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Wage Rigidities, Price Rigidities and Monetary Shocks

by R. Ford

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I Introduction

In this paper, we describe a macroeconomic model developed for purposes of examining the effects of price and wage rigidity on the determination of output, and on the output-price (or output-inflation) trade-off. To keep matters as simple as possible, the model is highly stylized. Moreover, such a stripped-down model allows close attention to be paid to economic structure. Nevertheless, it does capture some salient features that have been built into larger, more realistic macro models.

The interest in rigidities stems from the widespread belief that they are at least partially responsible for the transmission of nominal shocks into real effects. This is an important issue from the point of view of monetary policy since the answer to it conditions judgements about which policies are desirable or, alternatively, which structural reforms are required to make policy operate more smoothly.

There are two ways of examining rigidities. The first is to analyze the source of the rigidities. For example, why do economic agents enter into long-term contracts, and what economic roles do they play? This line of attack leads directly to issues of economic choice under imperfect information, agent-principal problems, and insurance markets. It is, therefore, a microeconomic approach. This paper makes no attempt to model the choice of rigidity, nor does it address the more fundamental question of why rigidities exist. Rather, stylized rigidities are assumed to exist and the behaviour of the economy is examined conditional on the rigidities. This methodology, although common among macroeconomists, has been attacked by Barro (1977) and, more recently, by Wright (1983).

II The Model

All variables (except interest rates) are in logs. There is assumed to be one output q_t with price p_t, one input, labour, denoted by n_t with price w_t. Output is produced by a diminishing-returns-to-scale Cobb-Douglas production function, and profit maximization under perfect competition yields the input demand function

$$n_t^d = -a(w_t - p_t) \qquad 0 < a < 1 \tag{1}$$

where the constant term has been normalized to zero. Note that output supply is proportional to input demand.

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Consumers (and suppliers of labour services) are assumed to maximize an (unspecified) utility function that yields an input supply function

$$n_t^s = b\,(w_t - p_t) - c\,(m_t - p_t) \qquad b,\ c > 0 \tag{2}$$

The real side of the economy is completed by noting that, from Walras' Law, $n^d = n^s$ implies $q^d = q^s$. There is therefore no need to model the output market explicitly[1]. Note that given real balances (1), (2) and output market equilibrium determine only the relative price $w_t - p_t$.

The model is closed by specifying an asset market. There are assumed to be two assets: money m_t and bonds that are traded internationally. Uncovered interest parity is assumed to hold

$$i_t = r_t - (s_t - {}_ts_{t+1})$$

where

i_t = the Canadian interest rate,
r_t = world interest rate,
s_t = log of the spot price of foreign exchange, and
${}_ts_{t+1}$ = the expectation of the future spot price conditional on information available in period t.

The world rate is normalized to zero. It is further assumed that purchasing power parity holds and, if the log of the world price is normalized to zero, this implies $s_t = p_t$. Money market equilibrium is assumed to be given by

$$m_t - p_t = kn_t - \ell i_t \qquad k, \ell > 0$$

which can also be written as

$$m_t - p_t = kn_t + \ell(p_t - {}_tp_{t+1}). \tag{3}$$

Finally, the expectations generating process must be modelled. It is assumed that expectations are rational in that ${}_tp_{t+1}$ would equal the actual price in period t+1 if the economy unfolded as expected by agents in period t. It will not so unfold, however, because of the presence of unexpected shocks. Although many such shocks could be modelled, the focus

1. The output supply function is determined by the same production function as was used to generate (1). The labour supply function could be found from (2) and the representative consumer's budget constraint, taking care to include the distribution of profits and the possibility of running a merchandise trade imbalance. The resulting labour supply function will not be log-linear and so will be of no use in terms of solving the model.

An alternative strategy is, of course, to specify a log-linear output demand function. Output market clearing then implies labour market clearing. In this case, however, the labour supply function will not be log-linear.

of this paper is the transmission of monetary shocks.[2]

An important distinction in policy analysis is between shifts in the level of the money supply and shifts in its rate of change. To capture this, the money stock is assumed to evolve according to

$$m_t = m_{t-2} + v_{t-2} + 2v_{t-1} + u_{t-1} + v_t + u_t \tag{4}$$

where

u, v have a joint normal distribution with zero means,
$E(u_t, v_s) = 0$ for all t, s,
$E(u_t, u_s) = E(v_t, v_s)$ for all $t \neq s$, and
$E(u_t, u_t) = \sigma_u^2$, and
$E(v_t, v_t) = \sigma_v^2$.[3]

The u_t permanently shocks the level of the money supply. That is, if $v_s = 0$ for all s, the money supply evolves as a random walk. The v_t shocks the level two periods in a row. Since agents have only a one-period horizon in this model, this is equivalent to a permanent change in the growth rate of the money stock.[4]

III No Rigidities

The solution in the absence of rigidities $n_t^s = n_t^d$ serves as a benchmark against which the effects of rigidities can be compared, and parts of the solution will be useful in computing the solutions that incorporate rigidities. The solution method is that of undetermined coefficients. If the equilibrium price is assumed to be a log-linear function of the "state variables", then

$$p_t = \pi_1 m_{t-2} + \pi_2 v_{t-2} + \pi_3 v_{t-1} + \pi_4 u_{t-1} + \pi_5 v_t + \pi_6 u_t \tag{5a}$$

$$_tp_{t+1} = \pi_1(m_{t-2}+v_{t-2}+v_{t-1}+u_{t-1}) + \pi_2 v_{t-1} + \pi_3 {}_tv_t + \pi_4 {}_tu_t. \tag{5b}$$

To evaluate $_tv_t$ and $_tu_t$ note that (5a), the observation of the market

2. It would be straightforward to incorporate a real shock (to the production function, for example). This would allow a discussion of confusion between real and nominal shocks (as in W7 (Ford (1984)), and a well-known host of closed economy papers). For the present purpose, the added computational cost is unrewarded by further insight.

3. These stochastic specifications can be relaxed, again at the cost of additional algebra. In particular, non-zero means and contemporaneous correlation are straightforward extensions.

4. If (4) is written $m_t = m_{t-1} + u_t - v_{t-1} + v_t$, then v_t represents a purely transitory shock, as in Barro (1978).

price (or, in view of purchasing power parity, the current spot rate), and knowledge of m_{t-1} and v_{t-1} are equivalent to an observation of $\pi_5 v_t + \pi_6 u_t$. Agents are assumed to compute the mathematical expectation of the value of each of the shocks from their sum. This computation yields

$$_t v_t = \theta(\pi_5 v_t + \pi_6 u_t)/\pi_5 \tag{6a}$$

$$_t u_t = (1-\theta)(\pi_5 v_t + \pi_6 u_t)/\pi_5 \tag{6b}$$

$$\theta = \pi_5^2 \sigma_v^2 / (\pi_5^2 \sigma_v^2 + \pi_6^2 \sigma_u^2). \tag{6c}$$

Solving (1), (2), and (3) for p_t, substituting in equations (5) and (6), and equating coefficients yields

$$p_t = (m_{t-2} + v_{t-2} + 2v_{t-1} + u_{t-1})$$
$$+ (1 + \ell/A - \ell(1-\theta)/A) v_t + (1 + \ell\theta/A)\, u_t \tag{7}$$

where $A = (1 + kca/(a+b) + \ell)$.

From the output market clearing conditions

$$w_t - p_t = -\, c(v_t(\ell - \ell(1-\theta)) - u_t \ell\theta)/A(a+b) \tag{8}$$

and

$$n_t = ac(v_t(\ell - \ell(1-\theta)) + u_t \ell\theta)/A(a+b). \tag{9}$$

A few words of interpretation are in order. The coefficients on the contemporaneous (v_t, u_t) shocks (π_5, π_6) are composed of two parts. The second part, multiplied by $1-\theta$ or by θ according to the shock, is due to the information extraction problem. Since agents do not observe the shocks themselves, they must assess the implications for p_{t+1} of an observed p_t. The other part of the solution is the effect of the shock in the absence of confusion. If, for example, $\theta = 1$ (i.e., all the observed price variance is due to v_t), then $\pi_5 = 1 + \ell/A > 1$. If $\theta = 0$, then $\pi_6 = 1$. In the absence of confusion, a permanent level shock increases the price level proportionally and has no effect on the real wage rate or on output. An inflation shock, however, leads to an anticipation of a future price increase, thus reducing money demand and requiring a more than proportional increase in the price level to clear the market. In this simple model, the reduction in the real money supply (i.e., the downward sloped demand for money) calls forth more labour and increases real output.[5] Therefore this economy is, by construction, neutral but not super-neutral. The non-super-neutrality arises from both the downward sloping money demand function and the real balance effect (or wealth effect). These are common features of many macroeconomic models.

Since agents are modelled as observing only p_t and not the individual shocks, an increase, for example, in p_t could be due to a positive level shock or to a positive growth rate shock. Agents average over the two shocks, the weights in the average being the relative contributions of the two shocks to overall price variance. The result is that the effect of the level shock is increased, while that of the inflation shock is decreased compared to what their values would have been had the shocks been observed.[6] Therefore, when agents cannot observe the shocks even a level shock will have non-neutral effects.[7] If these shocks are viewed as deliberate and announced policy, this suggests that credibility will have a bearing on the outcome. A "rebasing" (interpreted here as a level shock) could have inflation-like effects if agents are not convinced that it is a once-and-for-all event.

IV Wages Fixed

The model is now altered by assuming that firms and workers write one-period labour contracts that fix the nominal wage rate, i.e., $w_t = {}_{t-1}w_t$. In an ad hoc model such as this, the only motivation is that labour contracts of this type are commonly observed. It is assumed that in period t-1 agents set the nominal wage that in fact will prevail in period t. That is, they are assumed to choose the wage that would be the market clearing wage in period t if period t shocks were to take on their expected values (i.e., zero).

From (8), the market clearing nominal wage, when $v_t = u_t = 0$, is ${}_{t-1}w_t = {}_{t-1}m_{t-1} + {}_{t-1}v_{t-1}$. Since the nominal wage is fixed, the goods and asset markets cannot all clear. It is assumed that asset markets clear but the labour market does not. Rather, the "short side" of the market determines the quantity of labour actually transacted.[8]

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5. This depends crucially on the sign of the real balance effect. If the model had been specified in terms of the output market with a positive real balance effect in output demand, an inflation shock would have reduced output by reducing the equilibrium real money stock.

6. Indeed, $\pi_5 = \pi_6$ if agents cannot observe the shocks, whereas $\pi_5 \neq \pi_6$ if they can. The result that $\pi_5 = \pi_6$ under incomplete information is specific to this model, but the result that the coefficients are changed by the confusion factor is general.

7. Of course, this reasoning carries over to the standard case when agents confuse real with nominal shocks.

8. A widely used alternative to the short-side rule is to assume the economy is always on its labour demand (i.e., output supply) function (Fischer (1977)).

Therefore, all else equal, a real wage higher than anticipated means the economy is on its labour demand function, and one lower than expected puts the economy on its labour supply function.

From (7) and (8), the following expectations can be calculated directly

$$ {}_{t-1}w_t = m_{t-2} + v_{t-2} + 2\,{}_{t-1}v_{t-1} + {}_{t-1}u_{t-1} \quad (10a)$$

$$ {}_{t}p_{t+1} = m_{t-2} + v_{t-2} + 2v_{t-1} + u_{t-1} + 2\,{}_{t}v_t + {}_{t}u_t \quad (10b)$$

where[9] ${}_{t-i}v_{t-i} + {}_{t-i}u_{t-i} = (1+\theta)(v_{t-i}+u_{t-i})$ for $i = 0, 1$.

The solution can therefore be computed directly. There are two incompatible solutions, corresponding to whether the economy is in its labour demand (output supply) or labour supply (output demand) curve.

(a) $n_t^d = n_t$

$$ p_t^d = m_{t-2} + v_{t-2} + v_{t-1}(2-ka(1-\theta)/A_d) + u_{t-1}(1+ka\theta/A_d) $$
$$ + v_t(1+2\ell - \ell(1-\theta))/A_d + u_t(1+\ell - \ell(1-\theta))/A_d \quad (11a)$$

$$ n_t^d = -v_{t-1}\, ka^2(1-\theta)/A_d + u_{t-1}\, ka^2\theta/A_d \quad (11b)$$
$$ + v_t(a(1+2) - \ell(1-\theta))/A_d + u_t(1+\ell+\ell\theta)/A_d $$

$$ A_d = 1 + k_a + \ell $$

(b) $n_t^s = n_t$

$$ p_t^s = (m_{t-2}+v_{t-2}) + v_{t-1}(2+kb(1-\theta)/A_s) + u_{t-1}(1-kb\theta/A_s) $$
$$ + v_t(1+(kb+\ell-\ell(1-\theta))/A_s) + u_t(1+(kb+\ell\theta)/A_s) \quad (12a)$$

$$ n_t^s = v_{t-1}\, kb(c-b)(1-\theta)/A_s - u_{t-1}\, kb\theta(c-b)/A_s $$
$$ + v_t\, (b(1+2\ell) - c\ell + \ell(1-\theta)(c-b))/A_s $$
$$ - u_t(b(1+\ell) - \ell\theta(c-b))/A_s \quad (12b)$$

$$ A_s = 1 + k(c-b) + \ell $$

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9. A potential problem here is that the solution to the information extraction problem derived from (7) assumes, incorrectly, that the labour market cleared in period t-1. However, it turns out that the solution to the extraction problem does not depend on whether the market clears or not, so in practice the issue does not arise.

By the short-side rule, whether the economy is on its labour supply or labour demand function depends on the sign of $n_t^s - n_t^d$. The calculation of this sign is complicated by two factors. First, the effect of contemporaneous (i.e., u_t and v_t) shocks on n_t^s is ambiguous. An increase in the nominal money supply reduces the real money supply and the real wage rate (because the nominal wage rate has been locked in by the contract). The first effect increases labour supply, the second reduces it. For expositional convenience, the real balance effect will be assumed to be sufficiently small so that the net effect is a reduction in the supply of labour.

The second problem is more interesting. In contrast to the market clearing solution, the information extraction problem in period t-1 bears on the period t equilibrium. In period t-1 agents were unable to distinguish between the level and growth rate shocks when they set the wage rate. The effect of their error is expressed by the coefficients on v_{t-1} and u_{t-1} in equations (11) and (12). This implies that whether the economy experiences excess supply or excess demand for labour depends on both current and past shocks.

If the effect of past shocks is ignored (or, equivalently, if there is assumed to be no information extraction problem), then a positive (for example) monetary shock reduces the real wage and puts the economy on its labour supply curve. In view of the discussion above, this reduces output. A negative monetary shock puts the economy on its labour demand curve, and this also implies a reduction in output. Note that if the standard practice of assuming the economy to be on its labour demand curve (i.e., on its aggregate supply curve) were followed, then the standard result -- that money and output move together -- would also follow. On the other hand, use of the short-side rule brings home the truth that monetary surprises, coupled with rigid wages, always have a cost.[10] It also adds force to Barro's (1977) criticism that contracts imposing such unambiguous costs would not be entered into in the first place.

Finally, there is the well-known result that a wage rigidity restores a stabilization role for monetary policy. In this model, consider the u_t shock and abstract from the problem of incomplete information. By construction, such a shock has no impact on real output if all markets clear (equation (9)), but such a shock will reduce output in the presence of the fixed nominal wage. If u_t were considered to be part of a policy rule, this would mean that the monetary authority could "use" the contract to influence real output. The authority can do this because it has

10. It should be stressed that each realization of a positive monetary shock need not be coupled with a reduction in output. This is due to the influence of period t-1 shocks. If $v_{t-1} = 0$ and $u_{t-1} < 0$, then, in the absence of period t shocks, the economy would be on its labour demand curve. If $v_t = 0$ and $u_t > 0$, such that the economy remained on the demand curve, then output would rise.

information in period t that was not available to agents in period t-1 and, unlike private agents, can use the information because it is not bound by contract.

V Output price fixed

The symmetric rigidity to a fixed nominal wage is a fixed nominal price $p_t = {}_{t-1}p_t$. In this case, the wage rate is assumed to be free, but the price level (or, by PPP, the spot rate) is assumed to be fixed at the level that was, in the previous period, expected to be its equilibrium level. If it is assumed that asset markets clear, then (3) and calculations of ${}_{t-1}p_t$ and ${}_tp_{t+1}$ imply that output rises (falls) with a positive (negative) monetary shock. This result is equivalent to the standard fixed-price IS-LM model money multiplier for a small open economy. The short-side rule, however, may restrict the feasible output to below what is required to clear the money market. Consider the case of a positive shock. This raises the real money supply and so reduces the supply of labour at any real wage. Of course, raising the real wage is not a solution, since this simply shifts the economy onto its labour demand schedule. Thus, the short-side rule implies that output must fall in the case of a positive shock and that the asset market cannot clear. A negative shock, coupled with asset market clearing, will give rise to reduced output, and this will always be feasible. In this case, however, the model does not uniquely determine the nominal wage rate. There are two wage rates (one for labour demand, the other for labour supply) that generate the required output.

This discussion highlights the distinction between the standard IS-LM model, and the IS-LM model augmented by an aggregate supply curve. The former fixes prices and assumes that output adjusts freely. The present model shows that these are independent assumptions. The latter typically operates through wage rigidities and assumes the economy to be on its labour demand curve. These, also, are independent assumptions.

VI Relative Price Fixed

In the context of the present model there are two possible ways of fixing the relative price $w_t - p_t = {}_{t-1}(w_t - p_t)$. The first is to assume that the real wage is set to its ex ante equilibrium level (i.e., zero), but that both the nominal wage and the nominal output price are free to clear the asset markets. This is the case of fully indexed nominal wages (or, equivalently, fully indexed nominal prices). The second is to assume that nominal contracts are written in both the labour market and the output market. That is, the nominal wage and the nominal price are both set equal to their ex ante equilibrium values. In this case, the real wage will be zero, as in the indexing case, but the asset markets cannot clear.

(a) Full indexation

Since the ex ante market clearing real wage is zero, $n_t^d = 0$ and $n_t^s = -c(m_t - p_t)$. From this, and the asset market condition (3) it is straightforward to evaluate the supply of labour, conditional on the shocks, at a real wage rate of zero. It is

$$n_t^s = c\ell(v_t(1-(1-\theta)) + u_t\theta)/(1+\ell). \tag{13}$$

By the short-side rule the economy will be on its labour supply function if and only if the contemporaneous shocks are negative. Note also the importance of the confusion of the shocks by agents. If $\theta = 1$ (so all shocks are inflation shocks), a negative inflation shock reduces the amount of labour transacted, but not by the same amount as in the no-rigidity case (see equation (9)). If all shocks are level shocks ($\theta = 0$), there is no effect on the amount of labour transacted, as is the case in the absence of rigidities (equation (9)). This follows because the economy is not super-neutral (and so full indexation is inappropriate in the face of an inflation shock) but it is neutral (so full indexation does the job in the face of a level shock). Of course, if agents are unable to disentangle the two shocks, full indexation is never appropriate.[11]

If the economy is on its labour supply curve, the equilibrium nominal wage and price is

$$w_t = p_t = m_{t-2} + v_{t-2} + u_{t-1} + 2v_{t-1} + (v_t(1+2\ell-\ell(1-\theta)) + u_t(1+\ell+\ell\theta))/(1+\ell) \tag{14}$$

implying a real money supply of

$$m_t - p_t = -\ell\theta(v_t+u_t)/(1+\ell). \tag{15}$$

If the economy is on its labour demand curve (i.e., if the shocks are positive), then

$$w_t = p_t = m_{t-2} + v_{t-2} + 2v_{t-1} + u_{t-1} + (v_t(1+kc+2\ell-\ell(1-\theta)) + u_t(1+kc+\ell+\ell\theta))/(1+kc+\ell) \tag{16}$$

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11. This closely parallels the discussion in Gray (1976). She contrasted monetary (level) shocks with real shocks, but this example points out that the issue is not fundamentally about the monetary-real distinction. Rather, the indexation scheme is assumed to be invariant with respect to the source of the shock, and the shocks are assumed to lead to different market clearing prices. Therefore, regardless of the description of the shocks, no single indexation scheme can be fully satisfactory. It is especially plausible that the indexation scheme does not depend on the type of shock if it is also assumed that agents cannot observe the shocks.

$$m_t - p_t = - \ell\theta(v_t+u_t)/(1+kc+\ell). \tag{17}$$

Therefore, a positive (negative) shock will put the economy on its labour demand (supply) curve, implying a zero (negative) change in output, a positive (negative) change in both nominal prices, and a negative (positive) change in the real money stock. Recall that a positive shock reduces the real money supply because of its inflationary possibilities.

(b) Nominal contracting in both markets

In this case

$$w_t = p_t = m_{t-2} + v_{t-2} + (1+\theta)(v_{t-1}+u_{t-1}) \tag{18}$$

$$m_t - p_t = v_{t-1}(1-\theta) - u_{t-1}\,\theta + v_t + u_t \tag{19}$$

$$n_t^d = 0 \tag{20a}$$

$$n_t^s = - c\,(v_{t-1}(1-\theta) - \theta\, u_{t-1} + v_t + u_t). \tag{20b}$$

As stated in Sections IV and V, past shocks are important to the extent that incomplete information in period t-1 causes agents to err in their forecast of period t prices. Since p_t is fixed, an increase in the money stock increases the real money supply and reduces labour supply. Therefore a positive (negative) shock puts the economy on its labour supply (demand) curve, implying a negative (zero) change in output, no change in nominal prices, and a positive (negative) change in the real money supply.

The contrast between cases (a) and (b) points up the truth that fixing the relative price is not the same as fixing all the nominal prices.

VII Conclusions

Four types of price rigidity are explored: (i) nominal wage fixed; (ii) nominal output price fixed; (iii) real wage (relative price) fixed; (iv) both nominal prices fixed. In the case of fixed nominal wages (i), there is the possibility (depending on the parameter values) that any monetary surprise reduces output. This follows from the use of the short-side rule, and is in sharp contrast to the standard result that follows from the assumption that the economy is on its labour demand function. The short-side rule is, of course, appealing because the alternative implies that, under some circumstances, workers are forced to supply more labour than they wish.

The fixed output price, case (ii), yields similar results, i.e., that any monetary shock reduces output and serves to illustrate the importance of the assumption of perfectly elastic output supply. It is worth noting that this assumption does not follow from that of a fixed output price.

In case (iii), the indexation has no effect in the face of a fully perceived level shock (because full indexation mimics the market solution), but does have an effect in the case of an inflation shock. If agents cannot discern which is which, the equilibrium is always different from what it would have been in the absence of indexation.

If indexation is carried out by fixing both nominal prices, case (iv), the results are substantially different (almost the opposite, in fact) from case (iii). In this model, the difference is due to the response of the real money supply to nominal shocks. In case (iii), the possibility of inflation reduced the equilibrium real money supply in the case of a positive shock. In case (iv), the fixed output price, which is also the money demand deflator, means a positive shock increases the real money supply.

All conclusions are model-specific, but a few general statements are suggested. At root, the model presented is very neo-classical. Markets clear through relative price adjustment and the adjustment of the real asset stock. The question arises, why in such an economy do negative monetary shocks reduce (and positive monetary shocks increase) output? One answer is confusion on the part of agents as to the nature of the shock. This is built into the solution written as equation (9), and gives the "correct" answer by construction. Another possibility is price rigidities. This investigation suggests that fixing one of the nominal prices does not yield the "correct" answer. Of course, things could be changed. If the economy were assumed to operate always on its labour demand curve, then nominal price rigidities would give rise to the "correct" answer. If output were assumed to be supplied elastically, then a rigid output price would do the same. In these cases, however, more than just the rigidity is required.

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