RELATIVE PRICES, WAGE INDEXATION AND UNEMPLOYMENT

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No. 102 December 1987
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*This paper was written while Professor Carlson was a Visiting
Scholar at the University of Sydney. We are grateful to seminar
participants at the University of Sydney, Reserve Bank of
Australia, University of Melbourne, Flinders University, and
Macquarie University for helpful comments on an earlier version
of the paper.
ABSTRACT

When a firm and its workers try to agree now on contingent wages and employment at some future date, potential movements in several different prices enter into consideration. The firm's revenue depends on the selling price of its product. The workers have concerns about the price of the bundle of goods they buy, and the firm's owners may buy a different bundle of goods having still another price index. Unless owners want to acquire their firm's own output or are fairly risk averse relative to workers, wages will be indexed primarily to variations in the price index of what workers buy and not to variations in the firm's selling price.

This prediction, which has been reported to be the typical pattern empirically, does not depend on whether the agreement also calls for possible layoffs. For any strictly concave utility function for workers, potential relative price variations must be quite sizeable before contingent layoffs will be planned, unless laid-off workers, without direct compensation from the firm, are almost as well off as when employed. If there are some layoffs, then increased relative price dispersion will raise the average unemployment rate.
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1. Introduction.

Wage indexation is a contract which can protect to varying degrees the real wage received by workers. It has been suggested not only as a means of protecting the real value of nominal variables from fluctuations in prices but also as a policy tool to insulate the real sector of an economy from economic disturbances. In much of the macro literature, the degree of indexation is obtained by optimizing some social objective function on the macro level.

The works of Gray (1976), Fischer (1977b), and Cukierman (1980) show, for example, that full indexation will insulate an economy from purely nominal disturbances. When only real shocks occur, full indexation will exacerbate the effects of the disturbances. In the intermediate case in which real and nominal shocks both occur, optimality at the macroeconomic level requires partial indexation.\(^1\) Similar results hold in open economy macro models, where both wage indexation and exchange rate intervention are used as policy tools. See for example Calmfors and Viotti (1982), Aizenman and Frenkel (1985) and Marston and Turnovsky (1985).

Actual indexation, at least in North America, is not imposed by government rules. It is generally negotiated between a firm and its employees (or a union representing the employees). While all workers may be concerned about their real wages (nominal wages deflated by an index of product prices), the firm's decisions are based on its own product wage (the nominal wage deflated by the firm's product price). Algoskoufis (1983) is one author who emphasizes the dis-
tinction between real wages and product wages in a business-cycle model.

Our concern in this paper is to examine how firms and workers would choose a wage pattern in response to different variations in aggregate and product prices. By doing so, we can address a "fundamental question" posed by Card (1986, pp. 150-151): "Why not index-link wages directly to market-specific prices? Although there is some historical precedent for indexing wages to industry selling prices, it remains an interesting puzzle as to the nearly universal practice of escalation to the CPI."

Wage indexation at the micro level is usually studied within the context of implicit contract models. See Azariadis (1975), Baily (1974), and Gordon (1974) for seminal papers in this area. Risk-neutral firms choose state-contingent contracts to maximize expected profits. These same contracts must also maximize the expected utility of the risk-averse workers. The solution suggests that the contract must offer a wage which is independent of the state. It was not initially clear which wage was being fixed. Phelps (1977, p. 152) for one asks, "Is this 'wage', which is state-invariant during the contract, the money wage or the real wage?" Azariadis and Stiglitz (1983) make clear that the real wage is what is fixed in these early implicit contract models.

The key difference between the analysis that we undertake in this paper and previous implicit contract models is that the problem will be set up in terms of different prices that are relevant for different decision makers. There is the selling price for the firm, the price of the bundle of goods bought by workers, and the price of the bundle of goods bought by the owners of the firm with the firm's profits. In section 2, we show the extent to which these various prices influence the optimal contract.

Schultze (1985) in his presidential address at the American Economic Association 1984 meetings notes (p. 8) that wage indexation may not insulate the
real sector from purely nominal disturbances. "Moreover, even nominal shocks are likely, during the transition to a new equilibrium, to have nonneutral effects; the firm's product price and the Consumer Price Index may not move in parallel. As a consequence, indexing would have unwanted real effects even in the face of monetary shocks." Since, as we argue in Section 2, firms and workers will not choose a contract which offers extensive indexation to firms' selling prices, we turn to the question of the real effects of changing relative price disturbances.

McDonald (1986) has also investigated this question and suggests that relative price dispersion may not generally be great enough to obtain layoffs in bad states in this sort of model. We show in Section 3 that the thrust of McDonald's argument holds for any strictly concave utility function for workers and is not dependent on the specific functional form he uses for his simulations. Furthermore, it holds even when unemployment compensation is part of the contract and each firm fully insures its workers against layoffs so that the workers are indifferent between working and being laid off.

If there are contingent layoffs, however, an increase in relative price dispersion will increase the average rate of unemployment. This is demonstrated for a two-state type of model in which each firm's payments to its unemployed workers are part of the contract with its workers.
2. Wage Indexation with Different Relative Prices

In this section, we address the following question: If firms and workers were to choose a contingent wage and employment contract, how would the choice be influenced by various relative price outcomes that might occur? The structure of the model we use is similar to the one presented by Azariadis (1975).

Imagine that a group of firms and a group of workers in a labor market are looking ahead to a period in the future, which can be characterized by a set of possible price outcomes. Each such outcome will be denoted as a state \( s \). Let there be \( S \) such possible states. Workers and firms have the same perception about the probability that state \( s \) will occur. Let this probability be denoted \( \pi(s) > 0 \), and \( \pi(1) + \ldots + \pi(S) = 1 \).

Consider the problem initially of one firm \( i \), which has to announce in advance how many workers it wants to hire and what its wage and employment plans will be once it is known (to both the firm and its employees) that state \( s \) has occurred. When state \( s \) occurs, the firm's selling price will be \( P_i(s) \), the price index of the goods bought by workers will be \( P_W(s) \), and the price index of the goods bought with the firm's profits will be \( P_f(s) \). The firm will pay a nominal wage \( W_i(s) \) to its employed workers and \( C_i(s) \) to its unemployed workers. It will employ \( n(s) \) workers. If \( n \) is the total number of workers under "contract," then \( n(s)/n \) is the probability that an individual worker will be employed in state \( s \) and \( 1 - n(s)/n \) is the probability that a worker will be unemployed.

The workers are assumed to obtain utility \( U(w(s)) \) from the real wage \( w(s) = W_i(s)/P_W(s) \) if employed and \( U(k+c(s)) \) if unemployed, where \( k \) is the real pecuniary equivalent of the extra leisure plus any outside unemployment compensation and \( c(s) = C_i(s)/P_W(s) \) is the real value of any unemployment compensation paid directly by the firm. Assume that the utility function \( U \) is such that
$U' > 0$ and $U'' < 0$. The expected utility of a worker who agrees to be available to firm $i$ is:

$$EU = \sum_{s=1}^{S} \pi(s)\left([n(s)/n]U(w(s)) + [1 - n(s)/n]U(k+c(s))\right)$$

If a worker's best alternative employment elsewhere provides an expected utility of $U^*$ (which of course depends on overall market conditions) the firm must offer a contract such that $EU$ is at least as great as $U^*$. We assume that the firm can obtain all the labor it needs by making $EU = U^*$. Alternatively, one can think of the opportunity cost in terms of full time employment at a real wage $w^*$ such that $U(w^*) = U^*$. Since it is costly for the firm to provide any higher utility, it will choose a combination of $n(s)$, $w(s)$, $c(s)$, $s = 1, \ldots, S$ such that $EU = U^*$.

The firm's output is solely a function of labor input. Let $f(n(s))$ represent the firm's output when its labor input is $n(s)$ in state $s$ and let this production function satisfy the following conditions: $f' > 0$, $f'' < 0$, $f'(0) = \infty$ and $f'(\infty) = 0$. The firm's nominal profits in state $s$ are represented by the expression:

$$P_i(s)f[n(s)] - W_i(s)n(s) - C_i[n - n(s)].$$

In terms of what the owners wish to buy, these profits in real terms will be denoted by:

$$y(s) = \frac{P_i(s)f[n(s)] - W_i(s)n(s) - C_i[n - n(s)]]}{P_f(s)}.$$  

The utility for the firm in state $s$ will be represented by $V(y(s))$, with $V' > 0$ and $V'' \leq 0$. If the firm is risk neutral then let $V(y(s)) = y(s)$ so that $V' = 1$ and $V'' = 0$.

The mathematical specification of the first-order conditions is reported in Table 1. The firm chooses a contingent set of wages and employment levels to
Table 1
The Langrangean Function and First-Order Conditions

(3) \[ J(\bar{W}_i(s), n(s), \lambda(s), \mu) = \sum_{s=1}^{S-1} \lambda(s)[n(s) - n(s)] \]
\[ + \sum_{s=1}^{S} \pi(s) V[\{P_i(s)f(n(s)) - \bar{W}_i(s)n(s) - C_i(s)(n(S) - n(s))\}/P_f(s)] \]
\[ + \mu[\sum_{s=1}^{S} \pi(s)[(n(s)/n(S))U(\bar{W}_i(s)/P_w(s)) + (1-n(s)/n(S))U(k+C_i(s)/P_w(s)) - U^*} \]

The first-order conditions (setting equal to zero the partial derivatives of \( J \) with respect to the choice variables) are:

(4a) \( \bar{W}_i(s) \): \[ \pi(s)n(s)[-V'(y(s))/P_f(s) + \mu'U'(w(s))/[P_w(s)n(S)] = 0 \quad s = 1, \ldots, S \]

(4b) \( C_i(s) \): \[ \pi(s)[n(S) - n(s)][-V'(y(s))/P_f(s) + \mu'U'(k+c(s))/[P_w(s)n(S)] = 0 \quad s = 1, \ldots, S \]

(4c) \( n(s) \): \[ \pi(s)V'(y(s))[P_i(s)f'(n(s)) - \bar{W}_i(s) + C_i(s)]/P_f(s) - \lambda(s) \]
\[ + \mu \pi(s)[U(w(s)) - U(k+c(s))]/n(S) = 0 \quad s = 1, \ldots, S-1 \]

(4d) \( n(S) \): \[ \pi(S)V'(y(s))[P_i(S)f'(n(S)) - \bar{W}_i(S) - C_i(S)]/P_f(S) \]
\[ + \sum_{s=1}^{S-1} \lambda(s) - \mu \sum_{s=1}^{S} \pi(s)n(s)[U(w(s)) - U(k+c(s))]/n(S)^2 = 0. \]

(4e) \( \mu \): \[ \sum_{s=1}^{S} \pi(s)[(n(s)/n(S))U(w(s)) + (1-n(s)/n(S))U(k+c(s))] - U^* = 0. \]

(4f) \[ n(S) - n(s) \geq 0 \quad s = 1, \ldots, S-1. \]

(4g) \[ \lambda(s)[n(S) - n(s)] = 0 \quad s = 1, \ldots, S-1. \]

In each state \( s \):

\( w(s) = \bar{W}_i(s)/P_w(s) \) is the worker's real wage,

\( c(s) = C_i(s)/P_w(s) \) is the real value of the worker's unemployment compensation paid by the firm, and

\( y(s) = [P_i(s)f(n(s)) - \bar{W}_i(s)n(s) + C_i(s)(n(S) - n(s))]/P_f(s) \) is the firm's real profits.
maximize the expected utility of its real profits subject to the constraints that employment in any state is less than or equal to the firm's labor force \( \lambda(s) \) is a Kuhn-Tucker Lagrangian multiplier and that the firm be competitive in the labor market by providing a utility to workers of \( U^* (\mu \text{ is a Lagrangian multiplier}) \). The state \( S \) is designated as the one in which none of the firm's workers are laid off so that \( n = n(S) \) is the firm's desired labor force. The first-order conditions (4a) through (4e) are obtained by taking the partial derivatives of \( J \) with respect to the \( W_i(s), C_i(s), n(s) \) and \( \mu \). From (4f) and (4g), when \( n(s) < n(S) \), \( \lambda(s) = 0 \); and when \( n(s) = n(S) \), \( \lambda(s) \) may take on positive values to satisfy (4c) and (4d).

We concentrate in this section on interpreting the conditions represented by equations (4a). These can be written:

\[
 U'(\frac{W_i(s)}{P_i(s)}) = (\frac{n(S)}{\mu})(\frac{P_i(s) - P_f(s)}{P_i(s)})U'(y(s)) \quad s = 1, \ldots, S.
\]

To help understand this equation and to answer the question about when firms would want to index to local selling prices, we analyze a series of special cases of equation (5). Note also that equation (5) would still hold if, in each state, equation (1) was expressed in terms of the utility of expected income instead of the expected utility of income.

Direct Compensation of the Firm's Unemployed. Before analyzing special cases of equation (5), we consider the implication of having the firm's payment for unemployment compensation be part of the contract. If the firm does not bear any variable cost of compensating its workers on layoff, then \( C_i(s) = 0 \) in all states and equations (4b) are irrelevant.

Suppose \( C_i(s) \) can be chosen to maximize the firm's profits subject to satisfying the workers' expected utility constraint. A comparison of equations (4a) and (4b) reveals that

\[
 U'[k+c(s)] = U'[w(s)].
\]
The implication is that \( k+c(s) = w(s) \) in each state \( s \) and the worker will be indifferent between working and being on layoff. In Section 3 below, in dealing with the possibility of layoffs, we can compare this situation with the one in which none of the variation in unemployment costs is borne directly by the firm.

This result also implies that, when unemployment compensation is part of the contract, any influence of particular prices on the nominal wage in the cases to be considered will have a similar influence on the nominal payment by the firm to its unemployed workers.

**Case 1:** Risk-neutral firm \( (V' = 1) \) and \( P_w(s) = P_f(s) \). If the firm is risk neutral and if owners of the firm buy the same bundle of goods as workers so that nominal profits are deflated by the same price index as workers, then (5) reduces to

\[
U'(W_i(s)/P_w(s)) = n(S)/\mu
\]

Whatever the solutions for \( n(S) \) and \( \mu \), the marginal utility of the real wage must be the same in all states. Since \( U' \) is strictly decreasing \( (U'' < 0) \), there is a unique real wage which must hold in each state. Denote this by \( w \). With the real wage constant across all states, the nominal wage is fully indexed to variations in price of the bundle of goods bought by workers. This is the standard result for risk neutral firms with risk averse workers. By reducing the workers' real-wage variations the firm is able to decrease the real wage and hence increase its own expected profits. The firm fully insures the workers against fluctuations in the purchasing power of their wages.

Note in this case, however, that the nominal wage does not respond to any variations in the price of the firm's product. To change wages as selling prices change would introduce variations in workers' real wages. Because of workers' risk averseness, they would need to be compensated by a higher real wage. This would lower the firm's profits with no offsetting gain to the firm.
Case 2: Risk-neutral firm, $P_f(s) = 1$. Now suppose the risk-neutral firm is concerned with its accumulation of wealth. This would be the case in which owners of the firms wish to save any profits for future consumption and commodities are not a convenient way of storing wealth. We do not deal with what financial instruments are available but suppose that they are denominated in nominal money units. If the firm's current objective is in terms of nominal profits, then equation (5) becomes:

\[
U'(W_i(s)/P_w(s)) = (n(S)/\mu)P_w(s) \quad s = 1, \ldots, S.
\]

A higher $P_w(s)$ calls for a higher $U'$, which occurs when $w(s)$ is lower. Therefore when the aggregate price is higher, the real wage is lower. Indexation is less than full, but what indexation there is depends again only on the price of the bundle of goods bought by workers and not on the local product price.

Basically what is happening here can be understood by supposing initially that real wages were equal across states. Expected nominal profits could then be increased more by lowering $w(s)$ when $P_w(s)$ is high than would be lost by raising $w(s)$ when $P_w(s)$ is low. The extent of the gain to the firm from variations in real wages between states is limited by the concavity of the workers' utility function.

Assuming that workers' relative risk aversion is greater than 1 so that nominal wages would be adjusted in the same direction as any variation in the workers' price index, the contract could be specified in terms of guaranteeing the nominal wage that gives the highest real wage (for the lowest possible value of $P_w(s)$) and then specifying a partial indexing rule in accordance with equation (7).
Case 3: Risk neutral firm, $P_f(s) = P_i(s)$. Now suppose that the firm wishes to acquire its own goods. It is not clear that many firms would want to do this. If firms are so diversified as to produce a representative bundle of goods or there is a one-commodity model, there would be little point in making the distinction between the product price and an aggregate price. One possibility where this case could be relevant is a foreign-owned firm that is in business to extract a product from its operations in the domestic economy. Whatever the rationale, this case does result in some indexing to product prices with risk neutral firms. With $V' = 1$ and $P_f(s) = P_i(s)$, equation (5) becomes:

$$U'(W_1(s)/P_w(s)) = (n(S)/\mu)P_w(s)/P_i(s) \quad s = 1, \ldots, S.$$  

As in case 2 there is less than full indexation to variations in the aggregate price, ceteris paribus. What is different about this case is that there is now some indexation to the local price to the extent that it does not move with the aggregate price. Ceteris paribus, at higher $P_i(s)$, $U'$ is lower, which calls for a higher $w(s)$. Hence, if the firm is trying to maximize its product profits, then real wages will be higher when local prices are higher relative to the aggregate price. In this case, where the firm's objective is influenced by the local price, the firm has something to gain by adjusting wages to local prices and will accept a somewhat higher real wage to take advantage of variations in relative prices.

Case 4: Risk-averse firm, $P_f(s) = P_w(s)$. Now consider the case in which the same deflator is used for wages and for profits, but the firm is risk averse. The relative price $p(s) = P_i(s)/P_w(s)$ in this specification plays a similar role to a productivity shift term in a model specified by Simonsen (1983). Equation (5) now takes the form:
(9) \[ U'(w(s)) = (n(S)/\mu) V'(y(s)) \]

With a risk-averse firm variations in real profits need to be taken into account.

Suppose states are ordered from the lowest to the highest relative price. Then comparing adjacent states (for \( s = 1, \ldots, S-1 \))

\[ (10) \quad [U'(w+dw) - U'(w)]/U'(w) = [V'(y+dy) - V'(y)]/V'(y) \]

where \( dw = w(s+1) - w(s) \) and \( dy = y(s+1) - y(s) \). Define

\[ r_w = - \frac{[U'(w+dw)-U'(w)]/[U'(w)dw]}{[V'(y+dy)-V'(y)]/[V'(y)dy]} \]

as the absolute risk aversion of workers and the firm, respectively. These are discrete state counterparts to \(-U''/U'\) and \(-V''/V'\), the usual measures of absolute risk aversion at particular values of \( w \) and \( y \). It then follows from these definitions and from (10) that

\[ (11) \quad dw = (r_f/r_w) \frac{dy}{\frac{dy}{dp}} dp \]

and since the key exogeneous variable from state to state is the relative price:

\[ (11') \quad dw = (r_f/r_w) \frac{dy}{dp} dp \]

where \( dp = p(s+1) - p(s) \).

As in case 3, the risk-averse firm has something to gain by adjusting wages at least to some extent in response to variations in the firm's relative price. It can cut down the variations in its profits by paying lower wages when its selling price is depressed and higher wages when its selling price is higher. Since real profits are higher with a higher relative price (\( dy/dp > 0 \)), the extent to which real wages are adjusted in response to differences in relative prices depends on the risk averseness of firms relative to the risk averseness of workers. If \( r_f \) is very small relative to \( r_w \), then there will be little change in real wages as relative prices vary.

Shavell (1976) has developed a similar formula. State-contingent real
incomes are given exogenously and one party, say V, chooses a payment to a second party U to maximize V's utility subject to holding U's utility constant. In the case in which both parties have the same perceptions about the probability of each state occurring and U's outside income does not vary, Shavell's result can be written:

\[ w'(s) = Y'(s) \frac{r_f}{r_f + r_w}. \]

Our equation (11) would look the same if \( Y' = dy + dw \) denoted the total revenue that the firm had to divide between itself and the workers in going from one state to another and \( dw = w' \) were the change in the total wage bill.

Blinder (1977) utilizes Shavell's formula to make the following suggestion: "Firms which tend to do well in inflation \([Y'(s) > 0]\) will be eager to give generous escalators as a form of insurance to workers - in return for lower mean wages. Conversely, and for the same reasons, firms which tend to fare poorly in inflation \([Y'(s) < 0]\) will be reluctant to escalate wages very much, even though that implies higher mean wage costs."

Blinder is implicitly assuming that what indexation there is will be to changes in the aggregate price. If a firm's price moves with the aggregate price so that its relative price does not change, then such firms even if they are highly risk averse will keep real wages constant. Our analysis, introducing relative prices explicitly, indicates that, whether or not real profits move with aggregate prices, risk averse firms will tend to increase real wages when their own relative prices (and hence real profits) are higher. The extent of such wage adjustments, as we noted above, depends on risk aversion of the firm relative to that of workers.

Weitzman (1985) has stressed the desirable implications of greater profit sharing. The fact that it is not more widespread suggests, within the structure of our model, that firms are not very risk averse relative to workers.
Now consider Card's "puzzle as to the nearly universal practice of escalation to the CPI." If workers are very risk averse relative to firms ($r_f/r_w$ close to zero) and if firms are not concerned with acquiring their own product, then our analysis provides a ready answer to the puzzle. The only gain to the firm from reducing workers' risk is in moderating fluctuations in the workers' real wage and hence indexing primarily to the price of the bundle of goods that workers buy.


As financial markets become less regulated and exchange rates fluctuate more, economies may experience greater variations in relative prices. What does this model have to say about the possible contingent employment effects of greater price dispersion?

The relevance of the real implications of this model are somewhat more controversial than the implied indexing rules analyzed in the preceding section. By assumption, workers are able to enforce the constraint that the firm must provide an expected utility of $U^*$ (which implies some labor mobility to other firms, or some other market power such as a strike threat, at the time the contract is being set). At the same time, the firm offers a contract to a set number of workers as if the firm will be unable to obtain any additional workers, if desired, once the state is known (which implies some immobility of labor to the firm until a new contract is negotiated). Nevertheless, if firms feel compelled to be competitive in the labor market, or to meet some externally imposed expected utility for workers, and there are specific skills that cannot be obtained immediately from workers laid off elsewhere, then it is worth exploring the question of the real impacts of greater price dispersion within this sort of model.

To address the question, we return to case 1 in Section 2, with risk
neutral firms and with a common deflator \( P_f(s) = P_w(s) \). Since we know that the real wage, denoted by \( w \), will be the same across states, any employment effects will occur because of different relative prices. To simplify the analysis, we consider only two states. Let state 2 be the good state and state 1 the bad state in that \( p(2) = P_f(2)/P_w(2) \), the firm's relative price in state 2, is greater than \( p(1) \), the firm's relative price in state 1. There is no essential loss in assuming that \( \pi(1) = \pi(2) = 1/2 \).

We shall analyze two situations separately. The first, which closely parallels the formulation by McDonald (1986), ignores any direct variable costs to the firm of changing the number of its workers on layoff. The second assumes that payments by the firm to its unemployed workers is a part of the contract.

Without variable costs for unemployment compensation. When \( c(s) \) is zero and the real wage is the same across both states, the first-order conditions in Table 1 can be simplified by first using equation (6) to note that \( \mu = n(2)/U'(w) \). This in turn can be used to eliminate \( \mu \) from equations (4c) and (4d). The first order conditions can then be written:

\[
\begin{align*}
(12a) \quad f'(n(1)) &= \frac{w - [U(w) - U(k)]/U'(w) + \lambda(1)]}{p(1)}. \\
(12b) \quad f'(n(2)) &= \frac{w + [n(1)/n(2)][U(w) - U(k)]/U'(w) - \lambda(1)]}{p(2)}. \\
(12c) \quad [n(1)/n(2)]U(w) + [1 - n(1)/n(2)]U(k) + U(w) - 2U* &= 0. \\
(12d) \quad \lambda(1)[n(2) - n(1)] &= 0.
\end{align*}
\]

We want to solve these equations for \( w, \lambda(1), n(1), n(2) \) and hence also for \( n(1)/n(2) \). Assume for the moment that the solution calls for \( n(2) \) strictly greater than \( n(1) \). If that is the case, then \( \lambda(1) = 0 \). (We shall examine shortly the condition for this to be true.)

Equation (12b) indicates that, before the state is known, the firm would want to have available fewer workers than the number at which the marginal pro-
duct would equal the product wage \( w/p(2) \) once state 2 has occurred. This is because the firm will have layoffs if state 1 occurs. With its assumed labor market constraint, the firm would have to promise a higher real wage if it increased the probability of layoff in state 1. Thus, the cost of a contingent contract for an extra worker is in excess of the real wage \( w \). The effect of this is shown in Figure 1 with \( n(2) \) to the left of the employment \( n \) at which \( f'(n) = w/p(2) \).

Similarly, equation (12a) indicates that planned employment in state 1 is in excess of the number of workers at which the marginal product would equal the product wage. An increase in planned \( n(1) \) implies a smaller probability of layoff if state 1 occurs, so the marginal cost of a contingent expansion of \( n(1) \) is less than \( w/p(1) \). The effect of this too is depicted in Figure 1.

It is not necessarily true that \( n(2) \) will be greater than \( n(1) \). Azariadis (1975) has presented in general terms a necessary and sufficient condition for layoffs to occur, and McDonald (1986) provides numerical calculations of critical price ratios \( p(1)/p(2) \) for layoffs in this two-state model. Basically the idea is that if the term \( [U(w) - U(k)]/U'(w) \) in equations (12a) and (12b) is too large in relation to the relative price dispersion, then \( n(1) = n(2) \) and the shadow price \( \lambda(1) \) is positive.

To get the critical price ratio at which \( n(1) \) and \( n(2) \) are just equal, set \( f'(n(1)) \) in equation (12a) equal to \( f'(n(2)) \) in (12b), let \( n(1)/n(2) = 1 \) and \( \lambda(1) = 0 \). Solving for the price ratio \( p(2)/p(1) \), we find:

\[
(13) \quad p(2)/p(1) = (1 + X)/(1 - X)
\]

where

\[
X = [U(w) - U(k)]/[wU'(w)]
\]

McDonald assumes \( U(w) = w^{1-a}/(1-a) \), so that \( a \) is the degree of constant relative risk aversion. In that case \( X \) becomes \( (1 - r^{1-a})/(1-a) \), and \( r = k/w \) is
his "replacement ratio" of income when unemployed (or its equivalent in leisure) to the wage income when employed. The numbers in his Table 1 come from the inverse of this formula in that he computes $P(1)/P(2)$. He argues that the price dispersion necessary for a solution with layoffs is implausibly large. He suggests instead introducing a sales constraint into this sort of model to account for the existence of layoffs.

We can show that McDonald's results are not dependent on the particular functional form that he utilizes. Note by multiplying numerator and denominator by $w-k$ that $X$ can be written:

$$X = [(w-k)/w][(U(w) - U(k))/(w-k)U'(w)]$$

As is apparent in Figure 2, the ratio $[U(w) - U(k)]/(w-k)U'(w)$ is greater than one for any strictly concave utility function. Furthermore, given the utility function, the ratio is larger the greater the distance from $w$ to $k$; and for given $w$, $k$ and $U'(w)$, the ratio is larger the greater the curvature in $U$, i.e., the greater is $U(w) - U(k)$. If workers are almost risk neutral so that $U$ is close to linear in $w$, the ratio approaches one as a lower limit.

Thus, $X > (w-k)/w$. This implies that the critical price ratio satisfies the following inequality:

$$(13') \quad p(2)/p(1) > (2w-k)/k.$$  

The greater the curvature of the workers' utility function, the greater the critical price ratio relative to $(2w-k)/k$.

If $k$ is very close to $w$, in which case the workers are almost as well off when unemployed as when employed, then it would not take much price dispersion to call for layoffs in the bad state. In other words, workers will be readily laid off if they do not mind being laid off. But if $k$ is small relative to $w$, even with little risk averseness on the part of the workers, there would need to be substantial relative price dispersion for layoffs to be in the contract. For example, if $k$ is half of $w$, then $p(2)$ must be more than three times as large as
p(1) in order for the firm and workers to agree to a contingent contract with layoffs.

With explicit costs to the firm for its workers on layoff. If what the firm pays to its workers when they are on layoff is part of the contract, then, as noted in Section 2, \( k + c(s) = w(s) \). The risk-averse workers will be insured against the contingency of being laid off if state 1 occurs and so are indifferent between working and being laid off. This does not mean, however, that layoffs will now be sensitive to small variations in relative prices across states. The reason is that the firm now has to bear the costs of unproductive labor when it lays workers off.

To see the argument more formally, note that the term \( U(k+c(s)) - U(w(s)) \) is zero in the first-order conditions (4c) and (4d). In the two-state model with risk-neutral firms and a common deflator for wages and profits, the first order conditions now reduce to

\[
\begin{align*}
(14a) \quad f'(n(1)) &= \frac{w - c + \lambda(1)}{p(1)}. \\
(14b) \quad f'(n(2)) &= \frac{w + c - \lambda(1)}{p(2)}. \\
(14c) \quad [n(1)/n(2)]U(w) + [1 - n(1)/n(2)]U(k+c) + U(w) - 2U(w^*) &= 0. \\
(14d) \quad \lambda(1)[n(2)-n(1)] &= 0.
\end{align*}
\]

where \( c \) is the real compensation paid by the firm to its unemployed workers.

Since \( w = k+c \), we can see from equation (14c) that \( w = w^* \). The firm will provide real compensation so that its workers, whether working or laid off, receive the compensation that makes them as well off as receiving the wage for full-time employment elsewhere.

As before, we can get the critical price ratio at which employment will still be the same in both states and \( \lambda(1) = 0 \). From (14b) and (14c) this critical price ratio is given by
(15) \[ \frac{p(2)}{p(1)} = \frac{(w+c)}{(w-c)} = \frac{(2w-k)}{k}. \]

Note the similarity to the situation analyzed above in which \( c = 0 \). In that case the critical price ratio is greater than in (15) because of the risk averseness of workers but its lower bound is essentially the same as in this case in which the firm pays direct unemployment compensation as part of the contract. Thus, unless workers are at least as well off when unemployed without direct compensation from the firm laying them off as they are when employed, there will need to be a substantial relative price variability before this model calls for layoffs.

Sales constraints as suggested by McDonald may therefore be an important modification of this contract approach. In exploring the present model, however, we shall proceed along the following line. If this model calls for the existence of layoffs (when workers are relatively well off while laid off), how would an increase in relative price dispersion affect the probability of layoff and hence, if the laid-off workers are unable to find immediate alternative employment, how would the unemployment rate be affected by greater relative price dispersion?

The results of this analysis are similar whether or not the firm assumes responsibility to reimburse its workers on layoff. Since the analysis is much simpler assuming that the firm does insure its workers against the contingency of being laid off, we shall present that here. The analysis assuming that \( c = 0 \) is contained in extensive notes available from either author on request.
Real impact of greater relative price dispersion. If \( p(2)/p(1) \) is greater than the critical ratio given by equation \((15)\), then \( n(2) \) will be greater than \( n(1) \) and by condition \((14d)\), \( \lambda(1) \) will equal zero. We also know that \( w = w^* \) and \( c = w^* - k \). We can then rewrite equations \((14a)\) and \((14b)\) as:

\[
\begin{align*}
(16a) \quad f'(n(1)) &= k/p(1) \\
(16b) \quad f'(n(2)) &= (2w^* - k)/p(2).
\end{align*}
\]

The effects that different values of \( w^* \), \( k \), \( p(1) \) and \( p(2) \) will have on \( n(1) \), \( n(2) \) and the probability of employment \( n(1)/n(2) \) can be readily verified from these equations.

If \( k \), the real-wage-equivalent value to the worker of being unemployed without any direct compensation from the firm, is higher, the firm will respond by lowering \( n(1) \), because of the assumed diminishing marginal product of labor, and increasing \( n(2) \). This generates the following generally accepted proposition. If there is a rise in unemployment compensation that is not charged to the firm in proportion to its layoffs, then the probability of layoffs will increase.

If \( w^* \), the opportunity cost of employment with the firm rises, the firm responds by paying a higher wage to its employees and lowering \( n(2) \), its number of workers. This means that \( n(1)/n(2) \) rises. So a better overall labor market results in the individual firm not only raising its wage but also lowering the probability that an individual worker will be laid off.

Now suppose there is greater relative price dispersion in that there is a higher \( p(2) \) and a lower \( p(1) \). The individual firm responds by raising \( n(2) \) and lowering \( n(1) \). Thus, for firms that do have expected layoffs, greater relative price dispersion raises the demand for labor \([\text{higher } n(2)]\) and raises the probability that a worker will be laid off \([\text{higher } 1 - n(1)/n(2)]\).

What are the economy-wide effects of increased relative price dispersion? An answer involves several steps. For some and perhaps most firms there would
be no direct effect on their employment plans. Other firms, with sufficient expected price dispersion, will plan to have more layoffs if they draw their low relative price. We then need to examine the effect on the overall demand for labor. If the overall demand for labor is increased, market-clearing in the labor market will call for a higher real wage and that, as noted above, tends to reduce the probability of layoffs. We need to be sure that this secondary effect cannot outweigh the initial effect of greater price dispersion.

Let $F$ be the total number of firms and $N$ be the total number of perfectly inelastically supplied workers. Also let $n_i(2)$ denote the labor force of firm $i$. Assume that $w^*$ is determined by the following labor market clearing condition.

$$\sum_{i=1}^{F} n_i(2) = N.$$  \hfill (17)

From equation (16b), it can be seen that $n_i(2)$ for each firm, and hence the left side of (17), is a decreasing function of $w^*$.

Suppose the economy starts with every worker in the labor force having a contract with one firm. When the states are actually drawn, some firms have their high relative price and others have their low relative price. If half of those with $n_i(2) > n_i(1)$ find themselves in state 1, then those are the firms that have layoffs.

Now suppose that each firm $i$ faces a greater potential dispersion of its relative price. In terms of our two-state model, this means that $p_i(2)$ is higher and $p_i(1)$ is lower for firm $i$. For those firms which are not planning layoffs when $p_i(1)$ occurs, there would be no change in planned employment if the increase in $p_i(2)$ were the same size as the decrease in $p_i(1)$.

For firms planning layoffs when $p_i(1)$ occurs, the increase in $p_i(2)$ calls for an increase in $n_i(2)$ and hence, to the extent that there are such firms, the overall demand for labor will rise. To ration the available supply of labor,
the market wage $w^*$ must rise.

Let $\alpha$ be the fraction of firms that will have layoffs in their bad state. Also let $dp_1(2) = -dp_1(1) > 0$ for all firms. If $\alpha = 1$, all firms increase $n_1(2)$ and decrease $n_1(1)$. Then $w^*$ must rise until the total of the $n_1(2)$ is back where it was, but since the $n_1(1)$ are lower, the average unemployment rate will be higher.

If $\alpha < 1$, then $\alpha F$ firms will plan employment changes. They plan an increase in $n_1(2)$ and a decrease in $n_1(1)$. The increase in their $n_1(2)$ raises the total demand for labor and calls for an increase in $w^*$ until (17) is once again satisfied. A higher $w^*$ will decrease desired $n_1(2)$ for both types of firms. As a result the firms with planned layoffs do not go back to their original $n_1(2)$. The probability of unemployment among workers with these firms is still unambiguously increased by the greater anticipated price dispersion since $n_1(2)$ is higher and $n_1(1)$ is lower. Thus as long as some firms are planning contingent layoffs, this model predicts that increased price dispersion will result in higher average unemployment rates.

Friedman (1977) in his Nobel Lecture suggests the possibility of a positively sloped long-run Phillips curve. He argues (p. 466) that there is a "tendency for inflation that is high on the average to be highly variable ..." He also writes (p. 470): "The growing volatility of inflation and the growing departure of relative prices from the values that market forces alone would set combine to render the economic system less efficient, to introduce friction in all markets, and, very likely, to raise the recorded rate of unemployment."

Empirical studies by Levi and Makin (1982) and Holland (1986) have been supportive of Friedman's contention that higher aggregate price variability reduces levels of real economic activity.

It has been found by Vining and Elwertowski (1976), Parks (1978) and Fis-
cher (1982), among others, that relative price variability is also often positively associated with the level of inflation and with aggregate price variability. Furthermore, Blejer and Leiderman (1980) have shown empirically that increases in the variability of relative prices have been associated with reductions in aggregate real output and increases in the rate of unemployment.

This last result is what our model predicts (if there is enough relative price dispersion for some firms to plan on layoffs) and we do not need to resort to claims about a reduction in economic efficiency. Our firms are responding "efficiently" to the relative price signals they receive by planning to have more unemployment on average among their workers when the range of possible relative prices increases. An early recognition of the potential effect of greater price dispersion was by Azariadis (1975, p. 1194): "Layoffs should be more frequent in industries with relatively volatile ... demand schedules." We have argued that this effect extends to an economy-wide impact on the average rate of unemployment despite offsetting real wage adjustments, although the quantitative importance of the effect remains debatable.

4. Summary and Conclusions.

An implicit contract model has been used to determine the extent of wage indexation for a firm and its employees when they are faced with different fluctuations in both local and aggregate prices. An examination of a variety of cases helps to answer Card's puzzle about the almost universal practice of firms indexing to the CPI. If a firm is not very risk averse relative to workers and is not interested in acquiring its own output, then there is no incentive within our model for them to offer contracts that index to firm or industry-specific prices. These results hold whether or not the optimal solution calls for expected layoffs.

Note also that our result does not require asymmetric information. It may
be that firms have better information than workers about product prices and that this could contribute to indexation to a well-publicized aggregate price index, such as the CPI, but this is not a necessary rationale. Since, even with full symmetric information about all prices, the optimal contract in cases 1 and 2 calls for indexation only to the aggregate price, there is no incentive for workers without full information about their firm's selling prices to develop ways of getting such information.

Grossman, Hart and Maskin (1983) deal with the effects of increased relative price dispersion when firms but not the workers can observe the local price. They find that an interindustry shift in demand that would have no effect on total employment under symmetric information leads to a reduction in employment when firms and workers have asymmetric information. We find that even under symmetric information, an increase in the dispersion of output price variations that does not alter the total demand for labor among firms not planning layoffs will result in a higher unemployment rate if some firms do expect layoffs. Policies which bring about a permanent increase in the dispersion of relative prices would then bring about a higher "natural" rate of unemployment.
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1 Some authors advocate schemes that involve indexing wages to more than just prices. Pazner (1981) argues that it is better to index nominal wages fully to prices and partially to real income. This provides insulation of the real sector from nominal shocks and minimizes the impact of real shocks. Karni (1983) demonstrates that such a policy will dominate one of indexing only to prices. Barro (1977) considers a contract scheme that will bring about an "ex post" equilibrium in the labor market. As Fischer (1977a) and Cukierman (1980) note, however, such schemes are not, as a rule, found in the "real world."

2 Consider a utility function with constant relative risk aversion

$$U(W/P) = a - b(W/P)^{-R+1}$$

so that from (7):

$$b(R-1) = (n/\mu)P^{-R+1}.$$  

To find the effect on W of an arbitrarily small change in P in going from one state toward another, differentiate this expression and collect terms with the result that

$$\frac{dW}{W} = \left(\frac{R-1}{R}\right) \frac{dP}{P}.$$  

Thus, with R>1, W moves with P but in less than full proportion.

3 In a provocative article, Akerlof and Miyasaki (1980) argue that the assumption of ex post immobility of risk-averse labor allows the firm to lower its wage bill by giving workers a fixed employment as well as a fixed wage contract. However, they do not consider, with diminishing marginal product of labor, how the firm may gain expected profits by being able to vary employment in response to different relative prices. The firm may be willing to pay a higher real wage to have this flexibility. In effect, Akerlof and Miyasaki are allowing the bargaining to be reopened after the state has been observed and before the layoff decisions have been made.

4 For these firms, $n(1) = n(2) = n$. From (14a) and (14b),

$$p(1) = k + \lambda$$
$$p(2) = 2\mu - k - \lambda.$$  

Differentiating,

$$f'dp(1) + p(1)f''dn = d\lambda$$
$$f'dp(2) + p(2)f''dn = -d\lambda.$$  

Eliminating $d\lambda$ and collecting terms,

$$[p(1) + p(2)](-f'')dn = f'[dp(1) + dp(2)]$$  

It follows, if $dp(1) = -dp(2)$, that $dn = 0$. 

Figure 1
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