

NBER WORKING PAPER SERIES

IMPORTED MATERIALS PRICES, WAGE POLICY,
AND MACROECONOMIC STABILIZATION

Richard C. Marston

Stephen J. Turnovsky

Working Paper No. 1254

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
December 1983

An earlier version of this paper was presented to a meeting of the NBER International Studies Program. We are grateful to participants for their helpful suggestions. The research reported here is part of the NBER's research program in International Studies. Any opinions expressed are those of the authors and not those of the National Bureau of Economic Research.

Imported Materials Prices, Wage Policy, and Macroeconomic Stabilization

ABSTRACT

This paper analyzes two simple wage rules that keep employment constant when there are shocks to the prices of imported materials. One rule ties nominal wages to the GNP deflator rather than the consumer price index. The second rule, followed by Japan after the second oil price shock, ties the real wage to real GNP. The paper shows the effects on output, real income, and other macroeconomic variables of choosing either rule in place of the real wage stability provided by conventional wage indexation.

Richard C. Marston
Wharton School
University of Pennsylvania
Philadelphia, PA 19104

215-898-7626

Stephen J. Turnovsky
Department of Economics
University of Illinois
1206 South Sixth Street
Champaign, IL 61820

217-333-2354

I. INTRODUCTION

The response of an economy to increases in the prices of imported raw materials depends critically upon wage behavior, since real shocks of this kind require adjustment in relative factor prices. If real wages are rigid, as they are in many European countries, these price increases result in a fall in employment, together with a reduction in both gross output and domestic value added. The fall in employment is mitigated if real wages can adjust downward in some fashion. However, the amount of adjustment required depends upon the production structure of the economy. Without detailed knowledge of that structure, an appropriate wage policy is difficult to formulate.

This paper shows that two simple wage rules provide just the right amount of real wage adjustment to ensure that employment remains constant in the face of such price shocks. The first rule, which has been advocated in several different countries, is a wage indexation scheme that ties nominal wages to the GNP deflator, rather than to the consumer price index.¹ The second rule is a little less familiar, but can be shown to be equivalent to the first. This rule, which was followed by the Japanese trade unions after oil prices rose in 1979, ties the real wage to the real GNP. Shinkai (1980) attributes to this rule Japan's recent success in avoiding the macroeconomic stagnation experienced in other industrial countries.²

The choice between real wage stability on the one hand, and employment stability on the other, is not an easy one to make. But it is important to know the issues involved in making a particular choice. This paper analyzes how gross output, employment, real income, real wages and prices respond under alternative wage policies. Three wage policies, in fact, are considered.

These are:

- (i) fixing the real wage, i.e., tying the nominal wage to the consumer price index as is done in many countries with wage indexation;
- (ii) adjusting the real wage so as to keep employment constant, and
- (iii) adjusting the real wage so as to keep real income constant.

The responses of the key macroeconomic variables to these three policies follow systematic patterns which simplify the choices among policies considerably. Real wage resistance has definite costs which can be described in terms of employment and price behavior. But against these must be weighed the costs of alternative policies, as the analysis makes clear. Only when these costs are taken into account can sensible decisions about wage indexation and employment policy be made.

The setting of this analysis is a small open economy under flexible exchange rates. The country treats all foreign variables, including the foreign currency price of raw materials, as given. But the economy produces a final good which is distinct from the foreign final good, so that changes in the real exchange rate (between these final outputs) can occur. As a result, the real price of raw materials varies, depending upon the wage policy adopted. This provides another dimension which needs to be taken into account in choosing among the alternative wage policies.

The next section of the paper describes the production technology of the domestic economy, including the alternative concepts of value added relevant for the GNP-based wage rules discussed above. Section III then describes the three wage policies outlined above and shows how the employment stabilizing rule is equivalent to the two GNP-based rules. We also compare these policies with wage behavior in a full information, labor market clearing economy. Section IV analyzes and compares the impacts of the three policies in a world where domestic and foreign final goods are perfect substitutes so that the law

of one price for these goods prevails. Section V analyzes the general model and shows that the results of the simpler case continue to hold even when changes in the relative prices of final goods (the real exchange rate) occur. The main conclusions are reviewed in a final section.

II. DOMESTIC PRODUCTION BEHAVIOR

The key aspect of the model is the domestic production sector and accordingly this is described in some detail. In doing so, it is important to distinguish between the different concepts of value added and to define precisely what we mean by the value added deflator.

Gross output, Z_t of the domestic final good is assumed to take a separable form $Z_t = F[f(L_t, K_t), N_t]$ where L_t represents labor, K_t represents capital, and N_t denotes imported raw materials. The quantity $V_t = f(L_t, K_t)$ is defined to be domestic value added, measured in terms of inputs.³ For simplicity, value added is assumed to be a Cobb-Douglas function of labor and capital, while gross final output is a CES function of value added and imported materials

$$(1) \quad V_t = L_t^{(1-\alpha)} K_t^\alpha$$

$$(2) \quad Z_t = [\beta N_t^{-\rho} + (1 - \beta) V_t^{-\rho}]^{-1/\rho}.$$

Although it is reasonable to assume a Cobb-Douglas production function for domestic value added, existing estimates for the elasticity of substitution between N_t and V_t , denoted by $\sigma = 1/(1 + \rho)$, are typically much lower than unity, and hence production of gross output is more appropriately described by a CES function. Throughout our discussion we shall restrict σ to be less than or equal to one ($\sigma \leq 1$). While this is plausible for the situation we wish to analyze, it is of course theoretically possible for $\sigma > 1$, in which case some of the implications we draw would require appropriate modification.⁴

It is convenient to conduct our analysis using linearized approximations for these production functions with all variables expressed as percentage changes about an initial equilibrium (denoted by the subscript 0). Let lower case letters denote the percentage change in the corresponding level variable, so, for example, $z_t \equiv (Z_t - Z_0)/Z_0$. Then for small changes (1) and (2) may be approximated by

$$(1') \quad v_t = (1 - \alpha)l_t$$

$$(2') \quad z_t = c_1 n_t + c_2 v_t$$

where $c_1 = \beta(Z_0/N_0)^\rho$ $c_2 = (1 - \beta)(Z_0/V_0)^\rho$

and hence $0 < c_1 < 1, 0 < c_2 < 1, c_1 + c_2 = 1$.

In deriving (1') from (1) we assume that the time period being considered is sufficiently short so that capital remains fixed, i.e., $k_t = 0$. Note that (1') and (2') can also be derived as log-linear approximations for (1) and (2).⁵

Domestic producers are assumed to choose the short-run inputs L and N to maximize profit

$$P_t Z_t - W_t L_t - P_t^n N_t$$

where P_t denotes the price of gross output, W denotes the nominal wage rate, and P_t^n is the domestic price of imported raw materials. Given the separability of the production process, this optimization can be broken down to the following pair of decisions:

(i) Choose L_t to maximize: $P_t^v L_t^{(1-\alpha)} K_t^\alpha - W_t L_t$

(ii) Choose V_t and N_t to maximize: $P_t [\beta N_t^{-\rho} + (1 - \beta) V_t^{-\rho}]^{-1/\rho} - P_t^n N_t - P_t^v V_t$

where in subproblems (i) and (ii) P_t^v denotes the value-added deflator, to be defined below.

Linearizing the corresponding marginal productivity conditions for these two problems yields the following expressions for l_t , n_t , and v_t in terms of p_t , p_t^n , p_t^v and the nominal wage w_t :

$$(3a) \quad l_t = v_t - (w_t - p_t^v)$$

$$(3b) \quad n_t = z_t - \sigma(p_t^n - p_t)$$

$$(3c) \quad v_t = z_t - \sigma(p_t^v - p_t) .$$

As Arrow (1974) has shown, the value added price index is defined implicitly by the dual to the CES production function (2), namely

$$(4) \quad P_t = [\beta^\sigma (P_t^n)^{1-\sigma} + (1-\beta)^\sigma (P_t^v)^{1-\sigma}]^{\frac{1+\rho}{\rho}} .$$

In deriving (4) use is made of the facts, obtained from the marginal productivity conditions, that

$$c_1 = \beta(Z_0/N_0)^\rho = \frac{P_0^n N_0}{P_0 Z_0} ; \quad c_2 = (1-\beta)(Z_0/V_0)^\rho = \frac{P_0^v V_0}{P_0 Z_0}$$

so that c_1 and c_2 represent the shares of imported materials and value added, respectively, in gross output. Next, linearizing (4) yields

$$p_t = c_1 p_t^n + c_2 p_t^v$$

and hence

$$(5) \quad p_t^v = p_t/c_2 - (c_1/c_2)p_t^n .$$

The price of final output is thus a weighted average of the prices of raw materials and value added, the weights being their respective shares in final

output. This implies that the value added deflator is a weighted average of the price of final output and of imported inputs, with the weight on the former being greater than unity and the weight on the latter being negative; i.e., an "external average" in Arrow's (1974, pp. 15-16) terminology. Note also that equation (5) can be obtained directly by substituting the optimality conditions (3b) and (3c) into the production function (2') and using the fact that $c_1 + c_2 = 1$.

In addition to the value added concept already defined in (1) and (1'), there is a second measure of value added that is important in the discussion below; that measure is expressed in terms of the final good rather than in terms of the physical inputs. It is defined below both in natural units (6) and in percentage changes (6'):

$$(6) \quad V'_t = Z_t - (P_t^n/P_t)N_t$$

$$(6') \quad v'_t = z_t/c_2 - (c_1/c_2)(n_t + p_t^n - p_t) .$$

V'_t measures the real income accruing to the domestic factors of production, capital and labor,⁶ in contrast to V_t which measures the real net output of these factors. (We later define a second measure of real income defined in terms of a consumer price index).

Using (2') and (5), we can show that the two measures of value added are related in the following equivalent ways

$$(7) \quad v'_t = v_t + p_t^v - p_t$$

$$(8) \quad v'_t = v_t - (c_1/c_2)(p_t^n - p_t) .$$

Thus the two measures will be different to the extent that the relative prices

of final output and value added, or the relative prices of final output and imported materials, diverge.

To complete our description of the production sector we solve equations (1'), (2'), (3a), (3b), (3c) for the real variables: employment, l_t , value added measured in terms of inputs, v_t , and in units of the final good, v'_t , final output, z_t , and imported materials, n_t . We express each of these variables in terms of the two relative prices that are important in the discussion below; these are the real wage facing the producer ($w_t - p_t$) and the real price of the imported materials ($p_t^n - p_t$). The resulting expressions are

$$(9a) \quad \frac{v_t}{(1 - \alpha)} = l_t = -\frac{1}{\alpha} (w_t - p_t) - \frac{c_1}{\alpha c_2} (p_t^n - p_t)$$

$$(9b) \quad v'_t = -\frac{(1 - \alpha)}{\alpha} (w_t - p_t) - \frac{c_1}{\alpha c_2} (p_t^n - p_t)$$

$$(9c) \quad z_t = -\frac{(1 - \alpha)}{\alpha} (w_t - p_t) - \frac{c_1}{\alpha c_2} [1 - \alpha + \sigma\alpha] (p_t^n - p_t)$$

$$(9d) \quad n_t = -\frac{(1 - \alpha)}{\alpha} (w_t - p_t) - \frac{[c_1(1 - \alpha) + \sigma\alpha]}{\alpha c_2} (p_t^n - p_t) .$$

From these expressions it is evident that all quantities are inversely related to each real price.

III. ALTERNATIVE WAGE POLICIES

It is evident from the expressions (9a)-(9d) that the response of the economy to a change in the real materials price depends crucially upon the adjustment of real wages. We now introduce the three alternative wage policies we wish to analyze.

1. Stabilizing the Real Wage

This policy is the familiar one of setting the nominal wage so as to keep constant the real wage, defined in terms of labor's consumption basket.

Formally, this is described by an indexation rule,

$$(10) \quad w_t - p_t^I = 0 ,$$

where $p_t^I = \delta p_t + (1 - \delta)(p_t^f + e_t)$, $0 < \delta < 1$, is the consumer price index (CPI), p_t^f = foreign price of the foreign final good, e_t = exchange rate (expressed as the domestic price of foreign currency), and δ is the share of the domestic good in the domestic consumption basket. As in Section II all variables are expressed in terms of percentage changes. Defining the relative price of foreign to domestic goods, which we also call the real exchange rate, by

$$s_t = p_t^f + e_t - p_t$$

the domestic CPI can be written as

$$(11) \quad p_t^I = p_t + (1 - \delta)s_t .$$

Thus a wage policy of stabilizing the real consumer wage is equivalent to adjusting the real producer wage to the relative price in accordance with

$$(10') \quad w_t - p_t = (1 - \delta)s_t .$$

2. Stabilizing Employment

As already noted earlier, since the capital stock is fixed in the short run, (the percentage change in) value added v_t is proportional to (the percentage change in) employment. Accordingly, stabilizing employment is equivalent to stabilizing this form of value added. From equation (9a) it is seen that this policy involves setting the real producer wage $w_t - p_t$ in

accordance with the rule

$$(12) \quad w_t - p_t = -\frac{c_1}{c_2} (p_t^n - p_t) .$$

That is, in response to a one percent increase in the real domestic price of imported materials, the real producer wage must be reduced by (c_1/c_2) percent.⁷ From Section II c_1/c_2 is the ratio of the values of imported raw materials to domestic value added. This ratio almost certainly is substantially smaller than unity, in which case the required downward adjustment in the real producer wage is substantially less than proportional.

We show now that the rule described by (12) is equivalent to the two wage rules outlined in the introduction, namely: (i) tying the nominal wage to the value added deflator, p_t^v ; (ii) tying some measure of the real wage to some measure of real GNP. We consider these rules in turn.

First, equation (12) immediately implies

$$w_t = \frac{c_1 + c_2}{c_2} p_t - \frac{c_1}{c_2} p_t^n$$

and noting $c_1 + c_2 = 1$ together with (5) yields

$$w_t = p_t/c_2 - (c_1/c_2)p_t^n = p_t^v ,$$

thereby demonstrating case (i). The reason why this rule stabilizes employment is seen immediately from the production function (1') and the optimality condition (3a). What it does is to fix the real wage relevant for the employment decision, namely the nominal wage deflated by the value added deflator.

The second rule is a little more difficult to interpret, since there are several definitions of both value added and the real wage. We consider two natural variants. The first is to tie the real producer wage to value added

measured in units of final output (which is one measure of real income); i.e.,

$$(13) \quad w_t - p_t = v_t' .$$

The second is to tie the nominal wage deflated by the value added deflator to value added in physical units, v_t ,

$$(13') \quad w_t - p_t^v = v_t .$$

The two expressions are equivalent as can be seen by substituting (7) into (13).

Rules in either of these forms will stabilize employment and value added. To show this, we rewrite (9a) and (9b) in terms of the value added deflator using (5):

$$(9a') \quad v_t - (w_t - p_t^v) = -\frac{1}{\alpha} (w_t - p_t^v) ,$$

$$(9b') \quad v_t' - (w_t - p_t) = -\frac{1}{\alpha} (w_t - p_t) .$$

According to these expressions, either real wage rule (13 or 13') keeps the nominal wage equal to the value added deflator. But we have already shown that tying w_t to p_t^v keeps employment and value added constant because it stabilizes the real wage relevant for employment decisions. Hence either real wage rule can be used to stabilize employment and value added.

It is useful to compare the first two wage rules with wage behavior in a full information, frictionless economy. Gray (1976) has argued that if labor contract lags are the sole reason for departures from pareto optimality, a wage rule should be chosen which most closely resembles wage behavior in a frictionless economy without contract lags. To determine wage behavior in such an economy, we need to extend the previous model by including a labor

supply function. This is specified to be

$$(14) \quad l_t = n(w_t - p_t^I), \quad n > 0,$$

reflecting the fact that labor supply is a function of the real consumer wage.

In a frictionless economy, labor market equilibrium is assumed to hold. Thus equating labor demand, specified by (9a), with labor supply, specified by (14), we find that the equilibrium solution for the real producer wage is

$$(15) \quad w_t - p_t = \frac{n\alpha(1 - \delta)}{1 + n\alpha} s_t - \frac{c_1/c_2}{1 + n\alpha} (p_t^n - p_t) .$$

Recalling (10') and (12), we may express (15) in the form

$$(16) \quad (w_t - p_t)_f = \frac{n\alpha}{1 + n\alpha} (w_t - p_t)_1 + \frac{1}{1 + n\alpha} (w_t - p_t)_2 ,$$

where the subscripts 1, 2, and f denote the real wages under policies 1, 2, and full information, respectively. It is immediately seen from (16) that the real wage in a frictionless economy is a weighted average of those under policies 1 and 2, and therefore in general lies in between them. The weights depend upon (i) the elasticity of labor supply, n , and (ii) the elasticity of output with respect to capital, α . In the limiting case when the supply of labor is infinitely elastic, $n \rightarrow \infty$, the frictionless rule converges to policy 1. At the other extreme, the frictionless real wage coincides with policy 2, namely tying the nominal wage to the value added deflator, when the supply of labor becomes totally inelastic ($n = 0$). We will not explicitly analyze the effects of this intermediate wage rule on output and other macroeconomic variables, but it should be obvious that the effects of this rule will lie between those of policies 1 and 2.

3. Stabilizing Real Income

Policies 1 and 2 represent polar extremes of quantity and price adjustments in the labor market. In both cases, as will become apparent below, real income is reduced if the price of materials rises in real terms. Given the assumption of a Cobb-Douglas production function for v_t (which keeps the shares of wage income and profit income constant), a reduction in total income also implies a proportionate reduction in both components of income. As a third policy we consider one in which the nominal wage is adjusted so as to keep real income and its components constant. By real income we mean value added measured in units of the consumer basket which we denote by y_t , so the wage rule is

$$(17) \quad y_t = v_t' + p_t - p_t^I = 0 .$$

By combining (11) and (9b) we can show that for real income to remain constant, the real producer wage must be adjusted in accordance with the rule

$$(18) \quad w_t - p_t = \frac{-c_1}{c_2(1-\alpha)} (p_t^n - p_t) - \frac{\alpha(1-\delta)}{(1-\alpha)} s_t .$$

That is, the real producer wage must fall in response to either a rise in the real price of imported materials or a rise in the real exchange rate. The required reduction in the real wage in response to a rise in the price of imported materials, by $c_1/(c_2(1-\alpha))$, is greater than that required by the second wage policy of stabilizing employment (see (12) above). The extra fall in the real wage raises labor income relative to the second wage policy because the elasticity of labor demand with respect to the real producer wage exceeds unity (implying that employment rises more than proportionately as the

real wage falls). This tradeoff between real wages and real income is discussed further below.

In this third wage rule, s_t is an endogenous variable dependent upon demand as well as supply behavior. In all three wage rules, moreover, the real domestic price of imported materials, $p_t^n - p_t$, is an endogenous variable since it depends upon s_t . To show this, we express $p_t^n - p_t$ in terms of s_t as well as the real foreign price of imported materials, θ_t ,

$$p_t^n - p_t = s_t + \theta_t ,$$

where $\theta_t = q_t^f - p_t^f$, q_t^f being the nominal price of imported materials in foreign currency.

With the wage rules depending upon endogenous prices, we cannot generally assess the effects of the rules until we have specified demand behavior as well as supply behavior. In section IV we focus on the limiting case where domestic and foreign final goods are perfect substitutes so that the law of one price keeps the price of domestic output at its purchasing power parity (PPP) value. In this case the real exchange rate is constant, or $s_t = 0$. The real price of imported materials, moreover, is equal to the exogenous real foreign price. As a result the analysis of each wage rule is considerably simplified.

IV. IMPLICATIONS OF ALTERNATIVE WAGE POLICIES UNDER PPP

The main reason for beginning with this case is that it helps to clarify the general case to follow. Most of the effects we wish to consider can be obtained simply by a consideration of the production sector alone and carry over virtually unchanged to the general case where domestic and foreign final goods are imperfect substitutes. We shall focus on the effects of an exogenous increase in the real price of raw materials under the three

alternative wage rules, on:

- (i) the real wage;
- (ii) employment;
- (iii) real income;
- (iv) final output;
- (v) the domestic nominal price level (exchange rate).

These results are summarized in Table 1.

1. Stabilizing the Real Wage

If the real wage is stabilized, an increase in the real price of imported materials leads to a fall in employment, as well as a fall in real income and final output. The effects of the increase in this price can be traced throughout the production sector. First, the higher price of imported materials reduces the use of materials, as well as gross output, though to the extent that materials and value added are substitutable in production (as reflected in σ), the fall in the latter is smaller. Secondly, the policy of fixing labor's real wage also fixes the real producer wage if PPP holds. With the latter real wage fixed, employment must fall. With capital fixed in the short run, value added (v_t) must also fall as well. Thirdly, real labor income must fall since real wages are fixed and employment falls. Moreover, the fact that value added is produced by a Cobb-Douglas production function means that the share of labor income in total income remains constant. Thus the fall in real labor income implies a corresponding reduction in real income, y_t .

To consider the effects on the domestic price level, which under the assumption of PPP is equivalent to the nominal exchange rate, requires the introduction of the domestic money market. In general this is assumed to be described by the pair of equations

$$(19) \quad m_t - p_t^I = \gamma_1(v_t' + p_t - p_t^I) - \gamma_2 r_t \quad \gamma_1 > 0, \gamma_2 > 0$$

$$(20) \quad r_t = \bar{r}_t + e_{t+1,t}^* - e_t$$

where m_t = domestic money supply, measured as a percentage change;

$e_{t+1,t}^*$ = expectation of e_t for period $t+1$, formed at time t ;

r_t = domestic nominal interest rate;

\bar{r}_t = foreign nominal interest rate;

and all other variables are as defined previously. Equation (19) is just the usual money market equilibrium condition, where the demand for money depends positively upon real income (defined in terms of cost of living units) and negatively upon the domestic nominal interest rate. The assumption that domestic and foreign bonds are perfect substitutes is expressed by the uncovered interest parity condition (20).

We now invoke the additional assumption that the foreign price shock is unanticipated and is expected to be transitory; that is, θ_t is just a purely stochastic disturbance. This assumption simplifies the solution of the model when expectations are formed rationally, since in this case the expected exchange rate is just equal to a stationary value (which we assume to be zero, i.e., $e_{t+1,t}^* = 0$.) If we substitute (20) into (19) and invoke the PPP assumption, we find

$$m_t - (1 + \gamma_2)p_t = \gamma_1 v_t' - \gamma_2 \bar{r}_t .$$

Assuming m_t and \bar{r}_t remain fixed, we obtain

$$(19') \quad \frac{dp_t}{d\theta_t} = \frac{-\gamma_1}{(1 + \gamma_2)} \frac{dv_t'}{d\theta_t} > 0 .$$

An increase in the foreign materials price lowers real income, and therefore the demand for money. In order for the domestic money market to remain in

equilibrium, the real money stock must fall. Given the nominal money stock the domestic price level p_t must rise; i.e., the nominal exchange rate must depreciate.

2. Stabilizing Employment

Suppose now that the wage rate is set so as to stabilize employment. In this case an increase in the materials price leads to a fall in the real wage accompanied by an equivalent fall in real income and a fall in final output. The impact effect of such an increase in θ_t is to reduce the use of materials, thereby reducing the employment of labor and gross output, as for policy 1. In order to restore the employment of labor, the wage rate is reduced in accordance with (12). Given the complementarity of the two factors of production, the additional labor tends to increase the use of materials, thereby partially but not fully offsetting the initial fall in demand for materials, so that on balance final output falls. The fact that the real wage falls means that real labor income and hence total income falls, doing so by an amount which in general is in excess of the fall in gross output. The effect on the nominal price level is virtually the same as in policy 1 and the same reasoning applies.

3. Stabilizing Real Income

Real labor income is by definition equal to $l_t + w_t - p_t$. Both of the above policies lead to a reduction in this quantity. If the real wage is stabilized, the reduction occurs via a reduction in employment; if employment is fixed, the reduction is through a lower real wage. Either way, the real income of labor is reduced. Indeed, as we have noted before, given the Cobb-Douglas production function, total real profit and total real income, y_t , are reduced similarly. Thus as a third policy we consider one where wages are adjusted so as to maintain total real income (as well as real wage income)

fixed. In this case we see from Table 1 that the real wage falls, while employment and gross output rise.

To consider this policy, suppose that initially there is no adjustment in the real wage. An increase in the materials price thus leads to a fall in the demand for materials, leading to a reduction in employment, gross output, and real income. Now suppose that y_t (or equivalently, $\lambda_t + w_t - p_t$) is stabilized by adjusting the real wage in accordance with the rule specified in (18), which for PPP reduces to

$$(18') \quad w_t - p_t = \frac{-c_1}{c_2(1 - \alpha)} \theta_t .$$

The induced effect on employment stemming from this real wage cut exceeds the reduction directly due to the higher materials price, and hence on balance employment rises. Real labor income is maintained constant because employment rises enough to offset the lower real wage. The effect on final output is proportional to $(1 - \sigma)$, implying that final output rises if $\sigma < 1$ as we assume.

The effect on the price level is obtained from the money market equilibrium condition as before. In this case

$$\frac{dp_t}{d\theta_t} = - \frac{\gamma_1}{1 + \gamma_2} \frac{dv'_t}{d\theta_t} = 0 .$$

Stabilizing real income leaves the demand for real money balances unchanged, so the price level is also stabilized.

4. Comparison of Effects

The expressions summarized in Table 1 indicate a strong ordering in effects as we move through the three policies 1 - 3. Real wages are stabilized under policy 1 but decline under either alternative policy; the decline is largest when real income is stabilized. Even policy 3 does not

require a fall in the real wage as large (in absolute percentage terms) as the rise in the real price of materials as long as $c_1/(c_2(1 - \alpha)) < 1$, i.e., as long as the ratio of the value of materials to labor is less than one.

A similar ranking applies for employment. The negative and positive employment effects which correspond to stabilizing the real wage and real income, respectively, are bracketed about the zero effect when employment is stabilized. The ranking for real income is reversed from that for real wages. The adverse effects on real income are reduced as we move from the policy of stabilizing wages through stabilizing employment to stabilizing real income. These same algebraic orderings are obtained for final output, the only difference being that in policy 3, final output actually rises.

Finally, the same ordering as obtained for real wages applies to the nominal price level. Stabilizing the real wage has the greatest positive effect on the price level exceeding that when employment is stabilized; when income is stabilized, the price level remains constant.

Overall, these results indicate a range of tradeoffs associated with different wage policies. If the objective of wage policy is to stabilize the real wage, then employment and real income must fall; if the objective is to stabilize employment, then the real wage and real income must fall. So policies 1 and 2 provide a clear choice between real wage stability and employment stability. Wage behavior in a frictionless economy without contract lags, often used as a standard for judging wage policies, would lie somewhere between these two extremes. If the objective of wage policy is to stabilize real income or to stabilize prices, on the other hand, policy 2 dominates policy 1, since both real income and prices vary more under a real wage stabilization policy. Policy 3, moreover, dominates both alternative

policies since under that policy real income and the price level are completely stabilized.

V. ALTERNATIVE WAGE POLICIES IN THE GENERAL CASE

We now relax the assumption of PPP maintained in Section IV and allow the domestic and foreign goods to be distinct. This means that the relative price, s_t , becomes an endogenous variable. To determine it, we need to extend the model to include a demand side. In equation (21), the real demand for the domestic product is expressed as a function of real income, both deflated by the general price index, as well as the real interest rate and relative prices.⁸

$$(21) \quad z_t + p_t - p_t^I = d_1 [v_t' + p_t - p_t^I] - \\ d_2 [r_t - (p_{t+1,t}^{I*} - p_t^I)] + d_3 s_t ,$$

where $0 < d_1 < 1$, $d_2 > 0$, $d_3 > 0$. We assume that d_1 has a value between zero and one so that an increase in real income leads to a less than proportionate increase in real demand.

Because aggregate demand is a function of the real interest rate, $r_t - (p_{t+1,t}^{I*} - p_t^I)$, the behavior of the real part of the system depends upon future expectations, which in turn depend upon the nature of the materials price increases impinging on the economy. We assume that these disturbances are both unanticipated and temporary. Under these conditions, it can be established that the rational expectations solutions for expectations of the CPI and the exchange rate are equal to some stationary values (which we assume to be zero),

$$e_{t+1,t}^* = p_{t+1,t}^{I*} = 0 .$$

The aggregate demand equation can be simplified further by substituting in equation (21) the following equation for v'_t obtained by solving (3b) and (6'):

$$(22) \quad v'_t = z_t - \frac{c_1}{c_2} (1 - \sigma)(s_t + \theta_t) .$$

The result is the first of two equations describing how gross output and the relative price are jointly determined. The second equation, reproducing (9c), describes aggregate supply of the final good.

$$(23) \quad \begin{bmatrix} 1 & -d_5 \\ 1 & \frac{c_1}{\alpha c_2} (1 - \alpha + \alpha\sigma) \end{bmatrix} \begin{bmatrix} z_t \\ s_t \end{bmatrix} = \begin{bmatrix} -d_1 \frac{c_1}{c_2} \frac{(1 - \sigma)}{(1 - d_1)} \theta_t \\ -\frac{c_1}{\alpha c_2} (1 - \alpha + \alpha\sigma)\theta_t - \frac{(1 - \alpha)}{\alpha} (w_t - p_t) \end{bmatrix} .$$

The price coefficient in the aggregate demand equation,

$$d_5 = [d_2\delta + d_3 + (1 - d_1)(1 - \delta) - d_1c_1(1 - \sigma)/c_2]/(1 - d_1) > 0 ,$$

reflects the total effect of an increase in the relative price, s_t , on aggregate demand, including the indirect effect of s_t on real income. We assume that the total effect of a rise in s_t is to raise aggregate demand, so $d_5 > 0$. In obtaining the aggregate demand equation, we have assumed for convenience that the foreign interest rate and the price of the foreign good (in foreign currency) are constant ($\bar{r}_t = 0$ and $p_t^f = 0$). The increase in the real price of materials, θ_t , thus is due to an increase in the nominal price, q_t^f .

The two equations of (23) express output and relative prices as a function of the real price of materials, θ_t , and the real producer wage. The real wage, in turn, depends upon which of the three wage policies are followed. We express these policies, given by (10'), (12), and (18) above, in

terms of s_t and θ_t as follows:

$$(24a) \quad w_t - p_t = (1 - \delta)s_t, \quad \text{labor's real wage constant}$$

$$(24b) \quad w_t - p_t = -\frac{c_1}{c_2}(s_t + \theta_t), \quad \text{employment constant}$$

$$(24c) \quad w_t - p_t = -\frac{c_1}{c_2(1 - \alpha)}(s_t + \theta_t) - \frac{\alpha(1 - \delta)}{(1 - \alpha)}s_t. \quad \text{real income constant}$$

By substituting one of these expressions into (23), we obtain solutions for z_t and s_t . These are reported in Table 2 together with the real price of materials, $s_t + \theta_t$, as well as three other variables previously analyzed in the case of PPP: (i) labor's real wage, (ii) employment, and (iii) real income. The latter expressions are obtained by substituting $w_t - p_t$, s_t and θ_t into the following equations:

$$(25a) \quad w_t - p_t^I = (w_t - p_t) - (1 - \delta)s_t,$$

$$(25b) \quad l_t = -\frac{1}{\alpha}(w_t - p_t) - \frac{c_1}{\alpha c_2}(s_t + \theta_t),$$

$$(25c) \quad y_t = -\frac{(1 - \alpha)}{\alpha}(w_t - p_t) - \frac{c_1}{\alpha c_2}(s_t + \theta_t) - (1 - \delta)s_t.$$

Equation (25a) follows directly from the definitions of p_t^I and s_t ; equation (25b) reproduces (9a); while equation (25c) is obtained by solving (9b) and (17).

We begin with these last three variables which are described in the first three rows of Table 2.⁹ As is evident from this table, the qualitative effects of an increase in the real price of materials follow the same patterns as in the much simpler PPP case discussed in Section IV. In order to stabilize employment in policy 2, real wages must fall but real income falls less than in policy 1. In order to stabilize real income in policy 3, real wages must fall even more, but employment now rises. The reasoning is

basically unchanged from before. Similarly, in the fourth row we see that final output falls most when real wages are fixed and actually rises when real income is fixed.

Underlying these changes in production variables are changes in relative prices which are of interest in themselves. For policies 1 and 2, an increase in the real price of materials has an ambiguous effect on the relative price of final goods, s_t , while for policy 3 the effect is positive if $\sigma < 1$. The indeterminacy in the case of policy 1, for example, arises because the increase in the price of materials reduces both aggregate supply and aggregate demand (through its impact on real income). As the expressions in (23) indicate, an increase in θ_t reduces both demand and supply with the net effect on s_t , which can be viewed as the equilibrating price in the output market, depending upon which effect dominates. Similar reasoning applies for policy 2. In the case of policy 3, however, the fall in the real wage is large enough to offset the increase in θ_t so that aggregate supply function increases, causing z_t and s_t to rise unambiguously.

Despite the ambiguities regarding the direction of movement of s_t , we can establish that s_t always increases the most (in algebraic value) for policy 3 and increases the least (or decreases the most) for policy 1. This provides the key to understanding the adjustment of the real price of materials measured in domestic units, $p_t^n - p_t = s_t + \theta_t$. For all three wage policies $s_t + \theta_t$ rises, as one would expect. The more labor's real wage is allowed to adjust downwards (i.e., as we move from policy 1 through to policy 3), moreover, the greater is the positive effect of this foreign shock on the domestic real materials price. So by stabilizing employment, and even more so by stabilizing real income, we turn the price of materials measured in domestic units against the domestic economy. The reason is that s_t rises more

as we move from policy 1 to policy 2 and finally to policy 3, so $s_t + \theta_t$ must also rise more. This is one cost to be borne if we follow a policy of stabilizing employment or stabilizing real income.

Finally, we may note that the effects of the increase in the materials price on the domestic price level can be derived from the money market equilibrium condition, equation (19), as it was under PPP. The effects mirror those obtained for the relative price, s_t . We do not know whether p_t^I rises or falls for policies 1 and 2, but can establish that p_t^I definitely falls for policy 3. Moreover, we can derive the following ranking,

$$\left. \frac{dp_t^I}{d\theta_t} \right|_1 > \left. \frac{dp_t^I}{d\theta_t} \right|_2 > \left. \frac{dp_t^I}{d\theta_t} \right|_3 ,$$

where the subscript denotes the policy. Thus the price level always rises the most (or falls the least) under policy 1.

VI. CONCLUSION

Increases in the prices of imported materials confront policy-makers with a difficult set of choices involving real wages, employment, and real income. If real wages remain fixed in response to such price increases, whether because wages are indexed to the consumer price index or because they are linked to prices in negotiated settlements, costs are imposed on the economy. These costs include reductions in employment, GNP, and real income. Flexibility in the real wage, by contrast, may enable employment, and even real income, to remain constant in the face of such external shocks.

Real wage flexibility is difficult to achieve in practice.¹⁰ This paper has shown, however, that two indexation rules provide just the right degree of wage flexibility to stabilize employment. One rule is to tie nominal wages to

a value added deflator rather than the consumer price index, as is traditionally done. The other rule, which we have shown to be equivalent to the first, is to tie real wages to real GNP. Just how these rules would work out in practice is suggested by the recent macroeconomic performance of Japan which, after the second oil shock of 1979, kept its real wages in line with real GNP. We have also shown how real income, as well as real labor income, can be stabilized by further reductions in the real wage large enough to raise employment. No country has pursued this more extreme policy, but the pattern of results in this case reveals further the nature of the tradeoff between real wages and employment.

FOOTNOTES

¹Countries where such proposals have been debated include Denmark, Israel and the United Kingdom. See, for example, the study of wage indexation by Braun (1976). Recently the Congressional Budget Office (1981) has compared a variety of indexation rules for the United States including tying wages and federal benefits to the GNP deflator specifically to exclude the impact of import prices. Marston (1982) examines the effects of wage indexation to the price of the domestic (final) good, but imported materials are not included in that analysis.

²Shinkai (1980, p. 19) quotes a union 'white paper': "[O]ur wage demand is based on our assessment of the impact of [the] oil price rise and growth prospect, and aims at a real wage increase lower than the real GNP growth . . ."

³ Z_t must be separable in N_t and V_t in order for V_t to be well defined. (See Arrow, 1974, p. 4). There is some debate about whether a production function separable in N_t and V_t is appropriate for oil and other forms of energy (as opposed to raw materials). Berndt and Wood (1979), for example, propose an alternative production function where oil (O_t) combines with capital to form a composite separable from labor (and other raw materials), $Z_t = Z[L_t, Z^1(K_t, O_t)]$. Johnson (1981) analyzes the effects of an oil price increase in such a model.

⁴The combination of a CES function for gross output and a Cobb-Douglas function for value added was previously employed by Bruno and Sachs (1979) and Bruno (1981). Note that in their simulation model, Bruno and Sachs choose an elasticity of substitution between N_t and V_t equal to 0.2. (Bruno and Sachs, 1979, p. 36).

⁵Equations (1') and (2') are the first order terms of a Taylor series expansion around the initial equilibrium. If a log-linear approximation is instead used, with the lower case letters denoting logarithmic differences, then (1') holds exactly while (2') is a first-order approximation.

⁶ v' is sometimes called a single-deflated measure of value added since it is obtained by deflating nominal value added by the price of the final good. See Bruno (1981, p. 4).

⁷Bruno (1981, p. 7) derives a similar condition for keeping employment constant in response to an increase in raw materials prices. He points out that with employment stabilized, the marginal product of capital (and hence its rental) must fall by the same proportion as the marginal product of labor.

⁸Note that like the other equations in the model, (18) is in percentage changes. Thus d_1 and d_3 represent elasticities, while d_2 is a semi-elasticity.

⁹The determinants D_1 and D_2 are both necessarily positive if $d_5 > 0$, as assumed. We assume that the aggregate demand coefficients, d_2 and d_3 , are large enough so that $D_3 > 0$.

¹⁰If nominal wage rigidities inhibit the required adjustment of real wages, it may be possible to achieve the necessary adjustment in the real wage through the introduction of appropriate taxation on wages. We are grateful to Joshua Aizenman for this point.

REFERENCES

- Arrow, Kenneth J., 1974, "The Measurement of Real Value Added," in Paul A. David and Melvin W. Reder, eds., Nations and Households in Economic Growth: Essays in Honor of Moses Abramovitz (New York, Academic Press).
- Berndt, E. R. and D. O. Wood, 1979, "Engineering and Econometric Interpretations of Energy-Capital Complementarity," American Economic Review 69, June, pp. 342-55.
- Braun, A. R., 1976, "Indexation of Wages and Salaries in Developed Economies," International Monetary Fund Staff Papers 23, pp. 226-71.
- Bruno, Michael, 1981, "Raw Materials, Profits, and the Productivity Slowdown," NBER Working Paper No. 660, April.
- Bruno, Michael and Jeffrey Sachs, 1979, "Supply Versus Demand Approaches to the Problem of Stagflation," NBER Working Paper No. 382, August.
- Congressional Budget Office, 1981, Indexing with the Consumer Price Index: Problems and Alternatives (Washington, D.C., Congressional Budget Office).
- Gray, Jo Anna, 1976, "Wage Indexation: A Macroeconomic Approach," Journal of Monetary Economics 2, 221-35.
- Johnson, Karen H., 1981, "The Impact of an Oil Price Increase on Aggregate Supply," International Finance Discussion Papers No. 182, July.
- Marston, Richard C., 1982, "Real Wages and the Terms of Trade: Alternative Indexation Rules for an Open Economy," NBER Working Paper No. 1046, December.
- Shinkai, Yoichi, 1980, "Oil Crises and the Stagflation (or Its Absence) in Japan," Institute of Social and Economic Research, Osaka University Discussion Paper No. 110, November.

Table 1

Effects of an Increase in the Price of Imported Materials:
PPP Case

Policies Effect on	1. Stabilize Real Wage $w_t - p_t$	2. Stabilize Employment l_t	3. Stabilize Real Income v_t'
$w_t - p_t$:	0	$-\frac{c_1}{c_2}$	$-\frac{c_1}{c_2(1-\alpha)}$
l_t :	$-\frac{c_1}{\alpha c_2}$	0	$\frac{c_1}{c_2(1-\alpha)}$
$y_t = v_t'$:	$-\frac{c_1}{\alpha c_2}$	$-\frac{c_1}{c_2}$	0
z_t :	$-\frac{c_1}{\alpha c_2} [1 - \alpha + \sigma\alpha]$	$-\frac{c_1^\sigma}{c_2}$	$\frac{c_1}{c_2} (1 - \sigma)$
p_t :	$\frac{\gamma_1}{1 + \gamma_2} \frac{c_1}{\alpha c_2}$	$\frac{\gamma_1}{1 + \gamma_2} \frac{c_1}{c_2}$	0

Table 2

Effects of an Increase in the Price of Imported Materials:
General Case

Policies Effect on	1. Stabilize Real Wage $w_t - p_t^I$	2. Stabilize Employment λ_t	3. Stabilize Real Income y_t
$w_t - p_t^I$:	0	$-\frac{c_1 \phi_1}{D_2}$	$-\frac{c_1 \phi_1}{(1-\alpha)D_3}$
λ_t :	$\frac{c_1 \phi_1}{-\alpha D_1}$	0	$\frac{c_1 \phi_1}{(1-\alpha)D_3}$
y_t :	$-\frac{c_1 \phi_1}{\alpha D_1}$	$-\frac{c_1 \phi_1}{D_2}$	0
z_t :	$-\frac{c_1 \phi_2}{\alpha D_1}$	$-\frac{c_1 d_4 \sigma}{D_2}$	$\frac{c_1(1-\sigma)[d_2 \delta + d_3 + (1-\delta)]}{D_3}$
a_t :	$\frac{c_1[\alpha(1-\sigma) - (1-d_1)]}{\alpha D_1}$	$\frac{c_1(d_1 - \sigma)}{D_2}$	$\frac{c_1(1-\sigma)}{D_3}$
$a_t + \theta_t$:	$\frac{c_2[d_4 + \frac{(1-\alpha)}{\alpha}(1-d_1)(1-\delta)]}{D_1}$	$\frac{c_2 d_4}{D_2}$	$\frac{c_2(d_2 \delta + d_3)}{D_3}$

$$\phi_1 = d_2 \delta + d_3 + (1-\delta)(1-\sigma) > 0$$

$$\phi_2 = d_4(1-\alpha + \sigma) + d_1(1-\alpha)(1-\delta)(1-\sigma)$$

$$D_1 = (1-d_1)(c_2 d_5 + c_1 \sigma) + (1-d_1) \frac{(1-\alpha)}{\alpha} [c_2(1-\delta) + c_1]$$

$$D_2 = (1-d_1)(c_2 d_5 + c_1 \sigma)$$

$$D_3 = c_2(d_2 \delta + d_3) - c_1(1-\sigma)$$