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MONETARY POLICY AND THE INFORMATIONAL IMPLICATIONS OF THE PHILLIPS CURVE IN AN OPEN ECONOMY

George Alogoskoufis

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Centre for Economic Policy Research
6 Duke of York Street
London SW1Y 6LA

Tel: 01 930 2963

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ABSTRACT

In this paper I examine optimal monetary policy and the informational implications of the Phillips curve in a stochastic model of a small open economy. It is assumed that the economy produces both traded and non-traded goods, that capital mobility is perfect and that the economy faces a variety of unanticipated transitory disturbances to demand, supply and the foreign sector. It is also assumed that wages are not only indexed to the price level, but also respond to the state of the labour market. If the authorities have only imperfect information about current disturbances, this gives independent informational content to wages, over and above the information conveyed by other aggregate prices. The optimal policy in this model involves not only intervention in the foreign exchange market but also accommodation of wage growth, as the exchange rate and wages are only partially correlated signals about the unobserved disturbances.

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George Alogoskoufis
Department of Economics
Birkbeck College
University of London
7-15 Gresse Street
London W1P 1PA

Tel: 01 631 6493

NON-TECHNICAL SUMMARY

The appropriate form of stabilization policy is probably one of the most important policy questions facing both academic economists and policy-makers. Debates over stabilization policy focus on both the objectives of policy and the appropriate model. An important class of models of aggregate fluctuations assumes that the labour market fails to adjust adequately to disturbances and thus becomes the main source of the distortions usually associated with the business cycle. This of course was the main message of Keynes's General Theory, and is still the main difference between followers of the Keynesian and Classical traditions.

A number of recent papers have focused on stabilization policy in stochastic open economy models and its dependence on the exchange rate regime, the extent of wage indexation, and the information set currently available to the monetary authorities. The framework that these models use to characterize wage adjustment is usually that associated with Gray's 1976 paper, which assumed that nominal wages are negotiated in advance of the realization of the current disturbances, with a view of ensuring expected labour market equilibrium. Ex-post wages are only partially indexed to the price level, in which case there is scope for a stabilization policy rule involving feedback. It is also assumed that the information set currently available to the monetary authorities consists of full knowledge about past (but not current) disturbances and the current aggregate prices in the economy (which may or may not be a sufficient statistic for the current disturbances). If prices are not a sufficient statistic, then the monetary policy rule must be conditioned on all price variables with informational content, since policy cannot be directly conditioned on the disturbances themselves.

This paper is concerned with the design of stabilization policy in a small open economy. The discussion is conducted within the framework of a theoretical, stochastic model of an economy producing both internationally traded and non-traded goods, and

in which international capital mobility is perfect but wage adjustment is sluggish. On the demand side, I assume that the demand for money depends positively on the price level and output, and negatively on the domestic interest rate. I assume that uncovered interest parity holds, so that the domestic interest rate is equal to the world interest rate, minus the rate of expected exchange rate depreciations. Finally, relative purchasing power parity is assumed to hold for the traded goods sector. The change in the domestic prices of traded goods is equal to current exchange rate depreciations plus the world rate of inflation for traded goods.

In the traded-goods sector I assume that there are decreasing returns to employment and that the product market is competitive. Labour demand is a negative function of the real wage, and a positive function of productivity (supply) disturbances. The non-traded good is assumed to be a service, produced under constant returns to scale. The price of the non-traded good is then proportional to the wage, and the latter is assumed to be equal in the two sectors. There is a notional labour supply curve, in which supply responds positively to transitory increases in wages. Wages are assumed to adjust as postulated by a Phillips-type relationship: they are partially indexed to domestic inflation, and negatively related to the rate of unemployment.

This paper thus departs from previous analyses by replacing the Gray-type wage-adjustment assumption with a more conventional Phillips-type wage equation. There is overwhelming empirical evidence for most OECD economies that nominal wages respond not only to current inflation surprises but also to current unemployment.

The model can explain a number of stylized facts about aggregate fluctuations in open economies. The disturbances that disrupt equilibrium in the model are assumed to be of a transitory nature. The paper considers the effects of supply disturbances, autonomous wage push, money-demand disturbances and disturbances in world prices and interest rates. Because of the sluggish nature of wage adjustment, such disturbances cause real variables to deviate from their equilibrium paths, defined as the path where the labour market clears.

It is assumed that the objective of stabilization policy should be to minimize the deviations of real variables from equilibrium. The bulk of the paper is devoted to a discussion of the nature of the appropriate reactions of monetary policy to the various disturbances, both when the authorities have complete information concerning the disturbances affecting the economy and when they do not.

Under full information, perfect stabilization can be achieved through "first-best" policies. Money-demand shocks should be fully accommodated: this neutralizes the effects of the shocks on domestic inflation and hence any possible effects they might have on employment and output through changes in real wages. Optimal monetary policy should be tightened in response to increases in world interest rates or inflation. The optimal reaction coefficients are equal to the interest rate semi-elasticity of money demand. An optimal monetary policy under full information would accommodate "wage push": this tends to increase real wages and so a monetary accommodation which allows inflation to rise will help restore real wages to their equilibrium value. Finally, supply shocks are accommodated only to the extent that they cause a real wage increase which is higher than the equilibrium increase. Again monetary accommodation serves the purpose of reducing real wages, by increasing price inflation.

One common criticism of such first-best policies is that they may not be feasible, mainly because the monetary authorities do not possess full information about the disturbances affecting the economy. Thus, I also examine the case where the monetary authorities only observe current aggregate prices instead of the disturbances themselves. It turns out that prices do not capture fully all the information concerning the disturbances: they are not sufficient statistics for these disturbances and the authorities have a genuine inference problem.

The "second-best" policy is for the authorities to react to world interest rates and inflation in the same manner as in the first-best policy, and also to react to those prices that have independent informational content, namely the exchange rate and wages. This policy involves an optimal degree of exchange market intervention and an optimal degree of wage accommodation. The optimal second-best policy can also be expressed in terms of accommodation of inflation in the traded-goods sector, and accommodation (or non-accommodation) of real wage growth. This is because these pairs of variables contain information about the unobservable money-demand, productivity and wage-push disturbances. The nature of the second-best policy can be understood if one views the monetary authorities as first calculating the best estimates of the current values of the three unobserved disturbances (i.e. supply, money-demand and wage-push) based on their observations on wages and the exchange rate. The authorities then calculate their response to these estimated disturbances as suggested by first-best policy considerations. Because the estimates, although optimal, are not perfect, the resulting policy is second-best.

The main implication of the Phillips-type wage adjustment is that current nominal wages convey information concerning the disturbances, over and above the informational content of the exchange rate. Optimal stabilization policy therefore involves not only exchange market intervention, but also an optimal degree of wage accommodation (or non-accommodation for that matter). Thus the paper provides a rationale for wage accommodation in addition to exchange market intervention. In contrast to the models based on the Gray framework, wage accommodation is not a substitute for exchange market intervention, but a complement. Both are required as part of the second-best optimal monetary policy under imperfect information.

1. Introduction.

The appropriate form of stabilization policy is probably one of the most important policy questions facing both academic economists and policymakers.

As in all intelligent discussions about economic policy, disagreements focus on the appropriate model and the objectives of policy. An important class of models of aggregate fluctuations assumes that the labour market fails to adjust adequately to the various disturbances, and thus becomes the main source and propagating mechanism of the distortions usually associated with the business cycle. This of course was the main message of Keynes' *General Theory*, and is still the main difference between followers of the keynesian and classical traditions.

A number of recent papers have focused on stabilization policy in stochastic open economy models, and its dependence on the exchange rate regime, the extent of wage indexation, and the information set currently available to the monetary authorities.[1]

The main set of assumptions that these models use to characterize wage adjustment is the framework usually associated with Gray's 1976 paper. It is assumed that nominal wages are negotiated in advance of the realization of the current disturbances, with a view of ensuring expected labour market equilibrium, and that ex post they are only partially indexed to the price level. It is also usually assumed that indexation is non optimal, in which case there is scope for a feedback stabilization policy rule. As for commodity and asset markets, it is usually assumed that prices can jump to equilibrate them. Finally, it is assumed in many cases that the information set currently available to the monetary authorities consists of full knowledge about past disturbances, and the vector of current aggregate prices in the economy, which may or may not be a sufficient statistic for current disturbances. If it is not a sufficient statistic, then the monetary policy rule is conditioned on all price variables with informational content, as it cannot be directly conditioned on the disturbances themselves.

This paper differs from the previous ones in this strand of the literature, in that it complements the Gray-type wage adjustment assumption, with a more conventional Phillips-type wage adjustment assumption. There is overwhelming empirical evidence for most OECD economies, that nominal wages respond not only to current inflation surprises, but also to current unemployment (see for example Bruno and Sachs (1985) and Grubb (1986)). In addition, this is an assumption that has been used in many deterministic macroeconomic policy models (see Buiter and Miller (1981) for example). In this paper I explore its implications for the optimal design of stabilization policy in a stochastic model of the type described above, where the vector of current prices observed by the monetary authorities is not a sufficient statistic for the current disturbances.

The main implication of the aforementioned extension of the wage adjustment assumption is that current nominal wages have informational content, over and above the informational content of the exchange rate. The significance of this for optimal stabilization policy is that in addition to exchange market intervention, the monetary policy rule involves an optimal degree of *wage accommodation* (or non-accommodation for that matter). Thus, this paper provides a rationale for wage accommodation in addition to exchange market intervention. In contrast to the models based on the Gray framework (see for example Aizenman and Frenkel (1985, 1986)), wage accommodation is *not* a substitute for exchange market intervention, but a complement. Both are required as part of the second-best optimal monetary policy under imperfect information.

The model studied in this paper is one of an open economy which produces both tradable and non-tradable goods and which faces perfect capital mobility. It is a fairly general Mundell-Fleming structure, as it allows for the simultaneous occurrence of a number of shocks, and it can account for many of the stylized facts about aggregate fluctuations in small open economies. For example, it can account for positive output-inflation tradeoffs, the positive correlation between nominal and real exchange rates and nominal and real wages and the negative correlation between real wages and unemployment. On the other hand it allows for either positive or negative correlations between output and real wages, or output and competitiveness, as these correlations depend on the relative variances of demand and supply shocks. The structure studied is sufficiently rich to account for the aforementioned phenomena, but also sufficiently simple to allow for the model to be solved analytically, and for stabilization policy to be examined in the manner known to us from welfare economics. This simplicity stems from the assumption, common to macroeconomics, that growth and fluctuations can be analyzed independently. This is formalized in the context of this paper by assuming that all disturbances are transitory, that they do not affect the long-run evolution of the economy, and that the only adjustment costs that exist are those related to wage adjustment. These assumptions, especially the latter, ensure that the only source of aggregate distortions in this model is the labour market, and suggest, as in Aizenman and Frenkel (1985, 1986), a simple and intuitive measure of the welfare loss of aggregate fluctuations.[2]

The rest of the paper is organized as follows: In section 2 I present the model. Its structure and predictions are highlighted for flexible exchange rates, and a completely passive monetary policy. The nature of the welfare losses is also illustrated in this section. In sections 3 and 4 I analyze optimal policy, both under full information (*first-best*), and under imperfect information (*second-best*). Conclusions and suggestions for future research are summarized in the last section.

2. The Model.

In what follows I shall treat all variables as percentage deviations from their equilibrium levels in the absence of stochastic shocks.[3]

The economy is assumed to consist of two sectors, the one producing internationally traded commodities, and the other non-traded.

The deviation of the output of tradables from non-stochastic equilibrium is given by,[4]

$$y^T = \pi \ell^T + \mu \quad ; \quad 0 < \pi < 1 \tag{1}$$

where ℓ is employment, π the elasticity of output with respect to employment, and μ a transitory shock to the production function. It is assumed that $\mu \sim NI(0, \tau_{\mu}^{2})$.

Under profit maximization, the deviation in the demand for labour in the tradables sector is,

$$\ell^{T} = -\lambda(w-p^{T}) + \lambda\mu \quad ; \quad \lambda = \sigma/(1-\pi) \tag{2}$$

where w is the nominal wage, p^{T} the price of tradables in domestic currency units, and σ the elasticity of substitution between labour and capital. The capital stock is assumed fixed.

In the non-tradables sector, it is assumed that output is proportional to employment.

$$y^{N} = \ell^{N} \tag{3}$$

Thus, demand for labour is independent of the wage. I assume that,

$$\ell^{N} \sim NI(0, \tau_{\ell}^{2})$$

where ℓ^{N} is a transitory shock to employment in the N sector.

From (3), the price of tradables adjusts in the same proportion as the economy wide nominal wage.

$$p^{N} = w \tag{4}$$

Assume that in equilibrium the proportion of tradables in output, employment and consumption is ν. Then,

$$y = \nu y^T + (1-\nu)y^N \tag{5}$$

$$\ell = \nu\ell^T + (1-\nu)\ell^N \tag{6}$$

$$p = \nu p^T + (1-\nu)p^N \tag{7}$$

(5), (6) and (7) give us the short run deviations of aggregate output, employment and the price level.

I further assume a short run labour supply function for the whole economy. Labour supply is modelled as a positive function of the *real* wage.

$$\ell^s = \epsilon(w-p) = \epsilon\nu(w-p^T) \quad ; \quad \epsilon > 0 \tag{8}$$

where ϵ is the elasticity of labour supply with respect to transitory changes in the real wage.

The next assumption about wage adjustment is a very crucial one. Following a long tradition in macroeconomics, I shall assume that wages are negotiated in advance of the realization of the stochastic shocks in order to ensure expected labour market equilibrium. Ex post however, they are only partially indexed to the price level, and they respond only partially to excess supply in the labour market. The assumption is a generalization of the framework of Gray (1976), to allow for unemployment to affect wage adjustment.

Firms determine employment ex post, and thus, the labour supply (8) is only "notional". The wage adjustment equation is

$$w = \tilde{\theta}p - \tilde{\eta}(\ell^{S}-\ell) + \tilde{\omega} = \theta p^{T} - \eta(\ell^{S}-\ell) + \omega \qquad (9)$$

where $\tilde{\theta}$ is the degree of wage indexation to the price level, $\tilde{\eta}$ the responsiveness of nominal wages to unemployment, and $\tilde{\omega}$ a wage shock, distributed normally with zero mean and constant variance. From (6),

$$\theta = \tilde{\theta}\nu/(1-\tilde{\theta}(1-\nu)), \quad \eta = \tilde{\eta}/(1-\tilde{\theta}(1-\nu)), \quad \omega = \tilde{\omega}/(1-\tilde{\theta}(1-\nu))$$

From the properties of $\tilde{\omega}$, $\omega \sim NI(0, \sigma_{\omega}^{2})$. Clearly, $\theta \gtreqless 1$, as $\tilde{\theta} \gtreqless 1$. Thus, θ, the indexation parameter to the price of tradables, is smaller than unity if $\tilde{\theta}$ is smaller than unity, and equal to zero (one) as $\tilde{\theta}$ is equal to zero (one). (9) is a sufficiently general labour market adjustment equation, that encompasses most of the cases considered in the literature. If $\theta=1$ and $\eta=0$, then we have *real wage rigidity*, with neither inflation, not unemployment affecting real wages, as indexation is full and unconditional. If $\theta=0$ and $\eta=0$, we have *nominal wage rigidity*, with neither inflation nor unemployment affecting nominal wages, but with inflation affecting real wages (see Sachs (1980) among others). With $0 \leq \theta \leq 1$, $\eta=0$, we have the framework of Aizenman and Frenkel (1985), where wages are indexed to the price level but do not respond to unemployment independently. As $\eta \rightarrow \infty$, we approach to continuous labour market equilibrium, with wages being sufficiently flexible, to guarantee equality of labour demand and supply (see Alogoskoufis (1983) and Aizenman

(1986)). With $0<\theta<1$ and $0<\eta$, as will be assumed in this paper, we have a short run Phillips curve, a relationship that has been shown to hold for most OECD economies (see Bruno and Sachs (1985) and Grubb (1986), among others).

We next turn to the demand side. There is a demand for money function, given by,

$$m = p + y - \alpha i + k \qquad (10)$$

where k is a stochastic independent shock to money demand, $k \sim NI(0,\tau_k^2)$. α is the interest rate semi-elasticity of money demand, and i is the (deviation in the) domestic interest rate. i is determined by uncovered interest parity.

$$i = \rho + s^e \qquad (11')$$

where s^e is the expected rate of future depreciation of the exchange rate, and ρ is a shock to the world interest rate. $\rho \sim NI(0,\tau_\rho^2)$. Since all shocks to the economy are transitory, the expected rate of future depreciation is equal to minus the rate of current depreciation, i.e.

$$i = \rho - s \qquad (11)$$

where s is the current rate of depreciation.

We finally assume that perfect commodity arbitrage ensures that purchasing power parity holds for tradable goods, i.e.

$$p^T = s + \chi \quad (12)$$

where χ is a transitory shock to the foreign currency price of tradable goods. $\chi \sim NI(0, \tau_\chi^2)$.

The model described by (1) to (12) can be used to determine the values of the endogenous variables y, p, i, w, p^T, ℓ, $u=\ell^S-\ell$ and one of the pair (s, m), in terms of the shocks and the structural parameters. Under fixed exchange rates s=0 and the model determines m, whereas under flexible exchange rates s is endogenous and m can be controlled by the monetary authorities. Competitiveness in this model is defined as the relative price of tradables to non-tradables, i.e p^T-w.

In order to illustrate the properties of the model under flexible exchange rates, I shall assume that the money stock innovation is exogenous, and that it follows a white noise process. This is equivalent to a non-contingent monetary policy rule.

$$m \sim NI(0, \tau_m^2)$$

To solve the model let us define excess labour supply, i.e unemployment. From (2), (3), (6) and (8),

$$u = \ell^S - \ell = \nu(\epsilon+\lambda)(w-p^T) - \nu\lambda\mu - (1-\nu)\ell^N \quad (13)$$

From (9), (12) and (13), we can substitute out unemployment, and express the product wage as a function of the exchange rate, the world price of tradables, productivity, and employment and wage determination shocks. We get,

$$w-p^T = -w_p(s+\chi) + w_\mu \mu + w_\ell \ell^N + w_\omega \omega \tag{14}$$

where the respective elasticities are defined as:

$w_p=(1-\theta)/[1+\eta\nu(\epsilon+\lambda)] < 1$, $w_\mu=\eta\nu\lambda/[1+\eta\nu(\epsilon+\lambda)]$, $w_\ell=\eta(1-\nu)/[1+\eta\nu(\epsilon+\lambda)]$, $w_\omega=1/[1+\eta\nu(\epsilon+\lambda)]$.

From (1), (2), (3), (5), (12) and (14) we can define an *aggregate supply function*,

$$y = y_p(\chi+s) + y_\mu \mu + y_\ell \ell^N - y_\omega \omega \tag{15}$$

where $y_p=\nu\pi\lambda w_p$, $y_\mu=\nu[1 + \pi\lambda(1-w_\mu)]$, $y_\ell= 1 - \nu(1 + \pi\lambda w_\ell)$, $y_\omega=\nu\pi\lambda w_\omega$

Since y_p is unambiguously positive for $\theta<1$, output supply is positively related to exchange rate depreciations, because the latter cause a reduction in the product wage.

Before turning to the demand side, let us define deviations in the price level in terms of the various supply shocks, and the exchange rate. From (7), (9) and (13),

$$p = p_p(s+\chi) + p_\mu \mu + p_\ell \ell^N + p_\omega \omega \tag{16}$$

where $p_p = 1 - w_p(1-\nu)$, $p_\mu = (1-\nu)w_\mu$, $p_\ell = (1-\nu)w_\ell$, $p_\omega = (1-\nu)w_\omega$.

Turning to the demand side, from (10), (11) and (16), we can obtain an expression for *aggregate demand*:

$$y = m - p_p\chi - p_\mu\mu - p_\ell\ell^N - p_\omega\omega + \alpha\rho - k - (p_p+\alpha)s \qquad (17)$$

The aggregate demand schedule is negatively related to exchange rate depreciations, as exchange rate depreciations cause an increase in the price level, which depresses real money balances, and a decrease in the domestic nominal interest rate, which boosts the demand for real money balances. For the money market to equilibrate, output must go down to more than counteract the increase in money demand caused by lower interest rates, and make the lower real money stock willingly held.

The equilibrium exchange rate depreciation is determined by the intersection of the aggregate supply schedule (15), and the aggregate demand schedule (17). From these two schedules, the reduced form equation for the exchange rate is given by,

$$s = \frac{1}{y_p+p_p+\alpha}\left[m - k + \alpha\rho - (y_p+p_p)\chi - (y_\mu+p_\mu)\mu - (y_\ell+p_\ell)\ell^N + (y_\omega+p_\omega)\omega \right] \qquad (18)$$

The remaining endogenous variables are easily determined, by substituting (18) in the PPP condition for tradables, in the uncovered interest parity condition, in the wage equation, the unemployment equation, the employment equation, and the output equation. It is easy to show that unanticipated shocks in the money supply cause exchange rate depreciations and inflation, reduce real wages and unemployment, increase output and employment, and increase competitiveness. Shocks to money demand have the opposite effects. Shocks in world inflation, cause nominal appreciations, inflation, real wage and unemployment reductions, increases in output and employment, and increased competitiveness. World interest rate shocks have similar effects, only that they are associated with nominal exchange rate depreciations. Supply shocks cause nominal exchange rate appreciations, falls in the price level, real wage increases and unemployment reductions, increases in employment and output, but reductions in competitiveness.It is also easy to demonstrate that there is a positive correlation between nominal and real exchange rates, a positive correlation between output and inflation, and a negative association between unemployment and real wages.

The question naturally arises: What is the welfare cost of aggregate fluctuations in the context of this model? An appealling measure of the welfare cost has been proposed by Aizenman and Frenkel (1985, 1986). They propose and demonstrate that the welfare cost can be measured by the loss of producers' and consumers' surplus, induced by being away from labour market equilibrium. Given that the distortion in this model arises in the labour market because of incomplete wage adjustment, a sensible objective for the monetary authority would be to try to minimize the welfare loss associated with the perceived discrepancy between *equilibrium*, and *actual* employment, given the realization of the shocks. In order to compute the welfare loss, we need to multiply this discrepancy by one half of the difference between the demand and the supply real wages at the actual employment level. This procedure amounts to a computation of the area of the triangle representing the welfare cost in terms of the loss of consumers' and producers' surplus.

Using (2), (6) and (8), we can determine stochastic equilibrium (deviations in) employment, as,

$$\tilde{\ell} = \frac{\epsilon\nu}{\epsilon+\lambda} \left(\lambda\mu + \frac{(1-\nu)}{\nu}\ell^N \right) \tag{19}$$

This has to be compared with (deviations in) actual employment.

$$\ell = \nu\ell^T + (1-\nu)\ell^N = -\nu\lambda(w-p^T - \mu) + (1-\nu)\ell^N \tag{20}$$

From (19) and (20),

$$\ell-\tilde{\ell} = \nu\lambda[-(w-p^T) + \frac{\lambda}{\epsilon+\lambda}\mu] + (1-\nu)\frac{\lambda}{\epsilon+\lambda}\ell^N \tag{21}$$

From the demand for, and supply of labour, the demand and supply wages at the actual employment level can be written as:

$$(w-p^T)_d = - (\ell-\tilde{\ell})/\nu\lambda + (\tilde{w}-\tilde{p}^T) \tag{22a}$$

$$(w-p^T)_s = (\ell-\tilde{\ell})/\nu\epsilon + (\tilde{w}-\tilde{p}^T) \tag{22b}$$

From (21), (22a) and (22b), the welfare loss is given by

$$\frac{1}{2} (\ell-\tilde{\ell})^2 [\frac{1}{\nu\epsilon} + \frac{1}{\nu\lambda}] \tag{26'}$$

It is clear from (26'), that once we omit the irrelevant constants, minimizing the expected welfare loss amounts to minimizing,

$$H = E\{ (\ell-\tilde{\ell})^2 | A \} = E\{ [\nu\lambda\{-(w-p^T) + \frac{\lambda}{\epsilon+\lambda}\mu\} + (1-\nu)\frac{\lambda}{\epsilon+\lambda}\ell^N]^2 | A \} \tag{26}$$

where A is the information set of the monetary authorities.

3. Optimal Monetary Policy Under Perfect and Imperfect Information.

In order to analyze optimal policy, we have to specify the information set of the monetary authorities. Our main objective is to analyze optimal policy under imperfect information. However, in order to appreciate the nature of this second-best problem, it is useful to know the form of the first-best reactions of monetary policy to the various disturbances. Since the welfare objective is quadratic in the disturbances, the optimal monetary policy rule will be linear. Let us assume it is of the following form:

$$m = - m_k k - m_\chi \chi - m_\rho \rho - m_\mu \mu - m_\ell \ell - m_\omega \omega \tag{27}$$

where the m_is are parameters to be determined by minimizing the welfare loss function (26).

Substituting (27) for m in (18) we end up with the following reduced form exchange rate equation:

$$s = \frac{1}{y_p+p_p+\alpha} \Big[- (1+m_k)k - (y_p+p_p+m_\chi)\chi + (\alpha-m_\rho)\rho - (y_\mu+p_\mu+m_\mu)\mu - (y_\ell+p_\ell+m_\ell)\ell^N + (y_\omega+p_\omega-m_\omega)\omega \Big] \tag{28}$$

From (28) and (12), p^T is determined by:

$$p^T = \frac{1}{y_p+p_p+\alpha}\Big[-(1+m_k)k + (\alpha-m_\chi)\chi + (\alpha-m_\rho)\rho - (y_\mu+p_\mu+m_\mu)\mu - (y_\ell+p_\ell+m_\ell)\ell^N + (y_\omega+p_\omega-m_\omega)\omega \Big] \tag{29}$$

From (28), (14) and (21), the deviation between actual and equilibrium employment is given by:

$$\ell-\hat{\ell} = \frac{\nu\lambda}{y_p+p_p+\alpha}\Big[-w_p(1+m_k)k + w_p(\alpha-m_\chi)\chi + w_p(\alpha-m_\rho)\rho \Big] - \nu\lambda\Big[\frac{w_p}{y_p+p_p+\alpha}(y_\mu+p_\mu+m_\mu)+w_\mu-\frac{\lambda}{\epsilon+\lambda}\Big]\mu - \nu\lambda\Big[\frac{w_p}{y_p+p_p+\alpha}(y_\ell+p_\ell+m_\ell)+w_\ell-\frac{1-\nu}{\nu(\epsilon+\lambda)}\Big]\ell^N + \nu\lambda\Big[\frac{w_p}{y_p+p_p+\alpha}(y_\omega+p_\omega-m_\omega)-w_\omega\Big]\omega \Big] \tag{30}$$

Substituting (30) in the expected welfare loss function (26), and minimizing the resulting expression with respect to the μ_is, we end up with the following optimal monetary policy parameters.

$$m_k = -1 \tag{31a}$$

$$m_\chi = \alpha \tag{31b}$$

$$m_\rho = \alpha \tag{31c}$$

$$m_\mu = -(y_\mu+p_\mu) - \frac{y_p+p_p+\alpha}{w_p}\left(w_\mu - \frac{\lambda}{\epsilon+\lambda}\right) \tag{31d}$$

$$m_\ell = -(y_\ell+p_\ell) - \frac{y_p+p_p+\alpha}{w_p}\left(w_\ell - \frac{1-\nu}{\nu(\epsilon+\lambda)}\right) \tag{31e}$$

$$m_\omega = y_\omega + p_\omega - \frac{y_p + p_p + \alpha}{w_p} w_\omega \qquad (31f)$$

It is straightforward to show that under full information, the welfare loss can be fully eliminated by monetary policy. We are in a first best situation, and the impact of labour market rigidities such as imperfect indexation or insufficient response of wages to unemployment can be neutralized by monetary policy.

What are the properties of the first-best optimal policy?

First, monetary policy must fully accommodate shocks to money demand, in order to neutralize their impact on the domestic price of tradables, and hence the real wage, which is the only channel through which they affect the welfare loss.

Second, monetary policy must counteract shocks in the world price of tradables and the world interest rate, in such a way, as to neutralize their impact on the commodity market, and hence the domestic price of tradables, and the real wage. The reaction elasticity is equal to the interest rate semi-elasticity of money demand, because both of these disturbances operate through the interest parity condition.

The conditions for supply shocks and wage shocks have more to them. Unlike the other shocks which affect the real wage, and hence the welfare loss, only indirectly through the domestic price of tradables, supply and wage shocks also have a direct effect on the real wage. In addition, supply shocks like μ and ℓ^N also affect the *equilibrium* real wage, necessitating an adjustment in real wages if there is to be no distortion. Neither demand and external shocks, nor the wage shock necessitate such an adjustment. Thus, monetary policy must counteract wage shocks to the extent that they directly disrupt the commodity market $(y_\omega + p_\omega)$, but must also accommodate their direct influence on the real wage. This is because accommodation increases inflation and hence reduces real wages to their equilibrium value. Similar, if more complicated considerations arise with respect to the supply shocks. The extra complication arises because such shocks necessitate an adjustment in real wages. Monetary policy should neutralize their direct and indirect disruptive influence on real wages, but only to the extent that a change in real wages is different from the equilibrium change. This difference between their direct effects on actual and equilibrium wages is given by $w_\mu - \lambda/(\epsilon+\lambda)$ and $w_\ell - (1-\nu)/(\nu(\epsilon+\lambda))$ respectively. In the case of a wage setting disturbance, we need only be concerned about w_ω, as such a shock does not affect the equilibrium real wage.

Having the nature of first best monetary policy in mind, we can move on to examine second best monetary policy. Under imperfect information the first best will no longer be attainable, but the monetary authorities will still have the same objective. I shall assume, along with the rest of this literature, that what is currently observable by the monetary authorities is the whole vector of current prices in the economy. No current aggregate quantities are directly observed.

Thus, the authorities have to infer the current state of the economy from the vector $(i, s, \chi, \rho, p, p^T, w)$. It turns out that this vector is not a sufficient statistic for the current state. In addition, because of the definition of the aggregate price level, uncovered interest parity and purchasing power parity for tradables, the informational content of this vector is the same as that of the vector (s, χ, ρ, w). Given the observations of the exogenous χ and ρ, and assuming m = 0 in (18), the informational content of exchange rate depreciations s is equal to,

$$I_s = -k - (y_\mu + p_\mu)\mu - (y_\ell + p_\ell)\ell^N + (y_\omega + p_\omega)\omega$$

Given χ, ρ and s, the extra informational content of w (see (14)) is,

$$I_w = w_\mu \mu + w_\ell \ell^N + w_\omega \omega$$

No other price has extra informational content.

Thus, we can specify a monetary policy rule that reacts to world price and interest rate shocks, but also to current nominal exchange rate depreciations and nominal wage changes, as, given these, no other price has extra informational content. The monetary policy rule will take the following form:

$$m = -m_s s - m_w w - m_\chi \chi - m_\rho \rho \qquad (32)$$

where m_s is the exchange market intervention elasticity, $-m_w$ is the wage accommodation elasticity, and m_χ, m_ρ are defined as before. Substituting (32) for m in (18), we end up with the following reduced form exchange rate equation:

$$s = \frac{1}{y_p+p_p+\alpha+m_s+(1-w_p)m_w}\left[-k-(y_p+p_p+m_\chi+(1-w_p)m_w)\chi + (\alpha-m_\rho)\rho - (y_\mu+p_\mu+m_w w_\mu)\mu - (y_\ell+p_\ell+m_w w_\ell)\ell^N + (y_\omega+p_\omega-m_w w_\omega)\omega \right] \quad (33)$$

Substituting (33) in the real wage equation (14), and the resulting equation in the labour market disequilibrium equation (21), the welfare loss measure (26) is given by:

$$H = E\left[(\ell-\tilde{\ell})^2 \mid \Lambda \right] = \frac{\nu\lambda^2}{\Xi^2}\left[w_p^2\{ \tau_k^2 + (\alpha+m_s-m_\chi)^2\tau_\chi^2 + (\alpha-m_\rho)^2\tau_\rho^2 \} + \{ w_p(y_\mu+p_\mu+m_w w_\mu) + \Xi(w_\mu - \frac{\Lambda}{\epsilon+\lambda}) \}^2\tau_\mu^2 + \{ w_p(y_\ell+p_\ell+m_w w_\ell) + \Xi(w_\ell - \frac{1-\nu}{\nu(\epsilon+\lambda)}) \}^2\tau_\ell^2 + \{ w_p(y_\omega+p_\omega-m_w w_\omega) - \Xi w_\omega \}^2\tau_\omega^2 \right] \quad (34)$$

where $\Xi = y_p+p_p+\alpha+m_s+(1-w_p)m_w$.

The policy parameters that minimize (34) are the following:

$$m_\rho = \alpha \quad (35a)$$

$$m_\chi = \alpha + m_s \quad (35b)$$

$$m_w = -\frac{1-\phi_w}{\phi_s} \quad (35c)$$

$$m_s = -(y_p+p_p+\alpha) + w_p\frac{\phi_w}{\phi_s} - m_w \quad (35d)$$

where:

$$\phi_w = \frac{\Sigma_{ww}\tilde{\Sigma}_{ss} - \Sigma_{sw}\tilde{\Sigma}_{sw}}{\Sigma_{ww}\Sigma_{ss} - \Sigma^2_{sw}} \qquad (36a)$$

$$\phi_s = \frac{\Sigma_{sw}\tilde{\Sigma}_{ww} - \Sigma_{ww}\tilde{\Sigma}_{sw}}{\Sigma_{ww}\Sigma_{ss} - \Sigma^2_{sw}} \qquad (36b)$$

and

$\Sigma_{ss} = \tau^2_k + (y_\mu + p_\mu)^2\tau^2_\mu + (y_\ell + p_\ell)^2\tau^2_\ell + (y_\omega + p_\omega)^2\tau^2_\omega$, i.e the variance of the informational content of the exchange rate;

$\Sigma_{ww} = w^2_\mu\tau^2_\mu + w^2_\ell\tau^2_\ell + w^2_\omega\tau^2_\omega$, i.e the variance of the informational content of the wage;

$\Sigma_{sw} = -(y_\mu + p_\mu)w_\mu\tau^2_\mu - (y_\ell + p_\ell)w_\ell\tau^2_\ell + (y_\omega + p_\omega)w_\omega\tau^2_\omega$. i.e the covariance of the informational content of the exchange rate and the wage;

$\Sigma_{s\tilde{w}} = -[\lambda/(\epsilon+\lambda)](y_\mu+p_\mu)\tau^2_\mu - [(1-\nu)/(\nu(\epsilon+\lambda))](y_\ell+p_\ell)\tau^2_\ell$, i.e the covariance between the *equilibrium* wage and the informational content of the exchange rate;

$\Sigma_{w\tilde{w}} = [\lambda/(\epsilon+\lambda)]w_\mu\tau^2_\mu + [(1-\nu)/(\nu(\epsilon+\lambda))]w_\ell\tau^2_\ell$, i.e the covariance between the *equilibrium* wage and the informational content of actual wages.

The expressions for m_ρ and m_χ are essentially the same as in the first best policy. The additional dependence of m_χ on m_s, the exchange intervention parameter, is easily explained. Since a change in χ affects the welfare loss through $p^T = s+\chi$, to the extent that χ also affects s and triggers exchange market intervention, this must also taken into account.

The expressions for the wage accommodation and exchange market intervention parameters are more difficult to interpret as they stand. It would perhaps be easier if we went through the steps involved in deriving them.

To understand their derivation note that the authorities have a dual problem. First, they have to get the best estimate of the *equilibrium* real wage. Second, they want to use monetary policy to minimize the deviations of the actual real wage from the perceived equilibrium real wage (look at equation (26)).

Assuming that the authorities have rational expectations, their best estimate of the equilibrium real wage, because of normality, is given by the regression of equilibrium real wages on the informational contents of actual wages and the exchange rate.

$$E(\tilde{w}-\tilde{p}^T) = \phi_w I_w + \phi_s I_s$$

where ϕ_w and ϕ_s are defined as in equations (36a), (36b).

Using (14), (33) and the definitions of the informational content of wages and the exchange rate, the actual real wage is equal to,

$$w-p^T = -\frac{w_p}{\Xi}\left[(\alpha-m_\rho)\rho + (\alpha-m_\chi+m_s)\chi + I_s - m_w I_w \right] + I_w$$

Thus, deviations of the actual real wage from the equilibrium real wage are given by,

$$w-p^T - E(\tilde{w}-\tilde{p}^T) = -\frac{1}{\Xi}\Big[- w_p(\alpha-m_\rho)\rho - w_p(\alpha-m_\chi+m_s)\chi + (\Xi\phi_s-w_p)I_s +$$

$$+ (\Xi(1-\phi_w)+m_w w_p)I_w \Big]$$

Perceived deviations will be zero if $m_\rho=\alpha$, $m_\chi=\alpha+m_s$, and if, $\Xi\phi_s = w_p$, and $\Xi(1-\phi_w)=-m_w w_p$. These conditions are equivalent to (35a)-(35d).

4. Interpretation and Numerical Analysis of the Second-Best Policy.

The exchange market intervention parameter is very similar to that of Aizenman and Frenkel (1985). The main differences in my case arise because of the independent informational content of wages, which make m_w and ϕ_w different from zero. Thus, I shall avoid extensive discussion of the properties of the exchange market intervention parameter. As in Aizenman and Frenkel, there is a relationship between wage indexation and optimal exchange market intervention, and this can be discovered by substituting for y_p, p_p and w_p in (35d). If wage indexation is optimal (θ^* say), then any arbitrary degree of exchange market intervention would do. However, in my case, there is still a need for independent reactions of monetary policy to wage changes.

To interpret the optimal policy somewhat differently, let me use (32) and (35a)-(35d) to rewrite it as,

$$m = -\alpha\rho - \alpha\chi + \left(y_p+p_p+\alpha-w_p\frac{\phi_w}{p\phi_s} \right)(s+\chi) + \frac{1-\phi_w}{\phi_s}(w-s-\chi)$$

It is easy (although tedious) to show that $\phi_w > 0$ and $\phi_s < 0$, in which case the coefficient of $s+\chi$ is unambiguously positive. Thus, the first characteristic of the second best policy is *monetary accommodation* of inflation in the tradables sector. The accommodation coefficient will be higher the higher the elasticity of nominal income with respect to prices (y_p+p_p), the higher the elasticity of real wages with respect to tradables prices (w_p) and the higher the interest rate semi-elasticity of money demand (α).

The second interesting question relates to the sign and magnitude of monetary policy reactions to changes in real wages (m_w). The sign will depend on whether ϕ_w is greater or less than unity. In general, it is not possible to determine the sign of m_w for all configurations of parameters. Furthermore, the partial derivatives of m_w with respect to the various *deep* parameters are not easy to establish analytically. Thus, in Figure 1, I present numerical evaluations of the relationship between m_w and a range of values of the elasticity of substitution between labour and capital (σ), the degree of openess (ν), the elasticity of labour supply (ϵ), and the Phillips curve coefficient (η). In each case, the rest of the parameters are as in the basic calculation reported in the note to Figure 1. and the variances of the various disturbances are assumed equal and have been normalized to unity. For the elasticity of labour supply and the degree of openness the relations are monotonic in the relevant range. Thus, the greater the degree of openness and the greater the elasticity of labour supply, the more monetary policy should react to wage inflation. This is because, with a more elastic supply curve for labour, the excess burden from a given change in wages is higher. On the other hand, the more open the economy, the higher the optimal m_w. This is mainly because of my assumption that demand for labour in the non-tradable sector is independent of the wage. In the simulation presented, optimal monetary policy could even accommodate changes in real wages, for sufficiently closed economies. As can be seen from the simulations there is a relative insensitivity of the wage reaction coefficient m_w to the elasticity of substitution σ and the Phillips curve coefficient.

It is worth emphasizing the finding that m_w appears to be positive in most cases. This has a simple intuitive explanation. When wages go up, this is partly a signal that *equilibrium* wages have gone up. Thus, monetary policy, by reacting negatively to wage inflation, reduces price inflation, and thus increases real wages even further, towards the best estimate of the equilibrium wage that the monetary authorities can obtain from their incomplete information.

5. Conclusions.

In this paper I have examined optimal monetary policy and the informational implications of the Phillips curve using a model of a small open economy. The main difference from the existing literature arises when one examines second-best policy under imperfect information. The existence of a negative relation between inflation and unemployment gives independent informational content to wage inflation, over and above the informational content of other prices such as the exchange rate.

The second best policy involves both exchange market intervention (as in the series of papers by Aizenman and Frenkel), and monetary reactions to wage inflation. In a numerical simulation, for plausible parameter values, it turns out that monetary policy should counteract wage inflation. This is because wage inflation is positively correlated with changes in the equilibrium real wage, and monetary contractions serve to increase actual real wages, by causing prices to be lower from what they would have been otherwise.

Appendix 1.

The Production Function and Labour Demand.

Assume that output in the tradables sector is produced according to the following CES production function:

$$Y_t = \exp(\mu_t)\left[\delta L_t^{-\frac{1-\sigma}{\sigma}} + (1-\delta)K_t^{-\frac{1-\sigma}{\sigma}} \right]^{-\frac{\sigma}{1-\sigma}} \qquad \text{(A1)}$$

where m ~ NI(0, τ^2_μ), σ is the elasticity of substitution, and δ the distribution parameter.

Profit maximization implies that the marginal revenue product of labour will be equal to the wage. In this case,

$$[\exp(\mu_t)]^{-(1-\sigma)/\sigma}\delta\left(\frac{Y_t}{L_t}\right)^{1/\sigma} = \frac{W_t}{P_t} \qquad \text{(A2)}$$

where W_t is the nominal wage, and P_t the price of tradables.

From (A1), taking the first-order Taylor expansion of $\log(Y_t)$,

$$\log(Y_t) \simeq \text{constant} + \pi\log L_t + (1-\pi)\log K_t + \mu_t \qquad \text{(A3)}$$

where $\pi = \dfrac{\delta\bar{L}_t^{-\frac{1-\sigma}{\sigma}}}{\left[\delta\bar{L}_t^{-\frac{1-\sigma}{\sigma}} + (1-\delta)\bar{K}_t^{-\frac{1-\sigma}{\sigma}} \right]} < 1$, and bars denote equilibrium values.

Assuming $K_t = \bar{K}$ always, taking deviations from $\log\bar{Y}$, $\log\bar{L}$, and dropping the time subscripts, (A3) is transformed to,

$$y^T = \pi\ell^T + \mu \tag{A4}$$

where $y^T = \log Y_t - \log\bar{Y}_t$, $\ell^T = \log L - \log\bar{L}$. (A4) is equivalent to (1) in the main text.

From (A2), taking logarithms and deviations from $\log\bar{Y}$, $\log\bar{L}$, $\log\bar{W}$, and $\log\bar{P}$,

$$\ell^T = -\frac{\sigma}{1-\pi}(w-p^T) + \frac{\sigma}{1-\pi}\mu \tag{A5}$$

(A5) is equivalent to equation (2) in the text.

Footnotes.

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1. Most of the features of this extensive literature are subsumed in the recent papers of Aizenman and Frenkel (1985, 1986), and some of the papers in Bhandari (1986). These papers also provide additional references.

2. Simplicity of course has its price. Thus, although one can gain important insights from simple models, one cannot avoid numerical and quantitative techniques to corroborate such insights.

3. This is a convenient simplifying assumption, often employed in short-run macro models. It allows us to focus on the properties of a stochastic stationary state, for which the current values of transitory shocks do not affect expectations about future values of shocks. See Aizenman and Frenkel (1985, 1986), and the references therein, for other applications.

4. In the appendix, it is shown how equations (1) and (2) can be derived from a CES technology, and the assumption of profit maximizing firms.

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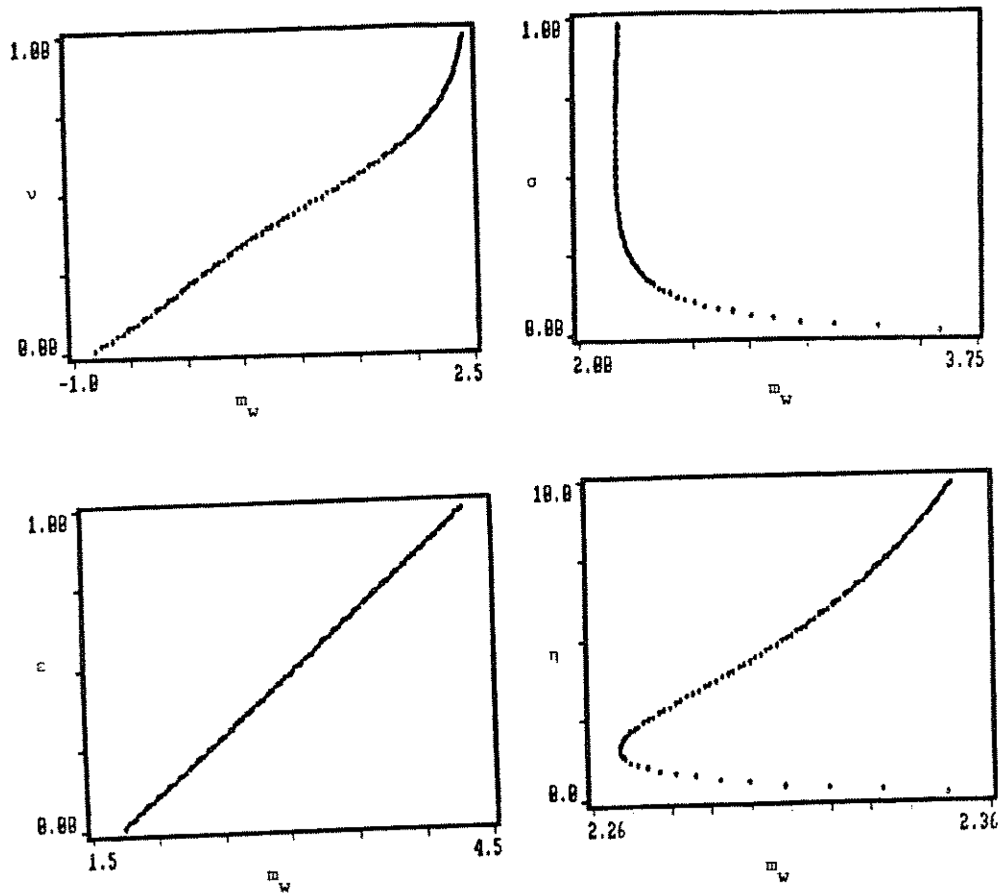
Figure 1

Wage Accommodation Coefficients for

Alternative Parameter Values



Notes: The values for the basic runs were

$\pi = 0.75$, $\sigma = 0.20$, $\varepsilon = 0.20$, $\nu = 0.80$, $\eta = 2$, $\theta = 0.70$, $\alpha = 3.00$

$T_k^2 = T_\mu^2 = T_\ell^2 = T_\omega^2 = 1$. For these values, $\phi_w = 0.18$, $\phi_s = -0.36$,

$m_w = 2.27$.