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UNIONIZATION AND PRODUCTIVITY: MICRO-ECONOMETRIC EVIDENCE

Kim B. Clark

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ABSTRACT

It is widely agreed that unionization affects the rules and procedures governing the employment relation in organized establishments. The effect of these changes on establishment productivity, however, is unclear. Existing evidence is based on a comparison of union/non-union differences in value added per hour worked. Although positive union effects have been estimated, possible differences in prices and technology in the union and non-union sectors render the results inconclusive. The effect of unions on productivity is examined in the present paper using establishment level data from the U.S. cement industry. The cement industry provides a useful empirical framework. Output is easily measured in physical terms, and data on both union and non-union establishments permit estimation of the union effect controlling for differences in technology. The results suggest that unionized establishments are 6-8 percent more productive than their non-union counterparts. This conclusion is supported in time series data, where a comparison of productivity before and after unionization reveals a positive union effect of similar magnitude. Since the statistical analysis controls for capital-labor substitution, scale effects and technological change, the evidence suggests that unionization leads to productive changes in the operation of the enterprise. The results are relatively robust. Specification changes and adjustments for omitted variables leave the basic findings intact.

Kim B. Clark
Harvard Business School
Morgan 5
Soldiers Field Road
Boston, MA 02163
(617) 495-6561

Trade unions have a perceptible influence on the production process in organized establishments.[1] Even a cursory glance through a modern labor agreement reveals the depth of union involvement in the operation of the enterprise. Contract provisions extend beyond matters of compensation and promotion to include the introduction of new technology, the assignment of workers to specific tasks, the size of crews, and the amount of work to be performed. Perhaps more important than specific rules, the typical labor agreement establishes a formal system for setting rules and resolving disputes.

With the extent of union interest and involvement in the production process it seems natural to question the impact of the union on enterprise performance, and in particular on productivity. Yet the question has received little analysis. In the late 1890's and early 1900's Marshall and Moore examined the union productivity effect theoretically, but the ideas they advanced were not followed up with empirical analysis.[2] Without evidence, discussions in the literature rarely rose beyond an inconclusive exchange of opinions.[3] However, in the recent papers by Brown and Medoff, and by Frantz attempts have been made to provide econometric analysis of the union impact.[4] Using value added per manhour to measure productivity, both studies find positive union effects. While the evidence is suggestive, the findings rest on untested assumptions about technology and pricing behavior. Since value added has been used to measure output in these studies, what appears to be an output effect may well be a difference in prices. Moreover, possible differences in technology between union and non-union establishments are not controlled for in the analysis. Brown and Medoff find the empirical results to be very sensitive to assumptions about differences in the parameters of the production process.[5]

This paper extends previous work by relaxing the technology and value added assumptions. The analysis focuses on the effect of unionization on productivity using establishment level data from the U.S. cement industry. The output of a cement plant is measured in physical terms, and data on both union and non-union establishments permit estimation of the union effect controlling for differences in technology. Furthermore, the availability of time series data on productivity before and after unionization makes possible estimation of the union impact while controlling for firm specific effects, as well as changes in labor quality. The paper is divided into five sections. After laying out the analytical framework in section I, the empirical model and the data are briefly described in the second section. Section III presents the basic empirical results, while section IV contains an analysis of firm specific effects and quality adjustments. Conclusions are found in section V.

Section I: An Analytical Framework

The theoretical description of the production process used in this paper is quite simple. Output is treated as a function of capital and labor input, where capital is presumably adjusted for the effects of depreciation, and labor is measured to reflect variations in quality. Given the level of inputs, output may also depend on organizational and institutional factors - i.e. methods of organization, effectiveness of management, and the motivation of workers. Within this simple framework, labor productivity, defined as the ratio of output to labor input, depends on the capital-labor ratio, the scale of operations and the various organizational factors.[6]

Unionization may affect each of these determinants. The traditional channel of influence links the union wage effect to capital-labor substitution.[7] In response to a rise in the relative wage, the firm seeks to raise the marginal product of labor by raising the capital-labor ratio. The net effect, however, is an increase in unit costs and a misallocation of resources. A second channel of influence recognizes that the rules governing the employment relation under trade unions are likely to affect methods of organization and other aspects of the internal operation of the firm.

While the traditional union effect is inefficient, the direction of the organization effect is unclear. If unionization puts pressure on management to improve operations the production process may yield a larger volume of output for any combination of capital and labor.[8] The opposite conclusion holds if unionization reduces motivation or otherwise impedes the effective operation of the enterprise. Thus, both the sign and magnitude of the organization effect are open to empirical question and analysis. The organization effects must be combined with the traditional substitution effects to assess the overall union impact on efficiency.

The link between unionization and the organizational determinants of productivity depends on changes in the labor contract under unions and on adjustments made by workers and management to new provisions. The distinction between changes in the rules of the employment relation, and the resulting changes in behavior which link the contract to productivity has often been overlooked in discussions of this issue. The existence of a rule, on its face inimical to productivity, has been treated as prima facie evidence of a negative organization effect.[9] Yet few contract provisions directly affect the determinants of productivity. Most operate indirectly through changes in incentives which affect the decisions of workers and managers.

Rules, both formal and informal, are common to all work situations.[10] In a non-union setting management generally determines the formal rules governing the terms and conditions of employment. Under trade-unions, the introduction of a mechanism for collective voice affects both the substantive rules governing the employment relation and the procedures for rule making and dispute settlement. Union influence extends beyond mere codification of existing rules. While workers may affect rules in a non-union setting through individual mobility, this channel is indirect and depends on management's ability and willingness to make complex inferences relating contract provisions to turnover.[11] Collective bargaining establishes a more powerful, direct means of influence, and may provide a more effective channel of information about worker preferences and potential trade-offs implicit in alternative contract provisions.

By introducing new procedures and new channels of information, and by altering the substantive rules of the workplace, unionization is likely to lead to changes in the behavior of workers and managers. For workers, perhaps the most significant change is a shift in relative power and increased control over conditions of work. Freeman has argued that the existence of collective voice under unions creates an alternative to "exit" behavior (quitting, absenteeism) and, ceteris paribus, can be expected to reduce turnover, with clear consequences for productivity.[12] Firms with lower rates of turnover are likely to have a higher level of investment in firm specific training, and may have more effective work groups. A similar effect may follow from the use of seniority rules, which tend to be more prevalent in union contracts. In those production processes where skills obtained on the job are important, seniority rules may reduce rivalry among workers and increase incentives for assistance and cooperation.[13] In addition, the arbitrariness inherent in rankings based on management's assessment of ability (or other subjective criteria) may adversely affect workers' perception of their jobs. Introduction of seniority criteria may thus have positive effects on motivation and morale.[14]

For managers, the introduction of a trade union affects the viability of previous methods and procedures. In the face of a rise in the price of labor, and union interest in the production process, management has an incentive to increase the effort obtained from a given level of labor input, and to address aspects of the production process which may have been neglected.[15] The upshot is that collective bargaining may encourage management to take steps to improve productivity. Yet collective voice contains the potential for reducing productivity. The power inherent in the potential for collective action may be used to protect malfeasance and codify reduced work effort.[16] Management's ability to fire undesirable workers may be reduced and the union contract may advance rules which require that work be done more than once, or that restrict managements' ability to adjust to changing conditions. Thus, seniority rules may hinder the effective matching of workers and jobs, and rules limiting displacement of workers may impede the introduction of new technology. The grievance procedure may be abused with numerous petty issues clogging the channels. Instead of providing useful information the day-to-day administration of the contract may result in a disruption of the production process.

It seems clear that the ultimate effect of unionization depends on complex union-worker-management interaction, at the bargaining table and on the shop floor. The direction and magnitude of productivity changes will depend on specific policies and adjustments. These considerations underscore the importance of empirical analysis in resolving the unionism-productivity issue.

Section II: Empirical Analysis of the Cement Industry

The basic problem facing any empirical analysis of the union impact on organizational aspects of the firm is to control for other differences in union and non-union establishments. Among the many potential differences identified in the literature, two have been singled out as deserving of particular attention. The first is the technology of production; the second is the measurement of output. Brown and Medoff have shown that few conclusions can be drawn when union and non-union establishments use different technologies, if those differences are not reflected in the analysis. Moreover, unless output is measured in physical terms, the potential effect of unionization on prices clouds the productivity comparison. These considerations justify the empirical focus adopted in this paper. Cement is one of the few industries in which union and non-union establishments with the same basic technology produce a relatively homogeneous product easily measured in physical units. With data on production in individual cement plants it is possible to control for technological differences and to compare productivity without invoking assumptions about pricing behavior.

Cement is a fine grey powder produced in a highly capital intensive process.[17] The basic flow of production in a cement plant consists of three stages. In the first, stone rich in calcium, silicon, aluminum, and iron is extracted, crushed and ground. The raw material is then fed into a large rotating kiln, fired to about 2700°F, and partly fused into small pebbles called "clinker". In the final stage clinker is ground and mixed with gypsum and other chemical agents to form cements with various strength and drying properties. Cement is produced to generally recognized specifications established by the American Society for Testing Materials.[18] The homogeneous nature of the product and the existence of established product specifications facilitates comparison of the output of different establishments.

The physical characteristics of the product have important implications for the structure of the industry and consequently for the analysis of productivity. Finished cement has a low value-to-weight ratio and shipping costs are a high proportion of the delivered price. The consequence of high shipping costs is a regional market structure. In 1972, fewer than five percent of industry shipments exceeded 300 miles, while close to 60 percent were less than 100 miles.[19] While the regional nature of the industry creates conditions of apparent oligopoly, historically the homogeneous nature of the product and the capital intensity of production have led to intense price competition.[20] Overt attempts to limit competition through a basing point pricing system were declared illegal in 1947, and there is substantial evidence of moderately competitive pricing behavior in the 1960's and early 1970's.[21]

The regional character of the cement product markets is reflected in the structure of collective bargaining where single employer agreements with substantial local negotiations are the rule. The dominant union in the industry is the United Cement, Lime and Gypsum Workers International Union which represents about 75 percent of all cement plants.[22] The UCLGWIU is relatively decentralized, and local and regional officers play a significant role in shaping the substance of negotiations. Slightly less than 9 percent of the plants in the industry are non-union, with the remainder divided among the Steelworkers, joint councils and independent unions. Taken together the regional nature of markets and the decentralized character of the union suggest that the impact of the union may vary by region. The empirical analysis allows for regional union effects, with primary focus on the South and Southwest where most competition between union and non-union plants takes place.

The Data

Since 1919 the Portland Cement Association has conducted an annual survey of association members requesting information on the production of clinker, finished cement, cement shipments, and manhours for each of the respondent firm's establishments. This survey constitutes the basic source of data used in the empirical analysis.[23]

The survey provides annual data on tons of finished cement produced, which is the output measure used here. The data on manhours is broken down by department, permitting the construction of variables measuring production and supervisory or non-production labor input. The supervisory category includes plant management, supervisors, clerical staff and laboratory personnel. The production category includes workers in the quarry, the raw grinding and finishing departments, and the general labor group.

Beginning in 1973 information is available on location, plant capacity, fuel usage, and the installation date and "practical" capacity of individual kilns. The location data permits construction of five regional categories - Northeast, North Central, South, Southwest and West.[24] Total capacity of the plant determines grouping into size categories, which provide an alternative to total manhours as a measure of scale effects. Data on kiln age and capacity have been used to construct a measure of the capital stock in the ith plant in year t given by

$$K_{it}=\sum_j \lambda^{t-j} C_{ijt} \qquad 0<\lambda<1 \tag{1}$$

where C_j is the capacity of kilns of the jth vintage.[25] The adjustment parameter reflects the effects of depreciation, obsolescence and vintage, and is determined empirically by searching for the value which minimizes the error sum of squares in the regression equation.

The data set is completed with information on union status. We initially obtained a record of plants operating under a collective bargaining agreement from the Cement Employers Association. Separate verification of union status was obtained from the staff of the United Cement, Lime and Gypsum Workers International Union. In one situation, the question of union status was answered through direct contact with the plant in question.

Table 1 presents a summary of the sources and definitions of the variables used in the analysis, and compares the cement industry data set with a hypothetical ideal. The ideal analysis would place establishments in the two sectors on a comparable basis by controlling for differences in the amount and quality of labor and capital, the parameters of the production function and returns to scale. In general, the cement data set measures up quite well to this standard. The existence of well known ASTM standards enables us to compare the output of different establishments in physical terms. Productivity and unionization can be examined at the establishment level with controls for possible union/non-union differences in technology. Reasonably good measures of the vintage of the plant and the operating kilns are available, and we have two measures of establishment size which should provide a reasonably good fix on returns to scale.

The principle weakness in the data is the absence of good measures of labor quality. The regional controls capture structural differences in labor quality, but fail to control for any substitution of higher for lower quality labor induced by the union wage effect. However, the likely effect of quality adjustments on productivity can be estimated from time series data on plants which change union status. In a time series context, the labor quality effect not only depends on technology and changes in compensation, but on the extent of turnover as well. Together with an estimate of the union wage effect, information on turnover can be used to determine the extent of bias induced by the omission of quality measures.[26]

TABLE 1

The Cement Industry Data Set and the Ideal

Measurement Issues	Ideal Characteristics	Cement Data Set: Characteristics	Cement Data Set: Definitions (and symbols)
1. measuring output	output measured in physical units; corrected for quality differences	production measured in tons; types of cement defined by official standards	output: tons of finished cement (Q)
2. labor input adjusted for quality	hours per worker adjusted for differences in innate ability	manhours available in unweighted form; no information on personal characteristics of workers; regional differences captured by dummy; check on bias through time series data	production workers: total manhours by production department (L); supervisory: total manhours of plant management, foreman, clerical and laboratory staff (S)
3. capital input adjusted for quality	capital stock adjusted for depreciation, obsolescence, and vintage effects; utilization of stock	capital measured by rated capacity adjusted for maintenance; data available on vintage of capacity; no independent measure of utilization	capital stock in the i^{th} plant: $\sum_j \lambda^{t-j} C_{ijt}$; j indexes vintage (C = kiln capacity)
4. returns to scale	measure of size reflecting proportionate change in all inputs	size measured by total manhours per establishment and plant capacity	size measures: (1) unadjusted capacity(size categories) (2) total production manhours per establishment (L)
5. union/non-union differences in technology	observations on union and non-union establishments	data available on characteristics of union and non-union plants; number of non-union plants is small	Age of plant: $\frac{1}{C_{it}} \Sigma C_{ijt}(t-j)$ vintage: t-age of plant

The Empirical Model

The cement data set provides measures of output (Q) and three inputs: capital (K), production worker hours (L) and the hours of supervisory personnel (S). These data may be summarized, and the effect of unionization measured using standard production function analysis. Output is assumed to depend on the three inputs, and organization factors. Apart from organization effects, labor productivity depends on the capital-labor ratio, the ratio of supervisory to production worker hours, and the scale of operations. Productivity also may differ between union and non-union establishments because of differences in the parameters of the production function. To control for these possibilities, and thus to identify union/non-union differences which stem from organization factors we specify a Cobb-Douglas production function for each sector.[27]

In intensive form, the two production processes may be written as:

$$\ln(Q/L)_k = \ln(A_u) + \alpha_u \ln(K/L)_k + \gamma_u \ln(S/L)_k + (\theta_u - 1)\ln L_k \qquad (2)$$

and

$$\ln(Q/L)_j = \ln(A_n) + \alpha_n \ln(K/L)_j + \gamma_n \ln(S/L)_j + (\theta_n - 1)\ln L_j \qquad (3)$$

where u and n indicate union and non-union respectively, k and j index establishments in the two sectors and returns to scale is given by $\theta = \alpha + \beta + \gamma$, where β is labor's share. The parameter A captures the organizational determinants of productivity, and is assumed to be invariant across establishments within the sector.

Equations (2) and (3) control for union/non-union differences in the production parameters, but within the two sectors, technology and productivity may vary because of vintage and region effects. While the basic production process in cement is much the same today as it was in 1920, changes in technology have increased the extent of mechanization and automation, increased the size and speed of machinery, and significantly altered plant layout and design. Since the vintage of the plant clearly affects the level of productivity, the appropriate union/non-union comparison is between plants of the same vintage. Two approaches to this problem are examined below. We first confine estimation of (2) and (3) to plants with roughly the same vintage. This procedure not only establishes the appropriate union/non-union comparison, but also allows the entire production function to change with the vintage of the plant. A second approach is to specify a common production function, but to allow the union effect to differ by vintage through union-vintage interaction terms.

Interaction terms may also be used to introduce regional union effects. As we noted earlier, cement is priced and sold in regional markets and the pattern of collective bargaining has a distinctly regional character in which local and regional union officers play key roles in determining the nature of labor-management relations. For these reasons we introduce region dummies and allow different union effects in different regions.

If region effects were absent and the union and non-union sectors were technologically identical except for differences in organizational factors, the union impact could be estimated using a simple dummy variable. The organizational differences could be written as $A_u = A_n(1 + b)$, and the coefficient on the union dummy would provide an estimate of b, the productivity differential. In equations (2) and (3), however, the input ratios have different effects on productivity in the two sectors, so that the estimated union effect not only may vary by region and vintage, but also may depend on parameter differences and the level of the input ratios at which the union/non-union comparison takes place. To see the implications of differences in technology, we make use of covariance analysis in which all parameters are allowed to vary between the sectors. Ignoring problems of heteroscedasticity, the union and non-union parameters may be estimated jointly using interaction terms between the basic independent variables and the union dummy.[28] If we confine the analysis to plants of the same vintage, the most general form of the model is given by:

$$\begin{aligned}\ln(Q/L)_i = {} & \ln A_n + bU + (\alpha_u - \alpha_n)\ln(K/L)_i U + (\gamma_u - \gamma_n)\ln(S/L)_i U \\ & + (\theta_u - \theta_n)\ln L_i U + \alpha_n \ln(K/L)_i + \gamma_n \ln(S/L)_i \\ & + (\theta_n - 1)\ln L_i + \sum_k^r (\pi_u - \pi_n)_k REG_k U \\ & + \sum_k^r \pi_{nk} REG_k\end{aligned} \tag{4}$$

where U takes a value of 1 if the plant is unionized and zero otherwise, and REG indicates the region dummies. By specifying the model at this level of generality we can assess the implications of constraining the region and production parameters to be identical.

The coefficients on the interaction terms provide estimates of the difference between union and non-union parameters, while the non-union parameters are given by the coefficients on the regular independent variables. In this formulation the union impact depends on region, the extent of differences in technology and the particular value of the independent variables chosen for comparison. The union productivity effect in the kth region is given by:

$$\begin{aligned}\left[\frac{\partial \ln(Q/L)}{\partial U}\right]_k = {} & b + (\alpha_u - \alpha_n)\ln(K/L)_i + (\gamma_u - \gamma_n)\ln(S/L)_i \\ & + (\theta_u - \theta_n)\ln L_i + (\pi_u - \pi_n)_k\end{aligned} \tag{5}$$

Equation (5) makes clear that if production parameter differences are large, and we ignore them in estimating $\frac{\partial \ln(Q/L)}{\partial U}$, a substantial bias may be introduced. In addition, the choice of comparison values of the input ratios may be of some consequence. In the work which follows mean values will be used in calculations of the productivity effect.

Section III: The Empirical Results

This section summarizes the cement industry data and presents estimates of several variants of the basic model developed in Section II. The means and standard deviations of the variables used in the empirical analysis are presented in Table 2. The data cover the period 1973 - 76 and include 29 non-union observations (9 plants) and 436 observations (119 plants) in the union sector Each plant-year has been treated as a separate observation.[29]

Turning first to data from the complete sample (columns 2 and 3), evidence on average productivity (line 1) in Table 2 reveals that non-union establishments are 18 percent more productive than establishments which are unionized. Part of the reason for the difference is evident in the higher non-union capital-labor ratio (22 percent) in line 2, and the higher rate of capacity utilization in line 3. The non-union sector also has a higher supervisor ratio, but the difference is quite small. Similarly small differences in size are found in line 5, with plants in the union sector about two percent larger.

The importance of controlling for vintage in comparing union and non-union establishments is evident in line 6, which contains data on average kiln age. Unionized establishments are significantly older than the plants in the non-union sector. The difference primarily reflects the almost complete organization of the industry by 1950, and the entry of new plants in the 1960's which have remained non-union. The average kiln age actually understates differences in the vintage of the capital stock. It is common practice in the industry to install new kilns in old plants. Thus two plants of the same kiln age may have very different grinding and crushing equipment, very different plant designs and manning requirements. The problem is especially acute in the case of union/non-union comparisons, since most non-union plants have been constructed since the late 1950's. To more fully

Table 2

Means and Standard Deviations of Productivity and Determinants

Basic Variables	Complete Sample (1) Total (T=465)	(2) Union (T=436)	(3) Non-Union (T=29)	New Vintage Sample (constructed since 1957) (4) Union (T=88)	(5) Non-Union (T=19)
	Mean (std.dev.)	Mean (std.dev.)	Mean (std.dev.)	Mean (std.dev.)	Mean (std.dev.)
1. Average Productivity of production workers (tons per manhour)	2.16 (.82)	2.13 (.81)	2.55 (.80)	3.07 (.86)	2.96 (.78)
2. Capital-labor ratio[a] (adjusted tons of capacity per manhour)	1.91 (1.84)	1.88 (1.88)	2.34 (1.20)	2.88 (1.19)	3.01 (1.15)
3. Average Utilization[b] rate	.86 (.19)	.85 (.19)	.94 (.22)	.88 (.17)	.92 (.27)
4. Supervisor-Labor[c] ratio	.31 (.13)	.31 (.13)	.36 (.14)	.41 (.18)	.40 (.15)
5. Average Cement Capacity (thousands of tons)	566.9 (330.8)	567.8 (333.6)	555.0 (296.9)	594.2 (308.9)	575.5 (341.4)
6. Average kiln age[d]	21.09 (13.01)	21.69 (13.13)	13.21 (8.08)	12.16 (3.32)	8.23 (3.36)

Notes:

a) the capital measure is calculated according to equation (1) with $\lambda = .985$

b) utilization is output divided by cement capacity

c) measured as ratio of non-production manhours to production manhours

d) kiln age is defined as $(\frac{1}{C_{it}})\sum_j C_{ijt}(t-j)$, where C is cement capacity, i indexes plants, t is time, and j indexes vintage correct for differences in the vintage of the plant, we have calculated means and standard deviations for plants built since 1957. The results are presented in columns 4 and 5.

The contrast between union/non-union comparisons based on the total sample and those based on the new plants is instructive. Among new plants, unionized establishments are more productive by 3.6 percent. As in the previous comparison, however, non-union establishments have a higher capital-labor ratio, and operate at higher rates of utilization. The data for newly constructed plants are thus not inconsistent with the existence of a positive union productivity effect. Union establishments are more productive in spite of operating at lower rates of utilization, and with a lower capital-labor ratio. In addition line 6 reveals that even among plants built since 1958, non-union establishments are significantly newer. Taken together these patterns suggest the plausibility of a positive union effect.

Estimates of the Basic Model

The basic model to be estimated has been laid out in equation (4). Several variants of the model are examined in this section, beginning in Table 3 with a version in which all parameters except the intercept are constrained to be identical in the union and non-union sectors. The estimated union effects are average effects across regions under the assumption of a common technology. The equality constraints on the region effects and on the parameters of the production process will be examined subsequently. The analysis in Table 3 does allow for vintage effects, first by estimating the model for the plants built since 1957, and second by using the complete sample and distinguishing between old and new union and non-union establishments. Finer vintage distinctions are not possible given the number of non-union observa-

Table 3

Estimates of the Union Effect with Alternative Controls for Plant Vintage

Specification	Cons	ln(K/L)	ln(S/L)	ln(L)	size dummies	region dummies	union (total)	union (new)	union (old)	non-union (old)	R^2	SEE
1. new plant sample												
a) constant returns	.725 (.114)	.445 (.057)	.110 (.043)	-	-	X	-	.070 (.046)	-	-	.650	.170
b) non-constant returns - total manhours	.883 (.271)	.447 (.053)	.103 (.044)	-.033 (.050)	-	X	-	.068 (.046)	-	-	.651	.170
c) non-constant returns - size dummies	.802 (.133)	.442 (.068)	.090 (.042)	-	X	X	-	.100 (.047)	-	-	.702	.160
2. complete sample with union effects by vintage												
a) constant returns	.353 (.069)	.327 (.021)	.175 (.077)	-	-	X	-	.071 (.056)	-.123 (.055)	-.084 (.087)	.649	.218
b) non-constant returns - total manhours	1.001 (.141)	.328 (.021)	.160 (.030)	-.032 (.027)	-	X	-	.070 (.056)	-.117 (.055)	-.079 (.087)	.650	.217
c) non-constant returns - size dummies	1.035 (.074)	.276 (.073)	.178 (.027)	-	X	X	-	.091 (.055)	-.140 (.053)	-.111 (.084)	.673	.211
3. complete sample with no union-vintage effects												
a) constant returns	.810 (.063)	.384 (.019)	.207 (.028)	-	-	X	-.027 (.045)	-	-	-	.617	.227
b) non-constant returns - size dummies	.933 (.070)	.356 (.022)	.213 (.029)	-	X	X	-.027 (.044)				.630	.224

Note: 1) the capital measure is calculated according to equation (1), with λ=.985

2) regions are defined in footnote 24

3) size categories are based on total cement capacity and breakdown as follows (in 1,000 tons): 0-250, 250-500, 500-750, 750-1000, 1000+

4) old and new are defined as before and after 1957, respectively ; the number of observations in each union-vintage cell are as follows:

	old	new	total
union	348	88	436
non-union	10	19	29
total	358	107	465

tions. Furthermore, since most plants in the industry were unionized by 1950, the data set contains little information about the union differential among older plants.

The results with the new plant sample in line 1 appear to provide a reasonable description of the cement production process among newer plants.[30] The size of the coefficient on the capital-labor ratio is consistent with the capital intensive nature of cement production, and with evidence from the Census of Manufacturers.[31] Other production function parameters are similarly consistent. We find that a 10 percent increase in the supervisor-worker ratio will increase productivity by 1 percent. In addition there is no evidence of a clear relationship between productivity and the scale of operations. The coefficient on total production manhours per establishment in line 1b is quite small, with a large standard error, suggesting that the sum of the output elasticities is not significantly different from one. Moreover, the size dummies referred to in line 1c show no consistent pattern. That does not imply, however, that productivity does not differ significantly between establishments of different size. Empirically, the size dummies provide a significant increase in explanatory power, even though the relationship between size and productivity is not monotonic.

The evidence on the union effect in line 1 supports the view that unionization in the newer plants increases productivity. A positive union effect is found in all specifications. In line 1a, which assumes constant returns, we estimate that unionization raises productivity by 7 percent. The addition of total production manhours in 1b has little effect on the estimated union effect. However, the union impact is significantly larger when size dummies are used to capture scale effects. With size dummies present, we estimate a union effect of 10 percent.[32]

In lines 2a - 2c the model is estimated with union effects by vintage using the complete sample. The results indicate that the older union and non-union plants are both less productive than the newer plants, and not significantly different from one another. The difference between the coefficients in line 2a, for example, is - .038(.070). The size of the coefficient and its standard error is not surprising given the small number of non-union observations. The addition of information from the complete sample does not affect the positive union effect among the newer plants. Under each specification, the estimated coefficient for new union plants is virtually identical to the estimates in line 1. However, when the new and old plants are forced to have the same union coefficient in lines 3a - 3b, the averaging process yields an insignificant negative coefficient and obscures the vintage effects.

Union Effects by Region and Differences in Technology

The estimates of the basic model in table 3 assume no regional differences in the union effect and identical production parameters in the union and non-union sectors. These assumptions are examined in table 4 by introducing region interaction terms (line 1) and by estimating the full unconstrained model with separate coefficients for the union and non-union establishments (line 2). The estimates of the union effect by region in line 1 are based on the new plant sample and cover the South and Southwest since these are the only regions in which new union and non-union plants co-exist.[33] The evidence clearly suggests a substantial difference between the two regions, with the effect in the Southwest much larger. The union effect in the South is negative in two of the specifications, although the coefficient is small, and about one-fifth the size of its standard error. The imprecision in the estimates reflects the few number of non-union observations (4) in the South. More information is available in the Southwest, which contain many of the non-union firms in the industry. The regional pattern evident in table 4 is consistent with one interpretation of the relative prevalence of non-union firms in the

Table 4

The Effect of Technology and Region on the Productivity Effect

Specifications	Cons	ln(K/L)	ln(S/L)	ln L	input-union interaction terms	size dummies	region dummies	region-union interaction terms	Union Effect by Region: South	Union Effect by Region: W/Southwest	Union Effect by Region: North Central	R^2	SEE
1. union effect by region													
a) constant returns	.840 (.169)	.429 (.060)	.119 (.044)	-	-	-	X	X	-.016 (.103)	.092 (.052)	-	.653	.170
b) non-constant returns - total manhours	1.021 (.306)	.431 (.060)	.113 (.045)	-.036 (.050)	-	-	X	X	-.023 (.104)	.091 (.052)	-	.655	.170
c) non-constant returns - size dummies	.938 (.184)	.427 (.070)	.098 (.043)	-	-	X	X	X	001 (.104)	.125 (.053)	-	.705	.160
2. union effect with and without region and technology differences													
a) no region or technology constraints; constant returns	.681 (.095)	.474 (.049)	.121 (.043)	-	-	-	X	-	—	.081 (.040)	—	.681	.172
b) region effects; no union/non-union differences in technology; constant returns	.662 (.117)	.437 (.052)	.135 (.043)	-	-	-	X	X	-.078 (.093)	.110 (.049)	.171 (.098)	.692	.170
c) region effects; separate union/non-union technologies; constant returns	.510 (.209)	.496 (.080)	.055 (.111)	-	X	-	X	X	-.043 (.102)	.111 (.052)	.165 (.106)	.695	.171

Note: (1) the sample in line 1 contains plants built since 1957; the sample in line 2 contains all of the plants in line 1, and adds non-union plants built before 1957

(2) the number of observations by union-region cell are as follows:

	line 1: south	line 1: southwest	line 1: N.C.	line 1: N.E.	line 1: total	line 2: south	line 2: southwest	line 2: N.C.	line 2: N.E.	line 2: total
union	13	38	23	14	88	13	38	23	14	88
non-union	4	15	-	-	19	5	20	4	-	29
total	17	53	23	14	107	18	58	27	14	117

(3) the union effect in 2a is an average over all regions; note that the input coefficients in 2c pertain to the non-union sector (see equation (4)).

Southwest. Given a union wage effect, and the regional nature of markets, union firms in the Southwest may face greater competitive pressure and a more immediate incentive to improve operations and reduce costs.

The effect of relaxing the technology constraint is examined in line 2 where estimates of the union effect from the full unconstrained model are presented (see equation (5)). The estimates are based on the new plant sample with the addition of older non-union plants. The use of all available non-union plants is designed to improve the precision of estimates in the non-union sector. While the use of older non-union plants may bias the union effect, our primary interest is not in specific estimates, but in the change in the union effect when the technology constraint is relaxed. Thus, the estimates in line 2 are to be viewed as no more than illustrative of the impact of specification changes.

In order to provide a basis of comparison, line 2a contains estimates of the model without region or technology effects. The assumption of constant returns has been imposed and is maintained when the region and technology constraints are relaxed. It is clear from comparison with the results in line 1a of table 3 that the use of older non-union plants has only minor effects. The production function parameters are very similar, and the union effect of 8 percent is only marginally higher. It appears that the larger sample conveys much of the same information as obtained when the older non-union plants are excluded. A greater measure of divergence is evident in line 2b where estimates are presented with the regional constraints relaxed. The production parameters are similar to those found in line 1, but the union effect shows greater variation across regions. The most striking change is found in the South, where the union effect is much more negative. The effect in the Southwest is quite close to the sample average, while the North Central estimate is large and positive. As with the earlier results, the union effect in the South is based on relatively few observations and there appears to be a good deal of divergence in productivity among the non-union plants within that region. The result is a large standard error on the Southern effect, so that when the three regions are averaged, the effects in the North Central and Southwest dominate.

In line 2c we present estimates of the model without constraining the production parameters in the union and non-union sectors to be identical. The results provide evidence of no significant differences in technology between the two sectors. Although the union sector emerges with a lower capital coefficient, and a higher coefficient on the supervisor-worker ratio the interaction terms have large standard errors.[34] The union effect by region has been calculated using equation (5) and mean values of (K/L) and (S/L) in each region. The results suggest that technology differences explain little of the union/non-union productivity differential. The estimated union effects in line 2c are very close to the effects estimated with the technology constraint imposed. The evidence thus suggests that constraining the production functions to be identical in the union and non-union sectors does not obscure important technological distinctions, and does not affect inferences about the union effect.

Section IV: Firm Effects and Quality Adjustments

The empirical analysis in section III found unionized establishments to be more productive than their non-union counterparts. The evidence suggests that unionization leads to productive changes in the operation of the enterprise. This conclusion, however, rests on two assumptions. First, the union coefficient only can be identified as a measure of the productivity effect of unionization if we assume the absence of individual firm effects, or that any effects specific to the enterprise are independent of union status and other determinants. Second, it is necessary to assume that quality adjustments are non-existent or small. The statistical design in section III failed to control for union induced changes in worker quality. The union coefficient, therefore, may capture more than organization effects.

These issues have been examined at length in Clark (1979) and will be addressed only briefly here. To estimate the impact of the union holding constant firm specific effects, we make use of data on productivity in six establishments before and after unionization. Information on turnover in each establishment sheds light on the extent of quality differences after the union is introduced, and permits a rough calculation of the bias caused by omission of quality measures.

Productivity Before and After Unionization

Empirical analysis of productivity using time series data on a given establishment requires modifications to the basic model developed in section III. Since the focus is on a change in union status in a specific establishment, controls for region and vintage may be omitted. However, changes in methods of organization and management which improve productivity are likely to occur over time and should be controlled for in estimating the union effect.[35] Assuming that disembodied technological change in the ith firm is of the sample exponential form, the basic model may be rewritten as:

$$\ln(Q/L) = \ln A_o + \delta t + bU_{it} + \alpha \ln(K/L)_{it} + \gamma \ln(S/L)_{it} + (\theta - 1) \ln L_{it} + v_{it} \quad (6)$$

where δ is the rate of technological change, v is the error term and all other variables are defined as before.

As specified in (6), the parameters of the production process are assumed to be identical in each firm, but productivity may vary across establishments because of differences in organizational factors. It is common in production function analysis, for example, to attribute part of any unexplained variation in output to firm specific differences in managerial ability.[36] If specific differences in organizational factors exist, ignoring them may lead to biased estimates of production parameters, including the union productivity effect. Firm specific effects may be held constant by assuming that the error term has the following "fixed effects" structure:

$$v_{it} = \mu_i + \varepsilon_{it}$$

$$Ev_{it} = \mu_i \qquad (7)$$

$$\operatorname{cov}(v_{it}, v_{is}) = E\varepsilon_{it}\varepsilon_{is} = \begin{cases} \sigma_v^2 & \text{when } i = j \text{ and } t = s \\ 0 & \text{otherwise} \end{cases}$$

Under this specification, consistent estimates can be obtained by introducing individual establishment intercepts.

Time series data from the PCA survey has been developed for six cement plants which were unionized in the 1953-1976 period. Since several of the establishments were constructed after 1953, we do not have data on each plant in each year of the period. There is an average of 17 years of data per establishment.[36] Table 5 presents a summary of the estimated union coefficient under alternative specifications. The sign of the union effect is invariably positive, while the exact order of magnitude and precision of the estimate depends on model specification. The evidence supports the conclusion, however, that unionization leads to gains in productivity within an establishment, with the size of the effect ranging from 8-10 percent. These results are not sensitive to adjustments in the model to allow for variation in capacity utilization or other omitted variables.[37]

Quality Adjustments

Both the cross section and the before/after analyses suggest that unionization leads to productive changes in the operation of the enterprise. Yet neither control for possible changes in labor quality. If unionization induces firms to acquire workers of higher quality, the estimated union effect may reflect quality differences as well as changes in organization. While sufficient data is not available to address the extent of union/non-union differences in quality, it is possible to place an upper bound on the potential bias due to omission of quality measures in the before/after analysis.

Table 5

Estimates of the Union Differential Controlling for

Firm Specific Effects

Specification	Firm Intercepts	Union	SEE	D.W.	ρ
1. non-constant returns to scale	✓	.107 (.064)	.179	.89	-
corrected for auto correlation	✓	.104 (.070)	.147	-	.576 (.091)
2. constant returns to scale	✓	.084 (.063)	.181	.83	-
corrected for auto correlation	✓	.103 (.070)	.147	-	.590 (.091)

Source: Adapted from Clark (1979), table 2

Note: The results corrected for auto correlation were estimated with input parameters set at cross section values.

The change in productivity which follows from union induced changes in labor quality depends on technology and the union wage effect. If unionization raises the wage, the firm will attempt to reduce costs by substituting higher for lower quality workers. But a distinction must be made between changing the quality of the workforce and changing workforce productivity. While it is clear that productivity and quality are related positively, the magnitude of productivity change resulting from a change in quality depends on the technology of production. Without precise specification of the way in which workers of different quality interact with each other and with other factors of production few conclusions can be drawn about the extent to which the firm can recover the incremental cost of an exogenous wage increase by hiring workers of higher quality. It is possible, however, to place an upper bound on the change in productivity. In order for the firm to achieve a stable equilibrium, a given change in quality must lead to a more rapid increase in the wage than in productivity.[38] This condition is intuitively reasonable, since if it were not true, the firm could lower unit costs by raising the wage. The implication is that the effect of quality adjustments on productivity is bounded by the union wage effect.

The stability condition can be used to gauge the effect of omitting quality adjustments in the before/after analysis. Assume that unionization raises the wage by ϕ percent. Because of contract rules and associated legal problems the firm is not likely to adopt the optimal overall level of worker quality immediately. Until the workforce has turned over completely, the firm will have old and new workers and the new workers will be of higher quality. The stability condition implies that the efficiency advantage of new workers will be less than ϕ percent. If we assume that unionization does not change the basic technology of production, the effect of unionization on productivity can be written as: $b + hD\beta$, where b is the organization effect as before, h is the efficiency advantage of new workers, D is the proportion of new workers in the workforce and β is the elasticity of output with respect to changes in production labor input.[39] The empirical analysis summarized in table 5 implicitly assumed $hD\beta=0$ so that the union coefficient could be identified as the organization effect. A more realistic upper bound on the quality effect can be estimated from available information on labor's share, the union wage effect, and turnover in the six plants.

Based on the estimation results in table 3, a likely value for β is 0.45. Evidence in Clark (1978) suggests that the union wage effect lies in the range from 12-18 percent. This estimate is based on data on the entry wage, with adjustments for fringe benefits, and changes in job classifications. Since the efficiency advantage of new workers is less than the wage effect, we shall use values of 11 and 16 percent for h in the calculations which follow. As part of a general case study of the effects of unionization in the six before/after plants, information has been obtained on the percentage of the 1976 workforce who were employed at the time the plant was organized (see Clark (1979) for details of the case studies). The average value of D in 1976 was 0.34, with estimates ranging from .05 to .65. This overstates the proportion of new workers relevant for present purposes, since D should be measured by an average value over the sample period. If the rate of growth of D was constant throughout the union era, then the estimated value at the midpoint of the period would be appropriate. Both midpoint and endpoint values will be used in calculations below.

Table 6 summarizes the assumed values of β, h and D and presents alternative calculations of the effect of quality on productivity. These calculations support the conclusion that changes in quality are likely to have had a small effect on productivity. Under the most generous assumptions, quality improvements raise productivity by a little over two percent. Under

Table 6

Calculations of Upper Bounds on the Effect of

Quality Adjustments on Producticity

Estimates of the Quality Effect

Turnover Assumption	(1) Upper Bound Estimates of Union Wage Effect	(2) Lower Bound Estimate of Union Wage Effect
(1) endpoint value	(ϕ = .18; h = .16)	(ϕ = .12; h = .11)
D = .34	q = .024	q = .017
(2) mid point value		
D = .17	q = .012	q = .008

Note: $q = hD\beta$; $\beta = .45$; $h = .9\phi$; ϕ = union wage effect more realistic assumptions about turnover, the effect is close to one percent. Given that these calculations provide upper bounds, the evidence suggests that omission of quality measures introduces at most a small bias into estimates of the union effect in the before/after analysis. Correcting for changes in quality leaves the basic findings intact.

Section V: Conclusion

The empirical evidence suggests that unionization increases the productivity of otherwise comparable establishments. This finding emerges in both cross section and time series data and is relatively robust with respect to model specification. Controls for capital-labor substitution, economies of scale, individual firm effects, technology differences and changes in labor quality have been introduced with only moderate effects on the magnitude of the union differential. Since the traditional channels of union influence have been held constant, we interpret the finding as a measure of the effect of unionization which works through changes in the internal operation of the firm.

The finding of a positive union effect in a particular situation does not warrant the conclusion that unionization raises productivity everywhere, always. Indeed, evidence from the coal industry suggests that the deterioration of industrial relations in that industry in the 1970's led to a significant decline in productivity in unionized establishments.[40] It is evident that the union effect in a particular setting will vary with the character of industrial relations. As Marshall argued long ago, the effect of unionization on productivity depends on union policy as well as management adjustment. Research reported here and elsewhere has uncovered positive union effects, but remains incomplete. The task ahead is to identify the actual channels of union influence and those practices and procedures which yield gains in productivity.

FOOTNOTES

1. The basic reference is Slichter, Healy and Livernash (1960).

2. See Marshall (1899), pp. 381-382, 387; and Moore (1961), pp. 187-189.

3. Bok and Dunlop (1970), pp. 260-261 provide a brief summary of this literature.

4. See Brown and Medoff (1978), and Frantz (1976).

5. The same is true of the value added assumption. Indeed, Brown and Medoff show that if unions have a wage effect and relative cost differences are fully reflected in prices, the estimated union coefficient identifies only a price effect. See Brown and Medoff (1978).

6. The analysis would be unchanged if framed in terms of total factor productivity. The only difference lies in the treatment of factor shares. See Griliches and Jorgensen (1965).

7. The traditional channel is discussed in Johnson and Miezskowski (1970), and the paper by Lewis in Bradley (1959).

8. This effect assumes the existence of unexploited opportunities to increase profits and is therefore closely related to Leibenstein's X-efficiency; see Leibenstein (1966) for an extended analysis.

9. The most prominent example of featherbedding rules are found in the construction and transportation sectors.

10. For a classic statement of these ideas, see Simon (1953).

11. See Freeman (1976) for a discussion of these issues.

12. See Freeman (1978).

13. The effect of seniority on training is discussed in Williamson, Wachter and Harris (1975).

14. Research in organizational behavior suggests that there is no necessary link between morale and productivity. The link between motivation and productivity is quite strong, however, and is affected by workers' perceptions. See Lawler (1973).

15. The neglect of some aspects of the production process is consistent with behavior characterized by bounded rationality and satisficing, rather than full optimization. For an analytical treatment of several satisficing models, see Radner (1975).

16. These issues are dealt with in great depth in Slichter, et.al (1960).

17. For information on the cement industry see Loescher (1959), Lesley (1924), Hadley (1945) and Hilts (1938). An informative booklet on the industry is published by the Portland Cement Association entitled The Cement Industry: An Economic Report (1974).

18. See Loescher (1959), pp. 135-136.

19. U.S. Department of Commerce, Construction Review (June, 1976).

20. Loescher (1959) presents an analysis of pricing practices in the industry.

21. See Clark (1978), pp. 45-48. Beginning in 1960, the industry experienced several years of excess capacity. In the face of increasing supply, the real price of cement fell 25 percent from 1960 to 1970.

22. See Heneghan (1957) for a discussion of the history of the union.

23. The survey covers about 80 percent of the establishments in the industry. While the composition of the sample varies slightly from year to year, there appears to be no systematic variation in participation by region, union status, size or productivity.

24. The regions were defined as follows: North East - Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, Delaware, New Jersey, Pennsylvania, Maryland, West Virginia; North Central - Ohio, Indiana, Illinois, Michigan, Iowa, Minnesota, Wisconsin, Missouri, Kansas, Nebraska, South Dakota, North Dakota; South - Florida, Georgia, Alabama, South Carolina, North Carolina, Virginia, Kentucky, Tennessee, Mississippi; Southwest - Louisiana, Arkansas, Texas, Oklahoma; West - New Mexico, Arizona, Utah, Idaho, Colorado, Nevada, Montana, Washington, Oregon, California.

25. It is important to note that the assumption that all capital is proportional to kiln capacity could result in a biased estimate of the union effect. If, for example, unionization raises the wage-rental ratio, firms will have incentive to substitute capital for labor. In the case where some part of the capital stock is not proportional to kiln capacity, our measure of the capital-labor ratio will understate the true ratio in union establishments, and so lead to an upward bias in the union coefficient. It is our view that this bias is quite small. Given the nature of the production process, the fraction of the capital stock not proportional to the size of the kiln is likely to be relatively small. If, for example, we set this fraction as high as 0.20, and assume a union wage effect of 15 percent, then with an elasticity of substitution equal to one, and a capital share of 0.4, the bias amounts to a little over one percentage point.

26. Brown and Medoff found that measured labor quality explained very little of the variation in productivity in aggregate data. In research in progress Chamberlain has used the Brown-Medoff data to estimate the union productivity effect with a model in which both observed and unobserved components of labor quality were introduced. He found that accounting for unobserved quality differences had little impact on the union productivity effect.

27. The Cobb-Douglas form is restrictive, but useful for its simplicity. Other functional forms leave basic conclusions unchanged. Using a CES specification, for example, we obtain a union effect of .093 (.050) in the Southwest region, and an effect of .015 (.100) in the South. These results should be compared with those in line 1 of table 4.

28. The formulation in (4) assumes that the standard deviations of the error terms in the union and non-union equations are identical. Re-running the equations separately results in standard errors of estimate not significantly different from one another, and consequently little change in the standard errors. of the coefficients.

29. The treatment of each plant year as a separate observation ignores the time series - cross section nature of the data. The most serious problem with the procedure is the failure to take into account firm specific effects which may lead to understatement of the standard errors as well as bias in the union effect. Because union status changes in only one establishment in the 1973-76 period it is not possible to identify both the effect of unionization and individual firm effects. We have assumed that the average firm effect in the union and non-union sector is identical, so that firm effects net out in any union/non-union comparison. We have examined the impact of entering a time trend in the analysis, and allowing for a time-varying intercept through year dummies. Neither of these adjustments affects the results. With year dummies, for example, the average union effect is .068 (.043) compared to .064 (.045) with a trend term, and .070 (.046) in the results reported in table 3.

30. Since gross output has been used to calculate productivity in table 3, the results rest on an assumed proportionality between materials (including energy) and gross output. The assumption is likely to be reasonably accurate for raw material, but there is evidence that the ratio of energy to output has changed quite substantially over the last 10 years. Even if energy use and unionization are uncorrelated, omission of energy may bias the results. As long as energy (or more accurately the ratio of energy to other inputs) is correlated with included variables which are in turn correlated with unionization, the union coefficient will be biased. The sign and extent of the bias will depend crucially on the relationship between the union dummy and the capital-labor ratio.

For example, a regression of ln (K/L) on U using the new plant sample and other control variables from line la, yields a coefficient of -.067 (.080). Assuming that the relationship between energy and capital is positive, as seems likely, the result implies that the omission of energy actually induces a downward bias in the union effect. In any case, given the magnitude of the coefficient, the extent of the bias is likely to be quite small. Similar conclusions apply to the question of bias induced by measurement error in the capital stock.

31. Calculation of the ratio of the wage bill to value added yields a value of 0.30, which implies a capital share of 0.7. Since (value added-wage bill) contains elements which are not payments to capital, this calculation considerably overstates capital's share.

32. The magnitude of the union impact in table 3 is roughly comparable to the estimated change in unit costs arising from the union wage effect. Using data on the entry wage in union and non-union establishments, Clark (1978) finds that rates in unionized establishments are about 12-18 percent higher than in comparable non-union establishments. This translates into an effect on cement costs of about 5-8 percent. With a productivity effect of 7 percent the evidence suggests that unionization has no effect on unit costs.

33. To preserve degrees of freedom, the West and Southwest have been grouped together in table 3 and table 4. In separate runs, these regions had almost identical coefficients; combining the two regions has no effect on the results.

34. The coefficients on the ineraction terms are: -.098 (.108) on the capital-labor ratio, and .055 (.111) on the supervisor-worker ratio.

35. In principle, variation in the utilization of the capital stock should also be included. In practice, controlling for utilization rates has only moderate effects on the estimated union coefficient. For example, under constant returns to scale, introduction of the utilization rate yields a union coefficient of 0.100(.040); when corrected for atuo correlation, the result is .064(.040).

36. There is an average of 8.7 years of data following unionization.

37. It might be argued that abrupt changes in the firm's environment, which raise productivity, may be correlated with unionization. Using data on plants which do not change union status Clark (1979) finds that omitted variable bias of this sort is not important. Controlling for variation in productivity in other plants, the union effect is .092(.046) under non-constant returns, and .069(.043) under constant returns.

38. This result holds in a model in which quality augments the efficiency of labor and in which the wage is an increasing function of quality. See Clark (1979).

39. After unionization the production process is $Q = AK^{1-\beta}(L_o + (1+h) L_n),^{\beta}$ where o and n indicate old and new respectively. We note that $A = A_o (1+b)$, $L = L_o + L_n$ and $D = (L_n/L)$. Pooling union and non union observations we have $\ln (Q/L) = \ln A_o + [b + hD\beta]U + (1-\beta) \ln (K/L)$, where U is the union dummy.

40. These results are based on work in progress by Margaret Connerton, Richard Freeman and James Medoff.

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