Our task is to estimate the parameter vectors θ_m and θ_h, as well as $h_{\varepsilon,i}$, the signal precision for each case i. To estimate θ_h, let $\hat{V}_i$ be an estimator of $\text{Var}\,(y_{u,i}|d_{1,i},x_i)$,[16] define $\hat{H}_i$ by substituting $\hat{p}_i$ for p_i in (15), and let $\hat{\zeta}_i \equiv \left[\hat{V}_i\left(1/\hat{H}_i + \hat{V}_i\right)\right]^{-\frac{1}{2}}$. Then, based on (16), we estimate θ_h as

$$\hat{\theta}_h \equiv \arg\min \sum_i \left[\hat{\zeta}_i - h(x_i;\theta_h)\right]^2.$$

We then estimate the signal precision *for each arbitration case* in the sample by solving for $h_{\varepsilon,i}$ in (14), using $h(x_i;\hat{\theta}_h)$ and $\hat{H}_i$ in place of h_i and H_i. Finally, to estimate θ_m, define $\hat{d}_{2,i}$ by substituting $\hat{h}_{\varepsilon,i}$, $\hat{p}_i$, $\hat{H}_i$ and $h(x_i;\hat{\theta}_h)$ for $h_{\varepsilon,i}$, p_i, H_i and h_i in (17), respectively. Then, in light of $(y_{u,i}+y_{e,i})/2 - d_{2,i} = M_p(s_{p,i})$ and $\text{E}\left[M_p(s_{p,i}) - m_i\right] = 0$ (see Proposition 1 and the proof of Proposition 3), we estimate θ_m as

$$\hat{\theta}_m \equiv \arg\min_{\theta_m} \sum\nolimits_i \left[\frac{y_{u,i}+y_{e,i}}{2} - \hat{d}_{2,i} - m(x_i;\theta_m)\right]^2.$$

We now discuss our estimates of ρ, θ_m, θ_h, and $h_{\varepsilon,i}$. Our estimate of the risk aversion parameter is $\hat{\rho} = 0.53$. By definition, the CARA risk aversion parameter has units of 1/(unit of the argument). Since the argument of the utility function in our setting has units of percentage points, a comparison to measures of CARA risk aversion in other settings requires a conversion. For example, if one percentage point of wage increase represents about \$500, our CARA parameter converts to about $0.53/500 = 0.00106$ in units of 1/\$. This amount is in the range of CARA estimates from various studies summarized by Babcock et al. (1993).

Next, Table 3 reports the estimates of θ_m and θ_h. For $m(x_i;\theta_m)$, we extend x_i by including the square of the number of years covered by the contract to allow for a nonlinear effect. Inflation, the size of the municipality's tax base, and *othermuni* each have a positive marginal effect on both the mean and the variance $1/h$ of the fair wage increase. These results are intuitive and consistent with the patterns presented in Section 2.3. Longer contracts, meanwhile, are associated with smaller variance,

[16]We obtain $\hat{V}_i$ by, first, using single index kernel regressions of the union's final-offer on $d_{1,i}$ and x_i to compute estimates of $\text{E}\left[y_{u,i}|d_{1,i},x_i\right]$ and $\text{E}\left[y_{u,i}^2|d_{1,i},x_i\right]$, and then applying the standard expression of the variance of a random variable in terms of the mean of its square and the square of its mean.

TABLE 3. Parameter estimates in $m(x_i;\theta_m)$ and $h(x_i;\theta_h)$

x_i	$\hat{\theta}_m$	$\hat{\theta}_h$
CPI 12mo pct change	0.10	0.08
Log tax base	0.07	0.03
Num years covered by contract	-0.85	-0.40
Squared num years covered by contract	0.13	- -
Othermuni	0.33	0.03
Year group fixed effects	Y	Y

Notes: Table reports estimates of the parameters, θ_m and θ_h, of the prior mean m and precision h of the fair wage distribution. Units are percentage points of initial wages.

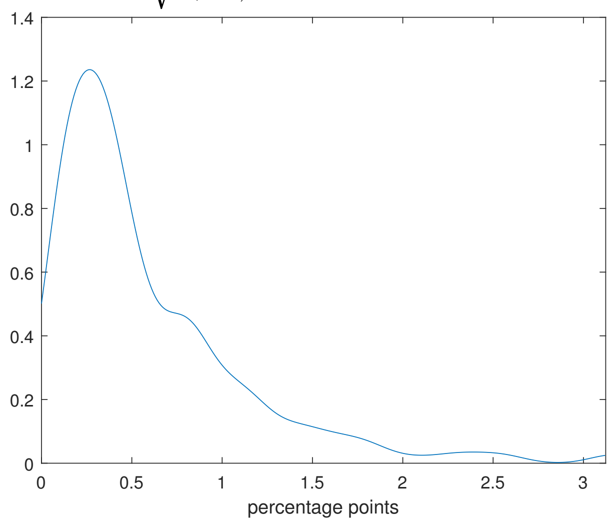
indicating that the range of wage increases considered appropriate is narrower when the contract has longer-term influence on wages.

The median of $m(x_i;\hat{\theta}_m)$, the prior mean of the fair wage, is 7.5 percentage points in the ARB_F data set, while the 1st and 99th percentiles are 4.4 and 9.1 percentage points, respectively. The median of $\sqrt{1/h(x_i,\hat{\theta}_h)}$, the prior standard deviation of the fair wage, is 1.7 percentage points, while the 1st and 99th percentiles are 0.6 and 2.7 percentage points, respectively. Figure 1 plots the kernel density of $\sqrt{1/\hat{h}_{\varepsilon,i}}$, the estimated standard deviation of the noise term ε in the players' signals of the fair wage. The median of $\sqrt{1/\hat{h}_{\varepsilon,i}}$ is 0.4 percentage points, so the variance of the signal noise is typically a fraction of the prior variance of the fair wage itself.

5.2. **Arbitration costs.** For each case i in the combined ARB_F and SET_F sample, let $e_i = 1$ if the dispute is resolved through arbitration (that is, the case belongs to the ARB_F data set), and $e_i = 0$ otherwise. Recall that σ_i denotes the settlement offer made by the employer at the negotiation stage, and $c_{u,i}$ and $c_{e,i}$ are the arbitration costs for the union and the employer, respectively.

In Proposition 4, the argument for separately identifying the two parties' arbitration costs involves an excluded variable, denoted by z_i, which affects arbitration payoffs but does not affect arbitration costs. In our empirical application, we specify *othermuni*, the mean arbitrated wage increase in other municipalities of the same county, as the instrument z_i. As discussed in Section 5.1, our estimates indicate that *othermuni* does indeed affect arbitration payoffs—which is not surprising, since, by the statutory criteria listed in Section 2, the arbitrator's judgement explicitly takes *othermuni* into account. At the same time, it is plausible to assume that this variable does not affect the costs of arbitrating a case in one's own municipality. Denote by

FIGURE 1. Density of $\sqrt{1/\hat{h}_{\varepsilon,i}}$, the standard deviation of signal noise



Notes: Figure displays kernel density of $\sqrt{1/\hat{h}_{\varepsilon,i}}$ based on Gaussian kernels and bandwidth given by Silverman's rule of thumb. The plot is truncated at the 95th percentile.

x_i^* the vector of all the covariates in x_i other than *othermuni*. Then, let $F_{c_u}(\cdot|x_i^*)$ and $F_{c_e}(\cdot|x_i^*)$ be the conditional distributions of $c_{u,i}$ and $c_{e,i}$, respectively, and denote by $f_{c_u}(\cdot|x_i^*)$ and $f_{c_e}(\cdot|x_i^*)$ the associated conditional densities. We parameterize $F_{c_u}(\cdot|x_i^*)$ and $F_{c_e}(\cdot|x_i^*)$ so that they are independently and normally distributed with mean $x_i^*\theta_u$ and $x_i^*\theta_e$, respectively, and variance γ^2. Define $\theta_a \equiv \{\theta_u; \theta_e; \gamma^2\}$.

Meanwhile, let $\mathrm{E}[y_i|x_i^*, z_i]$ and $\tilde{y}(x_i^*, z_i)$ be, respectively, the expected arbitrated wage increase and the union's certainty equivalent of going into arbitration, conditional on x_i^* and z_i. In other words, these values represent the expected payoffs of going to arbitration from the perspective of each party at the negotiation stage. As a preliminary estimation step, we compute these expected arbitration payoffs for each case in the combined ARB_F and SET_F data. Given each observed set of covariates x_i^* and z_i, the parameters $\hat{\rho}$, $\hat{\theta}_h$ and $\hat{\theta}_m$, and the nonparametric distribution of $\hat{h}_\varepsilon$ as estimated in Section 5.1, we simulate the arbitration game many times. Then, we numerically integrate over random draws of the stochastic components to form ex ante expectations of the payoffs. The stochastic components include h_ε, which we draw randomly from the distribution of $\hat{h}_\varepsilon$ conditional on the year group, and s, ε_a and ε_p, which are distributed according to Assumption 1. For each case i, denote by π_i^u and π_i^e the simulated values of $\tilde{y}(x_i^*, z_i)$ and $-\mathrm{E}[y_i|x_i^*, z_i]$, respectively.

In the negotiation stage, the observables are the arbitration dummy e_i and, in those cases where $e_i = 0$, the value of the settlement σ_i. We thus estimate θ_a using a maximum likelihood approach, by finding the value of θ_a that maximizes the likelihood of the observed e_i and σ_i values. That is, we estimate

$$\hat{\theta}_a = \arg\max_{\theta_a} L_n(\theta_a).$$

The log-likelihood $L_n(\theta_a)$ is given by

$$L_n(\theta_a) \equiv n^{-1} \sum\nolimits_i \left[(1-e_i)\log l_{s,i}(\sigma_i;\theta_a) + \Omega e_i \log l_{a,i}(\theta_a)\right],$$

where

$$l_{s,i}(\sigma_i;\theta_a) \equiv \left[1 - F_{c_u}\left(\pi_i^u - \sigma_i | x_i^*\right)\right] f_{c_e}\left(\xi_i(\sigma)|x_i^*\right)\xi_i'(\sigma),$$

$$\text{and} \qquad l_{a,i}(\theta_a) \equiv \int F_{c_u}(\pi_i^u - t|x_i^*) f_{c_e}(\xi_i(t)|x_i^*)\xi_i'(t)dt.$$

The term $l_{s,i}(\sigma;\theta_a)$ above is the likelihood of the observed settlement σ_i; it corresponds to the numerator of (12), the density of settlement offers conditional on settlement. The term $l_{a,i}(\theta_a)$ is the likelihood of $e_i = 1$, that is, the likelihood of arbitration in case i; it corresponds to one minus the denominator of (12). The proof of Proposition 4 provides the derivation of (12). The function $\xi_i(\cdot)$ is the inverse settlement offer function, as defined in (13), where we substitute π_i^u and π_i^e for $\tilde{y}$ and $-\mathrm{E}[y]$, respectively. Finally, the weighting term Ω is defined as

$$\Omega \equiv \frac{R}{1-R}\frac{N_{SET_F}}{N_{ARB_F}},$$

where R refers to the empirical arbitration rate and N_{SET_F} and N_{ARB_F} are the number of observations in the SET_F and ARB_F data sets, respectively. Recall from Section 2.3 that we compute $R = 0.264$. This weighting adjustment is necessary, as the SET_F data is a random sample of cases settled prior to arbitration, whereas the ARB_F data set comprises the universe of arbitrated cases. The term Ω adjusts the objective function L_n so that it converges to the same limit as it would would under a simple random sampling scheme across both settled and arbitrated cases.

Table 4 reports the maximum likelihood estimates of $\theta_a \equiv \{\theta_u;\theta_e;\gamma^2\}$. The costs of arbitration for both parties are positively associated with inflation, the local tax base and the number of years covered by the contract.

5.3. **Model fit.** To assess model fit, we perform Monte Carlo simulations with our estimated model to simulate 1000 cases for each set of covariates x_i observed in the relevant data. Figures A2 and A3 in the Appendix plot the observed versus model-simulated outcome distributions. The model achieves a close fit to the observed

Table 4. Estimates of arbitration cost parameters

	$\hat{\theta}_u$	$\hat{\theta}_e$
CPI 12mo pct change	0.10	0.64
Log tax base	0.83	2.95
Num years covered by contract	1.26	5.13
Year group fixed effects	Y	Y
$\hat{\gamma}$	7.62	

Notes: Table reports estimates of the arbitration cost distribution parameters, θ_u, θ_u and γ. Units are percentage points of initial wages.

distribution of final offers for both the union and the employer. The average observed and model-simulated probabilities of the employer winning arbitration are 0.374 and 0.387, respectively. In the negotiation stage, the average observed and model simulated probabilities of going to arbitration are 0.264 and 0.251, respectively. The model also fits well the observed settlement distribution, especially considering that we estimate a concise parametric specification for the distribution of arbitration costs.

6. Counterfactual analyses

Having estimated our model, we now turn to addressing questions about the properties of arbitration in practice. We begin by investigating the effects of asymmetric risk attitudes on arbitration outcomes given our two-stage model in which bargaining failure leads to arbitration. Next, we compare the two most popular forms of arbitration—final-offer and conventional—in terms of the offers they elicit from the disputing parties, the distribution of arbitrated outcomes, their conduciveness to information revelation, and the distance between arbitrated awards and the fair wage.

6.1. **The effect of risk aversion.** According to estimates from Section 5.1 and consistent with evidence in Section 2.3, New Jersey police and fire unions are risk-averse in the period that we analyze. Risk aversion is likely to be present in labor negotiations of other states and industries as well as in contexts other than labor, such as the arbitration of disputes between consumers and businesses. As such, an analysis of arbitration would not be complete without investigating how risk aversion interacts with the dispute resolution mechanism to affect the arbitration stage, the negotiation stage, and the ultimate outcomes (wage increases) in light of both stages.

To study this question, we counterfactually simulate a scenario in which both the union and the employer are risk-neutral. Specifically, we perform Monte Carlo simulations of both the arbitration and negotiation stages of the model, 1000 times for each set of covariate values x_i observed across the ARB_F and SET_F data sets. This results in a total of 1,482,000 simulated cases. In the arbitration stage, the simulation process involves taking random draws of h_ϵ, s, ϵ_p, and ϵ_a conditional on the covariates and simulating the parties' final offers and arbitrator's decision. The parties' expected payoffs from arbitration are simulated in the same manner as described in the estimation section, accounting for both parties now being risk neutral. In the negotiation stage, the simulation randomly draws arbitration costs c_e conditional on covariates and solves for the employer's settlement offer as well as the union's probability of rejecting it given the estimated distribution of c_u.

Table 5 compares simulated outcomes when the union is risk-averse, as estimated in our data, to the simulated counterfactual outcomes when the union is risk neutral. Table 5, row (a) shows that, when the union is risk-averse, it chooses a more conservative final offer than in the risk neutral scenario, asking for a smaller wage increase. The employer is also less aggressive in response, but its offer does not change as much as the union's. As a result, the risk-averse union wins more than half of the time, whereas both parties win with equal frequency when the union is risk neutral. Table 5, row (d) shows that, due to this difference in the probability of winning arbitration, the risk-averse union actually obtains a larger arbitrated wage increase, on average, than it would in the risk neutral scenario. Yet despite the larger arbitrated wage on average, the risk-averse union's certainty equivalent of arbitration is lower than in the risk neutral scenario because the risk premium of arbitration is sufficiently large.

This low certainty equivalent of arbitration weakens the union's position in the negotiation stage preceding arbitration; that is, it lowers the threshold of settlement offers that the union is willing to accept and consequently lowers the employer's settlement offers in light of the first-order condition in equation (10) and its properties in Lemma 1. Thus, while the probability of failing to settle and proceeding to arbitration is ultimately similar in both the risk-averse and risk neutral scenarios, the risk-averse union obtains lower settlement amounts than a risk-neutral union, as seen in Table 5, row (g). Finally, in Table 5, row (h), we consider the overall ex ante expected wage increase, incorporating both the negotiation and arbitration stages of the wage-setting process. We find that the union's risk aversion costs it 0.2 percentage points in annual wage increases on average, at 6.8 percentage points versus 7.0 in the risk

TABLE 5. Risk-averse union versus risk-neutral union

	risk averse	risk neutral
Arbitration stage outcomes:		
(a) Mean union offer	7.6	8.0
(b) Mean employer offer	6.0	5.8
(c) Probability of union win	0.60	0.50
(d) Mean arbitrated wage increase	7.1	6.9
(e) Union's certainty equivalent	6.3	6.9
Negotiation stage outcomes:		
(f) Probability of arbitration	0.25	0.26
(g) Mean settlement amount	6.6	7.0
Overall:		
(h) Ex ante expected wage increase	6.8	7.0

Notes: The arbitration and negotiation stages of the model are Monte Carlo simulated 1000 times conditional on each set of covariates in the ARB_F and SET_F data sets; thus, the table presents average outcome across a total of 1,482,000 simulated cases. Units are percentage points, excluding probabilities. Employer is risk neutral throughout.

neutral scenario. Together, rows (d) and (h) of Table 5 yield an interesting insight. When considering the arbitration stage in isolation, the arbitrated wage increase is favorable to the risk-averse party, as seen in the first versus second column of row (d). However, when considering the entire wage-setting process which includes pre-arbitration negotiations, the risk premium of arbitration ultimately places the more risk-averse party at a disadvantage, as seen in the lower wage increase in the first versus second column of row (h). This is broadly consistent with related insights from the theory literature including Crawford (1982) and Hanany et al. (2007) who find a disadvantage for the risk-averse party in Nash bargaining when the disagreement outcome is final-offer arbitration (with no learning by the arbitrator).

6.2. **Offers and awards in CA versus FOA.** In this section, we compare two commonly employed forms of arbitration, final-offer (FOA) and conventional (CA), in terms of the offers they induce from the disputing parties and the resulting distribution of arbitration awards. We complement observational comparisons of FOA and CA jurisdictions and cases, such as Feuille (1975), Bloom (1981) and Ashenfelter and Bloom (1984), by leveraging our structural model to compare how the same case would fare under FOA versus CA. Specifically, we compare outcomes observed under New Jersey's implementation of CA after 1996 to counterfactual model simulations of FOA for the same arbitration cases.

Whether the offers in CA differ from those in FOA is an empirical question. Unlike FOA, where the parties' offers directly affect payoffs because one of them must be chosen as the arbitration award, CA does not impose such a constraint. As a result, the parties' offers in CA may matter only indirectly through the information they convey to the arbitrator. In other words, the offers in CA are cheap-talk. Gibbons (1988) explains that if the arbitrator in CA enforces a large transfer from the party who seems to have made the less reasonable offer to the party who seems to have made the more reasonable offer—effectively mimicking the incentives toward reasonable offers created in FOA—then there is a separating equilibrium of CA that generates the same offers as FOA. However, like all cheap-talk games, that CA game has a continuum of payoff-equivalent separating equilibria that differ only by a translation, in which the distance between parties' offers are different from those in FOA. Moreover, we have no reason to believe that arbitrators enforce such transfers in practice. The effect of FOA versus CA on the distribution of arbitrated wages is also an empirical question. On the one hand, the pendulum nature of FOA, which forces the arbitrator to choose one party's offer or the other, may increase the variance of awards by eliminating awards in the middle. On the other hand, this restriction of FOA may also serve to eliminate the tails of potential awards and thus decrease variance, especially if the two parties' offers are closer together in FOA than in CA.

Since cheap-talk games raise the possibility that the equilibrium in play may not be separating, we do not posit any specific equilibrium for CA in our analysis. Instead, we simply report the observed outcomes of conventional arbitration in the ARB_C data set, defined in Section 2.3. We do make the following two assumptions that provide minimal structure for a meaningful comparison. The first is that in CA the arbitrator imposes y_a, her updated expectation of the fair wage after observing the offers, as the award. Recall that in FOA, the arbitrator chooses the offer that is closest to y_a as the award because the rules constrain her to choose one of the parties' offers. CA does not impose such constraints and gives the arbitrator freedom to impose y_a directly.[17] The second is that $\mathrm{E}[y_a] = m$ in CA, as it is in FOA. We can prove this assumption is true both in the case of a separating equilibrium and in the opposite case, when the arbitrator cannot infer any information from the parties' offers.[18]

[17]Indeed, that the arbitrator imposes her notion of the fair wage as the award is the standard view of arbitrator behavior in conventional arbitration; see, for example, Ashenfelter et al. (1992).

[18]In a separating equilibrium where the arbitrator infers s_p from the parties' offers, $y_a = (hm + h_\epsilon s_p + h_\epsilon s_a)/(h + 2h_\epsilon)$ by the normal learning model. In an equilibrium where the arbitrator infers nothing about s_p, $y_a = (hm + h_\epsilon s_a)/(h + h_\epsilon)$. By the definitions of s_p and s_a in Section 3, it follows immediately that $\mathrm{E}[y_a] = m$ in both cases.

As defined in Section 5, let x_i refer to a vector of covariates that describe case i, and let x_i^* refer to x_i excluding *othermuni*. Recall that the ARB_C data comprise the years 1996-2000. For purposes of simulation, we let these years belong to the same year-group as the last years in the estimation sample, 1993-1995. Then the model parameters for each post-96 case are specified as follows, using notation defined in Section 5. First, we specify $m_i = m(x_i; \theta'_m)$. Since we observe arbitration awards which equal y_a in CA, and $\mathrm{E}[y_a] = m$, we estimate θ'_m as $\hat{\theta}'_m \equiv \arg\min_{\theta'_m} \sum_i [y_{a,i} - m(x_i; \theta'_m)]^2$. Second, we use estimated parameters $\hat{\rho}$ and $\hat{\theta}_h$ from Section 5 to specify $\rho = \hat{\rho}$ and $h_i = h(x_i; \hat{\theta}_h)$. Finally, we draw $h_{\epsilon,i}$ randomly from the nonparametric distribution of $\hat{h}_{\epsilon,i}$ given the year group.

Given these model parameters, we perform Monte Carlo simulations of the final-offer arbitration model, 1000 times for each set of covariate values x_i observed in the ARB_C data set. The process of simulation is analogous to that described in the previous subsection. The second column of Table 6 presents the results of these simulations, while the first column presents observed CA statistics for comparison.

We note a number of interesting differences between CA and FOA. First, Table 6, row (a) shows that the gap between parties' offers is noticeably narrower in FOA than in CA; in other words, the parties take more reasonable positions in FOA. Since the arbitrator is constrained to choose one of the two offers in FOA, there is pressure for the parties to submit reasonable offers in order to be the one chosen. CA offers, meanwhile, diverge more, notwithstanding the theoretical possibilities discussed above. Second, examining rows (b)–(d) of Table 6, we find that the arbitrated wage increase would be slightly higher or similar in FOA even though the midpoint of parties' offers would be lower. This is driven by the winning offer being imposed without compromise in FOA while the union wins more than half of the time; the interaction of arbitration format with the union's risk aversion has consequences here. Third, the standard deviation of the arbitrated wage increase would be about forty percent higher in FOA, as shown in Table 6, row (e). This empirical finding supports the argument made in Stevens (1966) that FOA is likely to generate more uncertainty for the parties. However, we do not find support for Stevens' related prediction that FOA would significantly lower the parties' certainty equivalent of arbitration and thereby encourage settlement. Given the estimated risk aversion parameter $\rho = 0.53$ and the respective distributions of arbitrated wage increases shown in Table 6, the difference in the union's certainty equivalent of FOA versus CA is minor, at approximately 0.02

Table 6. Conventional versus final-offer arbitration, 1996-2000

	Conventional, observed	Final-offer, simulated
(a) Mean difference between parties' offers	2.5	0.9
(b) Mean midpoint of parties' offers	4.0	3.7
(c) Probability of union win	n/a	0.56
(d) Mean arbitrated wage increase	3.7	3.8
(e) Std. dev. arbitrated wage increase	0.5	0.7

Notes: Column 1 shows average outcomes of the 117 observations in ARB_C. Column 2 Monte Carlo simulates the arbitration model 1000 times conditional on each set of covariates in ARB_C; thus, it presents average outcomes across a total of 117,000 simulated cases. Offers and wage increases are in units of percentage points.

percentage points.[19] Thus, differences in certainty equivalents are not a major factor in the FOA-CA comparison in New Jersey.

Meanwhile, it is notable that the disputing parties' offers are more distant in CA than in FOA, meaning that the parties take more exaggerated positions. While this does not necessarily imply that offers in CA are less informative to the arbitrator as signals of the fair wage, it is nonetheless suggestive in that regard. We investigate this possibility in the next section.

6.3. **Information transmission in CA versus FOA.** As explained above, a key difference between the final-offer (FOA) design and the conventional arbitration (CA) design is that the latter is a cheap-talk game, in which it may be difficult for the arbitrator to infer precise information from the parties' offers. Our estimated model of FOA combined with observed data on CA grants us a unique opportunity to assess the degree of information transmission in CA relative to FOA in practice.

For tractable analysis, we first develop a concise representation of the degree of information transmission. Specifically, we represent the degree of information transmission by a scalar $\alpha \in [0, 1]$, where a higher value of α indicates better transmission; $\alpha = 1$ represents full communication or a separating equilibrium, $\alpha = 0$ represents no communication, and $\alpha \in (0, 1)$ represents the spectrum of imperfect information transmission in between. To aid intuition, the next paragraph provides one possible microfoundation for such a representation.

[19]Given that we are agnostic about the specific equilibrium in CA, we numerically approximate the union's certainty equivalent of CA by two separate methods: 1) exploiting the observed distribution of CA awards, and 2) exploiting the degree of information transmission we estimate in Section 6.3. We check these against 3) the analytical approximation based on normal distributions, $\mathrm{CE}(y) = \mathrm{E}(y) - 0.5\rho\mathrm{Var}(y)$. All three methods yield a CA-FOA difference of about 0.02 percentage points.

Suppose the arbitrator is unable to infer s_p perfectly from the arbitration process and can only infer a noisy measure of it, $s_p^* \equiv s_p + \epsilon_n$, where ϵ_n is an exogenous, mean-zero error that is normally distributed with precision h_n. Then, $s_p^* = s + \epsilon_p + \epsilon_n = s + \epsilon_p^*$, where $\epsilon_p^* \equiv \epsilon_p + \epsilon_n$ is normally distributed with mean zero and precision

$$h_p^* \equiv h_\epsilon \frac{h_n}{h_\epsilon + h_n}$$

by the Bienaymé formula for variance. The effective precision h_p^* of the signal the arbitrator infers, s_p^*, equals the original precision h_ϵ multiplied by a fraction $h_n/(h_\epsilon + h_n)$. This fraction goes to 1 as $h_n \to \infty$, the scenario in which the arbitration process perfectly reveals s_p, and goes to 0 as $h_n \to 0$, the scenario in which the arbitration process reveals nothing about s_p. Thus, we may reasonably represent the degree of information transmission by a scalar $\alpha \in [0, 1]$ so that $h_p^* = \alpha h_\epsilon$, where a higher value of α indicates better transmission.

Now consider the implications for the arbitrator's preferred award y_a as α increases. Intuitively, the more precisely the arbitrator is able to learn about s_p, the more weight she will give to it in forming her preferred award y_a. Therefore, we would expect more of the variance of y_a to be explained by s_p^* when α is larger.[20] Indeed, our simulation results, to be discussed below, verify this numerically.

Thus, as an intuitive measure of information transmission, we consider the R^2 of regressing the arbitrator's preferred award, y_a, on the signal she infers from the parties' offers, s_p^*. That is, we can assess the degree of information transmission in the observed conventional arbitration (CA) data by comparing the R^2 of such a regression to that in simulated data. Specifically, we simulate y_a data given each value of α over a grid in $[0, 1]$ and look for the value of α, or degree of information transmission, that generates the R^2 most consistent with the observed R^2. Note that we do not need to know the parties' equilibrium offer strategies in CA to be able to simulate the regressand y_a; as before, we remain agnostic in that regard. Regardless of how she does it, if the arbitrator ultimately infers s_p^* as defined above, and this has precision $h_p^* = \alpha h_\epsilon$, then $y_a = (hm + h_p^* s_p^* + h_\epsilon s_a)/(h + h_p^* + h_\epsilon)$ by the normal learning model.

Given this conceptual framework, we implement our assessment as follows. First, we simulate, given each value of α on a grid in $[0, 1]$, 1000 Monte Carlo samples of $s_p^* \equiv s + \epsilon_p^*$ and $y_a = (hm + h_p^* s_p^* + h_\epsilon s_a)/(h + h_p^* + h_\epsilon)$ per each set of covariates x_i observed in ARB_C. As explained above, ϵ_p^* is normally distributed with mean zero

[20]Let $\tilde{y}_a$ be the linear projection of y_a on s_p^*. Given the normal learning model, we can prove analytically that $\text{var}(\tilde{y}_a)/\text{var}(y_a)$ is strictly increasing in the degree of information transmission, α.

and precision $h_p^* = \alpha h_\epsilon$, where h_ϵ is drawn from the distribution of h_ϵ previously estimated. Then using the entire Monte Carlo sample associated with each α value, we run the OLS regression

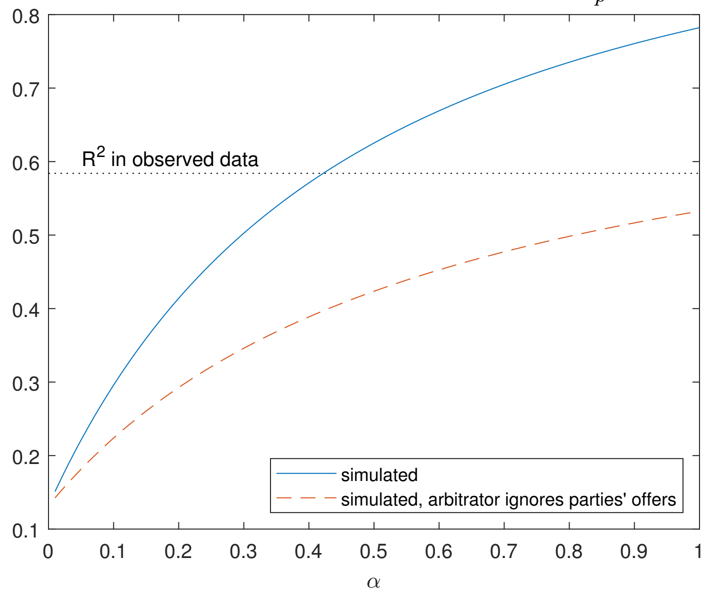
$$y_{a,i} = \beta_0 + \beta_1 m_i + \beta_2 s^*_{p,i} + \nu_i \tag{18}$$

and obtain the resulting $R^2(\alpha)$. The regressor $m_i = m(x_i; \hat{\theta}'_m)$ is simply a control for the heterogeneity of covariates across cases. In addition, we simulate at each value of α an alternative scenario in which the arbitrator ignores the s_p^* conveyed by the parties even though the offers do communicate it, in which case $y_a = (hm + h_\epsilon s_a)/(h + h_\epsilon)$. Note that, even in this alternative scenario, a mechanical correlation between y_a and s_p^* still arises because s_a and s_p^* are both correlated with s.

Second, we run an analogous regression using the observed CA data. Here, we observe the offers of the two parties but we do not know the functional form by which they convey s_p^*. What we do know is that s_p^* is by definition something the arbitrator infers from the offers, so it is some (unknown) function of the offers. Therefore, we substitute the regressor s_p^* in regression (18) with a fifth order polynomial of the observed offers of the parties, including interactions. We also subtitute the regressor m in regression (18) with the covariates listed in Table 2, being intentionally generous to allow the highest possible R^2 for the following reason. If the observed CA data, despite generous inclusion of regressors, achieves a lower R^2 than that simulated for full information transmission, that finding would be more indicative than it would be if we had not been so generous. As for the regressand y_a, we observe it directly in the data, since y_a corresponds to the observed arbitration award in CA. This one regression using observed data leads to one R^2 value, 0.584.

Figure 2 plots the R^2 from the simulated data as a function of α, using a solid curve for when the arbitrator uses the information s_p^* and a dashed curve for when she ignores it. The monotonic increase of the solid curve as a function of α numerically confirms our intuition that more of the variance of y_a is explained by s_p^* when α is larger. The R^2 for the observed conventional arbitration (CA) data, 0.584, is marked by a dotted line. The R^2 observed for CA is higher than all the simulated R^2 in which the arbitrator simply ignores whatever information is conveyed by the parties' offers. Meanwhile, among the simulations in which the arbitrator does use s_p^* to inform her preferred award y_a, the R^2 observed for CA is closest to that in which $\alpha = 0.42$. This result suggests that conventional arbitration does communicate some private information from the parties to the arbitrator, and the arbitrator does use

FIGURE 2. R^2 of regressing y_a on s_p^*



Notes: Figure displays simulated R^2 values of regression (18) as a function of α, the degree of information transmission. At each value of α, we Monte Carlo simulate 1000 cases per each set of covariates observed in ARB_C and run the regression. In the solid curve simulations, the arbitrator makes use of the information conveyed by offers to form her award; in the dashed curve simulations, she ignores the information conveyed. For comparison, the dotted, horizontal line marks the R^2 of a regression analogous to (18) run using the observed data from ARB_C.

this information to form her award, but the transmitted information is less precise than that in final-offer arbitration, which is represented by the benchmark of $\alpha = 1$. Thus, in contexts where communication of private information from the disputing parties to the arbitrator is particularly important, final-offer arbitration may indeed be preferable to conventional arbitration.

6.4. **Efficiency of awards in CA versus FOA.** As a final criterion of comparison, we consider the ability of each arbitration design to yield awards that are close to the fair wage s. As awards that are far from the ideal/fair wage can lead to misallocation of labor and resources, we call this criterion 'efficiency' and measure it by the arbitrator's objective function $u_a(y, s) = -(y - s)^2$.

As we saw in the previous section, final-offer arbitration (FOA) transmits more precise information from the parties to the arbitrator than conventional arbitration (CA). However, this comes at the cost of the one-offer-or-the-other constraint on the arbitrator in FOA, which may constrain the award away from the fair wage s even while the arbitrator is better informed of what this fair wage is. To assess which

Table 7. Efficiency of awards in CA and FOA

	Conventional $\alpha = 0.42$	Final-offer
$E[-(y-s)^2]$	-0.06	-0.21
$E[-\|y-s\|]$	-0.18	-0.35

Notes: The table displays the mean of the efficiency measure across 1000 Monte Carlo simulations conditional on each set of covariates in the ARB_C data set; thus, it presents average outcomes across a total of 117,000 simulated cases.

arbitration design is more efficient on balance, we numerically compare the mean of $-(y-s)^2$ across Monte Carlo simulations of FOA and CA. Specifically, for FOA we use the FOA sample simulated in Section 6.2, and for CA we use the CA sample simulated conditional on $\hat{\alpha} = 0.42$ in Section 6.3; i.e., we simulate CA given the estimated degree of information transmission. Both of these samples are conditioned on the set of covariates observed in ARB_C and are of equal sample size.

Table 7 displays the measure of efficiency thus simulated in CA versus FOA. We find that CA is more efficient; the average distance of the award from the fair wage is 0.18 percentage points in CA compared to 0.35 percentage points in FOA. This means that the gain in efficiency from the arbitrator not being constrained in CA outweighs the loss in efficiency from inferior information transmission. Thus, on balance, it is worth sacrificing information here to free up the arbitrator's choice. By this measure, CA is the better choice over FOA in New Jersey's public sector labor disputes. While there are dimensions in which FOA is superior, our analysis overall does not find fault with New Jersey's decision to switch from FOA to CA in 1996.

7. Conclusion

We combine economic theory and empirics to study arbitration, a widely used method of resolving disputes. Our model of the three-way strategic interaction between two disputing parties and an arbitrator highlights the following features of arbitration: First, risk attitudes affect the strategic actions of the players and the outcomes that ensue; asymmetry in these risk attitudes can tilt outcomes in favor of one side or another. Second, arbitration is a game of communication with the arbitrator. Under final-offer arbitration, we establish identification of the model from the joint distribution of offers submitted by the disputing parties and the arbitration awards. In addition, we establish identification of a supplementary pre-arbitration negotiation model from added data on negotiated settlements. Based on the identification strategy, we develop an estimator, which we then implement using data on wage negotiations between police and fire officer unions and their employers in the state of New Jersey.

When considering final-offer arbitration in isolation, we find that the more risk-averse party actually obtains superior outcomes (more favorable wages) on average because it submits conservative offers that are more likely to be chosen by the arbitrator. Nonetheless, when the shadow of arbitration on negotiated settlements is accounted for by taking an expectation across both settled and arbitrated cases, we find that the more risk-averse party obtains inferior outcomes overall (less favorable wages in expectation) because the risk premium of arbitration asymmetrically lowers the value of the disagreement outcome in bargaining.

Our data affords us a rare opportunity to study in the field a cheap-talk and a non-cheap-talk version of a communication game—conventional and final-offer arbitration, respectively. Noting that the disputing parties' offers are further apart in conventional arbitration, we leverage our structural model to quantify the relative precision of information transmission in the cheap-talk game. We find that, in our application, the information communicated in conventional arbitration is less than half as precise as that in final-offer arbitration. However, the superior information in final-offer arbitration comes at the cost of constraining the arbitrator's choice of award to one of the parties' offers, so there is a trade off between eliciting information and allowing more arbitrator discretion. On balance, we find that conventional arbitration achieves outcomes that are closer to the ideal outcome in our application.

Our analysis may be extended in various ways. Whereas we analyze one-dimensional information and actions in this paper, an important extension would be to characterize multidimensional disputes involving multidimensional information and action spaces. Also, the questions we ask of arbitration have analogs in dispute resolution more generally. For example, the lack of discretion faced by arbitrators in final-offer arbitration is of a similar nature to the constraints that structured sentencing systems, such as sentencing guidelines and mandatory minimum sentences, pose on judges in criminal cases. Adapting our framework to the investigation of the tradeoffs associated with judicial discretion, accounting for the possibility of strategic communication, would be an exciting avenue for further research.

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Appendices for Online Publication

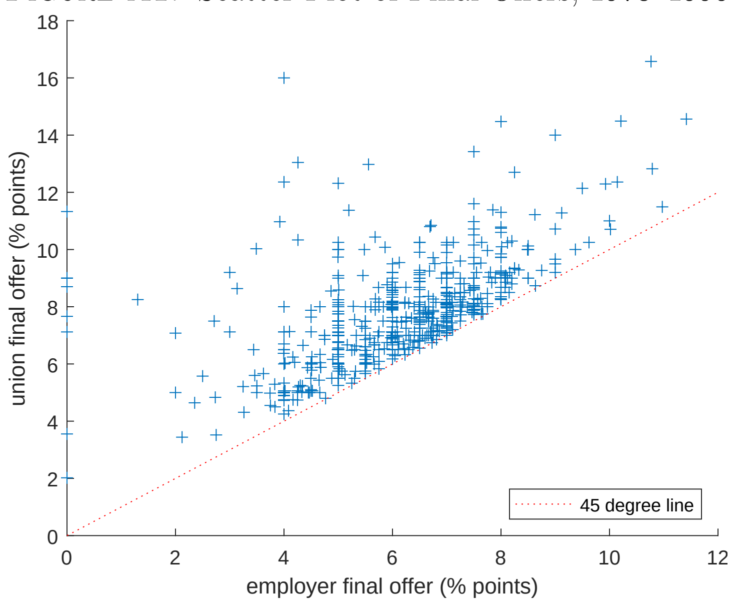
Appendix A. Supplementary Tables and Figures

Table A1. Offer Aggressiveness and Probability of Employer win, 1978-1995

	(1)	(2)	(3)
Union final offer residual	0.214		0.132
	(0.043)		(0.048)
Employer final offer residual		0.265	0.202
		(0.047)	(0.051)
Constant	-0.320	-0.337	-0.335
	(0.054)	(0.055)	(0.055)
Observations	580	580	580

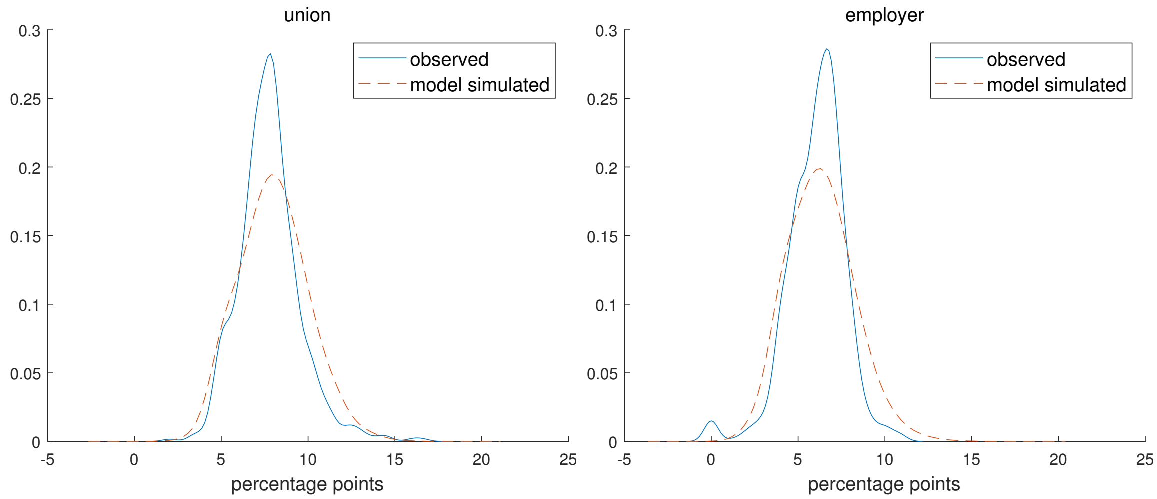
Notes: Table reports Probit results. The unit of observation is a case. In all specifications, the sample consists of cases from the ARB_F data set, which are resolved by final-offer arbitration. The dependent variable is a dummy indicating whether the employer wins the arbitration. The regressors are residuals of regressions of the final offers by the union and the employer on all the covariates in column (1) of Table 2. Standard errors provided in parentheses.

Figure A1. Scatter Plot of Final Offers, 1978–1995



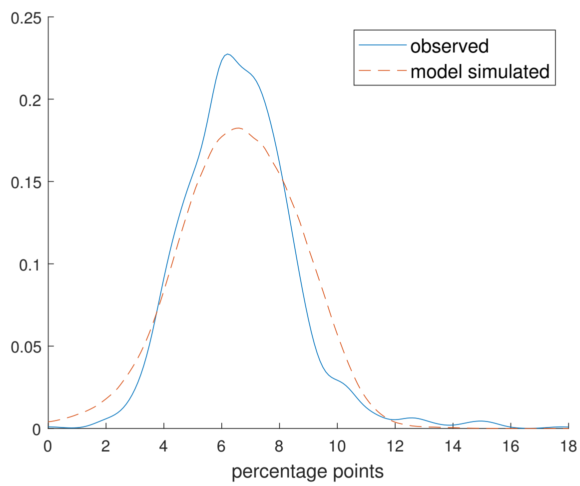
Notes: Employer and union final offers in all cases from the ARB_F data set. The 45 degree line is marked with a red dotted line.

FIGURE A2. Model fit: final offers



Notes: Figures display kernel density of observed vs. model-simulated final offers by the union and the employer, respectively.

FIGURE A3. Model fit: settlements



Notes: Figure displays kernel density of observed vs. model-simulated settlement amounts conditional on settlement.

Appendix B. Proofs

Proof of Proposition 1.

Proof. We adopt a "guess and verify" approach for the proof. Assume that offers take the form $y_u(s_p) = M_p(s_p) + \delta_u$ and $y_e(s_p) = M_p(s_p) - \delta_e$, where δ_u and δ_e do not depend on s_p.

First, we characterize the arbitrator's inference and the decision rule that best responds to the supposed $y_u(s_p)$, $y_e(s_p)$. As derived in the text following Proposition 1, the arbitrator's best response given the supposed $y_u(s_p)$, $y_e(s_p)$ is to infer s_p by the inference rule

$$s_p(\bar{y}) = \frac{(h + h_\varepsilon)\left[\bar{y} + (\delta_e - \delta_u)/2\right] - hm}{h_\varepsilon}.$$

Also, as derived in the text, the arbitrator then chooses y_e if and only if

$$s_a < \frac{h_\varepsilon \bar{y} + h(\bar{y} - m) + h_\varepsilon\left(\bar{y} - s_p(\bar{y})\right)}{h_\varepsilon} = \bar{y} - \left(\frac{h + h_\varepsilon}{h_\varepsilon}\right)\frac{\delta_e - \delta_u}{2} \equiv S(\bar{y}).$$

Second, we confirm that there exists a unique pair δ_u, δ_e such that the final offer strategies $y_u(s_p) = M_p(s_p) + \delta_u$ and $y_e(s_p) = M_p(s_p) - \delta_e$ in turn best respond to the inference and decision rules above and to one another. By Assumption 1, the parties' belief about the distribution of s_a conditional on s_p is normal with mean $M_p(s_p)$ and precision $H = \left[h_\varepsilon(h + h_\varepsilon)\right] / (h + 2h_\varepsilon)$. Let $\Phi(\cdot)$ and $\phi(\cdot)$ be the standard normal cumulative distribution and density functions, respectively. Then the decision rule above implies that the arbitrator selects y_e with probability $\Phi([S(\bar{y}) - M_p(s_p)]\sqrt{H})$.

We can then rewrite the problems solved by the union and the employer, respectively, as

$$\begin{aligned}
&\max_{\delta_u} u_u\left(M_p(s_p) - \delta_e\right)\Phi([S(\bar{y}) - M_p(s_p)]\sqrt{H}) \\
&\qquad\qquad + u_u\left(M_p(s_p) + \delta_u\right)\left[1 - \Phi([S(\bar{y}) - M_p(s_p)]\sqrt{H})\right], \\
\text{and } &\max_{\delta_e} u_e\left(M_p(s_p) - \delta_e\right)\Phi([S(\bar{y}) - M_p(s_p)]\sqrt{H}) \\
&\qquad\qquad + u_e\left(M_p(s_p) + \delta_u\right)\left[1 - \Phi([S(\bar{y}) - M_p(s_p)]\sqrt{H})\right].
\end{aligned}$$

The corresponding first-order conditions are

$$\frac{\sqrt{H}}{2}\frac{\phi([S(\bar{y}) - M_p(s_p)]\sqrt{H})}{1 - \Phi([S(\bar{y}) - M_p(s_p)]\sqrt{H})} = \frac{\rho}{\exp\left(\rho(\delta_u + \delta_e)\right) - 1},$$

$$\text{and} \quad \frac{\sqrt{H}}{2}\frac{\phi([S(\bar{y})-M_p(s_p)]\sqrt{H})}{\Phi([S(\bar{y})-M_p(s_p)]\sqrt{H})}=\frac{1}{\delta_u+\delta_e},$$

where we use the fact that the derivative of $S(\bar{y})$ with respect to the union's choice of δ_u and the employer's choice of δ_e are 1/2 and $-1/2$, respectively.

In equilibrium, δ_u and δ_e must satisfy these FOCs with $M_p(s_p) = (\bar{y} + (\delta_e - \delta_u)/2)$. Plugging in this expression and rearranging, we find that the equilibrium δ_u and δ_e must satisfy

$$\frac{\sqrt{H}}{2}\frac{\phi\left(\eta(\delta_u-\delta_e)/2\right)}{1-\Phi\left(\eta(\delta_u-\delta_e)/2\right)}=\frac{\rho}{\exp\left(\rho(\delta_u+\delta_e)\right)-1},$$

$$\text{and} \quad \frac{\sqrt{H}}{2}\frac{\phi\left(\eta(\delta_u-\delta_e)/2\right)}{\Phi\left(\eta(\delta_u-\delta_e)/2\right)}=\frac{1}{\delta_u+\delta_e},$$

where $\eta \equiv \sqrt{H}(h + 2h_\varepsilon)/h_\varepsilon$. These correspond to (4) and (5) in the text.

To show that there exists a unique pair δ_u, δ_e that solves the system of equations implied by these first-order conditions, define shorthand $t \equiv \eta(\delta_u - \delta_e)/2$, $d_1 \equiv \delta_u + \delta_e$, $f(d_1) \equiv \rho/(\exp(\rho d_1) - 1)$, $\lambda \equiv \phi/(1 - \Phi)$ and $\tilde{\lambda} \equiv \phi/\Phi$. We can rewrite (4) and (5) as

$$\frac{\sqrt{H}}{2}\lambda(t) = f(d_1) \quad \text{and} \quad \frac{\sqrt{H}}{2}\tilde{\lambda}(t) = 1/d_1. \tag{A.1}$$

This system admits a solution in $t \in \mathbb{R}$ and $d_1 \in \mathbb{R}_+$ if and only if

$$\frac{\sqrt{H}}{2}\lambda(t) = f\left(\frac{2}{\sqrt{H}\tilde{\lambda}(t)}\right) \tag{A.2}$$

admits a solution in $t \in \mathbb{R}$. By construct, λ is increasing, while $\tilde{\lambda}$ and f are decreasing in t and d_1, respectively. As $t \to -\infty$, we know that $\lambda(t) \to 0$, $\tilde{\lambda}(t) \to \infty$, and the r.h.s of (A.2) diverges to ∞. On the other hand, as $t \to \infty$, we have that $\lambda(t) \to \infty$, $\tilde{\lambda}(t) \to 0$, and the r.h.s. of (A.2) converges to 0. Therefore both sides of (A.2) are strictly monotonic in different directions, implying existence of a unique solution in t. Given t, (A.1) pins down a unique d_1. Then, since t determines the difference between δ_u and δ_e and d_1 determines their sum, existence and uniqueness of t and d_1 yields existence and uniqueness of the values of δ_u and δ_e that satisfy (4) and (5).

Finally, as s_p is absent from (4) and (5), we verify that neither δ_u nor δ_e vary with the parties' signal s_p. □

Proof of Proposition 2.

Proof. (i) Let $d_1 \equiv \delta_u + \delta_e$, the distance between final offers. In a proof by contradiction, suppose $h' > h$ and $d_1(h') \geq d_1(h)$. As the right-hand sides of (A.1) both decrease in d_1, we have $\sqrt{H(h')}\lambda(t(h')) \leq \sqrt{H(h)}\lambda(t(h))$ and $\sqrt{H(h')}\tilde{\lambda}(t(h')) \leq \sqrt{H(h)}\tilde{\lambda}(t(h))$. Since H is strictly increasing in h, this is only possible if $\lambda(t(h')) < \lambda(t(h))$ and $\tilde{\lambda}(t(h')) < \tilde{\lambda}(t(h))$. However, by definition, $\lambda(\cdot)$ is strictly increasing, while $\tilde{\lambda}(\cdot)$ is strictly decreasing, so it is impossible for these two inequalities to be satisfied simultaneously. Therefore, $d_1(h') < d_1(h)$ by contradiction. Repeat the same proof replacing h with h_ε to show that d_1 is strictly decreasing in h_ε.

(ii) While we use risk-neutrality for the employer and CARA utility for the union throughout this paper, here we relax the employer's risk-neutrality to prove a more general point. Let $U_u(\cdot)$ and $U_e(\cdot)$ be notation for the parties' CARA utility functions, which may differ in their risk aversion parameters. Taking a ratio of (4) and (5) yields

$$\frac{\Phi\left(\eta(\delta_u - \delta_e)/2\right)}{1 - \Phi\left(\eta(\delta_u - \delta_e)/2\right)} = \left(\frac{U_e(-y_e) - U_e(-y_u)}{U_u(y_u) - U_u(y_e)}\right)\frac{U_u'(y_u)}{U_e'(-y_e)}.$$

Now define a function $\tilde{U}_e(\cdot)$ such that $\tilde{U}_e(z + (y_u + y_e)) \equiv U_e(z)$. Note that, in terms of absolute risk aversion, if $U_u(\cdot)$ is more (less) risk-averse than $U_e(\cdot)$, it is also more (less) risk-averse than $\tilde{U}_e(\cdot)$. We can rewrite the equation above as

$$\frac{\Phi\left(\eta(\delta_u - \delta_e)/2\right)}{1 - \Phi\left(\eta(\delta_u - \delta_e)/2\right)} = \left(\frac{\tilde{U}_e(y_u) - \tilde{U}_e(y_e)}{U_u(y_u) - U_u(y_e)}\right)\frac{U_u'(y_u)}{\tilde{U}_e'(y_u)}.$$

By equation (22) in Pratt (1964), the r.h.s. of the above equation is < 1 if the union is more risk-averse, $= 1$ if the parties are equally risk-averse, and > 1 if the employer is more risk-averse. Then by the l.h.s. of the equation and properties of the standard normal cdf $\Phi(\cdot)$, $\delta_u < \delta_e$ if the union is more risk-averse, $\delta_u = \delta_e$ if the parties are equally risk-averse, and $\delta_u > \delta_e$ if the employer is more risk-averse.

Meanwhile, the l.h.s. above is the odds of the employer winning, by definition. Thus, the more risk-averse party wins more often in expectation. This proof is closely related to that of Farber (1980). □

Proof of Lemma 1.

Proof. We begin by showing part (i). Any offer $\sigma \geq \tilde{y} - \underline{c}_u$ is accepted for sure by the union, yielding a payoff of $-\sigma$ to the employer. The employer is thus strictly better off by offering $\sigma = \tilde{y} - \underline{c}_u$, rather than any settlement offer strictly greater than that. Given $\sigma = \tilde{y} - \underline{c}_u$, the union with cost $c_u = \underline{c}_u$ is indifferent between settling and going to arbitration.

To address part (ii), apply the change of variable $\tau \equiv \tilde{y} - \sigma$ to rewrite (10) as

$$\tau - \frac{1 - F_{c_u}(\tau)}{f_{c_u}(\tau)} = \tilde{y} - \mathrm{E}[y] - c_e.$$

Assumption 2.ii guarantees that the derivative of the left-hand side of (10) with respect to τ is strictly greater than one. The sign of the derivative implies that there is a unique solution to the employer's problem, given any values of c_e, $\mathrm{E}[y]$ and $\tilde{y}$. For the same reason, the solution τ is strictly decreasing (or, equivalently, the equilibrium settlement offer σ is strictly increasing) in both c_e and $\mathrm{E}[y]$. Finally, since the derivative of the left-hand side is greater than one, any increase in $\tilde{y}$ leads to a positive but smaller increase in τ, which, from the identity $\sigma \equiv \tilde{y} - \tau$, results in an increase in σ. □

Proof of Proposition 3.

Proof. Denote the final offers by the union and the employer, respectively, by $y_u(s_p, h_\varepsilon)$ and $y_e(s_p, h_\varepsilon)$. From Proposition 1, we have $y_u(s_p, h_\varepsilon) = M_p(s_p, h_\varepsilon) + \delta_u(h_\varepsilon)$ and $y_e(s_p, h_\varepsilon) = M_p(s_p, h_\varepsilon) - \delta_e(h_\varepsilon)$. Define $d_1(h_\varepsilon) \equiv y_u(s_p, h_\varepsilon) - y_e(s_p, h_\varepsilon) = \delta_u(h_\varepsilon) + \delta_e(h_\varepsilon)$ and $d_2(h_\varepsilon) \equiv (\delta_u(h_\varepsilon) - \delta_e(h_\varepsilon))/2$. Also, by (6), in equilibrium the arbitrator chooses the employer's final offer with probability $\Phi(\eta(h_\varepsilon)(\delta_u(h_\varepsilon) - \delta_e(h_\varepsilon))/2)$, where $\eta(h_\varepsilon) \equiv \sqrt{H(h_\varepsilon)}(h + 2h_\varepsilon)/h_\varepsilon$ and $H(h_\varepsilon) \equiv h_\varepsilon(h + h_\varepsilon)/(h + 2h_\varepsilon)$.

First, we show that ρ is identified. From (7), we have

$$\frac{\Phi(\eta(h_\varepsilon)\, d_2(h_\varepsilon)/2)}{1 - \Phi(\eta(h_\varepsilon)\, d_2(h_\varepsilon)/2)} = \frac{\rho d_1(h_\varepsilon)}{\exp(\rho d_1(h_\varepsilon)) - 1}.$$

Let $odds(y_u - y_e)$ denote the observed odds that the employer's final offer is chosen by the arbitrator, conditional on the observed offer difference $y_u - y_e$. Proposition 2(i) shows that $d_1(h_\varepsilon)$ is strictly decreasing in h_ε, allowing us to use $h_\varepsilon = d_1^{-1}(y_u - y_e)$ and write

$$odds(y_u - y_e) = \frac{\Phi\left(\eta\left(d_1^{-1}(y_u - y_e)\right) d_2\left(d_1^{-1}(y_u - y_e)\right)/2\right)}{1 - \Phi\left(\eta\left(d_1^{-1}(y_u - y_e)\right) d_2\left(d_1^{-1}(y_u - y_e)\right)/2\right)}. \tag{A.3}$$

Together, the equations above imply

$$odds(y_u - y_e) = \frac{\rho(y_u - y_e)}{\exp(\rho(y_u - y_e)) - 1}.$$

From Theorem 1 and equation (22) in Pratt (1964), the r.h.s. is strictly decreasing in ρ, so the equation above identifies this parameter.

Next, we show the identification of h and $G_{h_\varepsilon}(\cdot)$. First, since $\Phi(x)/[1-\Phi(x)]$ is strictly increasing in x, (A.3) identifies the product $\eta\left(d_1^{-1}(y_u-y_e)\right)d_2\left(d_1^{-1}(y_u-y_e)\right)$. Plugging this value into the left-hand side of (4) then identifies $H\left(d_1^{-1}(y_u-y_e)\right)$, as the r.h.s. of that equation is a ratio of two identified terms. Rearranging the definition of $H(h_\varepsilon)$ gives

$$\frac{1}{H(h_\varepsilon)}=\frac{1}{h_\varepsilon}+\frac{1}{h+h_\varepsilon}=\frac{h}{h_\varepsilon}\left(\frac{1}{h}+\frac{1}{h}\frac{1}{1+\frac{h}{h_\varepsilon}}\right). \tag{A.4}$$

Meanwhile, from the definition of $M_p(s_p,h_\varepsilon)$, we have that

$$\mathrm{Var}\left[M_p(s_p,h_\varepsilon)|h_\varepsilon\right]=\left(\frac{h_\varepsilon}{h+h_\varepsilon}\right)^2\mathrm{Var}\left[s_p|h_\varepsilon\right]=\frac{1}{h}\left(\frac{1}{1+\frac{h}{h_\varepsilon}}\right), \tag{A.5}$$

where the l.h.s. is an observed quantity because

$$\begin{aligned}\mathrm{Var}\left[M_p(s_p,h_\varepsilon)|h_\varepsilon=d_1^{-1}(y_u-y_e)\right]&=\mathrm{Var}\left[y_u(s_p,h_\varepsilon)-\delta_u(h_\varepsilon)|h_\varepsilon=d_1^{-1}(y_u-y_e)\right]\\&=\mathrm{Var}\left[y_u(s_p,h_\varepsilon)|h_\varepsilon=d_1^{-1}(y_u-y_e)\right]\\&=\mathrm{Var}\left[y_u|y_u-y_e\right].\end{aligned}$$

Equations (A.4) and (A.5) thus form a system of equations that can be solved for h and h_ε. Specifically, we rearrange (A.5) as

$$\frac{h}{h_\varepsilon}=\frac{1}{h\mathrm{Var}\left[y_u|y_u-y_e\right]}-1.$$

Plugging this into (A.4) gives

$$\frac{1}{H\left(d_1^{-1}(y_u-y_e)\right)}=\left(\frac{1}{h\mathrm{Var}\left[y_u|y_u-y_e\right]}-1\right)\left(\frac{1}{h}+\mathrm{Var}\left[y_u|y_u-y_e\right]\right),$$

which corresponds to (11) in the text. The only unknown in the equation above is h, and the right-hand side is strictly decreasing in this parameter. Hence, this equation identifies h, which, in turn, identifies h_ε by (A.5). As the distribution of y_u-y_e is observed, and we identify $h_\varepsilon=d_1^{-1}(y_u-y_e)$ for any value of y_u-y_e, we have nonparametric identification of $G_{h_\varepsilon}(\cdot)$.

Identification of h and h_ε implies identification of $\eta(h_\varepsilon)$. Then $d_2(h_\varepsilon)$ is identified since the product $\eta(h_\varepsilon)d_2(h_\varepsilon)$ is known. So we know both $d_2(h_\varepsilon)$ and $d_1(h_\varepsilon)$, implying recovery of $\delta_u(h_\varepsilon)$ and $\delta_e(h_\varepsilon)$ for all h_ε in the support of $G_{h_\varepsilon}(\cdot)$.

Finally, we identify the parameter m. We have

$$\mathrm{E}\left[M_p(s_p,h_\varepsilon)\right]=\mathrm{E}\left[\mathrm{E}\left[M_p(s_p,h_\varepsilon)|h_\varepsilon\right]\right]=\mathrm{E}\left[\frac{hm+h_\varepsilon\mathrm{E}\left[s_p|h_\varepsilon\right]}{h+h_\varepsilon}\right]=m.$$

Therefore, we have

$$m = \mathrm{E}\left[\mathrm{E}\left[M_p\left(s_p, h_\varepsilon\right)|h_\varepsilon\right]\right]$$
$$= \mathrm{E}\left[\mathrm{E}\left[y_u - \delta_u\left(h_\varepsilon\right)|h_\varepsilon\right]\right],$$

where the right-hand side is now known. □

Proof of Proposition 4.

Proof. From Lemma 1.ii, the function $\sigma(c_e, z)$ is increasing in its first argument. We can thus identify $\sigma(\bar{c}_e, z) \equiv \bar{\sigma}(z)$ as the supremum of the support of accepted offers, conditional on z. Moreover, Lemma 1.i, together with the fact that the union always rejects settlements less than $\tilde{y}(z) - \bar{c}_u$, implies that any settlement offer accepted with positive probability in equilibrium satisfies $\tilde{y}(z) - \bar{\sigma}(z) \in [\underline{c}_u, \bar{c}_u]$. From this result and Assumption 3.ii , we can thus identify $\underline{c}_u$ and $\bar{c}_u$ as

$$\underline{c}_u = \inf\left\{\tilde{y}(z) - \bar{\sigma}(z) : z \in \mathcal{Z}\right\},$$
$$\bar{c}_u = \sup\left\{\tilde{y}(z) - \bar{\sigma}(z) : z \in \mathcal{Z}\right\}.$$

Next, we show how to recover the inverse hazard rate of F_{c_u}, defined as $\nu(c) \equiv \frac{1-F_{c_u}(c)}{f_{c_u}(c)}$, over the entire support $[\underline{c}_u, \bar{c}_u]$. From Assumption 3.i, this rate does not vary with z. From (10), we thus have that, for any $z \in \mathcal{Z}$,

$$-\nu\left(\tilde{y}(z) - \bar{\sigma}(z)\right) = \bar{\sigma}(z) - \mathrm{E}\left[y|z\right] - \bar{c}_e.$$

Applying the implicit function theorem to the equation above, we obtain

$$\bar{\sigma}'(z) = -\frac{\tilde{y}'(z)\nu'\left(\tilde{y}(z) - \bar{\sigma}(z)\right) - \partial\mathrm{E}\left[y|z\right]/\partial z}{1 - \nu'\left(\tilde{y}(z) - \bar{\sigma}(z)\right)},$$

which implies

$$\nu'\left(\tilde{y}(z) - \bar{\sigma}(z)\right) = \frac{\bar{\sigma}'(z) - \partial\mathrm{E}\left[y|z\right]/\partial z}{\bar{\sigma}'(z) - \tilde{y}'(z)},$$

for all $z \in \mathcal{Z}$. From Assumption 3.ii, for any $c \in (\underline{c}_u, \bar{c}_u)$, we can select $z_c \in \{z : \tilde{y}(z) - \bar{\sigma}(z) = c\}$ and obtain

$$\nu'\left(c\right) = \frac{\bar{\sigma}'(z_c) - \partial\mathrm{E}\left[y|z_c\right]/\partial z}{\bar{\sigma}'(z_c) - \tilde{y}'(z_c)}.$$

Thus, we identify the inverse hazard rate as

$$\nu\left(c\right) = -\int_c^{\bar{c}_u} \nu'\left(t\right)dt,$$

for all $c \in [\underline{c}_u, \bar{c}_u]$. We can then recover F_{c_u} as

$$F_{c_u}(c) = 1 - \exp\left(-\int_{\underline{c}_u}^{c} \frac{1}{\nu(t)} dt\right),$$

for all $c \in [\underline{c}_u, \bar{c}_u]$.

It remains to show the identification of F_{c_e}, the distribution of arbitration costs for the employer. Temporarily abstracting away from z, let $B(\cdot)$ denote the unconditional distribution of settlement offers with density $b(\cdot)$, and let $B^*(\cdot)$ denote the distribution of settlement offers *conditional* on settlement. Let $\xi(\cdot)$ be defined as in (13). Then

$$\begin{aligned} B^*(\sigma) &\equiv \frac{\Pr(x \leq \sigma \text{ and } c_u > \tilde{y} - \sigma)}{\Pr(c_u > \tilde{y} - \sigma)} \\ &= \frac{\int_{x=\underline{\sigma}}^{\sigma} [1 - F_{c_u}(\tilde{y} - x)] h(x) dx}{\int_{x=\underline{\sigma}}^{\bar{\sigma}} [1 - F_{c_u}(\tilde{y} - x)] h(x) dx} \\ &= \frac{\int_{x=\underline{\sigma}}^{\sigma} [1 - F_{c_u}(\tilde{y} - x)] f_{c_e}(\xi(x)) \xi'(x) dx}{\int_{x=\underline{\sigma}}^{\bar{\sigma}} [1 - F_{c_u}(\tilde{y} - x)] f_{c_e}(\xi(x)) \xi'(x) dx}. \end{aligned}$$

where the last equality is due to $\xi(\sigma)$ being a monotonic function. By taking a derivative of the last expression with respect to σ, we obtain the associated density, $b^*(\cdot)$, as expressed in (12).

Let $P(z) \equiv \int_{x=\underline{\sigma}(z)}^{\bar{\sigma}(z)} [1 - F_{c_u}(\tilde{y}(z) - x)] f_{c_e}(\xi(x; z)) \xi'(x; z) dx$ denote the probability of settlement conditional on z. Then for *any* z and $\sigma \in [\underline{\sigma}(z), \bar{\sigma}(z)]$, rearranging (12) gives

$$f_{c_e}(\xi(\sigma; z)) = \frac{b^*(\sigma; z) P(z)}{[1 - F_{c_u}(\tilde{y}(z) - \sigma)] \xi'(\sigma; z)}.$$

As $b^*(\sigma; z)$ and $P(z)$ are observed, F_{c_u} is identified, and $\xi(\sigma, z)$ is known once F_{c_u} is known, the r.h.s. is a known function of σ. This identifies F_{c_e} and completes the proof. □