OUTPUT AND STRIKE ACTIVITY IN U.S. MANUFACTURING: HOW LARGE ARE THE LOSSES?

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This study analyzes the relationship between strike activity and output among disaggregated manufacturing industries. A major finding is that in many manufacturing industries, strikes have no discernible effect on industry output. Even when strikes are found to have a statistically significant effect on output, the net loss of output appears to be small. Overall, the evidence suggests that the ability of nonstruck firms to increase their output, and of struck firms to draw on inventories, makes it highly unlikely that strikes in manufacturing will cause a national emergency.

STRIKES have long commanded the attention of economists and other social scientists precisely because they are such striking events. Like wars, duels, and violent encounters of all kinds, the occurrence of strikes would seem to reflect either miscalculation or love of combat. When the parties to a bargain have adequate information about each other's capabilities and incentives, the carrying out of threats would appear unnecessary and, indeed, irrational. And usually such events do not happen: strikes occur only infrequently. Yet they do occur, and not only among inexperienced bargaining pairs. Moreover, when aggregated over firms or industries, strikes exhibit statistical regularities that affect economic decision making.

One possible explanation of this phenomenon is that even among mature bargaining pairs, strikes are the result of miscalculations, which would suggest that most often strikes are accidents.[1] But although any one strike may be interpreted as an accident, systematic differences across bargaining pairs in the frequency with which strikes occur must be explained by differences in the behavioral characteristics of the parties. Just as proper maintenance of a vehicle and prudent driving habits reduce the frequency of automobile accidents, the development of appropriate institutional arrangements for the conduct of collective bargaining — what we have previously called protocols[2] — curbs strike activity. Indeed, the development of binding arbitration as a means of resolving disputes over the interpretation of existing contracts has come close to eliminating strikes over contract interpretation.[3]

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[1]See John R. Hicks, *The Theory of Wages* (London: Macmillan, 1932).

[2]Melvin W. Reder and George Neumann, "Conflict and Contract: The Case of Strikes," *Journal of Political Economy,* Vol. 88., No. 5 (October 1980), pp. 867 - 86.

[3]In 1949, for example, strikes over what the U.S. Bureau of Labor Statistics labels "other working

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Why, then, are strikes not relegated to the museum of vestigial business practices, when such simple expedients as arbitration, or even coin flipping, are available? The answer is that just as strikes involve costs, so too does strike prevention. In the sphere of labor relations, the establishment of a protocol is akin to the installation of capital equipment and is done only when the expected gain exceeds costs. Thus, differences in both the costs and returns to preventing strikes are expected to be related across bargaining pairs to differences in the amount of strike activity observed.

Unfortunately, the central element in this story—the cost of a strike—is a matter about which we have little knowledge.[4] Although newspaper editorials routinely denounce both unions and employers for the losses caused by labor disputes, the plain fact is that we do not know whether such losses are big or small, or even if there are any.

The Model

Previous discussions of strike costs have focused almost exclusively on the immediate losses of output and workers' earnings caused by the cessation, partial or total, of production resulting from a strike. Implicit in these discussions is the view that what is lost today is lost forever; that is, output not produced and wages not earned during a strike will never be regained. This may indeed be the case in some situations—for example, in a monoply where the output cannot be stored—but it is not the case in all. The ability of struck firms to substitute production over time through inventory accumulation and decline implies that to some extent the immediate costs of a strike are offset. Consider the simple case of a nonstorable good produced by one firm only. If demand is separable over time, the costs of a strike are the sum of the losses of quasi-rents by the employer, the loss of wages and producers' surplus by workers, and the loss of consumer surplus by consumers. This calculation is consonant with the conventional view of strike costs; namely, both participants lose, and third-parties also suffer adverse effects.

In the polar opposite case of a constant-cost industry with many producers, a strike of some (but not all) firms causes loss to the two parties involved in the form of sacrificed quasi-rents and wages, but neither a loss to consumers nor a loss of producers' surpluses to the industry as a whole. Instead, other producers increase their output to offset reduced production by those engaged in striking, without generating any increase in total cost. In this case, that is, there is a *private* cost to strike activity, borne by the participants, but no cost to the industry or to society, because the loss to the participants is offset by the gains of other producers, with industry output and customer welfare unchanged. In general, the real effect of strikes lies somewhere between these two extremes.

If information on specific bargaining pairs were available, a stylized view of the effect of a strike could be depicted as in the figure. For a particular bargaining unit, the optimal production path during a no-strike period is given by Q_t. If we assume that strikes are perfectly anticipated, the firm will then deviate from Q_t by building up inventories in the pre-strike period $(t_1 - t_0)$, running them down during the strike period $(t_2 - t_1)$, and rebuilding them to the optimal level during the post-strike period $(t_3 - t_2)$. The net output lost due to a strike would be, apart from the interest paid on inventory accumulation, $B - A - C$.[5]

conditions," which include grievances and arbitration, accounted for 21.5 percent of all strikes. In 1959, such strikes represented 20.5 percent of all strikes. After the Supreme Court's decision in the Steelworkers' "Trilogy" cases (see Robert A. Gorman, *Basic Text on Labor Law: Unionization and Collective Bargaining,* St. Paul, Minn.: West, 1976, pp. 551-56) established the finality of arbitration, the number of such strikes declined both absolutely and relatively.

[4]Reder and Neumann, "Conflict and Contract," present evidence that strike activity varies inversely with the variability of inventories and shipments taken as a proxy for the cost of strike activity. George R. Neumann, in "The Predictability of Strikes: Evidence from the Stock Market," *Industrial and Labor Relations Review,* Vol. 33, No. 4 (July 1980), pp. 525-35 shows that the security prices of firms respond (negatively) to the onset and (positively) to the termination of a strike. These findings are suggestive, but neither provides an estimate of the cost (average, marginal, or total) of strike activity.

[5]It should be noted that in the context of intertemporal production decisions, costs attributable to the

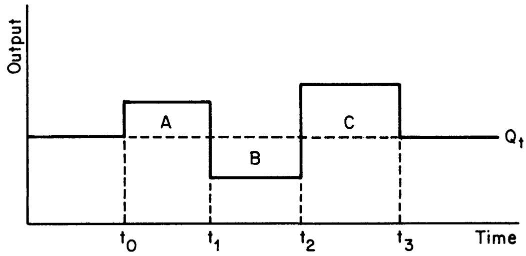

Figure.
Optimal Production with Known Strike Dates.

In essence, B is the output lost while the strike is in progress, and $A + C$ is the pre- and post-strike "catch up" output to satisfy a level of demand for output that is assumed to be unchanged. If data on bargaining pairs were available, estimates of $V_i = (B - A - C)_i$ could be obtained for all firms that undergo strikes, and some average cost measures for strikes could be estimated. Similarly, if there are J firms that do not strike, then

$$V = V_i - \sum_{j=1}^{J} (B - A - C)_j$$

would represent the extra output produced by nonstruck firms, and the sum over j would thus represent the amount of interfirm substitution of output. Clearly, one must know the behavior of struck and nonstruck firms to disentangle participant and industry costs. Industry costs can be inferred from aggregate (industry) data, but they may be small either because participant costs are small or because even though participant costs are large, there is much substitution of production between struck and nonstruck firms.

In the remainder of this paper, we focus on estimating the industry costs of strike activity, although our approach could be extended to estimating participant costs if the necessary data were available for individual bargaining pairs. To fix ideas, consider the following algebraic counterparts of the figure:

$$(1) \qquad Q_t = a_1 S^*_{t+1} + a_2 S^*_t + a_3 S_{t-1} + a_4 Q_{t-1} + \epsilon_t$$

and

$$(2) \qquad S_t = b_1 S_{t-1} + \eta_t; \quad \binom{\epsilon_t}{\eta_t} \sim N(0, \Sigma).$$

In Equation 1, the quantity of current production planned for period t, as of period $t - 1$, is affected by the expected number of strike days in the succeeding period, S^*_{t+1}; by the expected number of current strikes, S^*_t; by the actual number of strike days in the previous period, S_{t-1}; and by the entire past history of production represented by Equation 1. (Expected values for future periods as of period $t - 1$ are designated by an asterisk.) To facilitate exposition, we initially assume that strike activity follows the path of the simple first-order autoregression given by Equation 2.

The first term on the right-hand side of Equation 1 captures the effect of inventory buildup in anticipation of a future strike, while the third term, which reflects lagged strike activity, captures post-strike restocking. Similarly, one could interpret the effect of S^*_t on Q_t to be the anticipated effect (as of $t - 1$) of strike activity in t on output in t. In terms of the figure, we would expect a_1 and a_3 to be greater than zero and a_2 to be less than zero.

Unfortunately, it is not feasible to estimate Equation 1 because anticipations of strikes are not observable. To remedy this, it is necessary to relate expected strike activity to observable behavior. One such relationship that is frequently assumed is that expectations of behavior are formed as if they were determined by the structure of the process that generates actual behavior. Expectations are thus assumed to be rational in the sense of Muth.[6] Specifically, S^*_t and S^*_{t+1} are determined by Ω_{t-1}, the information available at $t - 1$, that is, the history of Q and S as of $t - 1$. Given these assumptions about the determinants of strike anticipations and the further as-

possibility of strikes may exist even if no strikes actually occur. These costs are the extra inventory costs and (possibly) higher marginal cost of production during nonstrike periods that result from precautions taken against potential strikes. But although this is indisputably a cost of (the possibility of) strike activity, it is very difficult to estimate it from recorded behavior, since all firms, even those never experiencing a strike, will bear them.

[6]John F. Muth, "Rational Expectations and the Theory of Price Movements," *Econometrica*, Vol. 29, No. 1 (January 1961), pp. 1–23.

sumption of independence among the disturbances of Equations 1 and 2, expectations of strike activity as of $t - 1$ satisfy the following:[7]

(3a) $$S_t^* = E(S_t \mid \Omega_{t-1}) = b_1 S_{t-1}$$

and

(3b) $$S_{t+1}^* = E(S_{t+1} \mid \Omega_{t-1}) = b_1^2 S_{t-1}.$$

Inserting Equations 3a and 3b into Equation 1 yields:

(1′) $$Q_t = (a_1 b_1^2 + a_2 b_1 + a_3) S_{t-1} + a_4 Q_{t-1} + \epsilon_t,$$

which is a reduced-form relationship combining the structural parameters of both the output and strike-activity processes and the expectations-formation process.

Obviously, a different specification of Equation 2, say a pth-order autoregressive structure, would introduce additional lagged values of strike activity into Equation 1. Still more complicated expressions would result if it were assumed that strike activity depends in part on expectations of future output, or on past output, as well as on the variables already in Equation 2.[8] Consider the model specified by Equation 4, for example:

(4) $$Z_t = \sum_{L=0}^{T} C_i Z_{t+i}^* + B(L) Z_{t-1} + \mu_t,$$

where Z_t is the vector $\{{Q_t \atop S_t}\}$, and T is the number of future periods, expectations of which affect current behavior. As Wallis shows, the solution to Equation 4 in terms of the observed values of the variables ($Z_{t-1}, Z_{t-2}, \ldots$) requires forecasts of all future values of Z_t;[9] these forecasts are themselves functions of weighted sums of past realizations that are determined by still earlier forecasts, and so on. To take this complication into account, consider vector-autoregressive models such as Equation 5 in which L is the lag operator defined by $A(L) = 1 - A_1 L - A_1 L^2 \ldots A_p L^p$:

(5) $$A(L) Z_t = \mu_t.$$

For many purposes (such as estimating the amount of pre-strike inventory buildup in production), "unrestricted" models such as that presented in Equation 5 are uninformative. But they are quite useful for the limited purpose of calculating the effect of strike activity on production, without resort to arbitrary restrictions on either the order of the lag structure of the process or on the horizon of the underlying process of production planning. An alternative way of writing this equation is the moving-average representation:

(6) $$Z_t = A(L)^{-1} \mu_t = \sum_{L=0}^{\infty} \psi_{-L} \mu_t.$$

In Equation 6, the ψ_i s are the impulse-response matrices defined by the matrix long division implicit in the equation; this sequence of matrices traces out the movement in the state variables (Q_t and S_t) induced by the innovations μ_t, μ_{t-1}, and so on. Thus, for a *particular* shock, say μ_t, the *contemporaneous* effect is $\psi_0 \mu_t = I\mu_t = \mu_t$, and the effect of this shock in the next period is $\psi_1 \mu_t$.[10] The cumulative effect on the system of such a shock is given by:

(7) $$F = \sum_{L=0}^{\infty} \psi_L \mu_t = G\mu_t,$$

where G is the 2×2 "steady state gain" matrix.[11] Thus, F contains the sum of

[7] The expressions given in Equations 3a and 3b are conditional expectations under the assumption of normality in the error term. If this assumption is dropped, those equations should be interpreted as the best linear predictors based on Ω_{t-1}.

[8] For a general treatment of the issues arising when expectations of several future values of a variable affect current realizations, see Kenneth F. Wallis, "Econometric Implications of the Rational Expectations Hypothesis," *Econometrica*, Vol 45, No. 1 (1980), pp. 49-74.

[9] Wallis, "Econometric Implications," p. 54.

[10] For example, if $A(L) = I$, strike activity would have only a contemporaneous effect on output, with $\psi_j \equiv 0$ for $j > 0$. If $A(L) = I - A_1 L$, current activity would be affected only by strike activity in the preceding period (both through expectations and adjustments thereto); in other words, $Z_t = A_1 Z_{t-1} + \mu_t$. In this case a particular shock, μ_t, has the effect $I\mu_t = \mu_t$ in the current period; $A_1 \mu_t$ in the second period; $A_1^2 \mu_t$ in the third period; and so on, with the impact multiplier, ψ_i, declining geometrically through time. See Christopher A. Sims, "Money, Income and Causality," *American Economic Review*, Vol. 62, No. 4 (September 1972), pp. 540-52, for a general discussion of the merits of this formulation. Edward J. Hannan, "The Identification and Parametrization of ARMAX and State Space Forms," *Econometrica*, Vol. 44, No. 1 (1976), pp. 713-22 and H. Akaike, "Markovian Representation of Stochastic Processes and its Application to the Analysis of Autoregressive Moving Average Processes," *Annals of the Institute of Statistical Mathematics*, Vol. 26, (1974), pp. 363-87 provide further developments of the basic idea.

[11] The steady state gain matrix is the matrix analogue to the "long run" multiplier effect familiar from single-

previous, current, and eventual responses to a particular shock; no further decomposition into, say, anticipated and unanticipated components can be made without imposing further restrictions on the model.

In the section on strike cost estimates below, we present estimates of the effect of strikes on output using Equations 5 and 7. But before discussing the estimates, some description of the data is necessary.

Data

The appropriate conceptual unit of analysis for strike activity is the bargaining unit, an entity that can be larger than an industry but (in the United States) is often smaller than a firm. Since relevant data, organized by bargaining units, are not available, we are forced to employ measures of aggregates of bargaining units; perforce, these measures make the industry our unit of observation and the social costs of strikes our focus.

As explained in the preceding section, we measure the cost of a strike by the loss in output with which it is associated. Because strikes vary in length, and anticipations of strikes influence the time path of production before the start and after the end of a strike, measurement of strike-caused output loss requires analysis of the time path of production. Information relevant to the time path of production is available for 73 three-digit industry groups from the *Manufacturers' Shipments, Inventories, and Orders*, M3 series.[12] These industry groupings are based on four-digit SIC codes, and are available for the years 1958 to the present.

Data on strike activity are available from the U.S. Bureau of Labor Statistics (BLS) Work Stoppages Historical File for the period 1953–78. These data are classified by three-digit SIC code, rather than four-digit, which leads to overlap in some industries when they are compared with the output data. Aggregating those groups that overlap yields the 63 distinct industry groups under study here.

Of these 63 industry groups, 38 consist of a single three-digit industry; three consist of a single two-digit industry (obtained by summing its component three-digit industries); and each of the remaining 22 is a sum of three-digit industries, all of which are located within a given two-digit industry but the aggregate of which constitutes less than the complete two-digit industry. These 63 "industries," which make up all of the U.S. manufacturing sector, are the entities to which our data refer.

These data yield measurements of the following variables available on a monthly basis for the period, January 1958 to December 1978.

(1) *Shipments.* The monthly value of shipments by the industry, in millions of current dollars.

(2) *Inventories.* The monthly value of total inventories by the industry, in millions of current dollars.

(3) *Output.* Defined as $Output_t \equiv Shipments_t + (Inventories_t - Inventories_{t-1})$.

(4) *Number of Strikes.* The number of strikes in progress for at least one day during a given month, the sum of the number of strikes continuing from the previous month, and strikes beginning in the given month.

(5) *Number of Workers Involved.* The sum of the number of workers involved in all strikes in progress for one or more days during a given month.

(6) *Workdays Lost.* For each strike in progress on one or more days in a given month, there is a reported number of individuals participating. During a given month, each strike is identified by the number of calendar days during which it was in progress. The product of the number of strikers and the number of days, for a given strike, is the number of workdays lost as a result of that strike in that month. The sum of these products, over all strikes in a given industry, is the number of workdays lost (by strikers) in that industry in that month. When strikes continue into an adjacent month, the workdays lost in each

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equation models with a lagged dependent variable; in other words, in the model $Y_t = AX_t + bY_{t-1} + \epsilon_t$, the "short run" multiplier is A, and the long-run effect of a change in X is $A(1 - b)^{-1}$.

[12] U.S. Department of Commerce, Bureau of the Census, *Technical Documentation: Manufacturers' Shipments, Inventories, and Orders (M3-18) Unpublished Data 1958–1978* (Washington, D.C.: GPO, 1979), pp. 4–6.

month are included in the report for the month during which the loss occurred.

(7) *Average Duration.* The average number of workdays spent in striking for all strikes that began in the month.

The estimates of strike costs presented below are constructed from the measures of these variables above. As the imperfections of these measures may cause estimation biases to arise, it is appropriate to warn the reader of these imperfections at the outset.

The construction of the production data series involves two mechanical procedures that may cause bias. The monthly records are collected from a sample of establishments with the probability of inclusion in the sample related to employment size. To offset sampling fluctuations, the U.S. Commerce Department adjusts the measured contribution of month-to-month variation in shipments (or inventories) made by any one firm whenever there is an unusually large monthly variation in the shipments of a single company that is judged to be atypical of the monthly variation in industry shipments.

The Commerce Department describes the procedure as follows (emphasis added):[13]

> From time to time, an individual company report may show unusually large changes from the previous month which differ substantially from the movement shown by the rest of the reporting panel. *An example of this is the effect of a strike upon an individual company.* Such extreme movements are isolated from the estimation procedure as follows: the data for the individual company are removed from the computation of the aggregate month-to-month percentage change and from the prior month's industry estimate; the modified percentage change is then applied to the reduced prior month's estimate, giving a current month's estimate of the entire industry excluding the company with the unusual month-to-month change; finally, the company's reported data are added to the modified current month's estimate to obtain the estimate for the entire industry. The effect of this procedure is to restrict the basis of estimation for nonrespondents and firms not in the survey panel to the general trend of the industry.

In effect, reporting units that are currently experiencing unusually large fluctuations in activity, such as might be expected from the occurrence or imminence of a strike, do not carry their normal sample weight into the calculated monthly industry data. For industries that have 100 percent sampling coverage, this procedure occasions no problem; but for those industries with less than full coverage, the amount of "smoothing" induced by this procedure will vary with the structure of collective bargaining in the industry.[14] If, for output purposes, the reporting unit is coextensive with the collective bargaining unit and if interfirm substitution of production is confined to the industry, the census procedure will generate "correct" results, but these conditions are not always satisfied. In our judgment, the census procedure usually has the effect of reducing the measured correlation of strike activity and output, leading to an underestimate of the output loss due to strikes.

A second source of bias may be that using production data (production defined as shipments plus change in inventories) to measure strike costs is appropriate only if inventories consist exclusively of final (finished) goods. Changes in inventories of

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[13] U.S. Department of Commerce, Bureau of the Census, *Current Industrial Reports M3-1.8* (Washington, D.C.: GPO, 1978), pp. IX-X.

[14] To see this, consider an industry that comprises 100 firms, all of which "normally" produce the same output, say, 100 units. Assume the sample to consist of four firms, each with a "normal" weight of 25 percent. Suppose that in a particular month, one of the sample firms undergoes a strike and produces nothing; another sample firm produces 200 units, perhaps by interfirm substitution; and the remaining two sample firms each produce 100. The census procedure amounts to treating the two changed output levels as extremes (and therefore unrepresentative) and calculating monthly output as 10,000 units (= 49 × 100 + 49 × 100 + 1 × 0 + 1 × 200). If, however, the two sample firms with changed output levels were representative of the normal fraction of unsampled firms, the correct level would be 10,000 units (= 25 × 100 + 25 × 100 + 25 × 200 + 25 × 0). In this case, the census procedure would not misstate output.

Alternatively, suppose that interfirm substitution was less than perfect, but was diffused equally throughout the sample so that three firms produced 120 units and one produced zero. The census procedure would then calculate an output of 11,880 (99 × 120 + 1 × 0); but in the event that the sampled firms truly represented the unsampled, output would have been 9,000 (75 × 120 + 25 × 0), so that the census correction would overestimate output by 32 percent.

final goods reflect current productive activity, whereas changes in inventories of raw materials do not. Unfortunately, at the three-digit industry level, only *total* inventories are reported, and hence what is measured as production includes changes in total inventories and will therefore be biased up or down to the extent that stocks of raw materials have changed. Stated differently, inventories of finished goods are a substitute for current production, whereas goods in process and inventories of raw materials are complements to current production.

To avoid this measurement difficulty, we have used shipments rather than production as the instrument for measuring the cost of strikes. Over a long period of time, shipments and production will vary similarly, but their short-term movements may differ. In what follows, we refer to this measure of shipments as *output*.

Strike data (from the BLS) also present conceptual problems. These data are not a sample; they purport to be a complete count of the number of strikes occurring. The method by which the data are collected (from newspaper accounts and reports from state labor departments) raises doubts about the completeness of coverage, however. Presumably, large strikes of "normal" length are accurately reported. But short strikes (of fewer than three days, for example), or strikes involving small numbers of workers, may be overlooked. Also, where very long strikes (longer than one year) are reported but without a termination date, it is uncertain whether the firm ceased operating or was able to continue operation without the strikers. In either event, average duration becomes ambiguous.[15]

Having issued these caveats, we remind the reader that these are the only data available for assessing the impact of strike activity on industry output in U.S. manufacturing, and we affirm that we believe them to be reasonably accurate. We shall not make further reference to these reservations, although we have borne them in mind in constructing the cost estimates presented below.

Estimates of Strike Costs

For strike activity to be costly, it is necessary that strikes affect at least the timing of production. In other words, strikes and output must bear some statistical relationship to each other. At least implicitly, earlier writers examined this relationship in the aggregate,[16] but so far as we know, behavior at the industry level has received little attention. For this reason, we consider first whether strike activity and output can be considered as independent stochastic processes. Then, conditional on finding nonindependence, we proceed to estimate the cost of an average strike in each industry.

The Interdependence of Strike Activity and Output

The vector autoregressions described in the section above on the cost of strikes were fitted to monthly shipment and strike data for the 63 industries that reported strikes in the 1958-77 period.[17] Since output was entered in logarithmic form, the effects of strike activity on output were therefore measured by the month-to-month percentage changes in output associated with absolute changes in strike activity. To measure strike activity, we used workdays lost (in 10,000s) during the month. Both

[15]Strike lengths in excess of a year, which are sometimes reported in the data, would suggest a collapse of the employment relation between employer and strikers, thereby destroying the applicability of the concept "strike." This is especially so when the firm has completely replaced the strikers and does not intend to deal with them further.

[16]Albert Rees, "Industrial Conflict and Business Fluctuations," *Journal of Political Economy,* Vol. 60, No. 5 (October 1952), pp. 371-82; Orley Ashenfelter and George E. Johnson, "Bargaining Theory, Trade Union and Industrial Strike Activity," *American Economic Review,* Vol 59, No. 1 (March 1969), pp. 35-49; and John Kennan, "Cyclical Fluctuations in Strike Activity," working paper (Iowa City, Iowa: University of Iowa, 1981).

[17]One industry group, wood buildings and mobile homes (SIC 245), had no strikes reported during the 1958-78 period. This is a small industry and one whose definition was changed from the 1967 to the 1972 SIC classification, but nevertheless we find it surprising that no strikes were reported. As one of us has personal knowledge of one strike in this industry, we suspect that such strikes as may have occurred were recorded for another industry.

equations also include a time trend and dummy variables for the month.

After some experimentation, the maximum number of lags in output and strike activity was set at 24. In no industry was there statistical evidence supporting a lag structure as long as 36 months, but in a number of industries statistical tests clearly rejected the hypothesis of "no effect" for all lags between 12 and 24 months. To avoid influencing cross-industry comparisons by the imposition of lag structures that differ from one industry to another, we allowed all industries lags of up to 24 months.

Column 1 of Table 1 presents the marginal significance levels of a test that strike activity and output are independent. The interpretation of these tests is the following: if the two processes are independent, there can be no output lost in the industry studied (no industry cost) from strike activity. The test proposed is to compare (1) the vector autoregressions of output on strikes with (2) the vector autoregressions of strikes on output when these vector autoregressions are estimated with and without restrictions. (The vector autoregressions are those specified by Equation 4).

Three restrictions are imposed on these calculations: lagged strike activity does not enter the output equation; lagged output does not enter the strike equation; and the covariance of strike activity and contemporaneous output is zero. A comparison of the generalized variance of the above autoregressions, when calculated with and without the above restrictions, generates the test statistic $S = (T - k) \ln|V_r| - \ln|V_u|)$,[18] where $|V_r|$ is the determinant of the covariance matrix of the restricted regressions; $|V_u|$ is the analogous determinant of the unrestricted regressions; k is the number of restrictions; and T is the number of observations. The total number of restrictions is 49, and the test statistic is distributed as χ^2 with 49 degrees of freedom.

The marginal significance levels of the test statistic are presented in column 1 of Table 1. (Small entries indicate low probabilities and thus rejection of the null hypothesis of "no effect.") Inspection of these marginal significance levels reveals that at the customary level of significance of 5 percent, only 34 of the 63 industries studied exhibited significant interdependence of strikes and output, while 29 (46 percent of the industries studied) did not. Even making a crude correction for power considerations by considering a 10 percent significance level would not change the story much: we would still find a sizable number of industries (24, or 38 percent of the total) in which strikes and output are independent of each other.[19]

A finding that strikes and output are "not independent" for a particular industry does not imply that strikes affect output. The direction of influence might run from output to strikes, or there might be feedback in both directions. Using a result of Sims,[20] we can rule out feedback if the lagged values of one series fail to predict the value of the other series, given the history (lagged values) of the series to be predicted. In the present context, this amounts to testing, via a conventional F test, first, the significance of the set of coefficients on the lagged values of strike activity in the output equation, Equation 4, and, second, the significance of the coefficients on the lagged values of output in the strike equation, Equation 4. The marginal significance tests are reported in columns 2 and 3 of Table 1.

Inspection of these columns shows that of the 34 industries that show a relationship between strikes and output, 22 show solely an effect of strikes on output; nine show solely an effect of output on strikes; and only three show "two-directional feedback" in the sense that lagged strike activity helps to predict output and lagged output helps

[18]As employed by Sims, "Money, Income, and Causality."

[19]One possible explanation of this phenomenon is that the industries exhibiting independence of strikes and output are those with low levels of unionization. A probit regression relating the presence or absence of independence (of strikes and output) to the degree of unionization (percentage of employees belonging to unions) in the industry yielded an insignificant effect, however, suggesting that the independence of strikes and output is reflective of other structural characteristics that differ among industries.

[20]Sims, "Money, Income, and Causality."

Table 1. Marginal Significance Levels of Tests of Independence and Tests of Prediction, 1958–77.

Industry	SIC Number	Independence[a] (1)	Prediction[b]: Strikes Predict Output (2)	Prediction[b]: Output Predicts Strikes (3)
1. Wooden Containers	244	.5613	.3079	.7124
2. All Other Wooden Products[c]	241-243, 249	.0193*	.9229	.0105*
3. Household Furniture	251	.5112	.4731	.5414
4. All Other Furniture	252-254, 256, 259	.4865	.2720	.6214
5. Glass Containers	322	.0001*	.0312	.0261*
6. Kitchen Articles and Pottery	326	.0001*	.0001*	.0261*
7. Other Stone Clay and Glass[d]	321, 323-325, 327-329	.0137*	.1262	.0001*
8. Blast Furnaces and Steel Mills	331	.1124	.5131	.2432
9. Iron and Steel Foundries	332	.0100*	.0023*	.9992
10. Other Primary Metal Products	333-339	.6100	.3609	.9631
11. Metal Cans, Barrels, and Drums	341	.0048*	.0001*	.7698
12. Cutlery, Handtools, and Hardware	342	.8710	.9231	.9994
13. Building Materials and Wire Products	343, 344	.4619	.9288	.3287
14. Ordnance and Accessories	348	.0017*	.0001*	.0288*
15. Other Fabricated Metal Products[e]	345-347, 349	.9785	.9900	.9492
16. Steam Engines, Turbines, and Internal Combustion Engines	351	.7333	.7708	.9985
17. Farm Machinery and Equipment	352	.0476*	.8405	.0230*
18. Construction, Mining and Material Handling Equipment	353	.0251*	.0001*	.9609
19. Metalworking Machinery, Miscellaneous Equipment, and General Industry Machinery	354, 356	.0614	.4181	.0742
20. Machine Shops	359	.0363*	.0019*	.5278
21. Special Industry Machinery	355	.9941	.9956	.9979
22. Office and Store Machines	357	.9910	.9817	.9944
23. Service Industry Machines	358	.0531	.9982	.0664
24. Electrical Transmission and Distribution Equipment	361	.0216*	.0001*	.9900
25. Electrical Industrial Apparatus	362	.0379*	.0180*	.3263
26. Household Appliances	363	.0912*	.6690	.9999
27. Radio and Television	365	.0214*	.0001*	.9679
28. Communication Equipment	366	.5615	.4305	.9891
29. Electronic Components	367	.0671	.1098	.9999

[a]The marginal significance level is calculated as the right-hand tail area of a χ^2 variable with 49 degrees of freedom. The variate is $(T - K)/T$ times the likelihood-ratio statistic comparing the constrained and unconstrained models.

[b]The marginal significance level is calculated as the right-hand tail area of an F variable with 24 degrees of freedom. The variate is the usual change in the residual sum of squares from the unconstrained and the constrained models.

[c]Some overlap exists between All Other Wood Products and Wooden Containers, because the former includes Wood Pallets and Skids (SIC 2448), which should be in the latter group.

[d]Some overlap exists between Other Stone, Clay, and Glass and Glass Containers, because the former includes Pressed Brown Glass, Not Elsewhere Classified (SIC 3229), which should be in the latter group.

[e]Some overlap exists between Other Fabricated Metal Products and Building Materials and Wire Products, because the latter includes Wire Springs (SIC 3495) and Miscellaneous Fabricated Wire Products (SIC 3496), which should be in the former group.

Table 1 (Continued).

Industry	SIC Number	Independence[a] (1)	Prediction[b] Strikes Predict Output (2)	Output Predicts Strikes (3)
30. Other Electrical Components	364, 369	.0146*	.0011*	.8019
31. Motor Vehicles and Parts	371	.0488*	.6545	.0373*
32. Aircraft and Parts	372, 376	.0076*	.0001*	.8360
33. Railroad Equipment	374	.0089*	.0001*	.8284
34. Shipbuilding, Military Tanks, and Other Transportation Equipment	373, 375, 379	.0312*	.6507	.0144*
35. Scientific and Engineering Instruments	381-384	.0091*	.0001*	.8284
36. Ophthalmic Goods, Watches, Clocks, and Watch Cases	385, 387	.1104*	.1040	.9995
37. Photographic Goods	386	.7219	.7583	.9554
38. Other Durable Goods	391, 393-396, 399	.7897	.8550	.9042
39. Meat Products	201	.0014*	.4656	.0028*
40. Dairy Products	202	.0237*	.0001*	.5491
41. Beverages	208	.0162*	.9867	.0132*
42. Fats and Oils	207	.0022*	.0001*	.9988
43. Grain Mill, Bakery, Sugar and Confectionary, and Other Food Products	203-206, 209	.3369	.5589	.2792
44. Tobacco Products	211-214	.0236*	.0001*	.9988
45. Broadwoven Fabrics and Other Textiles	221, 222, 224, 226, 228	.0287*	.0148*	.4171
46. Knitting Mills	225	.5808	.4111	.9946
47. Floor Covering Mills	227	.0436*	.0001*	.1742
48. Apparel and Related Products	231-239	.0481*	.2981	.0001*
49. Pulp and Paperboard Mills, Except Building	261-263	.0412*	.0312*	.9156
50. Building Paper	266	.9816	.9301	.9978
51. Paperboard Containers	265	.9800	.7856	.9999
52. Die-cut Paper and Board and Other Paper Products	264	.9913	.4720	.9972
53. Newspapers, Books, and Periodicals	271-273	.0036*	.0040*	.9815
54. Other Publishing and Printing	274-279	.9781	.9710	.9780
55. Industrial Chemicals, Paints, and Other Chemical Products	286, 289	.0329*	.0034*	.7330
56. Drugs, Soap, and Toiletries	283, 284	.0147*	.0088*	.9880
57. Fertilizers	287	.5714	.4696	.9986
58. Paving and Roofing Materials	295	.0267*	.8549	.0001*
59. Other Petroleum Products	291, 299	.2187	.2162	.9999
60. Rubber Tires and Tubes	301	.0489*	.0001*	.9300
61. Other Rubber Products	302-304, 306-307	.0489*	.0001*	.9300
62. Leather, Industrial Products, and Out Stock	311, 313	.0364*	.0001*	.7594
63. Other Leather Products	314, 317, 319	.6117	.9999	.4391

*Significant at greater than the 95 percent confidence level in a one-tailed test.

to predict strikes. This implies that there are at most 25 industries that exhibit some evidence of a (positive) cost of strike activity.

The question whether output drives strikes or strikes influence output is an old one in industrial relations, having been raised by both Griffin and Rees and indirectly by many other writers who have studied the empirical relation of the two variables.[21] That strikes may affect output is obvious, but the possibility of the reverse relation—that output may drive strike activity—is less so. Nevertheless, this reverse case is a distinct possibility and should not be dismissed a priori; for example, when business conditions are good, the opportunity cost of a strike to workers might be unusually low, thereby encouraging strikes. Aggregate studies bearing on this point have been inconclusive.[22] Our results show that where a relationship obtains between these variables, in most industries it is strike activity that affects output rather than the reverse.[23]

The Cost of Strike Activity

As explained above, we measure the cost of strike activity from the parameters of the vector autoregressions described there. These parameters are not of interest in themselves, since they are not structural parameters and, moreover, are highly correlated and alternate in sign. (These characteristics are similar to those exhibited in macroeconomic models.) Consequently, we report not those parameters but instead: (1) the loss in output in the month that a strike commences, labeled the *contemporaneous effect* in column 2 of Table 2; and (2) the *total loss* in output caused by a strike, after allowing for pre- and post-strike adjustments to production. To standardize the comparisons across industries, we present (columns 2 and 3 of Table 2) the results for a "standard" strike of 10,000 workdays lost. Because strikes vary widely across industries, both in number and size, this comparison is but one of several that might be made.

To put these results in perspective, we also calculated the average output loss per strike, *SC*. *SC* is defined as the product of percentage change in output per unit of strike activity; the average number of units per strike; and average output during the sample period. To adjust for industry size, we also present estimates of the annual output lost as a result of strike activity relative to annual output. Finally, since we know from Table 1 that strike costs can be measured plausibly in only a particular set of industries, we report results for only those 25 industries in which strikes were significant predictors of output.[24]

As an example, consider the results for blast furnaces and steel mills reported in row 3 of Table 2. Each 10,000 workdays of strike in a month leads to an initial loss (occurring during the month in which the strike begins) of .003 percent in monthly shipments (presented in column 2), with an eventual total loss in output of .214 percent (column 3). Translating these percentages into 1972 dollars and evaluating the losses at the sample means indicate that an "average strike" results in a loss of industry output of about $274,000 (column 4) and that over the entire sample period, the loss from an average strike amounted to about half of one percent (.491 percent) of annual output.

Two features of Table 2 warrant special attention. First, the contemporaneous effect of the average strike—the output lost in the month in which the average strike begins—is often negative. In the initial month of the average strike, that is, output is greater than it would have been in the absence of a strike, although the total effect of the average strike is to reduce industry output as shown in column 3. This suggests that the conventional method of measuring strike costs—estimated nonstrike produc-

[21]James I. Griffin, *Strikes in Quantitative Economics* (New York: Columbia University Press, 1939); and Rees, "Industrial Conflict."

[22]See Kennan, "Cyclical Fluctuation."

[23]This result is in keeping with Kennan's finding that strikes affected aggregate U.S. industrial production during the years, 1955 - 77, but that the reverse relation did not obtain (ibid.).

[24]A minus sign before an entry in Table 2 means that the sign of the output variation is *inverse* to that of the strike variation. Thus, a minus sign indicates that increases in strike activity are associated with decreases (losses) in output, and the converse.

Table 2. Output Loss Associated with Strikes in Manufacturing Industries, 1955–77.

Industry (1)	*Contemporaneous Effect (%)* (2)	*Total Effect (%)* (3)	*Output Loss Per Strike (millions of dollars)* (4)	*Percentage of Annual Output Lost Due to Strikes* (5)
1. Glass Containers	−.006	−.007	−.008	−.011
2. Kitchen Articles	.030	.267	.020	.139
3. Blast Furnaces and Steel Mills	−.003	−.214	−.274	−.491
4. Metal Cans, Barrels, and Drums	.016	.120	.0236	.057
5. Ordnance and Accessories	.015	−3.984	−1.348	−1.540
6. Construction and Mining Equipment	−.002	.030	.130	.110
7. Machine Shops	−.004	−.142	−.094	−.110
8. Electrical Transmission Equipment	.001	.223	.143	.352
9. Electrical Industrial Apparatus	.004	.210	.310	.295
10. Radios and Televisions	−.017	−.901	−.149	−.010
11. Other Electrical Components	.003	−.099	−.201	−.189
12. Aircraft and Parts	.001	−.043	−.943	−.172
13. Railroad Equipment	.005	−.385	−.382	−.283
14. Scientific Instruments	−.012	−.485	−1.194	−.617
15. Dairy Products	−.010	−.195	−.538	−.173
16. Fats and Oils	.004	−.341	−.591	−.103
17. Tobacco	.004	−.385	−.235	−.147
18. Broadwoven Fabrics	−.001	−.149	−.452	−.167
19. Floor Coverings	.034	.419	−.029	−.010
20. Pulp and Paperboard	−.005	−.193	−.806	−.408
21. Other Publishing	.002	−.205	−.471	−.226
22. Drugs, Soaps, and Toiletries	−.005	−.163	−.723	−.153
23. Fertilizers	−.023	−1.193	−1.163	−.391
24. Other Rubber Products	−.001	−.125	.042	.042
25. Industrial Leather Products	.014	−.771	−.105	−.086

tion less actual production—often leads to an understatement of strike costs.

Although a positive contemporaneous effect of strikes on output seems anomalous (it implies that output is greater in the presence of a strike than it would have been in its absence), it can hardly be termed unusual in light of column 1 of Table 2. As this column shows, 13 of the 25 industries exhibit a positive correlation between strike and output disturbances. Since intuition strongly suggests that the immediate effect of strikes on output is negative, this finding requires explanation.

We offer two possible explanations. First, during short intervals, shipments and production can diverge because of variations in inventories, although, as noted above, movements in shipments and production must tend ultimately to converge. The immediate effect of a strike could therefore be to reduce actual output but to increase shipments (the measure here of output). Our second possibility arises from the discrete nature of the data on shipments.[25] Suppose, for example, that an output surge occurred during the early part of a month because of a pre-strike inventory buildup, even though the strike commenced on the last day or two of the month. This would be recorded as a month with two days of strike and, say, 20 days of supernormal output; even less extreme cases could contribute to the illusion of a positive effect of strike activity on output.[26] This

[25]Although mutually independent, the two explanations are in no sense incompatible.

[26]As a matter of fact, but for unknown reasons, in manufacturing, strikes are more likely to start in the

dating problem, of course, also blurs the distinction between contemporaneous and delayed effects of strikes on output.

The second and more important feature of Table 2 is that, by almost any criterion, the reported effects of strike activity on output are small. Even if we exclude the six industries in which the strike cost is negative, we find the average loss of output per strike (during 1955-77) to be only about half a million dollars ($511,000). The costliness of an industry's strike pattern depends, however, not only upon the mean cost per strike, but also upon the number of strikes that occur per year.

Total strike costs per year, the product of average strike costs and number of strikes per year, as a percentage of annual shipments, are presented in column 5 of Table 2. In all industries, save ordnance and accessories, annual output lost as a result of strikes is a barely perceptible fraction of one percent *per year* of total shipments.[27] In ordnance and accessories, the annual loss is about 1.5 percent of shipments. Although not large in an absolute sense, this percentage is about ten times greater than that of any other industry in this study.

To understand better the meaning of this cost measure, let us see how it is calculated in the case of an unusually large strike—a strike that might bring about government intervention under Title II of the Taft-Hartley Act. As an example, we measure the cost of the "Great Steel Strike" of 1959.

As background to this event, it should be noted that this strike was the largest ever experienced in U.S. history: 41.9 million workdays idle were caused by this one strike, a figure exceeded by the entire economy in only nine years since World War II. The strike began on July 15, 1959, and was halted by injunction on November 7. Not all steel firms were affected, and of the major firms that were struck, one, Kaiser Steel, made its separate peace and resumed operations on October 26. By any standard, this was a monumental strike, and both contemporary and historical views indicate both parties suffered large losses.

Of the 41.9 million workdays lost, 36.3 million were lost in primary metals—36.1 in blast furnaces and steel mills (SIC 331) and 200,000 in the rest of the industry (SICs 332-339). Assuming that the response in the rest of the industry was the same as in blast furnaces, we calculate that the percentage of monthly output lost resulting from the Great Steel Strike was −36.3 million/10 thousand × .002137 or 7.76 percent of average monthly output.[28] On an annual basis, this amounts to a loss of .6 percent of output, about five times greater than the average annual loss resulting from strikes in these industries. In 1959 dollars, these estimates suggest that the Great Steel Strike caused an output loss of about 30 million dollars. This loss is what can be attributed to the largest strike in American history![29]

Summary and Interpretation

Although our method of estimating strike costs is novel, it is by no means the first attempt at an empirical assessment of the cost of strikes. We have a number of predecessors, most of whom would generally agree with our judgment that the cost of even a big strike is small. The principal contributors to the earlier literature on this subject were Cullen, Christenson, Bernstein and Lovell, Chamberlain and Schilling, and Livernash and Warren.[30]

latter part of the month than in the first half. This accentuates the likelihood of spurious positive contemporary correlation of output and strike activity.

[27] A more detailed description of the results for all manufacturing industries can be found in a working paper available from the authors.

[28] These numbers are taken from U.S. Bureau of Labor Statistics, *Analysis of Work Stoppages 1959* (Washington, D.C.: GPO, 1962), which chronicles the steel strike.

[29] To be precise, the $30 million output loss is the expected output loss given our estimates. Individual outcomes may differ from averages, however, for a variety of reasons. To check on the sensitivity of this estimate, we summed the residuals from the output equation for the period July to November 1959 and added this amount to expected strike costs; the total was $38 million. Adding (algebraically) the disturbances to output for the six-month intervals preceding July and following November 1959 reduced the estimated loss to $32 million.

[30] Donald E. Cullen, "The Taft-Hartley Act in National Emergency Disputes," *Industrial and Labor*

Our principal findings on the average cost of a strike, in three digit SIC manufacturing industries over the period 1955-77 may be summarized as follows. In 38 of the 63 industries analyzed, either there was no relationship between strike activity and output or output affected strike activity but not the reverse. In other words, in these 38 industries, the estimate of the industry cost of strike activity is zero.[31]

Second, in the remaining 25 industries, the impact of strike activity on output was sufficiently large to reject the hypothesis of no effect; among these 25 industries, however, six showed a positive effect of strike activity on shipments, implying that shipments increased (rather than decreased) with strike activity and that the average cost per strike was negative. This result is so counter-intuitive that we regard it as an anomaly subject to further research. For the present, we lump these six industries with the 38 mentioned above and treat the average cost per strike in all of them as indistinguishable from zero.

Third, the average cost per strike in each of the remaining 19 industries was positive and large enough to be reliably distinguished from zero, under conventional statistical criteria. But although reliably different from zero, these costs are small. To term these dollar magnitudes either small or large necessarily involves an element of arbitrariness, but we believe that most readers will concur in the judgment that the strike costs we have estimated are small. Our rationalization is as follows: in a debate on the merits of legislation intended to reduce strike activity, we believe our findings would be cited by those opposed to such legislation as evidence that strikes had not caused serious economic loss, and they would be denigrated by those favoring the legislation. This rationalization is not offered as a contribution to an imaginary legislative debate, but only as a way of clarifying our interpretation of "small."

To avoid misinterpretation, we would like to spell out in more detail the precise meaning of our results. We do not suggest that the participant cost of a strike is small, that is, the cost to either an individual firm or its workers. The evidence presented here pertains only to entire industries (in particular, three-digit SIC manufacturing industries) taken as entities. A finding of "no effect" of strikes on output is consistent with either no effect of strikes on the output of the firms that were struck or with a large adverse effect on the output of struck firms in the industry offset by a favorable effect on the output of those not struck. Our results indicate only that the effect on *aggregate* industry output is small in virtually all manufacturing industries.[32]

Our estimates of industry strike costs have not taken into account the offsetting benefits resulting from the substitution of production across industries during a strike. Apart from this omission, the data in Table 2 are estimates of what concerns public policymakers when they ask how much strikes cost as a possible first step in

Relations Review, Vol. 7, No. 1 (October 1953), pp. 15-30; Irving Bernstein and Hugh G. Lovell, "Are Coal Strikes National Emergencies?" *Industrial and Labor Relations Review,* Vol. 6, No. 5 (April 1953), pp. 352-67; Edgar L. Warren, "Thirty-Six Years of National Emergency Strikes," *Industrial and Labor Relations Review,* Vol. 5, No. 1 (October 1951), pp. 3-19; C. Laurence Christenson, "The Theory of the Offset Factor: The Impact of Labor Disputes upon Coal Production," *American Economic Review,* Vol. 43, No. 4, Part 1 (September 1953), pp. 513-47, and "The Impact of Labor Disputes upon Coal Consumption," *American Economic Review,* Vol. 45, No. 1 (March 1955), pp. 79-117; Neil W. Chamberlain and Jane M. Schilling, *Social Responsibility and Strikes* (New York: Harper, 1953); and Irving Bernstein, "The Economic Impact of Strikes in Key Industries," in *Emergency Disputes and National Policy,* Irving Bernstein, Harold L. Enarson, and Robin W. Fleming, eds. (New York: Harper, 1955), pp. 24-45.

[31]We reject a priori, that is, the possibility that during the progress of a strike, output could be greater than it would have been if the strike had not occurred. Any appearances to the contrary we interpret as measurement error, of one kind or another. When these errors are so large (relative to the "true" and necessarily positive effect of the strike on output) as to make strike costs appear negative, we say that strike costs are indistinguishable from zero.

[32]Although measured output losses in a given industry are small or zero, there are unmeasured resource costs of reallocating output over time (such as the increased use of overtime labor and extra costs associated with peak load rates of equipment utilization), or of changing suppliers during a strike, that we have not taken into account.

reconsidering laws governing collective bargaining. That these figures seem small suggests that, at least in manufacturing, the losses to individual bargainers are sufficient to induce them to adopt bargaining styles (protocols) that limit the size and frequency of strikes to levels that generate only such small losses of output as we report.

It must be emphasized again that our results refer only to *manufacturing,* in which output is characterized a tangible product, as distinguished from a service, which facilitates storage and substitution over time. Estimates of strike costs, analogous to ours, for economic sectors in which output is less storable or less transportable than in manufacturing (such as construction, wholesale and retail trade, and services) might well show substantially higher costs per unit of strike activity.

We should also mention the economic significance of the cross-industry differences among these costs. To assert that strikes do not cost much is not to say that they do not have important economic consequences. For example, in iron and steel manufacturing, as elsewhere, strike activity costs much less than one per cent of annual output. Yet, strike costs in steel were sufficient to motivate the bargainers involved to agree to binding arbitration of the terms of new contracts for a period of ten years (1973-83). Other examples of substantial modifications in bargaining behavior designed to lessen the burden of strike costs are not hard to find.

The motivating force for strike avoidance is the desire of collective bargaining pairs to avoid *participant* costs. We conjecture that these costs are appreciably larger than the *industry* costs that we have measured, the difference consisting largely of gains accruing to the employers and workers in the industry that does not experience a strike. We further conjecture that these unmeasured participant costs are positively correlated across industries with the industry costs that have been measured. In a forthcoming paper, we present evidence to support this hypothesis and describe its implications for the relationship between strike costs and contract terms.