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WAGE CONTRACTING, EXCHANGE RATE VOLATILITY, AND EXCHANGE INTERVENTION POLICY

by

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I. INTRODUCTION AND SUMMARY

A frictionless model of the economy, with wages and prices moving each period to clear the labor and goods markets, is generally considered to be inconsistent with certain stylized facts about the real world. In such a model, employment and output adjust immediately to any economic disturbance; there is no persistence of effects, no business cycle. Also, money is neutral in such an economy, and if monetary disturbances are the primary source of exchange rate and price level movements, the model is incapable of explaining the apparent fact that exchange rates are more volatile than prices. Dornbusch's (1976) approach to this problem was to postulate that the goods market clears more slowly than the money market. Representing price stickiness by a Phillips Curve, and assuming that the money market clears instantaneously, he derived his celebrated "overshooting" result for the exchange rate.

In this paper, we attribute the slow adjustment in the real side of the economy to wage contracting.[1/] We consider both the neo-Classicial contracting model of Gray (1976), Fischer (1977a) and Canzoneri (1980) and the neo-Keynesian model of Taylor (1980). This approach has a number of advantages. We do not have to assume that prices are fixed in the short-run; so the question of the relative variability of prices and exchange rates has more meaning. We can identify the degree of inertia imposed upon the real side of the economy with either the average length of contracts or the sensitivity of wages to expected demand conditions, and we can vary the degree of inertia to assess the effect of slower adjustment on persistence and the relative variablity of prices and exchange rates. More importantly, and also more controversially, we can give these positive results a normative interpretation. We can for example suggest which agents are helped or hurt by exchange rate overshooting. We can also suggest which agents would be helped or hurt by an intervention policy that curbed the exchange rate overshooting.

Some monetarists assert that price and exchange rate fluctuations are due primarily to monetary disturbances. It turns out that most of our results depend crucially upon the validity of this assertion. Our basic conclusions may be summarized as follows:

(1) If goods market disturbances, rather than monetary disturbances, are the primary source of price and exchange rate fluctuations, then a frictionless model of the economy may not be inconsistent with the observation that exchange rates are more volatile than prices. This real-world fact may not be a paradox that needs to be explained.

(2) If on the other hand the monetarist assertion is correct, then a frictionless economy can not explain the observed volatility of exchange rates relative to prices, but both contracting models can. In addition, increasing the degree of inertia embodied in the contracts increases the volatility of exchange rates relative to prices.

(3) Taylor's contracting model implies more persistence than Gray's and is more closely related to Dornbusch's fixed-price model.

(4) The existence of wage contracting presumably benefits labor market participants and may also benefit portfolio managers by stabilizing the real interest rate, especially if goods market disturbances are an important source of price and exchange rate variation. If however the monetarist assertion is correct, then the conversion of some one-period contracts to two-period contracts will hurt both portfolio managers and the labor market participants under existing contracts by destabilizing both the real interest rate and employment.

(5) An intervention policy that leans against the wind to stabilize exchange rate fluctuations will benefit both labor market participants and portfolio managers if the monetarist assertion is correct. If instead goods market disturbances are the primary source of price and exchange rate fluctuations, then such a policy may benefit portfolio managers at the expense of labor market participants by stabilizing the real interest rate but destabilizing employment.

II. THE POSITIVE IMPLICATIONS OF WAGE CONTRACTING

First we show how monetary and goods market disturbances affect the exchange rate and price level in the flexible-wage economy that we take as a benchmark. Then we impose two different forms of contracting on the labor market and examine their implications for the volatility of exchange rate and price level movements. In particular, we want to see whether either form of contracting helps to explain our stylized facts by increasing exchange rate volatility and/or decreasing price level volatility and by imparting more persistence to the effects of disturbances. The economy operates quite differently under these two forms of contracting; in fact, they really constitute two different views of the supply side of the economy. So we are also interested in identifying the particular features in the economy that are important if a given form of contracting is to help explain the stylized facts.

II.A. A Flexible-wage Model: The Benchmark Case

Our basic framework is similar to Dornbusch's (1976). We consider a single country that produces a differentiated product, but whose bonds are perfect substitutes for foreign bonds. Demand for the country's product is given by

$$(1) \quad y_t = \bar{y} - \delta(p_t - e_t - p_t^*) + u_t + \tilde{z}_t$$

where y, p, e and p* are (the logs of) output, its home currency price, the exchange rate, and the foreign currency price of foreign output, and u and $\tilde{z}$ are disturbance terms.2/ Supply of the product is fixed at its full-employment or "natural" rate, $\bar{y}$.

$$(2) \quad y_t = \bar{y}$$

This is a consequence of the flexible-wage assumption; the nominal wage moves each period to clear the labor market.3/

Incipient capital movements insure that

$$(3) \quad r_t = r_t^* + e_{t+1|t} - e_t$$

where r and r* are the nominal rates of return on domestic and foreign bonds, and $e_{t+1|t} - e_t$ is the expected rate of depreciation of the domestic currency. Expectations are assumed to be "rational;" $e_{t+1|t}$ is the expected value of next period's exchange rate based upon complete current and lagged information. Home country residents hold the entire domestic money stock; money demand is given by

$$(4) \quad m_t - p_t = -\lambda r_t + y_t - \tilde{v}_t$$

where m is the (log of the) domestic money stock, and $\tilde{v}$ is a velocity disturbance.4/

We want to model both temporary and permanent monetary and goods market disturbances. A "~" over a disturbance indicates that it is serially uncorrelated and normally distributed. $\tilde{v}$ is a temporary monetary disturbance, and $\tilde{z}$ is a temporary goods market disturbance. m and u are assumed to follow a random walk,

$$(5) \quad m_t = m_{t-1} + \tilde{m}_t \quad \text{and} \quad u_t = u_{t-1} + \tilde{u}_t,$$

so $\tilde{m}$ and $\tilde{u}$ are permanent monetary and goods market disturbances.

For simplicity, we set p_t^* and r_t^* equal to zero; then we have

Solution to Flexible-Wage Model:

$$(6) \quad p_t = \Sigma_0^\infty \tilde{m}_{t-i} + [1/(1 + \lambda)]\tilde{v}_t + [\lambda/\delta(1 + \lambda)]\tilde{z}_t$$

$$(7) \quad e_t = \Sigma_0^\infty \tilde{m}_{t-i} + [1/(1 + \lambda)]\tilde{v}_t - (1/\delta)\Sigma_0^\infty \tilde{u}_{t-i} - [1/\delta(1 + \lambda)]\tilde{z}_t$$

Solution techniques are discussed in an appendix.

Money is of course neutral in this frictionless economy. A permanent increase in the money supply produces permanent and proportionate increases in the price level and the exchange rate; it has no effect on the expected rate of depreciation, $e_{t+1|t} - e_t$. By contrast, a temporary increase (which is equivalent to a positive $\tilde{v}_t$) produces an expected rate of appreciation, and therefore has less than proportionate effects on the price level and the exchange rate. A permanent increase in demand for the home good is immediately offset by a permanent increase in the terms of trade, which is achieved by a permanent appreciation of the exchange rate; there is however no change in the expected rate of appreciation or in the price level. A temporary increase produces an expected rate of depreciation and a temporary increase in the terms of trade that is absorbed by both the price level and the exchange rate.

The important thing to note is that in our benchmark case monetary disturbances, be they permanent or temporary, have an equal impact on the exchange rate and the price level. This result is inconsistent with our stylized fact that exchange rates are more volatile than prices, and it is the paradox that the "sticky-price" models of Dornbusch (1976) and others were built to explain.

However, it is also interesting to note that goods market disturbances may have more impact on exchange rates than prices. Permanent disturbances are totally absorbed by the exchange rate, and temporary disturbances have a larger impact on the exchange rate than the price level if the interest semi-elasticity of money demand is small ($\lambda < 1$). If price and exchange rate movements are primarily determined by goods market disturbances, then our flexible-wage model is probably not inconsistent with our stylized fact.

In summary, our benchmark flexible-wage economy is inconsistent with the stylized fact that exchange rates are more volatile than prices if the monetarist view prevails and exchange rate movements are primarily monetary phenomena. If instead exchange rate movements result from goods market disturbances, then we may have no paradox to explain.

The flexible-wage model is definitely inconsistent with our second stylized fact concerning persistence. The effects of both monetary and goods market disturbances are immediate and complete within the period in which they occur. The system requires no further adjustment.

II.B. A Neo-Classical Contracting Model

Fischer (1977), Gray (1976, 1980) and Canzoneri (1981) have developed contracting models in which the nominal wage must be specified in a labor contract before markets meet and production occurs. In a popular version of these models, there is a supply of labor derived from utility maximization and a demand for labor derived from profit maximization, and wage setters choose the wage that is expected to clear the market.

If labor supply is perfectly inelastic, and if there are no productivity disturbances, then the market clearing real wage is a time-invariant constant, $\overline{w - p}$.[5/] The labor contract specifies nominal wage rates, so the wage setters must first predict the price levels that will prevail during the contract period and then set the wage rates accordingly. For example, the contract wage for period t + i will be

$$(8) \quad w_{t+i} = \overline{w - p} + p_{t+i|t}$$

in a contract negotiated at the end of period t; wage setters expect this wage to clear the market in period t + i.

Of course, the real wage that actually obtains in period t + i will not be the market clearing one unless the wage setters predict the price level perfectly; that is,

$$(9) \quad w_{t+i} - p_{t+i} = \overline{w - p} - (p_{t+i} - p_{t+i|t})$$

With probability one, the plans of both suppliers and demanders of labor can not be realized. So the contract also specifies (perhaps implicitly) an employment rule that relates employment in period t + i the real wage that actually obtains in period t + i. We follow the authors referred to above in assuming that the employment rule is identical to the profit maximizing firm's demand curve, but there are other possibilities.[6/] The output supply curve in period t + i for firms under this contract is

$$(10)\quad y_{t+i} = \overline{y} + \theta(p_{t+i} - p_{t+i|t})$$

and the slope of this curve, θ, depends positively upon the marginal productivity of labor.[7/]

The aggregate supply curve we use in place of equation (2) is

$$(11)\quad y_t = \overline{y} + (1 - \phi)\theta(p_t - p_{t|t-1}) + \phi[.5\theta(p_t - p_{t|t-1}) + .5\theta(p_t - p_{t|t-2})]$$

We assume that some firms are covered by contracts that last only one period while others are covered by contracts lasting two periods; ϕ is the fraction of firms covered by two-period contracts. If ϕ is equal to zero all of the contracts are renegotiated at the end of each period, and output fluctuates about its "natural rate" with one-period price prediction errors. If ϕ is greater than zero, all of the one-period contracts and half of the two-period contracts are being renegotiated at the end of each period; the other half of the two-period contracts are going into their second and final period. The second term on the RHS of (11) comes from the one-period contracts; the third is due to the two-period contracts.

By increasing ϕ from zero to one, we can increase the inertia in the labor market and assess its implications for the volatility of price and exchange rate movements and for the persistence of effects.[8/] We could also include contracts that lasted more than two periods, but the implications of such an extension will be obvious.

We consider first the case in which ϕ is equal to zero; all contracts last just one period. In this case, we have

Solution to Neo-Classical Contracting Model, $\phi = 0$:

(12) $p_t = \pi_1 \tilde{m}_t + \Sigma_1^\infty \tilde{m}_{t-i} + \pi_3 \tilde{v}_t + \pi_4 \tilde{z}_t$

(13) $e_t = \varepsilon_1 \tilde{m}_t + \Sigma_1^\infty \tilde{m}_{t-i} + \varepsilon_3 \tilde{v}_t - (1/\delta)\Sigma_0^\infty \tilde{u}_{t-i} - \varepsilon_4 \tilde{z}_t$

where

$$\pi_1 = \frac{(1-\rho)(1+\lambda)}{(1-\rho)(1+\lambda)+\theta} \qquad \varepsilon_1 = [1 + (\theta/\delta)]\pi_1$$

$$\pi_3 = \frac{(1-\rho)}{(1-\rho)(1+\lambda)+\theta} \qquad \varepsilon_3 = [1 + (\theta/\delta)]\pi_3$$

$$\pi_4 = [\rho/(1-\rho)]\pi_3 \qquad \varepsilon_4 = (1/\delta) - [1 + (\theta/\delta)]\pi_4 > 0$$

and

$$\rho = \lambda/(\lambda + \delta) < 1$$

The derivation of this solution is discussed in an appendix.

The first thing to note is that contracting decreases the impact of monetary disturbances on the price level and (if $\delta < 1$) increases the impact of monetary disturbances on the exchange rate.[9/] In this way, contracting can explain the stylized fact that exchange rates are more volatile than prices. Contracting does little however to help explain our stylized fact in the case of goods market disturbances. Permanent goods market disturbances are still totally absorbed by the exchange rate, and contracting mutes the impact of temporary disturbances on both the price level and the exchange rate.[10/]

These results for monetary disturbances can be explained in terms of "overshooting" of the exchange rate and "undershooting" of the price level. Figure 1 shows how a permanent increase in the money supply at time t_0 affects the price level and the exchange rate over time. (The analysis of temporary monetary disturbances is analogous.) In the flexible-wage model, the full effect of $\tilde{m}_{t_0}$ on p_t and e_t is immediate and permanent, as represented by the solid line in Figure 1. With one-period contracts however, the price level will undershoot in the first period; this is represented by a dashed line in Figure 1. The rising price level and falling real wage increase output and therefore money demand; consequently, a less than proportionate increase in the price level is needed to equilibrate the money market. The exchange rate will overshoot, as shown by the dotted line in Figure 1, if δ is less than one. The less than proportionate increase in the price level leaves an increase in the real supply of money that must be accomodated by an increase in demand. The increase in output raises transactions demand, and if this is not sufficient to fill the gap, the interest rate falls. It is clear from the interest parity equation, equation (3), that this requires the exchange rate to overshoot and create the expectation of an appreciation; otherwise, risk neutral portfolio managers would not hold domestic bonds. The condition on δ, which we assume to hold, keeps the output effect on money demand from reversing this result by limiting the effect of the fall in the terms of trade on demand for the domestic good.[11/]

From (11) and (12), output is given by

(14) $y_t = y + \theta\pi_1\tilde{m}_t + \theta\pi_3\tilde{v}_t + \theta\pi_4\tilde{z}_t$

The impact of monetary disturbances on output and the amount of exchange rate overshooting and price level undershooting all depend upon the size of θ.12/ A bigger θ implies a more elastic supply of output. Thus, in response to an unanticipated increase in the money supply, the increase in output does more to equilibrate the money market, and the price level does less; in terms of Figure 1, the price level undershoots more. And with a bigger supply effect, the terms of trade must fall further to equilibrate the goods market; the exchange rate overshoots more to produce this terms of trade effect.

So θ is an important parameter in this explanation of output, price and exchange rate fluctuations in response to monetary disturbances. As stated above, a large θ is implied by a high marginal productivity of labor and a relativley wage-elastic employment rule.13/14/

One-period contracts do allow deviations in output from its full-employment level, but they do not explain the persistence in these deviations that we have taken as our second stylized fact. Similarly, it is clear from equations (12) and (13) that the price level and the exchange rate adjust fully to any disturbance after only one period.

With $\phi > 0$, some contracts last two periods, and we have

<u>Solution to Neo-Classical Contracting Model, $\phi > 0$:</u>

(15) $p_t = \pi_1\tilde{m}_t + \pi_2\tilde{m}_{t-1} + \Sigma_2^\infty \tilde{m}_{t-i} + \pi_3\tilde{v}_t + \pi_4\tilde{z}_t$

(16) $e_t = \varepsilon_1\tilde{m}_t + \varepsilon_2\tilde{m}_{t-1} + \Sigma_2^\infty \tilde{m}_{t-i} + \varepsilon_3\tilde{v}_t - (1/\delta)\Sigma_0^\infty \tilde{u}_{t-i} - \varepsilon_4\tilde{z}_t$

where

$$\pi_1 = \frac{(1 - \rho)^2(1 + \lambda)^2 + .5\phi\theta(1 - \rho) + .5\phi\theta\rho(1 - \rho)(1 + \lambda)}{(1 - \rho)^2(1 + \lambda)^2 + \theta(1 - \rho)(1 + \lambda) + .5\phi\theta(1 - \rho)(1 + \lambda) + .5\phi\theta^2}$$

$$\pi_2 = \frac{(1 - \rho)(1 + \lambda)}{(1 - \rho)(1 + \lambda) + .5\phi\theta} \qquad \varepsilon_2 = [1 + .5\phi(\theta/\delta)]\pi_2$$

and π_3, π_4, ε_3 and ε_4 are as defined in (12) and (13).

With two-period contracts, it takes two periods for the price level and the exchange rate to adjust to a permanent monetary disturbance. A permanent disturbance that occurs in the first period of a two-period contract will also cause a price prediction error in the second period of the contract.[15] This implies a positive correlation in the deviations from full-employment for firms covered by two-period contracts.

$$(17) \quad y_t = \bar{y} + \theta(\pi_1\tilde{m}_t + \pi_3\tilde{v}_t + \pi_4\tilde{z}_t) + .5\phi\theta\pi_2\tilde{m}_{t-1}$$

Output cycles about its natural rate.

The size of ϕ, the proportion of contracts lasting two periods, also affects the magnitude of the immediate impact of a permanent monetary disturbance on the price level, the exchange rate and output. Figure 2 shows how price level undershooting and exchange rate overshooting are affected.[16] (The solid lines reproduce the results for the case $\phi = 0$; the dashed and dotted lines obtain if $\phi > 0$.) The overshooting of the exchange rate increases. It also turns out that the immediate impact on output and the real exchange rate, e - p, is magnified.[17] So the increase in exchange rate overshooting outweighs the decrease in price level undershooting, and the existence of two-period contracts helps explain the fact that exchange rates are more volatile than prices.

The reason for these results is that portfolio managers see the permanent monetary disturbance and understand that it will also affect the future output of firms with contracts that carry over to the next period. This recognition affects their exchange rate predictions, and thus their current demands for money and bonds. For example, for a positive disturbance, the existence of two-period contracts decreases the expected rate of appreciation of the home currency and lowers the current demand for it; this then increases the impact on the current price level, output and exchange rate.

Summarizing, neo-Classical contracting helps explain the stylized fact that exchange rates are more volatile than prices in the presence of monetary disturbances. Increasing the length of some of the contracts goes even further in explaining the fact in the presence of permanent monetary disturbances. This form of contracting does little to help explain the stylized fact in the presence of goods market disturbances, but then goods market disturbances already had more impact on exchange rates than on prices in the flexible-wage model; there wasn't really a paradox to be explained. Neo-classical contracting can also help explain persistence. The economy is fully adjusted to a permanent monetary disturbance only after the last existing contract is renegotiated. Persistence may however be better explained by the neo-Keynesian contracting model discussed in the next section; there temporary and permanent disturbances are passed from one contract to the next successively through time.

II.C. A Neo-Keynesian Contracting Model

Taylor (1979, 1980) has developed a contracting model that is less neo-classical in nature and more closely related to Dornbusch's (1976) sticky-price model. In Taylor's model, wages are set (with some modification for demand conditions) to preserve the relative wage structure over contracts. Contracting is once again staggered, with say half of the contracts being renegotiated each period. This is an important feature in Taylor's model because it allows the effects of a disturbance to be passed from one contract to the next; that is, disturbances affecting existing contracts are passed on to new contracts by the attempts of wage setters to preserve the relative wage structure over all contracts. The staggering of contracts is the source of the strong persistence of effects in Taylor's model. Price in Taylor's model is a constant markup over the average wage, and employment is determined by the demand for output; these features give the model a neo-Keynesian flavor despite its incorporation of "rational" expectations formation.[18/]

More specifically, the demand side of the economy -- equations (1), (3) and (4) -- is retained (though we will drop the permanent goods market disturbance, $\tilde{u}_t$, for simplicty of exposition), and the supply side is replaced by

$$(18)\quad x_t = .5(x_{t-1} + x_{t+1|t-1}) + .5\gamma[(m - p)_{t|t-1} + (m - p)_{t+1|t-1}] + \tilde{x}_t$$

$$(19)\quad p_t = w_t = .5(x_t + x_{t-1})$$

All contracts specify a fixed nominal wage for two periods; half of the contracts are renogotiated at the beginning of each period. x_t is the (log of the) wage specified in a contract negotiated at the beginning of period t. The first term in the wage-setting equation (18) reflects the fact that wage setters try to maintain their own wage relative to the wages that will exist in other contracts during the two periods covered by the contract. The second term says that expected demand pressures, as measured by expected real balances, are also taken into account;[19/] γ measures the importance of demand conditions in the negotiations, and it is an important parameter in Taylor's contracting model. $\tilde{x}_t$ is a disturbance in the wage setting process; we assume initially that it is independent of $\tilde{m}_t$, $\tilde{v}_t$, and $\tilde{z}_t$ even though this implies (perhaps unrealistically) that current actual demand conditions play no role in the wage-setting process. Equation (19) is the price-setting equation; w_t is the average wage across contracts at time t.

This model can be solved for[20/]

Solution to Neo-Keynesian Contracting Model:

$$(20) \quad x_t = \alpha x_{t-1} + (1 - \alpha)m_{t-1} + \tilde{x}_t$$

$$(21) \quad p_t = \alpha p_{t-1} + .5(1 - \alpha)(m_t - m_{t-1}) + .5(\tilde{x}_t + \tilde{x}_{t-1})$$

$$(22) \quad e_t = \beta_1 x_{t-1} + \beta_2 m_{t-1} - \beta_3 \tilde{x}_t + \beta_4 \tilde{m}_t + \beta_5 \tilde{v}_t - \beta_6 \tilde{z}_t$$

where

$$\alpha = (1 + .5\gamma - \sqrt{2\gamma})/(1 - .5\gamma)$$

$$\beta_1 = .5(1 - \delta)(1 + \alpha)/[\delta + \lambda(1 - \alpha)] \qquad \beta_2 = 1 + \beta_1$$

$\beta_3 = [.5(1 - \delta) + \lambda\beta_1]/(\delta + \lambda)$ $\beta_4 = 1 + \lambda\beta_2$

$\beta_5 = 1/(\delta + \lambda)$ $\beta_6 = 1/(\delta + \lambda)$

The absolute value of α is less than one for all positive values of γ, so the wage-price process is stable. A positive wage disturbance increases expected future prices and lowers expected future real balances; this has a moderating effect on next period's contract wage. The larger is γ, the smaller is α and the stronger is the moderating influence.21/

Permanent monetary disturbances and temporary wage disturbances generate persistent effects on all variables in the model, effects that last even after all of the existing contracts have been renegotiated. Any disturbance that gets into the wage setting process will have persistent effects. Permanent disturbances get in because they affect expected future real balances. Temporary monetary and goods market disturbances would get in if they were correlated with $\tilde{x}_t$, that is, if current actual demand conditions affected the wage setting process.

To illustrate how permanent monetary disturbances pass through the economy, we have solved equations (20), (21), (22) and (1) for their moving average representations under the assumption that all other disturbances are equal to zero:22/

(23) $x_t = \Sigma_{i=1}^{\infty} w_i \tilde{m}_{t-i}$ where $w_i = 1 - \alpha^i$

(24) $p_t = \Sigma_{i=1}^{\infty}\pi_i\tilde{m}_{t-i}$ where $\pi_1 = .5(1 - \alpha)$

$\pi_i = 1 - .5\alpha^{i-1}(1 + \alpha) \qquad i \geq 2$

(25) $e_t = \Sigma_{i=0}^{\infty}\varepsilon_i\tilde{m}_{t-i}$ where $\varepsilon_0 = \beta_4 > \varepsilon_1$

$\varepsilon_i = 1 + \beta_1\alpha^{i-1} \qquad i \geq 1$

(26) $y_t = \bar{y} + \Sigma_{i=0}^{\infty}\eta_i\tilde{m}_{t-i}$ where $\eta_0 = \delta\beta_4 > \eta_1$

$\eta_i = \delta[.5(1 + \alpha) + \beta_1]\alpha^{i-1} \qquad i \geq 1$

Permanent monetary disturbances are neutral in the long-run; that is, w_∞, π_∞, and ε_∞ are all equal to one, and η_∞ is equal to zero. However it takes an infinite amount of time for a given disturbance to work its way through the system.

Hence, the present model produces overshooting patterns for the exchange rate that are very similar to Dornbusch's. In response to a positive disturbance, the exchange rate overshoots its long-run value, and the price level undershoots; after one period, both begin a smooth exponential decay to their long-run values. The real exchange rate and output similarly go positive and then decay back to their natural rates. Smaller values of γ imply larger values of α, more overshooting of the exchange rate and output, and a slower decay to the long run values.

III. THE NORMATIVE IMPLICATIONS OF WAGE CONTRACTING AND MONETARY POLICY

In this paper we have abscribed the slow adjustment in the goods market, and the consequent overshooting of the exchange rate, to wage contracting. The neo-Classical type of contracting model discussed in section II.B suggests certain measures of volatility in exchange rates and prices that may be relevant from a normative point of view,[23/] and these measures are not necessarily the ones that were focused upon in the last section; there we were engaged in explaining certain stylized facts that are of interest to the observing economist.

Here we begin by identifying the measures of volatility that would seem to be relevant to the wage setters and the portfolio managers in our economy. Then we examine the implications of wage contracting and monetary policy for these normative measures of volatility. We consider two kinds of policy. One offsets the cycling of employment and output brought on by long-term contracting; the other smooths the exchange rate overshooting. Not surprisingly, we find some tradeoffs between the interests of wage setters and portfolio managers. Once again, the results depend crucially upon whether economic fluctuations are caused by monetary disturbances or by goods market disturbances.

III.A. Normative Measures of Volatility

The agents in our simple economy make decisions on the basis of their expectations of future prices and exchange rates. Wage setters are worried about price prediction errors and the deviations from full-employment that they cause. Portfolio managers are worried about the variability of real interest rates.[24/]

We realize that we are on precarious ground here. We have only modeled certain kinds of agents with certain kinds of problems. There are undoubtedly other agents in the real world for whom the size of prediction errors is not the only relevant measure of volatility. Some firms for example may have to incur adjustment or inventory costs for even perfectly foreseen fluctuations in demand. What's more, our labor contracts were not derived explicitly from a utility maximizing framework, and their form may not be invariant in some of the policy experiments we want to perform.[25/] Similarly, our specification of the asset sector may not provide a robust explanation of portfolio manager's behavior. The specific results we derive below are incomplete at best and should be viewed accordingly. However, we think that they provide an interesting and important complement to the positive implications of wage contracting discussed in the last section.

Wage setters in our model are worried about their price prediction errors. Those covered by one-period contracts are interested only in one-period price prediction errors; those covered by two-period contracts are interested in both one and two-period price prediction errors. Serial correlation in disturbances, lags in the economic struture and monetary policy can all cause the two to differ. Portfolio managers worry about unanticipated changes in the real interest rate,

$$(27)\quad [i_t - (pi_{t+1} - pi_t)] - [i_t - (pi_{t+1|t} - pi_t)] = -(pi_{t+1|t} - pi_t)$$

where

$$pi_t = (1 - \omega)p_t + \omega(e_t + p_t^*)$$

pi is a price index, and ω is the share of foreign goods in portfolio managers' market basket. So porfolio managers are interested in the one-period price index prediction error 26/ 27/

$$(28)\quad pi_t - pi_{t|t-1} = \omega(e_t - e_{t|t-1}) + (1 - \omega)(p_t - p_{t|t-1})$$

which depends upon both price and exchange rate prediction errors.

III.B. Wage Contracting and Agents' Normative Measures of Volatility

The one-period price and exchange rate prediction errors that are relevant to portfolio managers can be calculated from equations (15) and (16):

$$(29)\quad p_t - p_{t|t-1} = \pi_1\tilde{m}_t + \pi_3\tilde{v}_t + \pi_4\tilde{z}_t$$

$$(30)\quad e_t - e_{t|t-1} = \varepsilon_1\tilde{m}_t - (1/\delta)\tilde{u}_t + \varepsilon_3\tilde{v}_t - \varepsilon_4\tilde{z}_t$$

We showed in section II.B. that wage contracting causes the exchange rate and price level to overshoot and undershoot respectively their flexible-wage values in response to both permanent and temporary monetary disturbances.[28/] The price levels undershooting will help portfolio managers, but the exchange rate's overshooting will hurt them. On balance, wage contracting will be beneficial to portfolio managers if $(1 - \omega)$, the share of the domestic good in their market basket, is large enough. Increasing ϕ, the proportion of contracts that last two periods, will hurt portfolio managers because it increases the exchange rate overshooting and decreases the price level undershooting in response to permanent monetary disturbances.[29/]

Wage contracting does not matter to portfolio managers in the case of permanent goods market disturbances; they are always absorbed by the exchange rate. However, temporary goods market disturbances have less impact on both the price level and the exchange rate with wage contracting. It is difficult to assess the implications of this for portfolio managers since a positive price prediction error tends to cancel the negative exchange rate prediction error in the price index prediction error.[30/] However, we might expect that wage contracting benefits portoflio managers in the case of goods market disturbances.

For wage setters covered by one-period contracts, the relevant measure of volatility is the size of the one-period price prediction error (29). For wage setters covered by two-period contracts, the relevant measure may be taken to be

$$(31)\quad .5(p_t - p_{t|t-1}) + .5(p_{t+1} - p_{t+1|t-1}) = .5\pi_1(\tilde{m}_{t+1} + \tilde{m}_t) + .5\pi_2\tilde{m}_t + .5\pi_3(\tilde{v}_{t+1} + \tilde{v}_t) + .5\pi_4(\tilde{z}_{t+1} + \tilde{z}_t),$$

the average price prediction error over the life of the contract.

Wage setters must benefit from wage contracting; otherwise they would not do it. The interesting question here is how contractors under existing one and two-period contracts are affected by an increase in ϕ, that is, by the conversion of other one-period contracts to two-period contracts. We showed in section II.B. that increasing ϕ magnified the immediate impact of permanent monetary disturbances on prices, but muted the lagged effect; that is, $d\pi_1/d\phi$ is positive, but $d\pi_2/d\phi$ is negative.[31/] So an increase in ϕ makes one-period contractors worse off, and probably two-period contractors as well.

Summarizing, the existence of wage contracting will probably benefit both wage setters and portfolio managers, especially if goods market disturbances are an important source of price and exchange rate fluctuations. However, an increase in ϕ, the conversion of some one-period contracts to two-period contracts, will hurt both portfolio managers and wage setters under existing contracts if monetary disturbances are an important source of price and exchange rate fluctuations.

III.C. Wage Contracting and Monetary Policy

Wage contracting slows adjustment in the labor market, and this introduces persistence and exchange rate overshooting. A lagged feedback rule for monetary policy can take the persistence out of deviations in employment and output about their natural rates, and an exchange intervention policy can smooth exchange rate fluctuations. In this section, we examine the effects of these two policies on the various agents in our economy. Once again, the results depend upon whether monetary or goods market disturbances are the primary causes of price and exchange rate flucutations.

Counter-cyclical Policies:

Let the money supply process be represented by

$$(32)\quad m_t = m_{t-1} + \tilde{m}_t + h_t$$

where h_t represents "policy". It should be obvious that the lagged feedback rule

$$(33)\quad h_t = - m_{t-1} = - \Sigma_1^{\infty} \tilde{m}_{t-i}$$

offsets all expected effects due to permanent monetary disturbances. If it were imposed, equations (15), (16) and (17) would reduce to

$$(34)\quad p_t = \pi_3(\tilde{m}_t + \tilde{v}_t) + \pi_4\tilde{z}_t$$

$$(35)\quad e_t = \varepsilon_3(\tilde{m}_t + \tilde{v}_t) - (1/\delta)\Sigma_0^{\infty} \tilde{u}_{t-i} - \varepsilon_4\tilde{z}_t$$

$$(36)\quad y_t = \bar{y} + \theta[\pi_3(\tilde{m}_t + \tilde{v}_t) + \pi_4\tilde{z}_t]$$

It is clear from (36) that the cyclical effects in output and employment have been eliminated, even though two-period contracts still exist.[32/]

The lagged feedback policy (33) reduces two-period price prediction errors to one-period price prediction errors.

$$(37)\quad p_t - p_{t|t-2} = p_t - p_{t|t-1} = \pi_3(\tilde{m}_t + \tilde{v}_t) + \pi_4\tilde{z}_t$$

It converts the permanent monetary disturbances into temporary ones. Hence, there is no useful information embodied in one-period price predictions that is not already embodied in two-period price predictions. And in addition, one-period errors are smaller because temporary monetary disturbances have less impact on the price level than permanent ones; that is, π_3 is less than π_1.[33/] So the feedback policy (33) benefits both one and two-period wage contractors if permanent monetary disturbances are an important determinant of price fluctuations.

Portfolio managers are also better off in this case because

$$(38)\quad e_t - e_{t|t-1} = \varepsilon_3(\tilde{m}_t + \tilde{v}_t) + \varepsilon_4\tilde{z}_t$$

Temporary monetary disturbances also have less impact on the exchange rate, so both components of the price index prediction error (28) are reduced.[34/]

Exchange Intervention Policy:

A policy of the form

(39) $h_t = -m_{t-1} - ge_t \qquad g > 0$

can control the exchange rate's overshooting in addition to removing the cyclical effects on output and employment. If it is imposed (and assuming for simplicity that ϕ is equal to zero), then (34), (35) and (36) become

(40) $p_t = \pi_3(\tilde{m}_t + \tilde{v}_t) + \pi_4\tilde{z}_t + \pi_5 u_t - \pi_6\tilde{u}_t$

(41) $e_t = \varepsilon_3(\tilde{m}_t + \tilde{v}_t) - \varepsilon_4\tilde{z}_t - \varepsilon_5 u_t + \varepsilon_6\tilde{u}_t$

(42) $y_t = \bar{y} + \theta[\pi_3(\tilde{m}_t + \tilde{v}_t) + \pi_4\tilde{z}_t + (\pi_5 - \pi_6)\tilde{u}_t]$

where

$\pi_3 = \delta\eta \qquad \varepsilon_3 = (\delta + \theta)\eta$

$\pi_4 = (\lambda + g)\eta \qquad \varepsilon_4 = (1 + \theta)\eta$

$\pi_5 = g/\delta(1 + g) \qquad \varepsilon_5 = 1/\delta(1 + g)$

$\pi_6 = (\delta + \lambda + g)\theta\eta\pi_5 \qquad \varepsilon_6 = (1 - \delta)g\theta\eta\varepsilon_5$

and

$\eta = 1/[\delta(1 + \lambda + g) + \theta(\delta + \lambda + g)]$

For large values of g, all exchange rate fluctuations are eliminated.

The one-period price prediction errors of interest to wage setters are

$$(43)\quad p_t - p_{t|t-1} = \pi_3(\tilde{m}_t + \tilde{v}_t) + \pi_4\tilde{z}_t + (\pi_5 - \pi_6)\tilde{u}_t$$

where

$$\pi_5 - \pi_6 = g(1 + \lambda + g)n/(1 + g)$$

If price fluctuations are caused by monetary disturbances, then wage setters would favor a strong intervention policy to smooth, or even eliminate, exchange rate fluctuations.[35] Monetary disturbances and monetary policy push the exchange rate and the price level in the same direction; so a monetary policy that stabilizes the exchange rate will also stabilize the price level and make it more predictable. Goods market disturbances on the other hand either move the exchange rate and the price level in opposite directions (in the case of temporary disturbances) or are totally absorbed by the exchange rate (in the case of permanent disturbances). In either case, a monetary policy that stabilizes the exchange rate will destabilize the price level and make it less predictable.[36] Wage setters would prefer that monetary policy allow the exchange rate to fluctuate freely and absorb some of the impact of these disturbances.[37]

Portfolio managers are worried about the one-period exchange rate prediction error

$$(44)\quad e_t - e_{t|t-1} = \varepsilon_3(\tilde{m}_t + \tilde{v}_t) - \varepsilon_4\tilde{z}_t - (\varepsilon_5 - \varepsilon_6)\tilde{u}_t$$

where

$$\varepsilon_5 - \varepsilon_6 = \{\delta(1 + \lambda + g) + \theta[\delta(1 + g) + \lambda]\}n/\delta(1 + g)$$

in addition to the price prediction error (43), as both are components in their price index prediction error (28).

A strong intervention policy will always reduce exchange rate fluctuations and make the exchange rate more predictable. In the case of monetary disturbances, this will benefit both wage setters and portfolio managers. Monetary disturbances make the price level and the exchange rate fluctuate in the same direction; so there is no cancellation in (28). A strong intervention policy will make both fluctuate less and in this way decrease portfolio managers price index prediction errors.

However, unlike wage setters, portfolio managers will probably favor some intervention in the case of goods market disturbances. Goods market disturbances make the price level and the exchange rate fluctuate in opposite directions, so price and exchange rate prediction errors tend to cancel in (28). With no intervention at all, permanent goods market disturbances are absorbed totally by the exchange rate. Some intervention to stabilize the exchange rate will make part of the disturbance be absorbed by the price level. Thus, with some intervention, a smaller exchange rate prediction error in (28) will be further offset by a price prediction error in the opposite direction. This will clearly benefit portfolio managers. The case for temporary disturbances is less clear since the effect is shared with no intervention. The more important is the foreign good in the portfolio managers' market basket, the more likely are they to benefit from some intervention in this case as well.

Figure 1

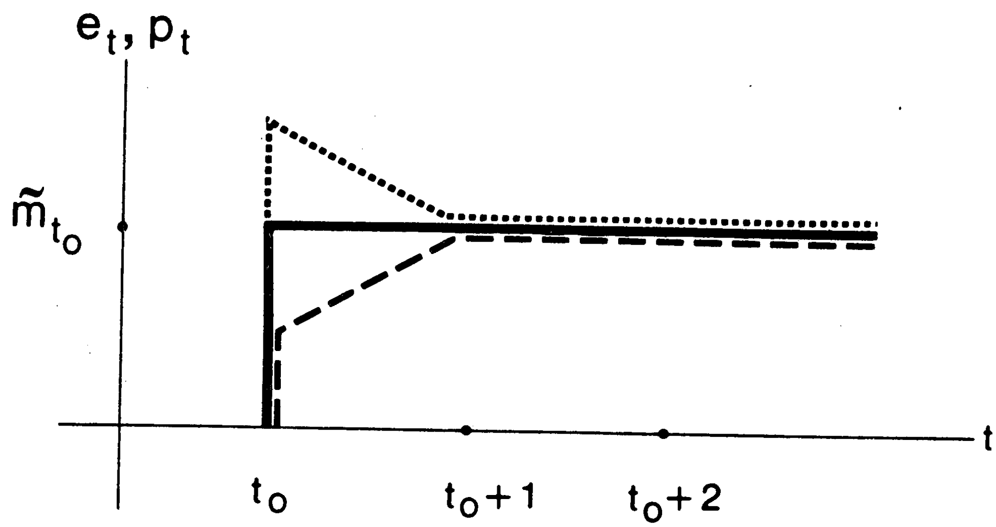
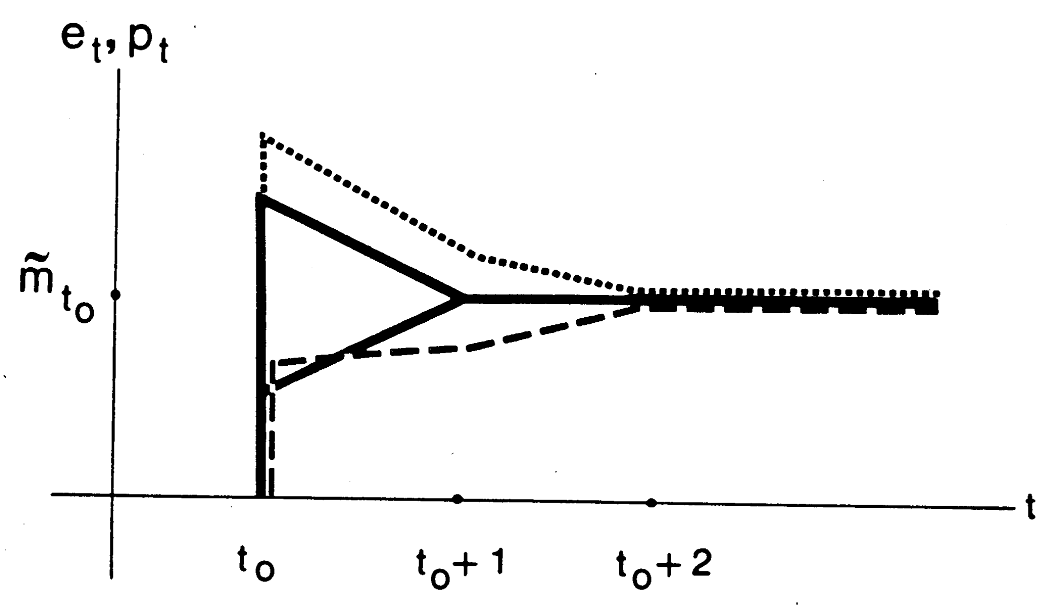


Figure 2



Summarizing, if monetary disturbances are the primary cause of price and exchange rate fluctuations, then both portfolio managers and wage setters will favor a strong exchange intervention policy to control the exchange rate's overshooting. Such a policy will stabilize the price level, the exchange rate and the price index; it will make both the price level and the real rate of interest more predictable. If however goods market disturbances are the primary source of price and exchange rate fluctuations, then the monetary authorities may have to choose between portfolio managers and wage setters. Intervention shifts the effects of these disturbances from the exchange rate to the price level, increasing price prediction errors, but quite possibly making the real interest rate more predictable.

Footnotes

1/ Dornbusch's (1976) paper stimulated many others. Weber (1981) and Bhandari (1981) for example replaced Dornbusch's Phillips Curve with the two familiar versions of the Lucas supply hypothesis. Flood and Hodrick (1982) use information asymmetries to try to explain some of the same stylized facts.

2/ Dornbusch's (1976) specification included the real interest rate. We have left it out for simplicity.

3/ More generally, full-employment output will not be a time-invariant constant. It will fluctuate with the terms of trade and with productivity disturbances.

Salop (1974) initiated a host of papers investigating the implications of the fact that labor supply is a function of wages deflated by an index of prices while labor demand is a function of wages deflated by just the price of the domestic product; one implication is that full-employment output depends upon the terms of trade. Gray (1976) initiated a host of papers investigating the implications of productivity disturbances and indexing in contracting models. Flood and Marion (1982), Marston (1982) and Turnovsky (1982) are a recent examples of both; our paper is an example of neither.

We assume that labor supply is perfectly inelastic, avoiding the issues raised by Salop, and that there are no productivity disturbances, avoiding the issues raised by Gray.

4/ The income elasticity of demand has been set equal to one so that the money supply is effectively deflated by the price of domestic output. More generally we would have

$$m_t - pi_t = -\lambda r_t + \eta(p_t + y_t - pi_t) - \tilde{v}_t$$

where pi is an index of domestic and foreign good prices. Letting $\eta = 1$, this specification becomes (4) above.

5/ See footnote 3.

6/ Barro (1977) and Waldo (1981), following the spirit of the "implicit contracts" literature, suggest that colluding suppliers and demanders of labor will settle upon some other rule. Barro (1977) is justly critical of this kind of contracting model because of its lack of utility maximizing foundation, but see also Fischer's (1977b) response.

7/ Assuming that the production function is Cobb-Douglas, the first-order condition for profit maximization (in logs) is:

$$(\psi - 1)n_{t+i} = \overline{w - p} + p_{t+i|t} - p_{t+i} - \ln \psi$$

where ψ is labor's share of output. Choosing units so that $n_{t+i|t} = 0$, $\ln\psi = \overline{w - p}$ and

$$n_{t+i} = [1/(1 - \psi)](p_{t+i} - p_{t+i|t})$$

making

$$y_{t+i} = [\psi/(1 - \psi)](p_{t+i} - p_{t+i|t})$$

Hence, $\theta = \psi/(1 - \psi)$ and $d\theta/d\psi = 1/(1 - \psi)^2 > 0$ for $0 < \psi < 1$.

8/ See Gray (1978) and Canzoneri (1981) for a discussion of the determinants of ϕ.

9/ Starting with permanent disturbances, π_1 is clearly less than 1, and

$$\varepsilon_1 = 1 + (1 - \delta)\theta\rho/\lambda[(1 - \rho)(1 + \lambda) + \theta]$$

is greater than 1 if $\delta < 1$. Similarly, for temporary disturbances

$$\pi_3 = [1/(1 + \lambda)] - \theta/(1 + \lambda)[(1 - \rho)(1 + \lambda) + \theta]$$

is less than $1/(1 + \lambda)$, and

$$\varepsilon_3 = [1/(1 + \lambda)] + (1 - \delta)\theta(1 - \rho)/\delta(1 + \lambda)[(1 - \rho)(1 + \lambda) + \theta]$$

is greater than $1/(1 + \lambda)$ if $\delta < 1$.

10/ Contracting does make the condition for $\tilde{z}_t$ to have a greater impact on e_t than p_t less stringent. $\varepsilon_4 > \pi_4$ if $\lambda < 1 + \theta$. In the flexible wage model, the conditon was $\lambda < 1$.

11/ It may be interesting to note that Dornbusch (1976) gets precisely the same condition for overshooting in his fixed-price model. A small δ keeps demand from increasing too much in equation (1) in response to the decrease in the terms of trade.

12/ The coefficients for the monetary disturbances in equation (14) depend directly upon θ; that is,

$$d(\theta\pi_1)/d\theta = (1 - \rho)^2(1 + \lambda)^2/[(1 - \rho)(1 + \lambda) + \theta]^2 > 0$$

$$d(\theta\pi_3)/d\theta = (1 - \rho)^2(1 + \lambda)/[(1 - \rho)(1 + \lambda) + \theta]^2 > 0$$

Exchange rate overshooting depends directly upon θ,

$$d(\varepsilon_1 - 1)/d\theta = (1 - \delta)(\rho/\lambda)(1 - \rho)(1 + \lambda)/[(1 - \rho)(1 + \lambda) + \theta]^2 > 0$$

as does price level undershooting

$$d(1 - \pi_1)/d\theta = (1 - \rho)(1 + \lambda)/[(1 - \rho)(1 + \lambda) + \theta]^2 > 0$$

13/ A relatively elastic employment rule is also consistent with another stylized fact. Real wages do not seem to follow a strongly countercyclical pattern. However, a formal empirical application of this model may benefit from the disaggregation suggested by Lucas, Sargent and Wallace; see Canzoneri (1978) and the references therein.

14/ The "implicit contracts" literature referred to in footnote 6 suggests instead that the employment rule should be relatively inelastic as wage setters try to smooth employment variation.

15/ Permanent goods market disturbances would have the same effect if they were not totally absorbed by the exchange rate.

16/ For permanent monetary disturbances, the increased impact on the price level is shown by

$$\frac{d\pi_1}{d\phi} = \frac{.5\theta(1 - \delta)\rho(1 - \rho)^2(1 + \lambda)[(1 - \rho)(1 + \lambda) + \theta]}{\{(1 - \rho)^2(1 + \lambda)^2 + \theta(1 - \rho)(1 + \lambda) + .5\phi\theta[(1 - \rho)(1 + \lambda) + \theta]\}^2}$$

which is positive for all ϕ. The increase in exchange rate overshooting is apparent from the fact that $d(\varepsilon_1 - 1)/d\phi = (1 + \theta/\delta)d\pi_1/d\phi$.

17/ As shown in footnote 16, $d\pi_1/d\phi > 0$; so the immediate impact on output is bigger for larger ϕ. From equation (1), this means that the immediate impact on $e - p$ must also be bigger.

18/ These latter features are not necessary. We could, as in the last section, specify an employment rule and let the price level move to clear the goods market. Taylor however wanted a model that de-emphasized the cyclical role of real wages; see footnote 13.

19/ Taylor (1979, 1980) uses $y_{t|t-1}$ and $y_{t+1|t-1}$ to measure expected demand pressure. In his model these measures reduce to expected real balances, but in ours they do not (except in special cases where $e_{t+1|t-1} - e_{t|t-1} = 0$). Our specification is necessary to retain the simplicty of Taylor's solution. In particular, if we had used $y_{t+1|t-1}$ and $y_{t|t-1}$, we would have had to solve the following cubic equation in α:

$$\alpha = .5(1 - .5\gamma)(\alpha^2 + 1) - .5\gamma\alpha + .25\gamma\rho(1 - \delta)(1 - \alpha^2)(\alpha + 1)$$

20/ Derivation of this solution is discussed in an appendix.

21/ We will assume γ is less than two. If γ is greater than two, the moderating effect of expected demand pressures is so great that α is negative.

22/ The moving average representations for $\tilde{x}_t$ disturbances are given in an appendix.

23/ The normative implications of the neo-Keynesian contracting model discussed in section II.C. are less clear to us; so we restrict our attention here to the neo-Classical model.

24/ Equation (3) asserts that risk neutral agents dominate the market, but that does not preclude the existence of risk averse agents. More generally, similar results would be obtained in a model in which bonds were imperfect substitutes.

25/ See footnote 6.

26/ Here, as above, we have set p_t^* equal to zero.

27/ Labor suppliers would be more like portfolio managers in this if we had not assumed that labor supply is perfectly inelastic; see footnote 3. Labor demanders would remain interested in own-price prediction errors.

28/ See footnote 9.

29/ See footnote 16.

30/ ε_4 falls less than π_4; see footnote 10. So it is possible that portfolio managers will be worse off if ω is large enough.

31/ See footnote 16 and the definition of π_2 in equation (15).

32/ Indeed, one might expect the number of two-period contracts to grow as a result of this policy because, as shown below, the variance of two-period prediction errors is diminished; see Canzoneri (1980).

33/ When $\phi = 0$, $\pi_1 = \pi_3(1 + \lambda) > \pi_3$. Since $d\pi_1/d\phi > 0$ (see footnote 6) and $d\pi_3/d\phi = 0$, $\pi_1 > \pi_3$ for all ϕ between zero and one.

34/ $\varepsilon_1 = [1 + (\theta/\delta)]\pi_1 > [1 + (\theta/\delta)]\pi_3 = \varepsilon_3$ since $\pi_1 > \pi_3$.

35/ $d\pi_3/dg$ is clearly negative, and $\pi_3 \to 0$ as $g \to \infty$.

36/ $d\pi_4/dg = \delta(1 + \theta)n^2 > 0$, and for permanent disturbances $\pi_5 - \pi_6 = 0$ if g is set equal to zero.

37/ Wage setters would actually prefer a policy that destabilized exchange rates in the case of temporary goods market disturbances. Setting $g = -\lambda$ would make $\pi_4 = 0$, but it would also increase ε_4 to

$\varepsilon_4 = (1 + \theta)/\ (\delta + \theta\delta) = 1/\delta$; with this policy, temporary goods market disturbances (rather than permanent ones) would be totally absorbed by the exchange rate. Turnovsky (   ) and Buiter and Eaton (1980) have found similar results.

Using the above equation and equations (18) and (19) from the main text, we can solve for the α's. We then postulate a solution for e_t.

$$e_t = -\beta_1 x_{t-1} + \beta_2 m_{t-1} - \beta_3 \tilde{x}_t + \beta_4 \tilde{m}_t + \beta_5 \tilde{v}_t - \beta_6 \tilde{z}_t$$

We use this equation together with the money market equilibrium condition, to solve for the β's.

Appendix: Moving Average Representation of the Solution to the Neo-Keynesian Contracting Model with Wage Disturbances

The following equations show how disturbances to the wage setting process affect wages, prices, the exchange rate, and output under the assumption that all other disturbances are zero.

$$x_t = \Sigma_{i=0}^{\infty} \alpha^i \tilde{x}_{t-i} \qquad e_t = -\beta_3 \tilde{x}_t - \beta_1 \Sigma_{i=1}^{\infty} \alpha^{i-1} \tilde{x}_{t-i}$$

$$p_t = .5\tilde{x}_t + .5(1 + \alpha)\Sigma_{i=1}^{\infty} \alpha^{i-1} \tilde{x}_{t-i}$$

$$y_t = -\delta(\beta_3 + .5)\tilde{x}_t - \delta(\beta_1 + .5(1 + \alpha))\Sigma_{i=1}^{\infty} \alpha^{i-1} \tilde{x}_{t-i}$$

With $\gamma < 2$ (see footnote 21 of the main text), $0 < \alpha < 1$, and the effect of a wage disturbance on wage setting dies out monotonically. The price of the home good rises for two periods and then drops monotonically. The exhange rate may appreciate and output may fall for two periods before decaying monotonically to their long-run values.

Appendix: Model Solutions

We solve the models given in the paper by the method of undetermined coefficients. We postulate that the dependent variables of interest, the exchange rate and the home good price, are linear functions of current and lagged disturbances. For example we might postulate that, given the flexible wage model,

$$(1A) \quad e_t = \tilde{m}_t + m_{t-1} + \varepsilon_3 \tilde{v}_t - \varepsilon_4 \tilde{z}_t - \varepsilon_5 \tilde{u}_t - \varepsilon_6 u_{t-1}$$

From the money market equilibrium condition we have

$$(2A) \quad p_t = \lambda(e_{t+1|t} - e_t) + m_{t-1} + \tilde{m}_t + \tilde{v}_t$$

We note that

$$(3A) \quad e_{t+1|t} - e_t = -\varepsilon_3 \tilde{v}_t + \varepsilon_4 \tilde{z}_t + (\varepsilon_5 - \varepsilon_6)\tilde{u}_t$$

From equation (1) in the main text, the goods market equilibrium condition is,

$$(4A) \quad e_t = p_t - 1/\delta(u_{t-1} + \tilde{u}_t + \tilde{z}_t)$$

Using (2A) and (3A) we can solve (4A) for e_t as a function of the exogenous shocks. We equate the coefficients in this solution to those in (1A) and solve for the ε's. The resulting values are those in text equation (7). Knowing the ε's, we can use (2A) and (3A) to solve for text equation (8).

The fixed wage model is solved in a similar manner. First assuming that $\phi = 0$, we postulate that

$$(5A)\quad e_t = \varepsilon_1\tilde{m}_t + m_{t-1} + \varepsilon_3\tilde{v}_t - \varepsilon_4\tilde{z}_t - \varepsilon_5\tilde{u}_t - \varepsilon_6 u_{t-1}$$

$$(6A)\quad p_t = \pi_1\tilde{m}_t + m_{t-1} + \pi_3\tilde{v}_t + \pi_4\tilde{z}_t + \pi_5\tilde{u}_t + \pi_6 u_{t-1}$$

We can then substitute for e_t, p_t, and $p_{t|t-1}$ in the goods market equilibrium condition,

$$\theta(p_t - p_{t|t-1}) - \delta(e_t - p_t) - u_{t-1} - \tilde{u}_t - \tilde{z}_t = 0 .$$

We can then solve for the ε's in terms of the π's. (Since this equation must hold for all possible values of the shocks, the coefficient of each shock must equal zero.) We can rewrite the money market equilibrium condition, equation (4) in the main text, as

$$(1 + \theta)p_t = \lambda(e_{t+1|t} - e_t) + m_{t-1} + \tilde{m}_t + \tilde{v}_t + \theta p_{t|t-1}$$

We can solve for p_t substituting for $e_{t+1|t} - e_t$ and $p_{t|t-1}$ using (5A) and (6A) and writing the ε's in terms of the π's. We can equate the coefficients from this equation with those in (6A) and solve for the π's. The model with ϕ different from zero is solved in the same way.

The neo-Keynesian contracting model is solved in two steps. First we postulate a solution for x_t.

$$x_t = \alpha_1 x_{t-1} + \alpha_2 m_{t-1} + \alpha_3\tilde{x}_t$$

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