Induced Inefficiency As a Response to the Union Threat

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Milkman and Mitchell (1995) extend Rosen’s (1969) threat-effect hypothesis to suggest that the threat of unionization can induce inefficient underutilization of labor by nonunion firms. If firms follow this strategy, the apparent paradox of competitive coexistence in the face of higher union wages reflects induced nonunion firm inefficiency rather than superior union firm efficiency. Furthermore, this strategy decreases demand for nonunion workers in a partially unionized industry. A generalized cost function analysis of data from sawmills in the Pacific Northwest yields evidence that nonunion firms use this strategy.

1. Introduction

Do nonunion firms in a partially unionized industry operate inefficiently as part of a union avoidance strategy? Milkman and Mitchell (1995) hypothesize that nonunion firms might attempt to reduce the probability of involuntary unionization by reducing the size of the workforce below the level that would appear price-efficient. They argue that this may help to explain the puzzle of competitive coexistence: If unions are successful in significantly raising wages, how can union and nonunion firms coexist within a single competitive industry?

Wilson et al. (1995) argue that competitive coexistence of union and nonunion firms implies some type of union efficiency to offset the wage premium disadvantage. Some analysts hypothesize that union firms generate operational efficiencies based on better communication between workers and management, more productive training, lower turnover rates, or higher morale. The wage premium disadvantage might also be offset by superior technical or vertical integration efficiencies if union organizing efforts target efficient firms, leaving the higher-cost firms nonunion.¹

Alternately, the coexistence puzzle might be explained by inflated average costs in the nonunion firms. If nonunion firms believe that involuntary unionization would reduce future profits, profit maximization may lead to actions intended to reduce the probability of unionization, even if these actions increase current production costs. Rosen (1969) asserted that nonunion firms might attempt to forestall threatened unionization by increasing wages, reducing or even eliminating the union wage premium. Milkman and Mitchell (1995) explore another strategy: If nonunion firms believe that union organizing efforts are more likely to occur and to succeed in larger
firms, they might maximize expected profits by hiring fewer workers than efficiency considerations would otherwise indicate. Union firms operate more efficiently than nonunion firms, under this hypothesis, not because unions are associated with efficiency gains, but because the threat of unionization induces inefficient factor utilization by nonunion firms.

The Milkman-Mitchell (hereinafter M-M) strategy also indicates that partial unionization within an industry can decrease the demand for nonunion labor, leading to employment reductions that are not accompanied by wage increases. This conclusion adds complexity to the controversy, summarized by Neumark and Wachter (1995), regarding the relative impacts on nonunion wages of the threat effect (nonunion firms respond to the threat of unionization by raising wages) and the crowding effect (decreased employment in union firms increases nonunion labor supply, putting downward pressure on wages). Neumark and Wachter (1995) and Freeman and Medoff (1984) conclude that nonunion workers benefit from partial unionization as the unionization threat puts upward pressure on nonunion wages and because decreased employment in the union sector shifts resources into the nonunion sector. The M-M argument, however, suggests that nonunion firms may use diverse strategies to attempt to reduce the probability of unionization, and the impact of partial industry unionization on nonunion firms is therefore complex. If nonunion firms use the M-M strategy as an alternative to paying above-market wages, partial unionization decreases the demand for nonunion workers. This decrease would magnify the crowding effect on the supply of nonunion workers, decreasing both employment and wages.

We present the results of an empirical test of a modified version of the M-M hypothesis of induced nonunion inefficiency. We first derive our refutable hypotheses based on a modified version of the M-M model. Using a generalized cost function approach to estimate the ratio of the value of marginal product to the observed wage, we then test whether nonunion firms hire a price-inefficient number of workers. Analysis of Mitchell’s (1988) data on a sample of 86 sawmills in the Pacific Northwest yields results consistent with the hypothesis that nonunion firms in this industry underutilize workers relative to other inputs, while union firms employ all inputs efficiently. This evidence that the modified M-M strategy is employed in this industry implies that the theoretical implications of this hypothesis must be considered carefully.

II. Induced Nonunion Inefficiency: Refutable Hypotheses

M-M focus on nonunion efforts to reduce the risk of involuntary unionization. The major prediction of the M-M model is that because unionization increases long-run average costs, nonunion firms may be willing to produce at a smaller scale than is technologically optimal if this strategy reduces the probability of unionization. In contrast with M-M’s focus on long-run changes in a plant’s employment, scale, production technology, or product niche, we investigate the short-run marginal effects of the
threat of unionization. This short-run analysis focuses on the price efficiency of the input mix. Since increased work force size increases the probability of unionization in this model, the shadow cost of marginal employment exceeds the wage. Nonunion plants respond by utilizing a price-inefficient input mix.

M-M assume that unionization reduces profit because union wages exceed nonunion wages and unionized firms utilize resources inefficiently. Since we focus on union impacts on nonunion production efficiency, we adjust three aspects of the M-M model. First, we assume that unionization may affect the revenue function, so that $R^N(L,H)$ differs from $R^U(L,H)$, where $R$ represents a production function scaled by a competitive output price; $L$ represents nonsupervisory labor inputs; $H$ represents the basket of other variable inputs; and $U$ and $N$ denote union and nonunion status. Our model incorporates the general assumption that the two revenue functions may differ but does not specify the direction of that difference, whereas M-M assume that managers believe unions will decrease productivity. This provides a basis for testing empirically the equal efficiency hypothesis against the two alternative hypotheses that unions might increase production efficiency by improving communication and supervision or reducing turnover, or that unions might decrease production efficiency by imposing inefficient work rules.

We next assume that the probability of unionization, $\mu$: $0 \leq \mu \leq 1$, is a function of the number of nonsupervisory workers, $L$, rather than a function of scale. As discussed in M-M, scale economies in union organizing provide an economic incentive to target large firms; organizational commitment on the part of workers may be easier to achieve in smaller firms; and union suppression tactics may be more successful in smaller firms. These hypotheses focus on $\mu$ as a function of $L$; so we assume that $\mu = \mu(L)$ directly, whereas M-M assume that $\mu = \mu(Q(L))$.

Finally, since we recognize that this strategy may be just one of many available to the nonunion firm, we focus on industries in which the nonunion firms do not attempt to forestall unionization by matching the union wage premium; thus, we treat the nonunion wage as a parameter, rather than a choice variable. Thus we model the probability of unionization as $\mu(L; b)$, where $b$ is the union wage premium. If data were available on other possible conditions that make unionization more likely, such as location in an area with a strong union tradition, the function $\mu$ could be extended to incorporate these factors.

For an already-unionized firm, we assume that $\mu$ equals one due to the difficulty of removing an established union. For nonunion firms, if unionization becomes more likely the larger the labor force or the larger the expected union wage premium, $\partial \mu / \partial L > 0$ and $\partial \mu / \partial b > 0$; furthermore, since a larger wage premium should not decrease the marginal probability of unionization due to a larger labor force, $\partial^2 \mu / \partial L \partial b \geq 0$.

If unionization is not certain, nonunion firms maximize expected profit $\pi^E$ given by:

$$\pi^E = \mu \pi^U + (1 - \mu) \pi^N,$$

(1)
where $\pi^U$ and $\pi^N$ are the profits the firm would earn if it is actually unionized or remains nonunion, respectively. These are defined as:

$$\pi^U = R^U(L, H) - (w + b)L - hH,$$

$$\pi^N = R^N(L, H) - wL - hH,$$

where $w$ is the competitive wage in each labor market; $b$ is the union wage premium; $h$ is the price of other inputs $H$; and both profit and revenue functions are concave functions of inputs. The firm does not adjust $L$ and $H$ if unionization occurs, in this one-period model, because the firm’s initial capital purchasing decisions and customer and supplier contracts constrain the firm’s short-run flexibility. Differentiating equation (1) with respect to $L$ and $H$ yields the first order conditions:

$$\pi^E_L = \mu(R^U_L - w - b) + \mu_L \pi^U + (1 - \mu)(R^N_L - w) - \mu_L \pi^N = 0,$$

$$\pi^E_H = \mu R^U_H + (1 - \mu)R^N_H - h = 0,$$

where subscripts denote first partial derivatives.

The first equality in equation (3) can be rewritten as:

$$\left[\mu R^U_L + (1 - \mu)R^N_L \right] = \left[\mu (w + b) + (1 - \mu)w \right] + \mu_L (\pi^N - \pi^U).$$

The term on the left-hand side is expected marginal revenue product for labor; the bracketed term on the right-hand side is the expected wage; and the marginal effect of labor on the probability of unionization drives a wedge between the wage and the marginal revenue product. Thus, while M-M posit a long-run decision to operate at a suboptimal scale, our model implies suboptimal use of labor for any given level of capital. This raises the question of whether the firm’s strategy to reduce the likelihood of unionization is credible, since the firm could hire additional workers at any time. Union response to the firm’s strategy may depend in part on the union’s ability to identify whether the strategy is employed. If unions are unaware of the underutilization of labor, and the consequent potential to simply increase hiring, unions will view this as a less attractive small firm. If unions are aware of the potential, the firm’s underutilization of labor signals opposition to unionization and willingness to incur costs to prevent it.

For a union firm with $\mu = 1$ and $\mu_L = 0$, $R^U_L = (w + b)$ and $R^U_H = h$ (hence, $\pi^U_L = \pi^U_H = 0$). If we define $k_L$ as the ratio of marginal revenue product $R_L$ over observed wage $W_L$ (where $W_L$ equals $w$ for nonunion firms, and $w + b$ for union firms), then the first order conditions imply that $k_L^U = k_L^H = k_L^N = 1$. Our model does not specifically consider union pressure that could potentially lead to “featherbedding.” The reasonableness of this specification for our data can be tested empirically, since featherbedding implies $k_L^U < 1$.

For nonunion firms the M-M strategy implies that:

$$k_L^N = 1 + \left(\mu_L / (1 - \mu)\right) \times (\pi^N - \pi^U) / w > 1 \text{ given } \pi^N > \pi^U.$$

(5)
Unionization is assumed to decrease profit because nonunion firms would only view unionization as a threat in cases where this condition holds. Thus the nonunion firm utilizes $H$ efficiently with $R^N_H = h$, but underutilizes labor, with $R^N_L > w$, in an attempt to avoid unionization. Using the chain rule and Cramer’s Rule, the partial derivative of $k^N_L$ with respect to the wage premium $b$ is given by:

$$
\frac{\partial k^N_L}{\partial b} = \frac{R^N_L}{w} \times \frac{\partial L}{\partial b} + \frac{R^N_{LH}}{w} \times \frac{\partial H}{\partial b} = (\mu + \mu_L \pi^N_L + \mu_H \pi^N_H - \pi^U) / w
$$

$$
\times (R^N_{LL} \pi^E_{HH} - R^N_{LH} \pi^E_{HL}) (\pi^E_{LL} R^E_{HH} - \pi^E_{LH} R^E_{HL}).
$$

(6)

The first term is positive since $\mu_L > 0$, $\mu_H > 0$, $\mu_{LH} \approx 0$, and $\pi^N > \pi^U$. Thus, the sign of $\partial k^N_L / \partial b$ is determined by the sign of the bracketed expression. The denominator in the bracketed expression is positive under the concavity conditions required for maximization of expected profit. The numerator can be rewritten as $[R^N_{LL} \pi^E_{HH} - R^N_{LH} \pi^E_{HL}]$, where $R^E$ is the expected revenue function, since $\pi^E_{HH} = \mu R^U_{HH} + (1 - \mu) R^N_{HH} = R^E_{HH}$, and $\pi^E_{HL} = \pi^E_{LH} = R^E_{LH}$. If $\mu = 0$, concavity of $R^N$ ensures that the bracketed expression is positive. For $0 < \mu < 1$, $R^E_{HH}$ and $R^E_{LH}$ are weighted averages of union and nonunion revenue function second derivatives. If unionization exerts only minor impacts on the ratio of second derivatives (e.g., changing them by a scalar):

$$
R^N_{LH} / R^N_{HH} = R^E_{LH} / R^E_{HH},
$$

(7)

and concavity of the revenue function ensures both a positive sign of the bracketed expression and a positive sign of the derivative $\partial k^N_L / \partial b$.

Therefore, the difference between the marginal revenue product of nonunion nonsupervisory labor and the wage rate will increase as the union wage premium increases. Nonunion firms respond to the threat of unionization by hiring fewer workers than the number required for factor-price efficiency, and the degree of labor underutilization is directly related to conditions favoring unionization, such as the difference between union and nonunion wages. In contrast, unionized firms utilize both workers and other inputs efficiently, equating marginal revenue product with factor price for both inputs.

This theoretical model generates two testable hypotheses: (1) Nonunion firms will hire an inefficiently small number of workers, given the market nonunion wage $w$, while union firms will hire workers to equate marginal revenue product with the union wage ($w + b$), and (2) Nonunion factor-price inefficiency is an increasing function of the union wage premium.

III. Northwest Sawmill Data

We test these hypotheses by analyzing 1982 and 1986 production and variable cost data collected by Mitchell (1988) for 86 sawmills in the Pacific Northwest. Related analyses of the 1986 data have been reported by M-M (1995), Wilson et al. (1995),
and Mitchell and Stone (1992). Output, measured in board feet, is categorized as high quality (clear of knots) or lower quality with knots, dried or green, lumber grade or lower-quality stud grade. Variable inputs include nonsupervisory labor, supervisory labor, and energy. Material inputs, measured by board feet of saw timber, are treated as fixed since no price information is available, along with capital stock (which is measured as the assessed value of the mill in 1986). Observed prices for variable inputs are measured by the average cost per unit of input. After excluding observations with missing data, the data set includes two-fifths of the 1982 ($n=36$) observations and two-thirds of the 1986 observations ($n=58$). The resulting data set includes an unbalanced panel of 94 observations; 53 are from union mills and 41 are nonunion.

Descriptive statistics are summarized in Table 1. Weighting the averages by board feet of output for 1986, union mills incur average variable costs (AVC) 38 percent higher than nonunion mill AVC. Since union mills pay a nonsupervisory wage almost 30 percent higher per man-hour than nonunion mills, unionization burdens these sawmills with costs in addition to higher wages for non-supervisory labor. The significant wage premium indicates that firms are not using Rosen’s (1969) strategy of deterring unionization by closing the wage gap; hence this industry provides an appropriate venue for testing the hypothesis that the nonunion firms may employ the M-M strategy. Calculating $t$-statistics to test the null hypotheses that the means for union mills are equal to the means for nonunion mills for each variable in the 1986 data, we find that the difference is significant for both average cost and the wage premium, together with the amounts of capital and energy used per unit of output, the number of supervisors per worker, and the price paid for energy.

To what extent do output characteristics account for the cost differences? Union mills produce almost 20 percent more board feet per mill than nonunion mills, but the mixes of output characteristics are similar for the two types of mills in this sample. Over 80 percent of mills have fixed plant facilities for drying lumber and about half of the lumber is dried. Less than ten percent of lumber is high-quality clear grade, and less than ten percent is low quality stud grade. No differences are significant.

To prepare these data for estimation, capital and timber inputs are expressed per unit of output, which simplifies the calculation of returns to scale without affecting the estimate (Parker, 1994). Price and cost data are normalized around their means for estimation, and variable inputs are correspondingly adjusted to ensure that cost and share relationships are unaffected by normalization.

IV. A Generalized Variable Cost Function Approach

The generalized (or nonminimum) cost function approach is appropriate for testing whether nonunion firms employ the M-M strategy because it focuses on minimization of shadow costs known to the decision-maker but unobserved in the data. The translog functional form of the generalized cost function was first derived by Atkinson and Halvorsen (1984). Eakins (1994) applies a generalized cost function approach to test for union productivity differences in construction, and rejects the Cobb-Douglas for-
Table 1  
Sawmill Data Description: 1986 Observations Only

<table>
<thead>
<tr>
<th></th>
<th>Union Mills</th>
<th>Nonunion Mills</th>
<th>t-Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weighted Average</td>
<td>Standard Deviation</td>
<td>Weighted Average</td>
</tr>
<tr>
<td>Share of observations in 1986:</td>
<td>60.4%</td>
<td>63.4%</td>
<td></td>
</tr>
<tr>
<td>Average Variable Cost ($VC/Q$):</td>
<td>7.5¢</td>
<td>[2.3¢]</td>
<td>5.4¢</td>
</tr>
<tr>
<td>Million Board Feet Output ($Q$):</td>
<td>103.79</td>
<td>[58.48]</td>
<td>88.31</td>
</tr>
<tr>
<td>Timber Inputs/Output ($I$):</td>
<td>0.71</td>
<td>[0.15]</td>
<td>0.63</td>
</tr>
<tr>
<td>Capital /Output ($K$):</td>
<td>14.3¢</td>
<td>[12.0¢]</td>
<td>7.8¢</td>
</tr>
<tr>
<td>Manhours ($V_p$) per 1000 Bd. Ft.:</td>
<td>3.65</td>
<td>[1.20]</td>
<td>3.37</td>
</tr>
<tr>
<td>Supervisors per Worker ($V_p/V_I$):</td>
<td>10.9%</td>
<td>[6.4%]</td>
<td>7.2%</td>
</tr>
<tr>
<td>KW Energy ($V_p$) per 1000 Bd. Ft.:</td>
<td>24.79</td>
<td>[20.06]</td>
<td>15.25</td>
</tr>
<tr>
<td>Energy Price per KW ($W_e$):</td>
<td>34.1¢</td>
<td>[13.9¢]</td>
<td>44.9¢</td>
</tr>
<tr>
<td>Share of Variable Cost:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor Share ($S_l$):</td>
<td>80.4%</td>
<td>[5.2%]</td>
<td>80.8%</td>
</tr>
<tr>
<td>Supervisor Share ($S_s$):</td>
<td>10.0%</td>
<td>[3.9%]</td>
<td>8.5%</td>
</tr>
<tr>
<td>Energy Share ($S_e$):</td>
<td>9.6%</td>
<td>[3.7%]</td>
<td>10.7%</td>
</tr>
<tr>
<td>Output Characteristics:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drying Facilities ($D$):</td>
<td>85.3%</td>
<td>[35.9%]</td>
<td>81.9%</td>
</tr>
<tr>
<td>Dry Output ($P$):</td>
<td>53.7%</td>
<td>[39.6%]</td>
<td>48.6%</td>
</tr>
<tr>
<td>Clear Output ($C$):</td>
<td>8.2%</td>
<td>[12.7%]</td>
<td>8.9%</td>
</tr>
<tr>
<td>Stud-Grade Output ($Z$):</td>
<td>7.7%</td>
<td>[23.0%]</td>
<td>14.0%</td>
</tr>
</tbody>
</table>

Note: (**, *) Significant at (5, 10), two-tailed test for equal-mean hypothesis with different variances

mulation in favor of the translog form. We use the variable cost form, which restricts capital to a fixed quantity in the short-run (Samuelson, 1953; Lau, 1976; Bhat- arya et al., 1994; Parker, 1994).

Derivation of the generalized form begins with the shadow variable cost function:

$$VC^* = \sum_{i=1}^{3} W_i^* V_i^* = VC^*(W^*, Q, I, U, T, C, D, P, Z),$$

(8)

where $VC^*$ is shadow variable cost; $W^*$ is a vector of shadow prices for inputs; and $V^* = [L, S, E]$ is the vector of variable-cost-minimizing quantity choices for the vari-
able inputs (including labor, supervisory staff, and energy). Shadow variable cost is also indirectly a function of output $Q$, two fixed inputs (capital stock $K$ and the input $I$ of saw timber), unionization (represented by a dummy variable equal to one for union mills and zero otherwise), a time variable $T$ (equal to zero in 1982 and four in 1986), and four variables representing output characteristics that affect technology choices. These latter four variables include the output share of clear lumber $C$, a dummy variable $D$ for production of dry lumber as well as the dry output share $P$, and the share $Z$ of stud-grade lumber.

Partitioning these twelve variables into $X = \{W^*_L, W^*_S, W^*_E, Q, K, I\}$, $X > 0$, and $Y = \{U, T, C, D, P, Z\}$, $Y \succeq 0$, we can specify the translog form of this function as:

$$
\ln VC^* = \alpha_0 + \sum_{i=1}^6 \alpha_i \ln X_i + \sum_{j=1}^6 \tau_j Y_j + \frac{1}{2} \sum_{i=1}^6 \sum_{m=1}^6 \beta_{im} \ln X_i \ln X_m
$$

$$
+ \frac{1}{2} \sum_{j=1}^6 \sum_{m=1}^6 \theta_{jm} Y_j Y_m + \sum_{i=1}^6 \sum_{j=1}^6 \phi_{ij} \ln X_i Y_j + \sum_{i=1}^3 \gamma_{QU_i} \ln Q U \ln W_i.
$$

(9)

Necessary restrictions include $\beta_{im} = \beta_{mi}$ and $\theta_{jm} = \theta_{mj}$ $\forall i, j, m$, by Young’s Theorem, and a number of $\theta$ terms cannot be estimated because these second-order interaction terms are singular when combined with the first-order terms. The third-order $\gamma$ terms are an addition to the standard translog form, and they allow the effect of scale on the shadow shares to vary between union and nonunion mills; this addition ensures that any interaction between union and scale in the estimated shadow price ratios is not an artifact of overly restrictive functional forms for the share equations.

With respect to shadow prices, this cost function must be nondecreasing, which requires positive first derivatives; concave, which requires a negative semidefinite Hessian of second derivatives; and linearly homogeneous, which requires that:

$$
\sum_{i=1}^3 \alpha_i = 1, \quad \sum_{i=1}^6 \beta_{im} = 0 \quad \forall m, \quad \sum_{j=1}^6 \phi_{ij} = 0 \quad \forall j, \quad \text{and} \quad \sum_{i=1}^3 \gamma_{QU_i} = 0.
$$

(10)

By Shephard’s Lemma, we can derive the shadow cost share of the $i$th variable input for all $i = L, S, E$:

$$
S^*_i = W^*_i V^*/VC^* = \frac{\partial \ln VC^*}{\partial \ln W^*_i} = \alpha_i + \sum_{m=1}^6 \beta_{im} \ln X_m + \frac{6}{\sum_{j=1}^6 \phi_{ij} Y_j + \sum_{i=1}^3 \gamma_{QU_i} \ln Q U}.
$$

(11)

The cost function and factor share equations thus far defined are similar to the system estimated by Wilson et al. (1995), with the following changes. First, we separate supervisory from nonsupervisory labor. Second, since our data set includes observations for 1982 and 1986, we have added the variable $T$ to capture any changes over time. Third, we add the variable $C$ to capture potential cost differences due to the production of higher-quality clear lumber.
The final change is most important for our purpose. We allow the shadow price for nonsupervisory labor, denoted here as the shadow wage \( W^* \), to differ from the observed wage \( W \), so that:

\[
W^*_L = k_L W_L.
\]

(12)

Consistent with our model, we also assume that \( W^*_S = W_S \) and \( W^*_E = W_E \) (implying that \( k_S = k_E = 1 \)). We cannot observe the shadow wage and the shadow cost directly; instead, we infer them by observing firm behavior. Observed variable cost is equal to:

\[
VC = \sum_{i=1}^{3} W_i V^*_i.
\]

(13)

In logarithmic form, the resulting observed generalized variable cost function can be shown to equal:

\[
\ln VC = \ln VC^* + \ln [1 + S_L^* (k_L^{-1} - 1)].
\]

(14)

and the observed share equations are:

\[
S_i = W_i V_i^*/VC = (S_i^*/k_i)[1 + S_L^* (k_L^{-1} - 1)].
\]

(15)

The shadow wage ratio \( k_L \), which is equivalent to the ratio of the value of marginal product to the observed wage, is defined as:

\[
k_L = \exp[\xi_U 0 U + \xi_N 0 (1 - U) + \xi_N G].
\]

(16)

This specification allows for the test of the union threat hypothesis for nonunion mills as well as the hypothesis of union featherbedding. \( G \) is the estimated union wage gap for nonunion mills. For union mills, this wage gap is by definition equal to zero. For nonunion mills, the wage gap \( G = (W^N_L/W^U_L - 1) = (w/(w+b) - 1) = -b/(w+b) \), so \( G < 0 \) if union firms pay a wage premium. For nonunion mills, the union wage \( W^U_L \) is unobserved. To estimate it, both union and nonunion wage rates are regressed using ordinary least squares on a hedonic expression containing all non-wage exogenous variables in the cost function:

\[
W_L = \delta_{N0} (1 - U) + \delta_{U0} U + \sum_{i=4}^{6} (\delta_{N1} (1 - U) + \delta_{U1} U) \ln X_i
\]

\[
+ \sum_{j=1}^{6} (\lambda_{Nj} (1 - U) + \lambda_{Uj} U) Y_j.
\]

(17)

From this hedonic regression equation, the potential union wage for a nonunion mill is estimated as:

\[
\hat{W}_L = \delta_{U0} + \sum_{i=4}^{6} \delta_{Ui} \ln X_i + \sum_{j=1}^{6} \lambda_{Uj} Y_j.
\]

(18)

The nonnegative functional form of equation (16) allows the shadow wage to deviate from the observed wage for both union and nonunion mills. If \( k_L \neq 1 \), then
VC > VC*, and we observe apparent input price inefficiency in the use of labor. It is important to note, however, that we are implicitly assuming that the nonunion mill is making an efficient input choice with respect to expected profits, even though this may differ from apparent profit maximization.

This model permits testing of the two hypotheses of the modified M-M model. First, we test the null hypothesis that nonunion mills utilize labor efficiently, which implies that \( k^N_f = 1 \) (specifically, this requires that \( \xi_{NG} = 0 \)), against the alternate hypothesis that the threat effect leads to a higher shadow wage, such that \( k^N_f > 1 \) (so, \( \xi_{NG} G > 0 \)). For completeness, we test this null hypothesis for union mills against the alternate hypothesis of featherbedding, which predicts that \( k^U_f < 1 \) (\( \xi_{NG} L < 0 \)). Second, we test the null hypothesis that the shadow wage ratio is independent of the wage gap against the alternate hypothesis that the threat effect for nonunion mills is a function of the wage premium; since \( \partial G / \partial b < 0 \), this null hypothesis implies that the parameter \( \xi_{NG} \) is zero. However, if \( k^N_f \) is directly related to the wage gap as predicted in the modified M-M model, then \( \xi_{NG} \) will be negative.

V. Estimation and Results

Estimation. Prior to the estimation of the cost equation system, the potential union wage for nonunion mills is calculated from equation (18). To do this, equation (17) is estimated (appending a normally distributed error term) using ordinary least squares. Since equation (17) is hedonic, most variables with insignificant coefficients can be excluded without sacrificing economic content (with an \( F_{(10, 76)} \) statistic of 0.43, the joint hypothesis for these restrictions is not rejected). Three statistically insignificant coefficients, \( \delta_{NG} \), \( \lambda_{NG} \), and \( \delta_{UQ} \), are retained in the equation to maintain economic logic. The resulting coefficient estimates are shown in Table 2. Note that nonunion wages increase significantly with higher mill output, but not with time; union wages increase over time but not with output, and decrease with a rise in the share of dry or stud-grade output.6

The generalized cost function estimation includes the observed variable cost function together with two of the three share equations,7 making the appropriate functional substitutions for the shadow wage, shadow shares, and shadow cost; hence we have a simultaneous system of equations with correlated errors. Consistent estimates, however, can be derived through a standard Davidson-Fletcher-Powell nonlinear iterative seemingly-unrelated regression procedure, available in the Shazam program, which converges to maximum likelihood.

Initial Results. With \( n = 12 \) variables, the translog functional form has \( 1 + 2n + (n^2 - n)/2 = 91 \) coefficients to estimate. The additional interaction between \( Q \) and \( U \) in the share equations adds three coefficients, and the shadow wage equation adds three more. Four interaction terms (\( U \times U \), \( T \times T \), \( D \times D \), and \( D \times P \)) cannot be identified, and restrictions for linear homogeneity remove another 14 coefficients. With 79 coefficients remaining and only 94 observations, degrees of freedom are minimal even with three equations. Following Wilson et al. (1995), we therefore
Table 2

Wage Estimate

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean Estimate</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta_N$</td>
<td>-4.512</td>
<td>(5.564)</td>
</tr>
<tr>
<td>$\delta_{NQ}$</td>
<td>1.552</td>
<td>(0.522)**</td>
</tr>
<tr>
<td>$\lambda_{NT}$</td>
<td>0.102</td>
<td>(0.180)</td>
</tr>
<tr>
<td>$\delta_{U}$</td>
<td>15.690</td>
<td>(4.538)**</td>
</tr>
<tr>
<td>$\delta_{UQ}$</td>
<td>0.106</td>
<td>(0.406)</td>
</tr>
<tr>
<td>$\lambda_{UT}$</td>
<td>0.360</td>
<td>(0.155)**</td>
</tr>
<tr>
<td>$\lambda_{UP}$</td>
<td>-2.197</td>
<td>(0.796)**</td>
</tr>
<tr>
<td>$\lambda_{UZ}$</td>
<td>-3.248</td>
<td>(1.207)**</td>
</tr>
<tr>
<td>Adj. $R^2$</td>
<td></td>
<td>0.499</td>
</tr>
</tbody>
</table>

Note: ** Significant at the 5 percent level, two-tailed test

Estimate in steps. First, all of the translog coefficients are estimated. Second-order coefficients with insignificant $t$-statistics are excluded only if the exclusion does not sacrifice economic content and is not expected to affect other coefficients; the hypothesis that 40 excluded coefficients are jointly insignificant is not rejected, with a $p$-value over 50 percent (the joint $F_{(40,203)}$ statistic is 0.94). The hypothesis that the translog could be restricted to either a simple or generalized Cobb-Douglas is rejected with one percent significance. Next, the restricted system (with 39 coefficients remaining) is re-estimated to test the hypothesis that the shadow wage ratio equals one. With a $t$-statistic of $-0.15$, this hypothesis is not rejected for union mills, and so these data are consistent with our assumption that union firms are not featherbedding, but rather employ labor to the point where wage equals marginal revenue product. The hypothesis that the shadow wage ratio equals one is rejected, however, for nonunion mills (the $\chi^2_{(2)}$ statistic equals 11.9). A final system is estimated which restricts $\xi_{U0}$ to zero, and these coefficient estimates are shown in Table 3.

Because of the unbalanced nature of the panel, together with the small sample size and large number of parameters to estimate, we do not have sufficient observations to account for mill-specific effects. However, analysis of the residuals does not indicate significant heteroskedasticity. To check whether autocorrelation might affect our results, we estimate our equations again for the 1986 cross-section alone, after setting all time parameters to zero. The results are qualitatively identical, though the smaller sample size does lead to larger standard errors.
Table 3

**Generalized Variable Cost Function Estimate**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean Estimate</th>
<th>Standard Error</th>
<th>Parameter</th>
<th>Mean Estimate</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_i$</td>
<td>-0.380</td>
<td>(0.067)**</td>
<td>$\alpha_L$</td>
<td>0.861</td>
<td>(0.030)**</td>
</tr>
<tr>
<td>$\alpha_s$</td>
<td>0.066</td>
<td>(0.011)**</td>
<td>$\sigma_Q$</td>
<td>0.226</td>
<td>(0.093)**</td>
</tr>
<tr>
<td>$\alpha_K$</td>
<td>0.183</td>
<td>(0.057)**</td>
<td>$\sigma_l$</td>
<td>-0.013</td>
<td>(0.114)</td>
</tr>
<tr>
<td>$\tau_U$</td>
<td>0.127</td>
<td>(0.041)**</td>
<td>$\sigma_T$</td>
<td>-0.023</td>
<td>(0.012)*</td>
</tr>
<tr>
<td>$\tau_C$</td>
<td>0.730</td>
<td>(0.146)**</td>
<td>$\tau_D$</td>
<td>-0.074</td>
<td>(0.071)</td>
</tr>
<tr>
<td>$\tau_P$</td>
<td>0.609</td>
<td>(0.063)**</td>
<td>$\tau_Z$</td>
<td>4.388</td>
<td>(0.736)**</td>
</tr>
<tr>
<td>$\beta_{2,L}$</td>
<td>0.054</td>
<td>(0.019)**</td>
<td>$\beta_{2,S}$</td>
<td>-0.035</td>
<td>(0.013)**</td>
</tr>
<tr>
<td>$\beta_{3,Q}$</td>
<td>0.011</td>
<td>(0.008)</td>
<td>$\beta_{3,S}$</td>
<td>0.037</td>
<td>(0.012)**</td>
</tr>
<tr>
<td>$\beta_{3,Q}$</td>
<td>-0.007</td>
<td>(0.006)</td>
<td>$\beta_{3,Q}$</td>
<td>0.247</td>
<td>(0.058)**</td>
</tr>
<tr>
<td>$\beta_{4,L}$</td>
<td>-0.241</td>
<td>(0.089)**</td>
<td>$\phi_{2,U}$</td>
<td>-0.055</td>
<td>(0.025)**</td>
</tr>
<tr>
<td>$\phi_{1,P}$</td>
<td>0.013</td>
<td>(0.012)</td>
<td>$\phi_{2,Z}$</td>
<td>-0.075</td>
<td>(0.024)**</td>
</tr>
<tr>
<td>$\phi_{3,U}$</td>
<td>0.031</td>
<td>(0.010)**</td>
<td>$\phi_{3,P}$</td>
<td>-0.000</td>
<td>(0.007)</td>
</tr>
<tr>
<td>$\phi_{4,Z}$</td>
<td>0.037</td>
<td>(0.018)**</td>
<td>$\phi_{4,U}$</td>
<td>-0.146</td>
<td>(0.064)**</td>
</tr>
<tr>
<td>$\phi_{5,T}$</td>
<td>-0.020</td>
<td>(0.014)</td>
<td>$\phi_{4,D}$</td>
<td>-0.233</td>
<td>(0.085)**</td>
</tr>
<tr>
<td>$\phi_{6,D}$</td>
<td>-0.366</td>
<td>(0.097)**</td>
<td>$\phi_{5,P}$</td>
<td>0.242</td>
<td>(0.091)**</td>
</tr>
<tr>
<td>$\phi_{7,K}$</td>
<td>-0.189</td>
<td>(0.096)**</td>
<td>$\phi_{5,Z}$</td>
<td>-3.298</td>
<td>(0.988)**</td>
</tr>
<tr>
<td>$\beta_{T,Z}$</td>
<td>-0.337</td>
<td>(0.085)**</td>
<td>$\phi_{6,Z}$</td>
<td>-4.863</td>
<td>(0.739)**</td>
</tr>
<tr>
<td>$\gamma_{U,L}$</td>
<td>-0.016</td>
<td>(0.011)</td>
<td>$\gamma_{Q,S}$</td>
<td>0.006</td>
<td>(0.009)</td>
</tr>
<tr>
<td>$\gamma_{V,N}$</td>
<td>0.145</td>
<td>(0.441)</td>
<td>$\bar{\xi}_{NG}$</td>
<td>-1.789</td>
<td>(0.512)**</td>
</tr>
<tr>
<td>$R^2 (\ln AVC)$</td>
<td>0.834</td>
<td></td>
<td>$R^2 (\bar{S}_L)$</td>
<td>0.997</td>
<td></td>
</tr>
<tr>
<td>$R^2 (\bar{S}_E)$</td>
<td>0.877</td>
<td></td>
<td>$R^2 (\bar{S}_E)$ implied</td>
<td>0.907</td>
<td></td>
</tr>
</tbody>
</table>

Note: (**, *) Significant at (5, 10) percent level, two-tailed test.

**Final Results.** The results shown in Table 3 are consistent with those in the more unrestricted versions not reported. The first null hypothesis that $\beta_{1,L} = 1$ is rejected with a one percent level of significance (the $\chi^2$ statistic now equals 12.8) against the alternate hypothesis that the nonunion shadow wage exceeds the observed wage. Both this result and the above result that $\xi_{U,Q}$ equals zero are consistent with the theoretical model of firms employing the M-M strategy. Consistent with the hypothesis that the threat of unionization induces inefficient underutilization of labor, nonunion mills' input decisions imply a shadow wage for labor that exceeds the observed wage by an average of 70 percent. Union mills, which do not face any further uncertainties, hire efficiently given the higher wages they pay.
The second null hypothesis, that the shadow wage ratio \( k_L \) is independent of the wage gap \( G \), is rejected since the coefficient \( \epsilon_{NG} \) is negative with one percent significance. The shadow wage ratio is inversely related to the union wage premium, as predicted by the model.\(^9\) As the union wage premium increases, nonunion mills hire fewer workers, and the ratio of labor’s marginal revenue product to the observed wage increases.

Additional statistics are calculated for each observation, with the output-weighted average and standard deviation reported for each statistic in Table 4, to verify that the fit for the underlying cost function is reasonable. The first derivatives with respect to shadow price are calculated to check for nonnegativity, and the Hessian matrix of second derivatives is calculated to check for concavity. Results indicate that this is a well-behaved cost function: All observations exhibit monotonicity in shadow prices, and over 90 percent exhibit proper concavity. The partial derivatives of the shadow cost function with respect to non-price variables are summarized in Table 4: For \( Q, K, \) and \( I \), this derivative is equivalent to the elasticity of shadow cost with respect to the variable; for \( U, T, C, D, P, \) and \( Z \), this derivative is equivalent to the percentage (logarithmic) change in shadow cost with respect to a unit increase in

<table>
<thead>
<tr>
<th></th>
<th>Union Mills</th>
<th>Nonunion Mills</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weighted Average</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>( G )</td>
<td>0.000</td>
<td>[0.000]</td>
</tr>
<tr>
<td>( k_L )</td>
<td>1.000</td>
<td>[0.000]</td>
</tr>
<tr>
<td>( S_{dL} )</td>
<td>0.814</td>
<td>[0.023]</td>
</tr>
<tr>
<td>( S_{dC} )</td>
<td>0.098</td>
<td>[0.014]</td>
</tr>
<tr>
<td>( S_{dF} )</td>
<td>0.088</td>
<td>[0.016]</td>
</tr>
<tr>
<td>( \partial \ln VC' / \partial Q )</td>
<td>0.982</td>
<td>[0.193]</td>
</tr>
<tr>
<td>( \partial \ln VC' / \partial K )</td>
<td>0.001</td>
<td>[0.108]</td>
</tr>
<tr>
<td>( \partial \ln VC' / \partial I )</td>
<td>-0.327</td>
<td>[0.831]</td>
</tr>
<tr>
<td>( \partial \ln VC' / \partial U )</td>
<td>0.030</td>
<td>[0.108]</td>
</tr>
<tr>
<td>( \partial \ln VC' / \partial T )</td>
<td>-0.061</td>
<td>[0.077]</td>
</tr>
<tr>
<td>( \partial \ln VC' / \partial D )</td>
<td>-0.679</td>
<td>[1.226]</td>
</tr>
<tr>
<td>( \partial \ln VC' / \partial P )</td>
<td>0.668</td>
<td>[0.178]</td>
</tr>
<tr>
<td>( \partial \ln VC' / \partial C )</td>
<td>0.730</td>
<td>[0.000]</td>
</tr>
<tr>
<td>( \partial \ln VC' / \partial Z )</td>
<td>-0.351</td>
<td>[1.976]</td>
</tr>
</tbody>
</table>
the variable. Partial derivatives with respect to input use and output characteristics indicate that the model's results are reasonable. Increased use of saw timber reduces average variable cost, as expected, while additional capital inputs do not appear to significantly affect \( AVC \). The presence of fixed plant facilities for drying lumber significantly lowers average variable cost, while the actual production of dry lumber increases it. Increased clear lumber production increases variable cost, while additional production of stud-grade lumber reduces it. Furthermore, returns to scale are nearly constant, though the average cost curve is clearly U-shaped. Thus, the smaller average size of nonunion firms does not impose a significant cost penalty. Rather, union firms incur higher average costs than nonunion firms, even after accounting for differences in output characteristics and wages.

The results presented thus far support the hypothesis that some nonunion firms respond to the threat of unionization by underutilizing labor and that this threat depends on the size of the union wage premium. The question remains whether this induced nonunion inefficiency offsets the cost disadvantages of union mills, permitting them to compete and coexist in the long run. To address this question, we decompose differences in average variable costs between union and nonunion mills.

**Decomposition of Cost Differences.** Decomposition of average variable cost differences between union and nonunion mills requires the calculation of the full derivative:

\[
\frac{d \ln (VC/Q)}{dU} = \sum_{i=1}^{6} \frac{\partial \ln (VC^{*}/Q)}{\partial \ln X} \times \frac{\Delta \ln X}{\Delta U} + \sum_{j=1}^{6} \frac{\partial \ln (VC^{*}/Q)}{\partial Y} \times \frac{\Delta Y}{\Delta U} - \Delta \eta/\Delta U,
\]

where \( \eta = VC^{*}/VC \) is the measure of relative factor-price efficiency. The partial derivatives of the shadow variable cost function are calculated using the weighted average of all 1986 data, both union and nonunion, to derive a single "representative mill." The differences in the \( X \) and \( Y \) variables are calculated by comparing the cost components in equation (19) for two representative mills, one union and one nonunion, in 1986, noting that \( \Delta U = 1 \) by definition. Factor-price efficiency is 100 percent for union mills and 97 percent for nonunion mills. Using the calculated full derivative as numerateur, the results are shown in Table 5.

This cost decomposition indicates that the union-nonunion cost difference is, as a first-order approximation, about equal to the cost impact of the union wage premium, with other effects roughly offsetting each other. Output characteristics account for 22 percent of the union cost differential. Lower energy prices and reduced use of saw timber reduce the union cost differential. Unionization itself, apart from all other factors included in this analysis, accounts for 22 percent of the cost differential. Most importantly, induced nonunion inefficiency, as measured by \( \eta \), accounts for only 16 percent of the cost differential. Thus, for this sample of sawmills in the Pacific
Northwest, induced nonunion inefficiency only offsets a small portion of the union wage premium cost disadvantage.

For our sawmill data, induced nonunion inefficiency is not sufficient to offset the wage premium cost disadvantage — a result consistent with estimates indicating inelastic demand for labor in this industry. We calculate Morishima elasticities of technical substitution,\(^\text{10}\) using the following equation for a linearly homogeneous cost function:

\[
M_{ij} = 1 + \hat{\beta}_{ij} \hat{S}_j - \hat{\beta}_{ii} \hat{S}_i.
\]

and find that these elasticities all average less than one. Elasticities of substitution between nonsupervisory and supervisory labor average 0.57 for union mills and 0.24 for nonunion mills, and between nonsupervisory labor and energy this elasticity averages 0.73 for union mills and 0.63 for nonunion mills. Converting this to an Allen own-price elasticity for nonsupervisory labor, we get −0.12 for union mills and −0.06 for nonunion mills. In an industry with greater substitution possibilities, the threat of unionization could potentially induce sufficient inefficiency in the hiring of labor to allow union mills to compete and coexist. In this industry, however, limited substitution
possibilities make it difficult for nonunion wage inefficiency to make up for the higher union costs.

VI. Conclusion

Analysis of data for a sample of Northwest sawmills provides evidence that firms in this industry employ the modified Milkman and Mitchell (1995) strategy of under-utilizing labor to reduce the probability of involuntary unionization. Evidence that firms employ this strategy has two implications. First, competitive coexistence of union and nonunion firms in the presence of a union wage premium does not necessarily imply that union firms offset the wage premium disadvantage with superior efficiency. Instead, if firms employ this low-employment strategy, union firms may compete successfully against lower wage nonunion firms by inducing wage inefficiency in the nonunion firms. Second, partial unionization can decrease the demand for nonunion workers and decrease nonunion employment by individual firms.

Cost decomposition indicates, however, that the short-run cost impact of induced nonunion inefficiency in this industry is substantially smaller than the cost disadvantage imposed by the union wage premium. Thus, the induced nonunion inefficiency measured here is not sufficient to enable union-nonunion coexistence. This result must be interpreted carefully, since the sawmill industry was shrinking during the 1982-1986 data collection period.

NOTES

1For discussion of these viewpoints, see Wilson et al. (1995).
2The M-M model predicts that individual plants operate at a smaller than optimal scale. Though the industry may as a result have more individual plants, the increase in average costs implies a leftward shift in the market supply curve.
3The incidence of strikes rises as the real wage falls, since the strike threat becomes more attractive (Cramton and Tracy, 1994). It is a logical extension, then, to argue that nonunion firms might be increasingly threatened by unionization the lower their wage rate relative to the union standard.
4Freeman and Medoff (1984) cite empirical evidence that this condition holds in a broad spectrum of industries.
5This result \((\partial k^u/\partial b > 0)\) is consistent with Rosen’s (1969) finding that the nonunion firm’s threat response is an increasing function of the probability of unionization. However, Rosen’s model focuses on nonunion firms that respond to the union threat by matching the union wage, but treats the firm size as exogenous.
6This result is consistent with Podgursky’s (1986) finding that the union wage gap is inversely related to the nonunion firm size.
7The results are invariant to the share equation dropped (Greene, 1980).
8In this case, the degrees of freedom for the unrestricted model is the number of simultaneous equations times the number of observations, less the number of parameters, or \(3(94) - 79 = 203\).
9An alternative specification for the shadow wage ratio is also estimated. Using mill output as an instrument for the nonunion wage gap, the system is re-estimated. The results are robust. Specifically, union
mills are still wage-efficient ($\xi^w = 1$); nonunion mills still hire less than the cost-minimizing amount of labor ($\xi^e < 1$); and this wage inefficiency decreases as $Q$ increases. This is consistent with: (1) the results in Table 2, which show a significant positive relationship between $Q$ and the nonunion wage, and (2) a direct regression of the nonunion wage gap on $Q$ (the t-statistic is +2.77). The cost function is largely unaffected by the substitution of $Q$ for $G$, but $\xi^w$ remains negative and statistically significant for nonunion mills.

10Allen-Uzawa elasticities are the traditional measures of the elasticity of substitution, and unlike Morishima elasticities they are symmetric. According to Blackorby and Russell (1989), however, they are inferior to the asymmetric ($M_q^w \neq M_q^e$) Morishima elasticities. Still, in this case the calculated Allen-Uzawa elasticities are almost identical to the Morishima elasticities.

REFERENCES


