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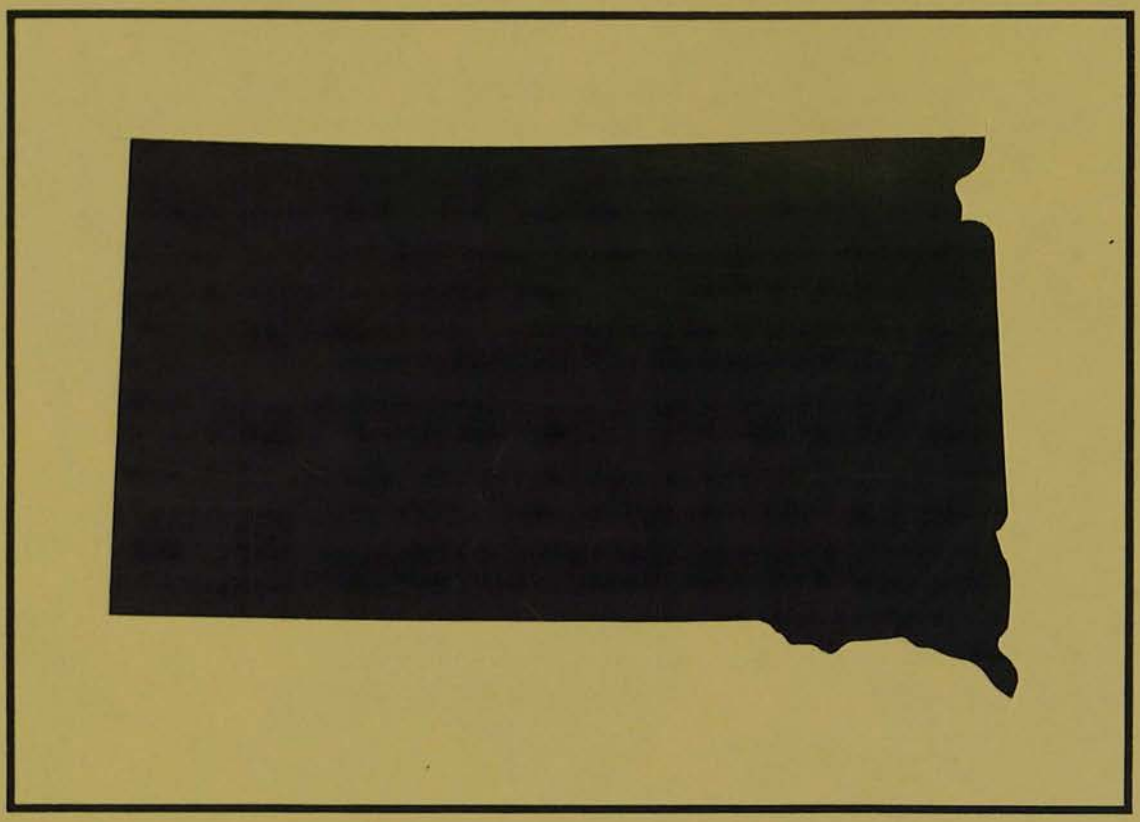

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THE INFLUENCE OF INTERNATIONAL ON UNION FIRM HIRING AND WORKER UNION CHOICE

by

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The Influence of International Trade on Union Firm Hiring and Worker Union Choice*

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The Influence of International Trade on Union Firm Hiring and Worker Union Choice

ABSTRACT

Union opposition to free trade policies suggests that international trade damages the union movement. Previous research has found little relationship between union *wages* and international trade. However, greater trade may hinder unions by reducing the likelihood that workers enter the union sector. A bivariate partial observability probit model is used to predict union choice with respect to risk aversion, union strategic behavior, and product market effects of trade. The model estimates the probability of workers entering the union sector queue and the probability of being hired from the union queue. The results suggest that trade has had some adverse effects on union choice, but it is exports rather than imports that have the greatest negative impact on unions. Sectorial results show that high-technology sector workers have a high likelihood of union choice, *ceteris paribus*, which acts to offset the adverse impact of trade. Finally, the empirical evidence implies that most of the determination of individual union status is due to firm behavior, not due to characteristics of the individual worker.

I. Introduction.

Union opposition to the North American Free Trade Agreement (NAFTA) exemplifies the staunch resistance to free trade in general by U.S. union leaders. Previous research has indicated that trade has relatively little influence on average U.S. wages (e.g., Partridge, 1993; Freeman and Katz, 1991). However, union opposition may arise because trade influences the likelihood that individuals belong to unions. In this case, greater trade either reduces the likelihood individuals are willing to work in the organized sector, or it reduces the likelihood that unionized employers will expand their work force. By separating workers' demand for unionization from unionized firms' hiring decisions, the effects of trade on union strength can be better understood.

U.S. union densities have steadily declined since the 1950s (Freeman, 1988), a period during which the U.S. economy became much more exposed to international trade. Thus, some analysts have claimed that trade has weakened the U.S. labor movement. However, other industrial nations, which are exposed to significantly greater international trade shares than the United States (e.g., Canada, Germany), have not experienced major declines in unionization. Therefore, international trade may not be a major cause of the decline of the U.S. union movement. Alternatively, trade may have a different influence on U.S. workers' demand for unions and U.S. unionized firms' hiring decisions. Thus, it is an empirical issue regarding trade's overall impact on the likelihood workers belong to unions.

Martinello and Meng (1992) and Belman (1988) have considered whether import shares influence the likelihood a worker belongs to a union by employing univariate probit specifications.[1] However, simple probit does not distinguish between the choice that individual workers make regarding whether to enter the queue for union jobs from the union firm's selection process regarding which workers to hire from the union queue. Thus, this study advances our understanding of the precise mechanism that trade influences union strength by using a partial observability probit model. Moreover, unlike previous studies (with the exception of Partridge, 1994), this study considers whether exports affect union status and how the relative comparative advantage of a sector affects the union choice decision.[2] This study advances previous research by jointly considering these issues by using 1978-1980 National Longitudinal Survey of Young Men (NLSYM) data.

II. Union Behavior and International Trade.

International trade can influence union status in three ways. First, it directly affects domestic product market power. Second, because trade is a signal of the future viability of the industry and future employment possibilities, trade can influence *strategic behavior* by unions and management. Third, greater international trade can trigger risk averse behavior by unions and management. These three hypotheses are summarized in Table 1. Closely related to these points is that individual union status can be affected by the characteristics that determine the relative comparative advantage of the sector, which is addressed in the next section.

The basis for most union choice studies is that workers decide to join a union when the benefits of unionism outweigh the costs. Net benefits of unionism are influenced by many factors including the worker's demand for unionization, the supply of unionization, and employer hiring decisions. Union choice is positively related to the union-nonunion wage gap, $(W^U-W^N)/W^N$, and other factors including industry, trade, labor market, and individual characteristics.[3] Equation (1) represents the union choice decision:

(1) $U = G((W^U-W^N)/W^N, Z, L, I)$, $G_{(W^U-W^N)/W^N} > 0$,

where U is a union choice indicator variable, Z, L, and I represent industry characteristics, labor market characteristics, and individual attributes, respectively.

The model shown in (1) does not fully illustrate the sequential decision that is undertaken by workers and their employers. First, workers decide whether to join the union queue. Second, union employers decide which workers to hire from the queue or whether to hire workers in the first place. This sequential model has been previously considered by Abowd and Farber (1982) and DeFreitas (1993) (Maddala, 1983 also discusses this model). Nevertheless, neither study considered industry characteristics (e.g., trade shares, etc.), which are the subject of this study. The individual worker's decision whether to join the union queue is represented by:

(2) $Q = X_1\beta_1 + e_1$,

where Q is a union queue indicator variable, X_1 is a vector of individual and industry characteristics, and e_1 is an error term. The firm's decision to hire from the queue is shown in (3):

(3) $HFQ = X_2\beta_2 + e_2$,

where HFQ is an indicator variable, X_2 is a vector of relevant individual and industry characteristics, and e_2 is an error term. A worker is only hired for a union job if both Q and HFQ equal 1 (i.e., both conditions are true).

An individual's union status using reduced form *univariate probit models* has been examined in several studies (e.g., Hirsch and Berger, 1984; Belman, 1988; Martinello and Meng, 1992; Lee, 1978). Most of these studies emphasize the role of the domestic industry's *product market* power on individual union status.[4] For example, both the four-firm concentration ratio (CR4) and exports are positively related while imports are negatively related to a domestic firm's product market power. Greater product market power implies a smaller labor demand elasticity and greater profits. Therefore, following from a rent sharing/extraction model (Abowd, 1989) or a monopoly union model (McDonald and Solow, 1981), greater product market power implies a larger union wage gap and a greater demand for union coverage. Thus, the *product market* analysis suggests that imports are negatively related to the demand for unionization with the opposite association holding for exports. Likewise, unions may be more willing to organize an industry if there are greater profits to appropriate (e.g., Hirsch and Berger, 1984; Belman, 1988). Consequently, imports are negatively related to the supply of unionization, while exports are positively related. Therefore, a worker's likelihood of belonging to a union in a reduced form probit model or a worker's probability of joining the union queue in the partial observability probit model is negatively (positively) related to the industry's import (export) share.

Greater wages as a result of product market power should increase the quality of the applicant pool (e.g., an adverse selection argument from efficiency wage theory). Thus, CR4 and exports are positively related to union firms hiring from the union queue with the opposite applying for imports.

The product market model ignores potential long-run *strategic* responses by unions after changes in trade. For example, Kahn (1993) examines the likelihood that labor and management cooperate in repeated games. Kahn found that union-management cooperation is negatively related to an industry's or firm's bankruptcy or failure rate, where a greater failure rate reduces the expected gains for the union from long-run cooperation. In our case, greater imports can signal that there is a greater likelihood that the firm will fail, while increased exports can signal the opposite.

Clearly, one dimension of long-run union-management cooperation is the tradeoff between short-term wages and the likelihood of long-term employment. For example, Farber and Saks (1980) show that employment security plays an important role in individual decisions to vote for union certification; thus, employment security likely plays a role in union bargaining strategy. Similarly, Lawrence and Lawrence (1985) examine the influence of international competition on union behavior through an end game, which is essentially a tradeoff between current wages and the probability of long-term employment.[5]

Lawrence and Lawrence suggest that slow demand growth reduces the opportunity for an industry to invest in new plant and equipment. Unions can extract *higher* wages because a slowly growing firm has more difficulty substituting capital for labor (i.e., smaller elasticities of factor substitution σ_{KL} and/or labor demand). Yet, the tradeoff for higher current wages is ultimately a reduction in long-term employment. Consequently, because greater imports are negatively related to the firm's (or industry's) demand growth and positively related to its failure rate, greater imports can induce a less cooperative union-management atmosphere. The implication is that greater imports could actually increase the union-nonunion wage gap. Conversely, robust product demand growth encourages the industry to expand its capacity. The union fears that if its wages are too "high," the firm will adopt a capital-intensive technology which could result in lower long-run union employment. Hence, greater exports, by inducing increased demand growth and union-management cooperation, can reduce the union wage gap.

The strategic behavior hypothesis suggests a positive (negative) relationship between the union wage gap and imports (exports). Thus, this hypothesis implies that greater imports are associated with a greater demand for unionization with the opposite holding for exports. Consequently, strategic behavior suggests that the likelihood of belonging to a union or joining the union queue is positively related to imports and negatively related to exports. Moreover, because greater import competition increases union wages and induces an uncooperative union-management atmosphere, greater import shares reduce the likelihood that unionized firms will hire from the union queue. Likewise, increased export shares increase the chance that unionized firms will hire from the union queue.

In addition to product market power and strategic behavior, union membership may be influenced by the increased *uncertainty* associated with international trade. Industries with a high export or import share are exposed to changes in tariffs, exchange rate risk, and other risks due to changes in the terms of international competitiveness (e.g., Dornbusch, 1987). Moreover, foreign product markets and cost structures may not be completely understood by domestic firms. Since domestic production in high trade share industries is at a higher risk of displacement by foreign producers, these industries may suffer from greater variability in output and profitability.

Collective bargaining agreements have characteristics that may add to the uncertainty of international trade. Union contracts are typically set for three years and may inhibit the necessary labor market flexibility to react to changing international competitiveness. Also, if unions extract higher wages via monopoly power, unionized firms will have a labor cost disadvantage and will be less competitive. Consequently, as risk aversion increases, firms exposed to greater international competition will be less likely to hire from the union queue.

Workers may also be willing to tradeoff greater job security for lower wages and forego the benefits of unionization. Greater international competition in the union sector increases the risk of union busting tactics, lay-offs, or negotiated wage reductions. Thus, as workers' risk aversion increases, they will be less likely to enter the union queue. Overall, the uncertainty effect may have a stronger influence on firm behavior than on employee behavior because it affects their actions the most directly.

The three competing hypotheses regarding trade's influence on union status: (1) product market, (2) strategic behavior, and (3) risk aversion/uncertainty each imply that trade shares have a different influence on union status. Again, these are summarized in Table 1. Product market effects from greater imports and exports on the demand for unionization offset the effects of strategic behavior.[6] Product market analysis suggests that greater *imports* (*exports*) *reduce* (*increase*) the likelihood of a worker joining the union queue, while strategic behavior implies the converse. Nevertheless, the uncertainty hypothesis implies that uncertainty arising from greater international trade has a negative impact on the probability of both joining the union queue and being hired from the union queue. Therefore, it is an empirical question as to which effect dominates. In fact, it is possible that trade has very little influence

on the demand for unionism because the three effects offset each other.

III. Industry Comparative Advantage and Union Status.

The discussion above focussed directly on how import and export shares alter union behavior. Aside from a sector's import and export shares, there are other technological characteristics inherent within a sector which determine its level of international competitiveness (e.g., technology). For example, standard Heckscher-Ohlin trade theory emphasizes the role of factor intensities such as physical capital or human capital in determining international trade flows. In fact, traditional trade models do not point to trade shares, *per se*, as a measure of how trade influences a sector. Instead, the emphasis is on factor intensities in the sector.

Since the 1960s, U.S. manufacturing has undergone tremendous changes in its trade balance where all industries have not fared equally. For example, the high-tech sector is very competitive while other sectors (e.g., autos and steel) have fared poorly. Johnson and Stafford (1993) suggest that foreign technological convergence has reduced the technological quasi-rents available in the medium-tech industries the United States dominated after World War II. By contrast, high-tech industries account for an increasing share of U.S. exports. Thus, technological differences across sectors should also influence union behavior.

To further investigate these matters, manufacturing will be divided into four sectors.[7] The division stresses both technological and factor endowment differences. The four sectors are natural resources (NR), labor-intensive common technology (CTL), capital-intensive common technology (CTK), and high-technology (HT) (e.g., computers, aerospace, chemicals, scientific instruments, and most machinery). NR goods intensively use natural resources in the manufacturing process (e.g., lumber, processed food). CTL (e.g., apparel, footwear) and CTK goods (e.g., steel, autos) utilize a readily available technology used throughout the world.[8] Arndt and Bouton (1987) show that there are significantly different product market and technological characteristics between these four sectors, and Partridge (1993) finds that union and nonunion wage patterns vary across these three sectors. For instance, the HT sector appears to possess greater product market power (e.g., greater CR4, trade surpluses, and value added per worker). In an international context, especially since the 1970s, the CTL

and CTK sectors have less product market power (e.g., large trade deficits), and for the most part, fall in the medium-tech industries that were referred to by Johnson and Stafford.

It is very likely that each sector has its own *separate* impact on union status that depends on the technological characteristics of the sector. Standard international trade theory suggests that the more skilled HT unionized labor-force should fare relatively better than the CTL and CTK sectors in response to international trade. Moreover, the product market analysis from above reinforces traditional international trade theory. In this case, the positive relationship between the product and labor demand elasticities suggests that HT unions have a superior wage-employment relationship to exploit, while CTL and CTK unions have an inferior wage-employment relationship. The implication is that the demand for unionization should be *greater* (*smaller*) in the HT (CTL, CTK) sector(s) *on average*.[9] However, because unions can influence the capital-intensity of the industry, the CTL and CTK results should be cautiously interpreted.

The superior union wage and long-run employment opportunities in the HT sector also suggest that the quality of the applicant pool will be superior in the HT sector. Thus, unionized HT firms will be more willing to hire workers than unionized firms in the CTL and CTK sectors.

IV. Empirical Methodology.

Following DeFreitas (1993), the sequential union model suggests that a worker will be unionized only if equations (2) and (3) are true (i.e., $Q=1$ and $HFQ=1$). In this case, a worker first decides whether to join the queue and second, the worker is hired from the queue. The probability of a worker being employed in a union job equals:

(4) $P(U=1)= P(Q=1)\bullet P(HFQ=1 \mid Q=1)$.

The probability of a worker not belonging to a union equals:

(5) $P(U=0)= P(Q=0) + P(Q=1)\bullet P(HFQ=0 \mid Q=1)$.

Unfortunately, we do not observe whether a worker has joined the queue or whether a firm has refused to hire a worker if they were in the queue. Instead, we observe the product of Q and HFQ. To account for this problem, a partial observability probit model is used. Thus, the errors in equations (2) and (3) are assumed to be normally distributed. The estimates of $ß_1$ and $ß_2$ are derived from maximizing the

following likelihood function:

(6) $L=\prod_{U=1}\{F(X_1\beta_1)F(X_2\beta_2)\}\bullet\prod_{U=0}\{1-F(X_1\beta_1)F(X_2\beta_2)\}$.

To identify β_1 and β_2, the variables in X_1 cannot be identical to the variables in X_2. Like Abowd and Farber (1982) and DeFreitas (1993), to identify the equation, union and nonunion tenure (UNTEN, NUNTEN) and their squares (UNTEN2, NUNTEN2) will be omitted from the firm's hiring equation.[10] Because wages and tenure are positively related, union tenure reflects a union worker's costs of leaving the union sector, while nonunion tenure reflects a nonunion worker's costs of leaving the nonunion sector. Consequently, it is expected that union (nonunion) tenure is positively (negatively) related to being in the union queue.

The worker's decision to join the union queue is based on 1978 data and the firm's decision to hire from the queue is based on 1980 data. This construction takes advantage of the longitudinal nature of our data set, and captures the sequential nature of the union choice decision. Thus, the time frame is workers with a given set of *ex ante* characteristics in 1978 decide whether to join the union queue. Then in 1980, firms decide to hire from the union queue based on relevant *ex post* characteristics in 1980. This formulation also improves the identification of equation (6).

A quasi reduced form probit is also estimated to measure the likelihood an individual belongs to a union. Like DeFreitas (1993), the reduced form estimates will be compared to partial observability probit estimates. The specification for individual i is:

(7) $P(U=1) = P(\mathbf{Y}\Gamma + \epsilon_i) > 0$, $\epsilon_i \sim$ i.i.d. N(0,1).

The dependent variable is the worker's union status (i.e., *union: U=1*). Vector **Y** contains the independent variables and ϵ_i is the error term. Vector **Y** contains variables that control for the net benefits of union membership including variables that influence the union wage gap.

Equation (7) is a reduced form of equation (1), which allows us to estimate the *total impact* of trade on union choice. Martinello and Meng (1992) also estimate a similar reduced form probit model for Canadian workers. Analogously, we estimate a reduced form representation of equation (6). Thus, the empirical specifications will measure the direct impact of the trade variables (e.g., on employment and labor demand elasticity) *plus* their indirect influence through the union wage gap.

V. Data.

NLSYM data from 1978-1980 is combined with three-digit industry data for the empirical analysis, resulting in a sample of 734 observations. The advantage of this time period is that the trade balance was approximately zero and the wild currency fluctuations of the 1980s had not affected manufacturing, which implies that we are considering a period that was approximately in equilibrium. Moreover, this period did not experience the dramatic declines in unionization and the tremendous changes in management attitudes towards unions that are attributed to the 1980s and 1990s. Hence, we do not confound these other effects with trade's influence. Previous studies use similar individual and industry control variables (e.g., Martinello and Meng, 1992; DeFreitas, 1993); and thus, we will only emphasize the predicted effects for the variables unique to our study.

To assess how comparative advantage influences union choice, HT, CTL, and CTK dummies are included where NR is the omitted category. The trade variables consist of the import share (M=imports/(imports+output)) and the export share (X=exports/output). The trade variables are from U.S. Department of Commerce data. Several industry variables are included to measure industry effects on the net benefits of union membership (e.g., the supply of unionism and the probability that a worker is hired from the queue). First, an international trade adjusted CR4 accounts for domestic product market power adjusted for imports and exports (CR4INT).[11] Industry dummy variables are included for durable goods (DUR) and nondurable goods (NONDUR) where the equipment, intermediate goods, and automobile producing industries are the omitted category (Lawrence, 1984). A steel dummy variable (STEEL) is also included. The three-year percent change in real industry output (RCHS) helps control for "temporary" shifts in the labor demand curve. (Freeman and Katz (1991) report that three-year changes seem to be the best choice.) For example, if domestic demand is growing rapidly, imports may increase even though the domestic industry is healthy, where RCHS accounts for this effect. Regional differences in labor markets and attitudes towards unions are captured by a dummy for the South (SOUTH). Similarly, dummies for residence in a metropolitan area (SMSA) and the unemployment rate multiplied by 10 (UNEMP) are also included.

Many individual characteristics are in **Y** to control for the demand for unionism and the

probability of being hired by a union employer. It is expected that less-skilled individuals will particularly desire union employment while firms will desire more skilled employees (DeFreitas, 1993). Years of completed education (ED) and dummies for part-time employment, marriage, health problems in the last year that affected the individual's work, and minorities (PART, MAR, HEALTH, MINOR) are included. Potential work experience along with its square are also added (EXP, EXPSQ). Occupational dummy variables represent professional and technical, managers, clerical, sales, craftsmen, operatives, and household and service workers (PROF, MANAG, CLER, SALES, CRAFT, OPER, SERV); laborers are the omitted category. Finally, the simple probit model controls for the worker's tenure and its square (TEN, TENSQ).

VI. Empirical Results.

Table 2, column (1) shows the descriptive statistics for the specific variables of each model. Column (2) reports the relevant parameter results for the non-queue or traditional univariate probit model. In general, the parameter estimates are consistent with results reported by previous studies. The sequential bivariate queuing model results follow in the next two columns. Column (3) reports the results for entering the queue and column (4) shows the results for being hired from the queue. Although these individual parameter estimates are not as precisely estimated as those of the simple probit, they are suggestive of separate worker and firm considerations. This point is shown by the union queue model being a statistically significant improvement over the simple reduced form probit model.[12]

The lack of any highly significant coefficient estimates in the entry into the queue model suggests that few specific individual characteristics determine the worker's entry decision. It may also reflect a diverse pool of workers queuing for manufacturing industries. This result is consistent with Farber and Saks (1980) who find that individual characteristics have little effect on worker's union voting preferences. Consequently, selection into the union sector is primarily dependent on the employer hiring decision, where the significant probit estimates in the hired from queue model imply that employers take advantage of the characteristics of the applicant pool.

The individual import and export parameter estimates are generally insignificant in all three cases. Nonetheless, since the data have been "stretched" by combining the NLS micro-data set with

aggregate industry data, the parameter coefficients and the t-statistics should be interpreted cautiously.[13,14] Specifically, in all three models, the export and import share variables are *jointly significant*, but are generally *individually insignificant*. Similarly, the HT, CTL, and CTK dummies are typically insignificant individually, but are jointly significant. Therefore, given the imprecision of the traditional hypothesis test, we utilize a likelihood ratio test to evaluate the *joint* restriction that the trade share and technological-based sectoral variables have no effect on union choice. The likelihood ratio test results for all three models are reported at the bottom of Table 2. Generally, these *joint* significance tests indicate that the trade share variables and the sectoral dummies influence union status as a group.

Table 3 illustrates the change in the probability of union choice after a one standard deviation change from the mean export share (mean = 9.3%, std. dev. = 7.3%) and the mean import share (mean = 8.3%, std. dev. = 7.7%), as well as the difference in union choice for the HT, CTL, and CTK sectors relative to the NR sector. Table 3 also describes how these probabilities were derived. Below, we will detail these trade and sectoral results.

Imports and Exports. For the non-queue model, Panel 1 of Table 3 shows that the probability of union coverage declines by 10.2% with a one standard deviation increase in the export share and increases by .6% with a one standard deviation increase in the import share. The results reflect the probit estimates in column (2) of Table 2. From Panel A of Table 1, the negative export effect implies that either uncertainty or strategic behavior effects dominate any product market effects. For imports, the positive relationship is consistent with the strategic behavior effect dominating, though the small import estimate suggests that, for the most part, the three effects offset.[15]

The non-queue model suggests that greater exports, not greater imports, have a negative influence on the likelihood an individual belongs to a union. Consequently, the real problem for the labor movement appears to be export expansion which was supposed to help offset union membership loss from imports. Moreover, the results seem to be weakly inconsistent with the experience in other industrial nations where greater trade has apparently not significantly weakened their labor movements.

To sort out how individual workers or firms alter their behavior in response to changes in the international environment, we turn to the union queue model's results. Panel 1 of Table 3 shows that

entering the union queue is negatively related to exports. For industries with high export shares, either increased trade exposure causes workers to view union employment as more uncertain or strategic behavior effects dominate entry into the union queue (Panel B of Table 1). Another possible explanation is that industries with a high export share tend to attract workers that have low taste parameters for unionization.

Imports also have a negative effect on entering the queue. This is consistent with the risk aversion argument, which suggests that workers perceive union employment as more risky in industries exposed to import competition (e.g., anti-union activities, lay-off, etc.). Alternatively, as import shares increase, product market effects dominate causing the union wage differential and, hence, union choice to decline as the import share increases. Overall, the negative influence of imports and exports are *both* consistent with greater trade increasing the risk of union employment, which suggests that greater trade may reduce the desire of workers join the union queue.

Panel 1 of Table 3 shows that the probability of being hired from the union queue is negatively related to the export share. The results are consistent with the uncertainty argument that unions cause export competition to become more risky, as hypothesized in Panel C of Table 1; and they are inconsistent with both the strategic behavior and product market effects. This suggests that firms resist unionization as their export share increases because management apparently views collective bargaining contracts as too costly (i.e., greater wage rates) or too confining for rapid response to maintain export competitiveness. This may be especially the case when the terms of international trade are rapidly changing.

The probability of being hired from the union queue is positively related to the import share. The import results are inconsistent with the arguments in Panel C of Table 1, since all three hypothesize a negative impact on the probability of being hired from the union queue. This result implies that import competition shifts employers' preferences from low wage nonunion workers to higher cost union workers--a counter-intuitive finding at first glance. Nonetheless, this still could be consistent with greater imports causing risk averse behavior. For example, Hirsch and Morgan (1994) found evidence that union firms may have been more risk averse than nonunion firms in the late 1970s where union

firms were able to shift their risk onto their unionized labor-force. In our case, this implies that if greater import competition increases uncertainty, the hiring rate of risk-averse union employers could be relatively greater than nonunion employers.

The union queue model is consistent with union claims that trade has been a factor--albeit a small factor--in the decline in union membership. The results, however, suggest that exports rather than imports have had the primary impact on union employment. The union queue results also show that trade's influence on union employment affects firm choice differently than worker choice (this issue cannot be identified using the ordinary probit model). The different pattern can be seen in the case of imports where the positive import response of employers is offset by workers' aversion to union coverage. Moreover, the negative impact of exports occurs because, not only are potential workers in the high export share industries less likely to enter the union queue, but also firms are less likely to hire union workers as their international market expands. Rather than export expansion offsetting the negative effects of import competition, such as the loss of jobs, exports have even further hindered the union movement. Consequently, it is understandable that union leaders feel threatened and oppose free trade measures such as NAFTA or GATT. They see no benefit for unions even if the free trade legislation provides the expected increase in exports.

The HT, CTL, and CTK Impact. Because the sectoral dummy coefficients are jointly significant, worker union choice appears to vary by sector of employment. After controlling for industry and individual characteristics, Panel 2 of Table 3 shows the difference in the non-queue union choice probability for each sector *relative* to the NR sector. These results are consistent with our *a priori* expectations. HT employees have a positive probability of joining a union, ceteris paribus. The CTL and CTK coefficients suggests that common-technology sector employees have the lowest likelihood of joining a union, especially workers in CTK industries. This result is not surprising since one would expect capital-intensive firms to substitute capital for higher cost union labor. Overall, the sectoral differences in international comparative advantage appear to be at least as important as the impact of trade shares in the determination of union status.

The results for the union queuing model parallel the standard probit estimates. Table 3 suggests

that HT workers are relatively more likely to join the union queue than CTL and CTK workers. The finding that CTL and CTK industry workers are less likely to enter the union queue probably reflects the perceived susceptibility of these sectors to greater domestic and foreign competition. Panel 2 also indicates that HT workers have the highest probability of being hired from the union queue (likely due to greater human capital) while CTL and CTK workers have the lowest probability of being hired from the union queue, which is likely due to greater foreign and domestic competition.

Panel 2 also shows that sectoral differences in union choice are influenced by the difference in the firm's willingness to hire from the queue as well as a worker's willingness to join the union queue (again, this cannot be identified in the ordinary probit model). The non-queue probit model suggests that a positive relationship appears to exist between a sector's product market power and the probability of its employees belonging to a union. As we can see from the queuing model, this is mostly due to a HT firm's relative desire to hire union workers and relative employee and employer aversion to unions in the CTL and CTK sectors.

These results imply that a cause of union decline in sectors threatened by international competition (e.g., in the case of textiles but not in the case of aerospace) is related to factors associated with the comparative advantage of the sector (e.g., technology or human capital). Thus, the technological factors that determine both sectoral comparative advantage and the relative degree of foreign technological convergence have an impact on union membership that is separate from the influence of the sector's trade share. Moreover, consistent pressure from international competition will likely force further industrial restructuring that should favor the HT sector at the expense of the CTL and CTK sectors. If there is any opportunity for unions to stabilize (or increase) their membership in the face of increasing international competition, it is in the HT sector. If unions were to focus their organizational efforts on these industries, they could likely offset the adverse impact they suffer from the trade share effects.

The sectoral results are consistent with Johnson and Stafford's (1993) claim that U.S. medium technology industries are under competitive pressures from foreign economic convergence. The resulting loss of quasi-rents in these industries hurt CTL and CTK union workers and reduced their

union membership. Foreign economic convergence in the common-technology industries can help explain why other industrial nations' union movements have not fared as poorly as in the United States. Presumably, the other industrial nations' economic convergence after World War II was concentrated in their common-technology industries. Because international convergence favorably influenced their common-technology sector, it did not pull down their union movement as in the United States. However, now that this convergence has run its course, other industrial nations' labor movements may increasingly feel the pressures that have been felt in the United States.

These results are also consistent with standard international trade theory where union workers in the higher skilled HT sector are predicted to fare better than union workers in the less skilled CTL and CTK sectors. Thus, if we were to only examine the effects of trade shares, we may incorrectly conclude that standard Heckscher-Ohlin trade theory has little impact.[16]

Lastly, the probit results suggest that workers in durable good industries are less likely to be unionized relative to the base group, while STEEL industry workers are more likely to be in a union. Moreover, the occupational dummy variables indicate that professional, managerial, clerical, and sales workers are less likely to be in a union than less skilled workers (as suggested by DeFreitas, 1993). The occupational estimates in the hired from the queue model also indicate that employer resistance prevents unions from organizing these occupations. Education is negatively related to union status in the simple probit, but surprisingly, this was mostly due to employer resistance to hire more educated union workers from the queue. The negative three-year change in the real shipments (RCHS) coefficient may indicate that union firms react to a perceived temporary increase in output by increasing overtime rather than hiring new workers from the union queue. Finally, the simple probit suggests that minorities, residents of metropolitan areas, and residents outside of the South are more likely to belong to a union.

VII. Conclusion.

This paper examines how international factors influence individual union choice. We presented a model that distinguishes between the effects of trade shares and the factors which influence international competitiveness in the determination of union choice. Overall, we found that firm hiring

from the union queue is a more significant determinant of union status than a worker's decision to join the union queue. The probit results, in general, find that exports have a greater negative influence on union choice than imports. One explanation is that greater export shares result in more uncertainty about union employment which reduces the probability of union choice by workers and employers. Similarly, greater imports reduce the likelihood that employees join the union queue, which is also consistent with worker risk aversion. Although there were exceptions, the product market and strategic behavior hypotheses were less satisfactory in explaining union status.

The study also divided manufacturing based on comparative advantage into HT, CTL, CTK, and NR sectors. The typical HT worker appears more likely to belong to a union than the typical CTL and CTK worker. The differing sectoral effects in union status were found to be consistent with Heckscher-Ohlin trade theory and they are at least as important as the effect of trade shares. Thus, if we were to only consider trade shares, the influence of international trade on worker union status would have been understated. Overall, the results suggest that international trade may have damaged unionism, but increasing trade is not a death knell for the union movement. If unions can adjust to industrial restructuring by increasing their organizational efforts in the expanding HT sector, unions may well offset the losses they have experienced due to declines of the CTL and CTK sectors.

Table 1
Summary of Union Status Models

Panel A
Reduced Form Univariate Probit

Model	Imports' impact on union status	Exports' impact on union status
Product Market/Rent Sharing: Predicts that imports (exports) are positively (negatively) related to labor demand elasticity and negatively (positively) related to profits. Thus, imports (exports) are negatively (positively) related to the union wage gap.	(-)	(+)
Strategic Behavior (End Game): Predicts that unions tradeoff current wages with the probability of future employment. Greater imports (exports) increase (reduce) the union wage gap.	(+)	(-)
Risk Aversion/Uncertainty: Predicts that greater trade increases the uncertainty of union members (and management's uncertainty).	(-)	(-)

Panel B
Bivariate-Partial-Observability Probit
Probability of Joining the Union Queue

Model	Imports	Exports
Product Market/Rent Sharing: See above.	(-)	(+)
Strategic Behavior (End Game): See above.	(+)	(-)
Risk Aversion/Uncertainty: See above.	(-)	(-)

Panel C
Bivariate-Partial-Observability Probit
Probability of Being Hired From the Union Queue

Model	Imports	Exports
Product Market/Rent Sharing: Predicts that greater imports (exports) reduce (increase) profits and (likely) union wages. This reduces (increases) the quality of the applicant pool, *ceteris paribus*, which increases (reduces) firm resistance to hiring union workers.	(-)	(+)
Strategic Behavior (End Game): Predicts that greater imports in a declining industry result in greater wages. This increases firm resistance to hiring more union workers. Greater exports in an expanding industry result in lower wages. This reduces firm resistance to hiring union workers.	(-)	(+)
Risk Aversion/Uncertainty: Predicts that greater trade increases uncertainty about the future prospects of the industry. Risk averse behavior by management increases firm resistance to hiring union workers.	(-)	(-)

TABLE 2
SELECTED MEAN VALUES AND PROBIT ESTIMATES[a]

	(1) MEANS (STANDARD DEV)	(2) NON-QUEUE PROBIT MODEL	(3) ENTER UNION QUEUE PROBIT MODEL	(4) HIRED FROM UNION QUEUE PROBIT MODEL
EXPLANATORY VARIABLES:				
UNTEN78	33.6		1.18	
	(53.0)		(0.80)	
UNTENSQ78	3935.7		5E-02	
	(8079)		(0.01)	
NUNTEN78	39.2		7E-02	
	(52.1)		(0.72)	
NUNTENSQ78	4249.2		-5E-04	
	(104.8)		(0.77)	
EXP78	11.5		-0.22	
	(4.12)		(1.10)	
EXPSQ78	150.3		-6E-02	
	(8102)		(0.75)	
ED78	12.8		-0.02	
	(2.50)		(1.02)	
MAR78	0.78		5E-02	
	(0.60)		(0.02)	
MINOR78	0.26		0.05	
	(0.44)		(0.15)	
HEATH78	0.08		0.56	
	(0.27)		(1.35)	
UNEMP78	57.0		-5E-02	
	(32.6)		(1.17)	
SOUTH78	0.39		-5E-03	
	(0.49)		(0.02)	
SMSA78	0.68		0.35	
	(0.47)		(1.03)	
PART78	8E-02		-0.33	
	(0.09)		(0.25)	
PROF78	0.13		-0.05	
	(0.47)		(0.06)	
MANAG78	0.09		2E-02	
	(0.29)		(0.01)	
CLER78	0.06		-0.40	
	(0.24)		(0.54)	
SALES78	0.04		0.29	
	(0.21)		(0.26)	
CRAFT78	0.26		0.30	
	(0.44)		(0.51)	
OPER78	0.35		-0.02	
	(0.40)		(0.04)	
SERV78	8E-02		0.18	
	(0.09)		(0.13)	
DUR78	0.04		-0.31	
	(0.19)		(1.05)	
NOND78	0.14		-0.27	
	(0.34)		(0.55)	
STEEL78	0.07		0.39	
	(0.25)		(0.53)	
HT78	0.30		-0.03	
	(0.43)		(0.04)	
CTL78	0.19		-0.39	
	(0.37)		(0.75)	
CTK78	0.27		-0.29	
	(0.44)		(0.69)	
NR78	0.24			
	(0.40)			
CR4INT78	36.8		-0.02	
	(11.9)		(1.30)	
RCHS78	20.6		-0.02	
	(12.7)		(1.24)	
M78	0.08		-3.23	
	(0.06)		(1.11)	
X78	0.08		-4.89	
	(0.06)		(0.86)	
TEN80	88.3	9E-02		
	(59.6)	(2.97)		
TENSQ80	11338	-3E-04		
	(12370)	(2.05)		
EXP80	13.5	0.09		-0.08
	(4.14)	(0.95)		(0.23)

TABLE 2 CONTINUED
SELECTED MEAN VALUES AND PROBIT ESTIMATES

	(1) MEANS (STANDARD DEV)	(2) NON-QUEUE PROBIT MODEL	(3) ENTER UNION QUEUE PROBIT MODEL	(4) HIRED FROM UNION QUEUE PROBIT MODEL
EXPLANATORY VARIABLES:				
EXPSQ80	199.3	-4E-02		-3E-02
	(121.0)	(1.26)		(0.28)
ED80	12.8	-0.09		-0.30
	(2.51)	(2.56)		(2.60)
MAR80	0.77	0.03		0.02
	(0.42)	(0.24)		(0.06)
MINOR80	0.26	0.32		-0.20
	(0.44)	(2.24)		(0.61)
HEATH80	0.06	0.13		0.58
	(0.23)	(0.54)		(0.31)
UNEMP80	63.0	2E-02		6E-02
	(35.4)	(1.16)		(1.40)
SOUTH80	0.39	-0.59		-0.48
	(0.49)	(4.44)		(1.33)
SMSA80	0.68	0.35		-0.31
	(0.47)	(2.73)		(0.09)
PART80	2E-02	-4.23		-4.01
	(0.05)	(0.08)		(0.01)
PROF80	0.13	-1.85		-2.30
	(0.33)	(4.91)		(2.63)
MANAG80	0.11	-1.50		-1.81
	(0.31)	(4.18)		(1.87)
CLER80	0.07	-1.13		-1.12
	(0.25)	(3.22)		(1.37)
SALES80	0.03	-1.87		-2.99
	(0.16)	(2.89)		(0.67)
CRAFT80	0.25	-0.17		-0.53
	(0.43)	(0.61)		(0.71)
OPER80	0.37	0.05		-0.05
	(0.48)	(0.18)		(0.07)
SERV80	4E-02	-0.56		-0.39
	(0.06)	(0.63)		(0.05)
DUR80	0.04	-1.10		-0.72
	(0.19)	(3.19)		(0.80)
NOND80	0.14	-0.07		0.32
	(0.34)	(0.36)		(0.50)
STEEL80	0.07	0.47		0.19
	(0.25)	(1.81)		(0.39)
HT80	0.30	0.17		0.98
	(0.43)	(0.69)		(1.11)
CTL80	0.19	-0.04		-0.12
	(0.37)	(0.21)		(0.21)
CTK80	0.27	-0.62		-1.03
	(0.44)	(3.17)		(2.10)
NR80	0.24			
	(0.40)			
CR4INT80	36.4	-5E-02		-8E-02
	(12.4)	(0.59)		(0.48)
RCHS80	2.0	-0.01		-0.23
	(14.3)	(1.87)		(1.34)
M80	0.08	0.20		4.04
	(0.08)	(0.17)		(1.05)
X80	0.09	-2.84		-5.29
	(0.07)	(1.98)		(1.12)
DEPENDENT VARIABLE:				
U80	0.41			
	(0.49)			
N	734			
Log-Likelihood		-346.7	-204.1	-204.1
Likelihood ratio tests:[b]				
1. X=M = 0		α=.1281 ($\chi^2_{(2)}$=4.11)	α=.0001 ($\chi^2_{(2)}$=199.9)	α=.0001 ($\chi^2_{(2)}$=204.8)
2. HT=CTK=CTL = 0		α=.0046 ($\chi^2_{(3)}$=13.04)	α=.0001 ($\chi^2_{(3)}$=203.2)	α=.0001 ($\chi^2_{(3)}$=197.8)

[a]Standard deviations and the absolute values of the t-statistics are in parentheses. The other variables in the specification are described in the text.

[b]The joint null hypothesis for the X=M = 0 or HT=CTK=CTL = 0 restriction can be rejected at the α observed significance level.

TABLE 3
THE IMPACT OF TRADE AND TECHNOLOGY ON THE PROBABILITY OF UNION COVERAGE

Panel 1

THE IMPACT OF A ONE STANDARD DEVIATION CHANGE IN THE EXPORT AND IMPORT SHARE ON THE PROBABILITY OF BEING IN A UNION

	EXPORTS Mean = 9.3% 1 std. dev. = 7.3%	IMPORTS Mean = 8.3% 1 std. dev. = 7.7%
NON-QUEUE PROBIT MODEL:[a]	-10.2%	0.6%
ENTERING UNION QUEUE MODEL:[b]	-8.7%	-5.1%
HIRED FROM UNION QUEUE MODEL:[c]	-2.0%	1.4%

Panel 2

THE IMPACT OF THE HT, CTL, AND CTK SECTORS COMPARED TO THE NR SECTOR[d]

	HT	CTL	CTK
NON-QUEUE PROBIT MODEL:	6.7%	-1.7%	-23.8%
ENTERING UNION QUEUE MODEL:	-0.6%	-7.5%	-5.6%
HIRED FROM UNION QUEUE MODEL:	4.1%	-0.5%	-4.2%

[a]The estimates are based on the coefficients in Table 2. The estimated impact of a one standard deviation change in the export share is measured by using the derivative of X. The estimated impact of a one standard deviation change in the import share is measured by using the derivative of M. The normal probability density function is evaluated at the sample mean union probability of 0.394. The pattern would be the same if the normal probability density function was instead evaluated at the mean for all of the variables.

[b]The entering union queue estimates are calculated in a manner similar to Abowd and Farber (1982). The estimates reflect measurements at zero tenure. This is done to offset the dominance of the tenure variables on the union choice decision. This adjustment only affects the magnitude of the estimates.

[c]The hired from union queue estimates are calculated in a manner similar to Abowd and Farber (1982).

[d]The estimates show how much each sector's probability of being union varies from the NR sector's probability (the omitted category).

NOTES.

1. Belman emphasized the influence of product market concentration on the union wage gap where he only controlled for the import share. Martinello and Meng, on the other hand, only considered Canadian data making it unclear how their results generalize to the United States. For example, one striking difference between Canada and the United States is Canadian labor law is decidedly more pro-union.

2. The exact opposite issue is whether unionization, in turn, influences export and import shares. However, Karier (1991) finds no evidence that union wages or coverage effect trade share levels.

3. Lee (1978) and Hirsch and Berger (1984) find a positive relationship between union choice and the union wage gap. Assuming workers have freedom over job choice, a union choice model is useful because unionization is one job characteristic which workers consider when deciding whether to accept a job (Hirsch and Berger, 1984). Union status can also change due to quits and certification and decertification drives. Hundley (1989) also discusses the effect of job attributes and occupation.

4. These studies generally find that four-firm concentration is positively related to individual union choice. Industry level data yield mixed results (e.g., Hirsch, 1982; Kahn, 1979).

5. Lawrence and Lawrence suggest that the steel and auto industries of the late 1970s and early 1980s are good examples of end game behavior by unions.

6. In the case of *union wages*, Partridge (1993) and Macpherson and Stewart (1990) find evidence consistent with product market effects offsetting strategic behavior effects. Lawrence and Slaughter (1993) summarize the literature regarding trade's impact on wages.

7. The classification directly follows from Partridge (1993), Arndt and Bouton (1987), and Lawrence (1984).

8. One reason for the CTL/CTK division is the Heckscher-Ohlin emphasis on the capital-labor ratio.

9. The HT/CTL-CTK union choice relationship should hold *after* controlling for the individual characteristics of the labor force. For example, HT (CTL, CTK) workers are more (less) educated on average and education is negatively related to union status.

10. Abowd and Farber provide more details of the interpretation of the coefficients and the interpretation of the model given that many union employees have job rights to their positions.

11. Let S, X, and M equal domestic output, exports, and imports. Then CR4INT equals: $CR4INT = CR4 \cdot ((S-X)/(S+M-X))$. Industry output is derived from U.S. Bureau of the Census (a and b) and industry CR4 is from U.S. Bureau of the Census (b) and Weiss and Pascoe (1986).

12. The standard probit model places 28 restrictions on the union queue model. As shown in Table 2, the negative of the log likelihood ratio for the standard probit is 346.7, and for the union queue model it is 204.1. This gives a likelihood ratio statistic of 285.2 with 28 degrees of freedom, which suggests that the restrictions are significant at the 0.001% level.

13. There are two offsetting considerations when using aggregate industry level data in a micro data set. First, Greenberg *et al* (1989) argue that data stretching of this type leads to an errors-in-variables problem which leads to parameter estimates that are biased towards zero. Since the estimates are smaller than the true parameter values, the results should be interpreted as a lower bound estimate. Second, Moulton (1990) shows that if the random disturbances within variable groups are correlated, then the standard

errors are downward biased and the t-statistics are inflated.

14. The t-statistics for the individual trade variable coefficients may also give a misleading indication of their statistical significance due to a high correlation between imports and exports that result from a high degree of *intra*-industry trade.

15. Previous reduced form probit results have found imports to be negatively related to union status (Belman, 1988; Martinello and Meng, 1992). However, these studies did not consider exports.

16. Traditional Heckscher-Ohlin trade theory suggests that trade's effect depends on the factor intensity of the sector (e.g., high skilled versus less skilled labor), not the import or export share of the sector.

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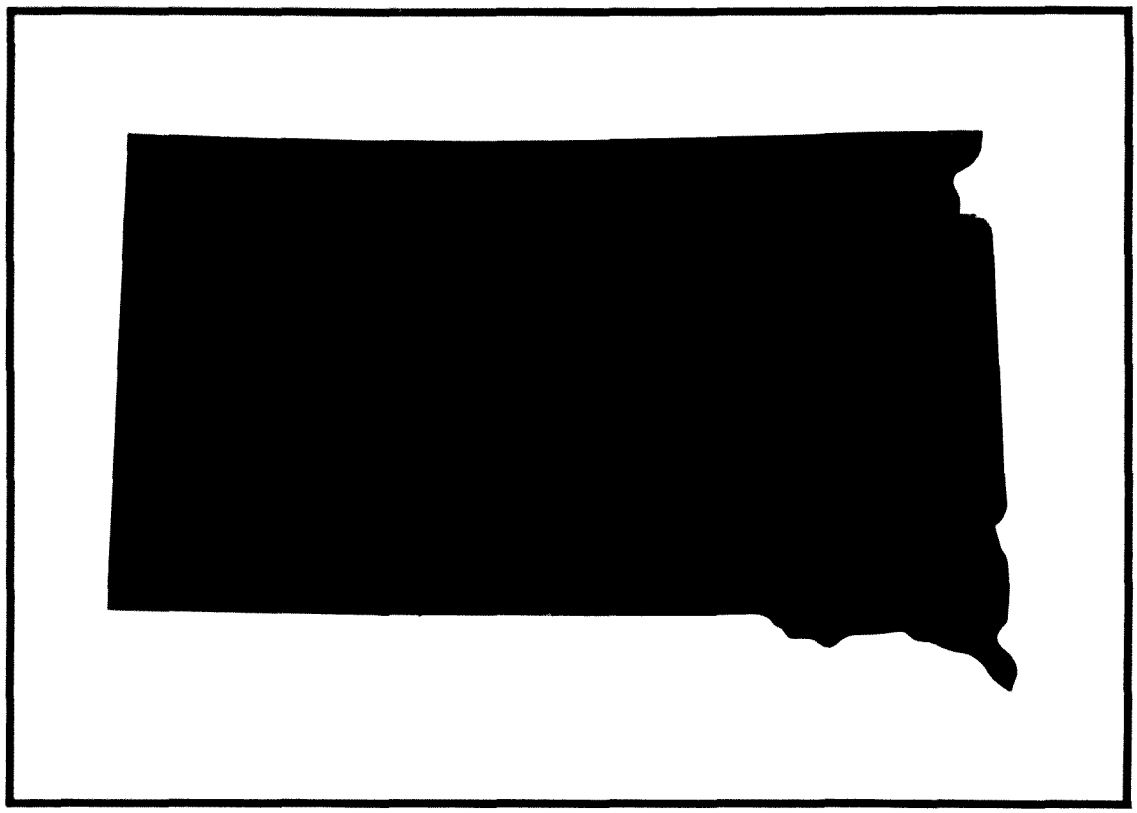

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UNCERTAINTY OVER THE QUALITY OF LABOR INPUTS: A NONMONOPOLY THEORY OF UNION WAGES AND HOURS WORKED

by

Dwight W. Adamson*
and
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Uncertainty over the Quality of Labor Inputs: A Nonmonopoly Theory of Union Wages and Hours Worked

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Uncertainty over the Quality of Labor Inputs: A Nonmonopoly Theory of Union Wages and Hours Worked

ABSTRACT

Traditional theoretical explanations of union wage effects rely on a monopoly theory of wage determination. Using union monopoly power to set wages implies that unions face a tradeoff between higher wages and lower union sector employment. Earle and Pencavel (1990) find a positive union effect (relative to the nonunion sector) on wages and hours of work. Their empirical result appears to be inconsistent with the theoretical implications of union monopoly power. If unions are able to force unionized firms off their labor demand curve to the point where both wages and hours worked increase, then in a competitive environment, nonunion firms would displace union firms in the long-run. This paper presents a theoretical competitive model that is consistent with positive union wage and hours worked effects. The model investigates firms short-run behavior under uncertainty about the quality of labor services. The model assumes that union labor services are known with certainty (based on the observed lower turnover rate in the union sector) and nonunion labor services are assumed to be uncertain. The theoretical results show that output declines under uncertainty. The decline in output is the result of the marginal productivity of nonunion workers being reduced by the presence of uncertainty. The model predicts that wages and hours worked will be greater for union workers relative to nonunion workers. As firm risk aversion increases, the model predicts that the union wage and hours worked effect will be larger than in the risk-neutral case. Finally, as uncertainty about nonunion services declines, the model shows that nonunion wages and hours worked converge to union wages and hours worked.

Uncertainty over the Quality of Labor Inputs: A Nonmonopoly Theory of Union Wages and Hours Worked

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I. Introduction

While union wage effects have been studied extensively, union effects on employment and hours worked have received little attention. The basic underlying assumption is that if unions have sufficient power to increase wages via monopoly control of the labor market, then, given a downward sloping labor demand curve, union sector employment should fall. However, a recent study by Earle and Pencavel (1990) finds a positive association between unions and annual hours and weeks worked.[1] Moreover, they find that the increase in hours worked is positively correlated with the size of the union wage differential (i.e., the larger the union wage effect, the greater the difference between union and nonunion hours worked). In combination with a positive wage effect, the positive employment effect in hours worked per worker suggests that either unionization actually increases the efficiency of the firm (i.e., the labor demand shifts out) or union bargaining power is strong enough to force unionized firms off their demand curve. Earle and Pencavel conclude that these findings merit further research. This paper addresses this issue by developing a theoretical model of labor demand under uncertainty.

II. Monopoly Union Effects

The prevailing models of union effects on wages and employment are based on the theoretical

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[1]The above association reflects cross-sectional estimates. Earle and Pencavel report a long-run finding of a negative relationship between unions and annual hours worked over time. This is consistent with Blanchflower *et al* (1991) who show that union sector firms have a lower employment growth than nonunion sector firms by about 2% to 4% per year. Also, Brannon and Craig (1994) find that union firms respond to output fluctuation by varying hours of work or wages rather than employment (in response to the higher benefits and thus fixed costs of union workers). The time series studies, however, are unable to control for all variables that influence long-run employment effects.

premise of union monopoly power. Demand models argue that unions set wages and fringe benefits at an optimal level and that management exercises control over the level of labor employment.[2] The efficient contract model of McDonald and Solow (1981) argues that unions and management have joint control over the determination of wages, hours of work, and number of workers employed along a pareto-optimal contract curve. Both the demand and efficient contract models imply a trade-off between a union wage differential and annual hours of work, and are theoretically inconsistent with Earle and Pencavel's finding of greater union wage and employment effects relative to similar nonunion firms.

The recursive or semi-efficient bargaining model by Johnson (1990) argues that powerful unions may in fact push union firms far enough off their labor demand curves to increase both wages and hours worked.[3] This model is theoretically consistent with Earle and Pencavel. However, such aggressive union bargaining behavior could induce capital substitution and intensify the threat of union busting. This model is not consistent with the long-run existence of a viable union sector.[4] The observed decline in the union sector employment during the 1980s while the union wage gap was near 30% may reflect the semi-efficient bargaining and potential end game effects.[5]

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[2]For example, Dunlop (1944) hypothesizes that unions set wages to maximize the wage bill.

[3]Unions essentially bargain over the capital-labor ratio using restrictive work practices or featherbedding.

[4]Navarro (1983) argues that aggressive union bargaining and featherbedding is partially responsible for the decline of the union sector in the coal industry. Other examples may include the railroads' and longshoremen's unions.

[5]Lawrence and Lawrence (1985) suggest that unions may trade off future jobs for higher current wages and employment in declining industries since they have limited opportunities to invest in new capital. Linneman *et al* (1990) show that the union wage differential rose during the 1980s while the union participation rate declined. Dickens and Leonard (1985), however, show that much of the decline in union participation from the 1960s to the 1980s was primarily due to shift in production from manufacturing to service sector and the changes in labor-force demographics, rather than semi-efficient bargaining practices.

Farber (1990) provides evidence that the rate of decline in union coverage was greatest in the heavily unionized industries (hence, shifts in the industrial structure are not the primary cause of the decline in the proportion of union employment). Farber's empirical results indicate that increased firm resistance has largely accounted for the decline in the percentage of union coverage. One plausible explanation is that increasing international trade shares has increased product market competitiveness and resulted in more aggressive firm resistance. (Firms cannot be perfectly competitive and share economic rents with unions; otherwise, the higher union wage levels would make these firms unprofitable and drive them out of business). Farber also finds that demand for unions declined in the 1970s and 1980s. If the change in workers' preferences are related to fears of job loss, then the decline in union coverage is also related to union monopoly power.

So has the semi-efficient bargaining model reconciled the finding of Earle and Pencavel? Not necessarily. Rather than competitive pressure, much of the decline in union coverage may be due to aggressive firm resistance related to drastic changes in the political environment of the 1980s (Freeman and Kleiner, 1990; Linneman *et al*, 1990). Moreover, unions are currently experiencing a resurgence. Total membership numbers have increased in 1993, and the proportion of unionized workers has remained at 15.8%, ending the declining trend that began in the 1960s. Recently, managers have been lauding a new era of cooperativeness where unions have helped improve productivity by endorsing new technology and innovative production systems such as self-managed work-place teams (*Business Week*, May 23, 1994). This evidence suggests that unions may act to increase firm productivity by increasing the efficiency by which raw labor units are converted into effective labor inputs in the production process. The efficiency argument may help explain why union firms have not been completely displaced by nonunion firms over the long-run.

II. Nonmonopoly Union Effects

Empirical evidence has established that union sector workers have a lower voluntary turnover rate than nonunion workers.[6] The lower probability of quits is attributed to the union voice versus nonunion exit tradeoff. Unions establish and enforce rules on grievance procedures, promotion, unsafe work conditions, and so forth, and provide a system of industrial jurisprudence through which workers voice their industrial relations problems. Nonunion workers, having no means (or power) to voice their labor-management disputes, must utilize a market response system and exit the firm.

Lower turnover rates in union firms suggests two efficiency implications. First, union workers should have higher firm-specific skills on average, since a lower quit rate reduces hiring and training of replacements. Hence, union firms should have greater labor productivity. Studies support a positive effect of unions on productivity, but the effect is small at best and insufficient to offset the larger union wage rates.[7] Second, lower turnover in union firms should reduce the variance of firm-specific training below that of nonunion firms, which suggest greater certainty about the quality of labor inputs. Nonunion firms, conversely, must hire and train more new workers; at any given point, there is a greater uncertainty of the quality of effective nonunion labor inputs in production. If there is greater certainty over work force quality, then there will be a decrease in the variability of worker productivity, which in turn will increase productive efficiency and labor demand. We contend that these theoretical arguments are consistent with Earle and Pencavel's finding of positive union effects

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[6]To the degree that the quit rate is lower due to higher union wages, the lower union turnover rate would be associated with monopoly union effects. Freeman (1980) controls for wages and other differences between union and nonunion workers and finds that the probability of union worker quits are about 3% lower.

[7]Brown and Medoff (1978) found a large union productivity effect, but Addison and Hirsch (1989) find evidence of small if any effect at all. A small positive effect is found by Clark (1980) in the cement industry, which Clark attributes to more professional management. Boal (1990) also finds a positive effect in large, labor-intensive coal companies (small ones actually have a negative effect) which is attributed to a reduction in labor turnover.

on wages and hours worked.[8]

Additionally, unions may increase contract efficiency because workers have greater assurance of receiving fair compensation under the explicit rules of a collective bargaining agreement. Thus, unions may act to decrease uncertainty by decreasing asymmetric information about workers' true productive capabilities and transaction costs associated with introducing new production technologies (like self-managed work teams). The issue of reduced quality uncertainty in a unionized work force has not been addressed by the literature. We propose a short-run production model with labor input uncertainty.

III. Assumptions and the Model

The analysis assumes a short-run time frame for the firm. The firm operates in a competitive setting in both the output and factor markets. All inputs are assumed to be fixed except labor, L. Define L to be the quantity of labor acquired for current use, and L_l to be the quantity of labor service actually supplied. It is assumed that L is a decision variable for the firm and that L_l is a random variable. This assumption is based on arguments presented by Ratti and Ullah (1976), and Walter's (1960, p.325) lucid exposition of why labor supplied is a random variable: " ...although the number of workers on the payroll is fixed, the flow of labor services does not stay at one value. It varies from day to day according to weather, sickness, whim, and other accidental influences."

We are interested in the differences in the flow of labor services of union and nonunion labor. We shall assume that Walter's "accidental influences" are identical for both types of labor. However, we argue that the variability in the flow of labor services is higher for nonunion workers due to higher turnover rates, less efficiency in contracting, *et cetera*. Under this assumption, ceteris paribus,

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[8]The exact magnitude of this argument remains an empirical issue and may not be sufficient to offset the observed union wage differential alone. However, a combination of both union labor unit certainty and productivity may be sufficient to give a positive wage and hours worked effect.

the flow of labor services from union labor is assumed, for simplicity, to be known with certainty.

In the short-run, the firm can acquire its labor L from two separate markets for labor inputs: 1) union; and 2) nonunion. The union market for labor is assumed to be the full information market for labor. That is, the flow of factor services from union labor is therefore known with certainty. Union labor is defined as L, actual labor hours. The nonunion labor market is assumed to be the incomplete information market. That is, there is uncertainty about the flow of factor services from nonunion labor. The flow of labor services provided by the nonunion market is defined as L_l, realized labor hours.

Following the modeling procedure developed by Ratti and Ullah, L and L_l are linked in the following way:

$$L_l = vL, \tag{1}$$

where v is a strictly positive random variable with the variable's density function defined as $f(v)$ with a unit mean.[9] The firm's short-run production function when it hires labor in the nonunion market is defined as

$$Q = h(L_l) = h(vL),\ h'(L_l) > 0,\ h''(L_l) < 0 \tag{2}$$

a random variable. The third derivative of the production function is assumed to exist, and the marginal product of the input is positive but declining.

Beginning with firm behavior under certainty with respect to the flow of labor services, it is assumed the firm's goal is to maximize profits (Π). The output price of final goods and the input price of labor services and the fixed cost of production are defined respectively as p, w, and C. The firm's profit function is defined as:

$$\Pi = p \cdot h(L) - w \cdot L - C. \tag{3}$$

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[9] In the following analysis, the model developed in this paper is a modified version of the model developed by Ratti and Ullah (1976). Ratti and Ullah give credit to Walters (1960), and Roodman (1972) for the method of specification of the input variables.

The first order condition for profit maximization is:

$$d\Pi/dL = p \cdot h' - w = 0. \tag{4}$$

The second order condition for profit maximization is:

$$d^2\Pi/dL^2 = p \cdot h'' < 0. \tag{5}$$

Rearranging the equation 4, the following equilibrium condition is arrived at:

$$p \cdot h' = w \text{ or } p = w/h'. \tag{6}$$

Equilibrium condition (6) is the standard result. The firm will pay the labor input its marginal value product (*MVP*), i.e., its marginal contribution to the production of output.

If the firm hires labor from the nonunion market, then there is uncertainty over flow of factor services from nonunion labor. Profits are now defined in terms of utility. Assuming that the firm's utility function conforms to characteristics of a von Neumann-Morgenstern utility function and its third derivative exists, the firm's expected utility from profits can be written as:

$$E[U(\Pi)] = E[U(p \cdot h(L_l) - w \cdot L - C)]. \tag{7}$$

It is assumed that the marginal utility of profit is positive $U'(\Pi) > 0$, and the value of $U''(\Pi)$ being negative if the firm is risk averse, 0 if the firm is risk neutral, and positive if the firm is risk preferring.

The first order condition for maximizing expected utility of profits is:

$$dE[U(\Pi)]/dL = E[U'(\Pi) \cdot (p \cdot v \cdot h'(L_l) - w)] = 0. \tag{8}$$

The second order condition is:

$$d^2E[U(\Pi)]/dL^2 = E[U''(\Pi) \cdot (p \cdot v \cdot h'(L_l) - w)^2 + p \cdot v^2 \cdot h''(L_l) \cdot U'(\Pi)] < 0. \tag{9}$$

IV. The Effect of Uncertainty on Firm Behavior

The first question to be addressed in this section is; "how does uncertainty over the flow of

labor services affect that firm's level of production as compared to the certainty case?" The certainty case is when the firm hires union labor. The uncertainty case is when the firm hires nonunion labor. This question leads to the first proposition:

PROPOSITION I: *The firm's expected output when employing nonunion labor, ceteris paribus, is less than the firm's output when employing union labor.*

To establish the above proposition, Jensen's inequality and the definition of expected value are applied to the firm's production function, $f(L_1)$. Certainty in this situation means to replace (L_1) with its expected value, L. Then by the Jensen Inequality,

$$E[f(L_1)] < f(L), \tag{10}$$

and proposition one is established.[10] Thus, the implication of the introduction of production uncertainty into the firm's production function is that the mere presence of uncertainty, ceteris paribus, reduces the firms output as compared to a world of certainty for a given fixed level of labor. Consequently, the model implies that the *MPP* of L_1 in an uncertain environment is less than the *MPP* of L_1 if production had taken place at the expected value of the random variable, L_1 (i.e., L or the certainty environment).

The second issue to be discussed is how does input quality uncertainty in conjunction with the firm's attitude toward risk affect the wage paid to labor by the firm. The analysis begins with rewriting equation (8) in the following manner:

$$E[U'(\Pi) \cdot (p \cdot v \cdot h'(L_1))] = E[U'(\Pi)] \cdot w. \tag{11}$$

Adopting Horowitz's (1970) alternative expression of equation (11),

$$p \cdot E[v \cdot h'(L_1)] = w - \{p \cdot \mathrm{Cov}(U', v \cdot h') / E[U'(\Pi)]\}. \tag{12}$$

From equations (11) and (12), the *MPP* and *MVP* of nonunion labor are now random

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[10] The Jensen inequality states that if a function is concave the following is true: $E[h(X)] < h[E(X)]$. See Rao (1973), page 58 for an explanation of Jensen's inequality. Ratti and Ullah employed Jensen's inequality in a similar fashion.

variables given by $v \cdot h'$ and $p \cdot v \cdot h'$ respectively. Examining the covariance term in equation (12), it is clear that when $U''(\Pi) = 0$, the covariance term is also equal to zero. The implication of equation (12) is that the risk neutral firm hiring labor from the nonunion labor market sets wages equal to $w = E[MVP]$. As in the paper by Ratti and Ullah, when $U''(\Pi) \neq 0$, the sign of the covariance term can not be ascertained. Furthermore, Ratti and Ullah demonstrate that given the assumption that the input elasticity of the marginal product curve has an absolute value of less than one, then *sign Cov* = *sign* $U''(\Pi)$:

$$\mathcal{E} = dh'(L_1)/dL_1 \cdot L_1/h'(L_1) = L_1 \cdot h''(L_1)/h'(L_1) > -1. \tag{13}$$

If equation (13) is true, then examining the derivatives of the two components of the covariance term with respect to v,

$$d[v \cdot h'(L_1)]/dv = h'(L_1) \cdot [1 + \mathcal{E}] > 0, \tag{14}$$

and

$$dU'(\Pi)/dv = U''(\Pi) \cdot p \cdot L \cdot h'(L_1), \tag{15}$$

verifies that *sign Cov* = *sign* $U''(\Pi)$. That is, since the sign of equation (15) is dependent on $U''(\Pi)$, and equation (14) is positive, *sign Cov* must equal *sign* $U''(\Pi)$.

Applying this result to equation (12), the following condition is arrived at

$$p \cdot E[v \cdot h'(L_1)] \gtreqless w, \tag{16}$$

depending on whether $U''(\Pi) \lesseqgtr 0$.

Following Ratti and Ullah's interpretation of these results, at the margin: 1) the risk-neutral firm will hire nonunion labor at a wage equal to its $E[MVP]$; 2) the risk-averse firm will hire nonunion labor at a wage less than its $E[MVP]$; and 3) the risk-preferring firm will hire nonunion labor at a wage greater than its $E[MVP]$. The implications of these results are that a firm's input

demand for nonunion labor is dependent on its attitude toward risk.[11]

V. Labor Separation and Wage Differentials

In this section the analysis will begin with the assumption that the firm is risk neutral. As stated above, the supply of labor is segregated into two markets, union and nonunion, and the firm decides from which market it will hire labor. This market structure implies that there are actually two distinct labor market facing the firm.[12] Thus, across the industry, some proportion of all firms will hire from the union labor market and the remaining firms will hire from the nonunion labor market. All firms will maximize profit by setting $MVP=MC$. Rearranging equations (6) and (12),

$$p = w/h', \tag{17}$$

and

$$p = [w - \{p \cdot \mathrm{Cov}(U', v \cdot h')/E[U'(\Pi)]\}] \; / \; E[v \cdot h'(L_I)]. \tag{18}$$

To simplify the analysis, replace w in equation (18) with w^*. Given that output price p is the same regardless of the input market the firm purchases in, the following equilibrium condition is derived from equations (17) and (18),

$$w/h' = [w^* - \{p \cdot \mathrm{Cov}(U', v \cdot h')/E[U'(\Pi)]\}] \; / \; E[v \cdot h'(L_I)]. \tag{19}$$

Equation (19) leads to the second proposition in the paper:

PROPOSITION II. *Risk neutral firms purchasing inputs from one of two (worker separated) distinct markets, where the two groups supply equal labor hours and differ only in the amount of information available on the flow of labor services, will purchase those inputs from the group with uncertainty about quality (flow of labor services) at a lower wage than from the group whose quality is known with prefect information.*

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[11] These results concur with the results derived in the paper by Ratti and Ullah (1976).

[12] This assumption implies that firms are constrained to hiring from either the union or nonunion labor market. In reality, union coverage is determined by workers' demand for union coverage relative to a firms resistance or cost of unionization. Thus, firms are union or nonunion by a union certification (or decertification) process which management typically opposes. This assumption is not critical as long as the union coverage rate is in equilibrium in the short-run (which seems to be reasonable).

To establish proposition II, it is assumed that the third derivative of the production function is negative. This implies that the marginal product function $h'(L_1)$ is itself a concave function. This assumption is consistent with equation (13) and implies that $d\pi/dL_1 < 0$. The implication of $h'''(L_1) < 0$ is that the *MPP* of L_1 is a non-increasing function of L_1.[13] Under the assumption that $h'''(L_1) < 0$, and employing Jensen's inequality the following result is attained:

$$E[h'(vL)] < h'(L). \tag{20}$$

Equation (20) implies that the risk-neutral firm's expected *MPP* generated by L_1 is less than the *MPP* that would be achieved under conditions of certainty given the same factor combination. Certainty implies a situation where the random variable v is replaced by its expected value. Due to the greater *MPP* in the union sector, the union firm's labor demand curve is always greater than the nonunion firm's. Thus, the result derived in equation (20) and (19) implies that w must be greater than w^* for a risk-neutral firm facing a fixed level of labor input. Thus, proposition II is established.

Proposition II demonstrates that when an industry of perfectly competitive firms faces a competitive but segregated labor market structure where the two distinct factor markets vary only in the information available on quality, the result will be a *market* wage differential between union and nonunion labor. That is, all workers are paid their expected marginal value product. Consequently, union and nonunion workers receive unequal wage rates due to the uncertainty associated with the quality of nonunion labor. This proposition presents an interesting and plausible explanation for union wage differentials in the labor market without unions having market power.

If it is assumed that the firm is risk-averse, then equation (19) demonstrates that the degree of wage differentials will increase. This last statement leads to the third proposition of the paper:

PROPOSITION III. *The size of union wage differentials will vary positively with the degree of firm risk aversion.*

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[13]Ratti and Ullah (1976) note that this assumption is consistent with many of the common forms of production functions used in the economics profession.

To established proposition III, proposition II is reasserted. Proposition II established that w is greater than w^* for the risk-neutral firm. Then by equations (16 & 19), w^* must be greater than say any w^{**}, the price that a risk-averse firm would pay for nonunion labor. Thus, proposition III is established.

VI. Comparative Statics: An Decrease in Uncertainty over the Flow of Nonunion Labor Services

In this section, the effect of a change in the amount of information available to the firm on the quality of labor services coming from the nonunion labor market is examined. A change in the amount of information available implies a change in the amount of uncertainty associated with nonunion labor. For example, the nonunion turnover rate in a specific industry converges to the union rate. To capture this effect of a marginal change in uncertainty, the distribution of v will undergo a mean preserving change in the dispersion of the distribution. The results developed below are only determinant in the risk-neutral case. A modification of equation (8) is now undertaken by replacing v with $v^*=(\alpha \cdot v + \beta)$, where α is a shift parameter and β is a function of α with the following properties:

1) $\beta' = -E[v] = -1$, and 2) $\beta(\alpha=1) = 0$. This transformation implies that $L_1 = (\alpha \cdot v + \beta) \cdot L$. Assuming the firm is risk neutral, equation (8) is now:

$$dE[\Pi]/dL = E[p \cdot v^* \cdot h'(L_1) - w] = 0. \tag{21}$$

Replacing v^* with $(\alpha \cdot v + \beta)$, and renaming equation (21) $E[Z]$,

$$E[Z] = E[p \cdot (\alpha \cdot v + \beta) \cdot h'(L_1) - w] = 0, \tag{22}$$

the comparative static analysis can begin. Invoking the implicit function theorem around the equilibrium value of L and $\alpha=1$, then taking the total differential of $E[Z]$ and setting all of the differentials to zero except dL and $d\alpha$, the partial derivative $\partial L/\partial \alpha$ is:

$$\partial L/\partial \alpha = -E[\{p \cdot (v-1) \cdot h'(L_1) \cdot (1 + \mathcal{E})\} / \{p \cdot v^{*2} \cdot h''(L_1)\}]. \tag{23}$$

The sign of the partial derivative derived above can be determined by examining the following

relationship:

$$p \cdot E[(v\text{-}1) \cdot h'(L_1) \cdot (1 + \varepsilon)] = \mathrm{Cov}((v\text{-}1),\ h'(L_1) \cdot (1 + \varepsilon)). \tag{24}$$

By ascertaining the sign of $\mathrm{Cov}((v\text{-}1),\ h'(L_1) \cdot (1 + \varepsilon))$, the sign of the numerator of equation (24) can be determined. Examining the derivatives of the two components of the covariance term with respect to v,

$$d[h'(L_1) \cdot (1+\varepsilon)]/dv < 0, \tag{25}$$

and

$$d(v\text{-}1)/dv = 1 > 0, \tag{26}$$

verifies that the sign of the covariance is negative and thus the sign of the partial derivative $\partial L/\partial \alpha < 0$.

The above result leads to the last proposition of the paper:

PROPOSITION IV: *As uncertainty over the flow of labor services for nonunion labor decreases, the magnitude of the union wage differential in the industry declines.*

To establish the above proposition the implications of $\partial X/\partial \alpha$ are analyzed. The negative sign indicates that as quality uncertainty decreases, demand for L via the nonunion market increases. The implication is that for a fixed level of L_1 a decrease in uncertainty increases the expected *MPP* of L_1. This means that $E[v \cdot h'(L_1)] < E[v^* \cdot h'(L_1)]$ when $\alpha < 1$. Examining this result in the context of equation (19), we can verify that an increase in the expected *MPP* of L hired via the nonunion market will increase w^* relative to w. Thus, the degree of the union wage differential declines as uncertainty declines and proposition IV is established.

VII. Wage and Labor Unit Effects

In this section we will discuss the effect of uncertainty over the flow of labor services on firm employment practices. Proposition I established that for a given level of labor input, the firm's

output will be greater with union labor than for nonunion labor. This result is shown in figure 1a, a graphical representation of equation (10). The graphical analysis demonstrates that the introduction of uncertainty reduces output from Q^c to Q^u. Proposition II demonstrates that the marginal product of nonunion labor is less than the marginal product of union labor. This result is shown in Figure 1b. The graphical analysis shows that the introduction of uncertainty with a fixed level of labor input (L) reduces wages from w to w^*. If we assume an upward sloping market labor supply, w^* is not an equilibrium wage. To restore the equilibrium, the market wage for nonunion labor must rise to w^u_{r-a}, which reduces hours worked in the nonunion sector to L^u_{r-a}. The implication is that in the union sector, the relative effects are higher wages and hours worked. Thus, proposition II supports Earle and Pencavel's finding of a positive association between unionization and wages and hours worked.

Proposition III demonstrates that for a risk-averse firm, the nonunion wage, w^{**}, given a fixed level of labor input, is even lower than the nonunion wage, w^*, for the risk neutral case. In Figure 1b, this effect is represented by the labor demand curve, MVP^u_{r-a}, which is farther to the left of the risk-neutral labor demand curve, MVP^u_{r-n}. Proposition III implies that the union wage differential and the hours worked vary positively with the level of firm risk aversion. Proposition III supports Earle and Pencavel's finding of a greater union effect on hours worked as the union wage effect increases (i.e., the more risk averse the firm the greater will be hours worked *and* wages). Hirsch and Morgan (1994) find evidence that union firms have a lower systematic risk component in their rate of return. This implies that risk-adverse firms (which is consistent lower beta values) may actually view union labor agreements as a management strategy to reduce risk exposure.

Finally, Proposition IV demonstrates that the nonunion wage converges to the union wage as the uncertainty over the flow of labor services declines. In Figure 1b, this effect would be shown by a rightward shift in the risk neutral labor demand curve, MVP^u_{r-n}, toward the union labor demand curve, MVP^c.

VIII. Conclusion

This paper deals with the issue of labor quality uncertainty in a short-run production function. The theoretical results derived in this paper are consistent with Earle and Pencavel (1990), who find a positive union effect on both wages and hours of employment. This paper makes a contribution by merging the literature on competitive firm behavior under uncertainty with the literature on labor union effects.

Proposition I demonstrates that the mere introduction of uncertainty over the flow of labor services will reduce firm output, as compared to firm output in a world of certainty about a fixed level of labor input.

Proposition II shows that for the risk neutral firm, the introduction of uncertainty over the flow of labor services reduces the marginal productivity of the nonunion labor unit relative to the union labor unit (or the certainty case). Consequently, given a fixed labor unit, the wage received by nonunion workers will be less than the wage received by union workers. At a market equilibrium, this implies a positive union wage differential and greater hours worked in the union sector.

Proposition III shows that the union wage differential and union hours worked will vary positively with the degree of firm risk aversion, suggesting that the more risk-averse firms become, the greater will be the union wage differential and the union effect on hours worked.

Finally, Proposition IV finds that as the uncertainty between union and nonunion labor quality declines, the union wage and hours worked differential will decline. Thus, with the elimination of uncertainty, the wage and hours worked will be identical for both union and nonunion labor services.

This paper only presents the theoretical results of a short-run determination of the union wage differential and hours worked. A further extension of the theoretical issues addressed by this study will be pursued in an empirical analysis of the hypotheses in propositions one through four.

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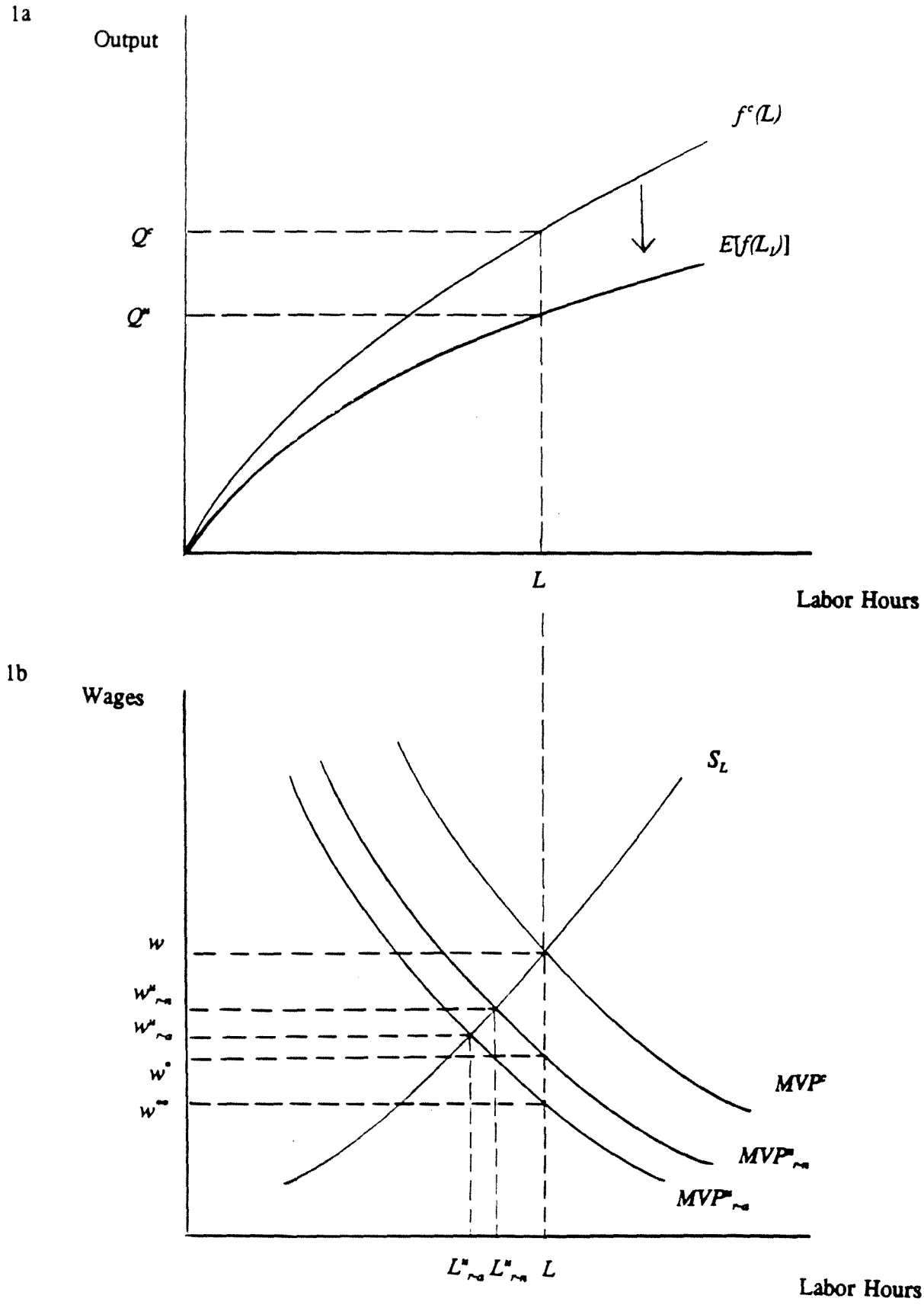
FIGURE 1.


1a
Output
$f^c(L)$
Q^c
$E[f(L_i)]$
Q^*
L
Labor Hours
1b
Wages
S_L
w
$w^*_{\sim a}$
$w^*_{\sim a}$
w^c
w^{**}
MVP^c
$MVP^*_{\sim a}$
$MVP^*_{\sim a}$
$L^*_{\sim a}$ $L^*_{\sim a}$ L
Labor Hours

UNCERTAINTY OVER THE QUALITY OF LABOR INPUTS: A NON-MONOPOLY THEORY OF UNION WAGES AND HOURS WORKED

MATHEMATICAL APPENDIX

$$EQ.\ 8: \quad \frac{dE[U(\Pi)]}{dL} = E\left[\frac{dU(\Pi)}{d\Pi} \quad \frac{d\Pi}{dL}\right]$$

$$\frac{dU(\Pi)}{d\Pi} = U'(\Pi)$$

$$\frac{d\Pi}{dL} = p \cdot \frac{dh(L_1)}{dL_1} \cdot \frac{dL_1}{dL} - w$$

$$\frac{d\Pi}{dL} = P \cdot h'(L_1) \quad \frac{dL_1}{dL} - w$$

$$\frac{dL_1}{dL} = v$$

$$\frac{d\Pi}{dL} = P \cdot v \cdot h'(L_1) - w$$

$$EQ.\ 8: \quad \frac{dE[U(\Pi)]}{dL} = E[U'(\Pi) \cdot (P \cdot v \cdot h'(L_1) - w)]$$

$$EQ\ 9: \quad \frac{d^2E[U(\Pi)]}{dL^2} = E\left[\frac{d^2U(\Pi)}{d\Pi^2} \quad \frac{d\Pi}{dL} + \frac{d^2\Pi}{dL^2} \quad \frac{dU(\Pi)}{d\Pi}\right]$$

In the paper EQ. 9 is derived in the same manner as EQ. 8. EQ. 9 in the paper can be derived following the mathematical expression given above.

EQ. 11: EQ(11) is just EQ (8) rearranged.

EQ. 12: Horowitz, p. 364-367 uses the following definition E(xy) = E(y) · E(x) + COV(x,y). Thus the left hand side of EQ. 11 is equivalent to $E\{U'(\prod)] \cdot E[P \cdot v \cdot h'(L_1)] + COV[U'(\prod), v \cdot h'(L_1)]$ replacing the LHS with this equivalent expression and solving for $E[P \cdot v \cdot h'(L_1)]$ gives us EQ. 12.

EQ. 13: Equation (13) gives the standard procedure for deriving an elasticity coefficient.

$$EQ.\ 14: \quad \frac{d[v \cdot h'(L_1)]}{dv} = h'(L_1) + v \cdot \frac{dh'(L_1)}{dv}$$

$$\frac{dh'(L_1)}{dv} = \frac{dh'(L_1)}{dL_1} \quad \frac{dL_1}{dv}$$

$$\frac{dh'(L_1)}{dL_1} = h''(L_1)$$

$$\frac{dL_1}{dv} = L$$

$$\frac{dh'(L_1)}{dv} = h''(L_1) \cdot L$$

$$\frac{d[v \cdot h'(L_1)]}{dv} = h'(L_1) + v \cdot [h''(L_1) \cdot L]: \quad \textit{where } L_1 = v \cdot L$$

$$= h'(L_1) + h''(L_1) \cdot L_1$$

$$= h'(L_1) \cdot [1 + \varepsilon] > 0$$

$$EQ.\ 15: \quad \frac{dU'(\Pi)}{dv} = \frac{dU'(\Pi)}{d\Pi} \quad \frac{d\Pi}{dv}$$

$$\frac{dU'(\Pi)}{d\Pi} = U''(\Pi)$$

$$\frac{d\Pi}{dv} = \frac{d\Pi}{dL_1} \quad \frac{dL_1}{dv}: \quad \textit{where } \frac{d\Pi}{dL_1} = p \cdot h'(L_1) \wedge \frac{dL_1}{dv} = L$$

$$EQ\ 15: \quad \frac{dU'(\Pi)}{dv} = U'' \cdot P \cdot L \cdot h'(L_1)$$

Given that P, L, $h'(L_1)$ are all positive, the sign of EQ (15) is the same as the sign of $U''(\Pi)$.

EQ. 16: Eq. (16) is expressing the implications coming from EQs. 13 - 15 on EQ. 12.

Equations 17 - 19 should be clear.

After proposition I, it is stated that if $h'''(L_1) < 0$, then $d\mathcal{E}/dL_1 < 0$.

$$\frac{d\mathcal{E}}{dL_1} = d\frac{\left[\frac{L_1 \cdot h''(L_1)}{h'(L_1)}\right]}{dL_1}$$

$$= \frac{h'(L_1)\ [h''(L_1) + h'''(L_1) \cdot L_1] - [h''(L_1) \cdot L_1 \cdot h''(L_1)]}{h'(L_1) \cdot h'(L_1)}$$

$$- \quad (+) \qquad - \qquad (-) \qquad +$$

$$= \frac{h''(L_1)}{h'(L_1)} + \frac{h'''(L_1) \cdot L_1}{h'(L_1)} - \frac{[h''(L_1)]^2 \cdot L_1}{[h'(L_1)]^2} < 0$$

Thus $h'''(L_1) < 0$ *assures that* $\frac{d\mathcal{E}}{dL_1} < 0$.

EQ. 21. The first order condition is rewritten to incorporate $\bar{V}$ and the assumption of a risk neutral firm.

$$21. \quad \frac{dE(\Pi)}{dL} = E[p \cdot V^* \cdot h'(L_1) - w] = 0$$

Eq. 22 replaces $\bar{V}$ with $(\alpha \cdot v + \beta)$ and renames the Foc E[Z].

$$22. \quad E[z] = E[p \cdot (\alpha \cdot V + \beta) \cdot h'(L_1) - w] = 0$$

EQ. 23 is the result of comparative static analysis. Taking the total differential of E[z] and setting all differentials to zero except dL, $d\alpha$, and

remembering that $dv^*/d\alpha = (v-1)$, we have,

$dE[z] = E[P \cdot [V^*]^2 \cdot h''(L_1)]\, dL + E[P \cdot v \cdot h'(L_1) - P \cdot h'(L_1) + P \cdot h''(L_1) \cdot (\alpha \cdot v + \beta) \cdot L \cdot (v - 1)]\, d\alpha$

Now the above equation reduces to:

$$dE[z] = E[P \cdot (V^*)^2 \cdot h''(L_1)]\, dL + E[P \cdot (v - 1) \cdot h'(L_1) \cdot (1 + \delta)]\, d\alpha$$

Setting dE[z] to zero allows $\partial L/\partial \alpha$ to be derived.

$$EQ.23. \quad \frac{\partial L}{\partial \alpha} = -\left[\frac{P \cdot E[(v - 1) \cdot h'(L_1) \cdot (1 + \delta)]}{P \cdot E[(V^*)^2 \cdot h''(L_1)]}\right] < 0$$

NOTE: When doing the comparative statics one must remember that $L_1 = (\alpha \cdot v + \beta) \cdot L$ so that

$$\frac{dL_1}{d\alpha} = (v - 1) \cdot L$$

The sign of equation 23 is dependent on the numerator, since the denominator is negative and the entire expression has a negative sign. The key to signing the numerator is the following relationship:

NEXT PAGE

$$E(x \cdot y) = E(x) \cdot E(y) + Cov(x,y) \text{ thus}$$

$$EQ.\ 24.\quad E[(v-1) \cdot h'(L_1) \cdot (1+\varepsilon)] = E[(v-1)] \cdot E[h'(L_1) \cdot (1+\varepsilon)] +$$

$$+ Cov[(v-1),\ h'(L_1)\ (1+\varepsilon)],\ but = E[(v-1)] = 0.$$

So we have EQ. 24.

$$24.\quad E[(v-1) \cdot h'(L_1) \cdot (1+\varepsilon)] = CoV[(v-1),\ h'(L_1) \cdot (1+\varepsilon)]$$

$$EQ.\ 25.\quad \frac{d[h'(L_1) \cdot (1+\varepsilon)]}{dv} = \frac{d[h'(L_1) + L_1 \cdot h''(L_1)]}{dv} =$$

$$\frac{d[h'(L_1)\ (1+\varepsilon)]}{dv} = h''(L_1) \cdot \alpha \cdot L + \alpha \cdot L \cdot h''(L_1) + L_1 \cdot h'''(L_1) \cdot \alpha \cdot L$$

Given that h'', h''' are negative,

$$\text{then } \frac{d[h'(L_1) \cdot (1+\varepsilon)]}{dv} < 0$$

$$EQ.\ 26.\quad \frac{d(v-1)}{dv} = 1 > 0$$

Thus equations 25 and 26 have opposite signs, so the covariance is negative, which means $\partial L/\partial \alpha < 0$ ∴.