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Effective Labor Relations Laws and Social Welfare

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EFFECTIVE LABOR RELATIONS LAWS AND SOCIAL WELFARE*

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Abstract

Effective labor relations laws determine the allocation of bargaining power between the parties involved in labor disputes, and hence, influence social welfare. The right to strike, the types of legal strikes, and the right to hire replacement workers are fundamental components of labor relations laws in the public sector. Strikes by public school teachers, which are common in real-world settings, involve particularly high social costs. We theoretically study the social welfare effects of labor relations laws that permit the effective use of replacement teachers in case of strikes. These laws refer to the explicit right to hire replacement teachers and to the prohibition of intermittent strikes. We present a sequential bargaining game of incomplete information. Our model explicitly includes a law component, which captures the impact of effective labor relations laws. We conduct social welfare analysis and demonstrate that these laws reduce bargaining impasse and increase social welfare.

KEYWORDS: Labor Relations Laws; Social Welfare; Bargaining Impasse; Replacement Teachers Laws; Intermittent Strikes Laws; Non-Cooperative Games; Asymmetric Information; Perfect Bayesian Equilibrium

JEL Categories: J58, J52, C72, D82

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1 Introduction

Effective labor relations laws determine the allocation of bargaining power between the parties involved in labor disputes, and hence, influence social welfare. The right to strike, the types of legal strikes, and the right to hire replacement workers are fundamental components of labor relations laws in the public sector. Strikes by public school teachers, which are common in real-world settings, involve particularly high social costs. This paper theoretically studies the social welfare effects of labor relations laws that permit the *effective* use of replacement teachers in case of strikes.

Labor relations laws differ across countries. Canadian labor relations laws allow school teachers to strike. In fact, on January 30, 2015, the Supreme Court of Canada issued a decision holding that the teachers' right to strike is constitutionally protected (*In Saskatchewan Federation of Labour v. Saskatchewan*). School teachers strikes are legal in twelve U.S. states, and are not explicitly prohibited in three states (Sanes and Schmitt, 2014).[1] Laws that grant school boards the right to hire replacement teachers in case of strikes also vary across U.S. states. For instance, labor relations laws in Pennsylvania, Minnesota and Oregon explicitly permit the use of replacement teachers in case of strikes.[2] Substitute teachers are employed to temporarily replace regular teachers in case of strikes.[3] In these circumstances, substitute teachers act as replacement teachers.[4]

[1]The twelve states where teachers strikes are legal are as follows: Alaska, California, Colorado, Hawaii, Illinois, Louisiana, Minnesota, Montana, Ohio, Oregon, Pennsylvania, and Vermont. In three states, South Dakota, Utah and Wyoming, the legality or illegality of teachers strikes is not explicitly established by statute or case law.

[2]See Najita and Stern (2001). See also the information available at the Oregon School Board Association website (http://www.osba.org; last visited on June 24, 2015). The use of replacement teachers in case of strikes has been also extensively discussed in the media (Galbally, 2002).

[3]In most U.S. school districts, substitute teachers do not pertain to the regular teachers' union. Only in July 2000, the National Substitute Teachers Alliance, the first nationwide organization for substitute teachers, was formed.

[4]The term "replacement teachers" used in this paper does not refer to practices of school districts related

Labor relations laws that permit the effective use of replacement teachers in case of strikes, which we will call "effective replacement teachers laws," encompass the following components. First, they refer to laws that explicitly grant school boards the right to hire replacement teachers in case of strikes or do not prohibit the use of these replacements. Without these laws, educational services cannot be provided by replacement teachers. Second, they refer to laws that prohibit unions to engage in selective or intermittent strikes. Selective or intermittent strikes are sporadic short-term strikes. By banning intermittent strikes, these laws allow school districts to effectively program the use of replacement teachers in case of strikes. Third, they refer to laws that relax the job permanence requirements for substitute teachers to qualify as replacement teachers without compromising the quality of educational services. Specifically, some U.S. states require applicants for replacement teacher positions to work as substitute teachers in the *specific* school district for a minimum period of time prior to the strike. Although strong requirements on academic credentials and experience are necessary for maintaining the quality of educational services, experience can be obtained in another school district without jeopardizing the quality of education. A relaxation of these job permanence requirements for substitute teachers will contribute to the effective use of replacement teachers in case of strikes.

Pennsylvania labor relations laws provide an illustrative example of effective replacement teachers laws. Before 1992, although school boards had the right to hire replacement teachers in case of strikes, union's intermittent strikes prevented school boards from hiring replacement teachers.[5] As a consequence, instructional days were lost and complains from the general public were widespread. In July 1992, the labor relations laws were modified. The *Pennsylvania Collective Bargaining Act 88* explicitly prohibits the use of intermittent

to hiring unqualified "scab" substitutes. It refers to the use of substitute teachers to replace regular teachers in case of strikes.

[5]As reported in the media, "Striking teachers who decide to work on a day-to-day basis say a selective strike calls to their cause, protects their income and prevents school districts from hiring replacement" (Pittsburgh Post-Gazette, 1990).

strikes, and hence, allows school boards to effectively hire replacement teachers. In 1997, the Pennsylvania School Board Association states "[T]he passage of Act 88 ... finally restored some balance to the bargaining process, dramatically reducing the number of strikes ... and controlling salary increases ... Act 88 has worked to level the bargaining table in public school negotiations, producing more economical settlements more quickly than ever before and more in line with community norms" (Pennsylvania School Board Association, 1997).

We model effective labor relations laws by using a sequential bargaining game of incomplete information. In this environment, an informed school board and an uninformed union negotiate in the shadow of a bargaining impasse, under the current labor relations laws. Our model explicitly includes a law component, which captures the impact of labor relations laws that permit the effective use of replacement teachers in case of strikes. In particular, this component allows for the study of laws that grant the explicit right to hire replacement teachers in case of strikes, laws that prohibit the use of intermittent strikes, and laws that relax the job permanence requirements for substitute teachers to qualify as replacement teachers without compromising the quality of educational services.

We demonstrate that laws that permit the effective use of replacement teachers in case of strikes reduce the likelihood of bargaining impasse. Two main effects are observed. First, these laws make strikes less costly for the school board. Educational services are provided by replacement teachers during strikes, and socially costly interruptions are avoided. Then, we might expect the probability of strikes to raise. However, there is a second effect of these laws, which offsets the previous one. The strategic union takes into account the reduction in the cost of strikes for the school board and lowers its demands. This implies that a wider range of school boards finds it optimal to accept the union's demands and avoid a strike. As a result, bargaining impasse is reduced.

We then conduct social welfare analysis and show that these effective labor relations laws are welfare enhancing. The result is mainly explained by the increase in the provision of educational services during strikes and by the lower likelihood of bargaining impasse. Finally, we extend our analysis by assessing the impact of an increase in the replacement teachers' reservation wage on social welfare. The laws studied in this paper permit school boards to effectively hire replacement teachers in case of strikes. The private incentives of school boards to hire replacement teachers are affected by the cost of hiring these replacements. Then, it is relevant to study the social welfare effects of an increase in the replacement teachers' reservation wage. Our results show that although an increase in replacement teachers' reservation wage makes these replacements more expensive, school boards still have private incentives to hire replacement teachers in case of strikes. Two effects influence the probability of strikes. First, strikes are more expensive for the school board. We might then expect a reduction in the probability of strikes. Second, the strategic union anticipates the increase in the cost of strikes for the school board and raises its demands. As a result, the probability of strikes should increase. We demonstrate that the first effect more than offsets the second effect. Hence, bargaining impasse is reduced and social welfare is enhanced.

Important policy implications are derived from our study. Motivated by the frequent teachers strikes in North American countries, legal commentators have proposed to explicitly prohibit teachers to strike (Levitt, 2015). Our paper suggests that less radical measures are available. We show that labor relations laws that allow school boards to effectively hire replacement teachers in case of strikes might balance the bargaining power between school units and unions, reduce the likelihood of bargaining impasse, and increase social welfare.

Our work provides significant contributions to the theoretical law and economics literature on legal institutions and bargaining impasse. In seminal work, Shavell (1982) studies the effects of laws that shift the burden of litigation costs to the losing party on bargaining impasse in civil litigation settings.[6] In his theoretical framework, the source of bargaining impasse is the litigants' divergent beliefs about the outcome at trial. Using game theoretic tools, Reinganum and Wilde (1986) investigate the effects of similar laws. Their study demonstrates that asymmetric information might generate bargaining impasse even in the

[6]The mechanism that assigns the litigation costs to the losing party is called the "English Rule."

absence of divergent beliefs. More recently, Landeo and Nikitin (2015), Landeo et al. (2007), Babcock and Landeo (2004), and Hylton (2002) study the effects of civil litigation laws on the potential injurers' care-taking incentives and bargaining impasse.[7] We extend this literature by presenting the first formal analysis of the impact of labor relations laws associated with the effective use of replacement teachers on bargaining impasse and by providing social welfare analysis of these laws. Our paper is also part of the small labor economics literature on replacement workers (Campolieti et al., 2014; Dachis and Hebdon, 2010; Cramton, et al., 1999; Cramton and Tracy, 1998).[8] We complement this empirical literature by providing a theoretical framework that allows for the social welfare analysis of effective of labor relations laws.

The rest of the paper is organized as follows. Section Two presents the model setup and discusses the replacement teachers laws component. Section Three outlines the equilibrium analysis. Section Four discusses the effects of laws that permit the effective use of replacement teachers in case of strikes on equilibrium outcomes. Section Five presents the social welfare analysis of these laws. Section Six extends our analysis by assessing the effects of replacement teachers' reservation wage on social welfare. Section Seven concludes the paper.

2 Theoretical Framework

This section presents the basic setup of the model, discusses the effective labor relations law component of the model, and outlines the game stages.

[7]See Landeo (forthcoming) and Daughety and Reinganum (2012) for recent surveys of theoretical and experimental work on bargaining impasse and tort law.

[8]The first three studies present empirical work on Canadian private firms. Their findings suggest that laws that grant the right to hire replacement workers reduce the likelihood of strikes. The fourth study refers to U.S. private firms and provides similar results. Currie (1991) and Tracy and Gyourko (1991) study collective bargaining in the public sector, focusing on employment and wage determination. See Kennan and Wilson (1989), McConnell (1989), Card (1990), Gunderson and Melino (1990) for seminal work on bargaining impasse in labor settings.

2.1 Basic Setup

Consider a bargaining game between two Bayesian risk-neutral players, an informed school board representative B and an uniformed teachers' union representative U. The source of information asymmetry is the school board's capacity to pay, θ. The union knows that θ is uniformly distributed over the interval $[\theta_L, \theta_H]$.[9] We denote the school board's and the union's payoff functions as V_B and V_U, respectively. We also denote the union's reservation wage (outside option) as w^o. It represents the union's payoff in case of strikes.

The payoff function V_B for school board of type θ is given by

$$V_B = g(\theta, N) - wN, \tag{1}$$

where $g(\theta, N)$ represents the school board's monetary valuation of the provision of N periods of educational services, and wN is the monetary cost of the labor resources needed to provide N periods of educational services. Our specification of N allows to measure the periods of educational services in different units: Hours, days, weeks, etc. The rationale for the school board's maximization of the difference between the valuation of labor services and the cost of these services relies on the budget constraint that school boards generally confront (Zwerling and Thomason, 1995).[10] The maximum number of periods of educational services is determined by law. We assume that the maximum number of periods of educational services is $n + 1$, where $n \geq 1$. Note that the maximum number of periods of educational services is not equal to the effective number of periods of educational services if a strike occurs.[11] We assume that each period of educational service requires the same amount of

[9] For exposition, we adopt a uniform distribution. Our results are general and hold across distributions.

[10] "While public sector organizations have no profit motive, school boards operate under cost constraints based on the limits of federal and state funding/revenue sharing, as well as the ability and willingness of the local community to fund education through increased taxes" (Zwerling and Thomason, 1995 p. 469). See also Dilts (1986).

[11] We abstract from make-up periods, where teachers recover the periods lost during a strike. The quality of education is what matters for the community and therefore, for the school district. Even if lost periods are recovered, the quality of education is already compromised by the interruption in the provision of educational

labor. Then, the amount of labor is normalized to 1. As a result, N can be also interpreted as the total amount of labor used in the provision of educational services.

We assume that the school board's monetary valuation of the provision of educational services is linear in θ:

$$g(\theta, N) = \theta v(N). \tag{2}$$

Then,

$$V_B = \theta v(N) - wN. \tag{3}$$

We also assume that $v(N)$ is a continuous and differentiable function, common knowledge. The first term in the school board's payoff function expressed in equation (3), the monetary valuation of provision of education $\theta v(N)$, is positively related to the school board's type. Intuitively, suppose that the school board's capacity to pay θ increases due to a higher community's willingness to support education via taxes. This reflects an increase in the community's valuation of educational services. It is expected that the school board's and community's valuations of education will be aligned. Then, the school board's monetary valuation of the provision of education will also increase. Hence, larger θ will imply higher school board's losses from strikes and hence, greater school board's willingness to accept higher union's demands to avoid strikes. We assume that $v'(N) > 0$. Intuitively, the school board's monetary valuation of periods of educational services is strictly increasing in the number of periods of educational services. Finally, we assume that $v'(N)$ is a continuous and differentiable function, and $v''(N) > 0$. The requirement of convexity of $v(N)$ is empirically-relevant. For instance, school boards in U.S. states are committed to provide the 180 days of instruction that the law mandates. It is then expected that the first day of strike will produce the highest loss. Once the strike has started and the legal requirement has been already violated, the loss of one extra day decreases as the number of previous days of strike increases.

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services.

2.2 Effective Replacement Teachers Laws Component

This section describes the strategy adopted for explicitly incorporating an effective replacement teachers laws component into our bargaining model.

We denote $\bar{\beta} \in [0,1]$ as the upper limit on the measure of replacement teachers hired by the school board in case of strikes. The upper limit $\bar{\beta}$ is determined by law. Then, labor relations laws associated with the effective hiring of replacement teachers in case of strikes are represented by $\bar{\beta}$. In particular, when the law totally bans the use of replacement teachers in case of strikes, $\bar{\beta} = 0$. When the use of replacement teachers in case of strikes are not prohibited by the law, $\bar{\beta} > 0$. If, in addition, the law facilitates the programming of replacement teachers, for instance, by prohibiting selective or intermittent strikes,[12] the upper limit on the share of replacement teachers $\bar{\beta}$ will be higher. When the law imposes too restrictive job permanence requirements on substitute teachers to qualify as replacement teachers, the upper limit $\bar{\beta}$ will be lower.

We assume that there is a measure 1 of potential replacement teachers. $\beta \in [0, \bar{\beta}]$ denotes the measure of replacement teachers who are hired as replacement teachers in case of strikes, and $(1-\beta)$ represents the measure of potential replacement teachers who are not actually hired. We assume that the representative replacement teacher is a risk-neutral Bayesian player. V_R denotes the payoff function for the representative replacement teacher.[13]

In our framework, productivity is measured in terms of time (hours, days, weeks, etc.) per unit of monetary compensation. Following empirical regularities, we assume that replacement teachers are less productive than regular teachers. In particular, one hour of educational services of a replacement teacher per unit of monetary compensation is equivalent to α hours of a regular teacher per unit of monetary compensation, where $\alpha < 1$. We denote $w_R^o = \gamma w^o$ as the reservation wage (outside option) for the representative replacement teacher. It indicates the representative replacement teacher's payoff when strikes do

[12] See, for instance, the *Pennsylvania Collective Bargaining Law Act 88* of 1992.

[13] We use the expressions "representative replacement teacher" and "replacement teachers" interchangeably.

not occur or the payoff for the representative potential replacement teacher when he is not actually hired in case of strikes.

Whether replacement teachers are actually hired in case of strikes by the school board, i.e., the value of the measure β, is influenced by the school board's private incentives to hire replacement teachers in case of strikes and by the replacement teachers laws $\bar{\beta}$.

2.3 Game Stages

Our game encompasses two stages. At the beginning of Stage 1, the union makes an offer w^1. After observing the union's offer, the school board decides whether to accept or reject it. If the offer is accepted, then the school board transfers $(n+1)w^1$ to the union in exchange for the provision of $(n+1)$ periods of educational service. If the offer is rejected by the school board, a one-period strike occurs. In case of a strike, the school board decides whether to hire replacement teachers and the offer to be made to the replacement teachers. If an offer is made by the school board, after observing the offer, the replacement teachers decide whether to accept or reject the offer. Then, the next stage starts.

At the beginning of Stage 2, the school board makes an offer w^2 to the union. After observing the school board's offer, the union decides whether to accept or reject it. If the offer is accepted, then the school board transfers nw^2 to the union in exchange for the provision of n periods of educational services (there is a one-period strike). If the offer is rejected, then the strike continues for n more periods. In case of a strike, the school board decides whether to hire replacement teachers and the offer to be made to the replacement teachers. If an offer is made by the school board, after observing the offer, the replacement teachers decide whether to accept or reject the offer.

3 Equilibrium Analysis

This section characterizes the equilibrium of the game and outlines the equilibrium outcomes.

3.1 Equilibrium Characterization

The solution concept adopted is the Perfect-Bayesian equilibrium. Our analysis demonstrates that effective replacement teachers laws permeate the decisions of all players involved in a labor dispute. We define uncertainty about the school board's type as the distance between θ_H and θ_L. Two mutually-exclusive equilibria can occur. We demonstrate that when uncertainty about the school board's type is high, there is a separating Perfect Bayesian equilibrium. In this equilibrium, only school boards of types higher than a threshold type, denoted by $\tilde{\theta}$, accept the union's demands. As a result, strikes occur in equilibrium. Intuitively, the credible threat of a strike allows the union to screen the school boards' types and wage discriminate, i.e., to force school board's types with higher costs of strikes to accept higher union's demands. We also show that under low uncertainty, there is a pooling perfect Bayesian equilibrium. In this equilibrium, all school board's types accept the union offer. Hence, strikes do not occur in equilibrium.

This equilibrium constitutes a perfect Bayesian equilibrium of the game under conditions (4)–(7).[14]

For any x and y, such that $0 \leq x < y \leq n+1$,

$$\theta_L[v(y) - v(x)] > (y - x)w^o. \tag{4}$$

$$\frac{1}{w^o} > \frac{\alpha}{\gamma w^o},$$

which simplifies to:

$$\gamma > \alpha. \tag{5}$$

[14]Condition (4) rules out long strikes, which rarely occur in real-world settings. Condition (5) ensures that the school boards will not benefit from permanent substitution of regular teachers with replacement teachers. Condition (6) ensures that all school board's types will be willing to hire replacement teachers in case of strikes. Condition (7) ensures that all school board's types will be willing to hire additional replacement teachers when the replacement teachers laws permits this additional hiring. See the proof of Proposition 1 for details.

$$\theta_L v(n+\alpha\bar{\beta}) - \bar{\beta} w_R^o - n w^o > 0. \tag{6}$$

For any $x \in [0, n]$ and for $\bar{\beta} \in [0, 1]$,

$$w_R^o < \theta_L \alpha v'(x+\alpha\bar{\beta}). \tag{7}$$

Proposition 1 formally characterizes the equilibrium of the game. The proof of Proposition 1 follows. The formal proofs of Lemmas A1–A4, used in the construction of the equilibrium, are presented in the Appendix.

PROPOSITION 1. *Assume that conditions (4)–(7) hold. The following strategy profile, together with the union's beliefs, characterize the perfect Bayesian equilibrium of the game.*

Separating Equilibrium (High Uncertainty): $\theta_L < \frac{\theta_H}{2} + \frac{(1-\bar{\beta}\gamma)w^o}{2[v(n+1)-v(n+\alpha\bar{\beta})]}$

(1) The union chooses an offer $\tilde{w}^1 = \left(\frac{1}{n+1}\right)\left\{\frac{1}{2}\theta_H[v(n+1) - v(n+\alpha\bar{\beta})] + \frac{1}{2}(1-\bar{\beta}\gamma)w^o + (n+\bar{\beta}\gamma)w^o\right\}$ *in Stage 1; the union accepts an offer* $\tilde{w}^2 = w^o$ *in Stage 2.*

(2) The school board of type $\theta \geq \tilde{\theta} = \frac{\theta_H}{2} + \frac{(1-b\bar{e}ta\gamma)w^0}{2[v(n+1)-v(n+\alpha\bar{\beta})]}$ *accepts an offer* $\tilde{w}^1 = \left(\frac{1}{n+1}\right)\left\{\frac{1}{2}\theta_H[v(n+1) - v(n+\alpha\bar{\beta})] + \frac{1}{2}(1-\bar{\beta}\gamma)w^o + (n+\bar{\beta}\gamma)w^o\right\}$ *in Stage 1, never makes an offer to the replacement teachers in Stage 1, and never makes an offer in Stage 2; the school board of type* $\theta < \tilde{\theta} = \frac{\theta_H}{2} + \frac{(1-\bar{\beta}\gamma)w^0}{2[v(n+1)-v(n+\alpha\bar{\beta})]}$ *always rejects offer* $\tilde{w}^1 = \left(\frac{1}{n+1}\right)\left\{\frac{1}{2}\theta_H[v(n+1) - v(n+\alpha\bar{\beta})] + \frac{1}{2}(1-\bar{\beta}\gamma)w^o + (n+\bar{\beta}\gamma)w^o\right\}$ *in Stage 1, chooses* $\beta = \bar{\beta}$ *in Stage 1, makes an offer* $w_R^o = \gamma w^o$ *to the replacement teachers in Stage 1, makes an offer* $\tilde{w}^2 = w^o$ *to the union in Stage 2, and never makes an offer to the replacement teachers in Stage 2.*

(3) The replacement teachers accept an offer $w_R^o = \gamma w^o$ *in Stage 1.*

(4) After observing the school board's decision in Stage 1, the union's equilibrium posterior beliefs are as follows: If the school board accepts the offer $\tilde{w}^1 = \left(\frac{1}{n+1}\right)\left\{\frac{1}{2}\theta_H[v(n+1) - v(n+\alpha\bar{\beta})] + \frac{1}{2}(1-\bar{\beta}\gamma)w^o + (n+\bar{\beta}\gamma)w^o\right\}$, *the union believes that* θ *is uniformly distributed over the interval* $[\tilde{\theta}, \theta_H]$*; if the school board rejects the offer* $\tilde{w}^1 = \left(\frac{1}{n+1}\right)\left\{\frac{1}{2}\theta_H[v(n+1) - v(n+\right.$

$\alpha\bar{\beta})] + \frac{1}{2}(1-\bar{\beta}\gamma)w^o + (n+\bar{\beta}\gamma)w^o\big\}$, *the union believes that* θ *is uniformly distributed over the interval* $[\theta_L, \tilde{\theta})$.

Pooling Equilibrium (Low Uncertainty): $\theta_L \geq \frac{\theta_H}{2} + \frac{(1-\bar{\beta}\gamma)w^o}{2[v(n+1)-v(n+\alpha\bar{\beta})]}$

(1) The union chooses an offer $\tilde{w}^1 = \big(\frac{1}{n+1}\big)\{\theta_L[v(n+1) - v(n+\alpha\bar{\beta})] + (n+\bar{\beta}\gamma)w^o\}$ *in Stage 1; the union accepts an offer* $\tilde{w}^2 = w^o$ *in Stage 1.*

(2) The school board of type $\theta \in [\theta_L, \theta_H]$ *accepts offer* $\tilde{w}^1 = \big(\frac{1}{n+1}\big)\{\theta_L[v(n+1) - v(n+\alpha\bar{\beta})] + (n+\bar{\beta}\gamma)w^o\}$ *in Stage 1, never makes an offer to the replacement teachers in Stage 1, and never makes an offer in Stage 2.*

(3) After observing the school board's decision in Stage 1, the union's equilibrium posterior beliefs are as follows: The union believes that θ *is uniformly distributed over the interval* $[\theta_L, \theta_H]$.[15]

PROOF: The proof includes several steps. To ensure sequential rationality, the model is solved using backward induction. Then, we start the proof by analyzing Stage 2.

Step 1: Equilibrium Strategies in Stage 2

Two steps are encompassed in this section of the proof: The analysis of the union's equilibrium response, and the analysis of the school board's equilibrium offer $\tilde{w}^2$.

Step 1.1: Union's Equilibrium Response

We first analyze the optimal decision of the union. If the union accepts the school board's offer w^2 in Stage 2 after one-period strike, then its payoff will be $V_U = (w^o + nw^2)$. If the union rejects the school board's offer w^2 in Stage 2 after one-period strike, the strike will continue for n more periods. Then, its payoff will be $V_U = (w^o + nw^o)$. Hence, the union will be willing to accept any offer $w^2 \geq w^o$.

[15]In the pooling equilibrium, all types of school boards accept the offer $\tilde{w}^1 = \big(\frac{1}{n+1}\big)\{\theta_L[v(n+1) - v(n+\alpha\bar{\beta})] + (n+\bar{\beta}\gamma)w^o\}$ in Stage 1. Then, the union's prior and posterior are the same.

Step 1.2: School Board's Equilibrium Offer $\tilde{w}^2$

Next, we analyze the optimal offer $\tilde{w}^2$ for a school board of type θ. We will show that $\tilde{w}^2 = w^o$.

First, any offer $w^2 > w^o$ is strictly dominated by an offer $w^2 = w^o$. In both cases, the offers are accepted by the union but the payoff for the school board is higher under an offer $w^2 = w^o$.

Second, we will show that any offer $w^2 < w^o$ is also strictly dominated by an offer w^o. Suppose the school board makes an offer $w^2 < w^o$ to the union in Stage 2. The union will rationally reject the offer. As a result, the strike will last for n more periods. Then, the school board decides whether to hire replacement teachers in Stage 2. The minimum acceptable offer by the replacement teachers is $w_R^o = \gamma w^o$. Then, this is the offer to be made by the school board in case of hiring replacement teachers (and rationally accepted by the replacement teachers). If the school board decides to hire β replacement teachers in Stage 2, the payoff for the school board will be:

$$V_B = \theta v(x + n\alpha\beta) - W - n\beta\gamma w^o, \tag{8}$$

where $x \in [0, \alpha\bar{\beta}]$ denotes the measure of educational services provided by replacement teachers during a one-period strike in Stage 1, $n\alpha\beta$ denotes the measure of educational services provided by replacement teachers during an n-period strike in Stage 2; and, W and $n\beta\gamma w^o$ denote the cost of educational services in Stage 1 and Stage 2, respectively.[16] If the school board decides not to hire replacement teachers in Stage 2, the payoff for the school board will be:

$$V_B = \theta v(x) - W. \tag{9}$$

By conditions (4) and (5),

$$\theta v(x + n\alpha\beta) - W - n\beta\gamma w^o > \theta v(x) - W.$$

[16] We take the expressions for x and W as parametric. The equilibrium values for x and W are determined in Stage 1.

Then, the school board will always hire replacement teachers in case of a strike in Stage 2.

Finally, we will show that any type of school board will prefer to offer $w^2 = w^o$ and avoid an n-period strike than to offer $w^2 < w^o$. This will be true if the school board's payoff from making an offer $w^2 = w^o$ is greater than or equal to its payoff from making an offer $w^2 < w^o$. The payoff for a school board of type θ that makes an offer $w^2 = w^o$ in Stage 2, which is accepted by the union, is:

$$V_B = \theta v(x+n) - W - nw^o. \tag{10}$$

Then,

$$[\theta v(x+n) - W - nw^o] - [\theta v(x+n\alpha\beta) - W - n\beta\gamma w^o] =$$

$$= \theta[v(x+n) - v(x+n\alpha\beta)] - n(1-\beta\gamma)w^o > n(1-\alpha\beta)w^o - n(1-\beta\gamma)w^o =$$

$$= n\beta(\gamma - \alpha)w^o > 0.$$

The first inequality holds by Condition (4), and the second inequality holds by Condition (5). This result is true for any $\beta \in [0, \bar{\beta}]$ and for any $\theta \in [\theta_L, \theta_H]$. Hence, the school board of type θ will offer $\tilde{w}^2 = w^o$, and the union will accept the offer. In equilibrium, strikes will not occur in Stage 2.

Step 2: Equilibrium Strategies in Stage 1

Three steps are encompassed in this section of the proof: The analysis of the school board's equilibrium response, the analysis of the union's equilibrium demand $\tilde{w}^1$, and the analysis of the equilibrium threshold $\tilde{\theta}$.

Step 2.1: School Board's Equilibrium Response

We first analyze the optimal decision of the school board of type θ. Suppose the school board rejects the union's demand w^1 in Stage 1. Then, a one-period strike will occur. The school board decides whether to hire replacement teachers in Stage 1. The minimum acceptable offer by the replacement teachers is $w_R^o = \gamma w^o$. Then, this is the offer to be made by the school board in case of hiring replacement teachers (and rationally accepted by the replacement teachers). If the school decides to hire replacement teachers in Stage 1, the payoff for the school board will be:

$$V_B = \theta v(n + \alpha\beta) - \beta w_R^o - nw^o. \tag{11}$$

where the term $\alpha\beta$ represents the benefits of hiring replacement teachers (i.e., additional provision of educational services), and the term $-\beta w_R^o$ represents the cost of hiring replacement teachers. The term nw^o represents the cost of hiring regular teachers for n periods.[17] If the school board decides not to hire replacement teachers in Stage 1, the payoff for the school board will be:

$$V_B = \theta v(n) - nw^o. \tag{12}$$

By conditions (4) and (5),

$$\theta v(n + \alpha\beta) - \beta w_R^o - nw^o > \theta v(n) - nw^o.$$

Then, the school board will always hire replacement teachers in case of a strike in Stage 1.

Importantly, by Lemma A1 in the Appendix:

$$\beta = \bar{\beta}.$$

Intuitively, the school board always benefits from hiring an extra replacement teacher. Hence, it will hire the maximum possible number of replacement teachers $\bar{\beta}$.

The payoff for a school board of type θ that accepts the union's demands in Stage 1, i.e, that does not endure a one-period strike, is:

$$V_B = \theta v(n + 1) - (n + 1)w^1. \tag{13}$$

The school board will accept an offer w^1 if its payoff from accepting the offer is greater than or equal to its payoff from rejecting the offer:

$$\theta v(n + 1) - w^1(n + 1) \geq \theta v(n + \alpha\bar{\beta}) - \bar{\beta}\gamma w^o - nw^o.$$

[17]Remember that rejection of the union's demands in Stage 1 generates a one-period strike. After the strike, the school board will offer $\tilde{w}^2 = w^o$, and the union will accept the offer.

Step 2.2: Union's Equilibrium Demand $\tilde{w}^1$

Next, we analyze the optimal decision of the union in Stage 1. Anticipating the school board's equilibrium strategies, the union will choose the equilibrium offer $\tilde{w}^1$ that makes the school board of type $\tilde{\theta}$ indifferent between accepting the offer and rejecting it:

$$\tilde{\theta}v(n+1) - \tilde{w}^1(n+1) = \tilde{\theta}v(n+\alpha\bar{\beta}) - \bar{\beta}\gamma w^o - nw^o. \tag{14}$$

Solving for $\tilde{w}^1$ yields:

$$\tilde{w}^1(\tilde{\theta}) = \left(\frac{1}{n+1}\right)\{\tilde{\theta}[v(n+1) - v(n+\alpha\bar{\beta})] + (n+\bar{\beta}\gamma)w^o\}. \tag{15}$$

Equation (15) defines one-to-one correspondence between $\tilde{\theta}$ and $\tilde{w}^1$. Lemma A2 in the Appendix demonstrates that $\tilde{w}^1(\tilde{\theta})$ is increasing in $\tilde{\theta}$ for any $\tilde{\theta} \geq \theta_L$:

$$\frac{\partial \tilde{w}^1(\tilde{\theta})}{\partial \tilde{\theta}} > 0. \tag{16}$$

For $\theta > \tilde{\theta}$:

$$\theta v(n+1) - \tilde{w}^1(n+1) > \theta v(n+\alpha\bar{\beta}) - \bar{\beta}\gamma w^0 - nw^0.$$

Then, the school board with $\theta > \tilde{\theta}$ will prefer to accept the union's offer $\tilde{w}^1$ and avoid a strike. The school board with type $\theta < \tilde{\theta}$ will prefer to reject the union's offer $\tilde{w}^1$ and endure a strike.

Step 2.3: Equilibrium Threshold $\tilde{\theta}$

We now derive the equilibrium threshold $\tilde{\theta}$. Three mutually-exclusive cases are evaluated: Case 1 ($\theta_L < \tilde{\theta} < \theta_H$), Case 2 ($\tilde{\theta} \geq \theta_H$), and Case 3 ($\tilde{\theta} \leq \theta_L$). These cases correspond to the potential separating perfect Bayesian equilibrium where strikes occur with strictly positive probability, the potential pooling perfect Bayesian equilibrium where strikes always occur, and the potential pooling perfect Bayesian equilibrium where strikes never occur, respectively.

Case 1: Potential Separating Perfect Bayesian Equilibrium with $\tilde{\theta} \in (\theta_L, \theta_H)$

We analyze whether the equilibrium threshold $\tilde{\theta}$ can be in the interval (θ_L, θ_H). This analysis corresponds to the evaluation of existence of the separating perfect Bayesian equilibrium where strikes occur with strictly positive probability.

Suppose that $\tilde{\theta} \in (\theta_L, \theta_H)$. Only school boards of types $\theta > \tilde{\theta}$ will accept the offer. Then, the union's expected payoffs will be:

$$V_U(\tilde{\theta}) = \left(\frac{\theta_H - \tilde{\theta}}{\theta_H - \theta_L}\right)(n+1)\tilde{w}^1 + \left(\frac{\tilde{\theta} - \theta_L}{\theta_H - \theta_L}\right)(n+1)w^0. \tag{17}$$

Substituting equation (15) into equation (17), we get:

$$V_U(\tilde{\theta}) = \left(\frac{\theta_H - \tilde{\theta}}{\theta_H - \theta_L}\right)(n+1)[\tilde{\theta}(v(n+1) - v(n+\alpha\bar{\beta})) + (n+\bar{\beta}\gamma)w^0] + \left(\frac{\tilde{\theta} - \theta_L}{\theta_H - \theta_L}\right)(n+1)w^0. \tag{18}$$

Equation (18) is a quadratic function in $\tilde{\theta}$ that achieves its maximum at:

$$\tilde{\theta} = \left\{\frac{\theta_H}{2} + \frac{(1-\bar{\beta}\gamma)w^0}{2[v(n+1) - v(n+\alpha\bar{\beta})]}\right\}. \tag{19}$$

By construction, the right-hand side of equation (19) is greater than θ_L.

Hence, if and only if

$$\theta_L < \left\{\frac{\theta_H}{2} + \frac{(1-\bar{\beta}\gamma)w^o}{2[v(n+1) - v(n+\alpha\bar{\beta})]}\right\}, \tag{20}$$

a separating perfect Bayesian equilibrium exists. A necessary and sufficient condition for a separating equilibrium is given by equation (20). Intuitively, a one-period strike occurs only under high uncertainty about the school board's type.

By Lemma A3 in the Appendix, the right-hand side of equation (19) is lower than θ_H.

$$\left\{\frac{\theta_H}{2} + \frac{(1-\bar{\beta}\gamma)w^o}{2[v(n+1) - v(n+\alpha\bar{\beta})]}\right\} < \theta_H. \tag{21}$$

Substituting equation (19) in equation (15), we obtain the union's equilibrium demand in Stage 1, $\tilde{w}^1$:

$$\tilde{w}^1 = \left(\frac{1}{n+1}\right)\left\{\frac{1}{2}\theta_H[v(n+1) - v(n+\alpha\bar{\beta})] + \frac{1}{2}(1-\bar{\beta}\gamma)w^o + (n+\bar{\beta}\gamma)w^o\right\}. \tag{22}$$

Lemma A4 in the Appendix verifies that $\tilde{w}^1 > w^o$.

Case 2: Potential Pooling Perfect Bayesian Equilibrium with $\tilde{\theta} \geq \theta_H$

We analyze whether the equilibrium threshold $\tilde{\theta}$ can be greater than or equal to θ_H. This analysis corresponds to the evaluation of existence of the pooling perfect Bayesian equilibrium where strikes always occur.

Suppose $\tilde{\theta} \geq \theta_H$. Then, $\tilde{w}^1(\tilde{\theta}) \geq \tilde{w}^1(\theta_H)$, by Lemma A2. If the union offers $\tilde{w}^1(\tilde{\theta})$, all school board's types will reject the offer. Then, there will be a one-period strike. Intuitively, the union's demands are so high that all school board's types reject them. The union's expected payoff is given by:

$$V_U = (n+1)w^o. \tag{23}$$

We will demonstrate that the threshold $\tilde{\theta} \geq \theta_H$ is not an equilibrium threshold. Consider the alternative threshold $\tilde{\theta}' \in (\theta_L, \theta_H)$. We will show that the union has an incentive for deviation.

The union's expected payoff under $\tilde{\theta}' \in (\theta_L, \theta_H)$ will be:

$$V'_U = \left(\frac{\theta_H - \tilde{\theta}'}{\theta_H - \theta_L}\right)(n+1)\tilde{w}^1(\tilde{\theta}') + \left(\frac{\tilde{\theta}' - \theta_L}{\theta_H - \theta_L}\right)(n+1)w^0. \tag{24}$$

We first show that $\tilde{w}^1(\tilde{\theta}') > w^o$:

$$\tilde{w}^1(\tilde{\theta}') - w^o = \left(\frac{1}{n+1}\right)\{\tilde{\theta}'[v(n+1) - v(n+\alpha\bar{\beta})] - (1-\alpha\bar{\beta})w^o\} > 0. \tag{25}$$

By construction, $\tilde{\theta}' > \theta_L$. Then, the last inequality holds by condition (4).

Second, using result (16), we demonstrate that $V'_U > V_U$:

$$V'_U - V_U = \left(\frac{\theta_H - \tilde{\theta}'}{\theta_H - \theta_L}\right)(n+1)[\tilde{w}^1(\tilde{\theta}') - w^o] > 0.$$

Then, $\tilde{\theta} \geq \theta_H$ is not an equilibrium threshold. Hence, the potential pooling perfect Bayesian equilibrium with $\tilde{\theta} \geq \theta_H$ is not an equilibrium. Intuitively, there is no pooling equilibrium where strikes always occur.

Case 3: Potential Pooling Perfect Bayesian Equilibrium with $\tilde{\theta} \leq \theta_L$

We analyze whether the equilibrium threshold $\tilde{\theta}$ can be lower than or equal to θ_L. This analysis corresponds to the evaluation of a pooling equilibrium where strikes never occur.

By Case 1, if $\theta_L \geq \frac{\theta_H}{2} + \frac{(1-\bar{\beta}\gamma)w^0}{2[v(n+1)-v(n+\alpha\bar{\beta})]}$, only pooling perfect Bayesian can exist. By Case 2, there is no a pooling equilibrium in which all school board's types reject the union's demands $\tilde{w}^1$. Then, the only remaining potential pooling perfect Bayesian equilibrium is the one in which all school board's types accept the union's demands $\tilde{w}^1$. The highest union's demand $\tilde{w}_1$ acceptable by all school board's types is the one that makes the school board of type θ_L indifferent between accepting and rejecting. Union's demands lower than $\tilde{w}_1$ are also acceptable by all school board's types but they are dominated by $\tilde{w}_1$ for the union. Hence,

$$\tilde{\theta} = \theta_L. \tag{26}$$

The indifference condition for the school board of type θ_L implies:

$$\tilde{w}^1 = \left(\frac{1}{n+1}\right)\{\theta_L[v(n+1) - v(n+\alpha\bar{\beta})] + (n+\bar{\beta}\gamma)w^o\}. \tag{27}$$

This condition defines the union's equilibrium demand $\tilde{w}^1$.

Intuitively, a pooling perfect Bayesian equilibrium with no strikes occurs under low uncertainty about the school board's type. When uncertainty about the school board's type is low, it is not beneficial for the union to discriminate among school board's types.

Step 3: Union's Equilibrium Beliefs

The union's equilibrium posterior beliefs in the separating and pooling equilibria, Cases 1 and 3, are as follows.[18]

[18]Remember that the potential pooling perfect Bayesian equilibrium associated with Case 2 is not an equilibrium.

Case 1: Separating Perfect Bayesian Equilibrium with $\tilde{\theta} = \left\{\frac{\theta_H}{2} + \frac{(1-\bar{\beta}\gamma)w^o}{2[v(n+1)-v(n+\alpha\bar{\beta})]}\right\}$

After observing the school board's decision in Stage 1, the union's equilibrium posterior beliefs are as follows. If the school board accepts the offer $\tilde{w}^1$, the union believes that $\theta \geq \tilde{\theta}$. By Bayes' rule, for any x and y such that $\tilde{\theta} \leq x \leq y \leq \theta_H$, the posterior probability is given by:

$$Prob(x \leq \theta \leq y) = \frac{\frac{y-x}{\theta_H-\theta_L}}{\frac{\theta_H-\tilde{\theta}}{\theta_H-\theta_L}} = \frac{y-x}{\theta_H - \tilde{\theta}}.$$

Hence, the union believes that θ is distributed uniformly over the interval $[\tilde{\theta}, \theta_H]$. Applying the same procedure, we can demonstrate that, if the school board rejects the offer $\tilde{w}^1$, the union believes that θ is distributed uniformly over the interval $[\theta_L, \tilde{\theta})$.

Case 3: Pooling Perfect Bayesian Equilibrium with $\tilde{\theta} = \theta_L$

After observing the school board's decision in Stage 1, and given that all school board's types accept $\tilde{w}^1$, the union's equilibrium posterior beliefs are equal to the prior beliefs: The union believes that θ is distributed uniformly over the interval $[\theta_L, \theta_H]$. ■

3.2 Equilibrium Outcomes

This section summarizes the equilibrium outcomes under high and low uncertainty.

Separating Equilibrium (High Uncertainty)

The union's equilibrium demand is $\tilde{w}^1 = \left(\frac{1}{n+1}\right)\left\{\frac{1}{2}\theta_H[v(n+1) - v(n+\alpha\bar{\beta})] + \frac{1}{2}(1-\bar{\beta}\gamma)w^o + (n+\bar{\beta}\gamma)w^o\right\}$. The school board's equilibrium offer is $\tilde{w}^2 = w^o$ if $\theta < \tilde{\theta}$. The school board never makes an offer $\tilde{w}^2$ if $\theta \geq \tilde{\theta}$. The probability of strikes across school board's types, p, is

$$p = \left(\frac{\tilde{\theta} - \theta_L}{\theta_H - \theta_L}\right). \tag{28}$$

The equilibrium payoffs for the school board of type θ, the regular teachers, and the replacement teachers are as follows.

$$V_B = \begin{cases} \theta v(n+1) - (n+1)\tilde{w}^1 & \text{if } \theta \geq \tilde{\theta} \text{ (No Strike)} \\ \theta v(n+\alpha\bar{\beta}) - \bar{\beta}\gamma w^o - n w^o & \text{if } \theta < \tilde{\theta} \text{ (Strike)} \end{cases} \tag{29}$$

$$V_U = \begin{cases} (n+1)\tilde{w}^1 & \text{if } \theta \geq \tilde{\theta} \text{ (No Strike)} \\ (n+1)w^o & \text{if } \theta < \tilde{\theta} \text{ (Strike)} \end{cases} \tag{30}$$

$$V_R = \begin{cases} (n+1)\gamma w^o & \text{if } \theta \geq \tilde{\theta} \text{ (No Strike)} \\ \bar{\beta}\gamma w^o + (n+1-\bar{\beta})\gamma w^o & \text{if } \theta < \tilde{\theta} \text{ (Strike)} \end{cases} \tag{31}$$

The equilibrium expected payoffs across school board's types for the school board, the regular teachers, and the replacement teachers are $E(V_B) = [1 - p(\theta)][\theta v(n+1) - (n+1)\tilde{w}^1] + p(\theta)[\theta v(n+\alpha\bar{\beta}) - \bar{\beta}\gamma w^o - n w^o]$, $E(V_U) = [1 - p(\theta)][(n+1)\tilde{w}^1] + p(\theta)[(n+1)w^o]$, and $E(V_R) = [1 - p(\theta)](n+1)\gamma w^o + p(\theta)[\bar{\beta}\gamma w^o + (n+1-\bar{\beta})\gamma w^o]$, respectively.[19]

Pooling Equilibrium (Low Uncertainty)

The union's demand $\tilde{w}^1 = \left(\frac{1}{n+1}\right)[\theta_L[v(n+1) - v(n+\alpha\bar{\beta})] + (n+\bar{\beta}\gamma)w^o]$. The school board never makes an offer $\tilde{w}^2$. The probability of strikes across school board's types, p, is zero. The equilibrium payoffs for the school board of type $\theta \in [\theta_L, \theta_H]$, the regular teachers, and the replacement teachers are as follows.

$$V_B = \theta v(n+1) - (n+1)\tilde{w}^1. \tag{32}$$

$$V_U = (n+1)\tilde{w}^1. \tag{33}$$

$$V_R = (n+1)\gamma w^o. \tag{34}$$

These payoffs are achieved in equilibrium with certainty.

[19] Note that $\bar{\beta}\gamma w^o + (n+1-\bar{\beta})\gamma w^o$ simplifies to $(n+1)\gamma w^o$. In other words, the replacement teachers receive the same expected payoff in case of strike and in case of no strike. See the proof of Proposition 1.

Note that strikes occur in real-world settings. Then, the separating perfect Bayesian equilibrium is more empirically-relevant. Hence, the rest of the paper will be focused on this equilibrium.

4 Comparative Statics: Impact of Effective Replacement Teachers Laws on Equilibrium Outcomes

Propositions 3 and 4 show the effects of laws that permit the effective use of replacement teachers in case of strikes (a change in $\bar{\beta}$) on the union's demands and on the probability of strikes p, in environments characterized by high uncertainty.

PROPOSITION 3. *Effective replacement teachers laws reduce the union's demand.*

PROOF:

$$\tilde{w}^1 = \left(\frac{1}{n+1}\right)\{\tilde{\theta}[v(n+1) - v(n+\alpha\bar{\beta})] + (n+\bar{\beta}\gamma)w^o\} =$$

$$= \left(\frac{1}{n+1}\right)\left\{\frac{1}{2}\theta_H[v(n+1) - v(n+\alpha\bar{\beta})] + \frac{1}{2}(1-\bar{\beta}\gamma)w^o + (n+\bar{\beta}\gamma)w^o\right\}.$$

Therefore,

$$\frac{\partial \tilde{w}^1}{\partial \bar{\beta}} = \left(\frac{1}{n+1}\right)\left[-\frac{1}{2}\theta_H \alpha v'(n+\alpha\bar{\beta}) + \frac{1}{2}\gamma w^o\right] <$$

$$< \left(\frac{1}{n+1}\right)\left[-\frac{1}{2}\theta_L \alpha v'(n+\alpha\bar{\beta}) + \frac{1}{2}\gamma w^o\right] < 0.$$

The result holds by condition (7). ■

Intuitively, laws that permit the effective use of replacement teachers in case of strikes (i.e., an increase in $\bar{\beta}$) decrease the cost of strikes for the school board. As a result, the bargaining power of the school board in negotiations with the union is enhanced. Anticipating this, the union decreases its demands.

LEMMA 1. *Effective replacement teachers laws reduce the threshold $\tilde{\theta}$.*

PROOF: Differentiating equation (19) with respect to $\bar{\beta}$:

$$\frac{\partial\tilde{\theta}}{\partial\bar{\beta}} = \frac{1}{2}\left\{\frac{-\gamma w^o[v(n+1) - v(n+\alpha\bar{\beta})] + v'(n+\alpha\bar{\beta})\alpha(1-\bar{\beta}\gamma)w^o}{[v(n+1) - v(n+\alpha\bar{\beta})]^2}\right\}.$$

By applying the mean-value theorem and taking into account that $v'(N)$ is an increasing function of N:

$$v(n+1) - v(n+\alpha\bar{\beta}) > v'(n+\alpha\bar{\beta})(1-\alpha\bar{\beta}).$$

Therefore:

$$\frac{\partial\tilde{\theta}}{\partial\bar{\beta}} < \frac{1}{2}\left\{\frac{-\gamma w^o v'(n+\alpha\bar{\beta})(1-\alpha\bar{\beta}) + v'(n+\alpha\bar{\beta})\alpha(1-\bar{\beta}\gamma)w^o}{[v(n+1) - v(n+\alpha\bar{\beta})]^2}\right\} =$$

$$= \frac{1}{2}\left\{\frac{w^o v'(n+\alpha\bar{\beta})(\alpha-\gamma)}{[v(n+1) - v(n+\alpha\bar{\beta})]^2}\right\} < 0.$$

The last inequality holds by condition (5). ■

PROPOSITION 4. *Effective replacement teachers laws reduce the probability of strikes p.*

PROOF:

$$p = \frac{\tilde{\theta} - \theta_L}{\theta_H - \theta_L}.$$

Differentiating with respect to $\bar{\beta}$, we get:

$$\frac{\partial p}{\partial\bar{\beta}} = \left[\frac{1}{(\theta_H - \theta_L)^2}\right]\frac{\partial\tilde{\theta}}{\partial\bar{\beta}} < 0.$$

The last inequality holds by Lemma 1. ■

Intuitively, laws that permit the effective use of replacement teachers in case of strikes (i.e., an increase in $\bar{\beta}$) reduce the cost of strikes for the school board. They do not affect directly the cost of strikes for the union because the replacement teachers are less productive than the regular teachers, i.e., regular teachers cannot be permanently displaced by replacement teachers (by condition (5)). We might then expect the probability of a strike to raise.

However, there is an additional effect of an increase in $\bar{\beta}$, which offsets the previous effect: The union takes into account the reduction in the cost of strikes for the school board and lowers its demands $\tilde{w}^1$ (by Proposition 3). This implies that a wider range of school boards will find it optimal to accept the union's demands and avoid a strike.

5 Social Welfare: Impact of Effective Replacement Teachers Laws

This section analyzes the social welfare effects of laws that permit the effective use of replacement teachers in case of strikes (changes in $\bar{\beta}$), in environments characterized by high-uncertainty.

5.1 Definitions

Let $p(\theta)$ represent the probability of strikes for a school board's type θ. We define the social welfare function for a school board's type θ as follows.

DEFINITION 1. *The social welfare function, given a school board type θ, is defined as follows.*

$$SW(\theta) = [1 - p(\theta)][\theta v(n+1) + w^o_R] + p(\theta)[\theta v(n + \alpha\bar{\beta}) + w^o + (1-\bar{\beta})w^o_R]. \qquad (35)$$

The first and second term represent the sum of equilibrium payoffs for the school board, the union, and the replacement teachers when strikes do not occur and occur, respectively. These payoffs are summarized in equations (29), (30) and (31).

Next, we define the social welfare loss across school board's types.

DEFINITION 2. *The social welfare function, across school board's types, is defined as* *follows.*

$$SW = \int_{\theta_L}^{\theta_H} \left(\frac{1}{\theta_H - \theta_L}\right) SW(\theta) d\theta = \int_{\theta_L}^{\tilde{\theta}} \left(\frac{1}{\theta_H - \theta_L}\right) [\theta v(n + \alpha\bar{\beta}) + w^o + (1 - \bar{\beta}) w_R^o] d\theta +$$

$$+ \int_{\tilde{\theta}}^{\theta_H} \left(\frac{1}{\theta_H - \theta_L}\right) [\theta v(n + 1) + w_R^o] d\theta. \quad (36)$$

5.2 Social Welfare Analysis

This section provides social welfare analysis of laws that permit school board to effectively hire replacement teachers in case of strikes.

First, we demonstrate that bargaining impasse is always welfare reducing. Proposition 5 summarizes this finding.

PROPOSITION 5. *For any school board type θ, the social welfare is higher when a strike does not occur.*

PROOF Using Definition 1, the difference between social welfare without and with strikes is given by:

$$[\theta v(n+1) + w_R^o] - [\theta v(n + \alpha\bar{\beta}) + w^o + (1 - \bar{\beta}) w_R^o] = \theta[v(n+1) - v(n + \alpha\bar{\beta})] - w^o + \bar{\beta} w_R^o \geq$$

$$\geq \theta_L[v(n+1) - v(n + \alpha\bar{\beta})] - w^o + \bar{\beta} w_R^o >$$

$$> (1 - \alpha\bar{\beta}) w^o - w^o + \bar{\beta} w_R^o = \bar{\beta}(w_R^o - \alpha w^o) > 0.$$

The second inequality holds by condition (4), and the third inequality holds by condition (5). ■

Next, we show that the effects of replacement teachers laws (i.e., an increase in $\bar{\beta}$) on social welfare depends on the school board's type. By Lemma 1, replacement teachers laws (an increase in $\bar{\beta}$) lower the threshold $\tilde{\theta}$. Denote the new threshold (the threshold after an increase in $\bar{\beta}$) as $\tilde{\theta}'$. We will analyze three relevant ranges of θ values: (1) $\theta_L \leq \theta < \tilde{\theta}'$; (2) $\tilde{\theta}' \leq \theta < \tilde{\theta}$; (3) $\tilde{\theta} \leq \theta \leq \theta_H$.

By considering these three ranges of θ values, the social welfare function can be written as:

$$SW = \int_{\theta_L}^{\tilde{\theta}'} \left(\frac{1}{\theta_H - \theta_L}\right) SW(\theta) d\theta + \int_{\tilde{\theta}'}^{\tilde{\theta}} \left(\frac{1}{\theta_H - \theta_L}\right) SW(\theta) d\theta + \\ + \int_{\tilde{\theta}}^{\theta_H} \left(\frac{1}{\theta_H - \theta_L}\right) SW(\theta) d\theta. \tag{37}$$

Case 1: School boards of low type endure strikes before and after a change in $\bar{\beta}$. Hence,

$$\int_{\theta_L}^{\tilde{\theta}'} \left(\frac{1}{\theta_H - \theta_L}\right) SW(\theta) d\theta = \int_{\theta_L}^{\tilde{\theta}'} \left(\frac{1}{\theta_H - \theta_L}\right) [\theta v(n + \alpha\bar{\beta}) + w^o + (1 - \bar{\beta}) w_R^o] d\theta.$$

The right-hand side of the equation positively depends on $\bar{\beta}$ because

$$\frac{\partial}{\partial \bar{\beta}} (\theta v(n + \alpha\bar{\beta}) + w^o + (1 - \bar{\beta}) w_R^o) = \theta v'(n + \alpha\bar{\beta}) - w_R^o > \theta_L \alpha v'(n + \alpha\bar{\beta}) - \gamma w^o > 0.$$

The last inequality holds by condition (7). Intuitively, social welfare is increased by the higher provision of educational services during strikes.

Case 2: School boards of intermediate type endure strikes only before a change in $\bar{\beta}$. Social welfare is higher if there is no strike because the provision of education services is higher. Then, the term $\int_{\tilde{\theta}'}^{\tilde{\theta}} \left(\frac{1}{\tilde{\theta} - \tilde{\theta}'}\right) SW(\theta) d\theta$, the second term of equation (37), positively depends on $\bar{\beta}$.

Case 3: School boards of high type do not endure strikes either before or after a change in $\bar{\beta}$. The social welfare function is

$$\int_{\tilde{\theta}}^{\theta_H} \left(\frac{1}{\theta_H - \theta_L}\right) SW(\theta) d\theta = \int_{\tilde{\theta}}^{\theta_H} \left(\frac{1}{\theta_H - \theta_L}\right) [\theta v(n + 1) + w_R^o] d\theta.$$

This term does not depend on β. Hence, social welfare is not affected.

Summing up, laws that permit the effective use of replacement teachers in case of strikes increase social welfare by increasing the provision of educational services during strikes (school boards with low type, Case 1), and by reducing the likelihood of strikes (school boards with medium type, Case 2).

Finally, Proposition 6 presents the formal proof of the impact of effective replacement teachers laws on social welfare.

PROPOSITION 6. *Effective replacement teachers laws increase social welfare.*

PROOF: Differentiating SW with respect to $\bar{\beta}$ yields:

$$\int_{\theta_L}^{\tilde{\theta}} \left(\frac{1}{\theta_H - \theta_L}\right)[\theta\alpha v'(n+\alpha\bar{\beta}) - w_R^o]d\theta +$$

$$+\left(\frac{1}{\theta_H - \theta_L}\right)[\tilde{\theta}v(n+\alpha\bar{\beta}) + w^o + (1-\bar{\beta})w_R^o]\frac{\partial\tilde{\theta}}{\partial\bar{\beta}} + \left(\frac{1}{\theta_H - \theta_L}\right)\{-[\tilde{\theta}v(n+1) + w_R^o]\}\frac{\partial\tilde{\theta}}{\partial\bar{\beta}} =$$

$$= \int_{\theta_L}^{\tilde{\theta}} \left(\frac{1}{\theta_H - \theta_L}\right)[\theta\alpha v'(n+\alpha\bar{\beta}) - w_R^o]d\theta +$$

$$+\left(\frac{1}{\theta_H - \theta_L}\right)\left(-\frac{\partial\tilde{\theta}}{\partial\bar{\beta}}\right)\{\tilde{\theta}[v(n+1) - v(n+\alpha\bar{\beta})] - w^o + \bar{\beta}w_R^o\}$$

The last expression is the sum of two terms. We will show now that both terms are positive. The first term is positive by condition (7). The second term encompasses the product of two positive terms. The expression $-\frac{\partial\tilde{\theta}}{\partial\bar{\beta}}$ is positive by Lemma 1. The expression in curly brackets, $\{\tilde{\theta}[v(n+1) - v(n+\alpha\bar{\beta})] - w^o + \bar{\beta}w_R^o\}$ is positive by Proposition 5. ■

Intuitively, effective replacement teachers laws allow school boards to hire replacement teachers in case of strikes, and hence, increase the provision of educational services. As a result, social welfare is enhanced.

6 Extension: Replacement Teachers' Reservation Wage

The laws studied in this paper permit school boards to effectively hire replacement teachers in case of strikes. The private incentives of school boards to hire replacement teachers in case of strikes are affected by the replacement teachers' reservation wage $w_R^o = \gamma w^o$. Then, it is relevant to study whether bargaining impasse and social welfare can be affected by an increase in the replacement teachers' reservation wage w_R^o. This section extends our previous analysis by evaluating the effects of an increase in the replacement teachers' reservation wage generated by an increase in γ.

6.1 Effects on the Union's Demands and the Probability of Strikes

This section analyzes the effects of an increase in the replacement teachers' reservation wage on the union's demands and the probability of strikes. Propositions 7 and 8 summarize these effects.

PROPOSITION 7. *An increase in replacement teachers' reservation wage increases the union's demand.*

PROOF: Differentiating equation (21) with respect to γ yields:

$$\frac{\partial \tilde{w}^1}{\partial \gamma} = \frac{\bar{\beta} w^o}{n+1} > 0.$$

■

Intuitively, an increase in the replacement teachers' reservation wage γw^o increases the cost of strikes for the school board and hence, school boards are more willing to accept high demands from the union to avoid strikes. Anticipating this, the union increases its demands.

LEMMA 2. *An increase in replacement teachers' reservation wage reduces the threshold $\tilde{\theta}$.*

PROOF: Differentiating equation (18) with respect to γ yields:

$$\frac{\partial\tilde{\theta}}{\partial\gamma} = -\frac{\bar{\beta}w^o}{2[v(n+1) - v(n+\alpha\bar{\beta})]} < 0.$$

■

PROPOSITION 8. *An increase in replacement teachers' reservation wage reduces the probability of strikes p.*

PROOF: Differentiating the probability of strikes p with respect to γ yields:

$$\frac{\partial p}{\partial\gamma} = \left(\frac{1}{\theta_H - \theta_L}\right)\frac{\partial\tilde{\theta}}{\partial\gamma}.$$

Hence, by Lemma 2:

$$\frac{\partial p}{\partial\gamma} = \left(-\frac{1}{\theta_H - \theta_L}\right)\left\{\frac{\bar{\beta}w^o}{2[v(n+1) - v(n+\alpha\bar{\beta})]}\right\} < 0.$$

■

Intuitively, an increase in the replacement teachers' reservation wage γw^o has two effects. First, it increases the cost of strikes for the school board. We might then expect the probability of strikes to be reduced. Second, it increases the union's demand $\tilde{w}^1$ (by Proposition 7), and hence increases the probability of strikes. This second effect operates through the union's anticipation of the higher cost of strikes for the school board. We demonstrate that the first effect more than offsets the second effect.

6.2 Effects on Social Welfare

This section analyzes the effects of an increase on replacement teachers' reservation wage on social welfare. We will first demonstrate that the effects depend on the specific school teacher board's type. By Lemma 2, an increase in replacement teachers' reservation value γw^o through γ lowers the threshold $\tilde{\theta}$. Denote the new threshold (the threshold after an increase in γ) as $\tilde{\theta}''$. We will analyze three relevant ranges of θ values: Case 1, $\theta_L \leq \theta < \tilde{\theta}''$; Case 2, $\tilde{\theta}'' \leq \theta < \tilde{\theta}$; and, Case 3, $\tilde{\theta} \leq \theta \leq \theta_H$.

By considering these three ranges of θ values, the social welfare function can be written as:

$$SW = \int_{\theta_L}^{\tilde{\theta}''} \left(\frac{1}{\theta_H - \theta_L}\right) SW(\theta) d\theta + \int_{\tilde{\theta}''}^{\tilde{\theta}} \left(\frac{1}{\theta_H - \theta_L}\right) SW(\theta) d\theta + \\ + \int_{\tilde{\theta}}^{\theta_H} \left(\frac{1}{\theta_H - \theta_L}\right) SW(\theta) d\theta. \tag{38}$$

Case 1: $\theta_L \leq \theta < \tilde{\theta}''$

School boards of low type endure strikes before and after a change in γ. Hence,

$$\int_{\theta_L}^{\tilde{\theta}''} \left(\frac{1}{\theta_H - \theta_L}\right) SW(\theta) d\theta = \int_{\theta_L}^{\tilde{\theta}''} \left(\frac{1}{\theta_H - \theta_L}\right) [\theta v(n + \alpha\bar{\beta}) + w^o + (1 - \bar{\beta}) w_R^o] d\theta.$$

The right-hand side of the last equation is independent of γ. Hence, social welfare is not affected.

Case 2: $\tilde{\theta}'' \leq \theta < \tilde{\theta}$

School boards of intermediate type endure strikes only before a change in γ. Social welfare is higher if there is no strike because of the higher level of education services. Then, the term $\int_{\tilde{\theta}''}^{\tilde{\theta}} \left(\frac{1}{\theta_H - \theta_L}\right) SW(\theta) d\theta$, the second term of equation (38), positively depends on γ.

Case 3: $\tilde{\theta} \leq \theta \leq \theta_H$

School boards of high type do not endure strikes either before or after a change in γ. Hence,

$$\int_{\tilde{\theta}}^{\theta_H} \left(\frac{1}{\theta_H - \theta_L}\right) SW(\theta) d\theta = \int_{\tilde{\theta}}^{\theta_H} \left(\frac{1}{\theta_H - \theta_L}\right) [\theta v(n + 1) + w_R^o] d\theta.$$

The right-hand side of the last equation is independent of γ. Hence, social welfare is not affected.

Summing up, an increase in the replacement teachers' reservation wage improves social welfare by reducing the probability of strikes, and hence, by enhancing the provision of educational services for school boards of intermediate type (Case 2).

Next, Proposition 9 presents the formal proof of the impact of an increase in replacement teachers' reservation wage on social welfare.

PROPOSITION 9. *An increase in replacement teachers' reservation wage increases social welfare.*

PROOF: Differentiating the social welfare function SW with respect to γ yields:

$$\left(-\frac{1}{\theta_H-\theta_L}\right)[\tilde{\theta}v(n+1)+w_R^o]\frac{\partial\tilde{\theta}}{\partial\gamma}+\left(\frac{1}{\theta_H-\theta_L}\right)[\tilde{\theta}v(n+\alpha\bar{\beta})+w^o+(1-\bar{\beta})w_R^o]\frac{\partial\tilde{\theta}}{\partial\gamma}=$$

$$=\left(-\frac{\partial\tilde{\theta}}{\partial\gamma}\right)\left(\frac{1}{\theta_H-\theta_L}\right)\{\tilde{\theta}[v(n+1)-v(n+\alpha\bar{\beta})]-w^o+\bar{\beta}w_R^o\}>0.$$

The last inequality encompasses the product of two positive terms. The term $-\frac{\partial\tilde{\theta}}{\partial\gamma}$ is positive by Lemma 3 ($\frac{\partial\tilde{\theta}}{\partial\gamma}<0$). The term in curly brackets $\{\tilde{\theta}[v(n+1)-v(n+\alpha\bar{\beta})]-w^o+\bar{\beta}w_R^o\}$ is positive by Proposition 5. ■

Intuitively, as a result of the reduction on bargaining impasse, the provision of educational services increases. Hence, social welfare is enhanced.

7 Summary and Conclusions

This paper studies the impact of effective labor relations laws on bargaining impasse and social welfare. In particular, we analyze the effects of laws that permit school districts to *effectively* hire replacement teachers in case of strikes. We model the bargaining negotiations between the school board and the teachers' union as a sequential game of incomplete information, and explicitly include a replacement teachers law component. This component captures labor relations laws that effectively permit school boards to hire replacement teachers in case of strikes. This component also allows for laws that grant the explicit right to hire replacement teachers in case of strikes and laws that prohibit the use of intermittent strikes. Finally, this component allows for laws that relax the job permanence requirements for substitute teachers to qualify as replacement teachers without compromising the quality of educational services.

We demonstrate that these effective labor relations laws lower bargaining impasse. Social welfare is also enhanced due to an increase in the provision of educational services during strikes for low-type school boards, and a reduction on the probability of strikes for medium-type school boards. We then extend our analysis to study the effects of an increase in the replacement teachers' reservation wage on social welfare. We show that, although an increase in replacement teachers' reservation wage makes replacement more costly, the school boards have still private incentives to hire replacement teachers in case of strikes. As a result of the reduction on bargaining impasse for medium-type school boards, the provision of educational services and social welfare increase.

Extensions to this paper might involve theoretical analysis of the effects of effective labor relations laws in bargaining environment that allow for divergent beliefs and asymmetric information. Empirical work by Babcock et al. (1996, 1995) suggests that bargaining impasse might be originated by cognitive biases. It might be interesting to investigate how these two sources of bargaining impasse operate in the presence of the effective labor relations laws studied in this paper.[20]

[20]See Farmer and Pecorino (2002) and Landeo et al. (2013) for theoretical frameworks that allow for self-serving beliefs and asymmetric information, applied to civil litigation.

Appendix

This section presents the formal proofs of Lemmas A1–A4.

LEMMA A1. $\beta = \bar{\beta}$.

PROOF: The school board's payoff when one-period strike occurs is:

$$V_B = \theta v(x + \alpha\beta) - W - \beta w_R^o,$$

where $x \in [0, n]$ denotes the measure of educational services provided in the other n periods, and W denotes the cost of the provision of these educational services. Differentiating V_B with respect to β yields:

$$\frac{\partial V_B}{\partial \beta} = \theta\alpha v'(x + \alpha\beta) - w_R^o > 0,$$

for any $\theta \in [\theta_L, \theta_H]$. The inequality holds by condition (7). Hence, $\beta = \bar{\beta}$. ■

LEMMA A2. $\frac{\partial \tilde{w}^1(\tilde{\theta})}{\partial \tilde{\theta}} > 0$ *for any* $\tilde{\theta} \geq \theta_L$.

PROOF:

$$\frac{\partial \tilde{w}^1(\tilde{\theta})}{\partial \tilde{\theta}} = \left(\frac{1}{n+1}\right)\{[v(n+1) - v(n + \alpha\bar{\beta})]\} > 0.$$

The result holds by $v'(N) > 0$. ■.

LEMMA A3. $\tilde{\theta} = \left\{\frac{\theta_H}{2} + \frac{(1-\bar{\beta}\gamma)w^o}{2[v(n+1) - v(n+\alpha\bar{\beta})]}\right\} < \theta_H$.

PROOF:

$$\theta_H - \tilde{\theta} = \theta_H - \left\{\frac{\theta_H}{2} + \frac{(1-\bar{\beta}\gamma)w^o}{2[v(n+1) - v(n+\alpha\bar{\beta})]}\right\} = \frac{\theta_H[v(n+1) - v(n+\alpha\bar{\beta})] - (1-\bar{\beta}\gamma)w^o}{2[v(n+1) - v(n+\alpha\bar{\beta})]} > 0.$$

The result holds by condition (4). ■

LEMMA A4. $\tilde{w}^1 > w^o$.

PROOF:

$$\tilde{w}^1 - w^o = \left(\frac{1}{n+1}\right)\left\{\frac{1}{2}\theta_H[v(n+1) - v(n+\alpha\bar{\beta})] + \frac{1}{2}(1-\bar{\beta}\gamma)w^o + (n+\bar{\beta}\gamma)w^o\right\} - w^o >$$

$$> \left(\frac{1}{n+1}\right)\left[\frac{1}{2}w^o(1-\bar{\beta}\gamma) + \frac{1}{2}(1-\bar{\beta}\gamma)w^o + (n+\bar{\beta}\gamma)w^o\right] - w^o = 0.$$

The inequality holds by condition (4). ■

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