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UNION WORK RULES AND EFFICIENCY IN THE BUILDING TRADES

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ABSTRACT

This paper estimates the effect of union work rules in the building trades on employment and costs by comparing factor demand elasticities for union and nonunion contractors and subcontractors over micro data from two different types of construction. The results show that the elasticities of substitution between labor and nonlabor inputs and own-price elasticities for nonlabor inputs are about the same for union and nonunion contractors. In contrast, the elasticities of substitution among different skill categories of labor and the own-price elasticities for each category are much lower under unionism. A simulation based on a typical office building subcontract shows that these lower factor demand elasticities result in excess staffing of 3.2 percent, excess labor costs of 5.0 percent, and excess total costs of 2.0 percent. This study also examines directly the effect of union work rules on the use of prefabricated components and finds that union contractors are just as likely to use them as nonunion contractors.

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I. Introduction

> *. . .unions had shackled the industry with make-work rules and jurisdictional distinctions even more preposterous, perhaps, than the restrictions that have all but ruined the railroads.*
>
> "A Time of Reckoning
> for the Building Unions,"
> Fortune, June 4, 1979,
> p. 82.

The conventional view of union work rules in construction stated above is that they result in excessive manning and technological stagnation. This view largely originates from journalistic accounts of such horror stories as the journeyman assigned to operate an automatic elevator and the master mechanic who earned $90,000 one year without touching his wrench. Many non-academic studies of the issue, frequently funded by business groups, reinforce this view. For instance, the Business Roundtable (BR) recently conducted a major study of construction industry productivity. The overall tone of their report was described in these terms by the Wall Street Journal, "Although the Roundtable spreads blame for the productivity problem widely, it clearly thinks the principal culprit is organized labor."[1]

This is difficult to reconcile with the results of academic research designed to measure the impact of work rules on factor allocation. Surveys of actual work practices in the 1950s and 1970s concluded the impact of union work rules on efficiency had been vastly overestimated in popular accounts. This is consistent with the conclusions of my quantitative estimates of productivity differences between union and nonunion contractors in Allen (1983, 1984a). Although these estimates did not consider work rules explicitly, it is difficult to reconcile my findings of generally higher productivity in union construction with highly restrictive work practices.

This paper directly estimates the impact of union work rules in construction by comparing factor demand elasticities for union and nonunion contractors. The hypothesis that work rules produce lower demand elasticities in the union sector was proposed by Freeman and Medoff. Union work rules either specify situations in which certain inputs cannot be used (occupational jurisdictions, restrictions on subcontracting, prefabrication, or certain types of equipment) or restrict the quantity of inputs (foremen or apprentice ratios, minimum crew sizes). In either case managers have less flexibility to select the least-cost combination of inputs. As a result, union contractors cannot adjust input quantities to a given differential in input prices as much as nonunion contractors, resulting in lower own-price elasticities and elasticities of substitution under unionism. Freeman and Medoff call this the relative inelasticity hypothesis.[2]

This study focuses on contractor behavior in samples of micro data in commercial office building and elementary and secondary school construction. These data sets are especially well-suited for testing the relative inelasticity hypothesis because the product and the technology are identical within each sample. This was not the case for the two-digit manufacturing industry data used by Freeman and Medoff. As a result they could not reject the possibility that their finding of lower demand elasticities under unionism was attributable to decisions by unions to organize sectors within each two-digit industry that had the lowest factor demand elasticities (so as to minimize the adverse employment effects of higher wages), rather than to the impact of union work rules. Since contractors are price takers in local labor markets, this study also avoids the simultaneity between price and quantity determination involved with most studies of factor demand elasticities.

The focus here is solely upon factor misallocation resulting from union work rules, as opposed to that resulting from union-nonunion wage gaps. The latter issue cannot be addressed without carefully standardizing for labor quality differences between union and nonunion labor. Such standardization is not necessary for this study. Even though my earlier studies show more labor services are embodied in an hour of union labor, this will not bias the elasticity estimates. Although the union contractors would make smaller adjustments in the number of hours for a given type of labor in response to a difference in relative prices, the percentage adjustment in hours relative to the percentage adjustment in prices would not be affected by this consideration.

This study also reports direct evidence on the effect of union work rules involving prefabrication. General contractors in a survey of hospitals and nursing homes were asked whether 15 different types of prefabricated components were used. The possible restrictive impact of unionism is gauged by comparing the questionnaire responses of union and nonunion contractors and by estimating prefabrication probability equations relating the usage of prefabricated components to unionism, wage rates, size and type of building, and other control variables.

This paper is organized in the following fashion. Section II reviews the literature on restrictive union work practices in construction. Section III describes the procedures used to estimate factor demand elasticities; Section IV, the data. I initially assume labor inputs are separable from capital and materials and present results on aggregated labor, capital, and materials in Section V. Differences in demand elasticities by union status for skilled labor, supervisory labor, and unskilled labor are reported in Section VI. The separability restrictions are tested in Section VII and results from models without those restrictions are discussed. Section VIII contains a simulation of the effect of union work rules as manifested by differences in factor demand elasticities on factor demand, costs, and productivity. Union-nonunion differences in prefabrication are examined in Section IX. The results are summarized and evaluated in Section X.

II. Previous Research

Two approaches have been used in previous studies to determine the effect of union work rules on factor allocation in the construction industry. In the first approach union contracts are examined to see if they contain restrictive language. This method can produce misleading conclusions because management and the union may agree to ignore the contract provisions. Even if the contract is followed, the restrictions need not be costly. On large jobs, minimum crew size provisions are not going to be binding constraints. In some cases excess labor can be used outside craft lines. On the other hand, restrictive practices may be followed at the work site even though they are not required by the contract.

The second approach is to interview union officials, union and open-shop contractors, and construction owners to determine which practices are actually being followed. This allows the researcher to determine whether the work rules in the contract are actually costly and whether practices not mentioned in the contract are imposing additional constraints. Both approaches are limited in one key respect--ad hoc assumptions about staffing requirements and factor demand elasticities have to be made to determine the quantitative impact of these provisions.

The most comprehensive study of contract provisions is the Bureau of Labor Statistics' (BLS) examination of 769 agreements for 16 building trades unions in the 66 largest SMSAs in 1972-73. The percentage of workers covered by each of nine productivity-related contract provisions is reported for each of ten major unions and for all 16 unions together in Table 1. Minimum crew size provisions and requirements for a foreman after a given number of workers are hired are the most widespread practices with potentially adverse effects on productivity. Crew size restrictions cover over one-third of all workers and over two-thirds of bricklayers, ironworkers, electrical workers, and operating engineers. This could reduce the own-price elasticity of skilled labor and the elasticity of substitution between skilled labor and other inputs on small jobs. About 60 percent of the contracts require foremen after so many workers are hired, with over half of these requiring a foreman after one to three workers. This could reduce the own-price elasticity of supervisory labor and the elasticity of substitution between supervisors and other types of labor on small jobs. In addition, 26.5 percent of the contracts contain foreman-to-journeyman ratios, which could reduce this elasticity for jobs in all size categories.

Considerably less widespread are provisions limiting prefabrication, tools and equipment, the ability of employers (usually subcontractors) to work with tools, and the use of non-bargaining unit personnel. These provisions are clustered within a few trades. Prefabrication limits cover 70 percent of the plumbers and 77 percent of the sheet metal workers. Limits on tools cover 83 percent of the painters (maximum brush size). Restrictions on the use of tools by employers are most often found in the contracts of painters, plumbers, and electrical workers. Three-fourths of the sheet metal workers are covered by contracts restricting the use of non-bargaining unit personnel. Nearly half of the workers in this sample are covered by contracts that bar limitations on the

Table 1. Percent of workers covered by productivity-related provisions in construction agreements, 1972-73

Union	Foreman minimum	Limits on prefabrication	Limits on tools and equipment	Crew size	Employer not permitted to work with tools	Employer permitted to work with tools under certain circumstances	Restriction on non-bargaining unit personnel doing unit work	Unrestricted work performance	Unrestricted technological change
Bricklayers	57.3	1.0	3.3	66.6	9.1	30.9	6.7	40.8	25.4
Ironworkers	88.7	7.4	-	94.0	1.9	-	7.7	94.6	29.9
Carpenters	65.1	8.5	11.0	22.9	5.2	36.7	14.4	51.9	65.0
Electrical workers	79.8	19.3	-	93.2	21.7	36.6	9.4	24.4	27.0
Operating engineers	74.8	0.1	9.6	84.4	-	1.2	13.8	62.1	56.9
Laborers	43.2	2.9	9.6	16.6	2.9	1.6	17.6	49.6	57.2
Painters	36.5	10.2	83.4	21.0	11.6	44.4	6.9	18.5	15.7
Plasterers	96.2	0.8	11.7	33.4	3.6	30.1	16.6	65.0	67.4
Plumbers	74.4	70.1	9.4	31.2	33.1	39.0	22.5	57.9	39.9
Sheet metal	58.2	77.2	-	8.0	12.3	21.9	74.8	21.4	25.2
Total	59.5	11.7	11.7	37.4	8.1	20.0	18.7	49.1	48.7

Source: Bureau of Labor Statistics.

amount of work performed per day or bar resistance to technological improvements or labor-saving devices. Such provisions are rarely found, however, in agreements covering painters or sheet metal workers. Since these sets of provisions are not widely observed, it will be difficult to assess their impact over samples that are pooled across various trades.[3]

As part of a larger study examining all aspects of productivity, BR (1982a) examined a sample of agreements in effect in 1979 representing 20 percent of all agreements and covering almost half of the union work force.[4] It found almost 20 percent of their sample contracts contained crew size restrictions. Most ironworker contracts contained such restrictions, along with a substantial proportion of boilermaker and operating engineer agreements. Assuming management would utilize 10 percent fewer workers for 10 percent of the tasks assigned to these crafts, BR estimated crew size provisions result in an annual excess cost of $42 million. In comparison, the BLS study found much greater use of these restrictions in its 1972-73 sample. Off-site fabrication restrictions were found in only a minor proportion of all contracts but in about half of the pipefitter or plumber agreements. This results in an annual excess cost of $30 million, using assumptions identical to those in the crew size case above.[5]

BR (1982b) cites exclusive jurisdiction as "the greatest. . .current handicap faced by union contractors," (p. 1) not only because of distortions in factor mixes but also because of disputes among unions. A Stanford University survey done for BR found these problems to be especially severe in the unloading and storage of materials, operation of small equipment, and installation of scaffolding and supports. BR (1982c) argued that restrictions on the use of semiskilled and unskilled workers may raise costs as much as 20 percent. Although the quantitative basis for all these claims and estimates is quite weak, they all suggest that factor demand elasticities are much lower in union construction.

The most thorough interview study was done in 1952 by Haber and Levinson. They interviewed 268 representatives of labor, management, and government in 16 cities to determine, among other things, how receptive labor unions were to new techniques, how widespread union work rules were, and how much impact they had on costs. While their back-of-the envelope calculations concluded union work rules raise costs by 3 to 8 percent, they noted "the building trades unions have been more receptive to new techniques than has been widely believed" (p. 153) and that "an over-all evaluation of the extent and importance of union working rules strongly suggests that their adverse impact is much less than has been widely alleged" (p. 189). Three fourths of their cost estimate is attributed to restrictions on the employment of different types of labor, whereas the remainder is attributed to restrictions on techniques.

Mandelstamm obtained cost and man-hour estimates for a standard small house from contractors in two Michigan cities in 1957: one heavily unionized and the other dominated by open-shop contractors. Contractors were also asked how their man-hours estimates were influenced by work rules and technological restrictions. Except for paint spray guns and prefabricated parts manufactured by nonunion labor, Mandelstamm found no union opposition to labor-saving techniques. In fact, other new techniques were utilized more frequently in the unionized city, a factor Mandelstamm attributed to better management. Mandelstamm found the only work rules with any restrictive effects were minimum crew sizes to lift glass, limits on overtime work, and a requirement to hire local men on jobs outside their home base. He found no evidence of organized slowdowns, absolute restrictions on output, insistence on unnecessary quality, barriers to discharge, or limits on working contractors. He concluded, "Although no reliable quantitative estimate can be made of the effect of these rules on efficiency, their total impact would appear to be very small" (p. 512).

More recently Bourdon and Levitt's survey of union and nonunion contractors in eight cities in 1976 found relatively few restrictive work practices in the union sector. Operating engineers and ironworkers set strict limits on the number of workers for a given job; the mechanical trades were very restrictive on work performed off-site. Such rules tend to be irrelevant for large projects, but they impose costly constraints on small specialty contractors. Even in these cases, rules are often ignored or loosely interpreted to fit the context. No work-rule restrictions were reported by 55 percent of the contractors interviewed. Another 92 percent said there were no restrictions on materials; 95 percent on tools. The only such restrictions that tended to be observed involved nonunion prefabricated products.

According to the union contractors interviewed by Bourdon and Levitt, the major restriction imposed by union work rules was that they rarely allowed workers to cross trade lines. Only 27 percent of the union contractors said that their workers crossed trade lines "occasionally to often," while 43 percent said "rarely" and 30 percent said "never." In contrast, 82 percent of the nonunion contractors responded "occasionally to often" and only 18 percent said "never." The authors concluded, "There is no question that at various times and places, various locals of the building trades unions have resisted technological innovation in tools or materials and have established unduly restrictive work rules or practices. Yet, the results of the survey, as of other field research, do not support the contention that this has been a widespread or consistent policy" (p. 63).

What are the common themes in all of these findings? First, despite popular conceptions, most union contracts are not riddled with provisions that seriously interfere with factor allocation. Second, the interview studies indicate many rules look more restrictive on paper than they are in practice because either they do not generally impose binding constraints or they are not followed. Third, although most trades seem relatively free of restrictive work practices, certain problem areas keep popping up in almost all of the studies summarized above. These include limits on prefabrication in plumbing and sheet metal work, limits on tools and equipment in painting, crew size limits among ironworkers and operating engineers, and restrictions on the use of tools by employers in electrical work. Fourth, the two most recent studies both concluded the major work rule problem facing employers today was the exclusive jurisdiction system. Contractors strongly believed they could significantly reduce manhour requirements if they could assign workers to tasks outside their craft's jurisdiction and make greater use of semiskilled and unskilled labor.

III. Specification

Estimates of union and nonunion factor demand elasticities are obtained from translog cost system parameters. This allows elasticites of substitution between factors to vary. The cost function is written:

$$\begin{aligned} \ln C = {} & \alpha_0 + \alpha_y \ln Y + \tfrac{1}{2}\gamma_{yy}(\ln Y)^2 + \sum_i \gamma_{yi} \ln Y \ln P_i \\ & + \sum_i \alpha_i \ln P_i + \tfrac{1}{2} \sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j, \end{aligned} \tag{1}$$

where C = cost, Y = output, and P_i = price of factor i, i = 1, ..., n. Two sets of restrictions are imposed in all cases: (1) symmetry $\gamma_{ij} = \gamma_{ji}$ and (2) degree one homogeneity of the cost function with respect to prices

$$\sum_i \alpha_i = 1; \sum_i \gamma_{yi} = 0; \sum_i \gamma_{ij} = \sum_j \gamma_{ij} = \sum_i \sum_j \gamma_{ij} = 0.$$

The partial derivatives of (1) with respect to factor prices are the demand equations for each factor, that is $\partial C/\partial P_i = X_i$. In logarithms this becomes

$$\partial \ln C/\partial \ln P_i = \frac{P_i X_i}{C} = S_i,$$

where S_i = share of factor i in total cost. In the translog case,

$$S_i = \alpha_i + \gamma_{yi} \ln Y + \sum_j \gamma_{ij} \ln P_j. \qquad (2)$$

Since both the cost function and the share equations contain information about the parameters of interest, they are jointly estimated below by iterated seemingly unrelated regression. One share equation is dropped to make the covariance matrix of the disturbances nonsingular. This produces maximum likelihood estimates that are invariant to the choice of which share equation is dropped.

Elasticities of substitution (σ_{ij}) and own-price demand elasticities (η_i) are computed from the estimates of (1) and (2) using the formulae

$$\sigma_{ij} = (\gamma_{ij} + S_i S_j)/S_i S_j,$$

$$\eta_i = (\gamma_{ii} + S_i(S_i - 1))/S_i .$$

With (1) and (2) estimated separately by union status, σ_{ij} and η_i can be compared for union and nonunion contractors. Two hypotheses about union and nonunion demand elasticities are tested. The first hypothesis is the equality of all union and nonunion coefficients. This is done by examining the likelihood ratio $\lambda = (|\Omega_p|/|\Omega_s|)^{-n/2}$, where Ω_p = determinant of the disturbance covariance matrix for the pooled specification, Ω_s = the same determinant for the specification with separate union and nonunion coefficients, and n = number of contractors in the sample. The test statistic $-2\ell n\lambda$ has a chi-square distribution with degrees of freedom equal to the number of restrictions being tested. Conceivably, the union and nonunion elasticities could be identical, even when the hypothesis of equal cost and share equation coefficients is rejected. Accordingly, the second test is to examine the difference between the elasticity estimates directly. Superscripting union (nonunion) values by u(n), this involves testing whether

$$\sigma^u_{ij} - \sigma^n_{ij} = 0,$$

$$\eta^u_i - \eta^n_i = 0$$

Standard errors of these differences are derived under two assumptions: (1) nonstochastic S_i and (2) $E(\sigma^u_{ij}\ \sigma^n_{ij}) = E(\eta^u_i\ \eta^n_j) = 0$. Under these assumptions the ratio of the union-nonunion difference in elasticities to its estimated standard error approximates the ratio of the union-nonunion difference in γ_{ij} to its estimated standard error.

A key issue in specifying the model is the separability of labor from other inputs. Five inputs are considered below: skilled labor (S), supervisory and administrative labor (B), semiskilled and unskilled labor including apprentices (U), materials (M), and equipment (K). If all five inputs are examined simultaneoulsy, there are as many as 21 parameters to estimate from five equations, a potentially extreme demand to place upon the data. Further,

P_K and, to a lesser extent, P_M are subject to measurement error, biasing the K and M elasticities downward and all other elasticities upward (because of the homogeneity restrictions).

A natural procedure for reducing the burden upon the data and reducing potential measurement error bias is to impose separability between the different types of labor and nonlabor inputs and to estimate two models: one examining labor (L), K, and M, where L is obtained by aggregating S, B, and U into a single input (KLM model) and the other examing S, B, and U as separate inputs while ignoring K and M (BSU model). This reduces the number of free parameters per model to 10 and the number of equations to three. Measurement error bias is no longer a serious factor in the BSU model, although it is still present in the KLM model. The risk involved with imposing separability is that the elasticity estimates may turn out to be biased if different types of labor are not separable from other inputs. Estimates both with and without the separability restrictions are reported below.

One limitation of this procedure is that it assumes that factor quantities are selected at points on the contractor's demand curve. In practice some union work rules specify factor quantities well to the right of the demand curve (e.g. minimum crew size restrictions), which means the isoquants of union contractors (as constrained by the work rules) contain flat segments and discontinuities, especially at small levels of output. By assuming normally distributed errors in the share equations, the model will be misspecified to some extent for the union contractors. The true union elasticities will be zero at some points, whereas the model will impose a smooth, continuous structure on the isoquants. Standard errors will be biased upwardly in the union sample.

In spite of the limitations of the translog specification, the model can approximate the curvature of isoquants under unionism and these results can be compared to the curvature of nonunion isoquants in order to get at the fundamental question of how much do union work rules matter in determining factor quantities.

IV. Data

Two different data sets are examined: one containing 83 commercial office buildings built in 1974 and the other containing 68 elementary and secondary schools built in 1972. Both data sets were gathered by BLS as part of its Construction Labor and Material Requirements series. I originally intended to use individual contractors and subcontractors as observations for the estimation of demand elasticities. Upon screening the data, I frequently found more than one subcontractor involved in a particular type of operation. In many cases one subcontractor provided only materials while others provided labor. Since focusing on individual contractors in such cases would be quite misleading, I decided to aggregate all subcontractors on a project doing the same type of work into a single observation. General contractors are omitted because their output is reported as the total value of the building rather than the value of the work done by their crews. They cannot be included in the sample without imposing homotheticity restrictions which, as will be shown below, are strongly rejected by the data.[6] This results in 823 union and 266 nonunion observations in the office building sample; 806 union and 155 nonunion observations in the school sample.[7]

Each contractor reports the amount of the contract, union status, type and cost of each material item, fair rental value or depreciation for each type of equipment, and hours and wages for each occupation employed onsite.

Since the focus here is on substitution patterns for onsite inputs, interest expenses are not included in capital costs. The cost measure used below is total labor, material, and equipment costs in the KLM model; total labor costs, in the BSU model. The contract amount is used as the output measure in both models.

Materials prices are not reported and must be constructed from other sources. The 1973 Dodge Manual for Building Construction Pricing and Scheduling reports a materials price index for eighty cities. These were aggregated into nine indices for each of the Census subregions, using 1972 construction employment in each city as weights. Since this index varies much more across rather than within regions, this aggregation is unlikely to seriously contaminate the results. Values of this variable for smaller geographic units could not be constructed because, to protect the confidentiality of contractors, individual states or SMSAs are not identified in the data.

The school survey reports hours and costs for each type of equipment, but only costs are reported for the office building sample. The capital price variable used for the latter sample is the rate of return from the 1972 Census of Construction Industries for each project's Census subregion. The ratio of equipment costs to equipment hours is the theoretically appropriate capital price measure for the school sample. Some contractors had no equipment costs. To impute capital prices in those cases, the mean-cost-to-hours ratio for the contractor's operation code (e.g., plumbing, carpentry, excavation, etc.) is used.

Factor prices also had to be imputed for occupational groups when they were not used on a particular project. These were obtained from the coefficients of an average hourly earnings equation estimated over each occupational group used by each contractor with separate intercepts for each building, each occupational group, and complete occupation-union interactions. The dependant variable was specified in linear form. The results, reported in Table 2, are generally consistent with what is known about the wage structure in the industry. Apprentices and unskilled workers earn about the same amount within each sector. Both groups earn less than skilled workers, who in turn earn less than supervisors. The union-nonunion wage gap is largest in percentage terms for the least skilled occupations.

V. KLM Model Results

The shares of labor, materials, and capital for all samples are reported in the first three lines of Table 3. The factor shares are quite similar for office buildings and schools. Labor's share is about 40 percent; materials', 55 percent; capital's, 5 percent. There is very little difference in the factor shares for union and nonunion contractors. Despite higher union wages, labor's share is near 40 percent for both union and nonunion contractors in both samples.

Table 2. Average hourly earnings equation estimates, office buildings and schools

Variable	Office buildings		Schools	
	Mean	Coefficient (S.E.)	Mean	Coefficient (S.E.)
Intercept	-	2.623 (.226)	-	3.390 (.216)
Skilled	.539	2.211 (.133)	.631	2.281 (.150)
Supervisory	.125	4.619 (.216)	.094	3.844 (.281)
Apprentice	.096	.228 (.288)	.075	.335 (.317)
Union skilled	.420	1.353 (.118)	.533	.788 (.125)
Union supervisory	.102	.057 (.222)	.081	.713 (.278)
Union apprentice	.084	1.131 (.300)	.065	.713 (.320)
Union unskilled	.165	1.253 (.142)	.144	.817 (.165)
Mean (S.D.) of dependent variable		7.262 (2.312)		7.080 (2.279)
SE		1.533		1.520
R^2		.574		.566
N		2946		2960

Note: Each equation also contains dummy variables for each project in the sample. There are 82 such dummies in the office building sample and 67 such dummies in the school sample.

Table 3. Translog cost system estimates, KLM model

Sample	Elementary and secondary schools			Commercial office buildings		
	Pooled	Union	Nonunion	Pooled	Union	Nonunion
Mean factor shares:						
Labor	.399	.397	.406	.404	.405	.400
	(.212)	(.205)	(.243)	(.216)	(.209)	(.238)
Materials	.559	.568	.516	.550	.554	.539
	(.241)	(.230)	(.288)	(.238)	(.230)	(.262)
Capital	.042	.035	.078	.046	.041	.061
	(.110)	(.094)	(.166)	(.099)	(.086)	(.129)
Parameter estimates:						
α_O	-1.837	-2.351	-1.172	-.628	-1.173	-.546
	(.197)	(.231)	(.500)	(.144)	(.204)	(.320)
α_Y	1.206	1.265	1.053	.989	1.048	.978
	(.036)	(.039)	(.099)	(.025)	(.031)	(.061)
γ_{YY}	-.020	-.026	-.003	.0003	-.004	.002
	(.003)	(.003)	(.010)	(.002)	(.003)	(.007)
α_L	.314	.484	.495	.308	.434	.481
	(.063)	(.093)	(.145)	(.053)	(.088)	(.114)
α_M	.584	.452	.315	.501	.399	.203
	(.066)	(.095)	(.158)	(.061)	(.092)	(.150)
α_K	.101	.063	.190	.190	.167	.316
	(.020)	(.020)	(.063)	(.040)	(.049)	(.126)
γ_{YL}	-.012	-.012	-.017	-.006	-.008	-.018
	(.004)	(.004)	(.011)	(.003)	(.004)	(.008)

Table 3 (continued)

Sample	Elementary and secondary schools			Commercial office buildings		
	Pooled	Union	Nonunion	Pooled	Union	Nonunion
γ_{YM}	.019 (.004)	.016 (.005)	.031 (.012)	.010 (.003)	.009 (.004)	.030 (.009)
γ_{YK}	-.007 (.002)	-.004 (.002)	-.013 (.006)	-.003 (.002)	-.002 (.002)	-.011 (.005)
γ_{LL}	.094 (.028)	.014 (.042)	.035 (.057)	.025 (.024)	-.022 (.038)	-.023 (.044)
γ_{LM}	-.083 (.028)	-.007 (.042)	.010 (.057)	.027 (.026)	.070 (.040)	.077 (.047)
γ_{LK}	-.011 (.005)	-.007 (.005)	-.044 (.014)	-.052 (.011)	-.049 (.015)	-.054 (.024)
γ_{MM}	.097 (.028)	.019 (.043)	.001 (.061)	-.072 (.036)	-.113 (.050)	-.094 (.079)
γ_{MK}	-.014 (.005)	-.012 (.006)	-.011 (.016)	.045 (.022)	.042 (.023)	.016 (.063)
γ_{KK}	.025 (.002)	.020 (.002)	.055 (.008)	.007 (.020)	.006 (.020)	.038 (.064)
N	961	806	155	1089	823	266
$-2\ln\lambda$		145.561			73.535	

Materials' share is slightly higher for union contractors, whereas capital's share is slightly lower.

Equality of the translog cost system parameters for union and nonunion contractors is strongly rejected in both office building and school construction. The test of equal union and nonunion coefficients involves 10 restrictions. The critical chi-square value at the 99.5 percent confidence level for 10 degrees of freedom is 25.2, well below the reported values of $-2\ell n\lambda$.

Conceivably, the γ_{ij} coefficients are equal for union and nonunion contractors but receive so little weight relative to the other seven restrictions that pooling by union status is still rejected. A more stringent test is to drop the cost function from the system. This leaves seven restrictions to test, three involving γ_{ij} coefficients. In this case, $-2\ell n\lambda$ is 14.62 for office buildings and 64.76 for schools. Both tests reject pooling of union and nonunion observations at conventionally accepted significance levels.

The translog coefficients show the production function for subcontractors in school and office building construction to be nonhomothetic and, in all but one case, constant returns to scale. Labor and capital shares shrink with output in both samples, with greater shrinkage among nonunion contractors. Materials share is greater in large projects, once again with a larger rate of increase with respect to project size in the nonunion sector. The hypothesis of constant returns to scale can be rejected only for union school subcontractors. They are subject to increasing (decreasing) returns for projects with value added of more (less) than $9451. These results are somewhat different from those I obtained in Allen (1984b) in which the unit of observation was the entire building project rather than individual contractors. This need not reflect aggregation bias in the earlier paper since general and miscellaneous contractors are omitted here. The two exercises are also conceptually different, as the results in the other paper reflect not only the behavior of subcontractors but also the coordination of many types of work going on at once.

Even though pooling by union status is rejected, the estimates of factor demand elasticities for labor, materials, and capital in Table 4 show no particular pattern for union as opposed to nonunion contractors. In both samples, there is little difference in the own price elasticity for labor by union status, with all of the estimates falling between .51 and .66. The own price elasticity for capital is somewhat larger for union contractors in both samples, and the own price elasticity for materials is slightly larger for nonunion contractors in the school sample, but the differences are not statistically significant.

The elasticity of substitution estimates show labor and materials to be substitutes in construction, as are materials and capital. Labor and capital are complements for both union and nonunion contractors in office building construction and for nonunion contractors in school construction. In union school construction, labor and capital are substitutes. Out of the four cases where factor pairs are substitutes for both union and nonunion contractors, the nonunion elasticity is larger in three cases, but the null hypothesis cannot be rejected in any of them.

A serious potential source of bias in the office building sample is measurement error in the capital price proxy variable. The γ_{KK} estimates are much smaller for that sample, whereas the standard errors for all parameters

Table 4. Factor demand elasticities at mean factor shares, KLM model

	Elementary and secondary schools				Commercial office buildings			
	Pooled	Union	Nonunion	Nonunion-union	Pooled	Union	Nonunion	Nonunion-union
Own price elasticites:								
Labor	-.364 (.069)	-.568 (.106)	-.508 (.141)	-.060 (.176)	-.534 (.059)	-.648 (.093)	-.657 (.110)	.009 (.144)
Materials	-.267 (.051)	-.398 (.075)	-.481 (.118)	.083 (.140)	-.580 (.066)	-.649 (.091)	-.635 (.147)	-.014 (.173)
Capital	-.368 (.054)	-.401 (.060)	-.213 (.109)	-.188 (.124)	-.791 (.437)	-.798 (.481)	-.318 (1.046)	-.480 (1.151)
Elasticities of substitution:								
Labor-materials	.626 (.124)	.970 (.186)	1.045 (.273)	.075 (.330)	1.121 (.116)	1.314 (.179)	1.359 (.218)	.045 (.080)
Labor-capital	.341 (.285)	.482 (.370)	-.404 (.447)	-.886 (.580)	-1.819 (.575)	-1.951 (.922)	-1.220 (.985)	.731 (1.349)
Materials-capital	.416 (.224)	.369 (.281)	.731 (.397)	.362 (.486)	2.771 (.869)	2.865 (1.026)	1.496 (1.904)	-1.369 (2.163)

associated with capital are much larger. This results in an upward bias in the other coefficients because of the homogeneity restrictions. It also makes it more difficult to estimate accurately union-nonunion differences.

One way to roughly assess this bias is to re-estimate the model over the school sample using the capital price proxy in place of the correct measure. The following elasticity estimates were obtained for the pooled sample:

	Own-price elasticities:	Union-nonunion difference:		Elasticities of substitution:	Union-nonunion difference
Labor	-.359	.075	Labor-materials	.922	.429
	(.069)	(.177)		(.135)	(.370)
Materials	-.582	.419	Labor-capital	-3.753	.931
	(.074)	(.288)		(.837)	(1.767)
Capital	-1.369	.316	Materials-capital	5.121	.416
	(.558)	(1.607)		(1.036)	(3.197)

The own price elasticity for capital is much larger in absolute value in this specification, as the γ_{KK} estimate falls from .025 to -.017. The elasticities of substitution between capital and both labor and materials bear little resemblance to the earlier estimates. This casts some doubt about the findings of complementarity between labor and capital and a large materials-capital elasticity in the office building sample.

Measurement error seems to have little effect on the finding of no difference in elasticities by union status. All of the nonunion elasticities are larger (but not significantly) than the union elasticities in this case, in contrast to only three out of six in Table 4. This suggests that if there is a bias in the office building estimates of union-nonunion differences, it is in favor of the relative inelasticity hypothesis.

In summary, there is no support for the hypothesis of lower factor demand elasticities for union contractors in the KLM model. This is consistent with the results of earlier academic studies. It also is consistent with the data on contract provisions showing limits on prefabrication or on tools and equipment to be relatively rare. This still leaves open the possibility of union work rules restricting the quantity or even the types of labor that can be hired, a matter that will now be examined.

VI. BSU Model Results

The allocation of different types of labor varies substantially by union status. As shown in the first three lines of Table 5, the share of skilled labor is substantially higher for union contractors. In the school sample, skilled labor's share is 85 percent for union contractors versus 74 percent for nonunion contractors. Skilled labor's share is 80 percent for union contractors in the office building sample as opposed to 71 percent for nonunion contractors. These differences may reflect lower prices for skilled relative to unskilled labor under unionism or jurisdictional rules keeping unskilled workers out of certain tasks.

Supervisory labor's share is slightly higher for union contractors in both samples. This may result from minimum foreman requirements or the relatively small difference between the wages of supervisory and other types of labor. Unskilled labor's share is much smaller for union contractors in both samples.

Table 5. Translog cost system estimates, BSU model

Sample	Elementary and secondary schools			Commercial office buildings		
	Pooled	Union	Nonunion	Pooled	Union	Nonunion
Mean factor shares:						
Skilled	.834 (.218)	.852 (.196)	.741 (.292)	.778 (.253)	.800 (.232)	.709 (.302)
Supervisory	.025 (.078)	.027 (.075)	.016 (.093)	.036 (.086)	.039 (.090)	.028 (.073)
Unskilled	.141 (.206)	.121 (.183)	.243 (.279)	.186 (.238)	.161 (.210)	.263 (.296)
Parameter estimates:						
α_O	-3.912 (.590)	-4.153 (.659)	-4.632 (1.581)	-2.744 (.364)	-3.515 (.479)	-2.117 (.763)
α_Y	1.213 (.115)	1.226 (.127)	1.483 (.336)	.930 (.071)	1.045 (.090)	.835 (.173)
γ_{YY}	-.028 (.011)	-.027 (.012)	-.062 (.035)	.002 (.007)	-.006 (.008)	.011 (.019)
α_S	.807 (.047)	.888 (.047)	.556 (.146)	.822 (.042)	.918 (.046)	.740 (.104)
α_B	-.024 (.018)	-.030 (.019)	-.022 (.053)	-.021 (.016)	-.033 (.019)	-.007 (.028)
α_U	.217 (.044)	.142 (.044)	.465 (.141)	.199 (.040)	.114 (.042)	.267 (.102)
γ_{YS}	.004 (.004)	-.005 (.004)	.024 (.014)	-.002 (.004)	-.010 (.004)	.001 (.011)
γ_{YB}	.005 (.002)	.006 (.002)	.001 (.004)	.006 (.001)	.006 (.002)	.007 (.003)
γ_{YU}	-.009 (.004)	-.0001 (.004)	-.025 (.014)	-.005 (.004)	.004 (.004)	-.008 (.011)
γ_{SS}	-.078 (.039)	.001 (.045)	-.086 (.094)	-.054 (.041)	.026 (.053)	-.121 (.068)
γ_{SB}	.018 (.016)	.042 (.019)	-.018 (.033)	-.021 (.015)	-.040 (.022)	.014 (.019)
γ_{SU}	.060 (.034)	-.043 (.039)	.105 (.087)	.075 (.036)	.014 (.045)	.106 (.065)

Table 5 (continued)

Sample	Elementary and secondary schools			Commercial office buildings		
	Pooled	Union	Nonunion	Pooled	Union	Nonunion
γ_{BB}	-.018 (.015)	-.031 (.018)	.051 (.040)	-.001 (.014)	.036 (.021)	-.047 (.021)
γ_{BU}	-.0001 (.013)	-.011 (.015)	-.032 (.036)	.022 (.013)	.004 (.018)	.032 (.019)
γ_{UU}	-.060 (.034)	.054 (.038)	-.072 (.088)	-.097 (.035)	-.018 (.043)	-.139 (.065)
N	961	806	155	1089	823	266
$-2\ell n\lambda$		80.241			53.558	

Once again, equality of all ten union and nonunion coefficients is rejected at extremely high confidence levels for the translog cost system. When the cost function was deleted from the system and the hypothesis retested with seven restrictions, pooling was still soundly rejected.[8]

The production function is nonhomothetic in all samples. The share of supervisory labor increases with output in all cases. The share of skilled labor falls with output for union contractors, but rises for nonunion contractors. The share of unskilled labor falls with output in the nonunion samples, but changes very little with output in the union samples.

How do own price elasticities for different types of labor and patterns of labor-labor substitution differ between union and nonunion contractors? These results, reported in Table 6, provide very strong support for the hypothesis that union work rules reduce management's flexibility to assign workers to jobs in the most efficient fashion. In five out of six cases, the own price elasticities are larger for nonunion contractors and in three such cases the differences are statistically significant from zero at a 90 percent or greater confidence level.

The estimated differences are especially pronounced in the case of skilled labor, as one would expect if occupational jurisdictions are the major restrictive aspect of union work rules. In both samples this elasticity is more than twice as large for nonunion contractors. In the school sample the elasticity for skilled labor is -.15 for union contractors as opposed to -.38 for nonunion contractors. The magnitudes of the estimates in the office building sample are quite similar: -.17 for union contractors and -.46 for nonunion contractors.

The magnitudes of the union-nonunion differences in the own price elasticity for unskilled labor are also quite large. This elasticity is -.44 for union

Table 6. Factor demand elasticities at mean factor shares, BSU model

	Elementary and secondary schools				Commercial office buildings			
	Pooled	Union	Nonunion	Nonunion -union	Pooled	Union	Nonunion	Nonunion -union
Own price elasticities:								
Skilled	-.259 (.047)	-.147 (.053)	-.376 (.127)	.229 (.138)	-.292 (.052)	-.168 (.066)	-.461 (.096)	.293 (.116)
Supervisory	-1.674 (.615)	-2.123 (.665)	2.094 (2.421)	-4.217 (2.511)	-.999 (.374)	-.034 (.538)	-2.669 (.770)	2.635 (.939)
Unskilled	-1.286 (.242)	-.436 (.315)	-1.055 (.364)	.619 (.481)	-1.336 (.189)	-.953 (.270)	-1.265 (.248)	.312 (.367)
Elasticities of substitution:								
Skilled-supervisory	1.845 (.775)	2.830 (.842)	-.507 (2.711)	-3.337 (2.839)	.262 (.534)	-.282 (.715)	1.728 (.954)	2.010 (1.192)
Skilled-unskilled	1.513 (.294)	.586 (.376)	1.582 (.482)	.996 (.611)	1.517 (.248)	1.112 (.348)	1.570 (.347)	.458 (.491)
Supervisory-unskilled	.960 (3.694)	-2.382 (4.756)	-7.079 (8.844)	-4.697 (10.042)	4.280 (1.891)	1.607 (2.938)	5.486 (2.595)	3.879 (3.920)

contractors in the school sample and -.95 in the office building sample. In contrast, they are -1.06 and -1.26, respectively, for nonunion contractors. Although the estimated standard errors for the union-nonunion difference are not small enough to reject the null hypothesis, the consistency of these results from two different samples is striking.

The results for supervisory labor in the office building sample are also consistent with the relative inelasticity hypothesis. The demand curve for supervisory labor in the union sector is practically vertical, perhaps reflecting foreman requirement rules. In contrast the demand elasticity is about -2.7 for nonunion contractors in this sample. Although this difference is significantly different from zero, it is difficult to reconcile with the results from the school sample in which the union elasticity is -2.1. The nonunion elasticity is positive, but estimated with very little precision.

Elasticities of substitution also generally tend to be smaller in the union sector. The elasticity of substitution between skilled and unskilled labor is near 1.6 for nonunion contractors in both samples. In contrast, this elasticity for union contractors in the school sample is 0.6; in the office building sample, 1.1. However, the hypothesis of no difference in the estimates in the office building sample cannot be rejected. This is also the case for the supervisory-unskilled elasticity in that sample.

The two samples produced conflicting results for substitution between skilled and supervisory workers. In the office building sample the union elasticity is negative (but not significantly different from zero), whereas the nonunion elasticity is 1.7. In contrast, the union elasticity in the school sample is 2.8, whereas the nonunion elasticity was negative.

All the elasticities for supervisory labor for nonunion school construction seem unreliable. The elasticity of substitution between supervisory and unskilled labor is negative and unaccountably large in magnitude, whereas the own price elasticity is positive. If γ_{BB} is too large and γ_{BU} and γ_{SB} are too small, the other nonunion elasticities are also biased because of the homogeneity restrictions. Larger values of γ_{BU} and γ_{SB} would imply either (1) larger own-price elasticities for skilled or unskilled labor or (2) a smaller elasticity of substitution between skilled and unskilled labor.

VII. Is Labor Separable from Other Inputs?

The results in the two preceding sections show the demand elasticities for different types of labor and for labor-labor substitution are lower for union than for nonunion contractors. In contrast, there is no difference by union status in demand elasticities for nonlabor inputs and for substitution between aggregate labor and nonlabor inputs. These results were obtained under the assumption of separability between aggregate labor and nonlabor inputs. The separability assumption requires the elasticities of substitution between the different types of labor and any nonlabor input to be equal. Algebraically, this means $\sigma_{SM} = \sigma_{BM} = \sigma_{UM}$ and $\sigma_{SK} = \sigma_{BK} = \sigma_{UK}$.

Denny and Fuss have developed tests of these restrictions. In this section, I report the results of those tests. They show labor inputs are separable from nonlabor inputs in the school sample but not in the office building sample. I then report union-nonunion elasticity differences for both samples when the separability restrictions are removed. Their removal has relatively little effect on the office building results, but produces estimates in the school sample that are difficult to believe (indicating their imposition was appropriate for that sample).

Denny and Fuss show the translog function is weakly separable between labor and nonlabor inputs if

$$\alpha_S/\alpha_B = \gamma_{SM}/\gamma_{BM} = \gamma_{SK}/\gamma_{BK},$$

$$\alpha_S/\alpha_U = \gamma_{SM}/\gamma_{UM} = \gamma_{SK}/\gamma_{UK}.$$

The determinants of the error covariance matrix with and without these restrictions are used to calculate log likelihood ratio test statistics. These are distributed chi-square with 4 degrees of freedom. The results are as follows:

Sample:	Test statistic:	Significance level:
Office buildings	57.2	.999
Schools	6.5	.835

Weak separability is strongly rejected for office buildings but cannot be rejected for schools. This suggests the LKM model produces misleading estimates of the elasticities of substitution between labor and nonlabor inputs for office buildings. Other elasticity estimates may also be biased by the homogeneity restrictions.

The alternative procedure of estimating a five-factor translog cost system has an equally serious limitation. The data may simply not be up to the task of estimating three different elasticities of substitution between labor and capital and three more for labor and materials, especially with measurement error in the prices of capital and materials.

With this proviso in mind, turn now to the elasticity estimates in Table 7. The five-factor model results for office buildings are similar to those obtained in the previous section. Once again, labor demand elasticities are much lower for union contractors. In fact, the gap between union and

Table 7. Factor demand elasticities at mean factor shares, five factor model

	Elementary and secondary schools				Commercial office buildings			
	Pooled	Union	Nonunion	Nonunion -union	Pooled	Union	Nonunion	Nonunion -union
Own-price elasticities:								
Skilled	-.683 (.112)	-.761 (.150)	-.717 (.227)	-.044 (.272)	-.536 (.099)	-.510 (.140)	-.865 (.190)	.355 (.236)
Supervisory	-.055 (1.169)	-2.989 (.942)	33.830 (7.213)	-36.819 (7.274)	-1.334 (.625)	-.587 (.720)	-3.997 (1.332)	3.410 (1.514)
Unskilled	-.983 (.264)	-.132 (.360)	-.770 (.450)	.638 (.576)	-1.660 (.234)	-.970 (.345)	-1.960 (.355)	.990 (.495)
Materials	-.270 (.062)	-.391 (.089)	-.092 (.159)	-.299 (.182)	-.602 (.081)	-.627 (.114)	-.653 (.173)	.026 (.207)
Capital	-.379 (.053)	-.407 (.060)	-.262 (.107)	-.145 (.123)	-.636 (.432)	-.742 (.476)	-.218 (1.044)	-.524 (1.147)
Elasticities of substitution:								
Skilled-supervisory	.775 (2.778)	1.317 (2.749)	-21.760 (8.685)	-23.077 (9.110)	.272 (1.533)	-1.490 (2.118)	3.660 (2.684)	5.150 (3.419)
Skilled-unskilled	3.272 (.955)	1.742 (1.311)	4.006 (1.324)	2.264 (1.863)	1.761 (.769)	-.368 (1.102)	2.691 (1.127)	3.059 (1.576)
Skilled-materials	.777 (.169)	1.143 (.238)	1.106 (.401)	-.037 (.466)	.686 (.171)	.956 (.246)	.822 (.338)	-.134 (.418)
Skilled-capital	.127 (.340)	.237 (.425)	-.104 (.592)	-.341 (.729)	.434 (1.076)	.730 (1.485)	1.829 (1.746)	1.099 (2.292)
Supervisory-unskilled	-11.796 (12.430)	-2.243 (13.083)	-83.440 (32.973)	-81.197 (35.474)	3.788 (5.445)	-2.665 (8.245)	14.357 (7.930)	17.022 (11.440)

Table 7 (continued)

	Elementary and secondary schools				Commercial office buildings			
	Pooled	Union	Nonunion	Nonunion -union	Pooled	Union	Nonunion	Nonunion -union
Supervisory-materials	.475	4.286	-37.069	41.355	8.003	7.883	10.586	2.703
	(1.679)	(1.660)	(9.924)	(10.062)	(1.303)	(1.516)	(3.142)	(3.489)
Supervisory-capital	5.144	6.543	-4.549	11.092	-74.909	-76.485	-68.634	7.851
	(2.468)	(2.428)	(6.575)	(7.009)	(11.221)	(13.402)	(23.695)	(27.222)
Unskilled-materials	-.076	-.923	.791	1.714	1.823	1.459	2.250	.791
	(.457)	(.693)	(.817)	(1.071)	(.484)	(.736)	(.764)	(1.061)
Unskilled-capital	1.864	2.822	-.244	-3.066	1.084	7.912	-2.896	-10.808
	(.963)	(1.324)	(1.084)	(1.711)	(3.659)	(5.426)	(4.763)	(7.220)
Materials-capital	.308	.192	.701	.509	2.807	2.230	1.290	-.940
	(.228)	(.284)	(.398)	(.489)	(.935)	(1.134)	(1.991)	(2.291)

nonunion elasticities is somewhat larger in the five-factor model, especially for the own price elasticities of supervisory and unskilled labor and all of the substitution elasticities between different types of labor. The absolute value of all nonunion elasticities involving supervisory labor is much larger in the five-factor model. Some are so large, especially the elasticity of substitution between supervisory and unskilled labor, that they cast doubt upon all the nonunion elasticity estimates.

One important difference between the five-factor and BSU model results is that all three types of labor are complements in the union sector. This suggests that jurisdictional rules allow little substitution among different types of labor. Each type of labor is substitutable for materials and two are substitutable for capital, results roughly consistent with the KLM model estimates. Once again, capital and materials elasticities do not differ by union status.

The rejection of separability implies the elasticities of substitution between labor and nonlabor inputs should vary for different types of labor. Recall in Table 4 that the elasticity of substitution between labor and materials for the pooled sample was 1.1. In Table 6 the elasticity between materials and skilled labor is 0.7; between materials and supervisory labor, 8.0; between materials and unskilled labor, 1.8. The larger elasticity estimate for unskilled labor is consistent with the notion of greater economies of prefabrication for simple, repetitive tasks. I have no explanation for the extremely large elasticity estimate for supervisory labor.

The elasticity of substitution between labor and capital for the pooled sample is -1.8. In the case of skilled labor, this elasticity is 0.4; supervisory labor, -75.9; unskilled labor, 1.1. Once again, the relative magnitude of the skilled and unskilled elasticities makes some sense, indicating construction equipment is considerably less substitutable for the former. Apparently the complementarity between supervisory labor and capital is so large that it makes the aggregate labor elasticity somewhat misleading. The magnitude of the supervisory labor elasticity at mean factor share values seems too large to take seriously. When supervisory labor and capital's share are each 10 percent, this elasticity becomes -4.2.

Even though the separability restrictions for schools cannot be rejected, the five-factor model was also estimated over that sample to determine the sensitivity of those results to an alternative specification. A larger nonunion elasticity for unskilled labor and elasticity of substitution between skilled and unskilled labor are the only results at all consistent with the BSU and KLM models. The supervisory labor elasticity estimates are more peculiar here than in Table 6, casting considerable doubt upon the reasonableness of the other elasticities. Since the separability restrictions cannot be rejected for schools, I don't believe the five-factor model results merit serious consideration in this case.

Because of the peculiar values of the elasticities for supervisory labor, a four-factor model in which skilled and supervisory labor were aggregated and examined along with unskilled labor, materials and capital was also estimated. Weak separability of skilled and supervisory labor was strongly rejected for the office building sample ($-2\ell n\lambda = 46.2$) but could not be rejected for schools ($-2\ell n\lambda = 3.6$). The results are fairly similar to those in Table 7 and are reported in Appendix Table A. Weak separability of the skilled-supervisory aggregate and unskilled labor from capital and materials was rejected at about the 90 percent confidence level for both samples ($-2\ell n\lambda = 4.9$ for offices and 4.5 for schools).

VIII. The Cost of Union Work Rules

The above results show own-price elasticities for labor and labor-labor substitution elasticities to be much lower for union contractors. How much of an effect do lower elasticities have on employment patterns, costs and productivity? To illustrate the magnitude of these adjustments, the change in factor allocation in the union sector resulting when wages fall to nonunion levels is simulated, using both union and nonunion elasticities. The quality of union labor available at union wage rates is assumed to be identical to that available at nonunion rates. This allows the results of the simulation using union elasticities to be interpreted as the magnitude of allocative inefficiency resulting from higher union wages minus the magnitude of the technical inefficiency resulting from union work rules. The results obtained with nonunion elasticities solely reflect the magnitude of the allocative inefficiency resulting from union wages. By comparing these two sets of results, the magnitude of the technical inefficiency resulting from union work rules can be determined.

The simulation is based on a commercial office building subcontract in which output, costs of each input and hours of each type of labor equal their union sample means. Wages for all three types of labor are assumed to fall from mean union to mean nonunion values. This amounts to a 22.2 percent decrease for skilled labor, 6.8 percent for supervisory, and 33.6 percent for unskilled. Constant output cross-price elasticities are obtained from the formula

$$\partial \ln X_i / \partial \ln P_j = S_j \, \sigma_{ij} .$$

Since the KLM model found no difference by union status in elasticities of substitution between labor and nonlabor inputs, I base the simulation solely on the BSU model results and ignore changes in capital and materials costs.

In both simulations a fall in wages to nonunion levels results in reduced employment of skilled and supervisory labor and increased employment of unskilled labor. The adjustments are much larger when nonunion elasticities are used, especially for skilled and supervisory labor. Under the union elasticities, the quantity of labor hours demanded increases by 0.8 percent, reflecting a shift from skilled to unskilled labor. Under the nonunion elasticities, the quantity of labor hours demanded actually decreases by 2.4 percent. This implies removal of union work rules would reduce staffing by 3.2 percent. Productivity would increase by the same proportion.

Labor costs for the average union project are $60,907. If wages fell to nonunion levels, costs would fall to $46,706 under union elasticities, a reduction of 23.3 percent. Under nonunion elasticities, labor costs fall to $44,388, a reduction of 27.1 percent. The ratio of labor costs under nonunion elasticities to those under union elasticities indicates that removal of union work rules could reduce labor costs by 5.0 percent and total costs by 2.0 (= 5.0 x .40, where .40 is labor's share of total cost) percent. These results are fairly consistent with the findings of earlier academic studies. Although their magnitude is by no means trivial, they create an impression quite different from that produced by journalistic horror stories or studies by "experts" in the business community. Another way of interpreting these results is that unions are willing to give up 5 percent of their wages in return for a 3 percent increase in staffing.

IX. Unions and Prefabrication

The effect of unions on the use of prefabricated components has already been addressed indirectly in the estimates of the elasticity of substitution between labor and materials reported above. This is far from an ideal test of the hypothesis that union work rules restrict the amount of prefabrication, as

Table 8. Simulations of the effect of reducing union wages to nonunion levels under union and nonunion elasticities for a typical office building subcontract

	Union elasticities	Nonunion elasticities
Percent change in skilled labor hours	-2.2	-4.0
Percent change in supervisory labor hours	-3.4	-57.5
Percent change in unskilled labor hours	11.8	16.7
Percent change in labor hours, total	0.8	-2.4
Percent change in labor costs, total	-23.3	-27.1
Percent change in value added per labor hour	-0.7	2.5

this elasticity also reflects factors such as building design and engineering. A more suitable approach is to compare the usage of prefabricated components for union and nonunion contractors in a sample of technologically similar structures. This can be done for 36 union and 8 nonunion hospitals and nursing homes completed in 1976 and included in a BLS Construction Labor and Material Requirements survey. The survey reports whether each of 15 different types of prefabricated components was used in the project.

There is very little difference in the usage of prefabricated components between union and nonunion contractors, as reported in Table 9. In eight of the 15 cases, union contractors are more likely to use the prefabricated component. Recall that, according to BLS, contractual limits on prefabrication are most widespread for sheet metal workers. Despite these limits, about half of the union contractors used prefabricated air handling ducts and air conditioning equipment and union contractors were more likely than nonunion contractors to use prefabricated underfloor ducts. Thus, there seems to be, even in the case where contractual language is most restrictive, little union impact on prefabrication.

Another way to examine this question is to use probit equations to estimate the effect of unions on the probability that a particular type of prefabricated component is used. This allows the impact of exogenous variables that may be correlated with union status to be held constant. These variables include average hourly earnings, square footage of the building (both in logs), and binary variables indicating region (3), location in an SMSA, whether the building is an addition to an existing structure, whether the building is a nursing home, and whether the building is owned by a government or public agency. The union coefficients for each of these 15 equations are reported in the last

Table 9. Percentage of projects using prefabricated components, by union status, and union coefficents in prefabrication probit equations

Type of prefabrication	Percentage of projects where used		Union coefficient (S.E.)
	Union	Nonunion	
Special prefabricated components			
Pre-cast concrete walls	17	12	-5.783 (12.138)
Air handling ducts	47	75	.485 (1.211)
Air conditioning equipment	56	62	1.623 (1.202)
Pre-cast concrete structural beams or columns	11	0	265.182 (.2E + 14)
Elevators and escalators	58	62	-3.573 (2.580)
Plumbing pipe "trees" or electrical conduit "trees"	3	25	14.388 (7.756)
Communication and alarm systems	42	88	.916 (1.289)
Stock prefabricated components			
Toilet partitions	69	38	1.356 (1.397)
Steel joists	39	25	1.441 (1.289)
Windows	67	88	1.495 (1.439)
Concrete forms	33	25	1.795 (1.307)
Movable or remountable wall partitions	19	12	-.248 (1.455)
Hung ceilings	53	38	3.533 (1.851)
Concrete or metal roof and floor decks	36	38	2.330 (1.434)
Underfloor duct	22	0	4.981 (9.650)

column of Table 9. All but three of these coefficients are positive, indicating greater use of prefabrication by union contractors. The largest coefficients are those for air conditioning equipment, plumbing pipe or electrical conduit "trees", windows, concrete forms, hung ceilings, roof and floor decks, and underfloor ducts. However, most of the union coefficients are smaller than their standard errors, which means that, despite the surprisingly large number of positive coefficients, this evidence cannot reject the hypothesis of no difference in the use of prefabricated components between union and nonunion contractors.

In summary, the direct evidence on prefabrication is fully consistent with the indirect evidence on elasticities of substitution between labor and materials. Both sets of evidence indicate no restrictive impact of union work rules on the choice of materials or the usage of prefabricated components.

IX. Conclusion

There are five major empirical results in this paper:

(1) The elasticities of substitution among different skill categories of labor and the own-price elasticities for each category are much lower in union than in nonunion construction.

(2) The elasticities of substitution between labor and nonlabor inputs and own-price elasticities for nonlabor inputs are about the same in union and nonunion construction.

(3) Labor is separable from nonlabor inputs in school construction but not in office building construction. Even when this lack of separability in the latter case is taken into account, the former results still hold. When separability restrictions are removed in the office building sample, all types of labor income become complements for each other. This indicates occupational jurisdictions

in the union sector may have a large effect on managerial flexibility.

(4) A simulation based on a typical office building subcontract shows that lower factor demand elasticities in the union sector result in excess staffing of 3.2 percent, excess labor costs of 5.0 percent, and excess total costs of 2.0 percent.

(5) Despite contractual provisions limiting prefabrication in some situations, there is no difference in the use of prefabricated components between union and nonunion contractors.

What emerges from this and earlier research by myself and others is the following view of the impact of union work rules in construction. First, these rules are restricted mainly to the allocation of different types of labor and tend to have little effect on the employment of capital or materials. This is consistent with the BLS contract provision data as well as with the field work of Bourdon and Levitt (who emphasize exclusive jurisdiction as the most costly set of restrictions) and Haber and Levinson (who base only one-fourth of their cost estimates on capital and materials restrictions). It is probably not a coincidence that this finding mirrors Freeman and Medoff's results for manufacturing. Second, although the costs of such work rules are not as alarmingly large as journalistic accounts and nonacademic studies suggest, sizable increases in productivity would result from their removal. Third, the forces linking unionism and efficiency are very complex, with tendencies pulling in opposite directions simultaneously. Even with work rules raising costs by 2.0 percent and higher wages raising costs by 9.3 percent (= .4 x .233) in office building construction, my earlier work has shown that productivity is sufficiently higher in the union sector to make unit costs competitive with open shop contractors in some cases. Superior training and reduced hiring costs seem to override the effects of work rules and wages.

Despite these appealing consistencies, these conclusions are subject to two general classes of criticisms. First, the results rely heavily on a particular functional form, the translog. These same issues were also explored with a more restrictive econometric approach, the relative factor input form of the CES. The results, available upon request, showed lower union elasticities of substitution between skilled and unskilled labor but higher union elasticities of substitution between labor and capital for both office buildings and schools. Clearly, work with less restrictive functional forms such as the generalized Box-Cox or the Fourier may yield different results. The frontier cost function approach is also applicable to union-nonunion elasticity comparisons (if you are willing to believe there is no such thing as good luck in construction).

Second, this paper shows some union demand elasticities to be lower and attributed this to union work rules. Since I have not produced an eyewitness account or ballistics evidence, this boils down to guilt by association. One way of "proving" union work rules cause lower elasticities is to compare elasticities across different types of contractors and then see if the patterns match up with those one would expect from the BLS contract provisions data (e.g., lower substitutability between labor and materials in plumbing and sheet metal work). When I tried this with both translog and CES specifications, I found most of the results to be inconsistent with production theory, presumably because the data were being asked to do too much. Another appropriate procedure would be to estimate elasticities on union work covered by project agreements (which usually waive most restrictive work rules) and compare them to those for similar work where the work rules are followed, but no such data are currently available.

Footnotes

[1] "Plan for Construction Productivity Stirs Industry, Takes Aim at Unions," Wall Street Journal, 21 April 1983, Eastern edition.

[2] Demand elasticity comparisons could produce misleading signals about managerial flexibility if the distributions of input prices for union and nonunion contractors did not overlap and elasticities varied with input prices. The former condition does not hold here. Union and nonunion contractors pay the same prices for materials and capital in a given area. Although union contractors do pay higher wages on average, many nonunion contractors pay union scale or above.

[3] Attempts to estimate separate union and nonunion elasticities for particular types of work (e.g., plumbing) were made, but the coefficients were either inconsistent with production theory (e.g., upward-sloping demand curves, all inputs complementary to each other) or much smaller than their standard errors.

[4] For an overview of the results of the entire BR construction productivity project, see BR (1983).

[5] BR (1982a) also dealt with provisions that increase labor costs such as overtime premiums, pay for time not worked, subsistence and travel pay, and shift premiums. The effect of such rules cannot be examined here directly because labor costs are not broken down in any detail. Although these provisions raise the price of labor, they do not generally prevent contractors from making adjustments in factor mixes to avoid such premiums and should have little or no effect on demand elasticities.

[6] Even if an output measure were available, the factor demand decisions of general contractors are not really comparable to those of subcontractors, as

one of their major functions is coordination of the entire project. This is reflected in a larger share of supervisory and administrative labor for general contractors. In the office building sample, seven general contractors hired only supervisory and administrative labor, and for 26 others this type of labor accounted for more than 20 percent of their labor costs.

[7] All of the models were also estimated over individual contractors with positive labor costs. These completely disaggregated estimates are very similar to those reported below and are available upon request.

[8] The values of $-2\ell n\lambda$ are 38.7 for office buildings and 56.7 for schools. Pooling of union and nonunion contractors can be rejected at the 99 percent confidence level in both cases.

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Table A. Factor demand elasticities at mean factor shares, four factor model

	Elementary and secondary schools				Commercial office buildings			
	Pooled	Union	Nonunion	Nonunion -union	Pooled	Union	Nonunion	Nonunion -union
Own-price elasticities:								
Skilled	-.614	-.751	-.849	.098	-.628	-.671	-.906	.235
	(.008)	(.147)	(.222)	(.266)	(.096)	(.130)	(.188)	(.228)
Unskilled	-1.014	-.152	-.888	.736	-1.757	-1.122	-1.991	.869
	(.259)	(.357)	(.438)	(.565)	(.232)	(.342)	(.351)	(.490)
Materials	-.266	-.359	-.385	.026	-.448	-.456	-.499	.043
	(.060)	(.086)	(.138)	(.163)	(.077)	(.109)	(.169)	(.201)
Capital	-.383	-.412	-.225	-.187	-.404	-.444	.152	.596
	(.053)	(.060)	(.109)	(.124)	(.432)	(.474)	(1.048)	(1.150)
Elasticities of substitution:								
Skilled-unskilled	3.064	1.707	3.136	1.429	2.373	.644	3.131	2.487
	(.918)	(1.270)	(1.265)	(1.792)	(.729)	(1.021)	(1.098)	(1.499)
Skilled-materials	.766	1.148	1.125	-.023	.835	1.138	.915	-.223
	(.164)	(.232)	(.382)	(.447)	(.164)	(.232)	(.331)	(.404)
Skilled-capital	.180	.350	-.288	-.638	-.258	-.097	1.586	1.683
	(.333)	(.417)	(.591)	(.723)	(1.019)	(1.365)	(1.709)	(2.187)
Unskilled-materials	-.190	-.941	-.172	.769	1.771	1.091	2.447	1.356
	(.433)	(.674)	(.713)	(.981)	(.470)	(.717)	(.752)	(1.039)
Unskilled-capital	1.812	2.718	-.076	-2.794	.107	7.360	-4.294	-11.654
	(.964)	(1.324)	(1.083)	(1.710)	(3.627)	(5.382)	(4.736)	(7.169)
Materials-capital	.387	.368	.625	.357	.874	-.046	-.358	-.312
	(.227)	(.283)	(.404)	(.493)	(.904)	(1.093)	(1.970)	(2.253)