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Nominal Price and Wage Interactions

Torben M. ANDERSEN*

ABSTRACT. – The interaction between price and wage setting is considered in a model with monopolistically competitive product markets and unionized labour markets. It is shown how differential information can cause nominal rigidities which are amplified by the wage-price interactions arising due to strategic complementarity in price and wage setting. Nominal wages may be less flexible than nominal product prices even when there are no informational asymmetries between price and wage decisions.

Interactions de prix et salaires nominales

RÉSUMÉ. – Nous considérons l'interaction entre formation de prix et salaires dans un modèle avec des marchés de produits monopolisés compétitifs et des marchés du travail syndiqués. Nous avons montré comment une information différentielle peut causer des rigidités nominales, qui sont amplifiées par les interactions prix-salaire qui se présentent par suite de complémentarité dans la formation de prix et des salaires. Des salaires nominals peuvent être moins flexibles que des prix nominals de produits, même quand il n'y a pas d'asymmétrie d'information entre les décisions de prix et salaires.

* T. M. ANDERSEN: Department of Economics, University of Aarhus. Comments and suggestions from participants and in particular the discussant Jacques le Cacheux at the conference "Recent Developments in the Macroeconomics of Imperfect Competition", Paris, January 1994 and an anonymous referee are gratefully acknowledged. This paper is based on Chapter 8 in ANDERSEN [1994].

1 Introduction

The failure of nominal prices and wages to adjust instantaneously is crucial to a number of macroeconomic phenomena. Although reasons for price rigidities have recently been extensively explored, most analysis have been confined to either prices or wages [1]. Although a natural starting-point, it leaves open whether the rigidities would also arise when the interaction between price and wage setting is taken into account, and in particular whether nominal shocks can affect real wages and thus employment.

The present paper addresses these issues within a setting of imperfectly competitive product and labour markets. The model is set up in such a way that it encompasses the possible sources of interdependencies between prices and wages. Due to the decentralized nature of the economy, information is dispersed, and this leads to a setting with differential information and thus heterogeneous expectations which cause nominal inertia in both price and wage adjustment. Moreover, it is shown that nominal prices and wages need not be equally responsive to nominal shocks even though there are no systematic differences in the information going into price and wage setting.

A key result of the recent literature on price and wage adjustment is that strategic complementarities are crucial in explaining rigidities (see ANDERSEN [1994]). These complementarities arise from the mutual interdependencies between prices and wages and can thus in the present setting be interpreted as reflecting the strength of the price-wage spiral. Although starting from another perspective the present analysis thus brings forth aspects found in previous ad hoc analyses of the price-wage spiral.

The paper is organized such that the basic price and wage setting model is setup in Section 2. Section 3 considers the basic interdependencies between prices and wages under full information to provide the background for the analysis of differential information and price and wage adjustment in Section 4. A few concluding remarks are given in Section 5.

2 Price and Wage Setting

To analyse the interaction between wage and price determination, we need to distinguish explicitly between product and labour markets. The structure of the product market follows recent models of menu cost and

1. A notable exception is BLANCHARD [1986] who generates nominal rigidities by asynchronized wage and price decisions implying that the real wage follows a saw toothed adjustment path to a nominal shock. The latter is empirically implausible.

staggered price-setting, (cf. BALL, MANKIW and ROMER [1988] and BALL and ROMER [1989]), while the labour market follows recent models with wage bargaining (cf. MOENE *et al.* [1993]).

Consider a right-to-manage structure where unions set wages subsequent to which firms decide on prices and thereby employment. The economy is separated in a continuum of markets indexed by j, where $j \in [0, 1]$. For each market j, there is one supplier of goods of type j which are produced by use of type j labour organised by the union in market j.

We start out by considering the product markets. There is one supplier for each type of good and the demand faced by this firm is given as

$$d^j = \left(\frac{P}{P^j}\right)^{\alpha}\left(\frac{M}{P}\right) \qquad \alpha > 1.$$

P is the aggregate price level defined as

$$\ln P = \int_0^1 \ln P^j \, dj$$

and M is an indicator of nominal demand (the money stock).

Demand depends thus on the relative price of the goods as well as the aggregate level of demand given by real balances.

The firm produces output by use of labour as the variable input factor according to the following production function

$$y^i = \frac{1}{\gamma}\,(l^j)^{\gamma} \qquad 0 < \gamma < 1.$$

Accordingly, the optimal price to quote for firm j is

$$\ln P^j = \pi_0 + \pi_1 \ln W^j + \pi_2 \ln P + \pi_3 \ln M \tag{1}$$

where

$$\pi_0 = \ln \gamma \left(\frac{\alpha}{\alpha - 1}\right) \pi_1$$

$$\pi_1 = \left(1 + \alpha\left(\frac{1}{\gamma} - 1\right)\right)^{-1} > 0$$

$$\pi_2 = \left(\alpha - \frac{1}{\alpha}\right)\left(\frac{1}{\gamma} - 1\right)\pi_1 > 0$$

$$\pi_3 = \left(\frac{1}{\gamma} - 1\right)\pi_1 > 0.$$

The homogeneity property is fulfilled as

$$\pi_1 + \pi_2 + \pi_3 = 1.$$

Demand for labour by the firm can be written

$$l^j = l\left(\frac{W^j}{P}, \frac{M}{P}\right). \tag{2}$$

Assume that all workers in market j supplying this particular type of labour are organized in a union with an objective function given as

$$V\,(W^j/P,\, W^j/W,\, l^j)$$

depending on the real wage, the wage relative to aggregate wages and employment. The second channel reflects the relative wage hypothesis (see e.g. GYLFASON and LINDBECK [1984]), but the same qualitative results would arise if we allow for substitution between different types of labour in production (see MOENE *et al*. [1993]).

The union perceives that employment is determined according to (2) and hence the aim is to choose a wage W^j so as to maximize

$$V(W^j/P,\, W^j/W,\, 1\,(W^j/P,\, M/P)) = \hat{V}\,(W^j/P,\, W^j/W,\, M/P).$$

Yielding the first order condition

$$\frac{1}{P}\,\hat{V}_1 + \frac{1}{W}\,\hat{V}_2 = 0. \tag{3}$$

Solving this problem, we can express the optimal wage by the following implicit function

$$W^j = W^j\,(P,\, W,\, M).$$

The wage function fulfils the homogeneity property, *i.e.*

$$\lambda\, W^j = W^j\,(\lambda\, P,\, \lambda\, W,\, \lambda\, M) \qquad \forall\, \lambda > 0$$

as is easily seen by noting that if W^{j*} is the optimal wage for P^*, W^*, and M^*, cf. (3), then $\lambda\, W^{j*}$ would be optimal for $\lambda\, P^*$, $\lambda\, W^*$, and $\lambda\, M^*$ for any $\lambda > 0$.

Making a log-linear approximation, the wage equation can be written

$$\ln W^j = \delta_0 + \delta_1 \ln P + \delta_2 \ln W + \delta_3 \ln M \tag{4}$$

where [2]

$$\delta_1 + \delta_2 + \delta_3 = 1, \quad \delta_1 > 0, \quad \delta_2 > 0, \quad \delta_3 > 0,$$

reflecting that homogeneity properties are fulfilled.

3 Price-Wage Multipliers

We can summarize the model by the following sectoral price and wage equations

$$\ln P^j = \pi_0 + \pi_1 \ln W^j + \pi_2 \ln P + \pi_3 \ln M$$

$$\ln W^j = \delta_0 + \delta_1 \ln P^j + \delta_3 \ln W + \delta_3 \ln M.$$

Considering the wage-price model, we find four different sources of interdependence. In the price equation (1) there is a strategic

2. The sign of δ_2 is in general ambiguous, see e.g. GYLFASON and LINDBECK [1984].

complementarity from both the wage rate (π_1) and the aggregate price (π_2) to the price quoted by each firm, similarly there is strategic complementarity between aggregate prices (δ_1) and wages (δ_2) in the sector specific wage rate (4). By endogenizing wage formation, we find that we have strategic complementarities in four dimensions: price-price, wage-wage, price-wage and wage-price. This is important since strategic complementarities are crucial to many issues related to price adjustment (ANDERSEN [1994]), and we thus get three new channels of complementarity on top of the one arising in the partial model of price formation.

In a symmetric equilibrium $(P^j = P \,\forall\, j$, and $W^j = W \,\forall\, j)$, we find that aggregate prices and wages can be written as

$$\ln P = \frac{1}{1-\pi_2}\left(\pi_0 + \pi_1 \ln W + \pi_3 \ln M\right) \tag{5}$$

$$\ln W = \frac{1}{1-\delta_2}\left(\delta_0 + \delta_1 \ln P + \delta_3 \ln M\right). \tag{6}$$

Equations (5) and (6) can be interpreted as semi-reduced form price and wage equations giving prices as depending on wages and vice versa. The terms $\frac{1}{1-\pi_2}$ and $\frac{1}{1-\delta_2}$ reflect partial multipliers arising from the price-price and wage-wage interactions, *i.e.*

$$\left.\frac{\partial \ln P}{\partial \pi_0}\right|_{\ln W} = \frac{1}{1-\pi_2} > 1$$

and

$$\left.\frac{\partial \ln W}{\partial \delta_0}\right|_{\ln P} = \frac{1}{1-\delta_2} > 1.$$

Equations (5) and (6) bring out the interdependence between prices and wages which is also illustrated in figure 1. Solving the wage-price model explicitly, we find

$$\ln P = \left(1 - \pi_2 - \pi_1 \frac{\delta_1}{1-\delta_2}\right)^{-1} \times \left(\pi_0 + \delta_0 \frac{\pi_1}{1-\delta_2} + \left(\pi_3 + \frac{\pi_1}{1-\delta_2}\,\delta_3\right) \ln M\right)$$

$$\ln W = \left(1 - \delta_2 - \delta_1 \frac{\pi_1}{1-\pi_2}\right)^{-1} \times \left(\delta_0 + \pi_0 \frac{\delta_1}{1-\pi_0} + \left(\delta_3 + \frac{\delta_1}{1-\pi_2}\,\pi_3\right) \ln M\right).$$

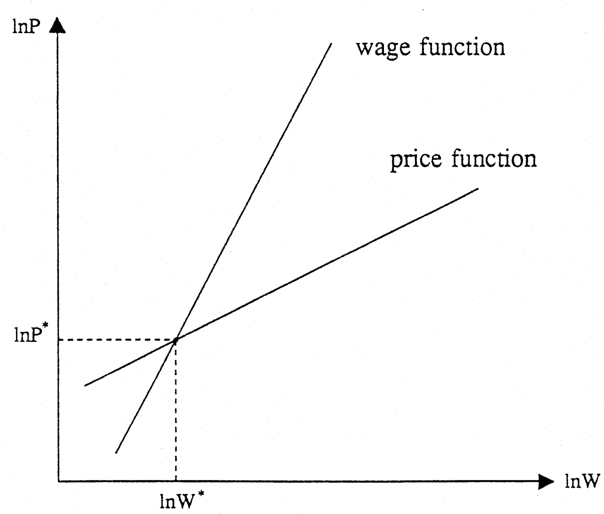

FIGURE 1

Price-Wage Interactions.

Obviously, the interdependence between wages and prices implies a wage-price spiral or multiplier effect; a price increase leads to wage increases which in turn leads to price increases, etc., and vice versa for wages.

We have that

$$\frac{\partial \ln P}{\partial \pi_0} = M_P^* = \frac{1}{1 - \pi_2 - \pi_1 \dfrac{\delta_1}{1-\delta_2}} > 1$$

and for wages

$$\frac{\partial \ln W}{\partial \delta_0} = M_W^* = \frac{1}{1 - \delta_2 - \delta_1 \dfrac{\pi_1}{1-\pi_2}} > 1.$$

It is noted that both multipliers depend on the four parameters capturing the strategic complementarities involved in the price-wage interactions. A strengthening of any of the four sources of strategic complementarities leads to a larger multiplier in both prices and wages.

Comparing the two multipliers, it is readily shown that

$$\frac{M_P^*}{M_W^*} = \frac{1-\delta_2}{1-\pi_2}$$

and hence

$$M_P^* \gtreqless M_W^* \qquad \text{for} \quad \pi_2 \gtreqless \delta_2.$$

The multipliers differ unless the "cross" complementarities are equal $(\delta_2 = \pi_2)$, and the multiplier is largest where the "cross" complementarity is the strongest. The intuition is that the larger π_2 the less prices depend on wages and the level of demand and the stronger will a push to prices be reinforced in the price-price interactions, and similarly for wages. The different multipliers suggest that the response of nominal wages and nominal prices may differ – an issue which is extensively analysed below.

The effect of a change in nominal income on equilibrium prices and wages can now be found. The initial effect is to change the position of both the wage and the price function. From (5) we find that the immediate effect on prices for given wages is less than one-to-one, and the same is seen from (6) to apply for wages given prices. The price-wage spill-overs or interactions imply, however, that the end result is a change in wages and prices proportional to the change in nominal income, cf. figure 2, that is, relative prices and other real variables are not affected by a change in nominal income, *i.e.*

$$\frac{\partial \ln P}{\partial \ln M} = \left(\pi_3 + \frac{\pi_1}{1-\delta_2}\,\delta_3\right) M_P^* = 1$$

$$\frac{\partial \ln W}{\partial \ln M} = \left(\delta_3 + \frac{\delta_1}{1-\pi_2}\,\pi_3\right) M_W^* = 1.$$

This reflects, of course, the homogeneity properties of the model, and the fact that we have not introduced any mechanisms generating nominal rigidities, hence nominal changes affect only nominal prices and wages, and not real variables.

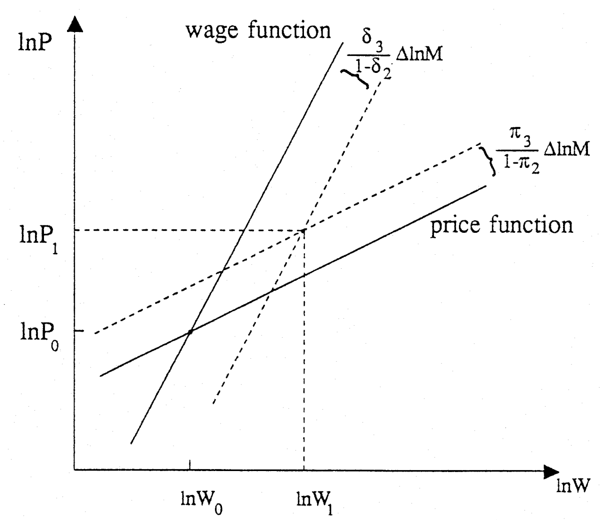

FIGURE 2

Adjustment to a Change in Nominal Income.

4 Nomical Price and Wage Rigidities

The strengthening of strategic complementarities by allowing for an explitic interdependence between wage- and price-setting suggests that previous results on nominal rigidities are also strengthened since they rely heavily on the presence of such complementarities, see ANDERSEN [1994]. This is shown to be the case by introducing informational problems. It is also of interest to question the extent to which nominal wages and prices adjust equally to nominal changes. If this is the case, real wages are unaffected by nominal shocks despite nominal price and wage rigidities.

It is assumed that local wages are set without knowledge of other wages, prices or demand. Local prices – cf. the right to manage structure – are set given knowledge of local wages, but other output prices and the level of demand are not known. Price- and wage-setters have thus to act upon the expected values of the unknown variables at the time of price and wage setting [3].

The optimal price can under the assumption of risk-neutral firms and log-normally distributed random variables be written (see ANDERSEN [1985a])

$$\ln P^j = \pi_1 \ln W^j + \pi_2\, E\,(\ln P \,|\, I^j) + \pi_3\, E\,(\ln M \,|\, I^j) \tag{7}$$

where

$$\pi_1 + \pi_2 + \pi_3 = 1.$$

For convenience, all constants are suppressed. Obviously, nothing qualitatively is lost by this procedure, and all variables can be interpreted as being measured in deviations from long-run.

Similarly the wage function can be written (see ANDERSEN and SØRENSEN [1988])

$$\ln W^j = \delta_1\, E\,(\ln P \,|I^j) + \delta_2\, E\,(\ln W \,|I^j) + \delta_3\, E\,(\ln M \,|I^j) \tag{8}$$

where

$$\delta_2 + \delta_2 + \delta_3 = 1.$$

The only state variable is nominal income since we focus on nominal price and wage adjustment. We shall now specify the information set. In general, there is a vast number of reasons why firms possess differential information, say, due to market-specific knowledge, better knowledge of own characteristics than those of others, past experience, different intensities of information acquisition, etc. In this way an elaborate information structure could be constructed by assuming the information set of any agent to consist of public information in the form of information freely available to all agents and private information specific to the agent. Proceeding in this way, an infinite number of more or less sophisticated information structures can be constructed, but the reward from doing so is small, and we may as well proceed by making the simplest possible assumption which ensures that information is dispersed.

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3. The aim here is to study the adjustment to particular shocks, not the potential real effects of different information structures leading to different forms of uncertainty. See e.g. RANKIN [1994] for an analysis of the implications of monetary uncertainty in the presence of nominal rigidities.

The information available to agents in the local labour and goods market j on nominal income is summarized by the signal $s^j \in I^j$ given as

$$s^j = \ln M + v^j$$

where

$$\ln M \sim N(0,\, \sigma_M^2)$$

$$v^j \sim N(0,\, \sigma_v^2).$$

It is noted that a tiny information problem is considered in that agents have access to the true state variable except for some measurement or observational noise v^j. This noise makes agents imperfectly informated and implies different information across markets. It is assumed that the noise terms are uncorrelated across markets and vanish upon aggregation, *i.e.*

$$E\, v^j\, v^k = 0 \qquad j \neq k$$

$$\int_0^1 v^j\, dj = 0.$$

It follows that if the agents could pool their information, they would have full information. It is a characteristic of a decentralized economy that all information is not collected by an economy-wide agency.

The predicted value of nominal income given local information can thus be written

$$E(\ln M \mid s^j) = h(\ln M + v^j)$$

where

$$0 \leq h = \frac{\sigma_M^2}{\sigma_M^2 + \sigma_v^2} \leq 1.$$

The price-wage model is fairly complicated due to the mutual price and wage interdependencies. To find the equilibrium it is useful to use the undetermined coefficient method and we conjecture the following equilibrium price and wage functions

$$\ln P^j = \rho_1 (\ln M + v^j). \tag{9}$$

$$\ln W^j = \rho_2 (\ln M + v^j). \tag{10}$$

Aggregating over (9) and (10) we find

$$\ln P = \rho_1 \ln M$$

$$\ln W = \rho_2 \ln M.$$

The expected average prices and wages can now be written as

$$E(\ln P \mid I^j) = \rho_1\, h\, (\ln M + v^j)$$

$$E(\ln W \mid I^j) = \rho_2\, h\, (\ln M + v^j).$$

Using these expressions, we can write local prices and wages as

$$\ln P^j = (\pi_1\,\rho_2 + \pi_2\,\rho_1\,h + \pi_3\,h)\,(\ln M + v^j) \tag{11}$$

$$\ln W^j = (\delta_1\,\rho_1\,h + \delta_2\,\rho_2\,h + \delta_3\,h)\,(\ln M + v^j). \tag{12}$$

For (11) and (12) to be consistent with our initial conjectures (9) and (10) of the equilibrium price and wage functions, we require

$$\begin{aligned}\rho_1 &= \left[1 - \pi_2\,h - \pi_1\,\frac{\delta_1\,h}{1-\delta_2\,h}\right]^{-1}\left(\pi_1\,\frac{\delta_3\,h}{1-\delta_2\,h} + \pi_3\,h\right)\\ \rho_2 &= \left[1 - \delta_2\,h - \delta_1\,\frac{\pi_1\,h}{1-\pi_2\,h}\right]^{-1}\left(\delta_1\,\frac{\pi_3\,h^2}{1-\pi_2\,h} + \delta_3\,h\right).\end{aligned} \tag{13}$$

These coefficients give us the unique rational expectations equilibrium within the class of (log) linear wage and price functions (9) and (10).

Having found an equilibrium, we can turn to the implications of informational problems and the first thing to note is that the price and wage multipliers are recovered to be

$$M_P = \frac{1}{1 - \pi_2\,h - \pi_1\,\dfrac{\delta_1\,h}{1-\delta_2\,h}}$$

$$M_W = \frac{1}{1 - \delta_2\,h - \delta_1\,\dfrac{\pi_1\,h}{1-\pi_2\,h}}\,.$$

It follows that multiplier effects are muted under differential information as

$$M_P < M_P^*$$

$$M_W < M_W^*.$$

The intuition is that firms and unions under lack of information do not react to actual wages and prices but to their expected values and this makes the adjustment more cautious.

Turning to the effects nominal changes have on aggregate prices and wages, we find

$$\frac{\partial \ln P}{\partial \ln M} = \rho_1 < 1 \qquad \text{for} \quad h < 1$$

$$\frac{\partial \ln W}{\partial \ln M} = \rho_2 < 1 \qquad \text{for} \quad h < 1.$$

In the benchmark case of full information $(h = 1)$ we have that $\rho_1 = \rho_2 = 1$.

That is, as a result of differential information neither nominal wages nor nominal prices are fully flexible with respect to nominal changes.

Even though nominal wages and prices do not respond proportionally to actual nominal changes, it might be conjectured that they would respond proportionally to expected nominal changes since homogeneity properties are fulfilled. Defining

$$\bar{E} \ln M = \int_i E(\ln M \,|\, I^i)\, di = h \ln M$$

aggregate prices and wages can be written

$$\ln P = \rho_1\, h^{-1}\, \bar{E} \ln M$$

$$\ln W = \rho_2\, h^{-1}\, \bar{E} \ln M.$$

We shall show that $\rho_1 < h$ for $h < 1$ (a similar argument can be used to show that $\rho_2 < h$) which by use of (13) is equivalent to proving that

$$\pi_1 \frac{\delta_3}{1 - \delta_2 h} + \pi_3 < 1 - \pi_2 h - \pi_1 \frac{\delta_1 h}{1 - \delta_2 h}.$$

Using that $\pi_3 = 1 - \pi_2 - \pi_1$ and $\delta_3 = 1 - \delta_2 - \delta_1$ we get

$$(h-1)\, \pi_1 \frac{\delta_1 + \delta_2}{1 - \delta_2 h} < \pi_2 (1 - h).$$

which is fulfilled since $h < 1$ and $\delta_2 h < 1$.

Given that $\rho_1 < h$ and $\rho_2 < h$ for $h < 1$, it follows that even (on average) expected nominal changes are not reflected one-to-one in wages and prices.

To see the importance of strategic complementarities for nominal rigidity, consider the following experiment. Let π_1 change for given π_2 implying that π_3 has to adjust $(1 = \pi_1 + \pi_2 + \pi_3)$, in which case the price becomes more dependent on the wage relative to the nominal state variable. Similarly for δ_1 changing for given δ_2 the wage becomes more dependent on prices relative to the state variable. We have (see appendix)

$$\text{(14)} \qquad \begin{array}{l} \left.\dfrac{\partial \rho_1}{\partial \pi_1}\right|_{\pi_2 = \bar{\pi}_2} < 0 \qquad \left.\dfrac{\partial \rho_1}{\partial \delta_1}\right|_{\delta_2 = \bar{\delta}_2} < 0 \\ \text{and} \\ \left.\dfrac{\partial \rho_2}{\partial \pi_1}\right|_{\pi_2 = \bar{\pi}_2} < 0 \qquad \left.\dfrac{\partial \rho_2}{\partial \delta_1}\right|_{\delta_2 = \bar{\delta}_2} < 0. \end{array}$$

It can be concluded that a strengthening of strategic complementarity in price-wage interactions unambiguously makes both prices and wages less nominally flexible.

It may be questioned whether prices and wages are equally responsive to actual or expected changes in nominal income. This is the case under full information and since wage and price decisions are contingent on the same information, it is plausible to conjecture that this will also be the case under imperfect information. We find, however, that

$$\rho_1 \gtreqless \rho_2 \qquad \text{for} \quad \pi_3 \gtreqless \delta_3 (1 - \pi_1) \quad \text{if } 0 < h < 1.$$

Hence, nominal wages and prices are not in general equally responsive to nominal shocks even though wage and price formation is based on the same information.

To interpret the condition determining whether wages or prices are most responsive to nominal changes, it is useful to note that two effects are involved.

First, prices depend on actual wages whereas wages depend on expected (average) prices. This makes a difference since expected values of nominal variables are less responsive to the nominal changes than the actual variables $(h < 1)$. This is seen by noting that

$$\ln P = \rho_1 \ln M$$

and

$$E\,(\ln P \,|\, I^j) = \rho_1\, h\, (\ln M + v^j).$$

Hence, even if wages and prices are equally dependent on nominal income $(\pi_3 = \delta_3)$, it will nonetheless be such that wages are less responsive than prices $(\rho_1 > \rho_2)$ to changes in nominal income. This suggests more nominal rigidity in wages than in prices.

Secondly, even if this difference between wage and price formation is eliminated, there is still a source for asymmetric responsiveness of nominal wages and prices through the direct importance of the state variable (captured by the coefficients π_3 and δ_3). To see this, eliminate the above-mentioned effect by considering the extreme case where $\pi_1 \rightarrow 0$ implying that prices also depend only on expected values [4]. In this case we find

$$\rho_1 \gtreqless \rho_2 \qquad \text{for} \quad \pi_3 \gtreqless \delta_3 \qquad \text{for} \quad 0 < h < 1.$$

That is, nominal prices are more responsive than nominal wages $(\rho_1 > \rho_2)$ if nominal income has a larger direct effect on price formation than on wage formation $(\pi_3 > \delta_3)$, and vice versa. The explanation is simple. The larger π_3, the more price-setting is directly dependent on the state variable rather than on other prices and wages, and hence the price follows the state variable more tightly. Note that a higher π_3 means that the strategic complementarities from wages and prices to prices in total are reduced, and mutatis mutandis for δ_3. It is noted that if unions have a real wage target, then $\delta_3 = 0$, and the above-mentioned condition is automatically fulfilled. It can be concluded that nominal wages are likely to be less flexible than nominal prices.

4. A more meaningful case would be to have prices determined simultaneously with wages, *i.e.*

$$\ln P^i = \pi_1\, E\,(\ln W^i \,|\, I^i\,) + \pi_2\, E\,(\ln P \,|\, I^i\,) + \pi_3\, E\,(\ln M \,|\, I^i\,).$$

In this case we find that $\rho_1 \gtreqless \rho_2$ for $\pi_3 \gtreqless \delta_3$ if $0 < h < 1$, that is, the relative responsiveness of wages and prices to the nominal variable depends only on the direct importance of the nominal variable for wages and prices.

5 Concluding Remarks

Differential information in combination with the strategic complementarities in price and wage setting turns out to have important qualitative implications for the adjustment of nominal prices and wages. Not only do nominal prices and wages become nominally rigid, but they need not adjust to the same extent even though price and wage decisions are based on the same information. Under plausible assumptions nominal wages are less flexible than nominal prices.

Is the information problem considered plausible? Obviously, the specific way of modelling the information structure cannot claim any direct empirical support, but it serves the purpose of showing that even a marginal deviation from full information has non-trivial implications for the adjustment of nominal wages and prices. The point that agents are differently informed can, however, claim empirical relevance – agents do in general possess different information concerning the future values of the state variables. The information problem could actually be strengthened by introducing the problem that agents cannot readily distinguish between transitory and persistent changes in the state variables which will imply that temporary nominal shocks can have persistent effects (see ANDERSEN [1985b]). It might be argued that if informational problems are that important, there would be a premium on information inducing agents to acquire the needed information with the implication that lack of information cannot be the cause of substantial fluctuations. This argument presumes that costs of acquiring information are moderate. Even if this is the case, it is, however, the case that the incentive to acquire information depends on the general level of information acquisition due to strategic complementarities (see ANDERSEN and HVIID [1994]), and hence equilibria without information acquisition can be sustained even for small costs.

Do the nominal rigidities found here have any policy implications? Systematic feedback rules for the money supply may work under differential information by essentially stabilizing the economy against shocks on which agents are differentially informed (see ANDERSEN [1986]). This can be interpreted in the sense that systematic policies can work by homogenizing the information set of agents and thereby reduce or eliminate the allocational implications of differential information.

The present analysis has not explicitly addressed the welfare implications of rigidities in price and wage setting. It is, however, well-known that positive monetary shocks can be welfare improving if the initial equilibrium is inefficiently low as is typically the case under imperfect information (MANKIW [1985] and BENASSY [1987]), while oppositely negative shocks reinforce the welfare losses.

Proof that

$$\frac{\partial \rho_1}{\partial \pi_1}\bigg|_{\pi_2=\bar{\pi}_2} < 0$$

It follows from (13) that

$$\rho_1 = \frac{\pi_1\,\delta_3\,h + (1-\pi_1-\pi_2)\,h\,(1-\delta_2\,h)}{(1-\pi_2\,h)\,(1-\delta_2\,h) - \pi_1\,\delta_1\,h}$$

where it has been used that $1 = \pi_1 + \pi_2 + \pi_3$.

Hence,

$$\frac{\partial \rho_1}{\partial \pi_1} = \frac{\left\{\begin{array}{r}(\delta_3\,h - h\,(1-\delta_2\,h))\,((1-\pi_2\,h)\,(1-\delta_2\,h)-\pi_1\,\delta_1\,h)\\ +\delta_1\,h\,[\pi_1\,\delta_3\,h + (1-\pi_1-\pi_2)\,h\,(1-\delta_2\,h)]\end{array}\right\}}{((1-\pi_2\,h)\,(1-\delta_2\,h)-\pi_1\,\delta_1\,h)^2}$$

It follows that

$$\operatorname{sign}\frac{\partial \rho_1}{\partial \pi_1} = \operatorname{sign}\Gamma$$

where

$$\Gamma = h\,(1-\delta_2\,h)\,((\delta_3-(1-\delta_2\,h))\,(1-\pi_2\,h)+\pi_1\,\delta_1^2+\delta_1\,(1-\pi_1-\pi_2)\,h)$$

and since Γ can be rewritten as

$$\Gamma = h\,(1-\delta_2\,h)\,(1-h)\,(-(1-\pi_2\,h)\,\delta_2-\delta_1) < 0$$

the proof follows.

The other results in (14) are proven similarly.

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