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MACRO-ECONOMIC ADJUSTMENT WITH IMPORT PRICE SHOCKS: REAL AND MONETARY ASPECTS

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Summary

In this paper we explore in detail the various ways by which the introduction of intermediate imports affects the comparative statics and the dynamics of adjustment in an open economy. The importance of integrating the role of intermediate imports into a theory of macro-economic adjustment derives from the particular set of events that have affected the industrial economies in the 1970's -- the unprecedented rise in raw materials prices, in particular the oil price shock, and the concomitant inflation and widespread unemployment.

The analysis lays out in detail the separate workings of the commodity, labor and exchange rate markets, under various adjustment mechanisms, with the objective of obtaining empirically quantifiable hypotheses. An empirical study based on the present formulation has been prepared by the authors (see Bruno and Sachs (1979)).

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*INTRODUCTION**

In this paper we explore in detail various ways by which the introduction of intermediate imports affects the comparative statics and the dynamics of adjustment in an open economy.[1]

The importance of integrating the role of intermediate imports into a theory of macro-economic adjustment derives from the particular set of events that have affected the industrial economies in the 1970's -- the unprecedented rise in raw material prices, in particular the oil price shock, and the concomitant inflation and widespread unemployment. A number of questions naturally arise. How does a raw material price increase affect the level of output and employment in an open economy? A negative final goods supply effect may, at least in part, be compensated by positive substitution effects both on the input use side as well as through enhanced domestic production of close domestic substitutes. But the level of output is also determined by domestic real income and aggregate demand which are also affected by such external price shocks. Obviously this will, among other factors, depend on the extent to which a country is a net importer of intermediate goods whose price has risen.

The derived effects on the demand and supply of labour are not only

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1 Important previous work in this field is represented by Turnovsky and Kaspura (1974), Findlay and Rodriguez (1977) and Rodriguez (1977).

compounded by the conflicting income and substitution effects but also by the particular course that will be followed by real wages in response to an anticipated or unanticipated price shock. Finally, the nature of exchange rate adjustment and the monetary mechanism should play an important role in the adjustment process. It is a well known fact that OECD countries have had widely varying inflation rates in the 1970's inspite of having faced very similar external shocks. How is that to be accounted for?

It is quite obvious that a standard open economy macro model is irrelevant for the discussion of these issues. Nor would a two sector tradable/non-tradable goods model be appropriate, since a real external shock must involve the relative price of at least two tradable goods.[2]

The present paper considers a model in which there are two traded goods (intermediate and final) and one domestic final good which uses imported or domestic intermediate goods in production and is an imperfect substitute for the traded final good in the demand for consumption and exports. Our analysis proceeds by looking first at the supply, demand, and equilibrium in the commodity market, at given parameter levels of the exchange rate and the real wage (Sections I-III). The labour market in which the real wage is determined and the disequilibrium dynamics of the joint system are analysed in Section IV. The first sections thus concentrate on the real substitution and income effects of exogenous relative import price changes on output, employment and the final goods terms of trade. Appendix A considers in greater detail the case of variable domestic

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[2] If the price of both imports and exports rises at the same rate, there may be inflation but there need be no real allocative effects (except possibly temporary ones).

production of intermediate goods. The real part of the model may offer insight into some of the developments of the 1970's even before any monetary considerations are introduced.

Section V introduces the effects of money and exchange rate determination under a flexible exchange rate regime, assuming perfect capital mobility. The real-nominal dichotomy is subsequently broken in Section VI to allow for nominal wage stickiness, and the effect of only partial wage indexation. Section VII finally discusses joint exchange rate and real wage dynamics with errors in price expectations, also allowing for differences in response to anticipated versus unanticipated changes in money and import prices.

Our analysis differs from previous work in the attempt to lay out in detail the separate workings of the commodity, labour and exchange rate markets, under various adjustment mechanisms, with the objective of obtaining empirically quantifiable hypotheses. In that respect the paper forms a sequel to previous work on adjustment in OECD countries done by the authors in separate papers [Bruno (1978), Sachs (1978)]. This paper is to be followed with further empirical study of these questions based on the present formulation.

We end this introduction with a caveat as to questions that have been left out of the present analysis. In particular it should be stressed that the study is confined to the effects on individual economies of exogenous price and demand shocks. No attempt is made here to look at the feedback of collective developments in industrial countries on the world markets for raw materials nor at the repercussions of increased income of net exporters of raw materials on the domestic market of the industrial countries. This is an obvious candidate for further study.

I. THE BASIC MODEL--OUTPUT SUPPLY

The aggregative structure of the model is as follows. A small open economy, with a flexible exchange rate, faces given world prices of intermediate (P_n^*) and imported final (P^*) goods. Their relative price will be denoted by $\Pi_n (= P_n^*/P^*)$. The economy produces intermediate goods at the world price, and a single final good with price P. The final domestic good is an imperfect substitute in consumption with the foreign final good; consumption and export demand for the domestic final good vary negatively with the relative price of the two final goods $\Pi = P/P^*E$, where E is the exchange rate. There are thus three different goods in the system, one fully tradable intermediate good and two imperfectly substitutable final goods, but to maintain two-sector simplicity only one final good is domestically produced.

Domestic production of the final good (Q) is a function of labour input (L), input of the tradable intermediate good (N) and exogenously fixed capital (K):

$$Q \;=\; F(L,\, N;\, K)\;. \tag{1}$$

We shall adopt the convention of using small letters to denote logarithms of corresponding capital letter variables (e.g., $q = \log Q$, $\ell = \log L$, $\pi = \log \Pi$, etc.). First differences (or time derivatives) will be denoted by a dot ($\dot{q} = q_t - q_{t-1}$) and percentage rates of change by circumflex (thus $\dot{q} = \hat{Q}$). If we denote the output elasticities of the two variable factors (L, N) in (1) by $\alpha (= F_\ell L/Q)$ and $\beta (= F_n N/Q)$ we can write $\hat{Q} = \alpha\hat{L} + \beta\hat{N}$ or:

$$\dot{q} \;=\; \alpha\dot{\ell} + \beta\dot{n} \tag{1'}$$

where we assume $\alpha + \beta < 1$.

We may now appeal to standard duality results, under cost minimization, and obtain a marginal cost (MC) schedule, or alternatively, assuming MC = P, obtain a general output supply schedule of the form $Q^S(W/P, P_n/P; K)$. Since, however, we are interested in empirically quantifiable relationships there is some advantage in more detailed specification of the production function (1). One that is useful and yet sufficiently general for our purposes is the nested CES production function $Q = F[V(L, K), N]$ where $V(L, K)$ is a value-added function which itself is CES with elasticity of substitution σ_1 while the constant elasticity of substitution between the intermediate input (N) and value added (V) in F will be denoted by σ.

One very useful property of the CES function is the fact that per unit input demand is a simple log-linear function of the relative input price, and the price elasticity is equal to the respective elasticity of substitution. Thus for the intermediate input we have in log form (and ignoring constant intercepts):

$$n - q = -\sigma(p_n - p) \tag{2}$$

It can similarly be shown (see Appendix A.1) that for the labour input we can write:

$$\eta\ell - q = -\sigma(w - p) \tag{3}$$

where $\eta = \sigma_1^{-1}(1 - \beta)^{-1}[\sigma_1 \alpha + \sigma(1 - \alpha - \beta)]$ and α, β are the output elasticities in (1) as above.[3] Also we have used the following notation:

[3] These will in general be functions of respective marginal products (see Appendix A.1). If, as is plausible, $\sigma \leq \sigma_1$ it follows that $\eta \leq 1$ ($\eta = 1$ in the simple CES case $\sigma_1 = \sigma$).

$w \quad = \log W$ (nominal wage)

$p \quad = \log P$ (price level)

$p_n = p_n^* + e \quad = \log P_n$ (domestic price of intermediate good)

Substituting equations (2) and (3) in terms of first differences (dots) into (1') and rearranging terms we obtain the following supply equation:[4]

$$\dot{q}^s = -\alpha'(\dot{w} - \dot{p}) - \beta'(\dot{p}_n - \dot{p}) \tag{4}$$

where $\alpha' = (1 - \alpha - \beta)^{-1}\alpha\sigma_1 > 0$

$\beta' = (1 - \alpha - \beta)^{-1}\beta\sigma_1\eta > 0$

One may note that equation (4) could also be turned around to represent an adjustment equation for the supply price:[5]

$$\dot{p} = (\alpha' + \beta')^{-1}(\alpha'\dot{w} + \beta'\dot{p}_n + \dot{q}). \tag{4'}$$

Equation (4) expresses changes in output supplied as a negative function of changes in the product wage and the relative price of the intermediate input. The real wage variable in terms of which we subsequently

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[4] It may be worth pointing out that in the most general (non-CES) case the corresponding supply equation can be shown to be the same as (4) with $\sigma_1 = \eta = 1$ but with the addition of a term $(1 - \alpha - \beta)^{-1}(\dot{\alpha} + \dot{\beta})$ (this is minus the rate of change of the elasticity of capital, under constant returns).

[5] Actually this is the equation for the rate of change of MC, under cost minimization, which thus holds irrespective of market conditions. If this is to hold for prices as well it is enough to assume a constant degree of monopoly (i.e. P/MC = constant, not necessarily = 1) (see Bruno, 1977).

want to analyse the labour market is not the product wage but the consumption wage ($w_c = w - p_c$) where the consumption basket determining p_c may consist of both domestic as well as imported final goods (with prices p and $p^* + e$ respectively). We now define the consumer price index as a log-linear fixed weight function of the domestic and foreign final goods prices, where the weights λ and $(1 - \lambda)$ represent the shares of domestic and foreign final goods in domestic final consumption:

$$p_c = \lambda p + (1 - \lambda)(p^* + e). \tag{5}$$

We may write (5) in the form $p_c - p = -(1 - \lambda)(p - p^* - e) = -(1 - \lambda)\pi$ and note that $w - p = w_c - (1 - \lambda)\pi$. Also $p_n - p = \pi_n - \pi$. We can thus express the supply equation in terms of the change in the price of the final goods terms of trade ($\pi = p - p^* - e$), with the change in the international price ratio ($\pi_n = p_n^* - p^*$) and the real consumption wage ($w_c = w - p_c$) as parameters:[6]

$$\dot{q}^s = \gamma_1\dot{\pi} - \gamma_2\dot{\pi}_n - \gamma_0\dot{w}_c \tag{6}$$

where $\gamma_1 = \alpha'(1 - \lambda) + \beta' > 0$, $\gamma_2 = \beta'$

$\gamma_0 = \alpha'$

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[6] As in (4'), equation (6) can alternatively be written as a price adjustment equation [see Bruno (1978)]:

$$\dot{p}_c = \lambda(\alpha' + \beta')^{-1}[\alpha'\dot{w} + \beta'(\dot{p}_n^* + \dot{e}) + (\lambda^{-1} - 1)(\alpha' + \beta')(\dot{p}^* + \dot{e}) + \dot{q}] \tag{6'}$$

Note that $\gamma_1 > \gamma_2$, a property of which use will be made later. According to (6) domestic final goods production is an *increasing* function of the final goods terms of trade,[7] a *decreasing* function of the international price ratio of intermediate inputs and a *decreasing* function of the real consumption wage. The international price ratio π_n is *exogenous* for the small economy, so that fluctuations in its level can be termed *external* shocks in intermediate good costs. The real wage will in general not be exogenous but must be determined from conditions in the labour market to which we shall turn in Section IV. For the moment we can think of the supply curve SS drawn in Figure 1 as being a very 'short-run' supply curve for a temporarily fixed real wage. Only in case of full wage indexation ($\dot{w} = \dot{p}_c$) will this also be the 'long-run' curve.[8]

In the figures and elsewhere in the text we shall consider equations like (6) as being time shifts in underlying relationships that are approximately linear in logs. Thus the curve SS in Figure 1 is drawn for *levels* of variables (q, π) rather than first differences, being approximately correct for small shifts around some basic reference print.[9] To help explain equation (6), consider the effect on output of an intermediate good price shock, $\dot{\pi}_n > 0$. At a constant final goods terms of trade (i.e. $\dot{\pi} = 0$), the price shock raises the price of the intermediate good relative to the

[7] Note that π can also be viewed as the reciprocal of the real domestic cost of the foreign good which in turn is the real exchange rate ($e - p$) multiplied by (plus log of) the foreign price (p^*).

[8] This should not be confused with a 'true' long-run supply curve in which capital too may change.

[9] In our empirical investigation estimates are anyway based on first differences in logs (see Appendix B).

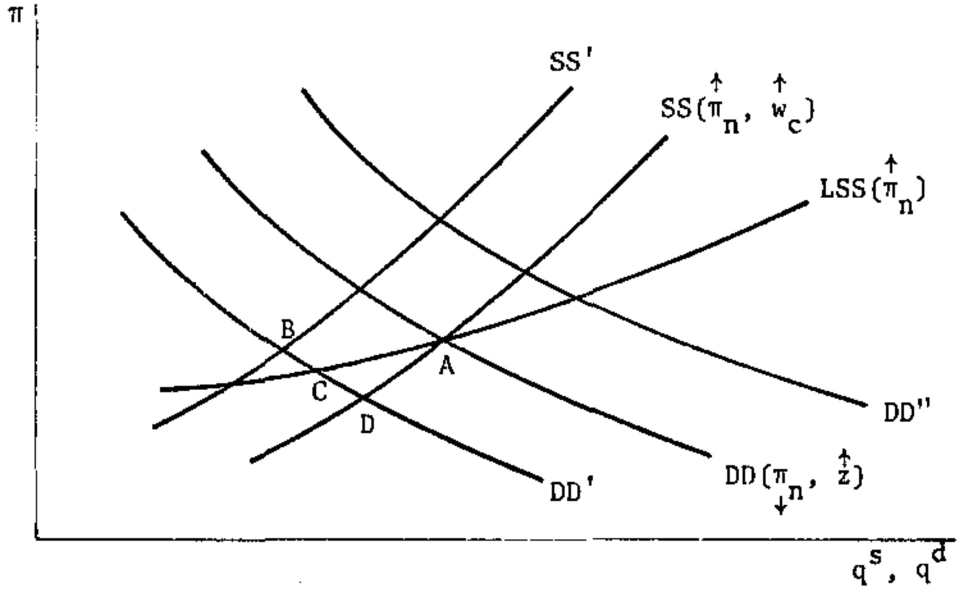

Figure 1

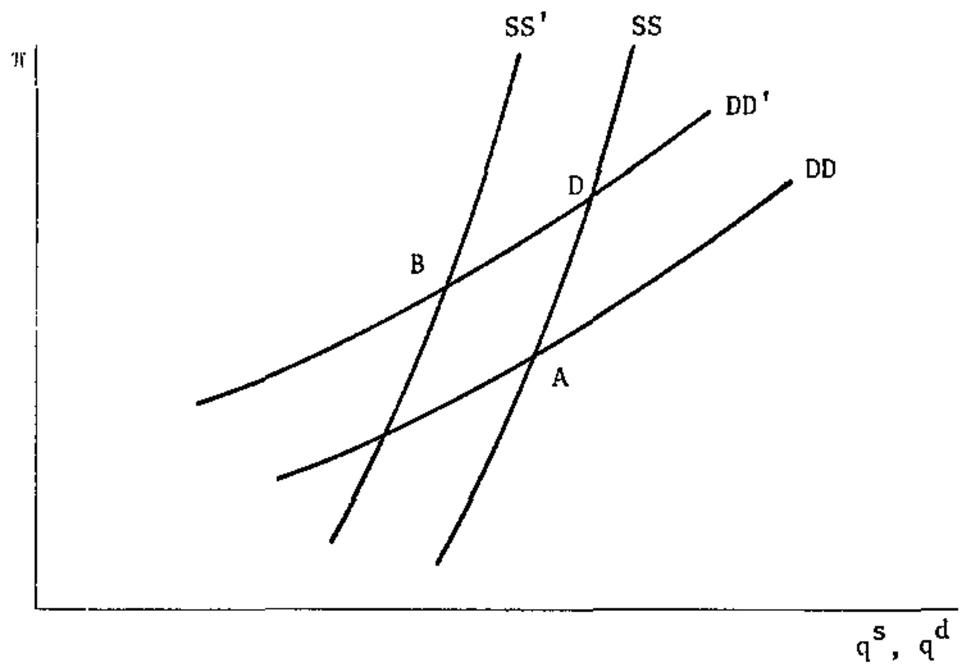

Figure 2

domestic final good. Firms will want to curtail production unless the real wage falls sufficiently.[10] We shall consider the labour market and the determination of real wages after analysing the demand side of the commodity market to which we turn first.

II. COMMODITY DEMAND

We first derive the aggregate demand schedule on the assumption of a fixed level of domestic production of the intermediate good. This simplification considerably clarifies the workings of the model. We shall subsequently allow for endogenous determination of domestic intermediate goods supply (details are given in Appendix A.2).

The total demand for domestic final good is given by

$$Q^d = C + I + G + X \tag{7}$$

where $C + I + G$ represents that part of total domestic final expenditure falling on the *domestic* final good (i.e. imports have already been netted out from C, I, G). Nominal gross national product is less than PQ by the value of net imports of the intermediate good. To see this, note that value added in the domestic final goods industry is $PQ - P_n N$. Value added in the intermediate goods industry is $P_n H$.[11] Ignoring inventory changes, $N - H$ equals net imports of the intermediate good. GNP in value terms

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[10] From equation (4) one can see clearly that $\dot{p}_n - \dot{p} > 0$ requires $\dot{w} - \dot{p} < 0$ for $\dot{q} = 0$. At a constant terms-of-trade, $\dot{p} = \dot{p}_c$, so $\dot{w} - \dot{p}_c$ must be negative.

[11] We are assuming that gross-output = value added in the intermediate goods industry.

(P_yY) is then given as the sum of value added:

$$P_yY = PQ - P_n(N - H) \tag{8}$$

The components of Q^d in (4) are assumed to follow standard macroeconomic specifications. Consumption of home goods can be expressed as a function of real income, in domestic good units (P_yY/P)[12] net of (real) taxes (T) and the final goods terms-of-trade $(\Pi = P/P^*E)$:

$$C = C[P_yY/P - T, 1/\Pi] \tag{9}$$

We will assume $1 > C_1 > 0$, $C_2 \geq 0$, though the second inequality need not hold.[13]

Interest rate effect on consumption as well as on investment will be ignored, and investment will, for simplicity, be treated as exogenous. This will enable us to keep the analysis of real effects for the time being separate from the nominal system to which we turn later. Export demand for the domestic final good is a function of world income (Y*) and the final goods terms of trade $(1/\Pi)$:

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[12]This is not the same as real GNP (Y) which will subsequently be measured as a Divisia index (see below p.). An alternative measure of real income for consumption purposes would be P_yY/P_c.

[13]C_2 is the derivative with respect to $1/\Pi$. According to the Slutsky decomposition, $C_2 = C_2^1 - C_fC_1$ where C_2^1 is the pure substitution effect $(C_2^1 > 0)$ and C_f is the consumption of importables. For stability a less restrictive assumption can be made [see Fraenkel and Hanoch (1977)].

This formulation also ignores the possibility that there may be direct final consumption of the intermediate good. In the latter case the real wage and the labour supply curve would be affected directly by a change in Π_n.

$$X = X(Y^*, 1/\Pi) \qquad X_1 > 0,\ X_2 > 0 \tag{10}$$

Finally, for the time being, domestic production of the intermediate good is taken as fixed:

$$H = \bar{H}\ . \tag{11}$$

Equations (7) - (11) determine an aggregate demand schedule. Substituting (8) - (11) into (7), logarithmically differentiating and substituting from (2) we eventually obtain an aggregate demand schedule which can be written as

$$\dot{q}^d = \delta_2(\dot{p}_n - \dot{p}) - \delta_3(\dot{p} - \dot{p}^* - \dot{e}) + \delta_0\dot{z} \tag{12}$$

or:

$$\dot{q}^d = -\delta_1\dot{\pi} + \delta_2\dot{\pi}_n + \delta_0\dot{z} \tag{13}$$

where $\dot{z} = Q^{-1}[\dot{I} + \dot{G} - c\dot{T} + X_1\dot{Y}^*]$ and z represents a general demand shift index. $\dot{\pi} = \dot{p} - \dot{p}^* - \dot{e}$ and $\dot{\pi}_n = \dot{p}_n^* - \dot{p}^*$, as before, are the rates of change of the two respective relative prices. The coefficients are:

$$\delta_0 = [1 - (1 - \beta)C_1]^{-1} > 0 \qquad \text{(Keynesian Multiplier)}$$

$$\delta_1 = \delta_2 + \delta_3$$

$$\delta_2 = \delta_0 C_1(\beta\sigma - \theta_n) \gtrless 0 \quad \text{where}$$

$\theta_n = P_n(N - H)/(PQ)$ = share of intermediate imports in gross output

and $\delta_3 = \delta_0 Q^{-1}\Pi^{-1}(C_2 + X_2) > 0$ (this is the response of final demand to a change in Π^{-1}), therefore $\delta_1 > \delta_2$.

The aggregate demand multipliers implied for the components of (I, G, -T, Y*) are familiar. Our attention rather turns to the multipliers on the final goods terms of trade (π) and the relative price of intermediate goods (π_n). Consider the effect of a rise in the intermediate good price relative to P (i.e. the sign of δ_2). At a *given* level of gross output Q, GNP will change according to changes in $\frac{P_n}{P}(N - H)$. Two effects are manifest. For given Q, a rise in $\frac{P_n}{P}$ will reduce the input of N if technology permits (i.e. $\sigma > 0$), in the amount $\sigma(\dot{p} - \dot{p}_n)$, which will raise GNP by $\beta\sigma(\dot{p} - \dot{p}_n)$ on account of a substitution effect. The reduction of N allows the economy to reduce its net imports of the intermediate good, or perhaps to increase its net exports. In either event, GNP *rises* relative to gross output. The other effect is a direct price effect on income, at given N and H. At initial Q, N, H, the relative price movement $\dot{p}_n - \dot{p} > 0$ changes income in the amount $-\theta_n(\dot{p}_n - \dot{p})$, where θ_n is the share of intermediate imports. For net importers of N, real income falls by the share of net imports in gross output. For net exporters, income rises.

In our empirical work, a large part of N is fuel, of which all but two of the OECD nations are net importers.[14] The sign $\delta_2 < 0$ or $\delta_2 > 0$ thus depends crucially on whether the positive substitution effect is outweighed by the negative income effect ($\beta\sigma < \theta_n$).[15] It is useful to

[14] In 1973, only Canada and Australia among the OECD nations were net exporters of S.I.T.C. 3, "Mineral Fuels." See *U.N. Yearbook of International Trade Statistics*, 1976 [ ]. Once one considers other raw materials there are additional net exporters for whom the terms of trade had hardly worsened (e.g. Sweden, Finland).

[15] We definitely have $\delta_2 < 0$ in the fixed proportions case ($\sigma = 0$), which is the one analyzed by Findlay and Rodriguez (1977).

determine at what point the two effects exactly cancel. Formally, this is given by $\delta_2 = 0$, or $\beta\sigma = \theta_n$. In the case of *no* domestic production, $\beta = \frac{P_n N}{PQ} = \frac{P_n(N - H)}{PQ} = \theta_n$, so that $\delta_2 = 0$ when $\sigma = 1$. With Cobb-Douglas technology for $F(V, N)$ $\frac{P_n N}{PQ}$ is constant; with no imports and constant Q, GNP is fixed. With $H = 0$, $\sigma < 1$ implies that the value of net imports of N rises as the relative price rises, so that GNP will decrease for fixed Q. With $\sigma > 1$, GNP rises, *mutatis mutandis*. With domestic production of N, the conditions for a decrease in GNP are more stringent. Since $\beta > \theta_n$ for $H > 0$, we need $\sigma < \frac{\theta_n}{\beta} < 1$. For most OECD economies, at least in the short-run, with little possibility for technical substitution, we should suppose that $\sigma < \frac{\theta_n}{\beta}$, and $\delta_2 < 0$.

The effects of final good terms-of-trade shifts on aggregate demand $(\delta_1 = \delta_2 + \delta_3)$ are similarly ambiguous. The consumption and export substitution effects cause an increase in domestic final good demand when $\dot{\pi} < 0$, of δ_3 $[= \delta_0 Q^{-1} H^{-1}(C_2 + X_2)]$. The coefficient δ_2, we have argued, is likely to be negative. δ_1 which is the sum of δ_2 and δ_3 may be positive even when $\delta_2 < 0$. Plausible parameter values suggest that it is in fact positive; stability may require it.[16] For the theoretical development, below, we will assert this condition except where stated. In the empirical work, we test explicitly for the sign of δ_1.

Equation (13) is represented in Figure 1 as aggregate demand schedule DD, tracing the relationship between $q^d(= \log Q^d)$ and $\pi(= p - p^* - e)$ for given π_n and the components of $z(I, G, -T, Y^*)$.[17] It is drawn as

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[16] See below, p. 16.

[17] Again we draw the curve for price and output *levels* as if there are no dots (time derivatives) on the variables in (13).

negatively sloped under the assumption of $\delta_1 > 0$. Consider the effect of an increase in π_n. For $\beta\sigma - \theta_n < 0$, the aggregate demand schedule shifts down and to the left to DD'; when $\beta\sigma - \theta_n > 0$, the schedule shifts up and to the right to DD". Similar shifts occur for increases in I (up), G (up), T (down) and Y* (up).

III. COMMODITY MARKET EQUILIBRIUM

The equilibrium of the commodity market may be found by combining both aggregate supply and demand. An oil price shock shifts SS to the left. For an oil exporting country, aggregate demand shifts out to DD". The effect on gross output is ambiguous, while the final goods term-of-trade unambiguously improve. For a heavily dependent oil importing country ($\beta\sigma - \theta_n < 0$), aggregate demand shifts to the left. Now, the decline in output is unambiguous, though the direction of the terms-of-trade shift is indeterminate. Shifts in G, T, I, and Y* all leave the SS curve unaffected, while moving DD in the appropriate direction. These variables all have an unambiguous effect on output and the terms-of-trade.

Equations (6) and 13) are readily solved algebraically. Equating $\dot{q}^d$ and $\dot{q}^s$, and solving we get:

$$\left.\begin{aligned} \dot{q} &= (\gamma_1 + \delta_1)^{-1}[(\delta_2\gamma_1 - \delta_1\gamma_2)\dot{\pi}_n + \delta_0\gamma_1\dot{z} - \delta_1\gamma_0\dot{w}_c] \\ \dot{\pi} &= (\gamma_1 + \delta_1)^{-1}[(\gamma_2 + \delta_2)\dot{\pi}_n + \delta_0\dot{z} + \gamma_0\dot{w}_c] \end{aligned}\right\} \quad (14)$$

The reader can trace out analytically the sign indeterminacies of the multipliers, examined graphically above. Although γ_1 can be negative, we definitely require $\gamma_1 + \delta_1 > 0$. Note that for $-\gamma_1 < \delta_1 < 0$, it is theoretically possible that $\frac{\delta_2\gamma_1 - \delta_1\gamma_2}{\gamma_1 + \delta_1} > 0$, so that $\dot{q}/\dot{\pi}_n > 0$ even for $\delta_2 < 0$. Graphically this is the case of an upward sloping aggregate demand schedule, with absolute slope less than the SS slope. Now, the upward shift of the DD curve which follows $\dot{\pi}_n > 0$ increases q (see Figure 2). Depending on the dynamic specification of the model, this configuration may be unstable (akin to the failure of the Marshall-Lerner condition). Empirically, we trust, this is a mere curiosum. If, as seems most likely $\delta_1 > 0$ and $\delta_2 < 0$, output definitely falls as π_n rises (for given z and w_c).

Consider now how varying degrees of dependence on foreign imports of the intermediate good affect the various multipliers. For given β, θ_n enters the reduced form of q only through δ_1 and δ_2. Since $\frac{d\delta_1}{d\theta_n} =$ $= -\delta_0 C_1 < 0$, higher net imports of the intermediate good increase the absolute slope (δ_1^{-1}) of the aggregate demand schedule. Increases in autonomous spending will therefore have larger effects on output the larger is θ_n. This can be seen diagramatically or else directly from the coefficient $[(\gamma_1 + \delta_1)^{-1}\delta_0\gamma_1]$ of $\dot{z}$ in the reduced form for $\dot{q}$ in (14). This result can be explained in the following way. A fiscal shift raises the terms of trade, cutting off some of the expansionary effect on q. Through the terms-of-trade, the fiscal expansion induces a second-round shift of spending from the home to the foreign final good. A countervailing effect of the terms-of-trade improvement is the reduction in real prices of the intermediate good. The larger is θ_n, the more benefit is reaped by the price reduction, reducing the net drag of the terms-of-trade on income.

For $\frac{dq}{d\pi_n}$ the impact on the multiplier is given by $\frac{d}{d\theta_n}\left[\frac{\delta_2\gamma_1 - \delta_1\gamma_2}{\gamma_1 + \delta_1}\right]$

which works out in terms of the coefficients of equations (6) and (13) to

$$\frac{d}{d\theta_n}\left[\frac{dq}{d\pi_n}\right] = \frac{C_1\delta_0\gamma_1[(\gamma_2 - \gamma_1) + (\delta_2 - \delta_1)]}{(\gamma_1 + \delta_1)^2} < 0 \quad \text{since} \quad \gamma_1 > \gamma_2 \quad \text{[see}$$

equation (6)] and $\delta_1 > \delta_2$ [see equation (13)]. This is an important result, and it is readily tested empirically: the greater the percentage of net intermediate imports in gross production, the larger will be the reduction of output upon an intermediate good price hike.[18]

Likewise we note that $\frac{d}{d\theta_n}\left[\frac{d\pi}{d\pi_n}\right] = \frac{-C_1\delta_0[(\gamma_1 - \gamma_2) + (\delta_1 - \delta_2)]}{(\gamma_1 + \delta_1)^2} < 0.$

Thus, if the final goods terms of trade (π) rise as result of a rise in the international price ratio (π_n) it will do so by less and if it falls it will do so by more, the higher the share of net imports of intermediates in gross output.

There is, of course, one limiting case in which the size of θ_n will not matter. This is the case of a flat demand curve (π = constant).[19] Letting $\delta_1 \to \infty$ we have $\frac{dq}{d\pi_n} = -\gamma_2$ which brings us back to pure supply shifts which will always be negative for $\dot{\pi}_n > 0$.

Until now everything has been expressed in terms of effects on gross output (Q) rather than on GNP(Y). The analysis of impact effects can readily be extended to the latter by using a suitable measure of GNP. Suppose this is measured as a Divisia Index. We can then write, on the basis of (8) that $(P_yY)\dot{y} = (PQ)\dot{q} - P_n(N - H)(\dot{n} - \dot{h})$. After suitable substitution it follows that

[18] This result remains correct when domestic production of intermediate goods is allowed to vary (see Appendix A.2).

[19] This is the case in which purchasing power parity in final goods holds everywhere ($\dot{p} = \dot{p}^* + \dot{e}$).

$$\dot{y} = (1 - \theta_n)^{-1}[(1 - \beta)\dot{q} + \beta\sigma(\dot{p}_n - \dot{p})] = \tag{15}$$

$$= (1 - \theta_n)^{-1}[(1 - \beta)\dot{q} + \beta\sigma\dot{\pi}_n - \beta\sigma\dot{\pi}]$$

Since $\theta_n < \beta$ the coefficient of $\dot{q}$ is less than one and thus any change in q will be reflected in a smaller rate of change in y on account of the commitant change in intermediate imports. In addition there is the direct positive substitution effect of a change in the relative price of intermediates ($\dot{p}_n - \dot{p} = \dot{\pi}_n - \dot{\pi}$) on value added.

By appealing to the original supply and demand functions (6) and (13) one can readily calculate the new coefficients (denoted by γ_i' and δ_i', respectively) for the modified supply ($\dot{y}^s$) and demand ($\dot{y}^d$) curves in terms of GNP rather than gross output. For the supply curve we find

$$\gamma_1' = \alpha_0'[1 - \lambda(1 - \beta)] > 0$$

$$\gamma_2' = \alpha_0'\beta > 0 \text{ (and } \gamma_1' > \gamma_2' \text{ as before)}$$

$$\gamma_0' = \alpha_0'(1 - \beta) > 0$$

where $\alpha_0' = (1 - \theta_n)^{-1}\alpha' = (1 - \theta_n)^{-1}(1 - \alpha - \beta)^{-1}\alpha\sigma_1 > 0$ so that all the previous signs are maintained. For the demand curve we have: $\delta_0' = (1 - \theta_n)^{-1}(1 - \beta)\delta_0$, $\delta_1' = (1 - \theta_n)^{-1}[\delta_1(1 - \beta) + \beta\sigma]$ so that $\delta_1' > 0$ if $\delta_1 > 0$ and the slope of the demand curve remains positive. Finally, $\delta_2' = (1 - \theta_n)^{-1}[\delta_2(1 - \beta) + \beta\sigma]$. Here we may find $\delta_2' > 0$ even though $\delta_2 < 0$ so that the shift of the corresponding demand curve may be upwards rather than downwards. For the equilibrium solution (14), using δ_i' and γ_i' rather than δ_i & γ_i it can be seen that $\frac{d\dot{y}}{d\pi_n}$ will still be negative providing $\delta_2'(\gamma_1' - \gamma_2') < \delta_3'\gamma_2'$ (remember that $\delta_1' = \delta_2' + \delta_3'$ where $\delta_3' =$

$= (1 - \theta_n)^{-1}(1 - \beta)\delta_3 > 0)$. This will always be true providing θ_n is large enough.

The last modification to be briefly considered comes from allowing variations in the output of the domestic intermediate good industry (H) in response to changes in π_n. This case is taken up in Appendix A.2, where it is shown that the final output demand curve (q^d) will now be: (i) steeper, (ii) will shift downwards by less (or upwards by more) for a given $\dot{\pi}_n > 0$ [20] and (iii) it will now shift down in response to a real wage increase ($\dot{w}_c > 0$) while the previous q^d curve was unaffected.

Again it is shown that the equilibrium gross output (and GNP) will be reduced by an increase in π_n providing the import share of intermediate goods (θ_n) is large enough relative to the combined effect of substitution between N & V and the income effect of increased domestic supply of H.

IV. THE LABOUR MARKET AND REAL WAGE DYNAMICS

Hitherto we have taken the real wage (W_c) as a given parameter in the commodity market. We now turn to a discussion of the labour market so as to provide a determinant of the real wage and a link to the commodity market and to the subsequent discussion of the dynamics of the whole system.

Consider first the derived demand for labour which can be obtained from the commodity output side.[21] From equations (3) and (5) we have

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[20] The reason for that is the positive income effect coming from the increase in the output of the domestic intermediate goods industry.

[21] Again we consider first the case $H = \overline{H}$, ignoring the constant level of employment in this industry.

$$\ell^d = \eta^{-1}[-\sigma w_c + (1 - \lambda)\sigma\pi + q] \tag{16}$$

After substituting from equation (14) in level (undotted) form we find:

$$\ell^d = -\eta_1 w_c + \eta_2 \pi_n + \eta_3 z \tag{17}$$

where

$$\eta_1 = \eta^{-1}(\gamma_1 + \delta_1)^{-1}[\sigma\beta' + \delta_1(\alpha' + \sigma)] > 0$$

$$\eta_2 = \eta^{-1}(\gamma_1 + \delta_1)^{-1}[(1 - \lambda)\sigma(\gamma_2 + \delta_2) + \delta_2\gamma_1 - \delta_1\gamma_2] \gtrless 0$$

$$\eta_3 = \eta^{-1}(\gamma_1 + \delta_1)^{-1}\delta_0[(1 - \lambda)\sigma + \gamma_1] > 0$$

In Figure 3 the demand curve for labour (again written in log form ℓ^d) is downward sloping in terms of the (log) consumption wage (w_c) with z and π_n as parameters. Any variable shifting up commodity demand (e.g. fiscal policy) will shift ℓ^d up and to the right. To the extent that $\eta_2 < 0$ a rise in π_n will shift ℓ^d downward. This is by no means guaranteed, however. First we note from equation (16) that we could in principle have ℓ^d rise, for given w_c, even when output is constant or falls in face of an external shock, providing π falls sufficiently. Next we may note that once the H-industry output is allowed to vary we have to add its derived demand for labour (ℓ_h) which will rise when $\dot{\pi}_n > 0$. In that case the analysis has to be modified along the following lines (see Appendix A.2). Denoting the labour elasticity in H by α_h and the elasticity of substitution (between labour and capital) by σ_h we have:

$$\dot{\ell}_h = -(1 - \alpha_h)^{-1}\sigma_h(\dot{w} - \dot{p}_n) = -(1 - \alpha_h)^{-1}\sigma_h[-w_c - \lambda\dot{\pi} + \dot{\pi}_n] \tag{18}$$

If the share of the Q-industry labour (call it L_q now) in total employment is u we now have: $\dot{\ell}^d = u\dot{\ell}_q + (1 - u)\dot{\ell}_h$ where $\dot{\ell}_q$ is given by equation (16) and $\dot{\ell}_h$ by equation (18). This will keep the modified signs on the new coefficients η_1, η_3 as in (17) but may reverse the sign on η_2 for large enough import substitution effects. We shall here ignore this possibility and assume $\eta_2 < 0$. It is plausible to expect this to be the normal case for an OECD country in the 1970's.

We now draw an upward sloping curve of labour which in terms of logs will take the form

$$\ell^s = \lambda_1 w_c \tag{19}$$

Equilibrium in the labour market is achieved at the intersection of the demand (ℓ^d) and supply (ℓ^s) curves, which is point E in Figure 3, with real wage w_{c_0} and full employment ℓ_0.

Consider now an exogenous shock in the form of an increase in $\pi_n =$ $= p_n^* - p^*$. We have already seen the effect in the commodity market. In the labour market the curve LD will shift down (if $\eta_2 < 0$) to LD' and the new equilibrium wage will be $w_{c_1} < w_{c_0}$ (and employment $\ell_1 < \ell_0$). If the real wage indeed falls this will have additional repercussions on the commodity market by shifting the supply curve SS back down (see Figure 1). How far down and at what speed?

Let us take up the first question first. If there were instantaneous adjustment in the labour market then one would have to consider w_c in the commodity supply function as endogenous by virtue of equation (19) and in fact solve for a longer run commodity supply function for which only π_n remains as exogenous shift parameter. Substituting for w_c in the commodity supply [equation (6)] from (16) and (19) under $\ell^s = \ell^d$ we obtain a modified general equilibrium supply equation which now takes the form

$$q = \gamma_1'\pi - \gamma_2'\pi_n \tag{20}$$

where

$$\gamma_1' = (1 + \gamma_0')^{-1}[\gamma_1 - \gamma_0'\sigma(1 - \lambda)] < \gamma_1$$

$$\gamma_2' = (1 + \gamma_0')^{-1}\gamma_2 < \gamma_2$$

and

$$\gamma_0' = \gamma_0(\lambda_1 + \eta^{-1}\sigma)^{-1} > 0$$

One can see that as we let $\lambda_1 \to \infty$ we obtain $\gamma_0' \to 0$ and $\gamma_i' \to \gamma_i (i = 1, 2)$ as in the original real-wage-indexed, supply curve. This would correspond to the case of a fully elastic labour supply curve. Another special case is that in which the labour supply curve is vertical $(\lambda_1 = 0)$ and we have a simple CES function $(\eta = 1)$. In that case we get $\gamma_1' = \gamma_2' = (1 - \beta)^{-1}\beta\sigma$ and the commodity supply curve can be written as $q = (1 - \beta)^{-1}\sigma\beta(\pi - \pi_n)$. In the general case we have an upward sloping commodity supply curve but it is obviously flatter than the original SS curve (see the curve LSS in Figure 1) and an exogenous shift in π_n will move it up by less than the original curve. This follows from the fact that $\gamma_i' < \gamma_i$ for $i = 1, 2$ as can be seen from the comparison above. A similar computation also shows that equilibrium output will fall by less when the real wage is allowed to fall in response to the external shock.

Consider now the second question mentioned above, namely the speed of adjustment of w_c to the long run labour market equilibrium. Empirical realism suggests that even when the real wage adjusts to excess supply (or demand) in the labour market it will do so only slowly and at a lag.

One plausible formulation for discrete time intervals is

$$w_{c_{t+1}} = \psi(\ell_t^d - \ell_t^s) + w_{c_t} \tag{21}$$

where $\psi > 0$.

Upon substitution from (17) and (19) this gives a recursive relationship:

$$w_{c_{t+1}} = [1 - \psi(\lambda_1 + \eta_1)]w_{c_t} + \psi(\eta_2 \pi_{n_t} + \eta_3 z_t) \tag{22}$$

What this means in terms of Figure 3 is that in face of an external shock the labour demand curve will fall from LD to LD' but the real wage will temporarily remain at w_{c_0}. At this real wage there will be exces⁻ supply of labour of the amount EF, giving a downward push $\Psi(\ell^d - \ell^s) < 0$ on $w_{c_{t+1}}$ 'next' period and so on.

Suppose there is an external shock (say $\pi_{n_t} > \pi_{n_{t-1}}$). In terms of Figure 1, the commodity market adjusts instantaneously in the familiar fashion from A to B (at given w_{c_t}). There follows a delayed downward adjustment of the real wage based on (22) until the system finally settles at the point of intersection (C) of LSS and DD' in Figure 1, and at the point G of the labour market in Figure 3.

Stability of the process (22) requires that $-1 < 1 - \psi(\lambda_1 + \eta_1) < 1$ and if we exclude the case of oscillations then in addition we really require $\psi < (\lambda_1 + \eta_1)^{-1}$.

A framework such as the above can be used to analyse the repercussions of the oil and raw material price stock of 1972-74 on individual countries.

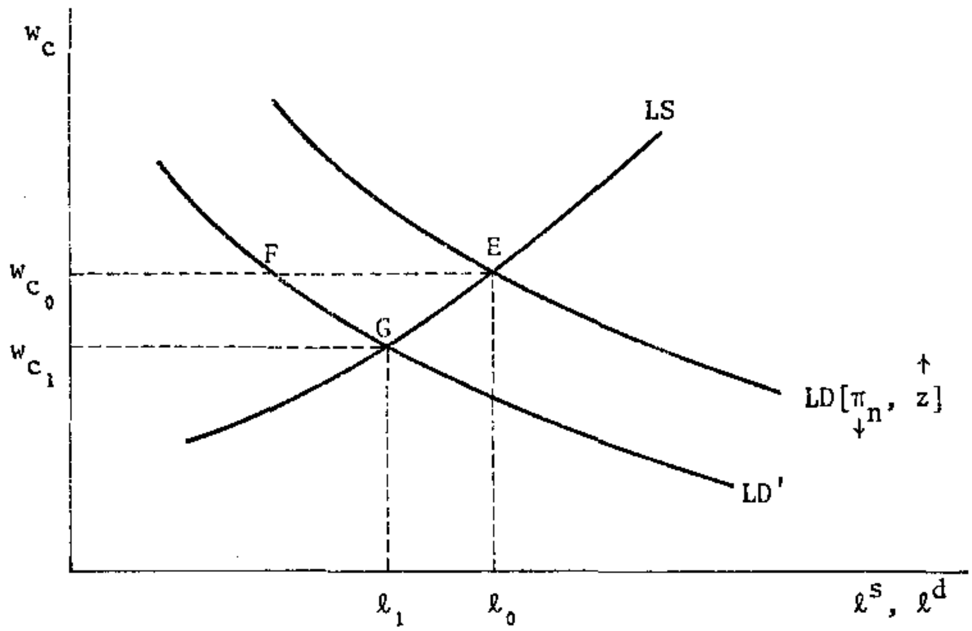

Figure 3

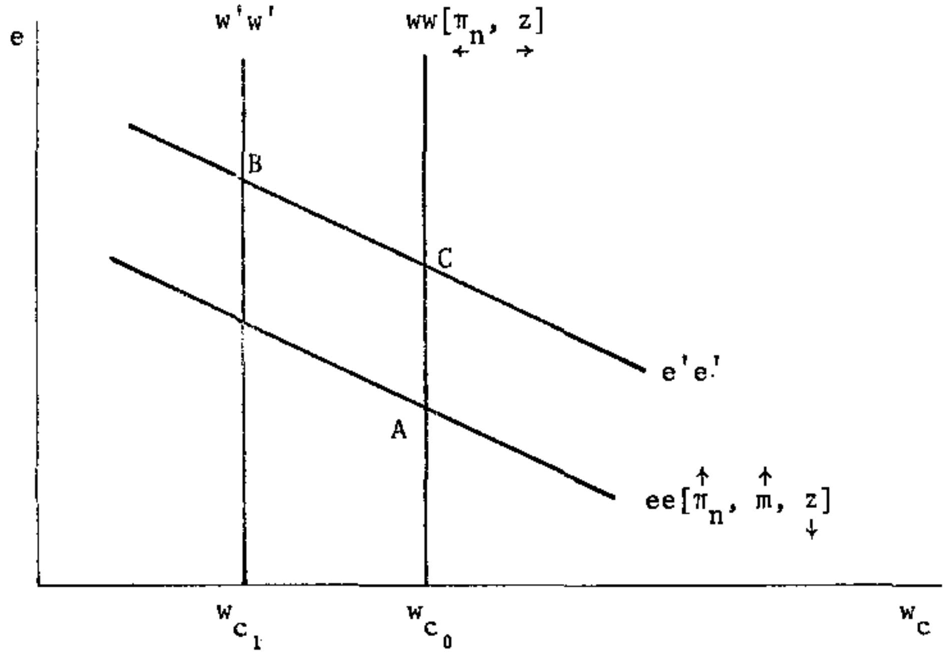

Figure 4

The typical response was a combination of a rise in π_n bringing about an upward shift in SS and downward shift in the DD curve, the latter being further compounded by restrictive demand management as well as the overall reduction in world export demand (i.e., $\dot{z} < 0$, making for a downward pull on the aggregate demand curves). In almost all OECD countries the result was a fall in output in 1975 (or already in 1974). Different countries reacted differently in terms of real wage performance relative to the long-run trend. Some of these developments have been analyzed in Bruno (1978) and Sachs (1978) and will be further studied in our subsequent work in the light of the present model (see also Appendix B).

V. *MONEY, EXCHANGE RATES AND PRICES UNDER A REAL-NOMINAL DICHOTOMY*

The reader may have wondered why no explicit monetary mechanism has so far been introduced and nothing has been said about the determination of the exchange rate and the domestic price level. Presenting a model with a real-nominal dichotomy enables one to pinpoint precisely where the nominal variables such as the exchange rate, money or nominal wage rates matter. As long as we ignore nominal interest-rate effects on real expenditure or possible direct effects coming from asset holdings, the real system is completely determined by real variables. Given relative world prices and world demand, domestic real demand management and real wage behaviour, output, real income, and relative prices are fully determined in both the short and the long run. The introduction of money up to this point would only help to determine the domestic price level (p_c) but would not change any *relative* price (such as the real exchange rate $e - p$ or π). Likewise, in a fixed exchange rate regime, once e is set, equilibrium levels of p and w follow. The above is a useful dichotomy which will also be explored in our empirical investigation,[22] but it obviously also has its limits.

In the introduction of the monetary part of our model we will take a gradual approach. First we append money and exchange rate determination to the real-wage adjustment model of the previous section, and discuss the comparative statics and dynamics of such a simple disjoint system. Then we introduce a model of <u>nominal</u> (as opposed to real) wage rigidity, discuss indexation and look at the more complex interplay of the two parts of the system under exogenous shocks, when the nominal-real dichotomy can no longer be considered valid for short-term effects.

Let us turn first to the asset markets. We assume that the small open economy faces a given world interest rate, and that domestic rates are tied to the world rate by covered interest arbitrage

$$R_t - R_t^* = F_t \tag{23}$$

where F_t is the percentage forward discount of the domestic currency. (23) is tantamount to assuming perfect substitutability of securities denominated in different currencies, except for exchange risk. With risk-neutral agents, the forward discount must equal the expected rate of depreciation:

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[22] It is, for example, important to point out how much of the macro developments following the commodity crisis in different countries can be explained in terms of <u>real</u> (as opposed to monetary) phenomena. This, of course, is no reflection on the original causes of the commodity crisis which in large measure had monetary (i.e., excess world liquidity) antecedents.

$$F_t = \frac{E^e_{t+1} - E_t}{E_t} \simeq e^e_{t+1} - e_t \tag{24}$$

Finally, we adopt a standard transaction-demand equation for real balances, following the empirical work of Goldfeld (1973) and others,

$$m_t - p_{c_t} = \phi q_t - bR_t \ . \tag{25}$$

Because we are abstracting from inside money, m is taken as the policy parameter of the monetary authorities. Combining equations (23)-(25) we obtain the following familiar money-exchange-rate expectations equation

$$m_t - p_{c_t} = \phi q_t - b(e^e_{t+1} - e_t) - bR^*_t \ . \tag{26}$$

This equation can be linked to the real system given by equations (14) which can be rewritten as

$$\left.\begin{aligned} p_c &= \lambda\pi + e + p^* = e + p^* - \alpha_1\pi_n + \alpha_2 z + \alpha_3 w_c \\ q &= \qquad\qquad\qquad\qquad - \beta_1\pi_n + \beta_2 z - \beta_3 w_c \ , \end{aligned}\right\} \tag{27}$$

where α_i and β_i are given by the coefficients of equation (14) [$\alpha_1 = -\lambda(\gamma_1 + \delta_1)^{-1}(\gamma_2 + \delta_2)$, $\beta_1 = -\lambda(\gamma_1 + \delta_1)^{-1}(\delta_2\gamma_1 - \delta_1\gamma_2)$, etc.] and we assume $\alpha_i > 0$, $\beta_i > 0$ $(i = 1, 2, 3)$. Consider first the time-free equilibrium obtained from (26) under static (and rational) expectations ($e^e_{t+1} = e_t$), substituting for p_c and q from equations (27). We obtain

$$e = (\phi\beta_3 - \alpha_3)w_c + (\alpha_1 + \phi\beta_1)\pi_n - (\alpha_2 + \phi\beta_2)z + (m - p^* + bR^*) \tag{28}$$

and

$$p_c = \phi\beta_3 w_c + \phi\beta_1 \pi_n - \phi\beta_2 z + (m + bR^*) \ . \tag{29}$$

For given values of all other exogenous variables (π_n, z, etc.) equation (28) gives a relationship between e and w_c (represented as line ee in Figure 4), whose slope depends on whether $\phi\beta_3 \lesseqgtr \alpha_3$. Inspection of the underlying coefficients shows that $\phi\beta_3 - \alpha_3 = (\gamma_1 + \delta_1)^{-1}\gamma_0(\phi\delta_1 - 1)$ so that the above condition in turn depends on whether $\phi \lesseqgtr \delta_1^{-1}$, where δ_1^{-1} is the slope of the commodity demand curve in Figure 1. In Figure 4 the assumption is that $\phi\beta_3 < \alpha_3 (\phi < \delta_1^{-1})$. Line ee will move up with an increase in π_n and in m and down with fiscal expansion ($\dot{z} > 0$).

The equilibrium real wage can be written in the form [see equations (17) and (19)]

$$w_c = \theta_1 \pi_n + \theta_2 z \ , \tag{30}$$

where $\theta_1 = -(\lambda_1 + \eta_1)^{-1}\eta_2$; $\theta_2 = (\lambda_1 + \eta_1)^{-1}\eta_3$, and we assume $\theta_i > 0$, $i = 1, 2$.

For given exogenous variables π_n and z , this can be represented as a vertical line ww in the e-w space (Figure 4). It will shift to the left with an increase in π_n and to the right with an increase in z .

Consider an increase in the relative price of intermediate imports (π_n). In Figure 4 this is represented as a movement from an equilibrium point, A, to another, B (at the intersection of e'e' and w'w'), with lower equilibrium real wage ($w_{c_1} < w_{c_0}$) and higher (depreciated) exchange rate.[23]

[23] This result obviously depends on the assumption that π_n shifts labour demand [$\eta_2 < 0$, $\theta_1 > 0$, see equations (17) and (30)] and equilibrium output ($\beta_1 > 0$) down. Neither assumption, as seen, need necessarily hold.

From (29) we know that the price level (p_c) will also increase. An increase in the nominal money supply (m) will affect the exchange rate but not the wage (e.g., move from A to C), while fiscal expansion will increase the real wage, appreciate the exchange rate and reduce the price level[24] (e.g., move from B to A in Figure 4).

Consider now the corresponding dynamic exchange-rate adjustment equation obtained from (26) when expectations are always assumed to be correctly held ($e^e_{t+1} = e_{t+1}$) while w_c adjusts slowly to its long-run value:

$$e_{t+1} = b^{-1}[(1 + b)e_t + (\alpha_3 - \phi\beta_3)w_{c_t}] + k_0 \ , \qquad (31)$$

where $k_0 = b^{-1}[-(\alpha_1 + \phi\beta_1)\pi_{n_t} + (\alpha_2 + \phi\beta_2)z_t - m_t + p^*_t - bR^*_t]$.

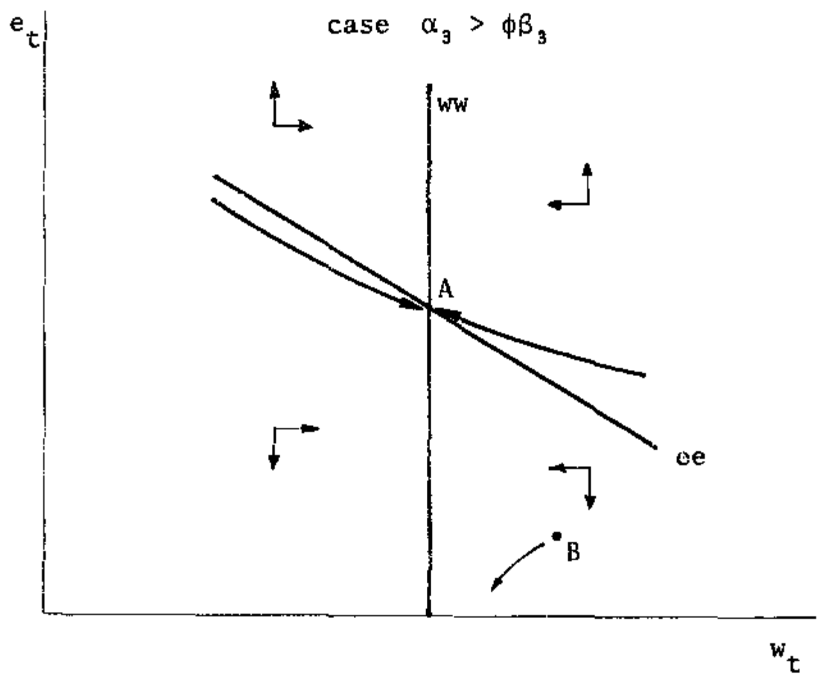
To this recursive relationship we can append the previous adjustment equation for the real wage

$$w_{c_{t+1}} = [1 - \psi(\lambda_1 + y_1)]w_{c_t} + k_1 \ , \qquad (22')$$

where $k_1 = (y_2 z_t + y_3 \pi_{n_t})$. The properties of the combined two-equation dynamic system are depicted in Figure 5 for the two cases $\alpha_3 - \phi\beta_3 \gtrless 0$. In both cases we get saddlepoint stability at the point of equilibrium A if $0 < \psi(\lambda_1 + y_1) < 1$.[25] Following Brock (1974), Dornbusch (1976) and others, one can assume that when any exogenous variable change, the exchange rate will jump instantaneously to keep the system moving along the stable

[24] This effect comes from the output expansion that increases real money demanded. For a given nominal money supply this is consistent only with a reduction in the equilibrium price level.

[25] We are ignoring the case of a saddlepoint with oscillations of w_t . (This will happen when $0 > \psi(\lambda_1 + n_1) > -1$.)


e_t
case $\alpha_3 > \phi\beta_3$
ww
A
ee
B
w_t

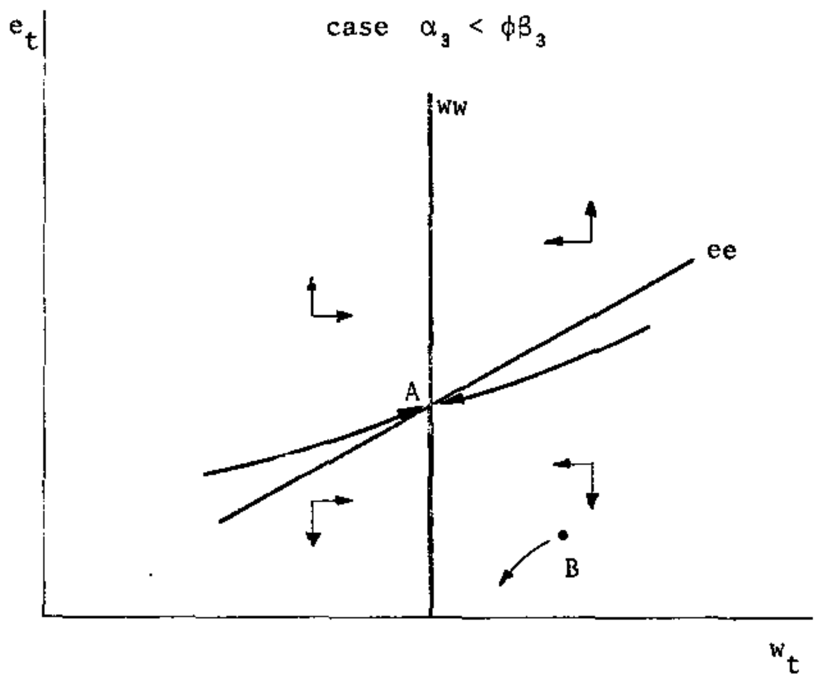

e_t
case $\alpha_3 < \phi\beta_3$
ww
ee
A
B
w_t

Figure 5

arm to the new equilibrium. A less sanguine view is that only by a fluke (or by design) will the system, once disturbed, reach an equilibrium. In the case of an external shock to the relative price π_n (as discussed above) the possible trajectory could be as from point B in Figure 5, a gradual reduction in real wages with systematic and limitless appreciation of the exchange rate.

Note that the real-nominal dichotomy is maintained throughout the above analysis, since the movement of the real system will only depend on the behaviour of real wages and not on any nominal quantities. We now move on to discuss an alternative specification for nominal wage-rate and exchange-rate dynamics.

VI. NOMINAL WAGE RIGIDITY AND PARTIAL INDEXATION

We now leave the world of full instantaneous indexation of wages and consider the case of nominal wage rigidity and partial indexation:

$w = w_0 + \theta p_c$, where $0 \leq \theta \leq 1$ or

$$w_c = w - p_c = w_0 - (1 - \theta)p_c \tag{32}$$

Proceed first by substituting the new expression for the real wage into the output equation (27) so that q now depends on the nominal price level when $\theta < 1$:

$$q = \beta_1\pi_n + \beta_2 z - \beta_3 w + \beta_3(1 - \theta)p_c$$

Now substitute for p_c from the long-run money equilibrium, $p_c = m-\phi q+bR^*$, to get

$$q = [1 + \beta_3(1 - \theta)\phi]^{-1}[-\beta_1\pi_n + \beta_2 z - \beta_3 w_0 + \beta_3(1 - \theta)(m + bR^*)] \qquad (33)$$

Equation (33) shows in the simplest way how a removal of the full wage indexation assumption affects the system. Now money obviously affects real output positively (as long as $\theta < 1$) since

$$\frac{\partial q}{\partial m} = [1 + \beta_3(1 - \theta)\phi]^{-1}\beta_3(1 - \theta) > 0 \quad .$$

How does the degree of indexation affect this response to monetary shocks? We have

$$\frac{\partial}{\partial \theta}\left(\frac{\partial q}{\partial m}\right) = -[1 + \beta_3(1 - \theta)\phi]^{-2}\beta_3 < 0 \quad .$$

The greater the degree of indexation the more immune will real output be to monetary shocks. In the limiting case $\theta = 1$ we are clearly back to the previous real-nominal dichotomy.

Next we consider real shocks in the form of an increase in the international price ratio. We have

$$\frac{\partial q}{\partial \pi_n} = -[1 + \beta_3(1 - \theta)\phi]^{-1}\beta_1 < 0$$

$$\frac{\partial}{\partial \theta}\left(\frac{\partial q}{\partial \pi_n}\right) < 0 \quad ,$$

Thus the greater the degree of indexation the *more negative* (and the less immune) will be the output response to the exogenous price shock. Both of these results are, of course, known from a closed economy context,[26] but it is reassuring to find analogous, intuitively plausible, results for an open economy subject to external real shocks. This explains the policy

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[26] See Fischer (1977), Gray (1976).

adopted by a number of small open economies which in the past used to index their wages. Once the commodity crisis set in indexation was in several countries either removed or relaxed. There are, of course, also examples of countries (Italy, Sweden) whose nominal wage behaviour continued, at least in the early stages of the crisis, to exhibit a high degree of *de facto* if not *de jure* wage indexation.

VII. EXCHANGE RATE AND REAL WAGE DYNAMICS WITH ERRORS IN PRICE EXPECTATIONS

The last model to be considered here is one in which we take a more integrated approach to the labour market. Suppose we have one-year labour contracts in which an attempt is made to reach a target real wage, h_t, which itself follows the real-wage dynamics described in Section V. The wage contract prevailing in period t is set in period $t - 1$. Because of the contract lag, the nominal wage does not adjust perfectly to the price level, so that w_{c_t} does not equal h_t at all times. It is assumed that the contract wage is partly linked to actual prices (with weight θ) and partly to expected prices [with weight $(1 - \theta)$]. Unless $\theta = 1$ or $p_c = p_c^e$, the real wage will deviate from the target level. We write

$$w_t = h_t + \theta p_{c_t} + (1 - \theta)p_{c_t}^e$$

or (34)

$$w_{c_t} = h_t - (1 - \theta)d_t$$

where $h_{t+1} = \psi(\ell^d - \ell^s)_t + h_t$ as in equation (21)[27] and $d_t = p_{c_t} - p_{c_t}^e =$

[27] When $\theta = 1$, i.e., there is full indexation to *actual* prices, we have $w_{c_t} = h_t$ as before.

expectation error. Substituting from (34) into the real system (27) we now have

$$\begin{aligned} \pi_{c_t} &= p_{c_t} - e_t - p^* = \alpha_3 h_t - \alpha_3(1-\theta)d_t - \alpha_1\pi_n + \alpha_2 z \\ q_t &= \qquad\qquad\qquad -\beta_3 h_t + \beta_3(1-\theta)d_t - \beta_1\pi_n + \beta_2 z\ , \end{aligned} \tag{35}$$

and [using (17)-(19) with (34)] the equation for the real part of wages becomes

$$\begin{aligned} h_{t+1} &= \psi(\ell^d - \ell^s)_t + h_t \\ &= [1 - (\lambda_1 + \eta_1)\psi]h_t + \psi(1-\theta)(\lambda_1 + \eta_1)d_t + \\ &\qquad + (y_2 z + y_3\pi_n)\ . \end{aligned} \tag{36}$$

Looking at (35)-(36) we are back to the old system when $d_t = 0$ or $\theta = 1$. From equation (35) we note that when $d_t > 0$, q_t will go up just as in the case of incomplete indexation of wages discussed in the previous section. We now proceed to look at the determination of d_t in terms of unexpected money shocks. Let us impose the rational expectations condition that

$${}_tEd_{t+1} = {}_tE(p_{c_{t+1}} - p^e_{c_{t+1}}) = {}_tEp_{c_{t+1}} - p^e_{c_{t+1}} = 0 \tag{37}$$

where ${}_tEx_{t+1}$ is the mathematical expectation of x_{t+1} taken at time t . Let us also assume that the money supply obeys a rule which can be written in the form

$$m_t = m^a_t + v_t \tag{38}$$

where $E(v_t) = 0$, m^a_t = anticipated money stock, and v_t = innovation (or unanticipated part of money stock).

We now follow a procedure due to Barro (1976) and guess a linear solution for the exchange rate of the form

$$e_t = \varepsilon_1 h_t + \varepsilon_2 d_t + \varepsilon_3 \pi_n + \varepsilon_4 z + \varepsilon_5 m_t^a + \varepsilon_6 v_t + \varepsilon_7 p^* \qquad (39)$$

Subsituting into equation (26), using equations (35)-(36), and equating coefficients it can be shown that

$$\left.\begin{aligned} \varepsilon_1 &= -[b(y_1 + \lambda_1)\psi + 1]^{-1}\alpha_3^{-1}[1 - \delta_1\phi] \lesseqgtr 0 \\ \varepsilon_2 &= \alpha_3(1 - \theta)(1 + b)^{-1}[1 + \psi b(\eta_1 + \lambda_1)]^{-1}[1 - \delta_1\phi] \gtrless 0 \end{aligned}\right\} \text{iff}^{28}\ \delta_1^{-1} \gtrless \phi$$

$$\varepsilon_3 = \alpha_1 + \beta_1 + b\psi\eta_3\varepsilon_1 > 0 \quad \text{if} \quad \varepsilon_1 < 0 \quad (\text{and} \quad \eta_3 < 0)$$

$$\varepsilon_4 = -(\alpha_2 + \beta_2) + b\psi\eta_2 t_1 < 0 \quad \text{if} \quad \varepsilon_1 < 0$$

$$\varepsilon_5 = 1$$

$$\varepsilon_6 = (1 + b)^{-1}$$

$$\varepsilon_7 = -1 .$$

Note that an unanticipated increase in the money supply has a smaller effect on the exchange rate than an anticipated one $[(1 + b)^{-1} < 1]$. The signs of all other disturbances (other than p^*) are indeterminate depending as before on whether $\delta^{-1} \gtrless \phi$ with a fiscal expansion causing an appreciation ($\varepsilon_4 < 0$) when $\delta_1^{-1} > \phi$.

Finally let us show that unanticipated movements in the money supply in fact cause unexpected inflation ($d_t = p_{c_t} - p_{c_t}^e > 0$) and thus short-run increases in output. From (35) and (39) we have

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[28] Cf. the discussion on p. 28.

$$p_{c_t} = (\varepsilon_1 + \alpha_3)h_t + [\varepsilon_2 - \alpha_3(1 - \theta)]d_t + (\varepsilon_3 - \alpha_1)\pi_n +$$

$$+ (\varepsilon_4 + \alpha_2)z + \varepsilon_5 m_t^a + \varepsilon_6 v_t \quad .$$

Therefore

$$d_t = p_{c_t} - E_{t-1}p_{c_t} = \varepsilon_6 v_t + [\varepsilon_2 - \alpha_3(1 - \theta)]d_t$$

and thus

$$d_t = [1 + \alpha_3(1 - \theta) - \varepsilon_2]^{-1}\varepsilon_6 v_t \quad .$$

We definitely have $\varepsilon_2 < \alpha_3(1 - \theta)$ and therefore $\partial d_t/\partial v_t > 0$. In (35) we have $\partial q_t/\partial v_t = \beta_3(1 - \theta)$, $\partial d_t/\partial v_t > 0$ provided that $\theta < 1$, and we again find

$$\frac{\partial}{\partial\theta}\left(\frac{\partial q_t}{\partial v_t}\right) < 0 \ .$$

Indexation reduces the effect of unexpected monetary shocks on real output.

One can further show that if π_n follows a random walk unanticipated changes of π_n will have a smaller negative effect on q than anticipated ones because w_c falls temporarily below the target real wage. A good empirical case in point is the significant drop in the real wage in all countries in 1974 in face of an unexpected oil price hike and the partial recovery in 1975 after the further rise in π_n could be anticipated (see Appendix B).

REFERENCES

Barro, Robert J. "Rational Expectations and the Role of Monetary Policy," *Journal of Monetary Economics*, Jan. 1976, 2, pp. 1-32.

Brock, William C. "Money and Growth: The Case of Long-Run Perfect Foresight," *International Economic Review*, XV, October 1974, pp. 750-77.

Bruno, Michael. "Price and Output Adjustment: Micro Foundations and Macro Theory" (Harvard Institute of Economic Research Discussion Paper No. 534), Cambridge, Mass.: Harvard University, 1977 (forthcoming in *Journal of Monetary Economics*).

———. "An Analysis of Stagflation in the Industrial Countries: Some Preliminary Results," Falk Institute Discussion Paper No. 788 Jerusalem, July 1978.

——— and Sachs, Jeffrey. "Macro-Economic Adjustment with Import Price Shocks: The Empirical Analysis," unpublished manuscript, Cambridge,1979.

Findlay, Ronald, and Rodriguez, C. R. "Intermediate Imports and Macroeconomic Policies under Flexible Exchange Rates," *Canadian Journal of Economics*, 1977.

Fischer, Stanley. "Wage Indexation and Macroeconomic Stability," in *Stabilization of the Domestic and International Economy*, edited by K. Brunner and A. Meltzer (Vol. 5 of Carnegie-Rochester Conference Series on Public Policy), Amsterdam: North-Holland, 1977, pp. 107-48.

Goldfeld, Stephen. "The Demand for Money Revisited," *Brookings Papers on Economic Activity*, 1973, 3.

Gray, Jo Anna. "Wage Indexation: A Macroeconomic Approach," *Journal of Monetary Economics*, II(2), 1976, pp. 221-35.

Hanoch, Giora and Fraenkel, M. "A Comment on 'The Two-Sector Open Economy and the Real Exchange Rate'," Research Report No. 99, Department of Economics, Hebrew University, Feb. 1977 (forthcoming in the *American Economic Review*).

Rodriguez, Carlos A. "Flexible Exchange Rates and Imported Inputs: A Dynamic Analysis of the Interactions between the Monetary and Real Sectors of a Small Open Economy," Discussion Paper 76-7708, Department of Economics Columbia University, New York, N.Y., March 1977.

Sachs, Jeffrey. "Wage Indexation, Flexible Exchange Rates, and Macro-economic Policy," Discussion Paper, Harvard University, 1978.

Turnovsky, Stephen J. and Kaspura, A. "Analysis of Imported Inflation in a Short-Run Macro-economic Model," *Canadian Journal of Economics*, 7, August 1974, pp. 355-80.

APPENDIX A.1. THE NESTED CES PRODUCTION FUNCTION

Suppose we write for the production function $Q = Q[V(K,L); N]$:

$$Q^{\rho} = aV^{\rho} + (1 - a)N^{\rho} \tag{A.1}$$

and

$$V^{\rho_1} = bL^{\rho_1} + (1 - b)K^{\rho_1} \tag{A.2}$$

where $\sigma = (1 - \rho)^{-1}$, $\sigma_1 = (1 - \rho_1)^{-1}$, are the respective elasticities of substitution.

From (A.1) we get, by differentiation,

$$\frac{\partial Q}{\partial L} = a\left(\frac{V}{X}\right)^{\rho - 1} \frac{\partial V}{\partial L} \tag{A.3}$$

From (A.2) we similarly have

$$\frac{\partial V}{\partial L} = b\left(\frac{L}{V}\right)^{\rho_1 - 1} \tag{A.4}$$

Substituting (A.4) into (A.3) we get $\frac{\partial Q}{\partial L} = abL^{\rho_1 - 1}V^{\rho - \rho_1}Q^{1-\rho}$.
Assuming $\partial Q/\partial L = W/P$ and transforming into log differences we have

$$\sigma(\dot{w} - \dot{p}) = \dot{q} - (1 - \frac{\sigma}{\sigma_1})\dot{v} - \frac{\sigma}{\sigma_1}\,\dot{\ell} \tag{A.5}$$

For equation (1') in the text we have $\dot{q} = \alpha\dot{\ell} + \beta\dot{n}$ where $\beta = \frac{\partial Q}{\partial N} \cdot \frac{N}{Q} =$ $= (1 - a)\left(\frac{N}{Q}\right)^{1-1/\sigma} = (1 - a)^{-\sigma}\left(\frac{\partial Q}{\partial N}\right)^{1-\sigma}$, and similarly for α . If $F(V, N)$ and $V(K, L)$ are linearly homogeneous we must have $\dot{q} = (1 - \beta)\dot{v} + \beta\dot{n}$ and $\dot{v} = \frac{\alpha}{1 - \beta}\,\dot{\ell}$ (assuming $\dot{k} = 0$). Thus, in (A.5) we get

$$-\sigma(\dot{w} - \dot{p}) = \dot{\ell}\left[\frac{\alpha}{1 - \beta}\left(1 - \frac{\sigma}{\sigma_1}\right) + \frac{\sigma}{\sigma_1}\right] - q = \eta\dot{\ell} - \dot{q} \tag{A.6}$$

where $\eta = \left[\frac{\alpha}{1 - \beta}\left(1 - \frac{\sigma}{\sigma_1}\right) + \frac{\sigma}{\sigma_1}\right] = \sigma_1^{-1}(1 - \beta)^{-1}[\sigma_1\alpha + \sigma(1 - \alpha - \beta)]$.

For small changes and ignoring constant intercepts we can thus obtain equation (3) of the text from (A.6).

APPENDIX A.2. DOMESTIC PRODUCTION OF INTERMEDIATE GOODS

Suppose we write $H = H(L_h)$, $\partial H/\partial L_h = W/P_n$. In the expression for the change in real income $[Q^d - (P_n/P)(N - H)]$ we must now add $(P_n/P)\dot{H}$ = $= -Q\theta_h\alpha_h\sigma_h(\dot{w} - \dot{p}_n)$ where α_h is the output-labour elasticity of the production function H and σ_h is the demand elasticity for labour. $\theta_h = P_nH/PQ$ is the output ratio of the two sectors.

In the expression for Q^d in equation (12) we must therefore subtract a term $\delta_4(\dot{w} - \dot{p}_n) = \delta_4(\dot{w}_c + \lambda\dot{\pi} - \dot{\pi}_n)$ where $\delta_4 = \delta_0 C_1\theta_h\alpha_h\sigma_h > 0$.

Therefore the modified demand curve becomes

$$\dot{q}^d = -(\delta_1 + \lambda\delta_4)\hat{\pi} + (\delta_2 + \delta_4)\dot{\pi}_n - \delta_4\dot{w}_c + \delta_0\dot{z} \tag{13a}$$

Note that this demand curve differs from the previous one in (i) being steeper; (ii) being shifted downward less (or upward more) by a given $\dot{\pi}_n > 0$; (iii) being shifted downward by a real wage increase (the previous curve stayed put).

Next we note that [after solving (13a) and (6)] the equilibrium values for $\dot{\pi}$ and $\dot{q}$ will now take the following modified form

$$\left.\begin{aligned} \dot{\pi} &= (\gamma_1 + \delta_1 + \lambda\delta_4)^{-1}[(\gamma_2 + \delta_2 + \delta_4)\dot{\pi}_n + (\gamma_0 - \delta_4)\dot{w}_c + \delta_0\dot{z}] \\ \dot{q} &= (\gamma_1 + \delta_1 + \lambda\delta_4)^{-1}\{[(\gamma_1\delta_2 - \gamma_2\delta_1) + \delta_4(\gamma_1 - \gamma_2)]\dot{\pi}_n - \end{aligned}\right\} \quad (14a)$$

$$- [\delta_1\gamma_0 + \delta_4(\gamma_1 + \gamma_0)]\dot{w}_c + \gamma_1\delta_0\dot{z}\}$$

The changes in multipliers are now as in Table A-1.

Table A-1.

	$\dot{\pi}_n$	$\dot{w}_c$	$\dot{z}$
$\dot{\pi}_n$	smaller	smaller[a]	smaller
$\dot{q}$	larger (less negative)	smaller[a] (more negative)	smaller

[a] The reduced effect of $\dot{w}_c$ is explained in terms of the new downward effect of a rise in real wages on the commodity demand curve.

For the effect of a change in θ_n on the multiplier $dq/d\pi_n$ we now find

$$\frac{d}{d\theta_n}\left(\frac{dq}{d\pi_n}\right) = (1 + \theta_h\alpha_h\sigma_h)\,\frac{\delta_0 C_1 \gamma_1 [(\gamma_2 - \gamma_1) + (\delta_2 - \delta_1)]}{(\gamma_1 + \delta_1 + \lambda\delta_4)^2} < 0$$

giving the same result as in the text, p. 17.

Next we note that the effect on total GNP now also has to be modified. Instead of (15) we get

$$\begin{aligned} \dot{y} &= (1 - \theta_n)^{-1}[(1 - \beta)\dot{q} + \beta\sigma(\dot{\pi}_n - \dot{\pi}) - \mu(\dot{w}_c + \lambda\dot{\pi} - \dot{\pi}_n) = \\ &= (1 - \theta_n)^{-1}[(1 - \beta)\dot{q} - (\beta\sigma + \lambda)\dot{\pi} + (\beta\sigma + \mu)\dot{\pi}_n - \mu\dot{w}_c] \end{aligned} \tag{15a}$$

where $\mu = \theta_h\alpha_h\sigma_h > 0$.

Thus a π_n rise will reduce GNP by less on account of an additional effect from the increased domestic production of intermediates. A decrease in real wage will *ceteris paribus* increase $\dot{y}$ by more than before for the same reason.

Finally consider the modified expression for labour demand in this case (cf. p. 20).

We can write

$$\dot{\ell}_n = -(1 - \alpha_h)^{-1}\sigma_h(\dot{w} - \dot{p}_n) = (1 - \alpha_h)^{-1}\sigma_h(-\dot{w}_c - \lambda\dot{\pi} + \dot{\pi}_n) \qquad (18)$$

If the share of labour in the Q-industry is u, we get from (18) and (16):

$$\begin{aligned} \ell_d &= u\dot{\ell}_q + (1 - u)\dot{\ell}_n = \\ &= -(\sigma\mu_1 + \mu_2)\dot{w}_c + [\sigma_h(1 - \lambda)\mu_1 - \mu_2\lambda]\dot{\pi} + \mu_2\dot{\pi}_n + \mu_1 q \end{aligned} \qquad (16a)$$

where $\mu_1 = u\eta^{-1}$, $\mu_2 = (1 - u)(1 - \alpha_h)^{-1}\sigma_h$.