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Contrary to recent criticism, the standard production function test can, in principle, reveal whether or not unionized workers or firms are more productive than their nonunion counterparts. In the long run, however, the forces of competition foreordain the result.

THE ANALYSIS OF UNION IMPACT on productivity has been the most thoroughly researched area of the union "effects" literature in the years following Brown and Medoff's (1978) pioneering study.[1] But the notion that union-induced changes in the workplace lead to productivity improvement has proven controversial for at least two reasons. First, the informal nature of the underlying collective-voice model advanced by Freeman and Medoff (1984) has not lessened the skepticism of those trained to regard unions as combinations in restraint of trade, despite a plethora of positive union coefficients from production function tests. Second, critics have seized upon other pieces of information generated by the evolving literature (e.g., lower rates of total factor productivity growth in the union sector and unionism's apparently negative effect on profitability) to argue that the scale of the union productivity effect obtained in many of the production function studies is considerably overstated.

Until recently, however, the production function test itself has not come under direct challenge, subject to the usual caveats concerning measurement error. That position changed with Reynolds' (1986) assertion that the test confuses movements along marginal product schedules with shifts in those functions, and that it is not possible empirically to distinguish between the two phenomena. Indeed, Reynolds argues that the *mechanical*

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[1] The extensive American literature is surveyed in Hirsch and Addison (1986) and Addison and Hirsch (1989). A survey of the growing British literature is provided by Metcalf (1990), and German results are given in Addison, Genosko, and Schnabel (1989).

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movement up the demand curve by employers confronted with a union wage premium—until marginal (revenue) product is once again equated with the wage—yields a spurious productivity differential in the production function test that is identical in magnitude to the observed union wage differential.

On the contrary, we argue that the production function test achieves more than this and that the weak hypothesis that unions are associated with higher productivity can be tested. We use "weak hypothesis" because of the observational equivalence between the strong hypothesis that unions raise productivity and alternative arguments to the effect that unions select the inherently more productive firms for unionization *or* that inefficient union firms have been selected out of the system. We know of no study that satisfactorily resolves the problem of union endogeneity,[2] although we argue that, in the long run, survival-selectivity reasoning preordains the stylized production function result.

In addition, the ensuing discussion is conducted within the framework of an on-the-demand-curve analysis. Here we simply follow the restrictions imposed by critics of the production function test. In fact, the test procedure does *not* hinge on the assumption that wage-employment outcomes are constrained to lie on the demand curve. Contract curve solutions do, however, imply that the wage exceeds labor's marginal (revenue) product, thus establishing that Reynolds' criticism, even if correct, is not general. As a matter of fact, settlements off the demand curve (though not necessarily on the contract curve) are likely to exist in some bargaining situations (Eberts and Stone, 1986; MaCurdy and Pencavel, 1986). For this reason, we shall not separately consider other criticisms of the production function test, such as Wessels' (1985) conjecture that estimates of equivalent wage and productivity effects cannot be believed simply because of the failure of union employment to fall sufficiently to square such results with extant estimates of the Hicksian elasticity of labor demand.

We also do not argue that the production function test is either the most appropriate or the sole vehicle for evaluating unionism's effect on productivity. Thus, the assumption of exogenous input quantities is unsatisfactory and leads one to favor a cost function approach in the manner of Allen (1987). Equally, the measurement of union impact, consistent with the route followed by the evolving literature, might also be expected to involve a consideration of union influence on investment, profitability, and productivity growth.[3]

[2] See, e g , Brown and Medoff's (1978, p 374) highly speculative discussion

[3] On the dynamic aspects of union behavior, see Addison and Hirsch (1989)

First, we outline the simple analytics of the production function test. Next, we address the source of confusion in the revisionist interpretation of the Brown-Medoff result. We then deploy a two-sector model to illustrate why there is no reason to expect identical union productivity and wage effects *and* to identify the special circumstances in which this equality will obtain. We conclude with a restatement of the real ambiguity in the production function literature.

Movements Along Versus Shifts in Curves

First, let us tackle the issue of whether the production function test picks up movements only along the labor demand curve, and hence measures nothing more than the difference in marginal products at the profit maximizing levels of labor inputs.

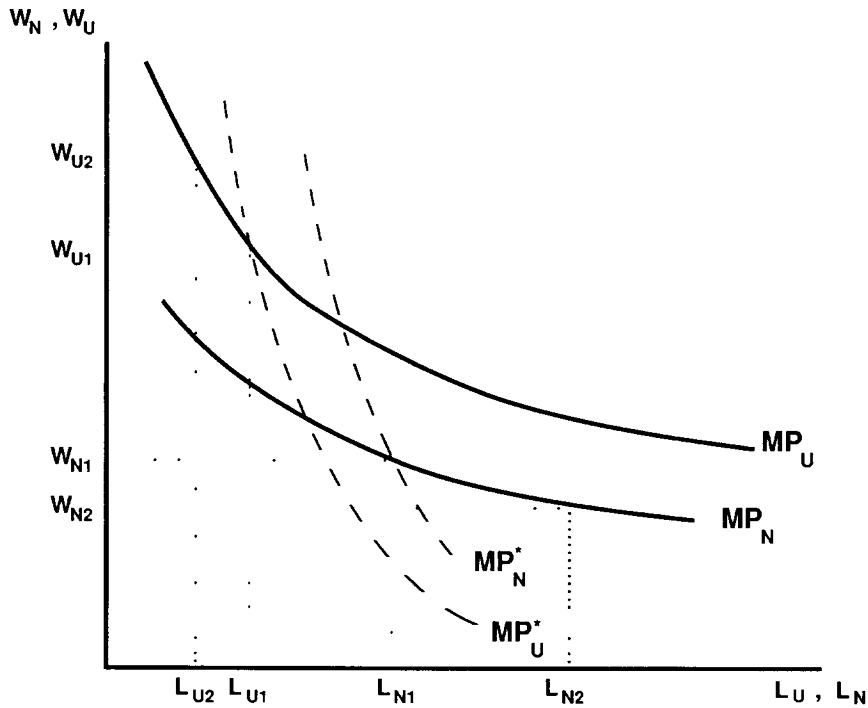
Suppose we observe two firms, just one of which is unionized. The *t*th observation of these firms, where t may refer to a unit of time, includes a (real) wage and quantity of employment pair for each firm (W_{Ut}, L_{Ut}; W_{Nt}, L_{Nt}). We assume (W_{Ut}, L_{Ut}) is a point on the unionized firm's demand for labor schedule. (W_{Nt}, L_{Nt}) is interpreted similarly for the nonunion firm. The capital stock is held constant and equal in each firm, as is labor quality. Similarly, it is assumed that each type of labor is measured in the same units, so that an exogenous switch of one unit of labor between firms would leave each firm's output unchanged. Finally, since (following Reynolds) we associate the demand for labor with its marginal product, firms are assumed to operate in a competitive output market.

Given the above, it is apparent that if $W_{Ut} > W_{Nt}$ and $L_{Ut} > L_{Nt}$, we would have a clear-cut contradiction of the null hypothesis that unions are not associated with higher productivity. If, as is typically presumed, unions raise wages, $W_{Ut} > W_{Nt}$, and lower employment, $L_{Ut} < L_{Nt}$, the possibility of such a definitive contradiction on the basis of any single observation is remote. Consider Figure 1. If we have just one observation (W_{U1}, L_{U1}; W_{N1}, L_{N1}), nothing can be ruled out: Both the solid pair of marginal product curves and their dashed counterparts remain possibilities.

But suppose we have more observations on these two firms. Fitting curves to points, we could begin to discern the two marginal product schedules, even though we may only have observations where $W_{Ut} > W_{Nt}$ and $L_{Ut} < L_{Nt}$. (For example, a second observation may yield (W_{U2}, L_{U2}; W_{N2}, L_{N2}), which better fits the hypothesis that unionization is associated with higher productivity.) Thus, it is possible for empirical studies to pick up more than differences in marginal products at their profit-maximizing levels.

FIGURE 1

The Identification of Union Productivity Effects and the Independence of W_U/W_N from c



In the Brown-Medoff approach, production functions are estimated rather than marginal product (factor demand) schedules. But this amounts to the same thing because of the equivalence of total product with the area under the marginal product schedule. Note that, given the previously stated controls for capital and labor quality, all that is necessary for the *association* of unions with higher productivity is that the appropriate area under the marginal product of union labor curve exceed that for nonunion labor at equal levels of employment. MP_U everywhere above MP_N is sufficient but not necessary.

The Source of Confusion

Next, consider the source of the erroneous notion that the production function test establishes little more than a naive productivity differential, namely, the difference in marginal products at their profit-maximizing levels. If individual firms have the production function *assumed by Brown* *and Medoff to hold in the aggregate,* then, in an interior solution, the ratio of the union wage to the nonunion wage will equal the measure of the union productivity differential. This result has been the source of some confusion because it is tempting to infer from the equality that all that has been observed is a movement along the demand curve.

Consider the modified Cobb-Douglas production function that forms the basis for the Brown-Medoff estimating equation:

$$Y = AK^a(L_N + cL_U)^{1-a}, \tag{1}$$

where Y is output, K is capital, and L_N and L_U are nonunion and union labor, respectively. L_N and L_U are measured in identical-quality units. A, a, and c are each positive parameters with $a < 1$. Assume that equation (1) is the production function available to any firm in the Y product market, again contrary to Brown and Medoff, who use it to represent an aggregate production function for the industry. It is immediately obvious that, regardless of L_N, L_U, or K, the rate of technical substitution of union labor for nonunion labor is equal to c:

$$MP_U(L_N, L_U, K)/MP_N(L_N, L_U, K) = c. \tag{2}$$

That is, one unit of union labor is a perfect substitute for c units of otherwise identical-quality nonunion labor. Unions are associated with higher productivity if and only if $c > 1$. It is assumed that firms take W_N (the nonunion wage) and W_U (the union wage) as given, are free to choose L_N and L_U, and choose them to maximize profit.

Profit maximization implies cost minimization. Are we therefore to conclude (as does Reynolds, p. 444) that profit maximization implies:

$$MP_U(L_N, L_U, K)/MP_N(L_N, L_U, K) = c = W_U/W_N. \tag{3}$$

The answer is in the negative precisely because c, W_U, and W_N are *parameters* for the firm. Thus, equation (3) refers to an interior solution, namely, a situation in which union and nonunion labor are employed alongside one another in the firm.[4] What cost minimization tells us more generally is that

$$\text{if } c \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} \frac{W_U}{W_N}, \text{ then } L_U \begin{Bmatrix} > \\ \geqq \\ = \end{Bmatrix} 0 \text{ and } L_N \begin{Bmatrix} = \\ \geqq \\ = \end{Bmatrix} 0. \tag{4}$$

What are the implications of this analysis for empirical work? Assuming that equation (1) correctly specifies the production function available to a

[4] This is not to say that interior solutions will be rare, at least if $c \geqq 1$, one would expect the union to choose $W_U = cW_N$ (and if $c \leq 1$, no worker would desire union status)

representative firm, the answer is quite simple. From equation (4), if $L_U > 0$, then $W_U/W_N \leq c$. Then, if $L_U > 0$ and $W_U/W_N > 1$, in conformity with casual observation, it follows that $c > 1$. Rather than revealing that tests of the weak hypothesis simply confound levels with shifts, profit-maximizing behavior on the part of firms makes it unnecessary to run a production function test. This conclusion is not intended as a criticism of Brown-Medoff since it hinges on the assumption that the production function expressed in equation (1) is available to each firm in the industry, which is not their intention. In short, *their* test has not been shown to be redundant on this analysis. Moreover, treatment of equation (1) as that available to all firms is institutionally naive to the extent that it allows the firm freely to choose whether to employ union or nonunion labor or even a mix of union and nonunion labor.

A Model with Union and Nonunion Sectors

It is more realistic to assume that the industry is made up of unionized and nonunionized firms. We will demonstrate that there is no reason for the ratio of the union to nonunion wage to equal the union productivity differential, thereby establishing the nonredundancy of the Brown-Medoff test. On the other hand, when the equality *does* obtain, the presumption is that we are in a long-run setting, which outcome compounds the difficulty of distinguishing between competing hypotheses as to the source of union productivity gain.

The short run. Assume each firm has a Cobb-Douglas production function. Thus, for nonunionized firms:

$$Y_N = AK_N^a L_N^{1-a}, \tag{5}$$

and for unionized firms:

$$Y_U = AK_U^a (cL_U)^{1-a}. \tag{6}$$

A unionized firm is (globally) more productive if $Y_U > Y_N$ when $K_U = K_N$ and $L_U = L_N$. From equations (5) and (6), the unionized firm is more productive if and only if $c > 1$. The presence of c in the unionized firm's production function means that with the same quantity of capital, a nonunion establishment would require c times as much identical-quality labor to produce the same level of output as a union establishment and is equivalent to labor-saving technical progress.[5] This does not mean the ratio of

[5] Of course, with equal labor and capital, $Y_U = c^{1-a}Y_N$, so that the presence of c in (6) is equivalent to disembodied technical progress This observation in no way disturbs our conclusions

marginal products, at equal amounts of labor and capital, will equal c. From equations (5) and (6),

$$MP_N = \frac{\partial Y_N}{\partial L_N} = (1-a)AK_N^a L_N^{-a} = (1-a)Y_N/L_N, \tag{7}$$

and

$$MP_U = \frac{\partial Y_U}{\partial L_U} = (1-a)Ac^{1-a}K_U^a L_U^{-a} = (1-a)Y_U/L_U. \tag{8}$$

Thus, at $K_N = K_U$ and $L_N = L_U$, the ratio of marginal products is:

$$(MP_U/MP_N)\big|_{L_N=L_U} = c^{1-a}.$$

Although this ratio is not c, the proportional vertical shift in MP_N to MP_U is c^{1-a}, at equal levels of capital. Note that when $c \gtrless 1$, we have $c^{1-a} \gtrless 1$.

What sort of comparison would be required to produce the result that the ratio of marginal products equals c? Answer: where $L_N = Cl_U$. Then, at $K_N = K_U$ and $L_N = Cl_U$:

$$(MP_U/MP_N)\big|_{L_N=cL_U} = c.$$

Figure 1 illustrates these results. The solid curves are drawn for the case $c = 2$, $a = 1/3$ Note that $L_{N1} = 2L_{U1}$ and $W_{N1} = 1/2 W_{U1}$, illustrating that, for $c = 2$, at twice the level of labor input MP_N is half the value of MP_U. Since $c^{1-a} = 1.587$ when $c = 2$ and $a = 1/3$, the figure is drawn so that at any given level of labor input, $MP_U/MP_N = 1.587$.

Also consider the pair of wages (W_{U2}, W_{N2}). Although W_{U2}/W_{N2} equals the ratio of the marginal products at the profit-maximizing levels of $L_U = L_{U2}$ and $L_N = L_{N2}$, there is no reason it must equal c. Our illustration gives the case of $W_U/W_N > c = 2$.

Long-run considerations. Brown and Medoff found that "the point estimate of the union-wage effect lies well within the 95 percent confidence intervals for the union-productivity effect" (p. 369). That is, they cannot reject the hypothesis that $W_U/W_N = c$ in their data set. Yet, as we have previously argued, it is, in principle, possible separately to identify the union wage and productivity effects. In these circumstances, is there a reason to expect that the data sets we are given would yield $W_U/W_N = c$?

Suppose our firms are free to select both L and K. In our argument, a nonunion firm has the production function $Y_N = f(L_N, K_N)$, and its unionized counterpart has the production function $Y_U = f(cL_U, K_U)$. Note that equations (5) and (6) are special cases of these production functions.

Suppose $(\hat{Y}_N, \hat{L}_N, \hat{K}_N)$ is a technically efficient action for a nonunion firm, that is, $\hat{Y}_N = f(\hat{L}_N, \hat{K}_N)$. Then the action $(\hat{Y}_N, \hat{L}_N/c, \hat{K}_N)$ must be feasible for a union firm: $\hat{Y}_N = f[c(\hat{L}_N/c), \hat{K}_N]$. At $(\hat{Y}_N, \hat{L}_N, \hat{K}_N)$, a nonunion firm's real profit will be $\hat{Y}_N - W_N\hat{L}_N - r\hat{K}_N$, where r is the real price of capital. If $W_U/W_N \leq c$, then the unionized firm will always be able to achieve the same profit level since it can earn at least:

$$\hat{Y}_N - W_U\hat{L}_N/c - r\hat{K}_N \geq \hat{Y}_N - W_N\hat{L}_N - r\hat{K}_N.$$

A parallel argument applies for $W_U/W_N \geq c$: A nonunion firm will always be able to achieve as much profit as a unionized firm.

If there is free entry (or constant returns to scale) for both types of firm, then, in the long run, all survivors will make zero profits. In order to survive, each must make nonnegative profit. This yields the conclusion that if both types do survive, $W_U/W_N = c$. Alternatively, assume only free entry of nonunion firms. If unions select W_U subject to unionized-firm survival, then $W_U/W_N = c$.

The above argument explains why it is that long-run data sets will tend to support the hypothesis $W_U/W_N = c$, given that union productivity effects show up as labor-saving technical change. Long-run considerations also have implications for the testing of productivity effects of unions quite apart from whether they take the form of labor-saving technical change.

Suppose that at equal input prices, unionized firms *are* more productive in the sense that minimum long-run average cost is lowest in unionized firms. Now there is scope for a union to extract a wage premium in the industry long-run equilibrium. If we do not question the joint hypotheses of price taking, the long run, and profit-maximizing choices of L *and* K, then observation of $W_U/W_N > 1$ is prima facie evidence that in surviving firms, unions either are pro-productive or can persist if attached to inherently more productive firms.[6]

Conclusions

Production function studies of union impact on productivity have not naively mistaken wage for productivity differences. Use of the $W_U/W_N = c$ condition is frankly a red herring. It is quite true that if we observe a wage differential, then we should observe an equal productivity differential, *if* the latter is computed simply by evaluating the marginal products of labor at the profit-maximizing levels of labor input (but no reason they must

[6] This conclusion also applies in the off-the-demand curve case If the union also sets employment, the survival argument applies a fortiori, since this is simply another constraint on the profitability of unionized firms

equal c). But this is emphatically *not* the measure of productivity used by the econometrician in the production function test.

Although estimating union and nonunion production functions can reveal whether unionized workers or firms are more productive than their nonunion counterparts, the result is foreordained by long-run competition. To the extent that the researcher's data set is composed of long-run survivors, unionism must be associated with greater productivity—the weak hypothesis. Therefore, the real ambiguity attaching to the production function test is whether the productivity differential is explained by the Freeman-Medoff hypothesis or is due solely to the advantage of inherently more productive firms in surviving the wage premium imposed by unions.

The claim that productivity studies cannot escape the naive association of wage and productivity differentials is, however, a distinctly different point, and to the extent that it has been given credence in the profession has diverted attention from the real issue. That issue is, of course, the design of an appropriate test of the collective-voice model, incorporating but hardly confined to survival-selection controls.

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