Work Stoppages and the Theory of the Offset Factor: Evidence from the British Columbian Lumber Industry

Harry J. Paarsch, *University of British Columbia*

One method of estimating losses resulting from work stoppages is to multiply the total number of man-days lost during disputes by the average product of workers. This statistic can be easily calculated using information typically available from government agencies but has obvious flaws. For example, the behavior of other firms not involved in disputes is ignored. Moreover, when output is durable, the impact on consumption is unknown since inventories can be used as buffers. To assess the importance of these and other considerations, I develop an alternative empirical framework and implement it using data from the British Columbian lumber industry.

This article is an abridged version of my doctoral dissertation submitted to Stanford University. I should like to thank my principal advisor, Tom MaCurdy, for his frequent encouragement and wise counsel during the completion of that project. Among others, I am particularly grateful to Takeshi Amemiya, Herb Emery, Robert Flanagan, Morley Gunderson, Ken Hendricks, Charles Kahn, John Pencavel, Jeremy Rudin, and Gregor Smith for their useful suggestions on various parts of the work. I, of course, bear all responsibility for errors. Fred Baker of Statistics Canada, Laurence Cater and John Friesen of *Madison's Canadian Lumber Reporter*, Harry Grosskleg of the Work Stoppages Section at Labour Canada, and Hartley Lewis of the British Columbia Ministry of Forests made a special effort in helping me create the data set used; my thanks to each. The generous financial support of my parents as well as the Social Sciences and Humanities Council of Canada and Tom MaCurdy during my graduate studies is gratefully acknowledged. Later work on this project was partially supported by the University of British Columbia and the Forest Economics and Policy Analysis Research Unit.

[*Journal of Labor Economics*, 1990, vol. 8, no. 3]

0734-306X/90/0803-0005$01.50

I. Introduction

The tension between labor and management is a well-known phenomenon in Western economies, with work stoppages being the most powerful weapon available to trade unions. Much has been written on the rationality of strikes—see, for example, the excellent survey by Kennan (1986) as well as the work of Kennan and Wilson (1988). Despite this work, there remains a common perception in many Western economies that work stoppages are too frequent, too large, and too lengthy and that the resulting disruptions to the provision of goods and services impose major costs on economies. In a few cases, such as fire and police protection, the claims of large costs would be indisputable, while in other cases there are reasons to suggest that the disruptions caused by work stoppages are likely small.

Two features make work stoppages involving fire and police protection important. First, the services provided are virtually perfectly perishable, and, second, they are typically provided by one "firm" that negotiates with one "union": the timeliness and virtual monopoly control over the provision of fire and police protection make them special. In most industries, however, some form of competition exists, and many products are relatively durable. Casual empiricism and economic intuition suggest that the ability to substitute production across firms as well as over time should be important in evaluating the importance of work stoppages.

To test this empiricism and intuition, I measure the effects of work stoppages in the British Columbian lumber industry. Although the industry employed only 3% of the provincial labor force in 1982,[1] wood products accounted for 22% of the province's manufactured output, while forest-related industries made up almost 10% of the entire provincial product.[2] Many perceive work stoppages in the lumber industry to be commonplace: between 1960 and 1984 there were on average more than six work stoppages in each year. On average, these work stoppages involved 1,019 workers and lasted over 18 days per dispute.[3] A glance at figure 1 suggests a strong negative relationship between man-days lost during disputes and aggregate lumber production and lends credence to the claim that work stoppages in the British Columbian lumber industry are important.

One way of determining the importance of disputes is to look at market prices. An increase in prices during a work stoppage supports the notion that disputes cause shortages and dislocation, but the converse is unfortunately not true, as no rise in prices is also consistent with significant dislocation in production within the province. Producers elsewhere in Canada and abroad could be making up the lost production, thus preventing

[1] British Columbia Ministry of Labour (1982); Statistics Canada (1983*b*), p. 8.

[2] British Columbia Ministry of Industry and Small Business Development (1983), table 11.

[3] Labour Canada (1985), for November.

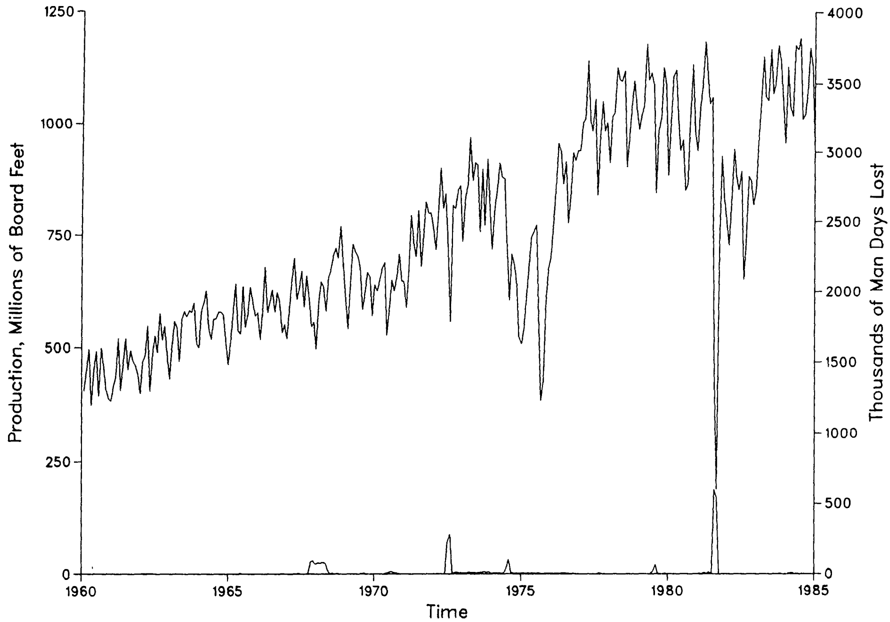

FIG. 1.—Aggregate monthly lumber production and man-days lost, 1960–84

the price increase. Alternatively, because lumber is a durable good, producers within British Columbia as well as those outside its borders could be drawing on inventories. The occurrence of this behavior is neither confirmed nor refuted by the graphs of lumber prices and man-days lost—see figure 2—as well as lumber stocks on hand at British Columbian mills and man-days lost—see figure 3.

To investigate the importance of interfirm and intertemporal considerations in evaluating the impact of British Columbian work stoppages, I develop an empirical framework within which one can interpret the estimated parameters, under certain conditions, as measuring the degree of dislocation induced by disputes. I then apply this framework to data on North American lumber prices as well as British Columbian lumber production and stocks on hand. My work is a step toward modeling, measuring, and understanding the empirical effects of strikes. This work expands significantly on that done by Maki (1985), who considered a subset of five contract strikes at British Columbian sawmills, and is related to studies by, among others, Neumann and Reder (1984) as well as Gunderson and Melino (1987).

The remainder of this article is in three parts: in Section II, I present an empirical framework within which the data can be interpreted and suggest an economic interpretation for this framework. The results of applying

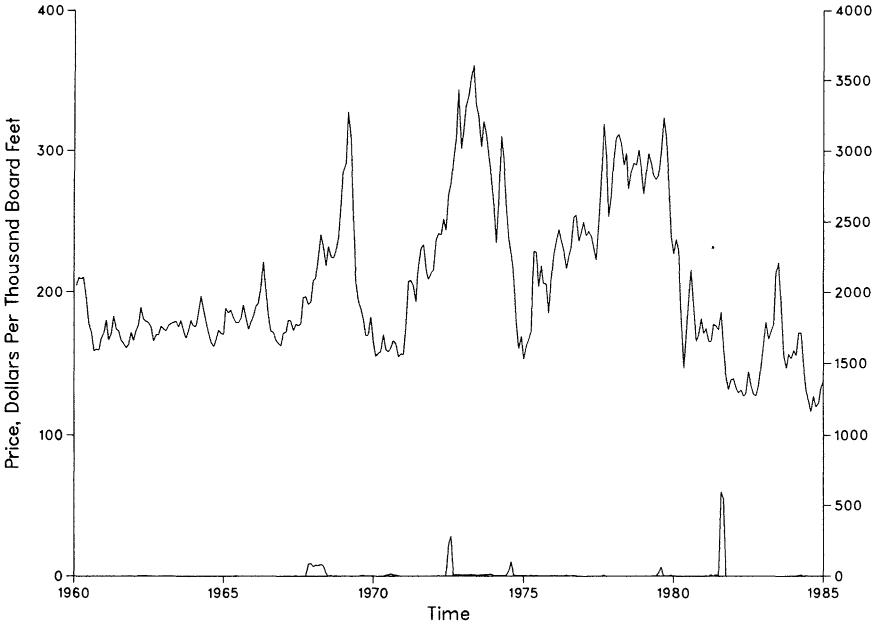

FIG. 2.—Real average monthly spruce-pine-fir 2 × 4 lumber prices and man-days lost, 1960–84

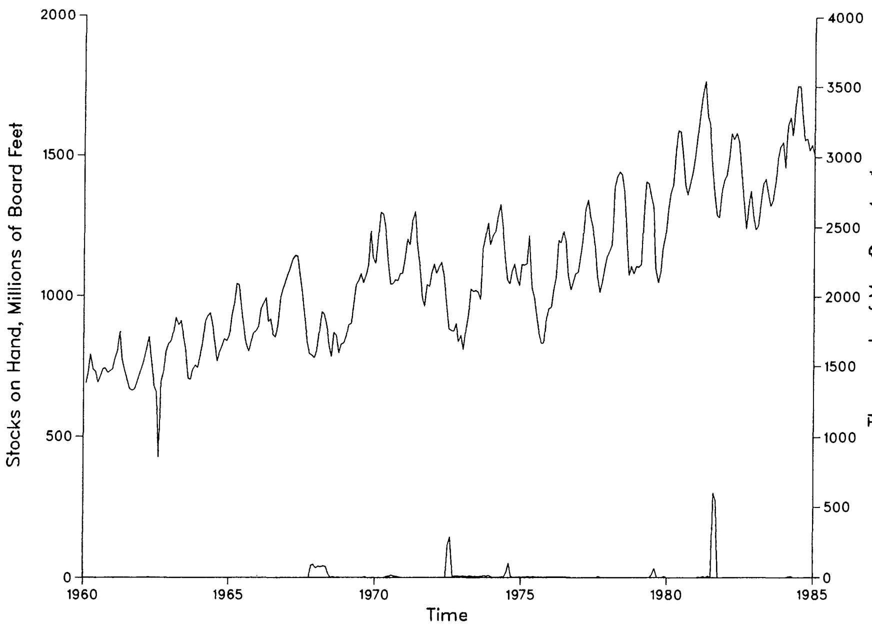

FIG. 3.—Aggregate monthly lumber stocks on hand and man-days lost, 1960–84

this model to lumber price, production, and inventory data are presented in Section III. In Section IV, I present my conclusions. The creation of the data set is described in the Appendix.

II. An Empirical Framework

One common way of estimating production losses due to work stoppages is to multiply the total number of man-days lost during a dispute by the average product of workers in the industry. This statistic, which I call "average output lost," or AOL, is attractive because it can be easily calculated using information typically available from government agencies, but the measure has obvious flaws. For example, implicit in its calculation is the assumption that a man-day lost at one firm cannot be made up at another. The behavior of firms in the industry that are not party to disputes is clearly important when evaluating the *total* effect of stoppages on an economy. Moreover, when output is durable, AOL provides little information concerning the impact of stoppages on consumption since inventories can be used as buffers. Because credible and robust estimates of losses are essential to any informed policy analysis concerned with evaluating the importance of work stoppages, addressing the limitations of AOL is important. In addition, deciding what other factors to consider when assessing the impact of disputes is also valuable.

A. Christenson's Theory of the Offset

When thinking about the effects of work stoppages on production, a simple and useful economic paradigm is to imagine a group of firms for which the in-plant investment decisions are complete. Each firm hires its labor inputs from a specific union. The output of any one firm can be stored and is a substitute (perhaps perfect) for that of the others. A work stoppage occurs when a particular firm-union pair chooses to end its relationship. Production at the firm involved in the dispute stops, and aggregate output falls. The question is, By how much? When the production technology is linear in man-days worked and is identical across firms, and if firms not involved in the dispute are constrained to hire no more labor, AOL is a meaningful measure of production losses. Suppose, however, that nonstruck firms can hire additional labor and expand output. What then is an appropriate measure of production losses?

To cast this measurement problem within a framework familiar to economists, I borrow from the work of Christenson (1953, 1955). Christenson (1953) described two actions that undermine the use of AOL. He called the outcomes of these actions the "current transfer offset factor" and the "time-shift offset factor." I introduce two additional geographical distinctions: local and foreign.

To begin, suppose output is perfectly perishable. Christenson argued that work stoppages will have the most impact if the entire industry (all of the firm-union pairs) is involved and if no substitute products exist. Almost all products have substitutes, and only a few industries are dominated by a monopolist negotiating with one union. Therefore, the effect of work stoppages on aggregate production can be mitigated by the willingness and ability of firms not involved in stoppages to augment supply by expanding output.

Christenson referred to any contemporaneous production response on the part of these firms as the current transfer offset factor and noted that its existence in any important respect requires the presence of excess capacity. British Columbian lumber production averaged 750 million board feet per month over the period 1960–84 and 1,100 million board feet per month in 1984.[4] In 1984, potential productive capacity for provincial mills was at least 1,400 million board feet per month.[5] In any case, all Christenson's argument really requires is that some firms be able to expand output quickly at less than infinite marginal cost; that is, the aggregate supply curve must not be vertical. Hereafter, I adopt this interpretation of excess capacity.

If other factors are held constant, two testable empirical implications emerge: in the absence of a full current transfer offset factor, aggregate production will fall, and market prices will rise when work stoppages occur. Only if the aggregate supply curve is perfectly elastic will no response obtain. Therefore, measuring the degree of current transfer offset is tantamount to estimating whether labor unions in the British Columbian lumber industry have enough power to shift the aggregate supply curve, while testing the hypothesis of a full current transfer offset involves deciding whether an event, in this case a work stoppage, affects either prices or production.

In the case of British Columbia, the current transfer offset factor can be of two types. The first, which I call the "local" current transfer offset factor, relates to British Columbian firms not party to the dispute, while the second, which I call the "foreign" current transfer offset factor, relates to firms producing outside of the province, either in another country, such as the United States, or in another Canadian province. Whether the current transfer offset factor consists of contributions by local or foreign firms is obviously important in calculating losses to British Columbia as well as in determining the economic significance of disputes within the province.

A significantly positive contemporaneous correlation between market prices and work stoppages would suggest the absence of a full current transfer offset factor in the North American market. Also, given the fact that disputes have never covered the entire industry, it would provide some evidence of market power as well as economic dislocation.

[4] Statistics Canada (1960–84*a*).
[5] British Columbia Ministry of Forests (1985).

When prices do not rise significantly, but output from British Columbia falls substantially, determining the origin of the offset is not straightforward, and other factors must be taken into account. For example, because lumber is durable, firms can accumulate inventories. Excess capacity allows for a second form of offset that Christenson called the time-shift offset factor and that has two forms.

When the time-shift offset factor is "anticipatory," union and nonunion firms (both local and foreign) increase production in anticipation of and prior to a work stoppage to accumulate inventories that can be drawn on later. An anticipatory time-shift offset factor requires that the timing and intensity of disputes be predictable, as in contract strikes. When the time-shift offset factor is "retroactive," firms produce extraordinarily after the resolution of a dispute to fill back orders. The retroactive feature of the time-shift offset factor does not depend on expectations but on the degree to which firms can increase production from one period to the next.

The two ingredients necessary to the offset factors—durable output and excess capacity—appear present in the British Columbian lumber industry. Moreover, sawmills compete in the North American market, which is highly competitive and in which not all firms are unionized. Estimating the net effects of work stoppages as well as determining the extent to which the local offset factors operate are important and interesting empirical tasks. They amount to unraveling the effect of work stoppages on the time paths of prices, production, and inventories.

While representative price data for British Columbian lumber sold in the North American market are available, similar data for total North American consumption and production are not. There are, however, aggregate data concerning lumber production at British Columbian mills as well as inventories held at provincial mills. Constructing an empirical framework within which the local current transfer and time-shift offset factors can be isolated using available data is one contribution of this article.

B. Modeling the Offset Factors

A natural approach to determine whether work stoppages affect output is to estimate average production in the absence and presence of disputes and then to test whether the difference in these averages is statistically significant. Work stoppages, however, vary in *duration*—the number of work-days lost—and in *magnitude*—the number of workers involved. Unless all disputes are identical, knowing only that a dispute has occurred is an inadequate measure of its *intensity*. Lumber is a continuous-process industry where output is approximately proportional to man-days worked. If the intensity of a dispute in period t is measured by man-days lost m_t (the product of duration and magnitude in period t), then an approximation to the relationship between aggregate production at British Columbian mills and man-days lost is

$$Q_t = Z_t\delta + \gamma_0 m_t + e_t,$$

where Q_t denotes aggregate British Columbian production and e_t is an error term. The term $Z_t\delta$ is introduced to represent average production in period t in the absence of work stoppages. The vector Z_t can include regressors other than a constant, while δ is unknown and must be estimated. (I want to delay discussing the regressors to be included until later in this section.)

According to Christenson's theory of anticipatory time-shift offset, a foreseen strike should induce changes prior to the work stoppage, while an unforeseen dispute should cause none. Moreover, when the retroactive feature of the time-shift offset factor is operative, some production lost because of an imperfect current transfer offset is made up after a dispute. These considerations suggest that, in addition to contemporaneous man-days lost, leads and lags of this variable should also be included in the specification. In modeling the impact of work stoppages, I consider a linear distributed lag model:

$$Q_t = Z_t\delta + \gamma(L)m_t + \eta_t,$$

where $\gamma(\mathrm{L})$ is a finite order two-sided polynomial in the lag operator L and η_t is an error term.

Similar specifications also can be examined for market prices p_t as well as changes in inventories of lumber held at British Columbian mills ΔI_t $(= (I_t - I_{t-1}))$. I introduce the convention of superscripting the parameters and errors of the processes for prices, production, and inventory changes by p, Q, and I, respectively. Thus, the specifications are

$$p_t = Z_t\delta^p + \gamma^p(L)m_t + \eta_t^p,$$

$$Q_t = Z_t\delta^Q + \gamma^Q(L)m_t + \eta_t^Q,$$

and

$$\Delta I_t = Z_t\delta^I + \gamma^I(L)m_t + \eta_t^I.$$

C. Measuring the Offset Factors

What do the coefficients within $\gamma^p(L)$, $\gamma^Q(L)$, and $\gamma^I(L)$ mean? Consider first the case where lumber spoils after one period, so inventories can be ignored. When sampling occurs every period,

$$\gamma^y(L) = \gamma_0^y, \quad y = p, Q.$$

The parameter γ_0^Q measures the amount that aggregate output responds to a man-day of lost production. A full local current transfer offset factor would imply γ_0^Q equals zero. Moreover, γ_0^p would also equal zero. If the AOL measure is used, then production is assumed proportional to man-days worked, and total available man-days are assumed fixed: a 1% loss in total man-days implies a 1% fall in total output. When AOL is an appropriate measure, γ_0^Q will equal the negative of the average product per man-day ($-\pi$). No time-shift offset factor can exist in this example because lumber is assumed perishable. Therefore, an imperfect local current transfer offset factor will imply that production falls during the period of the dispute ($\gamma_0^Q < 0$) and, depending on the importance of the foreign current transfer offset factor, prices may rise ($\gamma_0^p > 0$). For example, if $\gamma_0^p = 0$, and $\gamma_0^Q \ll 0$, then this would suggest that disputes are having a locally disruptive effect, which is being offset by foreign producers. When the local current transfer offset exists partially, γ_0^Q will be greater than $-\pi$.

As lumber is durable, leads as well as lags should be included in the distributed lag specification to admit the time-shift offset factor. Consider the simplest specification with just one lead and one lag:

$$\gamma^y(L) = \gamma_{-1}^y L^{-1} + \gamma_0^y + \gamma_1^y L, \quad y = p, Q, I.$$

In this case, a full time-shift offset factor implies

$$\gamma_{-1}^p = \gamma_0^p = \gamma_1^p = 0.$$

If the local current transfer and time-shift offset factors are imperfect, then γ_{-1}^p, γ_0^p, and γ_1^p may be positive. Whether this occurs depends on the importance of the foreign current transfer and time-shift offset factors. If the local time-shift offset factor is anticipatory and local mills increase production prior to stoppages, then γ_{-1}^Q will be positive, and if the local time-shift offset factor is retroactive and local mills make up for lost production after a dispute, then γ_1^Q will also be positive. If the anticipatory and retroactive features of the local time-shift offset factor perfectly make up an imperfect local current transfer offset factor ($\gamma_0^Q < 0$), then

$$\gamma_0^Q = -(\gamma_{-1}^Q + \gamma_1^Q), \qquad \text{or} \qquad \gamma_{-1}^Q + \gamma_0^Q + \gamma_1^Q = 0.$$

How inventories change in response to disputes depends on whether workers not party to disputes are willing to handle lumber at mills in dispute and whether mills not involved in disputes can find enough railway cars to move their lumber. Typically, members of the Teamsters Union will not cross the picket lines of members of the International Woodworkers of America (IWA), so shipments from struck mills should fall. Furthermore, access to additional boxcars is usually limited in the short run because railways have long-term obligations. Thus the sign of γ_0^I appears indeterminate. In response to these factors, mills will ship additional lumber to third parties before and after disputes. The signs of γ_{-1}^I and γ_1^I will clearly depend on the relative importance of the local time-shift offset factors. In any case, I interpret a full local time-shift factor to imply that the sum of the changes in inventories—before, during, and after disputes—is unaffected by disputes:

$$\gamma_{-1}^I + \gamma_0^I + \gamma_1^I = 0,$$

even though each of the $\{\gamma_j^I\}_{j=-1}^{1}$ may be nonzero.

Within this linear model, and assuming perishability, the sampling time frame is unimportant. To see this, suppose lumber has a shelf life of 1 week but that data are collected at monthly intervals. Suppose disputes always occur during the second week of the month and last but 1 week. Assuming 4 weeks per month and the following specification in week i of month t between aggregate weekly production q_{it} and aggregate weekly man-days lost m_{it},

$$q_{it} = \bar{q} + \gamma_0^q m_{it} + \eta_{it}^q, \quad i = 1, \ldots, 4,$$

and

$$m_{1t} = m_{3t} = m_{4t} = 0, \quad m_{2t} > 0,$$

where I have omitted the time dependency in the mean and introduced a constant for notational simplicity. This implies

$$Q_t = 4\bar{q} + \gamma_0^q m_t + \eta_t^Q,$$

where $Q_t = \sum_{i=1}^4 q_{it}$, $m_t = \sum_{i=1}^4 m_{it} = m_{2t}$, and $\eta_t^Q = \sum_{i=1}^4 \eta_{it}^q$.

If durability is admitted, then time sampling becomes important because, when disputes are brief and the interval between samplings long, the time-shift and current transfer offset factors will appear identical. For policy purposes, this is not that important since it is the sum of the two factors that is most interesting. Nevertheless, the interpretation of parameters depends critically on the sampling time frame, and this introduces complications since specific hypotheses concerning the offset factors imply particular response patterns in the parameters of $\gamma^Q(L)$.

For example, consider the case where both the anticipatory and retroactive local time-shift offset factors are perfectly operative in the weeks immediately before and after a dispute and fully make up an imperfect local current transfer offset factor. In this case,

$$q_{it} = \bar{q} + \gamma_{-1}^q m_{i+1t} + \gamma_0^q m_{it} + \gamma_1^q m_{i-1t} + \eta_{it}^q, \quad i = 1, \ldots, 4,$$

and

$$m_{1t} = m_{3t} = m_{4t} = 0, \quad m_{2t} > 0,$$

where $-(\gamma^q_{-1} + \gamma^q_1) = \gamma^q_0 < 0$. Consider now the monthly specification

$$Q_t = 4\bar{q} + \gamma^Q_{-1} m_{t+1} + \gamma^Q_0 m_t + \gamma^Q_1 m_{t-1} + \eta^Q_t,$$

and

$$m_{t-1} = m_{t+1} = 0, \quad m_t = m_{2t},$$

where the γ^Q_ks are not the same as the γ^q_ks. When strikes always occur in the second week, then the monthly parameters are

$$\gamma^Q_{-1} = \gamma^Q_0 = \gamma^Q_1 = 0.$$

If, however, disputes occur in the first week, then, depending on the relative importance of the anticipatory and retroactive time-shift offset factors, the parameters are

$$\gamma^Q_{-1} > 0, \qquad \gamma^Q_0 \gtrless 0, \qquad \gamma^Q_1 = 0,$$

while, if stoppages occur in the last week of the month, they are

$$\gamma^Q_{-1} = 0, \qquad \gamma^Q_0 \gtrless 0, \qquad \gamma^Q_1 > 0,$$

The γ^Q_ks are related to the γ^q_ks by the frequency of sampling and the distribution of man-days lost throughout the sampling time frame. This problem also exists in the case of market prices as well as inventory changes and is generally a problem in time-series models involving distributed lags—see, for example, Tiao and Wei (1976) and Wei (1978).

As a practical matter, whether work stoppages are foreseen is unknown. Some disputes (e.g., those involving the negotiation of a contract) may be perfectly predictable, but this need not imply that man-days lost are known with certainty since dispute duration and magnitude can be random. By introducing man-days lost as leads, I am essentially assuming perfect foresight. If the process depends on the predicted future values of m_t, then simultaneity is introduced because observed man-days lost and the error term are correlated.

I am also making a strong assumption concerning causality: basically, I assume that past production does not cause current *potential* man-days lost, which are the product of duration, incidence, and magnitude. Kennan (1985) has found dispute durations in U.S. manufacturing to be countercyclical, while Jurkat and Jurkat (1949) have found strike incidence in the United States to be procyclical. Harrison and Steward (1987), in work similar to Kennan's using a Canadian data set, have also found that dispute durations are countercyclical, while Gunderson, Kervin, and Reid (1986) have found that strike incidence for collective agreements in Canada is procyclical. Similar work examining dispute duration and incidence in the British Columbian lumber industry has not been attempted because of a paucity of data; there were but 156 work stoppages between 1960 and 1984, and only 55 involved contract negotiations.

The reader should note that this empirical framework cannot detect low frequency losses in production such as loss of market share, which may occur, for example, because of a reputation for unreliability. Such phenomena can be important, as U.S. Steel found out during the 1960s and 1970s.

The effects of contract strikes may be different from noncontract disputes. Therefore, I introduce a distinction between man-days lost by dispute type. The model is then

$$y_t = Z_t\delta^y + \gamma^{yc}(L)m_t^c + \gamma^{yn}(L)m_t^n + \omega_t^y, \quad y = p, Q, I,$$

where c denotes contract and n denotes noncontract disputes, while ω_t^y is an error term.[6]

Lumber production exhibits considerable seasonality, and, like lumber prices, it too is highly serially correlated: the ω_t's are surely dependent. Testing for the absence of dispute effects using results from a simple regression of production on a distributed lag of man-days is inappropriate since, in the presence of autocorrelation, the usual formulae for the standard errors of the estimates are typically incorrect. In addition, because man-days lost vary considerably and systematically across time, output effects may be grossly overestimated. This would be the case if disputes usually occur in seasons when production is lower than average. A richer dynamic specification of the error process is necessary.

One flexible approach to modeling the error structure of p_t, Q_t, and ΔI_t (i.e., the stochastic processes of the ω_t^ys) is as autoregressive moving-average processes:

$$\omega_t^y = \alpha_1^y\omega_{t-1}^y + \ldots + \alpha_r^y\omega_{t-r}^y + \varepsilon_t^y + \beta_1^y\varepsilon_{t-1}^y + \ldots + \beta_s^y\varepsilon_{t-s}^y,$$

$$y = p, Q, I.$$

[6] When used as a left-hand-side variable, the index y signifies $y = p$, Q, ΔI but when used as a superscript, it signifies $y = p$, Q, I. I adopt this convention for notational parsimony.

Here the α_k^ys represent the autoregressive parameters for a process of order r, while the β_k^ys represent the moving-average parameters for a process of order s and the ε_t^ys are independently distributed Gaussian error terms having zero mean and finite variance. The empirical specifications are then linear stochastic difference equations:

$$\alpha^y(L)y_t = X_t\phi^y + \psi^{yc}(L)m_t^c + \psi^{yn}(L)m_t^n + \beta^y(L)\varepsilon_t^y, \quad y = p, Q, I,$$

where

$$\alpha^y(L) = (1 - \alpha_1^y L - \ldots - \alpha_r^y L^r),$$

and

$$\beta^y(L) = (1 + \beta_1^y L + \ldots + \beta_s^y L^s).$$

Here $X_t\phi^y$ represents the mean when the autoregressive structure is imposed on $Z_t\delta^y$. That is,

$$X_t\phi^y = \alpha^y(L)Z_t\delta^y.$$

Moreover, the $\psi^{yi}(L)$s are related to the $\gamma^{yi}(L)$s and the $\alpha^y(L)$s by the nonlinear restrictions

$$\psi^{yi}(L) = \alpha^y(L)\gamma^{yi}(L), \quad i = c, n; \quad y = p, Q, I.$$

One can also use a time-series approach to deal with seasonality; that is, additive or multiplicative types of seasonal autoregression can be introduced to the model. Alternatively, seasonal dummy variables can be introduced to the Z_t (X_t).

Of course, there is no reason to constrain oneself to univariate models, and, in fact, for some of my work I consider a bivariate autoregressive model of the form

$$\omega_t^Q = Q_t - Z_t\delta^Q - \gamma^{Qc}(L)m_t^c - \gamma^{Qn}(L)m_t^n,$$

and

$$\omega_t^I = \Delta I_t - Z_t\delta^I - \gamma^{Ic}(L)m_t^c - \gamma^{In}(L)m_t^n,$$

where the vector $(\omega_t^Q, \omega_t^I)'$ follows an autoregressive process of the form

$$\begin{pmatrix}\omega_t^Q\\ \omega_t^I\end{pmatrix} = \begin{pmatrix}\alpha_1^{QQ}L + \ldots + \alpha_r^{QQ}L^r & \alpha_1^{QI}L + \ldots + \alpha_{k_Q}^{QI}L^{k_Q}\\ \alpha_1^{IQ}L + \ldots + \alpha_{k_I}^{IQ}L_{k_I} & \alpha_1^{II}L + \ldots + \alpha_s^{II}L^s\end{pmatrix}\begin{pmatrix}\omega_t^Q\\ \omega_t^I\end{pmatrix} + \begin{pmatrix}\varepsilon_t^Q\\ \varepsilon_t^I\end{pmatrix},$$

with k_Q and k_I being the order of the cross-correlations.

What else should be included in Z_t? As mentioned before, a constant and seasonal dummy variables may be included. In addition, since production has increased steadily over time, linear and perhaps quadratic time trends may be appropriate. If one thinks of the production equation as a reduced form equation for the supply of British Columbian lumber, where provincial sawmills are price takers in the world, then price may seem appropriate. I am hesitant to include it because a priori I believe that British Columbian work stoppages may be severe enough to move the North American price. If this is the case, then the interpretation of the coefficients on man-days lost in the production equation, with price included as a regressor, would be a convolution of the γ_k^{pi}s from the price equation and the γ_k^{Qi}s from the production equation. As in most empirical work, the list of other potential regressors is endless. In my work, however, the vector Z_t typically contains just a constant and, where necessary, a linear time trend as well as monthly dummy variables.

The empirical exercise is to identify, estimate, and verify the specifications for $\alpha^y(L)$, $\beta^y(L)$, $\psi^{yc}(L)$, $\psi^{yn}(L)$, and $Z_t\delta^y$ using available data $\{y_t, m_t^c, m_t^n, Z_t\}_{t=1}^T$ and then to test hypotheses concerning the offset factors, the parameters of the $\gamma^{yi}(L)$s. The $\gamma^{yi}(L)$s capture the effects of work stoppages on the time paths of prices, production, and inventories.

In subsequent sections, this empirical framework is applied to lumber price, production, and inventory data. I begin my empirical work by describing the effects of work stoppages on weekly North American lumber prices. Subsequently, I examine the effects on the monthly production of lumber in British Columbia as well as on monthly changes in inventories held at provincial mills to determine whether the local offset factors exist either partially or fully.

III. The Empirical Results

A. Lumber Prices and Work Stoppages

Price data for specific types of lumber manufactured in British Columbia are classified at Statistics Canada, and constructing a representative price index from other sources has proven difficult: over any extended period, few complete series exist, and when several do, the correct weighting of each remains unclear. To obtain a consistent, representative, and useful price series, I collected weekly lumber price quotations from the trade newsletter *Madison's Canadian Lumber Reporter* (1960–84). This series represents the real free-on-board mill price per 1,000 board feet for one boxcar of *Western, Spruce-Pine-Fir, 2 × 4*s, *Kiln Dried, Standard and Better,* and *Random Lengths* lumber. (These data are described in detail in the Appendix.)

The following considerations justify this choice: work stoppages in the lumber industry are typically brief, so weekly data can capture movements that might otherwise be lost in an aggregation to the month. Two-by-fours also form a major portion of all sawn lumber since they are heavily demanded in residential construction and can be easily sawn even from small dimensioned logs. Moreover, the combination of spruce, pine, or fir species makes up a major portion of British Columbian production. Because shipping costs are important in lumber sales, the free-on-board mill and *Western* qualifiers are crucial as they describe the lumber's origin. Finally, *Kiln Dried* and *Random Lengths* as well as *Standard and Better* lumber are included because they define a popular product for which a long consistent time series exists. Of equal importance to this analysis are the competitive conditions under which this lumber is traded. Hundreds of mills produce and sell to millions of consumers. The measure here is a North American price quoted in U.S. dollars, so its movements should reflect market conditions and expectations as well as any dislocation.

1. *Evidence of Weekly Price Effects*

Using time-series methods, I identified the error process for weekly real prices to be

$$\alpha^p(L) = (1 - L)(1 - \alpha_1 L - \alpha_2 L^2),$$

and

$$\beta^p(L) = 1.$$

Subsequently, I estimated by least squares a baseline specification with the following initial lag structure for both types of disputes:

$$\gamma^{pi}(L) = \gamma^{pi}_{-8} L^{-8} + \ldots + \gamma^{pi}_0 + \ldots + \gamma^{pi}_8 L^8, \quad i = c, n,$$

without imposing the nonlinear constraints,

$$\psi^{pi}(L) = \alpha^p(L)\gamma^{pi}(L), \quad i = c, n.$$

Leads and lags of eight were chosen because negotiations typically begin 2 or 3 months before a contract expires. For example, in the renegotiation of the *Coast Master Agreement* between the IWA and the Forest Industrial Relations Association (FIRA), talks usually begin before April, while the contract expires on June 14. Major obstacles to a successful agreement surface early, so a 2-month lead seems reasonable. Because the price series exhibits no seasonality, or any trending, Z_t is a constant that for notational parsimony, I suppress below. This specification contains 43 parameters, and the sample has 1,284 observations.

Subsequent to estimating this model, I verified it by testing the fitted residuals for any remaining autoregressive or moving-average terms using the methods proposed by Godfrey (1978*a*, 1978*b*). The calculated Lagrange multiplier statistic for either an ARIMA($2 + r$, 1, 0) or an ARIMA (2, 1, r) alternative when $r = 8$ is 9.4, considerably less than the critical $\chi^2(8)$ at size 0.01, 20.1, so neither null hypothesis could be rejected.

While no significant evidence of linear serial correlation was found using Godfrey's methods, nonlinear dependence could not be ruled out. The model failed Engle's (1982) test for autoregressive conditionally heteroskedastic (ARCH) errors of order $r = 8$. The calculated $\chi^2(8)$ is 265.0. As a more general specification, I estimated a model where

$$V(\varepsilon_t^p) = \xi_0^p + \varepsilon_1^p \xi_{t-1}^{p^2}$$

with ξ_0^p being positive, $0 \leq \xi_1^p < 1$ (conditions required for a finite positive variance; see Engle 1982), and

$$\varepsilon_t^p = \alpha^p(L)p_t - \psi^{pc}(L)m_t^c - \psi^{pn}(L)m_t^n.$$

Because this model appeared to characterize the price process fairly well, hypothesis testing concerning man-days lost was undertaken.

Using the above ARCH model as a baseline specification, I imposed the constraints implicit when noncontract disputes are unanticipated:

$$\psi_{-8}^{pn} = \ldots = \psi_{-1}^{pn} = 0.$$

The resulting decrease in the log-likelihood function is 2.06, which implies a test statistic that is less than the critical $\chi^2(8)$ value at size 0.01, that is, 20.9. In addition, noncontract disputes appear to have had no significant contemporaneous or lagged effect on prices; the decrease in the log-likelihood function when

$$\psi_0^{pn} = \ldots = \psi_{11}^{pn} = 0$$

is 3.5, implying a test statistic of 7.03, which is less than the critical value at size 0.01, 26.2. Within this specification the following constraints

$$\psi_{-8}^{pc} = \psi_{-7}^{pc} = \psi_{-6}^{pc} = \psi_{-5}^{pc} = \psi_8^{pc} = \psi_9^{pc} = \psi_{10}^{pc} = \psi_{11}^{pc} = 0$$

could not be rejected at size 0.01; the calculated $\chi^2(8)$ equals 12.56, considerably less than the critical value at size 0.01, that is, 20.1. When the restriction of one common factor within the distributed lag of contract man-days—that of a unit root—is tested, the calculated $\chi^2(1)$ is 0.39, which is less than the critical value at size 0.01, that is, 6.63. (Note that this is not a test of a unit root in the process for man-days lost.) I imposed the final two common-factor restrictions; the calculated $\chi^2(2)$ equals 2.02, which is less than 9.21, the critical value at size 0.01, suggesting that this specification is consistent with the data.

The final parameter estimates for the γ_i^{pc}s of this specification—hereafter model 1—are presented in table 1. (To see whether these results are sensitive to alternative transformations of prices—for example, the logarithm of price—I also performed the bulk of my analysis using the logarithm of prices. The results are qualitatively similar.) Note that aggregate man-days lost during contract strikes m_t^c are measured in thousands. These results suggest that the market begins to respond to an impending contract strike only 2 or 3 weeks prior to the stoppage. Furthermore, notice the rising and then falling pattern in the estimates of the γ_i^{pc}s.

2. *Aggregating over Time to the Month*

To investigate issues relating to time aggregation, I attempted my analysis using a monthly average of weekly prices. The estimates I report are for a model similar to (1) but are executed using monthly averages of the weekly data. The specification was not derived by aggregating the weekly autoregressive model to the month because the ARCH error term produces complications. (Therefore, the results are not directly comparable.) Instead, the model was identified, estimated, and verified using the approach of Subsection IIIA1.

The stochastic process for the average monthly series differs significantly from the weekly one. The specification ultimately chosen is an ARIMA

Table 1
Maximum Likelihood Estimates of ARCH Normal Weekly *Spruce-Pine-Fir* Price Equation

Parameter	Estimate	SE*
γ_{-4}^{pc}	−.05	.04
γ_{-3}^{pc}	.04	.04
γ_{-2}^{pc}	.04	.04
γ_{-1}^{pc}	.08	.02
γ_{0}^{pc}	.09	.02
γ_{1}^{pc}	.05	.04
γ_{2}^{pc}	−.06	.03
γ_{3}^{pc}	−.09	.03
γ_{4}^{pc}	−.05	.03

NOTE.—N = 1,284; log-likelihood function = −4,360.85.

* The standard errors were calculated by applying the δ method to the $\gamma^{pc}(L)$ defined by

$$\psi^{pc}(L) = \alpha^{p}(L)\gamma^{pc}(L).$$

Table 2
Maximum Likelihood Estimates of ARCH Normal Average Monthly *Spruce-Pine-Fir* Price Equation

Parameter	Estimate	SE*
γ_{-1}^{pc}	.03	.02
γ_0^{pc}	.03	.02
γ_1^{pc}	−.01	.02

NOTE.—N = 288; log-likelihood function = −1,151.26.
* The standard errors were calculated as in table 1.

(2, 1, 0) model that is conditionally heteroskedastic of autoregressive order 4, namely,

$$V(\varepsilon_t^p) = \xi_0^p + \xi_1^p \varepsilon_{t-1}^{p^2} + \xi_2^p \varepsilon_{t-2}^{p^2} + \xi_3^p \varepsilon_{t-3}^{p^2} + \xi_4^p \varepsilon_{t-4}^{p^2},$$

where $\xi_0^p > 0$; $\xi_i^p \geq 0$, $i = 1, \ldots, 4$; and $\sum_{i=1}^4 \xi_i^p < 1$. The final results are presented in table 2. Again noncontract disputes have had no significant effect on lumber prices. Moreover, contract strikes have had only a marginal effect on monthly prices. In short, because work stoppages are brief, the temporal effects of work stoppages are short-lived and are almost completely masked in an aggregation to the monthly level.

3. *Summary of Price Effects*

Weekly prices appear to have been unaffected by noncontract disputes, but contract strikes have had a significant, yet brief, effect on price changes. On average, there have been approximately 25,000 workers employed in British Columbian sawmills.[7] Coastal millworkers, virtually all of whom belong to the IWA, make up 40% of those employed. Only about two-thirds of the workers at interior mills belong to the IWA. Hence, a major contract strike could involve 20,000 (= 10,000 + (2/3)15,000) workers. Using model (1) to predict the impact of a contract strike involving 20,000 workers for 1 workweek (5 workdays) yields the response pattern presented in figure 4. (Note that to perform this exercise, no feedback from prices to man-days lost is required.) The resulting effect on the price path assuming an initial price of $206 per 1,000 board feet of lumber, the average weekly real price over the period 1960–84, is presented in figure 5. Prices rise prior to the strike but subsequently fall to normal. These predictions imply a cumulative price increase of 12% during the week of the strike, which is remarkable considering the small number of workers in the British Columbian lumber industry relative to that in North America.

[7] Statistics Canada (1980–84*b*).

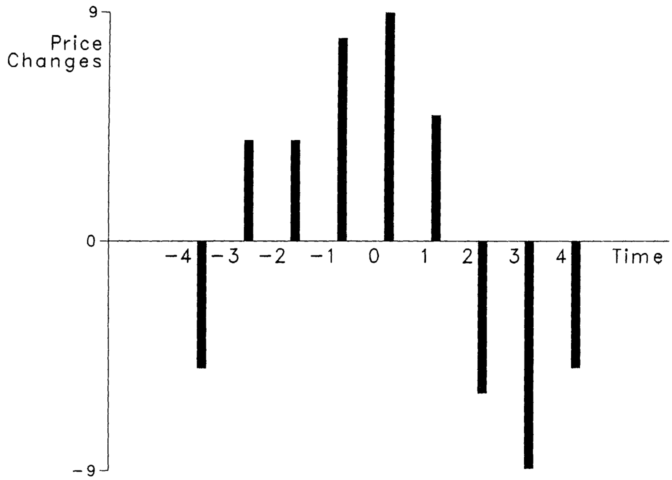

FIG. 4.—Time path of weekly price changes: 1 workweek strike of 20,000 workers

This evidence leads me to conclude that, while major contract strikes have had a positive effect on prices, this effect is short lived. Moreover, such disputes explain only a small portion of the variability in lumber prices. Because they represent a minority of total work stoppages—some 35%—only infrequently is any manifestation of union power measured.

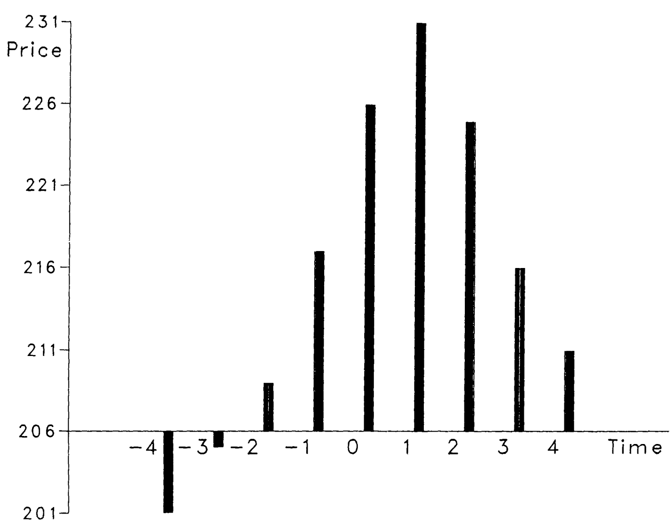

FIG. 5.—Time path of weekly prices: 1 workweek strike of 20,000 workers

B. Lumber Production, Changes in Stocks on Hand, and Work Stoppages

The next step in my analysis is to measure how work stoppages have affected lumber production in British Columbia and changed inventories held at provincial mills. In this section, I present the empirical results for a bivariate model of aggregate production and inventory changes for which only monthly data are available. This work can be effected using two different series for inventory changes. The difference arises because the inventory identity

$$I_t = I_{t-1} + Q_t - S_t$$

can be rewritten as $(I_t - I_{t-1})$ or as $(Q_t - S_t)$. These series differ because of measurement error. I report results for the series $I_t - I_{t-1}$; the results for $Q_t - S_t$ are virtually identical. Note that for parsimony I do not introduce monthly prices in light of the evidence presented above.

In addition to a constant, I introduced a time trend into Z_t because both inventories and production in the province have increased steadily over time. To deal with seasonality, I also included dummy variables for the months January–November. The interpretation of the coefficients on these variables is as deviations from average output (inventory changes) in December. The specification

$$\omega_t^Q = Q_t - Z_t\delta^Q - \gamma^{Qc}(L)m_t^c - \gamma^{Qn}(L)m_t^n$$

and

$$\omega_t^I = \Delta I_t - Z_t\delta^I - \gamma^{Ic}(L)m_t^c - \gamma^{In}(L)m_t^n,$$

where the vector $(\omega_t^Q, \omega_t^I)'$ follows an autoregressive process of the form

$$\begin{pmatrix} \omega_t^Q \\ \omega_t^I \end{pmatrix} = \begin{pmatrix} \alpha_1^{QQ}L + \ldots + \alpha_3^{QQ}L^3 & \alpha_1^{QI}L \\ \alpha_1^{IQ}L & \alpha_1^{II}L \end{pmatrix} \begin{pmatrix} \omega_t^Q \\ \omega_t^I \end{pmatrix} + \begin{pmatrix} \varepsilon_t^Q \\ \varepsilon_t^I \end{pmatrix}$$

with the specifications for the distributed lags of man-days encompassing the same time frame as that used for prices and taking the form

$$\gamma^{yi}(L) = \gamma_{-2}^{yi}L^{-2} + \ldots + \gamma_0^{yi} + \ldots + \gamma_2^{yi}L^2, \quad i = c, n, \quad y = Q, I,$$

was estimated using nonlinear regression techniques. The estimated parameters of

$$A(L) = \begin{pmatrix} 1 - \alpha_1^{QQ}L - \ldots - \alpha_3^{QQ}L^3 & -\alpha_1^{QI}L \\ -\alpha_1^{IQ}L & 1 - \alpha_1^{II}L \end{pmatrix}$$

Table 3
Nonlinear Least Squares Estimates for Bivariate Monthly Production and Changes in Stocks-on-Hand Model (N = 293)

Production			Stocks-on-Hand Changes		
Parameter	Estimate	SE	Parameter	Estimate	SE
γ_{-2}^{Qc}	−.07	.14	γ_{-2}^{Ic}	−.13	.13
γ_{-1}^{Qc}	−.05	.14	γ_{-1}^{Ic}	−.35	.15
γ_{0}^{Qc}	−.66	.15	γ_{0}^{Ic}	.37	.16
γ_{1}^{Qc}	−.13	.14	γ_{1}^{Ic}	.01	.15
γ_{2}^{Qc}	.03	.14	γ_{2}^{Ic}	.04	.13
γ_{-2}^{Qn}	.17	.59	γ_{-2}^{In}	.49	.55
γ_{-1}^{Qn}	.55	.60	γ_{-1}^{In}	.65	.60
γ_{0}^{Qn}	−2.11	.61	γ_{0}^{In}	−1.22	.60
γ_{1}^{Qn}	−1.44	.60	γ_{1}^{In}	−1.21	.60
γ_{2}^{Qn}	−.12	.60	γ_{2}^{In}	.50	.55
SE	54.84		SE	50.00	
R^2	.94		R^2	.43	

imply that all of the roots have modulus outside the unit circle. I examined the fitted residuals of these specifications for any higher-order autoregressive or moving-average parts and found no evidence of these. The squared fitted residuals indicate no obvious nonlinear relationship either. The final estimates of the $\gamma^{yi}(L)$s are presented in table 3.

1. *Lumber Production*

To provide an interpretation of the parameter estimates in table 3, I should like to consider first the data necessary in calculating the AOL statistic. In 1982, some 24,789 workers were reportedly paid for 45,460,000 hours. Assuming 8 hours per man-day, this implies 229 man-days per worker per year, or 19.1 man-days per worker per month.[8] Lumber production averaged 830 million board feet per month in 1982, implying that the average product of a millworker per man-day π was approximately 1,740 board feet per day. In 1983, in contrast, there were 25,500 workers directly employed in sawmills, but during that year these employees worked 20.40 days per month, and lumber production averaged 1,080 million board feet per month. These statistics indicate a π of 2,075 board feet per day.

Contract strikes.—A major contract strike involving 20,000 employees for 1 workweek would involve some 21.1% of available monthly man-days, so the AOL estimate would also be 21.1% of output or 175 million board feet of lumber. However, using the estimates from table 3 (namely, γ_0^{Qc}), a loss of 66 million board feet is predicted during the month of the strike. This represents only 8.0% of average monthly output in 1982, in-

[8] Statistics Canada (1983*b*), p. 8.

dicating that the local current transfer offset appears to exist. If the 1983 statistics are used, then these numbers indicate a monthly loss of 6.1%, while AOL is 19.2%. Of course, one must interpret these results carefully since the strike considered involves only 1 workweek. The bulk of the apparent local current transfer offset factor could, in fact, have resulted from either the local anticipatory or retroactive time-shift offset factors. Thus the importance of time aggregation in distinguishing between the local current transfer and time-shift offset factors should be clear.

When the sum of the coefficients on lead as well as lagged values of contract man-days lost is considered,

$$\gamma_{-2}^{Qc} + \gamma_{-1}^{Qc} + \gamma_{0}^{Qc} + \gamma_{1}^{Qc} + \gamma_{2}^{Qc},$$

a loss of some 88 million board feet of lumber is predicted. (See table 4 for the appropriate test statistic and fig. 6 for a graph of the response pattern for lumber production.) Total production losses appear to be significantly less than those predicted by AOL.

Noncontract disputes.—The effects of noncontract disputes on lumber production have been markedly different. First, the coefficient on contemporaneous man-days lost (γ_0^{Qn}) is more than three times its contract counterpart. Because noncontract disputes are probably less predictable than contract ones, one interpretation of this result is that unplanned interruptions have been more damaging than anticipated ones. Note, too, that the retroactive feature of the time-shift offset factor also appears to be absent; there is a significantly negative coefficient on the first lag of m_t^n. (See fig. 7 for a graph of the response pattern for lumber production.) In any case, the total effect of a typical noncontract dispute involving 3,000 workers for 1 workweek (3.2% of available man-days per month in 1982) is predicted to be 5.3% of output, but there is considerable imprecision in this estimate: the estimate is not significantly different from the AOL estimate.

Table 4
Test Statistics for Monthly Model of Production and Stocks on Hand

Null Hypothesis	Q	I
$\gamma_{-2}^{yc} = \gamma_{-1}^{yc} = \gamma_{0}^{yc} = \gamma_{1}^{yc} = \gamma_{2}^{yc} = 0$	26.5	16.0
$\gamma_{-2}^{yc} + \gamma_{-1}^{yc} + \gamma_{0}^{yc} + \gamma_{1}^{yc} + \gamma_{2}^{yc} = 0$	−2.3	−.4
$\gamma_{-2}^{yn} = \gamma_{-1}^{yn} = \gamma_{0}^{yn} = \gamma_{1}^{yn} = \gamma_{2}^{yn} = 0$	21.6	15.7
$\gamma_{-2}^{yn} + \gamma_{-1}^{yn} + \gamma_{0}^{yn} + \gamma_{1}^{yn} + \gamma_{2}^{yn} = 0$	−1.7	−1.0

NOTE.—The test statistics for the joint tests of zero are distributed $\chi^2(5)$ under the null, the critical value for which at size .01 is 15.1. For the sums, the test statistics are asymptotically distributed normal with zero mean unit variance under the null. Q = British Columbian production. I = stocks-on-hand changes.

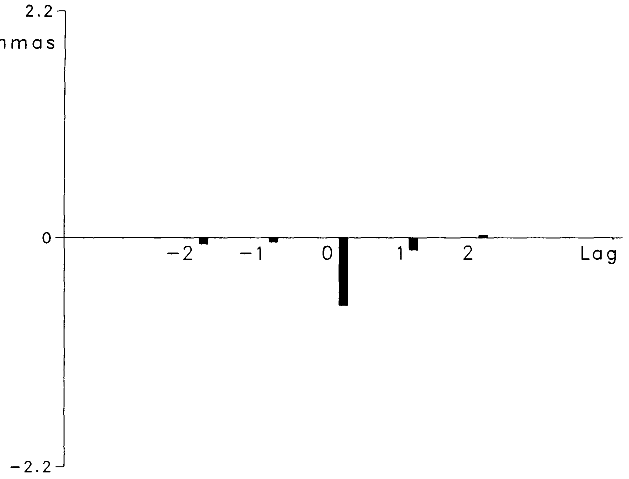

FIG. 6.—Production response function: contract strikes

Other factors.—The reader will, of course, argue that this analysis ignores potential nonlinearities in the relationship between lumber production (inventory changes) and man-days lost. To see if this is the case, I defined separate variables for man-days lost depending on dispute intensity. For example, if man-days were greater than some value (e.g., 100,000 man-days), then a different regressor was introduced into the model than if they were below that value. I found no major differences in the results

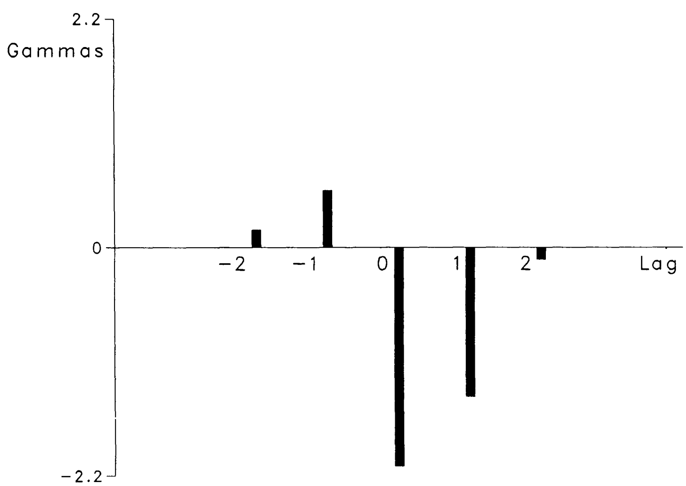

FIG. 7.—Production response function: noncontract disputes

using several different split points, suggesting that the results are robust to the unusually large number of man-days lost in the early 1980s.

The reader will also point out that man-days lost measure the intensity of stoppages that have occurred. What about those stoppages that were avoided; how is the intensity of these disputes measured? The dates of noncontract disputes appear to be unpredictable, so strategic behavior is unlikely to be important in these cases. Contract expiration dates are, however, known with certainty and signal the possibility of strikes. In these cases, strategic behavior is surely important. According to an official at the International Woodworkers of America, virtually all contract negotiations during the period examined were accompanied by stoppages of some duration and magnitude.[9]

2. *Changes in Lumber Stocks on Hand*

How inventories change in response to work stoppages is of particular interest since such adjustments are central to the local time-shift offset factors.

Contract strikes.—In 1982, inventories averaged 1,421 million board feet, while in 1983 they were 1,411 million board feet.[10] Using the estimates presented in table 3 (namely, γ_0^{Ic}), inventories are predicted to rise significantly by 2.6% in response to a 21.1% loss in man-days during the month of a contract strike. This is a somewhat perplexing result since one interpretation of the time-shift offset factor suggests that inventories should be drawn on during strikes; that is, γ_0^{Ic} should be negative. During contract strikes, however, mills are typically picketed by striking employees, and other workers (e.g., those belonging to the Teamsters Union) honor these picket lines. Thus lumber at such mills is embargoed. In addition, those mills not involved in disputes usually cannot ship much extra lumber because in the short run boxcars are scarce. Consequently, mills will attempt to ship additional lumber prior to a contract strike. This prediction is confirmed by the data: the coefficient γ_{-1}^{Ic} is significantly negative. (See fig. 8 for a graph of the response pattern for inventory changes.)

Noncontract disputes.—The results for noncontract disputes suggest that these stoppages have been perfectly offset by local transfers over time within the province. Figure 9 depicts the response pattern for inventory changes. The net effect of these disputes on inventories has been small and insignificant, that is, the hypothesis that

$$\gamma_{-2}^{In} + \gamma_{-1}^{In} + \gamma_0^{In} + \gamma_1^{In} + \gamma_2^{In} = 0$$

cannot be rejected. (See table 4 for the appropriate test statistic.)

[9] Legg (1988).

[10] Statistics Canada (1982–83*b*), monthly issues.

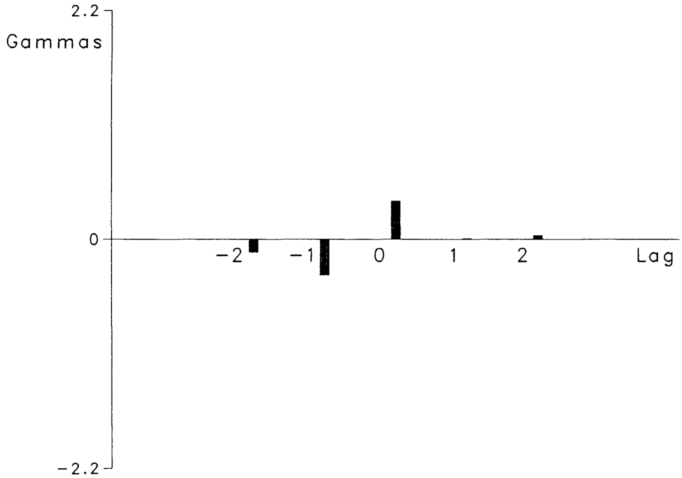

FIG. 8.—Changes in stocks on hand response function: contract strikes

What is different about noncontract disputes? First, these disputes are typically much smaller than contract ones. Next, they are usually less organized than those that occur during contract negotiations. Finally, such disputes are local ones. These factors likely prevent the embargo effects.

IV. Conclusions

Except for major contract strikes, work stoppages in the British Columbian lumber industry appear to have had no significant effect on North

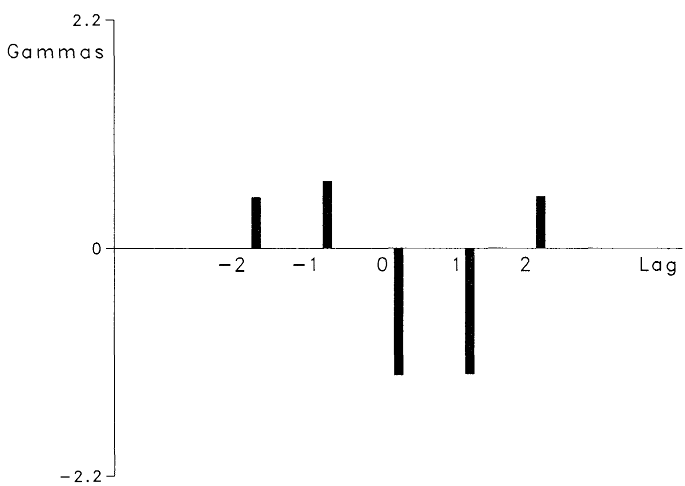

FIG. 9.—Changes in stocks on hand response function: noncontract disputes

American lumber prices. While major contract strikes have had a significantly positive effect on the price of North American lumber, this effect has been short-lived. In fact, when prices are averaged to the monthly level, the effect is virtually imperceptible, suggesting that any dislocation, however large, is brief.

Contract and noncontract disputes appear to have had different effects on production. In the former case, no significant local anticipatory time-shift offset factor appears present. Moreover, the local retroactive time-shift offset factor also appears absent. Nevertheless, some local current transfer offsetting appears present, as estimated losses are predicted to be significantly less than what AOL would predict; time aggregation could, however, be important in this result.

In the case of noncontract disputes, the current effects of stoppages on production are predicted to be three times those of contract strikes. Estimated total losses are not, however, predicted to be significantly different from the AOL estimate. Because these disputes are typically small, they likely result in only small disruptions.

At first, the behavior of stocks on hand (inventories) held at provincial mills appears somewhat paradoxical. Prior to major contract strikes, stocks on hand are predicted to fall significantly. One possible interpretation of this result is that agents seek to get lumber out of the mills and into the marketplace to avoid embargoes that occur when the IWA pickets mills. During the month of a strike, inventories are predicted to rise, suggesting that the embargo effects may be important. The total net effects are not, however, predicted to be significantly different from zero.

Prior to noncontract disputes, stocks on hand are predicted to rise, but the impulse parameters are estimated imprecisely. In the months during and after stoppages, inventories are predicted to fall. The local time-shift factor appears to reduce the importance of these disputes, evidence certainly consistent with the results from the price series.

The above evidence suggests that work stoppages in the British Columbian lumber industry may not be as important as some would predict. There are two basic reasons: lumber is a durable good, and the industry has excess capacity. These factors admit the substitution of production over time and across firms. Moreover, in cases where the two factors do not mitigate the losses, dislocation (as signaled by an increase in lumber prices) is short-lived. Intertemporal and interfirm considerations certainly appear important in measuring the impact of work stoppages.

Appendix

Data Sources

In this appendix, I describe the sources from which the data were taken as well as the transformations used in creating the final data set.

I. Work Stoppage Data

For data concerning work stoppages, I relied exclusively on the *Work Stoppages File* (*WS* file). This file is compiled from provincial records by Labour Canada (1985) and contains a detailed account of each work stoppage in every province involving three or more workers or lasting more than 10 man-days. For example, a dispute at a firm of 50 workers lasting just over one-fifth of a shift is recorded as something over 10 lost man-days. In my copy of the file, there are 20,501 records documenting disputes from January 1946 until November 1985. For each dispute, inter alia, Labour Canada records the Standard Industrial Classification (SIC) code, the start and termination data, the status of the labor contract, the primary and secondary issue of the dispute, the number of workers involved, the number of workdays lost as well as the total number of man-days lost and, in the case of recent stoppages, dispute location and firm name.

By selecting only those disputes in the British Columbian lumber industry (i.e., those with province number equal to 59 and SIC code equal to 251) between January 1960 and December 1984, I reduced the number of records to 164. The total number of disputes is less because several records are redundant and represent the carryover of data for a dispute from a previous year. There were, in fact, 156 disputes during this period. Man-days lost per month were then aggregated across disputes by type (e.g., contract and noncontract) to create aggregate man-days lost. The sample descriptive statistics are presented in table A1.

For some of my work, weekly price data (to be described below) are available. To investigate the effect of disputes on weekly prices, I had to create weekly series of aggregate man-days lost by type of dispute. This involved attributing monthly man-days lost per dispute to particular weeks. To do this, every dispute was assigned a vector, each element of which contained the number of man-days lost per day. I then aggregated across dispute vectors for a particular type of dispute and subsequently over days of the week.

The number of man-days lost per day was estimated by prorating man-days lost per month to the workdays lost in that month. For example, if 1,000 man-days were lost in 1 month over 10 workdays,

Table A1
Sample Descriptive Statistics (Monthly Series, 1960–84)

Variable	Mean	SD	Minimum	Maximum
m_t^c	8,375.0	44,719.1	.0	480,000.0
m_t^n	1,410.5	9,719.6	.0	117,000.0
p_t	206.0	53.5	116.4	360.8
I_t	1,089.0	268.1	424.3	1,770.1
Q_t	751.5	222.1	187.2	1,193.5
S_t	748.7	224.9	259.9	1,241.4

then 100 man-days were attributed to each workday lost. The workdays in specific weeks to be counted were identified by the start and termination date information provided in the *WS* file. Considerable care was taken to exclude holidays observed in the lumber industry.[11] Therefore, in addition to Saturdays and Sundays, New Year's Day (January 1), Good Friday, Easter Monday,[12] Victoria Day (the third Monday in May), Dominion Day (July 1), British Columbia Day (the first Monday in August after 1974), Labour Day (the first Monday after a Sunday in September), Thanksgiving Day (the second Monday in October), Rememberance Day (November 11), Christmas Day (December 25), and Boxing Day (December 26) were excluded as potential workdays. If New Year's Day, Dominion Day, Rememberance Day, Christmas Day, or Boxing Day fell on a weekend, then the holiday was assumed to occur on the following Monday, but if Christmas Day fell on a Saturday, then December 24 was observed as a holiday.

II. Lumber Data

The data concerning lumber production, shipments, and stocks on hand (inventories) are from Statistics Canada (1960–84*a*). Over the 25-year period considered here, Statistics Canada (formerly the Dominion Bureau of Statistics) has kept remarkably complete and comparable records for total production, shipments, and stocks on hand of lumber and ties in the province. Despite the care taken in collecting these data, they are nevertheless imperfect. For example, if a mill does not report, then its output is estimated. This nonreporting problem does not appear great on the coast, where less than 5% of the mills typically do not report, but often 25% of interior mills are delinquent. Also of some importance is the fact that mills err in their reporting.[13] Because of these errors, as well as the fact that production, shipments, and stocks on hand are estimated for delinquent mills, the inventory identity does not hold exactly.

Another potentially important issue concerns the survey. Statistics Canada does not canvass mills that produce less than a specific amount that has varied over time. For example, in 1984 "sawmills producing less than three million ft.b.m.—7,080m^3 (cubic metres) per year"[14] were excluded. Consequently, the sample need not be random. This may be important in the interior region where many of the small mills are not unionized and their output could offset production lost during strikes.

A common problem with historical data, present here, too, is comparability. During the early periods, the coastal region dominated total

[11] I am grateful to Kevin Gudgeon of the Policy and Planning Branch at the British Columbia Ministry of Labour and Phillip Legg of the International Woodworkers of America—Western Regional Council no. 1 for providing helpful information and advice.

[12] The dates for the Eastern religious holidays are from the *Book of Common Prayer* (1976), p. 882.

[13] Martin (1986).

[14] Statistics Canada (1984*a*), p. 1.

production, but over time, with the development of the interior mills, this has changed. Moreover, the composition of output by species has evolved, so the meaning of aggregate production as measured in millions of board feet has changed. While production records exist by region and species, complementary ones by species for shipments and stocks on hand do not. Therefore, I was obliged to aggregate the production data across regions and species. The sample descriptive statistics are tabulated in table A1.

III. Price Data

Price data by species and type of British Columbian lumber are secure at Statistics Canada for reasons of privacy; the samples used often contain but a few firms, so firm-specific prices could potentially be identified from information in the indices. My only recourse was to collect data from trade publications. I chose one of the best-known publications in North America, *Madison's Canadian Lumber Reporter.*

The issue of which price series to use is a complicated one. I hoped to form a representative series of *all* commodities by species, but for such a long period few complete series exist. Had several comparable ones existed, the issue of which weights to use in an index remains unclear. After consulting with Laurence Cater (publisher) and John Friesen (editor) of *Madison's Canadian Lumber Reporter,* I decided that the only consistent and meaningful series that could be recovered from *Madison's Canadian Lumber Reporter* (1960–84) is that per 1,000 board feet (*1M*) for one boxcar of *Spruce-Pine-Fir* (*SPF*), *Western, Kiln Dried* (*KD*) 2 × 4s, *Standard and Better* (*Std&Btr*), *Random Lengths* (*R/L*). In early issues, this product was referred to as *1M Dry White Spruce* 2 × *4*s, *Std&Btr, R/L.* The introduction of pine and fir is a relatively recent one and reflects the fact that both have become acceptable substitutes for spruce. When *SPF* was introduced in lieu of *Dry White Spruce,* no obvious change in the price series appeared.

In my empirical work, the weekly price series used is the real, free-on-board (FOB) mill price excluding discounts. (For some of the analysis, these data were averaged to form a monthly series as well.) Converting the raw data involved three types of adjustments: first, in early issues prices are reported in U.S. funds per 1,000 board feet delivered to the New York area. In addition to the price, however, a freight rate that represents the cost per hundred weight of shipping a boxcar from a representative mill to New York is also reported. (The location of this mill is not mentioned in *Madison's*.) One thousand board feet of 2 × 4s weigh approximately 1,800 pounds, so to find the price FOB mill, I subtracted [18 × (freight rate)] from the reported price.

Next, in recent issues of *Madison's,* prices are quoted net of discounts, where such discounts are typically listed as "less 5 & 2 percent." Thus the net FOB mill price is 0.931 (= (0.95)(0.98)) times the FOB price. But because it is not always clear in early issues of *Madison's* whether the discount to be applied is 5% or 5% and 2% I decided to convert the net prices of recent years into ones excluding discounts; that is, I divided later prices by 0.931.

Finally, the weekly nominal price series had to be deflated. Although *Madison's* is a Canadian publication, the price of *SPF* 2×4s is quoted in U.S. funds, so I chose the U.S. consumer price index (CPI) to scale the data. This index is only available at the monthly level; to get a weekly series, I interpolated the monthly one. For example, in calculating the rate for the first week between the end of month t and the end of month $(t + 1)$, I defined r as follows:

$$(1 + r) = (\mathrm{CPI}_{t+1}/\mathrm{CPI}_t)^{(1/nw)},$$

where nw is the number of weeks in month $t + 1$. Therefore, the CPI for the first week after the end of month t is $(1 + r)\mathrm{CPI}_t$. This procedure can introduce some "seasonality" because those months with 31 days are more likely to have nw equal to five than February is. Moreover, any time-series properties of the CPI are slighted. I ignore these problems as they are probably of second-order importance and hope that the time-series specification can deal with them. The weekly CPI series was normalized so that the first week of 1981 is one.

As all the other data are monthly, I also averaged the weekly SPF nominal data to the monthly level. For weeks that straddled months, I attributed the week in question to the month having the majority of days. The sample descriptive statistics for the monthly data are tabulated in table A1.

References

Book of Common Prayer. New York: Seabury, 1976.

British Columbia Ministry of Forests, Timber Management Branch. *Major Primary Timber Processing Facilities in B.C.—1984.* Victoria, Canada: Ministry of Forests, 1985.

British Columbia Ministry of Industry and Small Business Development, Central Statistics Bureau. *British Columbia Economic Accounts: 1963–1982.* Victoria, Canada: Ministry of Industry and Small Business Development, 1983.

British Columbia Ministry of Labour. Labor force participation statistics, 1982.

Christenson, C. "The Theory of the Offset Factor: The Impact of Labor Disputes upon Coal Production." *American Economic Review* 43 (September 1953): 513–47.

———. "The Impact of Labor Disputes upon Coal Consumption." *American Economic Review* 45 (March 1955): 79–112.

Engle, R. "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation." *Econometrica* 50 (July 1982): 987–1007.

Godfrey, L. "Testing against General Autoregressive and Moving Average Error Models When the Regressors Include Lagged Dependent Variables." *Econometrica* 46 (November 1978): 1293–1301. (*a*)

———. "Testing for Higher Order Serial Correlation in Regression Equations When the Regressors Include Lagged Dependent Variables." *Econometrica* 46 (November 1978): 1303–10. (*b*)

Gunderson, M.; Kervin, J.; and Reid, F. "Logit Estimates of Strike Incidence from Canadian Contract Data." *Journal of Labor Economics* 4 (April 1986): 257–76.

Gunderson, M., and Melino, A. "Estimating Strike Effects in a General Model of Prices and Quantities." *Journal of Labor Economics* 5 (January 1987): 1–19.

Harrison, A., and Steward, M. "Cyclical Variation in Strike-Settlement Probabilities." Discussion paper. Hamilton, Canada: McMaster University, 1987.

Jurkat, E., and Jurkat, D. "Economic Functions of Strikes." *Industrial and Labor Relations Review* 2 (July 1949): 527–45.

Kennan, J. "The Duration of Contract Strikes in U.S. Manufacturing." *Journal of Econometrics* 28 (April 1985): 5–28.

———. "The Economics of Strikes." In *Handbook of Labor Economics,* vol. 2, edited by O. Ashenfelter and R. Layard. New York: North-Holland, 1986.

Kennan, J., and Wilson, R., "Strategic Bargaining Models and Interpretation of Strike Data." Mimeographed. Stanford, Calif.: Stanford University, 1988.

Labour Canada. *Work Stoppages File.* Ottawa, Canada: Labour Canada, 1985.

Legg, Phillip. Personal communication with author. International Woodworkers of America—Western Regional Council no. 1, Vancouver, Canada, June 15, 1988.

Madison's Canadian Lumber Reporter. Vancouver, Canada: Madison's Publications, weekly issues, 1960–84.

Maki, D. "Output Losses due to Strikes: The Case of Sawmills in British Columbia." *Empirical Economics* 10 (1985): 121–24.

Martin, Patrick. Personal communication with author. Ottawa, Canada: Statistics Canada, Industry Division, January 15, 1986.

Neumann, G., and Reder, M. "Output and Strike Activity in U.S. Manufacturing: How Large Are the Losses?" *Industrial and Labor Relations Review* 37 (January 1984): 197–211.

Statistics Canada. *Production, Shipments, and Stocks on Hand of Sawmills in British Columbia.* Catalog no. 35-003. Ottawa, Canada: Statistics Canada, monthly issues, 1960–84. (*a*)

———. *Sawmill, Planing Mill, and Shingle Mill Products Industries.* Catalog no. 35-204. Ottawa, Canada: Statistics Canada, yearly issues, 1980–84. (*b*)

Tiao, G., and Wei, W. "Effect of Temporal Aggregation on the Dynamic Relationship of Two Time Series Variables." *Biometrika* 63 (1976): 513–23.

Wei, W. "The Effect of Temporal Aggregation on Parameter Estimation in Distributed Lag Model." *Journal of Econometrics* 8 (October 1978): 237–46.