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Testing between Competing Models of Wage and Employment Determination in Unionized Markets

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Two models of wage and employment determination in unionized markets are routinely exposited. According to one, wage and employment outcomes are on the firm's labor demand curve; according to the other, wages and employment are on the parties' contract curve. This paper spells out an empirical procedure that discriminates between these two models and applies this procedure to the particular case of the newspaper industry and the International Typographical Union. The labor demand curve model is inconsistent with our data, while the contract curve model comes closer to describing our observations.

I. Introduction

The existing literature in economics on the determination of wages and employment in unionized markets reveals three general approaches to the problem. The first approach can be traced to Dunlop's (1944) seminal work, and it characterizes the union as setting the wage rate to satisfy some objective while the firm responds by deter-

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mining employment according to its labor demand function. Dunlop himself suggested the wage bill as the relevant objective for the union in many circumstances, and it was Fellner (1947) and Cartter (1959), among others, who generalized this to an ordinal objective function involving the wage rate and employment. This approach has had considerable appeal to labor economists because most American collective bargaining contracts appear to grant management considerable discretion over matters concerned with employment.[1] Also, because the position and shape of the labor demand function are the ultimate constraint on trade union behavior, it is well suited to Marshall's (1920) and Friedman's (1951) conjectures about the effects of different types of unions on relative wages, and it lies behind Lewis's (1963) well-known estimates of the relative wage effects of unionism from 1920 to 1958.

This is a conventional model of a monopolist's (the union) setting prices and a buyer's (the employer) reading off his quantities to be purchased from his demand curve. As is the case when price-setting power is exercised on only one side of the market, the wage-employment combination determined by this model lies off the contract curve (save for pathological cases) and, as such, runs counter to a respected tradition in economics that is strongly disposed toward outcomes in which such unexploited gains to trade do not exist.

A second approach to modeling union-management behavior, therefore, yields wage and employment contracts that are Pareto efficient. This approach can be traced to Edgeworth's (1881) model of bargaining and to Bowley's (1928) bilateral monopoly, and, as Leontief (1946) demonstrated, such an efficient solution may result when a union presents management with an "all-or-nothing" wage and employment combination. Although the emphasis placed on self-interest often inclines economists toward disregarding all inefficient solutions, it should be noted that the standard of efficiency used here is one that neglects the transactions costs of negotiating an agreement. In fact, the collective bargaining process is one in which, through threats and guile, each party attempts to conceal its true valuations from the other party, and in such circumstances whether or not the Pareto frontier (defined as excluding these negotiating costs) is attained should not be presumed but should have the status of a testable hypothesis.

These two approaches to modeling union-management behavior present determinate solutions to the bargaining problem but are silent about the process by which these solutions are reached. Put dif-

[1] A perusal of the four most popular American undergraduate labor economics textbooks finds this approach exposited in three of them, while the second approach is not presented in any of them.

ferently, they specify the characteristics of the final outcomes yet say nothing about the convergence over time of a sequence of offers and counteroffers on the part of the union and management. It is toward remedying this neglect of the time-dependent bargaining process that the third approach to modeling union-management behavior is directed. This approach is identified with the work of Zeuthen (1930), Hicks (1932), Cross (1965), and others who drew attention to the formation of each party's expectations about the other party's behavior and to the costs imposed on each party as time passes without agreement having been reached. The problem with the work in this approach has been that a well-defined contract is not normally determined unless certain (unappealing) asymmetries or arbitrary learning assumptions are imposed on the behavior of the bargainers.[2] Hence, while a bargaining model providing a characterization of the dynamic sequence of negotiating moves and concluding with a determinate agreement would considerably enhance our understanding of collective bargaining, no satisfactory model of this type exists at the moment. Consequently, this paper focuses on the first two approaches to wage and employment determination.

The purpose of this paper is to specify for each of these two approaches the particular solutions for the employment contract and to implement them empirically in such a way as to determine the relevance of the one or the other approach in a given labor market setting. Although our procedures could be implemented with data from a number of different labor markets, in this paper we take up the case of the American newspaper industry and its primary labor union, the International Typographical Union (ITU). This choice was determined by several factors. First, the institutional characteristics of the newspaper industry and the ITU render it particularly suitable for an analysis of this sort. These characteristics are spelled out in Section III below. Second, the issue of employment determination has been a recurrent issue of contention between newspaper owners and the union, the employers charging the union with "featherbedding" practices and the union describing them as "job security" provisions (see Porter 1954). Third, the industry's and the union's publications provide an unusually rich source of detailed data that permit the construction of variables corresponding closely to their theoretical concepts. Fourth, both the technological conditions of newspaper

[2] For example, in Cross's (1969) highly original model, at every round of the negotiations, each party assumes that he will not make any further concession, and yet, after having investigated his opponent's offers, each party revises his negotiating position. In Coddington's (1970) words, "each bargainer always trusts himself to stand firm in spite of an unbroken record of failures to do so in the past. Self-deception is rife for each bargainer learns something about the other's behavior but nothing about his own."

production and the issue of wage and employment determination of typographers have already been the subjects of investigation by economists (see, e.g., Rosse 1970, 1977; Dertouzos 1979; Dertouzos and Pencavel 1981; Pencavel 1984*a*, 1984*b*), so there exists a body of research findings on which our work may build.

The following section specifies the objectives assigned to the union and to the firm, and it formalizes the two approaches to determining wages and employment with which this paper is concerned. Section III describes the critical institutional features of the ITU and of the American newspaper industry and introduces the data that are used in the empirical work. The results from this work are presented in Section IV, and conclusions are drawn in Section V.

II. Alternative Characterizations of Union-Management Contracts

A. *The Objectives*

The trade union is characterized as behaving as if it possesses a twice continuously differentiable, strictly quasi-concave, ordinal objective function

$$U = g\left(\frac{w}{p}, L, \frac{w_a}{p}\right), \quad (1)$$

where w measures the money wage rate, p is the price level of commodities consumed by the workers, L is union employment, and w_a represents an alternative wage rate or a wage index that may be relevant to the union when determining its employment and wage choices.

The first partial derivatives of this function with respect to w/p and L are assumed to be strictly positive. Following Leontief (1946), Fellner (1947), and McDonald and Solow (1981), a graphical analysis helps to clarify the difference between the models, and so we graph the indifference curves between w and L associated with the union's objective function in figure 1. The union is assumed to produce such a small fraction of the economy's total output that it may disregard any effect of its decisions on the overall price level, p. This objective function is "the" union leader's, who is assumed to integrate the welfare of all the union's members. This finesse of the well-known problems in aggregating over individual utility functions appears slightly less heroic in the particular case of the ITU in view of the fact that "from a socio-economic point of view [it] is as homogeneous as any group of that size could be" (Lipset, Trow, and Coleman 1956, p. 309).

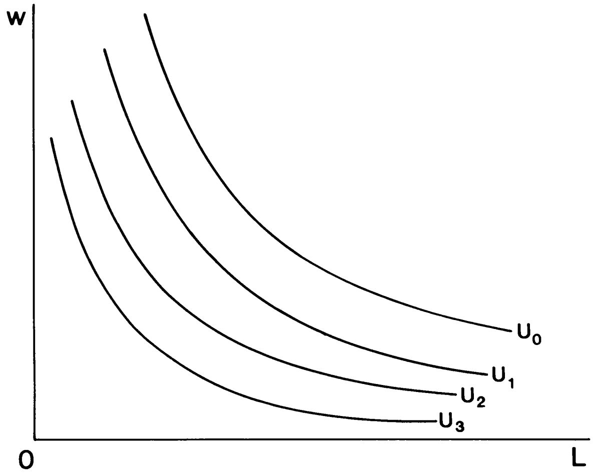

FIG. 1.—The union's indifference map

As for the newspaper firm, it is convenient to characterize it as producing $n + 1$ different dimensions of output, with the level of output of each given by $X, Y_1, \ldots, Y_n$. Here X represents output from the composing room of the newspaper, which is that stage of the production process in which typographers work. We posit for the firm a very general objective, namely, the maximization of the function V:

$$V = f(X, Y_1, \ldots, Y_n, C, C_o), \qquad (2)$$

where C denotes the costs incurred in producing X, C_o stands for all other costs, and different product market conditions imply different expressions for f. Function V is assumed to be strictly increasing in X and in each Y_i and strictly decreasing in C and C_o. The costs from operations in the composing room are given by $C = wL + \Sigma_i R_i K_i$, where L represents the number of typographers employed, w their wage rate, K_i the level of input i used, and R_i the given rental price of one unit of input i. This objective function, equation (2), is consistent not merely with conventional cost minimization and profit maximization, but also with certain "managerial" theories of the firm. The advantage of writing the firm's objective in this fashion arises from the fact that the typographer's work in the composing room represents one stage in the chain of a newspaper's production, and, while the composing room's output is not explicitly sold to the stereotyping room and to the pressroom, the integrated newspaper firm nevertheless places a corresponding *implicit* value on the output from the composing room. Under conditions that will become evident, our analysis may focus exclusively on the activities of the composing room or, equivalently, on the behavior and technology involved in producing the output X.

Suppose that changes in the employment of typographers and of m other inputs affect the composing room's output X through a conventional production function $X = X(L, K_1, \ldots, K_m, Y_1, \ldots, Y_s)$, where $Y_1, \ldots, Y_s$ represent intermediate inputs produced by other components of the newspaper that are needed to produce X. With this specification of $X(\cdot)$, changes in L or in the K_j's affect V or the profitability of the firm only through their impact on X. The equation defining combinations of w and L that yield the same value of V (i.e., the firm's indifference curve) is $dw/dL = -[(\partial f/\partial X)(\partial X/\partial L) + w(\partial f/\partial C)]/[L(\partial f/\partial C)]$, which depends on the particular expression for f. For an important class of objective functions (including profits), the firm's indifference curves will have the shape given in figure 2—a positive slope with respect to L until $-(\partial f/\partial X)(\partial X/\partial L) = w(\partial f/\partial C)$ and then a negative slope.[3] In the graph, $V_0 > V_1 > V_2 > V_3$. The dashed line L^d connecting the maximum points on each of the indifference curves denotes the firm's optimal level of employment for given values of w. In other words, L^d is the firm's labor demand curve.

B. *Alternative Models*

According to the first approach to the determination of wages and employment in unionized markets, the firm selects its optimum use of labor and other inputs for any configuration of input prices while, subject to these decisions by the firm, the union sets the wage rate to maximize the value of its objective function, equation (1). For inputs used in positive amounts, the firm's first-order conditions for the maximization of equation (2) are as follows:[4]

$$\begin{aligned} \frac{\partial f}{\partial X}\frac{\partial X}{\partial L} + \frac{\partial f}{\partial C}w &= 0, \\ \frac{\partial f}{\partial X}\frac{\partial X}{\partial K_j} + \frac{\partial f}{\partial C}R_j &= 0, \end{aligned} \tag{3}$$

or, combining the two equations,

$$R_j\left(\frac{\partial X/\partial L}{\partial X/\partial K_j}\right) = w. \tag{4}$$

All equilibrium combinations of w, L, and K_j must satisfy first-order condition (4) so that at all times the firm is on its V-maximizing input

[3] See Fellner (1947) and McDonald and Solow (1981) on the shape of the firm's indifference curves when it maximizes profits.

[4] For both models of wage and employment determination, the second-order conditions for a maximum are assumed to be satisfied.

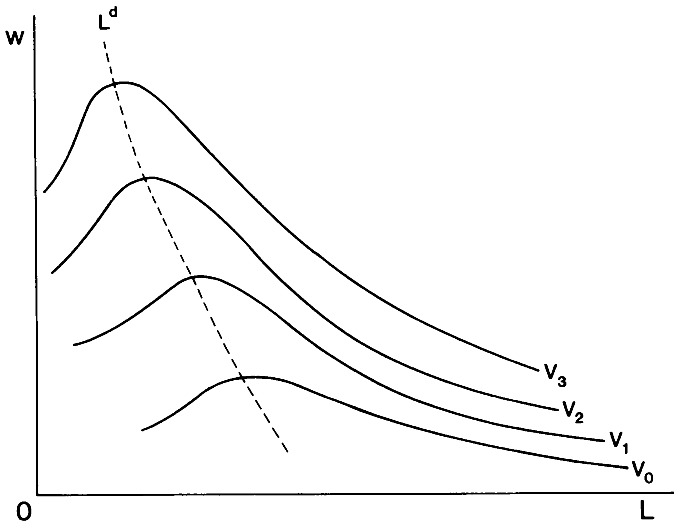

FIG. 2.—The firm's indifference map and labor demand curve (L^d)

demand curves (though at points different from those that would obtain if there were no union setting the wage rate). In recognition of this, we designate this characterization of union contracts as the *labor demand curve equilibrium model* (LDEM). One important special case, of course, occurs when V represents profits and the firm is always on its profit-maximizing input demand curves. The LDEM has the property that all inputs are employed such that, in the production of any output, the ratio of their marginal products equals the ratio of the prices, and it is this property that is exploited in the empirical analysis below.

The union's policy is to set w to maximize equation (1) subject to the satisfaction of the firm's marginal conditions such as equations (3).[5] Equilibrium in the LDEM is defined by point A in figure 3, where w_r is the wage that would exist in the absence of the union. Of course, insofar as the union sets the wage rate above the transfer price of labor, then some mechanism such as long apprenticeship programs, high entrance fees and dues, or nepotism must be adopted to ration employment among those offering themselves for work. On the other hand, because employment is always adjusted such that the marginal value product of labor is equal to the union-determined wage rate, this sort of employment contract should *not* be characterized by work practices such as make-work and featherbedding.

[5] One way to think of the inefficiency of the LDEM is as the outcome of a standard principal-agent problem: w and L appear in the objective functions of both parties and the principal (the union) sets w, but it cannot prevent its agent (the firm) from determining L according to the agent's own interests.

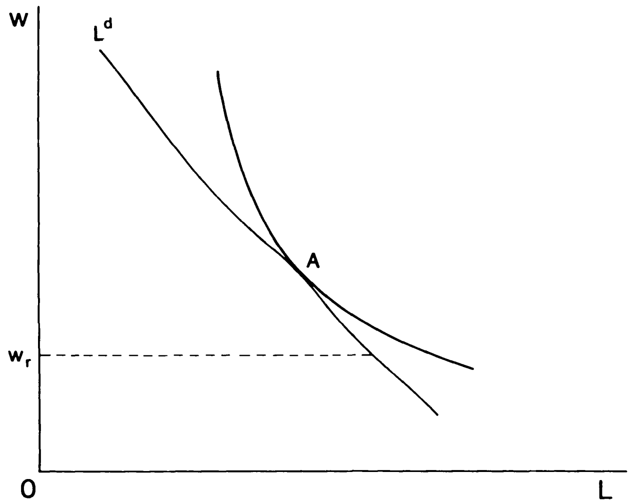

FIG. 3.—Equilibrium in the labor demand curve equilibrium model

The second approach to the bargaining problem has the union and the employer explicitly or implicitly entering into agreements such that the wage-employment combination lies somewhere on their contract curve, and, from the point of view of the parties (but not necessarily of society), the contract is Pareto efficient. We label this the *contract curve equilibrium model* (CEM). The contract curve is defined by the locus of the points of tangency between the union's and the employer's indifference curves as illustrated by the line *CC'* in figure 4. The contract curve can take a wide variety of shapes as shown in figure 5, the relevant shape and range depending on the particular forms of the objective functions of the union and the firm.[6] In some research, the shape of the contract curve is presumed to take one of the three possibilities drawn in figure 5, and typically the results of this research depend crucially on the form of the contract curve presumed.[7] By contrast, the empirical work in this paper is consistent with the contract curve's taking any of the three shapes in figure 5.

The expression for the contract curve may be derived by charac-

[6] In fig. 5 we have drawn the contract curves as originating at the wage-employment combination that would exist in the absence of the union. This arises when the union's indifference curves are horizontal at w_r and when the union's threat point is given by w_r.

[7] For instance, some authors maintain the hypothesis that the contract curve is vertical. If this is the case, then a test of whether wages and employment are determined by the CEM consists in whether the partial correlation between wages and employment is zero. Unfortunately, a finding that the partial correlation between these variables is not zero is consistent with the hypothesis that contracts are efficient, but the contract curve is not vertical. Indeed, this alternative explanation is consistent with our empirical results below, which reject the special case of a vertical contract curve.

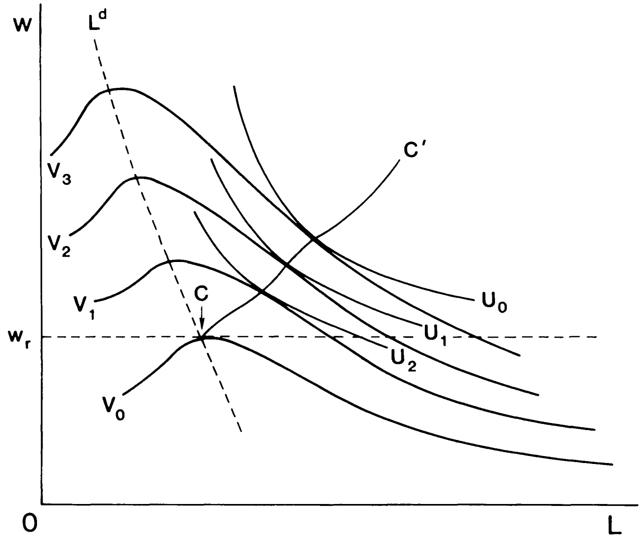

FIG. 4.—The contract curve CC'

terizing w, L, and each other input being selected such that the union's objective function, equation (1), is maximized subject to a given level of V for the firm's objective function, equation (2). In this analysis it is important to keep in mind that we are assuming that the firm operates on (not inside) its production frontier. As before, with changes in the employment of typographers and of another input j

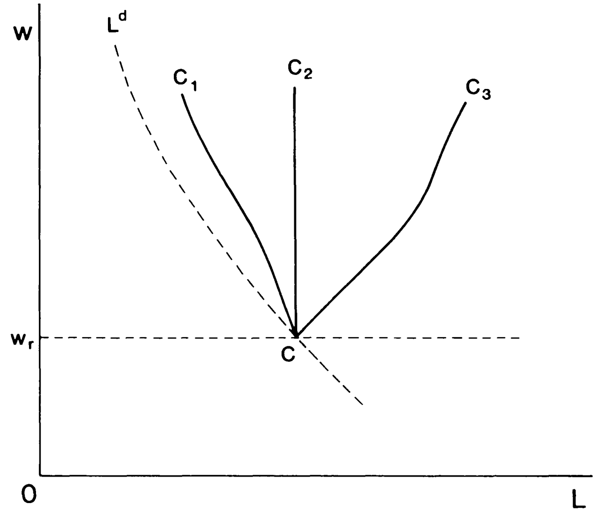

FIG. 5.—Alternative contract curves

affecting V only through the production of X, the first-order conditions for CEM include the following:

$$g_\omega = p\lambda \frac{\partial f}{\partial C} L,$$

$$g_L = \lambda\left(\frac{\partial f}{\partial X}\frac{\partial X}{\partial L} + \frac{\partial f}{\partial C} w\right),$$

$$\frac{\partial f}{\partial X}\frac{\partial X}{\partial K_j} = -\frac{\partial f}{\partial C} R_j,$$

where $g_\omega = \partial U/\partial(w/p) > 0$, $g_L = \partial U/\partial L > 0$, and λ is the Lagrange multiplier, which is equal (at the optimum) to the slope of the payoff frontier. Using the first two equations to eliminate λ and combining this expression with the third equation yields the relation

$$R_j\left(\frac{\partial X/\partial L}{\partial X/\partial K_j}\right) = w - pL\frac{g_L}{g_\omega}. \tag{5}$$

Because the term pLg_L/g_ω is strictly positive, inputs are *not* being employed such that the ratio of their marginal products equals the ratio of their input prices; instead, labor is employed such that the marginal product of labor to the marginal product of input j falls short of the ratio of the wage rate to the price of input j. Expressed differently, the union is obliging the firm to employ more workers than it would otherwise choose to do at the negotiated wage, and these "superfluous" workers may be accommodated through minimum crew sizes and featherbedding arrangements.[8] Also, a wage rate in excess of the transfer price of labor will require some mechanism to ration employment among those offering themselves for work (just as in the case of the LDEM). In other words, the CEM will be characterized both by devices to restrict entry into union employment and by rules that serve to absorb the excessive number of workers employed (excessive, that is, given the relationship between marginal products and input prices). The presence of restrictive work practices, therefore, is not some haphazard or incidental element of various labor contracts but rather a distinguishing feature and an integral property of a particular class of models of wage and employment determination in unionized markets.

With the structure thus imposed on the problem so far, equation (5) could be satisfied with a number of different combinations of wage rates and employment, each combination distinguished by the property that the welfare of one party can be improved only at the cost of

[8] Here our use of the term "featherbedding" corresponds to a situation not where the marginal revenue product of labor is zero but simply where the marginal revenue product of labor falls short of the wage rate.

some reduction in the other's welfare. To determine which single combination of these many efficient wage and employment exchanges will obtain requires the introduction of particular behavioral postulates that yield specific solutions (such as Nash's proposed solution). It is important to recognize, however, that equation (5) applies to all specific solutions of the CEM.

C. *Means of Testing the Models*

First, let us consider if there exist inclusion or exclusion restrictions that allow us to determine from equation (5) whether labor market contracts are efficient. Unfortunately, with respect to each of the variables w/p, L, and w_a/p, no such inclusion or exclusion restrictions are implied unless strong assumptions are imposed on the nature of union objectives. For instance, w may be included in equation (5) or it may be excluded: if we were willing to maintain the hypothesis that the union's objective function is given by $U = [(w/p) - \delta(w_a/p)]L$ (i.e., a form of rent maximization), then w is excluded from equation (5) and the contract curve is vertical. This objective function also leads to a situation in which L does not enter relation (5). However, there are no compelling a priori reasons or persuasive empirical evidence to assume such a special form for the union's objectives, and so, in general, neither w nor L is excluded from equation (5). Consider, further, the role of the alternative wage variable, w_a. Clearly, if w_a is not an argument of the union's objective function, then w_a is absent from equation (5). Of course, such a situation does not imply that the negotiated solution of w and L in the CEM is unaffected by w_a because the union's threat point is likely to be a function of this variable. Even if w_a directly enters the union's objective function, it need not be included in the first-order condition given by equation (5). As an illustration, suppose $U = \phi(L)(w/w_a)^{\xi}$, where ϕ is some monotonically increasing function of employment. In this case, g_L/g_ω is independent of w_a, and consequently the alternative wage does not enter the first-order condition of the CEM considered here. In short, the absence of w_a from equation (5) does not permit us to infer that employment contracts are efficient.[9] In general, the CEM cannot be tested in a particular labor market context by determining whether any of the variables w/p,

[9] This conclusion stands in sharp contrast to Brown and Ashenfelter's (this issue) arguments. They base their empirical work on determining whether w_a enters into eq. (5). They assume that the left-hand side of eq. (5) represents the marginal revenue product of labor and specify an expression for it. They then explore whether this expression is correlated with various measures of w_a, arguing in the context of eq. (5) that "at a minimum, however, it is clear that in any efficient bilateral contract, the alternative wage rate must determine, at least in part, the marginal revenue product of employment." By contrast, we have argued that the absence of w_a from eq. (5) does not allow us to reject the CEM.

L, and w_a/p are either included or excluded from equation (5)—no such inclusion or exclusion restrictions are implied.

Now let us consider whether exclusive restrictions exist to test the LDEM. In fact, it is straightforward to observe that equation (4) characterizing the LDEM is a special case of equation (5) describing the CEM, namely, the special case in which the term $-Lpg_L/g_\omega$ is absent. In other words, through a specific exclusion restriction, equation (5) nests the LDEM as a special case, and, by subjecting this exclusion restriction to conventional testing procedures, equation (5) becomes potentially a very fruitful form for discriminating between the CEM and the LDEM in any particular labor market context. It should be noted, however, that this procedure will discriminate between the CEM and the LDEM only if $g_L > 0$ and $g_\omega > 0$. Thus, in terms of figure 1, if the union's indifference curves are horizontal straight lines (the union cares only about wages and not about employment), then all wage-employment combinations lie on the labor demand curve. This illustrates once again the fundamental point that ultimately a rigorous test of the CEM depends on the specification of the union's objective function.

Observe that both models have been set up in such a way that they describe the newspaper firm's behavior *within* any given stage of the multistage process of producing a newspaper, and for their application equations (4) and (5) do not require information on outputs or factor inputs in other stages. This is important because typographers (the labor represented by the ITU in the union locals used in our empirical analysis) are employed at one such stage, namely, in the work undertaken in the composing room, so the relevant marginal products in equation (5) relate to the production technology within the newspaper's composing room. We turn now to consider the specification of the composing room's production technology and also to describe the critical institutional features of the ITU that affect the appropriate form for the union's objective function.

III. The Institutional Setting

The data used in this paper to test between the LDEM and the CEM consist of annual observations on wages, employment, and other variables describing the members of the ITU and the daily newspapers for 13 American towns in various years from 1945 to 1973. These data were compiled for this particular study and are a different set of ITU locals from those used in previous analyses of this labor market.[10] The major data problem relating to this industry has always

[10] The data collected by Dertouzos (1979) and used in Dertouzos and Pencavel (1981) and Pencavel (1984*a*, 1984*b*) form the basis of the observations also used by Brown and

been the generation of an accurate series on the employment of typographers in the production of newspapers. In previous work, this problem was handled by not using observations on very large cities (such as New York, Boston, and Chicago) that have major book and job establishments so that the local ITU membership data were likely to be dominated by ITU members working in newspapers rather than those employed in commercial (book and job) printing establishments. Further investigation of this issue by James Dertouzos of the Rand Corporation, who has corresponded with a number of ITU locals, indicates that the association between local ITU membership and newspaper employment is closest for the smallest locals. For this reason we restricted ourselves in this study to such locals and compiled a new data set for these locals only. These locals are listed in table 1, and their membership (L) ranges from a high of 59 for Pittsfield, Massachusetts, to a low of 21 for Boone, Iowa.

Table 1 also provides information on the mean values of the other variables that differ across union locals used in this study. Variables K_1 and K_2 are, respectively, the number of typesetters and teletypesetters, which constitute the capital inputs used in the composing room of the newspapers listed, while X denotes each newspaper's annual advertising linage sold. The hourly contract wage (w) for our sample of observations averages $2.62, although the range is almost $1.00—from an average of $2.16 for Salina, Kansas, to $3.12 for Butte, Montana. This illustrates the considerable variation in typographers' wage rates across cities, and a full explanation for this variation for a group of workers with very similar skills and other characteristics from city to city has yet to be provided. The difference between the real hourly wage of typographers and the real hourly earnings of production workers in the durable goods manufacturing industry is given in table 1 by the column headed $(w - w_a)/p$. In all cases, the typographers enjoyed a wage premium over that received by workers in the durable goods manufacturing industry, although the size of that premium varied across cities.

The characteristics of the ITU make it an almost ideal union for the purposes of a study of this kind. The structure of the ITU is highly decentralized, and collective bargaining takes place at the local level. A national or regional minimum wage has never been established, and in any year there exists the opportunity for the researcher to construct a number of observations on many different bargaining

Ashenfelter (this issue). These data cover both very small union locals and medium-sized locals, and previous analysis found significant differences in the objective functions between these union locals. Moreover, James Dertouzos has advised us that he believes some of these observations may contain serious measurement errors. For these reasons we collected a completely fresh data set and restricted it to relatively small union locals.

TABLE 1

CHARACTERISTICS OF THE SAMPLE OF OBSERVATIONS

Union Local	Newspaper(s)	Number of Observations	Mean Values						
			L	K_1	K_2	X	w	w/p	$(w - w_a)/p$
73. Ottumwa, Iowa	*Courier*	18	29.1	9.8	0	7,534	2.20	2.64	.34
149. Saratoga, N.Y.	*Saratogan*	19	29.5	9.8	0	4,145	2.31	2.86	.61
163. Superior, Wis.	*Telegram*	21	48.9	10.7	2.2	6,331	2.56	3.00	.62
586. Greeley, Colo.	*Tribune*	20	31.6	7.6	.5	7,970	2.40	2.82	.47
735. Casper, Wyo.	*Star-Tribune*	23	34.8	7.4	2.0	8,994	2.57	3.08	.75
108. Hagerstown, Md.	*Herald* and *Mail*	26	38.8	10.0	2.0	19,850	2.69	2.92	.49
576. San Luis Obispo, Calif.	*Telegram-Tribune*	27	26.2	5.8	.4	5,511	3.09	3.40	.96
381. Boone, Iowa	*News Republican*	26	21.2	6.8	.8	3,212	2.43	2.62	.14
126. Butte, Mont.	*Montana Standard*	19	66.8	12.8	1.6	12,448	3.12	3.55	1.17
134. Paducah, Ky.	*Sun-Democrat*	25	37.7	12.2	.9	10,726	2.71	3.02	.60
109. Pittsfield, Mass.	*Berkshire Eagle* and *Sampler*	15	58.6	17.7	3.7	11,756	2.76	3.22	.79
638. Salina, Kan.	*Journal*	20	36.2	9.1	2.5	7,846	2.16	2.62	.35
365. Nashua, N.H.	*Telegraph*	20	28.1	9.4	.8	8,377	2.90	3.12	.63
All cities together		279	36.5	9.6	1.3	8,844	2.62	2.99	.60

NOTE.—The data on L are taken from various issues of the *Typographical Journal*. The data on w relate to hourly wage rates for day work and are constructed by dividing the weekly contract wage by normal hours of work as given in issues of the *ITU Bulletin* (and in some cases in the *Typographical Journal*). The observations on typesetters (K_1) and teletypesetters (K_2) are from issues of *Editor and Publisher International Yearbook* and *Editor and Publisher* magazine. *Editor and Publisher* also served as the source for the advertising linage (X) data. The typographers' hourly wage rate divided by the consumer price index is given by w/p, while the difference between this real wage and the real hourly earnings of production workers in durable goods manufacturing is given by $(w - w_a)/p$. The data on p and w_a are taken from well-known published Bureau of Labor Statistics sources. Finally, the number under the column "union local" is simply the ITU's local identification number.

units. The ITU is a highly democratic union in which many members have occupied some union office at one time and in which a large fraction of the membership participate in elections and referenda on a number of different issues. Moreover, there are no important skill differentials within the union.[11] Consequently, there is no compelling case in the ITU's objective function for distinguishing between the interests of the union leadership and of the rank and file or between the interests of different groups within the rank and file.

As we have already noted, our analysis assumes production to be efficient; that is, production takes place on and not within the production frontier.[12] This may not be an innocuous assumption according to some interpretations of the effects of the ITU's control over employment and conditions of work. The regulation whereby a standard advertisement carried nationally is "unnecessarily" reset by union locals, a so-called bogus rule, has received special attention, although the extent to which practice actually conforms to this rule is uncertain, and it is likely to be of little consequence for our work with small newspapers. The reasons for this are twofold. First, for the very small newspapers in our sample, national advertising represents no more than 10 percent of all advertising linage. Second, the procedure is such that the bogus rarely gets set. The items awaiting to be reset by the bogus rule are put aside until work slackens and there is ample time to attend to it. According to the jargon, the bogus material sits on the "hook." There are local rules about the length of time that bogus material sits on the hook—sometimes 1 month, sometimes 3 months, sometimes 6 months—before being destroyed. It is not unusual for bogus material to be destroyed without ever being reset. Moreover, it may well become a bargaining chip between the management and the union whereby the union will ask for a few cents more on the contract wage in return for destroying the inventory of bogus on the hook. In other words, the employer buys out the bogus.

The Taft-Hartley Act notwithstanding, the ITU operates a closed shop whereby all individuals hired for work in the composing room are drawn from the pool of union members. Its concern with the employment effects of new technology is well known, and, indeed, today its very existence as an organization of highly skilled workers whose lineage can be traced back to the medieval guilds is threatened by the diffusion of typesetting computers, which eliminate many of

[11] A fascinating analysis of these characteristics is found in the classic study by Lipset et al. (1956).

[12] Production is thus assumed to be efficient, but we do not assume wage-employment contracts to be efficient (i.e., to be on the contract curve). The two concepts of efficiency are quite distinct.

the special skills once required for printers.[13] This radically new technology is not represented in our data set, but other, less drastic, changes in the composing room's operations did take place during the period under study.

Newspaper type can, of course, be set by hand, though this practice largely disappeared during our period of study except for the setting of some headlines or large display advertising. Otherwise, composition was by typesetting machine with which a skilled operator can produce solid lines of leaden words and assemble them automatically into columns. The next mechanical advance was the teletypesetter, which requires less attention from specialized labor. Here a worker uses a keyboard similar to a typewriter to punch copy onto a tape. This is then fed into the composing machine, which automatically sets the type. Teletypesetters can be used together with the old typesetters, and, indeed, there is some anecdotal evidence to suggest that this combination is desirable (see Rucker and Williams 1969, pp. 76–77). The next development in mechanical composition, the phototypesetter, which uses photographic processes, did not make an appearance for any observations in our sample. As is evident from the descriptive statistics in table 1, typesetters were far more common to our data set than the teletypesetters, and, indeed, for some newspapers in the earlier part of our period, no teletypesetters were used.

According to the technology that dominated our sample of observations, the news and advertising departments would send their copy to the composing room, and this copy would be set by machine and by hand and assembled in steel chases (frames). After proofing and "making up" (i.e., the final reorganization to adjust the various news and advertising items to fit each page), the chases would be sent to the stereotyping room in the case of newspapers with larger circulations or straight to the pressroom in the case of smaller daily and weekly newspapers. The activities of the composing room, therefore, represent one step in the multistage process of producing a newspaper so that, if Y_1 represents the copy or output of the news and advertising departments, then the composing room's output, X, is produced according to the function $X(L, K_1, K_2, Y_1)$. Because all of Y_1 is typecast by the composing room, X is simply proportional to Y_1, so the relevant production function for our analysis is simply $\tilde{X}(L, K_1, K_2)$, and the model outlined in Section II (as was argued there) may be applied to the operations within the composing room.

[13] The parlous consequences of this new technology for the ITU are illustrated in Rogers and Friedman (1980).

IV. Empirical Analysis

A. *The Production Function*

The estimation of the stochastic version of equation (5) requires knowledge of the marginal products of each of the inputs into the production of the composing room's output. Therefore, the first step of our empirical research consisted in determining an accurate representation of the production technology, and we considered many specifications. Much of this research involved estimating production functions of the form

$$\ln X = \sum_j \beta_j D_j + \mathbf{Z}\boldsymbol{\alpha} + \epsilon, \tag{6}$$

where D_j is a dummy variable taking the value of unity for newspaper j and of zero otherwise, X is the amount of advertising linage sold annually, $\mathbf{Z}$ is the vector whose elements are known functions of inputs, the coefficients β_j and $\boldsymbol{\alpha}$ are parameters, and ϵ is an error term representing the effects of omitted variables. To carry out this empirical analysis of the production technology we employed a comprehensive data set consisting of outputs and inputs associated with composing room activities for 13 newspapers for various years between 1945 and 1973.[14]

Extensive work was undertaken on investigating alternative functional specifications of the production relationship. We started by considering a simple Cobb-Douglas technology after allowing for fixed differences between the 13 newspapers. In particular, in terms of equation (6), we set $\mathbf{Z} = [\ln(L), \ln(K_1 + 1), \ln(K_2 + 1)]$ and $\boldsymbol{\alpha}' = (\alpha_L, \alpha_1, \alpha_2)$, where L is the number of typographers listed as members of the ITU local, and K_1 and K_2 (i.e., the number of typesetters and the number of teletypesetters) are the capital inputs used in each of the newspapers' composing rooms. (Mean values for the whole sample and for each city for these variables are given in table 1.) Perhaps the most important omitted variable in this specification of the production function is some measure of the hours worked by the typographers in the composing room (although, of course, systematic dif-

[14] The period from 1945 to 1973 allows for a maximum number of annual observations of 29 for each union local. In fact, as is evident from table 1, the largest number of observations on any union local is 27 for San Luis Obispo. The reason for not having 29 observations is simply that we encountered missing data on the reporting of mechanical equipment in particular years, and occasionally ITU contracts for certain locals were not reported. Also, we deleted all observations for which photocopiers served as an input in the composing room to avoid having to deal with structural shifts arising from technological change.

ferences in hours worked across newspapers will be accounted for by the coefficients β_j in [6]). Data on "normal" weekly hours (i.e., the number of hours before overtime rates apply) are available, but information on actual hours worked could not be located. Otherwise, equation (6) includes the primary determinants of composing room output. We would have preferred using total linage as our measure of output, but we were unable to obtain complete data on news linage, so we assume that total linage is proportional to advertising linage, where the factor of proportionality varies from firm to firm. The firm-specific intercepts β_j in equation (6) account for these factors of proportionality.

The consequences of estimating equation (6) for this Cobb-Douglas specification of $\mathbf{Z}$ and $\boldsymbol{\alpha}$ yield coefficient estimates as follows (with estimated standard errors in parentheses):

$$\underset{(.146)}{\hat{\alpha}_L = .730}; \quad \underset{(.284)}{\hat{\alpha}_1 = .489}; \text{ and } \underset{(.038)}{\hat{\alpha}_2 = .082}.$$

The estimation technique here is instrumental variables, where the instruments are given by the dummy variables (D_j) and the interaction of these dummy variables with linear and quadratic time trends.[15] Because it is not reasonable to assume that observations are independently distributed over time for the same newspaper, one cannot use conventional formulae for calculating standard errors in instrumental variable estimation. The Appendix to this paper gives the precise details of the estimation procedure and the computation of standard errors implemented in this analysis. The standard errors reported here are computed in a way to be robust against heteroscedasticity and autocorrelation up to the third order. These estimates of the production function coefficients are consistent with what is known about the technology of the composing room, and, indeed, the increasing returns to scale that our point estimates suggest ($\hat{\alpha}_L + \hat{\alpha}_1 + \hat{\alpha}_2 = 1.301$) are a well-known feature of the entire newspaper production technology.[16]

It is important for our testing procedure that an accurate characterization of the marginal rate of substitution among inputs in production be determined, and the Cobb-Douglas specification is, of course, a very simple representation of production technology. Therefore, we went to considerable lengths to determine whether a

[15] Very similar estimates were derived using a different set of instrumental variables, namely, a set including the dummy variables (D_j) and all the terms making up a fully interacted cubic in variables measuring retail sales and the number of households in a given year for a given city.

[16] When a time trend is added to eq. (6), the coefficient estimates of α_L, α_1, and α_2 are virtually unchanged.

less straightforward representation was more appropriate for the composing room's output by estimating numerous forms of the production function. These included the transcendental logarithmic (translog), restricted forms of the translog, the quadratic, the Box-Cox transformation applied to all inputs and output, the transcendental,[17] the generalized Stone-Geary (which nests the constant elasticity of substitution function), and elaborate splines that allow the form to vary in different regions of the production function. The estimates corresponding to several of these production functions appeared at first sight to be satisfactory, but in ascertaining whether they implied an economically meaningful technology, we determined whether the fitted values implied (*a*) diminishing marginal returns to successive applications of a single input (with other inputs held fixed at their observed mean values) and (*b*) positive marginal products at the levels of the inputs actually used. Although for some of the estimated production functions these criteria were satisfied for a large number of observations, they were not met for every single observation. The explanation for this appears to be that the estimates of the production functions were unduly affected by combinations of inputs that represented outlying observations.

However, we were anxious not to impose too restrictive a form of the production technology onto the next stage of our estimation procedure. Therefore, even though for some observations the estimates of the translog production function do not meet the two criteria specified in the previous paragraph, we also present results corresponding to a more general production function, the translog. This means in terms of equation (6) that

$$\mathbf{Z} = \{\ln(L), \ln(K_1+1), \ln(K_2+1), [\ln(L)]^2, [\ln(K_1+1)]^2, [\ln(K_2+1)]^2, [\ln(L)]\cdot[\ln(K_1+1)], [\ln(L)]\cdot[\ln(K_2+1)], [\ln(K_1+1)]\cdot[\ln(K_2+1)]\}$$

and

$$\boldsymbol{\alpha}' = (\alpha_L, \alpha_1, \alpha_2, \alpha_{LL}, \alpha_{11}, \alpha_{22}, \alpha_{L1}, \alpha_{L2}, \alpha_{12}),$$

where, as before, L represents employment, K_1 the number of typesetters, and K_2 the number of teletypesetters. The estimates of this translog production function (with estimated standard errors in parentheses) are as follows:

$$\underset{(1.499)}{\hat{\alpha}_L = -2.130}; \quad \underset{(3.686)}{\hat{\alpha}_1 = 8.337}; \quad \underset{(.473)}{\hat{\alpha}_2 = .407}; \quad \underset{(.617)}{\hat{\alpha}_{LL} = -.372};$$

[17] By transcendental we mean $X = A\Sigma_i Z_i^{a_i}\exp(b_i Z_i)$, where a_i and b_i are parameters and Z_i denotes the level of input i.

$$\hat{\alpha}_{11} = \underset{(1.074)}{-3.591}; \; \hat{\alpha}_{22} = \underset{(.079)}{.014}; \; \hat{\alpha}_{L1} = \underset{(1.383)}{2.448}; \; \hat{\alpha}_{L2} = \underset{(.142)}{.072};$$

$$\hat{\alpha}_{12} = \underset{(.258)}{-.263}.$$

Again, these are instrumental variable estimates, where the instruments are the newspaper dummy variables (D_j) and the interaction of these dummy variables with linear and quadratic time trends. As before, the computation of the standard errors takes account of third-order serial correlation and heteroscedasticity. For the next step in our procedure, we make use of estimates of both the Cobb-Douglas and the translog production functions.

B. *A Specification for Union Preferences*

The subsequent empirical analysis assumes that g_L/g_ω, the marginal rate of substitution (MRS) function associated with the union's objective function $g(\cdot)$, is given by

$$\frac{g_L}{g_\omega} = \frac{m_1}{m_2}, \tag{7}$$

with

$$m_i = \mu_{i1} + B\mu_{i2} + \theta_{i1}\left(\frac{w}{p} - \delta\frac{w_a}{p}\right) + \theta_{i2}L; \quad i = 1, 2,$$

where μ_{i1}, μ_{i2}, θ_{i1}, θ_{i2}, and δ are parameters assumed to be constant over unions and time, B is a dummy variable that takes a value of one for the three largest unions in the sample (i.e., locals 163, 126, and 109) and of zero otherwise, w_a is a wage index representing the alternative wage rate measured here by the real average hourly earnings received by production workers in durable goods manufacturing, and L represents employment. Setting one of the μ_{j1}'s or θ_{j1}'s equal to one represents an arbitrary normalization and is needed to identify the remaining parameters when carrying out estimation.

Many familiar objective functions imply a specification for the MRS that is a special case of (7). In particular, setting $\theta_{11} = \theta_{22}$ in (7) yields a specification consistent with any monotonic transformation of quadratic preferences given by

$$U = \mu_1 L + \mu_2\left(\frac{w}{p} - \delta\frac{w_a}{p}\right) + \theta_{11}\left(\frac{w}{p} - \delta\frac{w_a}{p}\right)\cdot L + \frac{\theta_{12}}{2}L^2 + \frac{\theta_{21}}{2}\left(\frac{w}{p} - \delta\frac{w_a}{p}\right)^2,$$

where the parameters μ_1 and μ_2 are defined as $\mu_1 = \mu_{11}$ and $\mu_2 = \mu_{22}$ for a relatively small union and as $\mu_1 = \mu_{11} + \mu_{12}$ and $\mu_2 = \mu_{21} + \mu_{22}$ for a union classified as large in our sample. With $\theta_{12} = \theta_{21} = 0$ and $\theta_{22} = 1$ in (7), we obtain the MRS corresponding to monotonic transformations of a Stone-Geary preference function given by

$$U = \left[\frac{\mu_1}{\theta_{11}} + \left(\frac{w}{p} - \delta\frac{w_a}{p}\right)\right](\mu_2 + L)^{\theta_{11}}.$$

If we specialize this Stone-Geary function even further by imposing the additional restrictions $\mu_{11} = \mu_{12} = \mu_{21} = \mu_{22} = 0$ and $\theta_{11} = 1$, then the union acts to maximize rents given by

$$U = \left(\frac{w}{p} - \delta\frac{w_a}{p}\right)L.$$

Hence the specification for the MRS considered here admits a wide range of possible objective functions characterizing union preferences.

C. *Formulating the Basic Empirical Relation*

To complete the development of an estimable specification for the equilibrium conditions associated with either the LDEM or the CEM, we require a measure for the firm's marginal valuation of labor (MVL) given by

$$\text{MVL} = R_i \cdot \frac{\partial X}{\partial L} \bigg/ \frac{\partial X}{\partial K_i} \equiv R_i \cdot Q_i,$$

which, of course, equals the marginal revenue product of labor when the firm is a profit maximizer. For the specification of the production given by (6), the marginal rate of technical substitution Q_i between the inputs L and K_i equals

$$Q_i = \frac{\sum_{j=1}^{J} \frac{\partial Z_j}{\partial L}\alpha_j}{\sum_{j=1}^{J} \frac{\partial Z_j}{\partial K_i}\alpha_j}, \quad i = 1, 2, \tag{8}$$

where J is the number of elements in the vectors $\mathbf{Z}$ and $\boldsymbol{\alpha}$, and Z_j and α_j, $j = 1, \ldots, J$, are the jth elements of these vectors. For a measure of the rental price of capital input i, we assume that R_i is proportional to an annual user cost of capital given by the quantity

$$\bar{R} \equiv \left(\frac{PM1 + PM2}{2}\right)(r + b),$$

where $PM1$ and $PM2$ are the price indices for all machinery and equipment used in manufacturing and for electrical machinery and equipment, respectively, r is Moody's Aaa domestic corporate bond rate, and b is an annual depreciation rate set equal to 0.1 in this analysis.[18] Thus we have $R_i = \gamma_i \bar{R}$, with γ_i representing a time-invariant factor of proportionality that is constant across firms. Combining results, we obtain MVL $= \gamma_i \bar{R} Q_i$.

According to condition (5), equilibrium in the CEM implies

$$\gamma_i \bar{R} Q_i = w - pL \frac{m_1}{m_2}, \tag{9}$$

which holds for each type of capital input K_i employed in the composing room in conjunction with typographers. Because typesetters are used at positive levels for all observations while teletypesetters are not employed by newspapers for some or all years (which indicates corner solutions for this input during these years), we consider relation (9) for only the case of typesetters with $Q_i = Q_1$.

Throughout this discussion we have implicitly assumed that the number of hours worked by each employee and union member is fixed and, thus, can be ignored as an argument of either the union preference specification or the production function. The interpretation and the validity of relation (9) continue to rely crucially on maintaining this assumption. The wage rate in this relation is measured in terms of dollars per hour, while employment is in terms of number of workers. This apparent discrepancy, however, creates no conceptual difficulty as long as typographers work the same number of hours both across unions and over time; the parameters of the union's preference and the firm's production functions implicitly translate employees into hours worked and vice versa. In addition to employment we would have liked to have modeled the determination of hours per employee, but we are not aware of any data available on hours actually worked by typographers.

Our empirical analysis estimates an equation based on a stochastic variant of relation (9). Suppose that union preferences depend on an unobserved random disturbance ν that varies both across unions and

[18] The price indices and the corporate bond rate are taken from issues of the *Survey of Current Business*. The value of the depreciation b assumed in our analysis was suggested by our colleague James Rosse, who has extensive personal and professional knowledge of the newspaper industry and typographers. For the term $r + b$ to represent a cost of capital, it is necessary to interpret b as accounting for the physical depreciation as well as the financial depreciation of capital. We considered other values for b covering a fairly wide range in our empirical analysis, and our results were not sensitive to the choice of b. For $b = 0.1$, which is the value used in obtaining the estimates reported below, the variable $\bar{R}$ has a sample mean equal to 11.94, a standard deviation equal to 3.62, and minimum and maximum values of 5.48 and 20.4.

over time. This is introduced by replacing the parameter μ_{11} in specification (7) and determining the function m_1 by the quantity $\mu_{11} - \nu$. Multiplying both sides of (9) by m_2/pL yields

$$\left(\gamma \frac{\bar{R}Q_1}{pL} - \frac{w}{pL}\right)m_2 + m_1 = \nu, \qquad (10)$$

where we have specified this relation with typesetters serving as the capital input (i.e., $i = 1$), and we have suppressed the subscript on γ for convenience.[19] For most specifications estimated below, this equation is nonlinear in parameters, and, consequently, we treat (10) as a nonlinear simultaneous equation in our empirical analysis with all variables appearing in this equation considered endogenous.[20] Besides γ, other parameters determining union preferences enter this equation through the functions m_1 and m_2 as given by (7). Inspection of (8) also reveals that the coefficients $\boldsymbol{\alpha}$ of the production function are present in equation (10) through Q_1, but we do not treat these coefficients $\boldsymbol{\alpha}$ as parameters when estimating (10). Instead, using the estimates $\hat{\boldsymbol{\alpha}}$ obtained from our empirical analysis of the production function described above, we compute $\hat{Q}_1$ based on formula (8) setting $\boldsymbol{\alpha}$ equal to $\hat{\boldsymbol{\alpha}}$ and then substitute $\hat{Q}_1$ for Q_1 in (10). With this substitution, a conventional nonlinear two-stage least-squares (2SLS) procedure applied to equation (10)—interpreting $\hat{Q}_1$ as simply an observed endogenous variable—produces consistent estimates for γ and for the parameters of the union's objective function, though adjustments are needed when computing standard errors.

Given the assumptions maintained in deriving equation (10), it is easily verified that setting $m_1 = 0$ and $m_2 = 1$ yields the empirical relation consistent with the LDEM, whose equilibrium condition is given by equation (4); that is, the structural equation above nests the LDEM. In particular, after normalizing one of the coefficients of the polynomial m_2 to achieve parametric identification, a wage and employment contract determined according to the LDEM implies that the remaining coefficients of m_2 and all the coefficients of m_1 are equal to zero. We denote the null hypothesis implying the parametric restrictions yielding $m_1 = 0$ and $m_2 = 1$ as H_0.

To understand more fully the conclusions that can be drawn on the

[19] There are, of course, many potential sources for the error term ν other than unobserved differences in union preferences as we have assumed here, such as errors arising from measurement problems or optimization error. It creates no difficulties in the following analysis to interpret ν as being an error from one of these other sources as long as its expectation conditional on the instrumental variables equals zero.

[20] There is no compelling reason for treating the variables p and $\bar{R}$ as endogenous when estimating eq. (10), but adding these variables to the other instrumental variables used in our empirical analysis changes the estimates and the standard errors only slightly.

basis of a test of the null hypothesis H_0, consider initially the implications of a rejection of H_0. This rejection clearly provides solid evidence against the LDEM, but it certainly does not establish the veracity of the CEM. Without introducing strong functional form assumptions about union objectives (such as presuming that a union maximizes rents), no rigorous tests are available for establishing whether a CEM characterizes the determination of wages and employment. No doubt there are many models of the labor market that imply parametric restrictions incompatible with H_0. While a rejection of H_0 does not allow one to claim the validity of the CEM, the estimation of equation (10) does provide some information suggestive about whether a CEM might apply. With the CEM the relevant model, for example, one would expect the resulting estimates of the coefficients of m_1 and m_2 to imply a specification for union objectives that is a quasi-concave function of w and L.

Now consider the possible conclusions that can be drawn from an acceptance of H_0. If H_0 is indeed true, it is not the case that the LDEM necessarily applies for two reasons. First, H_0 restricts the MVL only to be proportional to w for all observed values of w and L, and it does not require that MVL $= w$ as dictated by the LDEM. Thus, if H_0 is valid, the admissible combinations of w and L need not even be on the labor demand curve. Second, there exist specifications of the CEM in which the contract curve is the labor demand curve, and for these specifications the CEM and the LDEM are observationally equivalent and both are consistent with H_0. Such is the case, for example, when a union cares only about wages and not at all about employment, which arises in figure 1 when indifference curves are horizontal lines; in this case, MRS $= m_1/m_2 = 0$ for all combinations of w and L. Thus, even if H_0 is true and wage-employment combinations are known to lie on the labor demand curve, the CEM may still apply.

D. *Empirical Findings*

Tables 2 and 3 present estimates for the parameters of equation (10) for eight distinct formulations of the MRS functions, whose specification is given by (7). Table 2 reports results assuming that a Cobb-Douglas production function describes the technology of the composing room, while table 3 presents an analogous set of results for the translog production function. Rows 1–3 of these tables list the estimates obtained assuming that the MRS is approximated by a simple linear function of the variables w/p, w_a/p, and L. Rows 4–6 and 7–8, respectively, present parameter estimates assuming that union objectives are characterized by three variants of a Stone-Geary preference function and by two variants of a quadratic specification for prefer-

TABLE 2

PARAMETER ESTIMATES FOR THE MARGINAL RATE OF SUBSTITUTION FUNCTION ASSUMING A COBB-DOUGLAS PRODUCTION FUNCTION

Specification	θ_{11}	θ_{12}	θ_{21}	θ_{22}	μ_{11}	μ_{12}	μ_{21}	μ_{22}	γ	δ	Percentiles of MRS (10%, 50%, 90%)
Linear	.045	−.00088	0	0	.057	−.0051	1	0	.19	1	(.037, .049, .067)
	(.011)	(.00041)			(.039)	(.0059)			(.15)		
Linear	.025	−.0014	0	0	.035	.0082	1	0	.15	0	(.042, .061, .082)
	(.0080)	(.00060)			(.024)	(.0048)			(.10)		
Linear	.042	−.0013	0	0	.040	.0034	1	0	.17	.62	(.037, .056, .077)
	(.0084)	(.00059)			(.025)	(.0035)			(.11)	(.16)	
Stone-Geary	.24	0	0	1	−.021	0	−24.36	−28.83	.45	1	(−.033, .0083, .041)
	(.23)				(.12)		(2.63)	(6.89)	(.65)		
Stone-Geary	.12	0	0	1	−.21	0	−25.53	−27.62	.43	0	(−.038, .010, .046)
	(.12)				(.21)		(1.92)	(7.43)	(.61)		
Stone-Geary	.22	0	0	1	−.19	0	−24.65	−27.05	.44	.63	(−.038, .010, .045)
	(.21)				(.19)		(2.69)	(6.79)	(.63)	(.56)	
Quadratic	−.016	−.00064	−.49	−.016	.037	.011	1	.27	.20	1	(.030, .036, .046)
	(.0052)	(.00050)	(.14)	(.0052)	(.020)	(.013)		(.18)	(.20)		
Quadratic	−.0075	−.00029	−.22	−.0075	.035	.0065	1	.16	.24	0	(.030, .035, .042)
	(.0042)	(.00037)	(.044)	(.0042)	(.027)	(.0072)		(.093)	(.22)		

NOTE.—Asymptotic standard errors are in parentheses.

TABLE 3

PARAMETER ESTIMATES FOR THE MARGINAL RATE OF SUBSTITUTION FUNCTION ASSUMING A TRANSLOG PRODUCTION FUNCTION

Specification	θ_{11}	θ_{12}	θ_{21}	θ_{22}	μ_{11}	μ_{12}	μ_{21}	μ_{22}	γ	δ	Percentiles of MRS (10%, 50%, 90%)
Linear	.042	−.0023	0	0	.15	.0087	1	0	.0030	1	(.059, .094, .13)
	(.0095)	(.0029)			(.010)	(.0073)			(.0046)		
Linear	.029	−.0026	0	0	.096	.020	1	0	.0017	0	(.059, .091, .12)
	(.0029)	(.00038)			(.010)	(.0086)			(.0024)		
Linear	.039	−.0027	0	0	.10	.019	1	0	.0023	.39	(.057, .091, .12)
	(.0082)	(.00034)			(.012)	(.0082)			(.0031)	(.24)	
Stone-Geary	−5.56	0	0	1	3.42	0	−32.21	−37.50	1.33	1	(−.52, −.020, .75)
	(36.53)				(20.37)		(5.33)	(32.35)	(9.45)		
Stone-Geary	1.10	0	0	1	−3.14	0	−31.96	−24.49	.55	0	(−.12, .040, .22)
	(1.90)				(5.85)		(5.36)	(33.18)	(2.45)		
Stone-Geary	−3.32	0	0	1	−6.54	0	−32.39	−34.90	.68	2.07	(−.40, .048, .31)
	(13.01)				(17.14)		(4.91)	(28.90)	(3.26)	(1.61)	
Quadratic	−.024	−.0024	−.34	−.024	.096	.084	1	1.01	.022	1	(.057, .091, .13)
	(.0018)	(.00031)	(.062)	(.0018)	(.012)	(.022)		(.28)	(.038)		
Quadratic	−.013	−.0014	−.19	−.013	.088	.057	1	.69	.011	0	(.048, .089, .13)
	(.0032)	(.00018)	(.017)	(.0032)	(.0068)	(.017)		(.22)	(.011)		

NOTE.—Asymptotic standard errors are in parentheses.

ences. (See the discussion above for the restrictions implied by these various objective functions.) The normalization $\mu_{21} = 1$ is used to identify parameters in rows 1–3 and 7–8, and the normalization $\theta_{22} = 1$ is imposed in rows 4–6. The constraint $\delta = 1$ is invoked in rows 1, 4, and 7, while rows 2, 5, and 8 report estimates assuming that $\delta = 0$. The column designated "Percentiles of MRS" in these tables presents the 10 percent percentile, the median, and the 90 percent percentile of the quantities m_1/m_2 computed for each observation in the sample evaluated at the parameter estimates associated with the specification under consideration.

All the estimates presented in tables 2 and 3 are computed using nonlinear 2SLS,[21] with city dummies and city dummies interacted both with time and with time squared serving as instrumental variables.[22] As noted above, we use an estimate $\hat{Q}_1$ in place of Q_1 in the implementation of the estimation procedure. The calculation of standard errors reported in tables 2 and 3 fully recognizes that $\hat{Q}_1$ is the estimated quantity. While this calculation of standard errors does assume that the disturbances ν are distributed independently across unions and firms, it uses asymptotic formulas that permit the ν's to be heteroscedastic and that allow the time-series observations on ν for a given union and firm to be freely autocorrelated up to at least the third order. Admitting this autocorrelation is particularly important in the current context because one would not expect the unobserved components of a particular union's preferences that are captured by ν to be uncorrelated from one year to the next. The exact formulas used to compute standard errors and a brief justification for their use are given in the Appendix of this paper. We consider these standard errors to be very conservative because they are about three to five

[21] The parameterization of eq. (10) used to obtain estimates of the coefficients of the Stone-Geary specifications reported in rows 4–6 is given by

$$\frac{\bar{R}Q_1}{pL} - \phi \frac{w}{pL} m_2 + \phi m_1 = \nu^*. \qquad (*)$$

This reparameterization is obtained by multiplying eq. (10) through by the coefficient $\phi \equiv 1/\gamma$. Given the functional forms of m_1 and m_2 implied by a Stone-Geary objective function, a nonsensical global minimum for the conventional nonlinear 2SLS metric can be readily shown to exist by setting $\gamma = \mu_{11} = \mu_{12} = \mu_{21} = \mu_{22} = \delta = 0$ and $\theta_{11} = 1$. While applications of the estimation procedures with the Cobb-Douglas production function were able to avoid this portion of the parameter space, difficulties were encountered in the translog case. The use of structural equation (*) rules out this nonsensical global minimum and, thus, avoids computational problems. The estimate $\hat{\gamma}$ and its standard error s_γ reported in rows 3–6 of tables 2 and 3 are derived using the familiar asymptotic formulas $\hat{\gamma} = 1/\hat{\phi}$ and $s_{\hat{\gamma}} = \hat{\gamma}^2 s_{\hat{\phi}}$.

[22] As with the production estimates, qualitatively similar results were obtained when a different set of instrumental variables were specified, namely, a set including city dummies and all terms making up a fully interacted cubic in variables measuring retail sales and the number of households in any given year for a given city.

times larger than the conventional standard errors reported by a nonlinear 2SLS computer routine that makes no allowance for heteroscedasticity or serial correlation of the disturbance or for estimation error induced by use of the estimated quantity $\hat{Q}_1$ in place of Q_1.[23]

We may draw three main conclusions from the estimates of tables 2 and 3. First, these results provide solid evidence against the LDEM. The parametric restrictions implied by this model (i.e., $\mu_{11} = \mu_{12} = \mu_{22} = \theta_{11} = \theta_{12} = \theta_{21} = \theta_{22} = 0$ with normalization $\mu_{21} = 1$ and $\mu_{11} = \mu_{12} = \mu_{21} = \mu_{22} = \theta_{11} = \theta_{12} = \theta_{21} = 0$ with normalization $\theta_{22} = 1$) are easily rejected at conventional levels of significance for every specification considered. This finding is not simply an artifact arising from the imposition of nonlinear restrictions involved in the estimation of equation (10). Indeed, use of the specifications based on the linear MRS function to test the LDEM involves nothing more than determining whether standard exclusion restrictions are satisfied for these specifications.

As we have already emphasized, in the context of equation (5) there exists a simple exclusion restriction by which to test the LDEM, but there are no tests of either inclusion or exclusion restrictions available for determining whether contracts are efficient. The findings in tables 2 and 3 are generally consistent with more than one set of these restrictions. For example, the results for the linear specification of the MRS function with the Cobb-Douglas production function reported in row 3 imply that each of the variables L, w/p, and w_a/p enters equation (10) at conventional levels of significance as determinants of the MVL, whereas the estimates for the corresponding specification assuming the translog production function imply that only the variables L and w/p enter this equation.[24] Unfortunately, knowledge that

[23] As an example, the unadjusted standard errors for the coefficients in row 3 of table 2 are as follows: .0015 for θ_{11}, .000053 for θ_{12}, .0037 for μ_{11}, .0011 for μ_{12}, and .031 for δ.

[24] To test for the relevance of w/p, w_a/p, and L as determinants of the MVL for the case of the linear specification of the MRS function, write eq. (10) as

$$\gamma \frac{\bar{R}Q_1}{pL} - \frac{w}{pL} + \mu_{11} + B \cdot \mu_{12} + \theta_{11}\frac{w}{p} + \theta_{13}\frac{w_a}{p} + \theta_{12}L = \nu.$$

The estimates of the θ-coefficients and the associated asymptotic standard errors obtained with the Cobb-Douglas production function are

$$\underset{(.0084)}{\hat{\theta}_{11} = .042}, \quad \underset{(.0058)}{\hat{\theta}_{13} = -.026}, \quad \text{and } \underset{(.00059)}{\hat{\theta}_{12} = -.0013}.$$

The corresponding results with the translog production function are

$$\underset{(.0082)}{\hat{\theta}_{11} = .039}, \quad \underset{(.012)}{\hat{\theta}_{13} = -.015}, \text{ and } \underset{(.00034)}{\hat{\theta}_{12} = -.0027}.$$

The implied t-statistics associated with these estimates are all well above 2 in absolute value with the exception of θ_{13} in the translog case, whose t-value is 1.22.

the alternative wage w_a/p may not enter equation (10) as suggested by the translog results provides no information about whether contracts are Pareto efficient. Naive tests of either zero or nonzero parameter restrictions using estimates based on an equation such as (10) do not permit one to argue either in favor of or against the concept of contract efficiency.

A second conclusion concerns the relevance of the CEM to this labor market. While it is not possible to perform conventional statistical tests of the CEM, the results of tables 2 and 3 are generally consistent with this model. In situations in which this model applies, the parameter estimates of equation (10) should satisfy certain inequality restrictions: the parameter γ should be positive, and, far more demanding, the estimated relationship obtained for the MRS should imply a function describing union objectives that is quasi-concave. The estimates of γ are clearly positive for every specification considered in these tables. With regard to quasi concavity, the estimates obtained for the linear specifications of the MRS function in both tables provide the most obvious evidence supporting this property. Inspection of these estimates reveals that the MRS is strictly increasing in w/p and decreasing in L. Furthermore, the estimated MRSs for these specifications are positive for every single observation in the sample. When combined, these two findings indicate that the underlying function describing union objectives is quasi-concave over the range of the data covered by our sample. The results corresponding to the quadratic specifications imply concave utility functions and MRS functions that satisfy quasi concavity for most of the relevant values of w/p and L. The results for the Stone-Geary specification of union objectives are far less supportive of the CEM: a nontrivial fraction of the estimated values of the MRSs are negative, and the point estimates in the translog case imply noncredible properties for union objectives. These latter results indicate that either the Stone-Geary form of preferences or the CEM is inapplicable. In the light of the apparent consistency of the CEM when considered in the context of other preference specifications, we are inclined to reject Stone-Geary preferences rather than the CEM.

The third conclusion to be drawn from the results in tables 2 and 3 relates to inferences concerning union preferences. There are two main points. The first concerns the functional form describing union objectives. Because the linear, the Stone-Geary, and the quadratic specifications for preferences do not nest one another, it is difficult to determine which specification best fits the data. As noted above, the estimated Stone-Geary formulations for preferences exhibit several disconcerting properties that suggest that such formulations are inappropriate. With Cobb-Douglas technology assumed, the primary source of difficulties with properties of the Stone-Geary function arises from the large estimates obtained for the "translation parameters" μ and δ that define "reference" employment and wages, a situation that is commonly encountered when such functions are fitted in consumer demand analysis. In addition to this source of difficulty, the point estimates of θ_{11} based on translog technology reported in rows 4 and 6 of table 3 are negative, which is quite implausible and lends further evidence against a Stone-Geary formulation of union objectives. Of course, the large standard errors associated with many of the estimates of the Stone-Geary parameters indicate that considerable caution should be exercised in rejecting it as an appropriate specification. As for the linear and the quadratic preference specifications, the percentiles of the estimated MRS reveal similar trade-offs in equilibrium between wage rates and employment at the margin. The principal source of variation in the measured MRS arises from altering assumptions about production technology, with the estimates of the MRS higher when the translog production function is assumed. Aside from the Stone-Geary results in the translog case, the relaxation of the constraint on the coefficient δ that determines the influence of the alternative wage on union objectives produces a value greater than zero but less than one. This indicates that an ITU local perceives itself as being worse off if there is an increase in other workers' wages but would prefer this event to a comparable decrease in its own wage rate. While there is little basis for choosing among the various specifications considered in tables 2 and 3, the results of these tables do provide a clear indication that one popular formulation for union objectives does not apply for the ITU. In particular, an inspection of the estimates of the Stone-Geary function and the associated standard errors offers strong support against the view that these unions maximize rents; the parameter restrictions implied by rent maximization are readily rejected at conventional levels of significance.

The second point about union objectives that can be inferred from the results of tables 2 and 3 concerns the degree to which a union substitutes between wages and employment. According to the medians of the implied estimates of the MRSs for the linear and quadratic specifications, a reduction of employment by one worker may be offset by an increase in the real hourly wage rate of 3.5–9.5 cents in 1967 dollars to make the union indifferent to this loss of employment. The median real wage rate for this sample is \$3.01, so this compensating increase represents approximately a 1–3 percent adjustment in hourly wages. For a union of size 36—the average size in the sample—this increase in the wage rate translates into a \$2,520–\$6,840 rise in the total annual real earnings of its 36 members assuming 2,000 hours are worked per year, which compares with a \$3.01 × 2,000 = \$6,020 reduction in earnings lost, a consequence of one fewer union member being employed.

Perhaps a more instructive way to interpret this trade-off between wage rates and employment is to define e as the total rents from unionization and to write the union's objective function as $U = g[(w/p) - \delta(w_a/p), L] = g(eL^{-1}, L)$, where $e = [(w/p) - \delta(w_a/p)]L$. Then the marginal rate of substitution, s, between employment and rents is given by the following expression:

$$s \equiv \frac{\partial U/\partial L}{\partial U/\partial e} = \left(\frac{g_L}{g_\omega}\right)L - \left(\frac{w}{p} - \delta\frac{w_a}{p}\right).$$

Now if the union cares only about wages and not about employment (i.e., if $g_L = 0$), then $s = -(w/p) + \delta(w_a/p)$, while at the other extreme, if the union cares only about employment and not about wages (i.e., if $g_L \rightarrow \infty$), then $s \rightarrow \infty$. In the special case of rent maximization where $U = [(w/p) - \delta(w_a/p)]L$, s is zero. In other words, as the union's indifference curves between w/p and L move from being horizontal to vertical (in terms of fig. 1), s ranges from a minimum of $-(w/p) + \delta(w_a/p) < 0$ through zero toward infinity. For our Cobb-Douglas production function estimates, the average of $L(g_L/g_\omega)$ for the linear specification of the MRS function is 1.93 and $\hat{\delta} = 0.62$, so the average of s is 0.41. For our translog production function estimates, the corresponding average of $L(g_L/g_\omega)$ is 2.98 and $\hat{\delta} = 0.39$, which implies an average of s equal to 0.92. These values of s suggest that these ITU locals place greater weight on employment in pursuing their goals compared with a rent-maximization objective.

V. Conclusions

Two models describing the determination of wages and employment in unionized labor markets have been routinely exposited in the literature for several decades. We have called one the labor demand curve equilibrium model (LDEM) and the other the contract curve equilibrium model (CEM). On some occasions one of these models has been used as a framework for empirical research, and on other occasions the second model has been used. On all these occasions, however, each model was taken to be the maintained hypothesis. By contrast, the primary motivation of this paper is to determine which of these two models (if either) is the empirically relevant one in any given labor market setting. To this end, we have set up these two models in a manner in which the choice between them comes down to a standard test for determining whether a particular term may be excluded from a regression equation.

In one sense, this test is asking much more of the LDEM because it specifies a unique solution for wage rates and employment for any given values of the variables (a solution that satisfies eq. [4]), whereas the CEM is compatible with a whole combination of different wage rates and employment depending on the particular objective functions of the parties (as is evident from figs. 3 and 4 and the inspection of eq. [5]). Therefore, the LDEM imposes sharper restrictions on the parameters of our critical estimating equation than does the CEM. On the other hand, it should be recognized that this is not simply a property of the test that has been devised in this paper but is present in any attempt to discriminate between the two models.

Our particular case study concerns the ITU and the operations in a newspaper's composing room, and we find, for a wide variety of specifications for trade union objectives, that the exclusion restriction in our critical estimating equation is not justified, that the LDEM is not an appropriate description of this labor market, and that the CEM comes closer to providing a satisfactory explanation. When the fitted relationship is interpreted in terms of the CEM, the estimated parameters of the union's objective function provide a clear indication, rejecting the popular view that unions maximize rents. One inference about union objectives suggested by our estimates is that the ITU appears on the margin to place a higher value on employment than is implied by a pure rent-maximization objective.

Naturally, at this stage of the research, it would be imprudent to hold to these conclusions with great confidence. There is clearly a good deal more work that should be done on this and on other bodies of data. Our purpose has not been to act as advocates for the CEM or for the LDEM—surely neither of these models is the relevant one in *all* labor markets at *all* times. Our main purposes are simply to stress the fact that these two models imply the satisfaction of different relationships, to present a simple procedure for discriminating between the two models in any given context, and to encourage the application of this procedure in other contexts.

Appendix

This Appendix presents the formulas used to compute the standard errors reported in the text for parameter estimates of the production and the marginal rate of substitution (MRS) functions. We have available a panel data set consisting of data on J unions and newspapers with T_j time-series observations (not necessarily a year apart) on the jth union and newspaper. Thus estimation is carried out using a total of $n = \Sigma_{j=1}^{J} T_j$ observations. It is assumed here that over time the errors for any particular union or newspaper appearing in the relations for the production and the MRS functions given by equations (6) and (10) follow an mth-order moving average process and that these errors are distributed independently across the different unions and newspapers. The notation used in this Appendix is distinct from that used in the body of the paper; the reader is cautioned not to confuse symbols here with those introduced earlier. Some details are presented in the following discussion to motivate the methods and formulas used to compute the estimates and the standard errors reported in the text, but rigorous proofs are absent. For the interested reader, many of the ingredients for such proofs can be found in White and Domowitz (1984).

Computing Standard Errors for 2SLS Estimates Accounting for Arbitrary Heteroscedasticity and Autocorrelations

Regarding the estimation of the production function given by equation (6), write the tth observation for the jth newspaper on this structural relation as $f_{jt} \equiv f(\mathbf{Y}_{jt}, \boldsymbol{\gamma}) = \epsilon_{jt}$ where the elements of the vector $\mathbf{Y}_{jt}$ provide data on output, inputs, and the dummy variables appearing in equation (6), and the vector $\boldsymbol{\gamma}$ includes parameters of the production function. Stack these observations to form the n-component vector $\mathbf{f}'(\boldsymbol{\gamma}) \equiv (f_{11}, \ldots, f_{1T_1}, f_{21}, \ldots, f_{JT_J})$; let $f_i = \epsilon_i$ denote the ith element of $\mathbf{f}(\boldsymbol{\gamma})$; let $\mathbf{F}(\boldsymbol{\gamma}) \equiv \partial \mathbf{f}/\partial \boldsymbol{\gamma}'|_{\boldsymbol{\gamma}}$ represent the matrix of first partials evaluated at the parameter value $\boldsymbol{\gamma}$; and define $\mathbf{X}$ as an $n \times K$ matrix of instrumental variables used to calculate two-stage least-squares (2SLS) estimates, and the vector $\mathbf{X}_i'$ as the ith row of $\mathbf{X}$. To compute an estimate $\hat{\boldsymbol{\gamma}}$ for the value $\boldsymbol{\gamma}_0$ that represents the "true" value of the coefficients of the production function, the application of 2SLS calculates $\hat{\boldsymbol{\gamma}}$ by minimizing the distance function $\mathbf{L}(\boldsymbol{\gamma}) \equiv \mathbf{f}'(\boldsymbol{\gamma})\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{f}(\boldsymbol{\gamma})$ with respect to $\boldsymbol{\gamma}$. Thus the solution to the system of equations $\mathbf{L}_{\boldsymbol{\gamma}}(\hat{\boldsymbol{\gamma}}) \equiv \partial L/\partial \boldsymbol{\gamma}|_{\hat{\boldsymbol{\gamma}}} = 0$ defines $\hat{\boldsymbol{\gamma}}$.

Taking an exact first-order Taylor expansion of this equation around the point $\boldsymbol{\gamma}_0$ and solving for the quantity $\hat{\boldsymbol{\gamma}} - \boldsymbol{\gamma}_0$ yields the relation

$$(\hat{\boldsymbol{\gamma}} - \boldsymbol{\gamma}_0) = -\mathbf{L}_{\boldsymbol{\gamma}\boldsymbol{\gamma}}^{-1}(\boldsymbol{\gamma}_b)\mathbf{L}_{\boldsymbol{\gamma}}(\boldsymbol{\gamma}_0), \tag{A1}$$

where $\mathbf{L}_{\boldsymbol{\gamma}\boldsymbol{\gamma}}(\boldsymbol{\gamma}) \equiv \partial^2 L/\partial \boldsymbol{\gamma}\partial \boldsymbol{\gamma}'|_{\boldsymbol{\gamma}}$ denotes the matrix of second partials evaluated at $\boldsymbol{\gamma}$, and $\boldsymbol{\gamma}_b$ is a point between $\hat{\boldsymbol{\gamma}}$ and $\boldsymbol{\gamma}_0$. As in a conventional application of 2SLS, the consistency and the asymptotic distribution of $\hat{\boldsymbol{\gamma}}$ depend on the large-sample behavior of the gradient vector $\mathbf{L}_{\boldsymbol{\gamma}}(\boldsymbol{\gamma}) = 2\mathbf{F}'\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{f}$ evaluated at $\boldsymbol{\gamma}_0$ and, in particular, on the asymptotic properties of the quantity $\mathbf{X}'\mathbf{f}(\boldsymbol{\gamma}_0)$, which is the key component of this gradient.

The quantity $n^{-1}\mathbf{X}'\mathbf{f}(\boldsymbol{\gamma}_0) = n^{-1}\Sigma_{i=1}^{n}\mathbf{X}_i\epsilon_i \equiv n^{-1}\Sigma_{i=1}^{n}\mathbf{u}_i$ represents an average of random vectors each of which has zero mean. Under the conditions considered here, one may view the observations $\mathbf{u}_1, \ldots, \mathbf{u}_n$ as being generated by an m-dependent stochastic process, where:

DEFINITION. The sequence $\mathbf{u}_1, \mathbf{u}_2, \ldots$ is said to be m-dependent if the two subsequences $(\ldots, \mathbf{u}_{r-1}, \mathbf{u}_r)$ and $(\mathbf{u}_s, \mathbf{u}_{s+1}, \ldots)$ are independent whenever $s - r > m \geqslant 0$.

To possess this property it is not necessary that the $\mathbf{u}_i$'s have common variances or that a stable correlation structure relate the $\mathbf{u}_i$'s to their respective adjacent observations. In particular, if the errors for each newspaper in a panel data setting follow generally specified moving average schemes, even ones whose coefficients vary over time and across newspapers, and the errors are independently distributed across newspapers, then $(\mathbf{u}_1, \ldots, \mathbf{u}_n)$ can be interpreted as being m-dependent. It is irrelevant for this property whether observations are two or more periods apart or whether adjacent observations in the sequence $\mathbf{u}_1, \ldots, \mathbf{u}_n$ are associated with different newspapers (which occurs at the beginning and the end of the subsequence corresponding to any particular newspaper). Consequently, to obtain standard errors for 2SLS in this panel data context, one can apply asymptotic distribution results found in the time-series literature for m-dependent processes.

To this end, we turn to theorem 7.7.9 of Anderson (1971), which provides the basis for the following result.

THEOREM. If $\mathbf{u}_1, \mathbf{u}_2, \ldots$ is an m-dependent sequence of random vectors with zero mean and with uniformly bounded third moments and if the matrix

$$\mathbf{V}_0 = \lim_{n\to\infty}\left[n^{-1}\sum_{i=t}^{n} E(\mathbf{u}_i\mathbf{u}_i') + 2n^{-1}\sum_{j=1}^{m}\sum_{i=t+j}^{n} E(\mathbf{u}_i\mathbf{u}_{i-j}')\right]$$

exists and is independent of t, then the normalized sample average $\sqrt{n}^{-1}\Sigma_{i=1}^{n}\mathbf{u}_i$ converges in distribution to $N(0, \mathbf{V}_0)$.

In the panel setting considered here, the u_i's will satisfy the conditions of this theorem for a wide variety of circumstances, in which case we have the asymptotic results $n^{-1}\mathbf{X}'\mathbf{f}(\boldsymbol{\gamma}_0) \xrightarrow{p} 0$, and $\sqrt{n}^{-1}\mathbf{X}'\mathbf{f}(\boldsymbol{\gamma}_0) \xrightarrow{d} N(0, \mathbf{V}_0)$, with $\mathbf{V}_0$ being the probability limit of the matrix $\mathbf{V}(\boldsymbol{\gamma}_0)$, where

$$\mathbf{V}(\boldsymbol{\gamma}) \equiv n^{-1}\sum_{i=1}^{n}\mathbf{X}_i f_i f_i \mathbf{X}_i' + 2n^{-1}\sum_{t=1}^{m}\sum_{i=t+1}^{n}\mathbf{X}_i f_i f_{i-t}\mathbf{X}_{i-t}'.$$

Using these implications in conjunction with relation (A1), one can infer the approximate large-sample distribution of the estimator $\hat{\boldsymbol{\gamma}}$. In particular, assuming satisfaction of familiar regularity conditions of the sort maintained in theorems 4.1.3, 8.1.1, and 8.1.2 of Amemiya (1985), one can prove the following four results: (i) $\hat{\boldsymbol{\gamma}} \xrightarrow{p} \boldsymbol{\gamma}_0$; (ii) $\sqrt{n}\mathbf{L}_{\gamma\gamma}^{-1}(\boldsymbol{\gamma}_b)\mathbf{L}_{\gamma}(\boldsymbol{\gamma}_0) - \mathbf{B}(\boldsymbol{\gamma}_0)\sqrt{n}^{-1}\mathbf{X}'\mathbf{f}(\boldsymbol{\gamma}_0) \xrightarrow{p} 0$ with the matrix

$$\mathbf{B}(\boldsymbol{\gamma}) \equiv n[\mathbf{F}'\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{F}]^{-1}\mathbf{F}'\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1};$$

(iii) $\mathbf{B}(\hat{\boldsymbol{\gamma}}) \to \mathbf{B}(\boldsymbol{\gamma}_0)$; and (iv) $\mathbf{V}(\hat{\boldsymbol{\gamma}}) \to \mathbf{V}(\boldsymbol{\gamma}_0)$.

Combining these findings leads to the conclusion that in large samples

$$\hat{\boldsymbol{\gamma}} \approx N[\boldsymbol{\gamma}_0, n^{-1}\mathbf{B}(\hat{\boldsymbol{\gamma}})\mathbf{V}(\hat{\boldsymbol{\gamma}})\mathbf{B}'(\hat{\boldsymbol{\gamma}})]; \tag{A2}$$

that is, $\hat{\boldsymbol{\gamma}}$ is approximately normally distributed with mean $\boldsymbol{\gamma}_0$ and variance-covariance matrix $n^{-1}\mathbf{B}(\hat{\boldsymbol{\gamma}})\mathbf{V}(\hat{\boldsymbol{\gamma}})\mathbf{B}'(\hat{\boldsymbol{\gamma}})$. The standard errors reported in the paper for coefficients of the production function are based on (A2) with $m = 3$.

Computing Standard Errors for 2SLS Estimates Based on Preestimated Quantities Accounting for Arbitrary Heteroscedasticity and Autocorrelations

Concerning the estimation of the MRS function given by equation (10), write the tth observation for the jth union newspaper on this structural relation as $g_{jt} = g(\mathbf{Z}_{jt}, \boldsymbol{\theta}, \boldsymbol{\gamma}) = v_{jt}$, where the vector $\mathbf{Z}_{jt}$ incorporates all the measured variables appearing in this equation, the vector $\boldsymbol{\theta}$ contains parameters of the MRS function, and $\boldsymbol{\gamma}$ is the parameter vector of the production function. Define $\mathbf{g}'(\boldsymbol{\theta}, \boldsymbol{\gamma}) = (g_{11}, \ldots, g_{JT_J})$, g_i as the ith element of $\mathbf{g}(\boldsymbol{\theta}, \boldsymbol{\gamma})$, $\mathbf{G}_{\boldsymbol{\theta}}(\boldsymbol{\theta}, \boldsymbol{\gamma}) \equiv \partial\mathbf{g}/\partial\boldsymbol{\theta}'|_{\boldsymbol{\theta},\boldsymbol{\gamma}}$, and $\mathbf{G}_{\boldsymbol{\gamma}}(\boldsymbol{\theta}, \boldsymbol{\gamma}) \equiv \partial\mathbf{g}/\partial\boldsymbol{\gamma}'|_{\boldsymbol{\theta},\boldsymbol{\gamma}}$. To compute an estimate for the true value of the MRS parameters denoted by $\boldsymbol{\theta}_0$, we apply nonlinear 2SLS fixing $\boldsymbol{\gamma}$ equal to the estimate obtained by the 2SLS method described above. Thus this procedure involves calculating the estimate $\hat{\boldsymbol{\theta}}$ by minimizing the distance function $\mathbf{Q}(\boldsymbol{\theta}, \hat{\boldsymbol{\gamma}}) \equiv \mathbf{g}'(\boldsymbol{\theta}, \hat{\boldsymbol{\gamma}})\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{g}(\boldsymbol{\theta}, \hat{\boldsymbol{\gamma}})$ with respect to $\boldsymbol{\theta}$. Thus $\mathbf{Q}_{\boldsymbol{\theta}}(\hat{\boldsymbol{\theta}}, \hat{\boldsymbol{\gamma}}) \equiv \partial\mathbf{Q}/\partial\boldsymbol{\theta}|_{\hat{\boldsymbol{\theta}},\hat{\boldsymbol{\gamma}}} = 0$ defines $\hat{\boldsymbol{\theta}}$.

An exact first-order Taylor expansion of this system of equations around the points $\boldsymbol{\theta}_0$ and $\boldsymbol{\gamma}_0$ yields

$$\mathbf{Q}_{\boldsymbol{\theta}}(\boldsymbol{\theta}_0, \boldsymbol{\gamma}_0) + \mathbf{Q}_{\boldsymbol{\theta\theta}}(\boldsymbol{\theta}_c, \boldsymbol{\gamma}_c)(\hat{\boldsymbol{\theta}} - \boldsymbol{\theta}_0) + \mathbf{Q}_{\boldsymbol{\theta\gamma}}(\boldsymbol{\theta}_c, \boldsymbol{\gamma}_c)(\hat{\boldsymbol{\gamma}} - \boldsymbol{\gamma}_0) = 0,$$

where $\mathbf{Q}_{\boldsymbol{\theta\theta}}(\boldsymbol{\theta}, \boldsymbol{\gamma}) \equiv (\partial^2\mathbf{Q}/\partial\boldsymbol{\theta}\partial\boldsymbol{\theta}')|_{\boldsymbol{\theta},\boldsymbol{\gamma}}$ and $\mathbf{Q}_{\boldsymbol{\theta\gamma}}(\boldsymbol{\theta}, \boldsymbol{\gamma}) \equiv (\partial^2\mathbf{Q}/\partial\boldsymbol{\theta}\partial\boldsymbol{\gamma}')|_{\boldsymbol{\theta},\boldsymbol{\gamma}}$ are matrices of second partials, and $(\boldsymbol{\theta}_c, \boldsymbol{\gamma}_c)$ is a point between $(\hat{\boldsymbol{\theta}}, \hat{\boldsymbol{\gamma}})$ and $(\boldsymbol{\theta}_0, \boldsymbol{\gamma}_0)$. Solving this equation system for $\hat{\boldsymbol{\theta}} - \boldsymbol{\theta}_0$ and using (A1), it follows that

$$(\hat{\boldsymbol{\theta}} - \boldsymbol{\theta}_0) = \mathbf{H}(\boldsymbol{\theta}_c, \boldsymbol{\gamma}_c, \boldsymbol{\gamma}_b)\mathbf{h}(\boldsymbol{\theta}_0, \boldsymbol{\gamma}_0), \qquad \text{(A3)}$$

where $\mathbf{H}(\boldsymbol{\theta}_c, \boldsymbol{\gamma}_c, \boldsymbol{\gamma}_b) \equiv [\mathbf{H}_1 : \mathbf{H}_2]$ is a partitioned matrix with $\mathbf{H}_1 \equiv -\mathbf{Q}_{\boldsymbol{\theta\theta}}^{-1}(\boldsymbol{\theta}_c, \boldsymbol{\gamma}_c)$ and $\mathbf{H}_2 \equiv \mathbf{Q}_{\boldsymbol{\theta\theta}}^{-1}(\boldsymbol{\theta}_c, \boldsymbol{\gamma}_c)\mathbf{Q}_{\boldsymbol{\theta\gamma}}(\boldsymbol{\theta}_c, \boldsymbol{\gamma}_c)\mathbf{L}_{\boldsymbol{\gamma\gamma}}^{-1}(\boldsymbol{\gamma}_b)$, and $\mathbf{h}(\boldsymbol{\theta}_0, \boldsymbol{\gamma}_0) \equiv (\mathbf{h}_1, \mathbf{h}_2)'$ is a partitioned vector with $\mathbf{h}_1 \equiv \mathbf{Q}_{\boldsymbol{\theta}}(\boldsymbol{\theta}_0, \boldsymbol{\gamma}_0)$ and $\mathbf{h}_2 \equiv \mathbf{L}_{\boldsymbol{\gamma}}(\boldsymbol{\gamma}_0)$. A comparison of (A3) with (A1) reveals that the expressions for $\hat{\boldsymbol{\theta}} - \boldsymbol{\theta}_0$ and $\hat{\boldsymbol{\gamma}} - \boldsymbol{\gamma}_0$ have the same basic structure. In particular, the matrix $\mathbf{H}$ in (A3) plays a role analogous to $\mathbf{L}_{\boldsymbol{\gamma\gamma}}^{-1}$ in (A1) and, since $\mathbf{h} = \mathbf{MW}$ with

$$\mathbf{M} \equiv 2\begin{bmatrix} \mathbf{G}_{\boldsymbol{\theta}}'\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1} & 0 \\ 0 & \mathbf{F}_{\boldsymbol{\gamma}}'\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1} \end{bmatrix}$$

and $\mathbf{W} \equiv \mathbf{W}(\boldsymbol{\theta}, \boldsymbol{\gamma}) \equiv \Sigma_{i=1}^{n}\mathbf{w}_i(\boldsymbol{\theta}, \boldsymbol{\gamma}) \equiv \Sigma_{i=1}^{n}(g_i\mathbf{X}_i', f_i\mathbf{X}_i')'$, the vector $\mathbf{h}$ has the same structure as $\mathbf{L}_{\boldsymbol{\gamma}}$ with $\mathbf{M}$ and $\mathbf{W}$ corresponding to the quantities $\mathbf{F}'\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}$ and $\mathbf{X}'\mathbf{f}$. Consequently, one can directly apply the analysis of the previous discussion to determine the asymptotic properties of the estimator $\hat{\boldsymbol{\theta}}$.

Assuming that the error terms of the MRS and the production functions for a given union newspaper follow a bivariate moving average process and are independently distributed across the different union-newspaper observations, the quantity $\sqrt{n}^{-1}\mathbf{W}(\boldsymbol{\theta}_0, \boldsymbol{\gamma}_0)$, like $\sqrt{n}^{-1}\mathbf{X}'\mathbf{f}(\boldsymbol{\gamma}_0)$ in the preceding analysis, represents a normalized sample average of an m-dependent error process with each observation having zero mean. Assuming the conditions alluded to in the theorem above, it follows that $\sqrt{n}^{-1}\mathbf{W}(\boldsymbol{\theta}_0, \boldsymbol{\gamma}_0) \xrightarrow{d} N(0, \boldsymbol{\Omega}_0)$, with $\boldsymbol{\Omega}_0$ being the probability limit of the matrix $\boldsymbol{\Omega}(\boldsymbol{\theta}_0, \boldsymbol{\gamma}_0)$, where

$$\boldsymbol{\Omega}(\boldsymbol{\theta}, \boldsymbol{\gamma}) \equiv n^{-1}\sum_{i=1}^{n}\mathbf{w}_i\mathbf{w}_i' + 2n^{-1}\sum_{t=1}^{m}\sum_{i=t+1}^{n}\mathbf{w}_i\mathbf{w}_{i-t}'.$$

With this result, satisfaction of standard regularity assumptions permits one to show the following four asymptotic results: (i) $\hat{\boldsymbol{\theta}} \xrightarrow{p} \boldsymbol{\theta}_0$; (ii) $\sqrt{n}\mathbf{H}(\boldsymbol{\theta}_c, \boldsymbol{\gamma}_c, \boldsymbol{\gamma}_b)\mathbf{h}(\boldsymbol{\theta}_0, \boldsymbol{\gamma}_0) - \mathbf{R}(\boldsymbol{\theta}_0, \boldsymbol{\gamma}_0)\sqrt{n}^{-1}\mathbf{W}(\boldsymbol{\theta}_0, \boldsymbol{\gamma}_0) \xrightarrow{p} 0$, where $\mathbf{R}(\boldsymbol{\theta}, \boldsymbol{\gamma}) \equiv [\mathbf{R}_1 : \mathbf{R}_2]$ is a partitioned matrix with

$$\mathbf{R}_1 \equiv \mathbf{R}_1(\boldsymbol{\theta}, \boldsymbol{\gamma}) \equiv -n[\mathbf{G}_{\boldsymbol{\theta}}'\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{G}_{\boldsymbol{\theta}}]^{-1}\mathbf{G}_{\boldsymbol{\theta}}'\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1},$$

and

$$\mathbf{R}_2 \equiv \mathbf{R}_2(\boldsymbol{\theta}, \boldsymbol{\gamma}) \equiv [\mathbf{G}_{\boldsymbol{\theta}}'\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{G}_{\boldsymbol{\theta}}]^{-1}[\mathbf{G}_{\boldsymbol{\theta}}'\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{G}_{\boldsymbol{\gamma}}]\mathbf{B};$$

(iii) $\mathbf{R}(\hat{\boldsymbol{\theta}}, \hat{\boldsymbol{\gamma}}) \xrightarrow{p} \mathbf{R}(\boldsymbol{\theta}_0, \boldsymbol{\gamma}_0)$; and (iv) $\boldsymbol{\Omega}(\hat{\boldsymbol{\theta}}, \hat{\boldsymbol{\gamma}}) \xrightarrow{p} \boldsymbol{\Omega}(\boldsymbol{\theta}_0, \boldsymbol{\gamma}_0)$.

Accumulating these findings implies that in large samples

$$\hat{\boldsymbol{\theta}} \sim N[\boldsymbol{\theta}_0, n^{-1}\mathbf{R}(\hat{\boldsymbol{\theta}}, \hat{\boldsymbol{\gamma}})\boldsymbol{\Omega}(\hat{\boldsymbol{\theta}}, \hat{\boldsymbol{\gamma}})\mathbf{R}'(\hat{\boldsymbol{\theta}}, \hat{\boldsymbol{\gamma}})]. \qquad \text{(A4)}$$

The standard errors reported in this paper for the coefficients of the MRS function are based on (A4) with $m = 3$.

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