Market Integration and Strike Activity*†

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Abstract

We consider a two-country model of wage determination with private information in unionized, imperfectly competitive, industries. We investigate the effects of opening up markets to trade as well as of further market integration on the negotiated wage and the maximum delay in reaching an agreement. From an initial situation of two-way intra-industry trade, an increase in product market integration decreases the maximum delay in reaching an agreement. However, opening up markets to trade has an ambiguous effect on both the wage outcome and the maximum real delay time.

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1 Introduction

The pursuit of bilateral and regional trade agreements in recent decades has raised the question of how further trade liberalization will affect unionized labor markets. Brander (1981) and Brander and Krugman (1983) were the first to develop models that motivate two-way trade in homogeneous products as the reciprocal dumping outcome of oligopolistic rivalry in imperfectly competitive industries. They have shown that moving from autarky to trade has an ambiguous effect on welfare when countries are non-unionized. More recently, several papers have addressed how further market integration will affect the outcome on unionized labor markets. Naylor (1998) has shown that, in the case of two-way trade, an increase in product market integration will raise wages because monopoly unions respond by increasing the wage in response to the increase in demand for labor. However, Huizinga (1993) and Sørensen (1993) have shown that moving from autarky to free trade will reduce wages.[1]

The empirical literature suggests that the extent of international competition is one of the key determinants of strike activity.[2] Despite this evidence, the theoretical literature on wage bargaining in industries with market power has neglected the analysis of the relationship between strike activity and market integration. Indeed, all previous papers have considered monopoly union models (i.e. the union unilaterally determines wages) with complete information, which predict efficient outcomes of the bargaining process. In particular, agreement is always reached immediately, so that strikes cannot occur in equilibrium. This is not the case once we introduce private information into wage bargaining, in which the first rounds of negotiation are used for information transmission between the two negotiators.

In the present paper we consider a model that encompasses earlier models in which

[1] Product market integration is interpreted as a reduction in costs related to international trade. These costs are divided into fixed costs associated with exporting and variable costs proportional to the level of exports. Recently, Munch and Skaksen (2002) have shown that a reduction in fixed costs leads to an unambiguous decrease in wages, whereas a reduction in variable costs has an ambiguous effect on wages, due to the fact that the introduction of international competition for some goods neutralizes the effect on the demand for labor.

[2] Tracy (1986), Abowd and Tracy (1989), and Cramton and Tracy (1994) have studied the determinants of U.S. labor disputes. They have found that key determinants are the type of industry, the industry or market size, industrial concentration, and international competition. In addition, Cutcher-Gershenfeld, Kochan and Calhoun-Wells (1998) have examined union and management perceptions of factors heavily influencing negotiations or the process of collective bargaining and its outcomes in the U.S. The results suggest that, in addition to other factors such as falling real wages, fear of job loss, and increased domestic competition, increased international competition is a central feature motivating the parties to reach agreements.

international trade occurs between economies with imperfectly competitive product markets and unionized labor markets. The main feature of our model is that both the union and the firm may have private information. Hence, our model allows us to investigate the effects of moving from autarky to two-way trade as well as the effects of further product market integration on the negotiated wage, strike activity, and welfare. To describe the wage bargaining process, we adopt Rubinstein's (1982) alternating-offer bargaining model with two-sided incomplete information, which allows for the occurrence of strikes in equilibrium.[3]

For two-way intra-industry trade, we show that an increase in product market integration will have an ambiguous effect on wages even when bargaining is under complete information. More precisely, if transport costs are high enough, an increase in product market integration will decrease wages. However, if transport costs are low enough, an increase in product market integration will increase wages. With respect to strike activity, we show that an increase in product market integration will decrease the maximum delay in reaching an agreement.

Opening up markets to free trade will decrease wages and prices while consumer surplus, profits and total quantities sold in each country will increase. However, opening up markets to trade (or free trade) has an ambiguous effect on the maximum real delay in reaching an agreement. Indeed, each union-firm pair expects to be able to alter its relative wage position in order to gain a larger share of the product market in each country.[4] The incentive is stronger the more integrated the markets since a lower wage gives the union-firm pair a larger market share. This explains why it is likely that more concessions and fewer conflicts in wage negotiations will occur once markets become integrated. However, opening up markets raises the potential payoffs for the union and the firm, and in expanding the payoff set (or range of possible payoffs), also increases the scope for delay (longer strikes and lockouts may be needed to screen private information).

The paper is organized as follows. In Section 2, the model is presented. Section 3 describes the wage bargaining game and solves this game for the case of complete information. It also analyzes the relationship between wages and market integration. Section 4 is devoted to the wage bargaining game with private information and derives the maximum delay in reaching an agreement. Finally, we present our conclusions in Section 5.

[3] Strike data seems to have a significant impact on the wage-employment relationship for collective negotiations. See Kennan and Wilson (1989, 1993) for surveys of bargaining models with private information and their relation to strike data. See Kennan (1986) for a survey of the empirical results of strike activity.

[4] Davidson (1988) and Horn and Wolinsky (1988) were the first to study the impact of wage spillover effects on the interaction of union-firm bargaining and duopolistic quantity-setting. Dowrick (1989) studied how product market power and profitability are related to wages.

2 The model

Following Brander (1981), Brander and Krugman (1983) and Naylor (1998), we assume that there are two identical countries (1 and 2) and that in each country there is one firm (Firm 1 in Country 1 and Firm 2 in Country 2) producing some homogeneous good. We assume that product demand is linear

$$P_i = a - b(X_{ii} + X_{ji}), \text{ for } i, j = 1, 2, \, i \neq j,$$

where P_i is the price of the homogeneous good in country i, X_{ii} is production by firm i for consumption in country i, and X_{ji} is production by firm j for consumption in country i. There is a constant cost of T per unit of the commodity exported. We interpret this cost as capturing all the costs associated with international trade, such as transactions and transport costs. Let $\overline{T}$ be the upper limit on T such that for $T \leq \overline{T}$ there is two-way intra-industry trade which means that $X_{12} > 0$ and $X_{21} > 0$. We will focus on three cases: free trade or fully integrated markets ($T = 0$), open markets with two-way trade ($T \in (0, \overline{T}]$), and autarky ($T = \infty$). For open markets, we interpret a marginal decrease in T as an increase in product market integration. Each firm regards each country as a separate market (i.e. goods markets are segmented) and chooses the profit-maximizing quantity for each market separately, taking as given the other firm's output in each market.

Production technology exhibits constant returns to scale with labor as the sole input and is normalized in such a way that $(X_{ii} + X_{ij}) = L_i$, where L_i is the labor input. The total labor cost to firm i of producing quantity $(X_{ii} + X_{ij})$ is $(X_{ii} + X_{ij}) \cdot W_i$, where W_i is the wage in firm i. Thus, firm i's profits are given by

$$\Pi_i = (P_i - W_i)X_{ii} + (P_j - W_i - T)X_{ij}, \text{ for } i, j = 1, 2, \, i \neq j.$$

Each firm is unionized and each union is assumed to maximize the wage rate. Without loss of generality, the reservation wage is set equal to zero in each country. Hence, $U_i = W_i$, for $i = 1, 2$. This implies that the union places no value on employment. Although this may seem implausible, the notion that, in negotiating wages, unions do not take into account the employment consequences of higher wages has a long tradition, including the influential work of Ross (1948), and is often stated by union leaders (Pencavel, 1991). This assumption is made to obtain closed-form solutions in order to carry out the analysis under incomplete information. Cramton and Tracy (2003) concluded that disputes are largely motivated by the presence of private information and the sharply conflicting interests of the union and the firm over the wage. In the appendix we show that our results under complete information are robust to an alternative specification where unions maximize the economic rent $L_i W_i$. Moreover, Mauleon and Vannetelbosch (2005) showed that, if the union is not too strong (in fact, the range of union bargaining power we will consider), it is optimal for the union that seeks to maximize the rents to send to the negotiating table delegates who seeks to maximize the wage.[5]

Interactions between market integration and wage bargaining are analyzed according to the following game structure. In stage one, wages are negotiated at the firm-level in both countries. In stage two, each firm chooses its output (and hence employment) levels for the separate product markets, taking as given both (i) the output decisions of the other firm and (ii) the negotiated wages. The two-stage game makes the model an appropriate description of a situation in which wages are determined for a relatively long period while production decisions are made for a relatively short period. The model is solved backwards.

In the last stage of the game, the wage levels have already been determined. Both firms compete by choosing their outputs simultaneously to maximize profits, with the price adjusting to clear the market. For open markets with two-way trade, the unique Nash equilibrium of this stage game yields

$$X_{ii}(T) = \max\left[\frac{a+T-2W_i+W_j}{3b}, 0\right], \; X_{ji}(T) = \max\left[\frac{a-2T-2W_j+W_i}{3b}, 0\right],$$

for $i, j = 1, 2$, $i \neq j$. The Nash equilibrium outputs of a firm (and hence, the equilibrium level of employment) are decreasing with its own wage, but are increasing with the other firm's wage and total industry demand. Under autarky, the unique Nash equilibrium of this stage game yields

$$X_{ii}\left(T=\infty\right) = \max\left[\frac{a-W_i}{2b}, 0\right], \; X_{ij}\left(T=\infty\right) = 0, \text{ for } i, j = 1, 2, \; i \neq j.$$

3 Wage bargaining with complete information

The negotiations occur simultaneously in both countries. Two assumptions are made. First, when negotiations are taking place, the agents are unaware of any proposals made (or settlement reached) in related negotiations. Second, production and market competition occur only when either both firms have come to an agreement with their workers, or when one firm has settled with its union and the other union has decided to leave the bargaining

[5] Mauleon and Vannetelbosch (2005) developed a model of wage determination with private information, in which the union has the option to delegate the wage bargaining to either surplus-maximizing delegates or to wage-maximizing delegates (such as senior union members). In addition, Mauleon and Vannetelbosch (2006) considered a unionized duopoly model to analyze how unions affect the incentives for merger when surplus-maximizing unions have the option to delegate the wage bargaining to wage-maximizing delegates. One of their results is that, with linear demands, the union in each firm will choose a wage-maximizing delegate if and only if the union bargaining power is not too strong.

table forever. Hence, in each country each union-firm pair takes the decisions of its foreign rival pair as given while conducting its own negotiation.

Each negotiation proceeds as in Rubinstein's (1982) alternating-offer bargaining model. The firm and the union make alternate wage offers, with the firm making offers in odd-numbered periods and the union making offers in even-numbered periods. The length of each period is Δ. The negotiation starts in period 0 and ends when one of the negotiators accepts an offer. No limit is placed on the time that may be expended in bargaining and perpetual disagreement is a possible outcome. The union is assumed to be on strike in every period until an agreement is reached. Both the firm and the union are assumed to be impatient. The firm and the union have time preferences with constant discount rates $r_{\mathrm{f}} > 0$ and $r_{\mathrm{u}} > 0$, respectively. To capture the notion that the time it takes to come to terms is small relative to the length of the contract, we assume that the time between periods is very small. This allows a study of the limiting situations in which the bargaining procedure is essentially symmetric and the potential costs of delaying agreement by one period can be regarded as negligible. As the interval between offers and counteroffers shortens and shrinks to zero, the alternating-offer model has a unique limiting subgame perfect equilibrium (SPE), which approximates the Nash bargaining solution to the bargaining problem (see Binmore, Rubinstein and Wolinsky, 1986). Thus the predicted wages are given by

$$W_i^{\mathrm{SPE}} = \arg\max \left[U_i - U_i^0\right]^{\alpha} \cdot \left[\Pi_i - \Pi_i^0\right]^{1-\alpha}$$

where $U_i^0 = 0$ and $\Pi_i^0 = 0$ are, respectively, the disagreement payoffs of the union and the firm. The parameter $\alpha \in (0, 1)$ is the union bargaining power which is equal to $r_{\mathrm{f}}/(r_{\mathrm{u}}+r_{\mathrm{f}})$.

When markets are open we restrict the analysis to the case of symmetric pure strategy equilibria associated with two-way intra-industry trade. The necessary and sufficient condition for two-way intra-industry trade is $F(\alpha, T) > 0$, where $F(\alpha, T) = 4(2a - T)^2(2 - \alpha)^2 - 8(2a^2 - 2aT + 5T^2)\alpha(4 - 3\alpha)$. The upper limit $\overline{T}$, such that for $T \leq \overline{T}$ there is two-way intra-industry trade, is given by

$$\overline{T}(\alpha) = \frac{4a(1-\alpha)}{(2(1-\alpha) + 3\sqrt{\alpha(4-3\alpha)})}.$$

This assumption implies that, given trade costs T, the union bargaining power is below some critical level $\widehat{\alpha}$ given by

$$\widehat{\alpha}(T) = \frac{16a(a-T) + 22T^2 - 6T\sqrt{4a(a-T) + 10T^2}}{16a(a-T) + 31T^2} \leq 1.$$

Notice that as the demand parameter a becomes very large, $\widehat{\alpha}$ approaches 1. Then, the equilibrium wages are

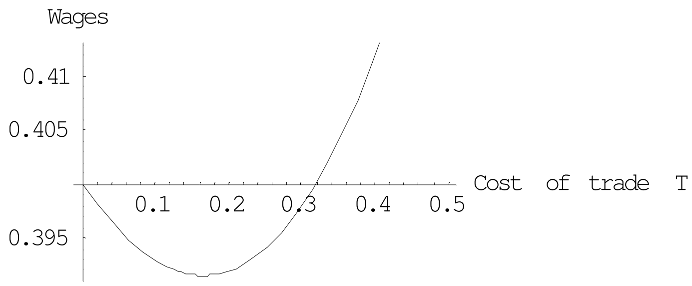

Figure 1: The relation between wages and product market integration.

$$W_i^{\mathrm{SPE}}(\alpha, T) = \frac{2(2a - T)(2 - \alpha) - \sqrt{F(\alpha, T)}}{4(4 - 3\alpha)}, \tag{1}$$

which can also be expressed in terms of r_{u} and r_{f},

$$W_i^{\mathrm{SPE}}(r_{\mathrm{u}}, r_{\mathrm{f}}, T) = \frac{(2a - T)(r_{\mathrm{f}} + 2r_{\mathrm{u}}) - \sqrt{G(r_{\mathrm{u}}, r_{\mathrm{f}}, T)}}{2(r_{\mathrm{f}} + 4r_{\mathrm{u}})}, \tag{2}$$

where $G(r_{\mathrm{u}}, r_{\mathrm{f}}, T) = 16ar_{\mathrm{u}}^2(a - T) - (9r_{\mathrm{f}}^2 + 36r_{\mathrm{f}}r_{\mathrm{u}} - 4r_{\mathrm{u}}^2)T^2$. Notice that $G(r_{\mathrm{u}}, r_{\mathrm{f}}, T) > 0$ is the necessary and sufficient condition for two-way intra-industry trade when α is expressed in terms of r_{u} and r_{f}. We find that

$$\frac{\partial W_i^{\mathrm{SPE}}(\alpha, T)}{\partial T} > 0 \Leftrightarrow T > \frac{2a\left(3\sqrt{10}(\alpha - 2) - 20(\alpha - 1)\right)(1 - \alpha)}{5\left(4 + \alpha(31\alpha - 44)\right)} \equiv \widehat{T}(\alpha).$$

So $\widehat{T}(\alpha)$ is decreasing with the union bargaining power α and $\widehat{T}(\alpha) < \overline{T}(\alpha)$. The relation between wages and the degree of market integration is depicted in Figure 1 for $a = 2$.

Proposition 1 *If the level of two-way intra-industry trade is low enough ($T > \widehat{T}(\alpha)$) an increase in product market integration will decrease wages. However, if the level of two-way intra-industry trade is high enough ($T < \widehat{T}(\alpha)$) an increase in product market integration will increase wages.*

This result is due to a trade-off between two effects. First, when markets are open and there is two-way trade, each union-firm pair expects to be able to alter its relative wage position. Each union-firm pair has an incentive to lower wages in order to gain a larger share of the product market in each country. Second, an increase in product market integration means that, for given wages, firms face a lower cost of exporting, raising the demand for labor. The union then exploits the higher labor demand to obtain higher wages from negotiations. Depending on the degree of market integration (the level of transport costs) one effect will dominate the other.[6]

Equilibrium outputs when markets are open and there is two-way trade are given by

$$\begin{aligned} X_{ii}^*(\alpha,T) &= \frac{8a(1-\alpha)+2T(10-7\alpha)+\sqrt{F(\alpha,T)}}{12(4-3\alpha)b}, \\ X_{ij}^*(\alpha,T) &= \frac{8a(1-\alpha)-T(28-22\alpha)+\sqrt{F(\alpha,T)}}{12(4-3\alpha)b}, \end{aligned}$$

for $i,j=1,2$, $i\neq j$. Profits, prices, and consumer surplus are, respectively, given by

$$\begin{aligned} \Pi_i^*(\alpha,T) &= \frac{(1-\alpha)\left[16a^2(1-\alpha)-16aT(1-\alpha)+2T^2(38-29\alpha)+(2a-T)\sqrt{F(\alpha,T)}\right]}{9b(4-3\alpha)^2}, \\ P_i^*(\alpha,T) &= \frac{2a(8-5\alpha)+4T(1-\alpha)+\sqrt{F(\alpha,T)}}{6(4-3\alpha)}, \\ CS_i^*(\alpha,T) &= \frac{\left(4(2a-T)(1-\alpha)+\sqrt{F(\alpha,T)}\right)^2}{72b(4-3\alpha)^2}. \end{aligned}$$

The consumer surplus is increasing with an increase in product market integration. However, the effect of an increase in product market integration on profits and on welfare are ambiguous and depend on the level of unionization and the degree of product market integration. Indeed, a reduction in transport costs has three effects on firm's profits. First, the product price falls with increased product market competition. Second, wages could either increase (for low enough T) or decrease (for high enough T). Finally, the transport costs are reduced. When the degree of product market integration is high enough, a reduction in T increases profits because the beneficial effect of the reduction in T is large enough to compensate for the two negative effects on profits due to the reduction in product prices and the increase in wages. However, when the degree of product market integration is small, a reduction in T increases profits only if the unions are stronger than the firms. In this situation, firms gain from the unions' loss of market power (i.e. from the lower wages), and this gain is greater than the loss due to lower product market power.

Defining welfare as the sum of consumer surplus and profits, we find that, if unions are very weak, then, if the level of two-way intra-industry trade is low enough, an increase in product market integration will decrease welfare; however, if the level of two-way intra-industry trade is high enough, an increase in product market integration will increase

[6] In the appendix we show that this relationship is also observed under an alternative specification where unions maximize the surplus. Naylor (1998) showed that, if unions maximize the surplus and choose wages, then an increase in product market integration will unambiguously increase wages.

welfare. This result complements and points in the same direction as those of Brander (1981) and Brander and Krugman (1983), who showed that moving from autarky to trade has an ambiguous effect on welfare. Here we find that moving to higher levels of trade also has this ambiguous effect on welfare. However, if unions are not so weak we get similar results to those obtained by Naylor (1998) and Munch and Skaksen (2002), who showed that welfare increases with product market integration when the union has all the bargaining power. In our model, welfare is increasing with product market integration if unions are not too weak.

When markets are in autarky, equilibrium wages are

$$W_i^{\mathrm{SPE}}\left(\alpha, T=\infty\right) = \frac{\alpha}{2-\alpha}a, \tag{3}$$

which can be expressed in terms of r_{u} and r_{f} as

$$W_i^{\mathrm{SPE}}\left(r_{\mathrm{u}}, r_{\mathrm{f}}, T=\infty\right) = \frac{r_{\mathrm{f}}}{r_{\mathrm{f}}+2r_{\mathrm{u}}}a = U_i^*(r_{\mathrm{u}}, r_{\mathrm{f}}, T=\infty). \tag{4}$$

Equilibrium outputs when markets are in autarky are given by

$$X_{ii}^*\left(\alpha, T=\infty\right) = \frac{a\left(1-\alpha\right)}{b\left(2-\alpha\right)},\ X_{ij}^*\left(\alpha, T=\infty\right) = 0, \text{ for } i,j=1,2,\ i\neq j.$$

Profits, prices, and consumer surplus are, respectively, given by

$$\begin{aligned}
\Pi_i^*\left(\alpha, T=\infty\right) &= \frac{a^2}{b}\frac{\left(1-\alpha\right)^2}{\left(2-\alpha\right)^2}, \\
P_i^*\left(\alpha, T=\infty\right) &= \frac{a}{\left(2-\alpha\right)}, \\
CS_i^*\left(\alpha, T=\infty\right) &= \frac{\left(2a(1-\alpha)\right)^2}{8(2-\alpha)^2 b}.
\end{aligned}$$

Comparing autarky ($T=\infty$) with two-way intra-industry trade ($T\in[0,\overline{T}]$) leads to the following proposition.

Proposition 2 *When moving from autarky to two-way trade, wages and prices decrease while consumer surplus and total quantities sold in each country increase.*

Two remarks deserve to be made. First, the results we obtain in the case of moving from autarky ($T=\infty$) to free trade ($T=0$) are similar to those of Huizinga (1993) and Sørensen (1993). The underlying reason for these results is that firms in both countries start to compete in a common market. This rise in the degree of competition spills over to the labor market by increasing the elasticity of the demand for labor. The response of the negotiators is to set lower wages. The lower wages, as well as the increased degree of competition in the product market, tend to increase employment and output and, thus, to lower product prices. Due to this loss of product market power, the profits are lower under free trade than under autarky when the unions are weak. However, if the unions are not too weak, then moving from autarky to free trade will increase profits. Finally, moving from autarky to free trade increases welfare even when the unions are weak.

Second, the results we obtain in the case of moving from autarky ($T = \infty$) to two-way trade ($T \in (0, \overline{T}]$) are similar to those obtained when moving from autarky to free trade except that now, if the unions are very weak, two-way trade might first decrease (for high enough T) and then increase (for low enough T) the level of welfare. This result is similar to that obtained by Brander (1981) and Brander and Krugman (1983), who showed that, in the absence of unions, a move from autarky to two-way trade has an ambiguous effect on welfare that depends on the level of the transport costs. However, we have shown that if the unions are not too weak, then trade will definitely increase welfare. Thus, the impact of moving from autarky to two-way trade on the welfare depends crucially on the level of unionization in the two countries. This last observation, together with the fact that moving from autarky to free trade increases welfare, may be a possible justification for the claim that opening up markets to competition within Europe has increased welfare by increasing the level of competition.

4 Maximum delay in reaching an agreement

Both the asymmetric Nash bargaining solution and Rubinstein's model predict efficient outcomes of the bargaining process (in particular, agreement is reached immediately). This is not true if we introduce incomplete information into the wage bargaining. In this case, the early rounds of negotiation are used for information transmission between the two negotiators.

We now suppose that negotiators have private information. Neither negotiator knows the impatience (or discount rate) of the other party. It is common knowledge that the firm's discount rate is included in the set $[r_{\rm f}^{\rm P}, r_{\rm f}^{\rm I}]$, where $0 < r_{\rm f}^{\rm P} \leq r_{\rm f}^{\rm I}$, and that the union's discount rate is included in the set $[r_{\rm u}^{\rm P}, r_{\rm u}^{\rm I}]$, where $0 < r_{\rm u}^{\rm P} \leq r_{\rm u}^{\rm I}$. The superscripts "I" and "P" identify the most impatient and most patient types, respectively. The types are independently drawn from the set $[r_i^{\rm P}, r_i^{\rm I}]$ according to the probability distribution p_i, for $i =$u,f. We allow for general distributions over discount rates. This uncertainty implies bounds on the union bargaining power which are denoted by $\underline{\alpha} = r_{\rm f}^{\rm P} \cdot \left[r_{\rm u}^{\rm I} + r_{\rm f}^{\rm P}\right]^{-1}$ and $\overline{\alpha} = r_{\rm f}^{\rm I} \cdot \left[r_{\rm u}^{\rm P} + r_{\rm f}^{\rm I}\right]^{-1}$. We assume that, given trade costs $T \in \left[0, \overline{T}\right]$, the upper bound on the union bargaining power is below some critical level. That is, $\overline{\alpha} < \widehat{\alpha}(T)$. This assumption guarantees that, for all $T \in \left[0, \overline{T}\right]$, there is two-way intra-industry trade ($X_{12} > 0$ and $X_{21} > 0$) when bargaining occurs in the presence of private information.

Inefficient outcomes are possible, even as the period length shrinks to zero. The wage bargaining game may involve delay (strikes or lock-outs), but not perpetual disagreement, in equilibrium.[7] In fact, delay is positively related to the distance between the discount rates of the most and least patient types of the players. If the range of types is reduced, then this leads to a smaller range of possible payoffs and less delay. Delay can occur even when the game is close to one of complete information (as the type distributions converge to point mass distributions).

We propose to identify strike activity with the maximum delay time in reaching an agreement. Only on average is this measure a good proxy for actual strike duration.[8] It is not uncommon in the literature on bargaining to analyze the maximum delay before reaching an agreement.[9] In the appendix we compute the maximum delay in equilibrium which shows that an agreement is reached in finite time and that delay time equals zero as incomplete information vanishes (in that r_i^{P} and r_i^{I} converge).

With two-way trade, the maximum real delay time in reaching an agreement is given by

$$D(T) = \min\left\{D^{\mathrm{u}}(T), D^{\mathrm{f}}(T)\right\} \tag{5}$$

where

$$D^{\mathrm{u}}(T) = -\frac{1}{r_{\mathrm{u}}^{\mathrm{P}}} \cdot \log\left[\left(\frac{4r_{\mathrm{u}}^{\mathrm{P}} + r_{\mathrm{f}}^{\mathrm{I}}}{4r_{\mathrm{u}}^{\mathrm{I}} + r_{\mathrm{f}}^{\mathrm{P}}}\right) \frac{(2a-T)(r_{\mathrm{f}}^{\mathrm{P}} + 2r_{\mathrm{u}}^{\mathrm{I}}) - \sqrt{G(r_{\mathrm{u}}^{\mathrm{I}}, r_{\mathrm{f}}^{\mathrm{P}}, T)}}{(2a-T)(r_{\mathrm{f}}^{\mathrm{I}} + 2r_{\mathrm{u}}^{\mathrm{P}}) - \sqrt{G(r_{\mathrm{u}}^{\mathrm{P}}, r_{\mathrm{f}}^{\mathrm{I}}, T)}}\right] \tag{6}$$

is the maximum real time the union would spend negotiating, and

$$\begin{aligned} D^{\mathrm{f}}(T) \quad = \quad & -\frac{1}{r_{\mathrm{f}}^{\mathrm{P}}} \cdot \log\left[\left(\frac{r_{\mathrm{u}}^{\mathrm{P}}}{r_{\mathrm{u}}^{\mathrm{I}}}\right)\left(\frac{4r_{\mathrm{u}}^{\mathrm{I}} + r_{\mathrm{f}}^{\mathrm{P}}}{4r_{\mathrm{u}}^{\mathrm{P}} + r_{\mathrm{f}}^{\mathrm{I}}}\right)^2 \cdot \right. \\ & \left. \frac{8a(a-T)r_{\mathrm{u}}^{\mathrm{P}} + (9r_{\mathrm{f}}^{\mathrm{I}} + 38r_{\mathrm{u}}^{\mathrm{P}})T^2 + (2a-T)\sqrt{G(r_{\mathrm{u}}^{\mathrm{P}}, r_{\mathrm{f}}^{\mathrm{I}}, T)}}{8a(a-T)r_{\mathrm{u}}^{\mathrm{I}} + (9r_{\mathrm{f}}^{\mathrm{P}} + 38r_{\mathrm{u}}^{\mathrm{I}})T^2 + (2a-T)\sqrt{G(r_{\mathrm{u}}^{\mathrm{I}}, r_{\mathrm{f}}^{\mathrm{P}}, T)}}\right] \end{aligned} \tag{7}$$

[7] Watson (1998) has characterized the set of perfect Bayesian equilibrium (PBE) payoffs which may arise in Rubinstein's alternating-offer bargaining game and constructed bounds (which are met) on the agreements that may be made. The bounds and the PBE payoffs set are determined by the range of incomplete information and are easy to compute because they correspond to the SPE payoffs of two bargaining games with complete information. These two games are defined by matching one player's most impatient type with the opponent's most patient type. In addition, Watson (1998) has constructed equilibria with delay in which the types of each player behave identically (no information is revealed in equilibrium), players use pure strategies, and players make non-serious offers until some appointed date.

[8] In the literature on strikes, three different measures of strike activity are usually proposed: the strike incidence, the strike duration, and the number of work days lost due to work stoppages. See, for instance, Cheung and Davidson (1991) and Kennan and Wilson (1989). Since we allow for general distributions over types and we may have a multiplicity of PBE, we are unable to compute these measures of strike activity.

[9] See, for instance, Cramton (1992) and Cai (2003).

is the maximum real time the firm would spend negotiating. In fact, $D^{\mathrm{u}}(T)$ is the maximum real time the union would spend negotiating if it were of the most patient type. Similarly, $D^{\mathrm{f}}(T)$ is the maximum real time the firm would spend negotiating if it were of the most patient type. So, $D^{\mathrm{u}}(T)$ and $D^{\mathrm{f}}(T)$ are the upper bounds on the maximum time the union of type r_{u} and the firm of type r_{f} would spend negotiating. This maximum time decreases with type r_{u} (r_{f}). So, the more patient a player is the greater the delay that may be observed. Since $D^{\mathrm{u}}(T)$ and $D^{\mathrm{f}}(T)$ are positive, finite numbers, the maximum real delay in reaching an agreement in the case of two-way trade is finite and converges to zero as r_i^{I} and r_i^{P} become close, for i =u,f. We have that

$$\frac{\partial D^{\mathrm{u}}(T)}{\partial T} > 0 \text{ and } \frac{\partial D^{\mathrm{f}}(T)}{\partial T} > 0.$$

Proposition 3 *From an initial situation of two-way intra-industry trade, an increase in product market integration will decrease the maximum delay in reaching an agreement.*

When markets are open and there is two-way trade, each union-firm pair expects to be able to alter its relative wage position. That is, each union-firm pair has an incentive to lower wages in order to gain a larger share of the product market in each country. This incentive is stronger the more integrated the product markets are, since with integrated markets a wage decrease can enable the union-firm pair to win a more substantial market share of its foreign rival. This explains why it is likely that more concessions and fewer conflicts in wage negotiations will occur once markets have become more integrated.

With autarky, the maximum real delay time in reaching an agreement is given by

$$D(T=\infty) = \min\left\{D^{\mathrm{u}}(T=\infty), D^{\mathrm{f}}(T=\infty)\right\}, \tag{8}$$

where

$$D^{\mathrm{u}}(T=\infty) = -\frac{1}{r_{\mathrm{u}}^{\mathrm{P}}} \cdot \log\left[\left(\frac{2r_{\mathrm{u}}^{\mathrm{P}} + r_{\mathrm{f}}^{\mathrm{I}}}{2r_{\mathrm{u}}^{\mathrm{I}} + r_{\mathrm{f}}^{\mathrm{P}}}\right)\left(\frac{r_{\mathrm{f}}^{\mathrm{P}}}{r_{\mathrm{f}}^{\mathrm{I}}}\right)\right] \tag{9}$$

is the maximum real time the union would spend negotiating, and

$$D^{\mathrm{f}}(T=\infty) = -\frac{1}{r_{\mathrm{f}}^{\mathrm{P}}} \cdot \log\left[\left(\frac{2r_{\mathrm{u}}^{\mathrm{I}} + r_{\mathrm{f}}^{\mathrm{P}}}{2r_{\mathrm{u}}^{\mathrm{P}} + r_{\mathrm{f}}^{\mathrm{I}}}\right)^2\left(\frac{r_{\mathrm{u}}^{\mathrm{P}}}{r_{\mathrm{u}}^{\mathrm{I}}}\right)^2\right] \tag{10}$$

is the maximum real time the firm would spend negotiating. Since $D^{\mathrm{u}}(T=\infty)$ and $D^{\mathrm{f}}(T=\infty)$ are positive, finite numbers, the maximum real delay in reaching an agreement in the case of autarky is finite and converges to zero as r_i^{I} and r_i^{P} become close, for i =u,f.

Let us compare the strike activity when markets go from autarky to free trade. We have $D^{\mathrm{u}}(T=0) > D^{\mathrm{u}}(T=\infty)$; the maximum real time the union would spend negotiating is shorter in the case of autarky. However, we have $D^{\mathrm{f}}(T=0) < D^{\mathrm{f}}(T=\infty)$; the maximum real time the firm would spend negotiating is shorter in the case of free trade. Let us assume that $r_{\mathrm{u}}^{\mathrm{P}} = r_{\mathrm{f}}^{\mathrm{P}} = r^{\mathrm{P}}$ and $r_{\mathrm{u}}^{\mathrm{I}} = r_{\mathrm{f}}^{\mathrm{I}} = r^{\mathrm{I}}$. Then,

$$D(T = \infty) > D(T = 0) \Leftrightarrow D^{\mathrm{u}}(T = \infty) > D^{\mathrm{f}}(T = 0) \Leftrightarrow 22r^{\mathrm{P}}r^{\mathrm{I}} - (r^{\mathrm{P}})^2 - (r^{\mathrm{I}})^2 > 0.$$

For instance, when $r^{\mathrm{P}} = 0.01$ and $r^{\mathrm{I}} = 0.1$ we have $D^{\mathrm{u}}(T = \infty) > D^{\mathrm{f}}(T = 0)$, but when $r^{\mathrm{P}} = 0.001$ and $r^{\mathrm{I}} = 0.1$ we have $D^{\mathrm{u}}(T = \infty) < D^{\mathrm{f}}(T = 0)$. Thus, the possibility of being a very patient type (i.e. a relatively strong negotiator) makes strikes more likely when markets open up to free trade.

Thus, opening up markets to free trade has an ambiguous effect on the maximum real delay time in reaching an agreement. When markets become open, each union-firm pair has a stronger incentive to lower wages and to concede earlier in order to gain a larger share of the product market in each country. However, opening up markets raises the potential payoffs for the union and the firm, and in expanding the payoff set (or range of possible payoffs), also increases the scope for delay (longer strikes and lockouts may be needed for screening the private information).

We now provide an example of the maximum delay. In this example, let $r_{\mathrm{f}}^{\mathrm{P}} = r_{\mathrm{u}}^{\mathrm{P}} = r^{\mathrm{P}}$, $r_{\mathrm{f}}^{\mathrm{I}} = r_{\mathrm{u}}^{\mathrm{I}} = r^{\mathrm{I}}$, $r^{\mathrm{I}} = 0.33 - r^{\mathrm{P}}$ with $r^{\mathrm{P}} \in [0.04, 0.16]$ and $a = 2$. Table 1 gives the integer part of the maximum delay for different values of the parameter T.[10] We observe that (i) D^{u} and D^{f} are increasing with the amount of private information $\left|r_i^{\mathrm{P}} - r_i^{\mathrm{I}}\right|$; (ii) D^{u} and D^{f} are slightly increasing with T for $T \leq \overline{T}$. Notice that the real delay time in reaching an agreement is not negligible: many bargaining rounds may be needed in equilibrium before an agreement is reached. Results (i) and (ii) hold in general.

5 Conclusion

We have investigated the effects of opening up markets to trade as well as of further market integration on the wage and on strike activity in unionized countries. From an initial situation of two-way intra-industry trade, an increase in product market integration decreases the maximum delay in reaching an agreement. However, opening up markets to trade has an ambiguous effect on both the wage outcome and the maximum real delay time in reaching an agreement.

Thus, contrary to the results found in the literature on the situation with complete information, we have shown that, in the presence of private information, opening up markets

[10] We can interpret r_i as the annual discount rate and the numbers in Table 1 as the maximum number of days needed to reach an agreement. Indeed, the integer part of the maximum delays for $\Delta = 1/365$ are exactly the numbers in Table 1. The data in Table 1 seem consistent with U.S. strike durations as reported in Cramton and Tracy (1994).

	$T=0$		$T=\frac{1}{8}$		$T=\frac{1}{4}$		$T=\frac{1}{2}$		$T=\infty$	
r^{P}	D^{u}	D^{f}	D^{u}	D^{f}	D^{u}	D^{f}	D^{u}	D^{f}	D^{u}	D^{f}
0.16	0	0	0	0	0	0	0	0	0	0
0.15	1	0	1	0	1	0	2	1	1	1
0.14	3	1	3	1	3	1	3	1	2	2
0.13	5	2	5	2	5	2	5	2	4	4
0.12	7	3	7	3	7	3	7	4	6	6
0.11	9	5	10	5	10	5	10	5	8	8
0.10	13	7	13	7	13	7	14	7	10	11
0.09	17	9	17	9	17	9	19	10	14	15
0.08	22	12	22	12	22	12	-	-	18	19
0.07	29	16	29	17	29	17	-	-	24	26
0.06	38	23	38	23	39	24	-	-	32	35
0.05	52	33	52	33	53	35	-	-	43	49
0.04	74	50	74	50	76	55	-	-	62	73

Table 1: Maximum delay in reaching an agreement

to trade has an ambiguous impact on the negotiated wage. Our model suggests that policy recommendations with respect to the impact of product market integration on wages and employment levels should only be made with caution. Nevertheless, this ambiguity does not prevent us from drawing some very interesting conclusions. Indeed, we have shown that the stronger the union is, the more likely it is that the country's wage will decrease when markets are opened up to trade. Finally, notice that being very patient (i.e. a relatively strong negotiator) makes strikes more likely when opening up markets to competition.

Appendix

A Unions maximizing economic rents

Suppose that each firm is unionized and each union maximizes its economic rents. Hence, $U_1 = L_1(W_1, W_2) \cdot W_1$ and $U_2 = L_2(W_1, W_2) \cdot W_2$. In order to get a closed form solution to the wage bargaining we need to fix the union bargaining power. For instance, let us assume that the firm and the union have equal bargaining power: $\alpha = \frac{1}{2}$. Then, the equilibrium wage outcome is

$$W_i^{\mathrm{SPE}}(T, \alpha = \frac{1}{2}) = \frac{1}{14}\left(10a - 5T - \frac{16a^2 - 16aT - 59T^2}{\sqrt[3]{Z}} - \sqrt[3]{Z}\right),\ i = 1, 2,$$

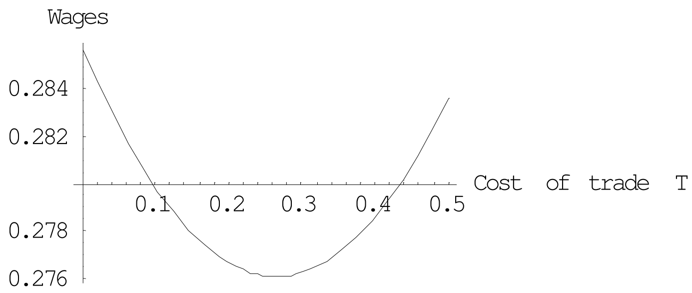

Figure 2: Unions maximizing rents and $\alpha = \frac{1}{2}$.

where

$$Z = 64a^3 - 96a^2T + 552aT^2 - 260T^3 + 21T\sqrt{256a^4 - 512a^3T + 528a^2T^2 - 272aT^3 + 619T^4}.$$

Notice that, given the upper limit on trade costs, neither union-firm pair has an incentive to agree on a lower wage that would deter imports. The relation between wages and the degree of market integration is similar to that obtained assuming that unions maximize wages, and is depicted in Figure 2 for $a = 2$.

B Maximum delay

The negotiation proceeds as in Rubinstein's (1982) alternating-offer bargaining model. The firm and the union make alternate wage offers, with the firm making offers in odd-numbered periods and the union making offers in even-numbered periods. The negotiation starts in period 0 and ends when one of the negotiators accepts an offer. No limit is placed on the time that may be expended in bargaining and perpetual disagreement is a possible outcome. The union is assumed to be on strike in every period until an agreement is reached. Both the firm and the union are assumed to be impatient. The firm and the union have time preferences with constant discount factors $\delta_{\mathrm{f}} \in (0,1)$ and $\delta_{\mathrm{u}} \in (0,1)$, respectively. It is assumed that each union-firm pair takes the other wage settlement as given during the negotiation. For any wage bargaining which leads to an agreement W_i at period n, $\delta_{\mathrm{f}}^n \cdot \Pi_i(W_i, L_i(W_i, W_j))$ and $\delta_{\mathrm{u}}^n \cdot U(W_i, L_i(W_i, W_j))$ are, respectively, firm i's payoff and union i's payoff. For any wage bargaining which leads to perpetual disagreement, disagreement payoffs are set to zero. As in Binmore, Rubinstein and Wolinsky (1986), the

SPE wage outcome is such that

$$\begin{cases} \Pi_i(T, W_{i\mathrm{u}}, L_i(W_{i\mathrm{u}}, W_j)) = \delta_\mathrm{f} \cdot \Pi_i(T, W_{i\mathrm{f}}, L_i(W_{i\mathrm{f}}, W_j)) \\ U_i(T, W_{i\mathrm{f}}, L_i(W_{i\mathrm{f}}, W_j)) = \delta_\mathrm{u} \cdot U(T, W_{i\mathrm{u}}, L_i(W_{i\mathrm{u}}, W_j)), \end{cases}$$

where $W_{i\mathrm{u}}$ is the SPE wage outcome if the union makes the first wage offer, and $W_{i\mathrm{f}}$ is the SPE wage outcome if the firm makes the first offer. Let $H(T, \delta_\mathrm{u}, \delta_\mathrm{f}) = 4(1 + \delta_\mathrm{f} - 2\delta_\mathrm{f}\delta_\mathrm{u})^2(2a - T)^2 - 8(1 - \delta_\mathrm{f})((1 - \delta_\mathrm{f}(1 - \delta_\mathrm{u})^2)(2a^2 - 2aT + 5T^2)$. Since the union makes the first offer, the unique symmetric SPE wages for two-way trade are given by

$$W_i^{\mathrm{SPE}}(T, \delta_\mathrm{u}, \delta_\mathrm{f}) = \frac{2(1 + \delta_\mathrm{f}(1 - 2\delta_\mathrm{u}))(2a - T) - \sqrt{H(T, \delta_\mathrm{u}, \delta_\mathrm{f})}}{4(1 - \delta_\mathrm{f}(1 - 2\delta_\mathrm{u})^2)}, \; i = 1, 2,$$

from which we get the SPE profits and the SPE unions payoffs,

$$\begin{aligned} U_i^*(T, \delta_\mathrm{u}, \delta_\mathrm{f}) &= \frac{2(1 + \delta_\mathrm{f}(1 - 2\delta_\mathrm{u}))(2a - T) - \sqrt{H(T, \delta_\mathrm{u}, \delta_\mathrm{f})}}{4(1 - \delta_\mathrm{f}(1 - 2\delta_\mathrm{u})^2)}, \; i = 1, 2, \\ \Pi_i^*(T, \delta_\mathrm{u}, \delta_\mathrm{f}) &= \frac{\delta_\mathrm{f}(1 - \delta_\mathrm{u})}{9b(1 - \delta_\mathrm{f}(1 - 2\delta_u)^2)^2} \left[2(4a^2(1 + \delta_f(1 - 2\delta_u)^2)(1 - \delta_u)(a - T) + (1+ \right. \\ & \left. 8\delta_u + \delta_f(1 - 2\delta_u)^2(1 - 10\delta_u))T^2) - (1 - 2\delta_u)(2a - T)\sqrt{H(T, \delta_\mathrm{u}, \delta_\mathrm{f})} \right]. \end{aligned}$$

Similarly, the unique symmetric SPE wages in the case of autarky are given by

$$\begin{cases} \Pi_i(T = \infty, W_{i\mathrm{u}}, L_i(W_{i\mathrm{u}}, W_j)) = \delta_\mathrm{f} \cdot \Pi_i(T = \infty, W_{i\mathrm{f}}, L_i(W_{i\mathrm{f}}, W_j)) \\ U_i(T = \infty, W_{i\mathrm{f}}, L_i(W_{i\mathrm{f}}, W_j)) = \delta_\mathrm{u} \cdot U(T = \infty, W_{i\mathrm{u}}, L_i(W_{i\mathrm{u}}, W_j)) \end{cases}$$

where $W_{i\mathrm{u}}$ is the SPE wage outcome if the union makes the first wage offer, and $W_{i\mathrm{f}}$ is the SPE wage outcome if the firm makes the first offer. Since the union makes the first offer, the SPE wage is

$$W_\mathrm{i}^{\mathrm{SPE}}(T = \infty, \delta_\mathrm{u}, \delta_\mathrm{f}) = \frac{1 - \sqrt{\delta_\mathrm{f}}}{1 - \sqrt{\delta_\mathrm{f}}\delta_\mathrm{u}} a, \; i = 1, 2,$$

from which we get the SPE profits and the SPE unions payoffs,

$$\begin{aligned} U_i^*(T &= \infty, \delta_\mathrm{u}, \delta_\mathrm{f}) = \frac{(1 - \sqrt{\delta_\mathrm{f}})a}{1 - \sqrt{\delta_\mathrm{f}}\delta_\mathrm{u}}, \; i = 1, 2, \\ \Pi_i^*(T &= \infty, \delta_\mathrm{u}, \delta_\mathrm{f}) = \frac{\delta_\mathrm{f}(1 - \delta_\mathrm{u})^2 a^2}{4(1 - \sqrt{\delta_\mathrm{f}}\delta_\mathrm{u})^2 b}, \; i = 1, 2. \end{aligned}$$

Suppose now that the players have private information. They are uncertain about each others' discount factors. Player i's discount factor is included in the set $\left[\delta_i^\mathrm{I}, \delta_i^\mathrm{P}\right]$, where $0 < \delta_i^\mathrm{I} \leq \delta_i^\mathrm{P} < 1$, for $i =$u,f. Since we allow for general probability distributions over discount factors, multiplicity of PBE is not an exception.

From Watson (1998), we have that: (i) in the case of two-way trade, for any PBE, the payoff of the union belongs to $[U_i^*(T, \delta_\mathrm{u}^\mathrm{I}, \delta_\mathrm{f}^\mathrm{P}), U_i^*(T, \delta_\mathrm{u}^\mathrm{P}, \delta_\mathrm{f}^\mathrm{I})]$ and the payoff of the firm belongs to $[\Pi_i^*(T, \delta_{\rm u}^{\rm P}, \delta_{\rm f}^{\rm I}), \Pi_i^*(T, \delta_{\rm u}^{\rm I}, \delta_{\rm f}^{\rm P})]$; (ii) in the case of autarky, for any PBE, the payoff of the union belongs to $[U_i^*(T=\infty, \delta_{\rm u}^{\rm I}, \delta_{\rm f}^{\rm P}), U_i^*(T=\infty, \delta_{\rm u}^{\rm P}, \delta_{\rm f}^{\rm I})]$ and the payoff of the firm belongs to $[\Pi_i^*(T=\infty, \delta_{\rm u}^{\rm P}, \delta_{\rm f}^{\rm I}), \Pi_i^*(T=\infty, \delta_{\rm u}^{\rm I}, \delta_{\rm f}^{\rm P})]$.

For two-way trade, the maximum number of bargaining periods the union would spend negotiating, $I\left(m^{\rm u}(T)\right)$, is given by

$$U_i^*(T, \delta_{\rm u}^{\rm I}, \delta_{\rm f}^{\rm P}) = \left(\delta_{\rm u}^{\rm P}\right)^{m^{\rm u}(T)} \cdot U_i^*(T, \delta_{\rm u}^{\rm P}, \delta_{\rm f}^{\rm I}),$$

from which we obtain

$$m^{\rm u}(T) = \frac{1}{\log\left(\delta_{\rm u}^{\rm P}\right)} \cdot \log\left[\frac{2(1+\delta_{\rm f}^{\rm P}(1-2\delta_{\rm u}^{\rm I}))(2a-T) - \sqrt{H(T, \delta_{\rm u}^{\rm I}, \delta_{\rm f}^{\rm P})}}{2(1+\delta_{\rm f}^{\rm I}(1-2\delta_{\rm u}^{\rm P}))(2a-T) - \sqrt{H(T, \delta_{\rm u}^{\rm P}, \delta_{\rm f}^{\rm I})}} \frac{(1-\delta_{\rm f}^{\rm I}(1-2\delta_{\rm u}^{\rm P})^2)}{(1-\delta_{\rm f}^{\rm P}(1-2\delta_{\rm u}^{\rm I})^2)}\right].$$

Notice that $I\left(m^{\rm u}(T)\right)$ is simply the integer part of $m^{\rm u}(T)$. It is customary to express the players' discount factors in terms of discount rates, $r_{\rm u}$ and $r_{\rm f}$, and the length of the bargaining period, Δ, according to the formula $\delta_i = \exp\left(-r_i \Delta\right)$, for $i =$u,f. With this interpretation, player i's type is identified with the discount rate r_i, where $r_i \in [r_i^{\rm P}, r_i^{\rm I}]$. We thus have that $\delta_i^{\rm I} = \exp(-r_i^{\rm I}\Delta)$ and $\delta_i^{\rm P} = \exp(-r_i^{\rm P}\Delta)$, for $i =$u,f. Note that $r_i^{\rm I} \geq r_i^{\rm P}$ since greater patience implies a lower discount rate. As Δ approaches zero, we have (using l'Hopital's rule): (i) $(1-\delta_{\rm f}^{\rm I}(1-2\delta_{\rm u}^{\rm P})^2)/(1-\delta_{\rm f}^{\rm P}(1-2\delta_{\rm u}^{\rm I})^2)$ converges to $(4r_{\rm u}^{\rm P}+r_{\rm f}^{\rm I})/(4r_{\rm u}^{\rm I}+r_{\rm f}^{\rm P})$, (ii) $(2(1+\delta_{\rm f}^{\rm P}(1-2\delta_{\rm u}^{\rm I}))(2a-T)-\sqrt{H(T, \delta_{\rm u}^{\rm I}, \delta_{\rm f}^{\rm P})})/(2(1+\delta_{\rm f}^{\rm I}(1-2\delta_{\rm u}^{\rm P}))(2a-T)-\sqrt{H(T, \delta_{\rm u}^{\rm P}, \delta_{\rm f}^{\rm I})})$ converges to $((2a-T)(r_{\rm f}^{\rm P}+2r_{\rm u}^{\rm I}) - \sqrt{G(r_{\rm u}^{\rm I}, r_{\rm f}^{\rm P}, T)})/((2a-T)(r_{\rm f}^{\rm I}+2r_{\rm u}^{\rm P}) - \sqrt{G(r_{\rm u}^{\rm P}, r_{\rm f}^{\rm I}, T)})$, and (iii) $\Delta/\log(\delta_{\rm u}^{\rm P})$ converges to $(-1/r_{\rm u}^{\rm P})$. These facts imply that

$$D^{\rm u}(T) = \lim_{\Delta\to 0}\left(m^{\rm u}(T)\cdot\Delta\right) = -\frac{1}{r_{\rm u}^{\rm P}} \cdot \log\left[\left(\frac{4r_{\rm u}^{\rm P}+r_{\rm f}^{\rm I}}{4r_{\rm u}^{\rm I}+r_{\rm f}^{\rm P}}\right)\frac{(2a-T)(r_{\rm f}^{\rm P}+2r_{\rm u}^{\rm I}) - \sqrt{G(r_{\rm u}^{\rm I}, r_{\rm f}^{\rm P}, T)}}{(2a-T)(r_{\rm f}^{\rm I}+2r_{\rm u}^{\rm P}) - \sqrt{G(r_{\rm u}^{\rm P}, r_{\rm f}^{\rm I}, T)}}\right],$$

which is a positive, finite number. Notice that $D^{\rm u}(T)$ converges to zero as $r_i^{\rm P}$ and $r_i^{\rm I}$ become close, for $i =$u,f. We have

$$\frac{\partial D^{\rm u}(T)}{\partial T} = \frac{9aT}{r_{\rm u}^{\rm P}(2a^2-2aT+5T^2)}\left(-\frac{r_{\rm f}^{\rm P}+2r_{\rm u}^{\rm I}}{\sqrt{G(r_{\rm u}^{\rm I}, r_{\rm f}^{\rm P}, T)}} + \frac{r_{\rm f}^{\rm I}+2r_{\rm u}^{\rm P}}{\sqrt{G(r_{\rm u}^{\rm P}, r_{\rm f}^{\rm I}, T)}}\right) > 0.$$

The maximum number of bargaining periods the firm would spend negotiating, $I(m^{\rm f}(T))$, is given by

$$\Pi_i^*(T, \delta_{\rm u}^{\rm P}, \delta_{\rm f}^{\rm I}) = (\delta_{\rm f}^{\rm P})^{m^{\rm f}(T)} \cdot \Pi_i^*(T, \delta_{\rm u}^{\rm I}, \delta_{\rm f}^{\rm P}),$$

from which we obtain

$$m^{\rm f}(T) = \frac{1}{\log(\delta_{\rm f}^{\rm P})} \cdot \log\left[\frac{\Pi_i^*(T, \delta_{\rm u}^{\rm P}, \delta_{\rm f}^{\rm I})}{\Pi_i^*(T, \delta_{\rm u}^{\rm I}, \delta_{\rm f}^{\rm P})}\right],$$

and as Δ approaches zero,

$$D^{\mathrm{f}}(T) = \lim_{\Delta\to 0}\left(m^{\mathrm{f}}(T)\cdot\Delta\right) = -\frac{1}{r_{\mathrm{f}}^{\mathrm{P}}}\cdot\log\left[\left(\frac{r_{\mathrm{u}}^{\mathrm{P}}}{r_{\mathrm{u}}^{\mathrm{I}}}\right)\left(\frac{4r_{\mathrm{u}}^{\mathrm{I}}+r_{\mathrm{f}}^{\mathrm{P}}}{4r_{\mathrm{u}}^{\mathrm{P}}+r_{\mathrm{f}}^{\mathrm{I}}}\right)^2\cdot \frac{8a(a-T)r_{\mathrm{u}}^{\mathrm{P}}+(9r_{\mathrm{f}}^{\mathrm{I}}+38r_{\mathrm{u}}^{\mathrm{P}})T^2+(2a-T)\sqrt{G(r_{\mathrm{u}}^{\mathrm{P}},r_{\mathrm{f}}^{\mathrm{I}},T)}}{8a(a-T)r_{\mathrm{u}}^{\mathrm{I}}+(9r_{\mathrm{f}}^{\mathrm{P}}+38r_{\mathrm{u}}^{\mathrm{I}})T^2+(2a-T)\sqrt{G(r_{\mathrm{u}}^{\mathrm{I}},r_{\mathrm{f}}^{\mathrm{P}},T)}}\right].$$

which is a positive, finite number. We have

$$\frac{\partial D^{\mathrm{f}}(T)}{\partial T} = \frac{a}{r_{\mathrm{f}}^{\mathrm{P}}(2a^2-2aT+5T^2)T}\cdot \left(-\frac{8a(a-T)r_{\mathrm{u}}^{\mathrm{I}}+(2r_{\mathrm{u}}^{\mathrm{I}}-9r_{\mathrm{f}}^{\mathrm{P}})T^2}{\sqrt{G(r_{\mathrm{u}}^{\mathrm{I}},r_{\mathrm{f}}^{\mathrm{P}},T)}}+\frac{8a(a-T)r_{\mathrm{u}}^{\mathrm{P}}+(2r_{\mathrm{u}}^{\mathrm{P}}-9r_{\mathrm{f}}^{\mathrm{I}})T^2}{\sqrt{G(r_{\mathrm{u}}^{\mathrm{P}},r_{\mathrm{f}}^{\mathrm{I}},T)}}\right) > 0$$

since $\overline{\alpha} < \widehat{\alpha}$. The maximum real delay time before reaching an agreement is given by

$$D(T) = \min\left\{D^{\mathrm{u}}(T), D^{\mathrm{f}}(T)\right\}.$$

For autarky, the maximum number of bargaining periods the union would spend negotiating, $I\left(m^{\mathrm{u}}(T=\infty)\right)$, is given by

$$U_i^*(T=\infty,\delta_{\mathrm{u}}^{\mathrm{I}},\delta_{\mathrm{f}}^{\mathrm{P}}) = \left(\delta_{\mathrm{u}}^{\mathrm{P}}\right)^{m^{\mathrm{u}}(T=\infty)}\cdot U_i^*(T=\infty,\delta_{\mathrm{u}}^{\mathrm{P}},\delta_{\mathrm{f}}^{\mathrm{I}}),$$

from which we obtain

$$m^{\mathrm{u}}(T=\infty) = \frac{1}{\log\left(\delta_{\mathrm{u}}^{\mathrm{P}}\right)}\cdot\log\left[\left(\frac{1-\sqrt{\delta_{\mathrm{f}}^{\mathrm{P}}}}{1-\sqrt{\delta_{\mathrm{f}}^{\mathrm{I}}}}\right)\left(\frac{1-\delta_{\mathrm{u}}^{\mathrm{P}}\sqrt{\delta_{\mathrm{f}}^{\mathrm{I}}}}{1-\delta_{\mathrm{u}}^{\mathrm{I}}\sqrt{\delta_{\mathrm{f}}^{\mathrm{P}}}}\right)\right],$$

and as Δ approaches zero

$$D^{\mathrm{u}}(T=\infty) = \lim_{\Delta\to 0}\left(m^{\mathrm{u}}(T=\infty)\cdot\Delta\right) = -\frac{1}{r_{\mathrm{u}}^{\mathrm{P}}}\cdot\log\left[\left(\frac{2r_{\mathrm{u}}^{\mathrm{P}}+r_{\mathrm{f}}^{\mathrm{I}}}{2r_{\mathrm{u}}^{\mathrm{I}}+r_{\mathrm{f}}^{\mathrm{P}}}\right)\left(\frac{r_{\mathrm{f}}^{\mathrm{P}}}{r_{\mathrm{f}}^{\mathrm{I}}}\right)\right],$$

which is a positive, finite number. Similarly, the maximum number of bargaining periods the firm would spend negotiating, $I(m^{\mathrm{f}}(T=\infty))$, is given by

$$\Pi_i^*(T=\infty,\delta_{\mathrm{u}}^{\mathrm{P}},\delta_{\mathrm{f}}^{\mathrm{I}}) = (\delta_{\mathrm{f}}^{\mathrm{P}})^{m^{\mathrm{f}}(T=\infty)}\cdot\Pi_i^*(T=\infty,\delta_{\mathrm{u}}^{\mathrm{I}},\delta_{\mathrm{f}}^{\mathrm{P}}),$$

from which we obtain

$$m^{\mathrm{f}}(T=\infty) = \frac{1}{\log(\delta_{\mathrm{f}}^{\mathrm{P}})}\cdot\log\left[\left(\frac{\delta_{\mathrm{f}}^{\mathrm{I}}}{\delta_{\mathrm{f}}^{\mathrm{P}}}\right)\left(\frac{1-\delta_{\mathrm{u}}^{\mathrm{I}}\sqrt{\delta_{\mathrm{f}}^{\mathrm{P}}}}{1-\delta_{\mathrm{u}}^{\mathrm{P}}\sqrt{\delta_{\mathrm{f}}^{\mathrm{I}}}}\right)^2\left(\frac{1-\delta_{\mathrm{u}}^{\mathrm{P}}}{1-\delta_{\mathrm{u}}^{\mathrm{I}}}\right)^2\right],$$

and as Δ approaches zero,

$$D^{\mathrm{f}}(T=\infty) = \lim_{\Delta\to 0}\Big(m^{\mathrm{f}}(T=\infty)\cdot\Delta\Big) = -\frac{1}{r_{\mathrm{f}}^{\mathrm{P}}}\cdot\log\left[\left(\frac{2r_{\mathrm{u}}^{\mathrm{I}}+r_{\mathrm{f}}^{\mathrm{P}}}{2r_{\mathrm{u}}^{\mathrm{P}}+r_{\mathrm{f}}^{\mathrm{I}}}\right)^2\left(\frac{r_{\mathrm{u}}^{\mathrm{P}}}{r_{\mathrm{u}}^{\mathrm{I}}}\right)^2\right].$$

Then, the maximum real delay time before reaching an agreement is given by

$$D(T=\infty) = \min\Big\{D^{\mathrm{u}}(T=\infty), D^{\mathrm{f}}(T=\infty)\Big\}.$$

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