

REAL ADJUSTMENT AND EXCHANGE-RATE DYNAMICS

J. Peter Neary
University College, Dublin.

and

Douglas D. Purvis
Queen's University, Kingston

NUMBER 203

WARWICK ECONOMIC RESEARCH PAPERS

DEPARTMENT OF ECONOMICS

UNIVERSITY OF WARWICK
COVENTRY

REAL ADJUSTMENT AND EXCHANGE-RATE DYNAMICS

J. Peter Neary
University College, Dublin.

and

Douglas D. Purvis
Queen's University, Kingston

NUMBER 203

Revised November 1981.

An earlier version of this paper was presented to the Workshop in International Economics at the University of Warwick, July 1981 and the Institute for International Economic Studies in Stockholm, August 1981. We are grateful to our NBER discussants, Jeffery Sachs and Kent Kimbrough, to Paddy Geary, and to other conference participants for the many useful comments we received.

This paper is circulated for discussion purposes only and its contents should be considered preliminary.

December, 1981

ABSTRACT: REAL ADJUSTMENT AND EXCHANGE-RATE DYNAMICS

This paper presents a model designed to cast some light on the nature of macroeconomic responses to sectoral shocks and to provide a basis for investigation of the interaction between resource allocation and exchange-rate variability. We first develop the implications for the dynamics of the real exchange rate of a Marshallian distinction between short- and long-run supply responses to an endogenous disturbance. Marshall's partial-equilibrium analysis stressed the overshooting of a relative price due to short-run factor fixity; our analysis derives this result in a general equilibrium context. (However, in the general-equilibrium model it is possible that the long-run price response is perverse so that, rather than overshooting, the short-run relative price response would actually be in the "wrong direction".)

We then extend the framework to incorporate the behaviour of money prices in the face of these changing relative prices. The model focusses on monetary equilibrium combined with rational speculation; the dynamic behaviour of the nominal exchange rate exhibits a straightforward dependence on that of the real exchange rate. But the latter is independent of monetary equilibrium and, in particular, of any speculative behaviour; any influence of speculators on the nominal exchange rate gives rise to identical movements in the equilibrium nominal price of services.

J. Peter Neary
University College, Dublin

and

Douglas D. Purvis
Queen's University, Kingston

The 1970s witnessed numerous events which called into question much of the "accepted wisdom" of macroeconomics as it was perceived at the start of the decade. Stagflation and the resistance of inflation to contractionary policy constituted a major challenge to closed economy macroeconomists. For those analysts who focus on open-economy macroeconomics, two further phenomena can be added to the list of problems.

First, there was a frequent occurrence of sector-specific disturbances or shocks which buffeted many economies, and which set in motion a variety of perplexing dynamic responses. Most prominent, of course, were disturbances in the petroleum sector; macroeconomic difficulties were frequently encountered in adjusting to oil price increases of foreign origin and, perhaps surprisingly, in adjusting to discoveries of new domestic sources of petroleum products.

Second, the volatility of exchange rates following the adoption of a system of flexible exchange rates in the early 1970s has been far greater than expected by most economists who advocated such a system. Of course such variability does not present a prima facie argument that the system failed; indeed, it is possible to argue that the flexibility represented by such variability in the face of an uncertain and unstable international economic environment represents a virtue of the system, not a fault. Nevertheless, such variability does raise a number of interesting questions. To the extent that exchange rate fluctuations are caused by external factors, do they lead to inappropriate domestic resource allocation by temporarily altering relative prices? To what extent are such exchange rate movements a response to exogenous domestic disturbances,

and to what extent are they a concomitant part of the domestic response to external shocks?

This paper presents a model designed to capture the two possibilities raised by the last question. However, as by-products it also casts light on the nature of macroeconomic responses to sectoral shocks and provides a basis for initiating investigation of the resource allocation effects of exchange-rate variability.

A currently popular analysis of the role of domestic disturbances in generating exchange rate variability is the "overshooting" result of Dornbusch (1976). By postulating sticky goods prices, Dornbusch shows that the exchange rate, which is viewed as being perfectly flexible, responds to a domestic monetary disturbance by more in the short run when goods prices remain at their initial value than in the long run when all variables are allowed to adjust to their new equilibrium values. Dornbusch enhances this scenario with a version of the efficient markets hypothesis which views participants in the foreign exchange market setting the initial value of the exchange rate following the monetary disturbance at a level consistent with the expected change in the exchange rate required to equate domestic and foreign yields.¹ The appeal of the model draws in part from its simple explanation of the variance of the exchange rate exceeding that of underlying fundamentals (i.e., the money supply) and of its characterization of a dynamic path involving negatively correlated domestic price and exchange rate changes, in contrast to the prediction based on purchasing power parity that such movements will be positively correlated.

The model presented in this paper also generates exchange-rate

dynamics as a result of a rigidity in the economy. However, in contrast, our model does not rest on a rigidity in nominal prices but instead focuses on the dynamic adjustment elicited by sluggish reallocation of capital in response to change in relative returns. This adjustment, which we refer to as "Marshallian" dynamics, gives rise to a framework in which resource allocation and exchange-rate movements are interrelated. It is also possible that in the short run the exchange rate overshoots its new long-run equilibrium level; in this case the dynamic paths of nominal variables in response to a real shock are qualitatively equivalent to those in the Dornbusch model in response to a monetary shock.

The plan of the paper is as follows. In section I we outline our real model of sectoral resource allocation and in section II we derive the basic overshooting result in terms of the 'real' exchange rate. In section III we expand the model to incorporate a macroeconomic structure to allow for the determination of the nominal exchange rate given an exogenous value of the domestic money supply; the response of the nominal exchange rate to monetary and real shocks is then examined. Section IV presents the conclusions and draws some comparisons between Marshallian and macroeconomic sources of exchange-rate dynamics.

I. A MODEL OF SECTORAL SHIFTS AND RESOURCE ALLOCATION

In this section we introduce the basic consumption and production relationships which constitute the real part of our model, and then examine its properties in terms of short- and long-run equilibrium and dynamic adjustment. The particular specification we have chosen is

designed to permit, in as simple a manner as possible, an analysis of the two features mentioned in the introduction. The model is multi-sectoral in order to allow both for sectoral shocks and for re-allocation of resources in response to other disturbances.

A key feature of the model is that prices adjust instantaneously to clear markets, yet we distinguish between situations of short-run equilibrium, contingent on predetermined values of some variables, and long-run or full equilibrium. The distinction arises due to the multi-sectoral framework combined with the assumption that factor reallocation, in particular changes in sectoral capital stocks, is costly and hence takes time.

There are three sectors in the model: two traded goods, benzine and manufactures; and one non-traded good, services. The first two are produced and consumed domestically; both have perfect substitutes available in infinitely elastic supply in world markets so their foreign currency prices, and hence their relative price, can be taken as given. The price of services adjusts instantaneously to equate the domestic demand and supply for services.

Since the economy is "small" in traded-goods markets, demand repercussions of various shocks impinge only on the services sector. Hence most of our focus is on the structure of production. In one traded-goods sector capital is combined with a sector-specific factor, or natural resource, to produce benzine. In the other, capital and labour are used in combination to produce manufactured goods. In the non-traded goods sector, services are produced using only labour.²

Factors differ not only with respect to where they are used, but

also with respect to how quickly they can move between uses. Labour is assumed to be mobile between the sectors in which it is used -- services and manufacturing -- with the wage rate adjusting to clear the labour market. Capital, however, is "bolted down" and hence sector-specific in the short run; only with time can the capital stock in the sectors in which it is used -- manufacturing and benzine -- adjust in response to changing factor rewards. Note that there is no direct factor market link between the benzine and services sector, but that over time there is an indirect link operating through the manufacturing sector.³

This plays an important role in the behaviour of the model.

The Market for Services

The domestic demand for services depends on all prices and on domestic real income.⁴

$$(1.1) \quad c_S = -\epsilon_S p_S + \epsilon_B p_B + \epsilon_M p_M + \eta y$$

The only source of changes in national income which we consider is a discovery of the resource or "specific factor" used in the production of benzine, denoted by v , so we can write real income as

$$(1.2) \quad y = \theta_v v$$

where θ_v is the share of the specific factor in national income.⁵

Letting e be the nominal exchange rate (i.e., the domestic price of foreign currency), we define the real exchange rate, π , as

$$(1.3) \quad \pi \equiv e - p_S$$

By appropriate choice of units we can set the levels of the foreign currency prices of manufactures and benzine equal to unity, so their domestic prices are given simply by the nominal exchange rate; i.e., $p_B = p_M = e$. Noting that the compensated price elasticities in (1.1) must be related by $\underline{\epsilon}_B + \underline{\epsilon}_M = \underline{\epsilon}_S$, and using (1.2) and (1.3), we can rewrite (1.1) as

$$(1.4) \quad c_S = \epsilon_S \pi + \eta \theta_V v$$

Equation (1.4) shows that the domestic demand for services is an increasing function of the real exchange rate and of the availability of the natural resource.

As noted earlier, we postulate that the production of services involves only labour, a useful simplification which reflects the relative labour intensity of service sectors in most economies. This allows us, by appropriate choice of units, to identify the demand for services with the demand for labour in the services sector, $c_S = \underline{l}_S$, and the price of services with the wage rate, $p_S = w$. Recalling that $p_M = e$, we can therefore reinterpret the real exchange rate as the inverse of the real wage in the manufacturing sector:

$$(1.3') \quad \pi = - (w - p_M)$$

Equation (1.4) thus shows that the demand for labour in services

depends negatively on the manufacturing real wage and positively on the stock of the natural resource.

Short-run Equilibrium in the Market for Labour

Labour, it will be recalled, is assumed to be fully employed at all times, with the total stock of labour allocated between the manufacturing and services sectors. The demand for labour in manufacturing, l_M , depends on the (predetermined) capital stock in that sector, k_M , and on the manufacturing real wage rate:

$$l_M = k_M - \gamma_M(w - p_M)$$

where γ_M is the real wage elasticity of the demand for labour in manufacturing. Using equation (1.3') we can rewrite this as

$$(1.5) \quad l_M = k_M + \gamma_M \pi$$

For given values of v , p_M , and k_M , equilibrium in the labour market arises when π adjusts so that (1.4) and (1.5) together satisfy the full employment condition:

$$(1.6) \quad \lambda_{LS} l_S + \lambda_{LM} l_M = 0$$

where the λ 's are the fractions of the labour force employed in the respective sectors.

This equilibrium is illustrated in Figure 1-1, where the

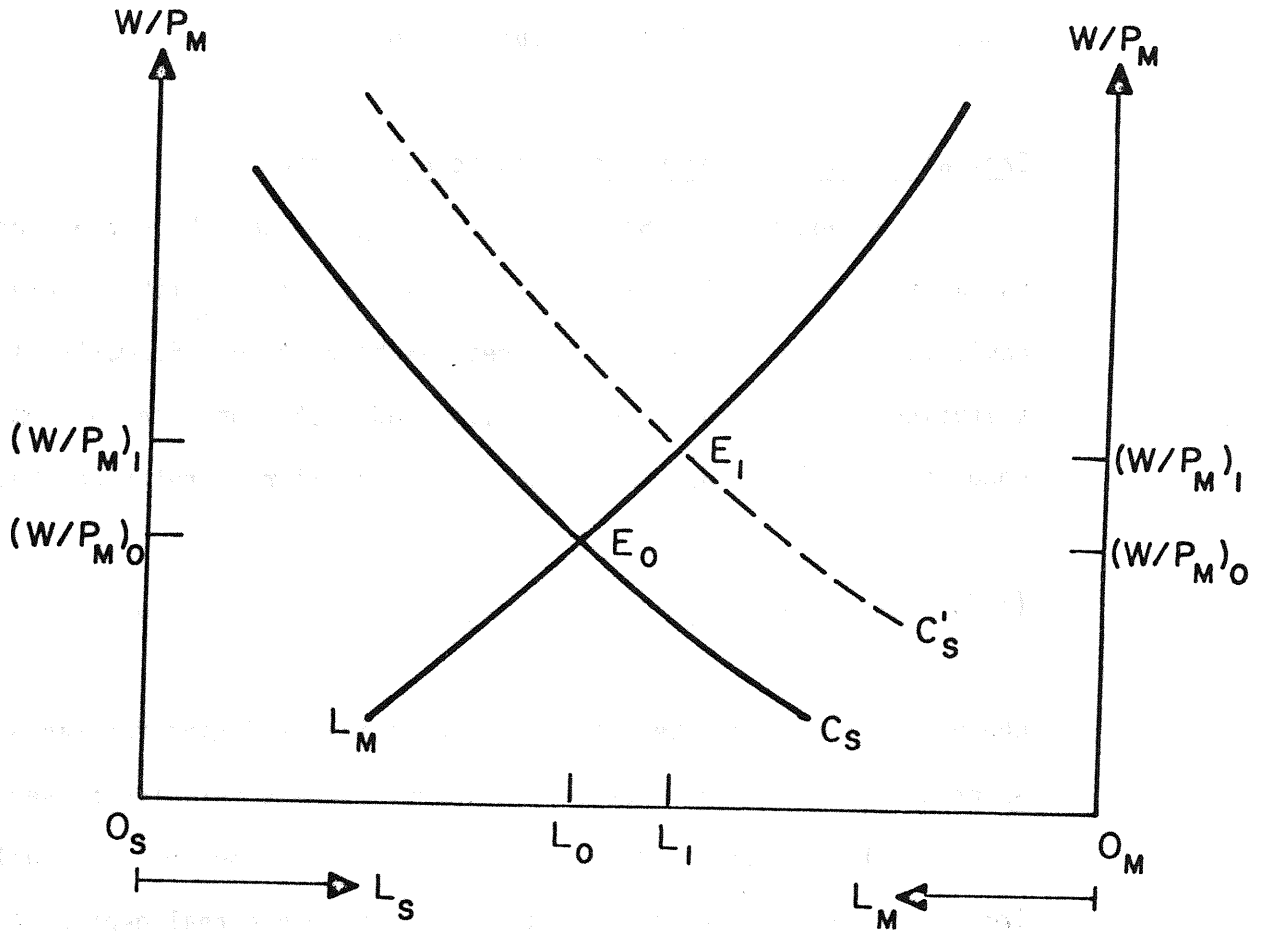
horizontal axis equals the economy's endowment of labour measured in natural units. The demand for labour in services, equation (1.4), is depicted by the negatively sloped line C_S , drawn for a given value of v . The demand for labour in manufacturing, equation (1.5), is depicted by L_M drawn with respect to the right-hand axis as a negative function of the real wage. Equilibrium is at E_0 where the wage is such that the demand for labour in the two sectors just exhausts the total available supply of labour, L .⁶

Short-run Response to a Resource Boom

The effects of a resource boom in the sense of an exogenous increase in the availability of the natural resource can now readily be determined. The income effect arising from an increase in v leads to an increased demand for services and hence to an increased demand for labour in the services sector. In Figure 1-1 the increase in v causes the C_S curve to shift up and to the right to the dashed line C_S' . As can be seen from equation (1.5) the boom has no effects on the demand for labour in manufacturing so the new equilibrium obtains at E_1 with an increased wage and a shift of L_0L_1 units of labour from manufacturing to services. Hence, on impact the resource boom causes an increase in national income but a reduction in the output of the manufacturing sector.

The equilibrium illustrated in Figure 1-1 is contingent on the predetermined stock of capital in the manufacturing sector. But the boom, by drawing labour into the service sector and away from manufacturing, causes a decline in the return to capital in manufacturing and thereby

FIGURE 1-1
THE MARKET FOR LABOUR



creates incentives for disinvestment in manufacturing. As that disinvestment proceeds, there will be further changes in the equilibrium wage rate and allocation of labour depicted in Figure 1-1. In order to set the stage for the dynamic analysis that follows, it is useful to examine how a change in the manufacturing capital stock influences the shortrun equilibrium.

Capital Stock Adjustment and Domestic Equilibrium

By equation (1.5) a decrease in k_M reduces the demand for labour in manufacturing; this leads to a decrease in the equilibrium wage or, equivalently, an increase in the real exchange rate. Formally, substituting the two labour demands (1.4) and (1.5) into the full employment condition (1.6) yields the labour market equilibrium relationship:

$$(1.7) \quad \varepsilon\pi + \lambda_L k_M + \eta_V v = 0; \quad \varepsilon \equiv \varepsilon_S + \lambda_L \gamma_M \text{ and } \lambda_L \equiv \lambda_{LM}/\lambda_{LS}$$

where $\underline{\varepsilon}$ is the aggregate real wage elasticity of demand for labour and $\underline{\lambda}_L$ measures the labour intensity of manufacturing relative to services.

This is depicted in Figure 1-2 by the labour market equilibrium locus LL; its negative slope indicates that both a real depreciation (i.e., an increase in $\underline{\pi}$) and an increase in the manufacturing capital stock lead to an increased demand for labour. Accordingly, above and to the right of LL there is excess demand for labour, and conversely below and to the left.⁷

Further, as shown in Figure 1-1, an increase in v also creates an excess demand for labour and hence leads to a leftward

shift in LL to the dashed line L'L' shown in Figure 1-2. This leftward shift arises due to the increased expenditure on services; following Corden and Neary we refer to it as the spending effect of the resource discovery.

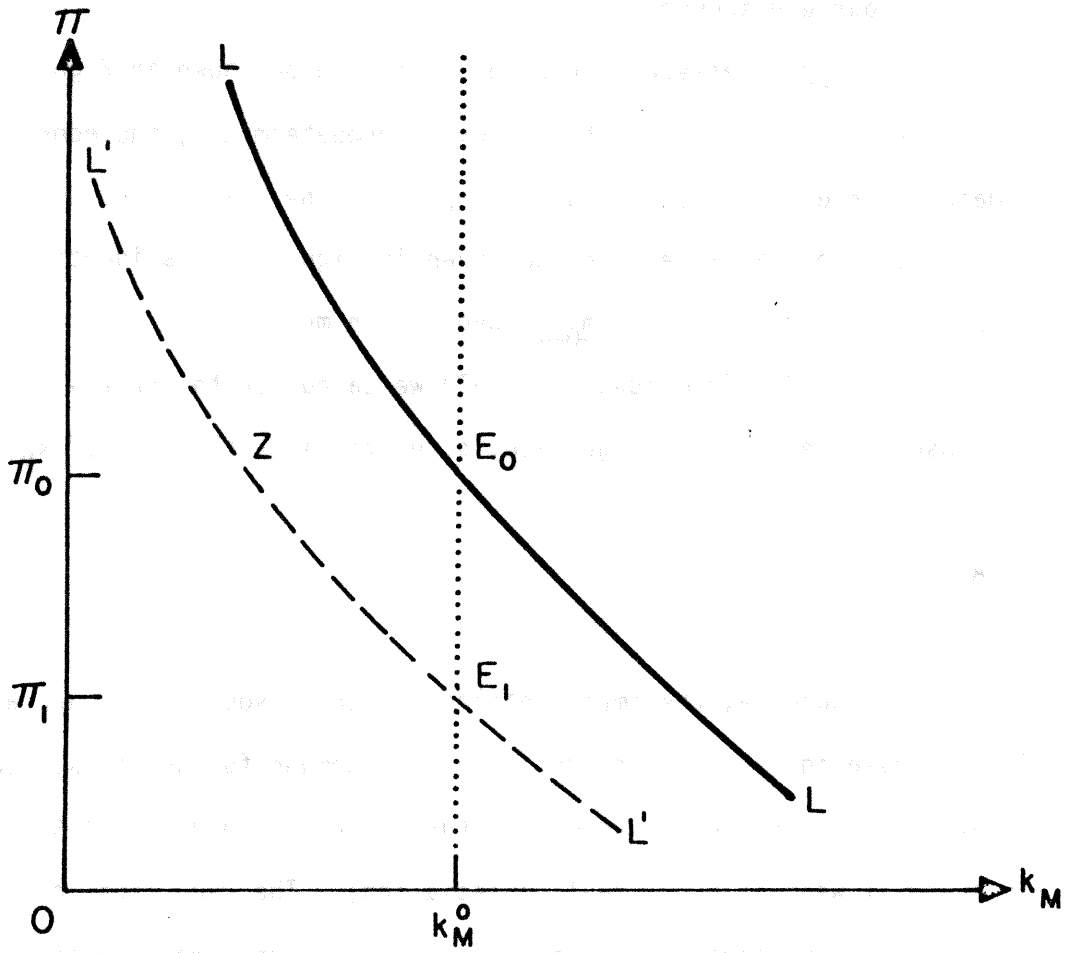
The impact effect of the boom can also be shown in Figure 1-2: since the manufacturing capital stock is predetermined, the economy remains on the vertical dotted line k_M^0 , and the new equilibrium is at E_1 . The real wage increase shown in Figure 1-1 is identical to the real appreciation of $\pi_0\pi_1$ involved in moving from E_0 to E_1 in Figure 1-2. From equation (1.7) we calculate the short-run response of the real exchange rate, given the initial value of k_M , as:⁸

$$(1.8) \quad \pi_1 = -(\eta\theta_V/\epsilon)v.$$

In summary, the impact effects of the resource boom are as follows. The increase in national income raises the demand for services, causing a shift of labour out of the manufacturing sector into services and a rise in the real wage (i.e., a real appreciation). The reduction in the manufacturing labour force causes a fall in the return earned by capital in that sector; this, of course, is the opposite of the change in the return to capital in the benzine sector since the initial disturbance being considered is an increase in the factor used in conjunction with capital in producing benzine. We turn next to consider the medium-run evolution of the model as the sectoral capital stocks respond to these changes in returns.

FIGURE 1-2

LABOUR MARKET EQUILIBRIUM AND THE
MANUFACTURING CAPITAL STOCK



II. THE ALLOCATION OF CAPITAL AND LONG-RUN EQUILIBRIUM

In this section we examine the dynamic adjustment that occurs in response to the quasi-rents generated by the short-run effects in the labour market described above. We consider two alternative models of long-run capital stock adjustment. In model 1, physical capital is internationally mobile, and so the total stock of capital located in the home country is variable. In model 2, following the Heckscher-Ohlin tradition, the total stock of capital in the economy is fixed. In both models the long-run equilibrium allocation of capital between sectors requires that the return to capital in the two sectors be equalized; in model 1 the common rental also equals that available in world markets, r^f .

In either model, the relationship between the return to capital in manufacturing and the real exchange follows from the requirement that price equals unit cost in that sector:

$$p_M = \theta_{LM}w + \theta_{KM}r_M$$

where the θ 's are the distributive factor shares in manufacturing.

Using the association of the real exchange rate with the inverse of the manufacturing real wage, we can therefore write:⁹

$$(2.1) \quad r_M - p_M = \theta_L \pi; \quad \theta_L \equiv \theta_{LM}/\theta_{KM}$$

Equation (2.1) states that a real depreciation, by lowering the manufacturing real wage, leads to an increase in the return to capital in manufacturing. In model 1 international capital mobility, by fixing the long-run return to capital, also fixes the long-run real exchange rate. In model 2, the long-run real exchange rate must be determined endogenously along with the return to capital. We now examine each of these models in turn.

Model 1: International Capital Mobility; Exogenous Returns and Endogenous
Total Capital Stock

This model is particularly simple for the purpose of studying real exchange rate dynamics. In the long run both r_M and r_B must equal $(r^f + e)$, hence if the initial equilibrium E_0 in Figure 1-2 were a position of long-run equilibrium, then the new long-run equilibrium is at Z. We can specify a capital-stock adjustment equation for the manufacturing sector of the form:¹⁰

$$(2.2) \quad \dot{k}_M = \phi(r_M - p_M - r^f)$$

In terms of Figure 1-2 we see that \dot{k}_M is negative at E_1 . There is an initial jump real appreciation followed by continuous depreciation until the real exchange rate has returned to its initial value.

But while the resource boom leaves the long-run exchange rate unchanged, it causes a permanent reduction in manufacturing sector output; the higher domestic income commands that more resources (i.e., labour) be

allocated to the services sector. Production of manufactures falls; increased domestic consumption of manufactures is effected via increased imports, paid for by increased exports of benzine. The decline in manufacturing output, rather than constituting a macroeconomic problem, simply reflects the appropriate resource allocation response to a change in comparative advantage caused by the resource discovery.

In contrast to the response of the manufacturing capital stock, the stock of capital in the benzine sector rises. What happens to the total demand for capital in the long run? The demand for capital in the benzine sector is given by:

$$(2.3) \quad k_B = v - \gamma_B(r_B - p_B)$$

where γ_B is the real-rental elasticity of demand for capital in benzine. Equation (2.3) is depicted in Figure 2-1, where the horizontal axis measures the initial total stock of capital in natural units, by the negatively sloped solid line K_B , drawn for given values of v and p_B . As can be seen in equation (2.3) the resource discovery causes a proportionate increase in the demand for capital in the benzine sector; in terms of Figure 2-1, K_B shifts up and to the right to the dashed line K_B' .

Using the labour market equilibrium condition (1.10), the demand for capital in manufacturing can be written as the reduced form:

$$(2.4) \quad k_M = -\lambda_L^{-1} [(\epsilon/\theta_L)(r_M - p_M) + n\theta_V v]$$

This is shown in Figure 2-1 as the solid line, K_M , drawn, for given v and

e, as negatively sloped with respect to the right-hand vertical axis. The resource boom, operating through the income effect, causes K_M to shift down to the dashed line K_M' .¹⁰ The impact effects on the rates of return are also shown in Figure 2-1 where at the initial capital stocks r_M falls to r_M' and r_B rises to r_B' .

There is an ambiguous effect of a resource boom on the total demand for capital, k_T , defined by (2.5):

$$(2.5) \quad k_T \equiv \lambda_{KB} k_B + \lambda_{KM} k_M$$

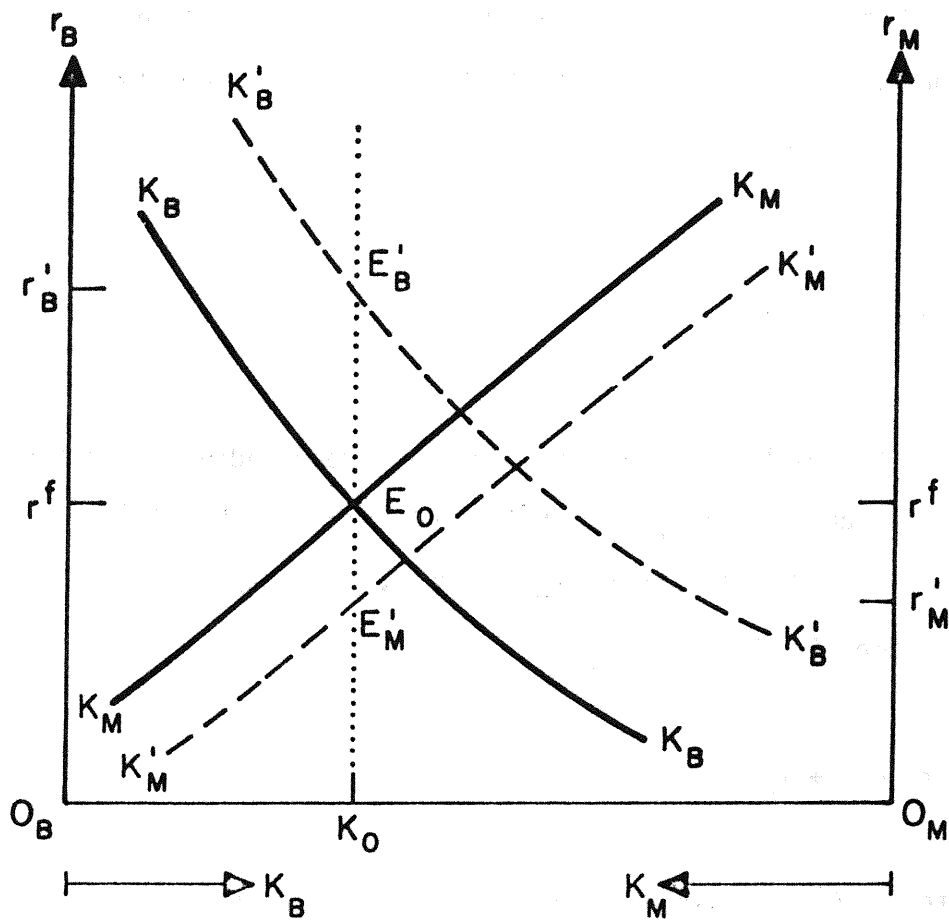
where the λ 's are the fractions of the total capital stock allocated to the respective sectors. Figure 2-1 depicts the case where k_T rises at the initial value of $r_B = r_M$; however that need not be the case, as is apparent from (2.6), derived by substituting (2.1) and (2.4) into (2.5).

$$(2.6) \quad k_T = \lambda_{KB} v - \lambda_{KM} (\epsilon\pi + \eta\theta v) / \lambda_L$$

As is also apparent from equation (2.6), a full analysis of the long-run response to a resource boom must take into account the long-run response of the real exchange rate.

FIGURE 2-1

IMPACT OF A RESOURCE BOOM ON THE RETURNS TO CAPITAL



Model 2: Intersectoral Capital Mobility: Exogenous Total Capital Stock
and Endogenous Returns

The alternative model pursued in this subsection is in the tradition of the Heckscher-Ohlin model in its specific factor variant -- see, e.g., Jones (1971), Mayer (1974), Mussa (1974, 1978), Neary (1978). The long-run equilibrium allocation of the given capital stock occurs when the returns to capital are equalized. Hence we now specify the dynamic adjustment as

$$(2.8) \quad \dot{k}_M = \phi(r_M - r_B).$$

Note that this completely characterizes the dynamic adjustment since, with k given, changes in k_M just reflect opposite changes in k_B .

Use (2.1) to substitute for r_M in (2.8), and invert the k_B demand function (2.3) to get r_B :

$$r_B = e + \gamma_B^{-1}(v - k_B),$$

Substitute for k_B from equation (2.5) -- choosing units so that the exogenous value of k is zero -- and substitute the resulting expression for r_B into (2.8) to write the adjustment equation as:

$$(2.9) \quad \dot{k}_M = \phi[\theta_L \pi - \gamma_B^{-1}(\lambda_K k_M + v)]$$

Equilibrium in the capital market arises when $\dot{k}_M = 0$, or

$$(2.10) \quad \theta_L \pi = \gamma_B^{-1}(\lambda_K k_M + v)$$

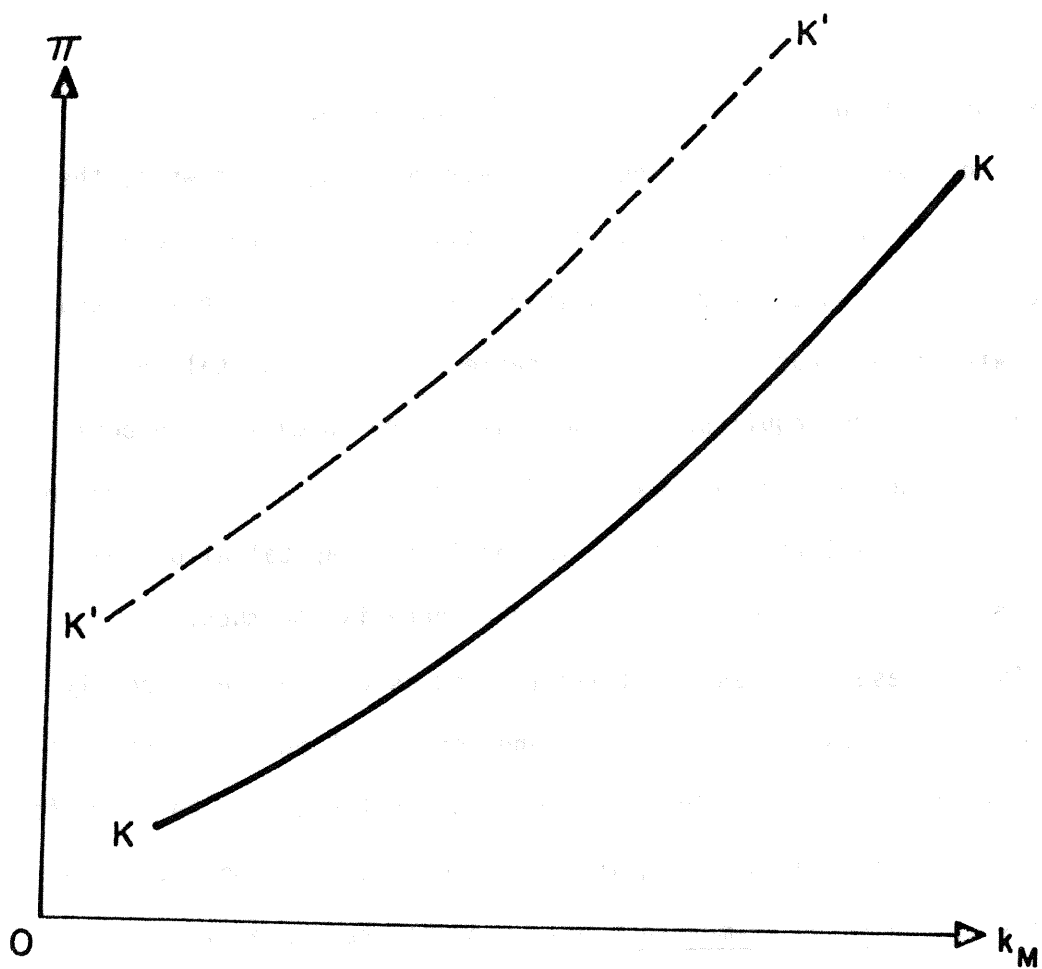
Hence for a given value of v , the real exchange rate and the manufacturing capital stock must be positively related, as shown by the solid line KK in Figure 2-2. It is positively sloped because a real depreciation is associated with a lower real manufacturing wage and hence with an increase in the sustainable return to capital in manufacturing; for equilibrium, the real return to capital in benzine must also rise which necessitates a fall in k_B and, hence, a rise in k_M . Above and to the left of KK there is too little capital allocated to manufacturing, below and to the right there is too much.

An increase in v , as noted earlier and as can be seen directly from equation (2.4), reduces the demand for k_M . Either k_M must fall or π must rise, hence the equilibrium locus shifts up and to the left following a resource boom. Again following Corden and Neary, we refer to this as the resource-movement effect of the resource discovery.

Long-Run Equilibrium

Long-run equilibrium obtains when the conditions for both capital-market equilibrium (2.10) and labour-market equilibrium (1.7) are satisfied, as illustrated at E_0 in Figure 2-3. Letting stars indicate the new long-run equilibrium values (recalling that we set the initial equilibrium

FIGURE 2-2
RESPONSE OF THE ALLOCATION OF A FIXED
TOTAL STOCK OF CAPITAL TO A RESOURCE BOOM



values of both k_M and π equal to zero), the response to a resource boom is as follows:

$$(2.11) \quad \begin{aligned} k_M^* &= -(b_1/a)v \\ \pi^* &= (b_2/a)v \end{aligned}$$

where $a \equiv \lambda_L \theta_L \gamma_B + \lambda_K \epsilon > 0$

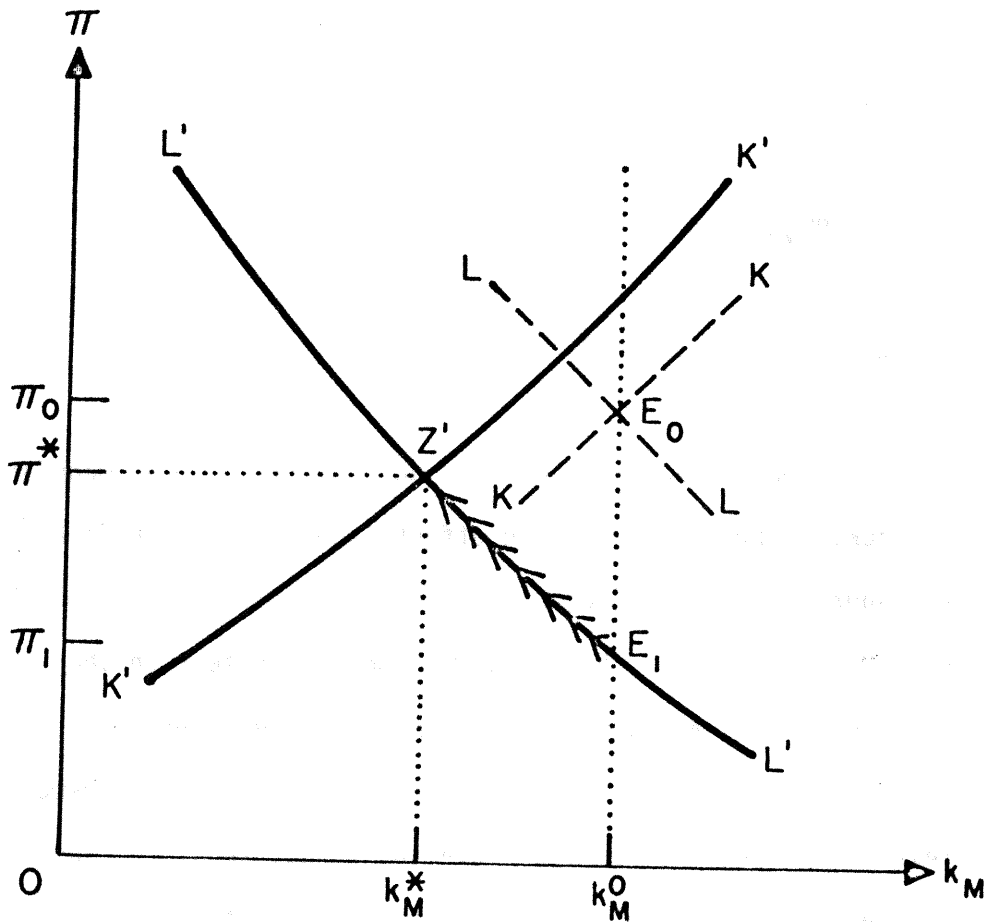
$$b_1 \equiv \eta \theta_V \theta_L \gamma_B + \epsilon > 0$$

$$b_2 \equiv (\lambda_L - \lambda_K \eta \theta_V) \geq 0$$

A resource boom leads in the long run to a fall in the manufacturing capital stock, as both the spending effect (the leftward-shift of L'L' to LL) and the resource movement effect (the leftward-shift of K'K' to KK) operate in this direction. However, the long-run effect on the real exchange rate is ambiguous. The spending effect tends to cause a real appreciation by stimulating the demand for services and hence raising their relative price; the resource-movement effect tends to cause a real depreciation by pushing labour out of manufacturing into services, thus stimulating the supply of services and lowering their relative price.

In Figure 2-3 the new long-run equilibrium at Z depicts what we consider to be the more plausible case -- that the resource boom causes a long-run real appreciation. Note that the condition for π to fall ($b_2 < 0$) is identical to the condition that k fall in equation (2.7).¹² If the manufacturing sector is small in its use of capital

FIGURE 2-3
EQUILIBRIUM EFFECTS OF A RESOURCE BOOM



so that the expulsion of labour to the services sector is small, real appreciation will ensue.

Manufacturing output also falls unambiguously in model 2. The capital stock in that sector falls, but there is the possibility, associated with real depreciation, that labour input per unit of capital rises. That rise, however, cannot be large enough to lead to a net increase in manufacturing output. Using the labour demand condition (1.5) and the labour market equilibrium condition (1.8), the logarithm of manufacturing output can be written as:

$$x_M = \varepsilon^{-1} [(\varepsilon - \lambda_L \theta_{LM} \gamma_M) k_M - (n \theta_V \lambda_{LM} \gamma_M) v]$$

Using the definition of $\underline{\varepsilon}$, the coefficient of k_M is seen to be positive. Hence the level of manufacturing output falls by more the greater is the outflow of capital into the benzine sector: the direct output-reducing effect of this outflow is more than sufficient to offset any reaction in costs brought about by a real depreciation.

Short-Run Dynamics

Using the long-run solutions (2.11), the dynamic adjustment equation (2.9) can be rewritten as

$$(2.9') \quad \dot{k}_M = \phi_1 (k_M^* - k_M) ; \quad \phi_1 \equiv (a/\gamma_B \varepsilon) \phi$$

The dynamics can now be illustrated in Figure 2-3 where on impact, with k_M fixed, the economy moves from the initial equilibrium E_0

to E_1 . Since the labour market clears continually, and by (2.9') k_M declines steadily to k_M^* , the economy follows the path E_1Z' marked by the arrows along $L'L'$. In the short run the real exchange rate overshoots its long-run value.¹³ This overshooting is the result of Marshallian dynamics: it is worth repeating that it is overshooting of the real exchange rate, in response to real shocks, and caused by real inertia.

III. REAL SHOCKS AND THE NOMINAL EXCHANGE RATE

In this section we combine the real model of resource allocation and output of the previous sections with a simple monetary model of nominal exchange-rate determination in order to examine the effect of a resource boom on the nominal exchange rate. The nominal money stock is treated as exogenously determined; we continue to assume that relative prices adjust instantaneously to clear markets so that there is no role for monetary policy. As before, the dynamics of the model arise from the adjustment of sectoral capital stocks in response to perceived changes in returns.

International financial markets are treated as being closely integrated. Domestic and foreign interest-bearing assets are assumed to be perfect substitutes, so domestic and foreign nominal interest rates are linked by the uncovered interest rate parity (IRP) condition, $i = i^f + x$, where x is the expected rate of change of the nominal exchange rate. We restrict our attention to equilibrium dynamic paths so we impose long-run perfect foresight on the model. With x equal to the actual change in the exchange rate, we write the IRP condition as:

$$(3.1) \quad i = i^f + \dot{e}$$

According to equation (3.1), the domestic interest rate can exceed the foreign interest rate only if there is a (fully anticipated) depreciation of the domestic currency to offset the nominal yield differential.

Alternatively, depreciation of the domestic currency is only consistent with asset-market equilibrium if holders of domestic assets are compensated by a yield premium.

The demand for domestic money balances in real terms depends upon real income and the nominal interest rate,

$$(3.2) \quad m - p = \alpha y - \delta^{-1} i$$

The domestic price index, p , is given by

$$(3.3) \quad p = \beta p_S + (1-\beta)e$$

where β is the expenditure share of non-traded goods.

Monetary Equilibrium

Using the definition of the real exchange rate (1.3), the price index can be rewritten as $p = e - \beta\pi$; using the definition of real income (1.2) the money market equilibrium condition becomes

$$(3.4) \quad m - e = \alpha\theta_V v - \delta^{-1} i - \beta\pi$$

This is depicted in Figure 3-1 as the positively sloped locus MM drawn for given values of π , v , and m ; its upward slope reflects the fact that an increase in e creates an excess demand for money by reducing the supply of real balances while an increase in i creates an excess supply by reducing demand. Above and to the left of MM there is excess supply of money balances, below and to the right there is excess demand. A resource boom shifts the MM curve left for given π ; but since π itself adjusts in response to a resource boom, a full analysis of the effects on e is deferred.

For simplicity, we abstract from domestic or foreign inflation so in long-run equilibrium the exchange rate must be constant. Imposing $\dot{e} = 0$ in (3.1) and substituting into (3.4), we can solve for the long-run nominal exchange rate:

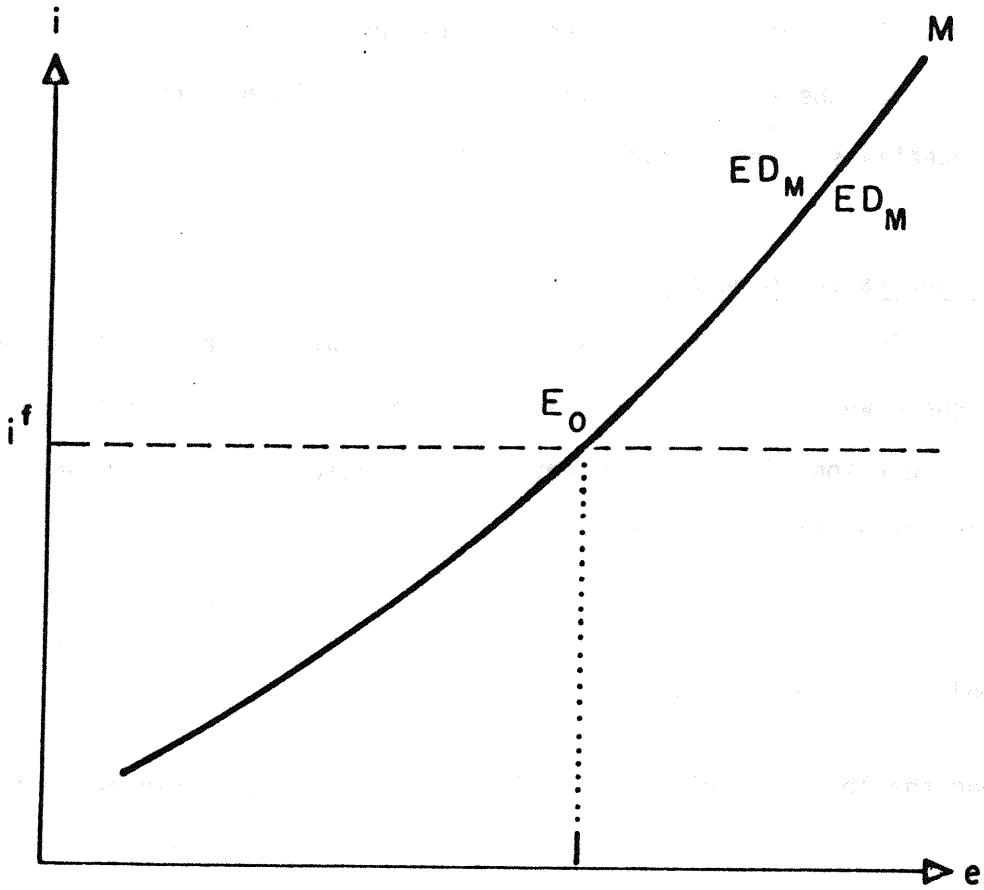
$$(3.5) \quad e^* = m + \delta^{-1}i^f + \beta\pi^* - \alpha\theta_v v$$

where we also have set the real exchange rate at its long-run value. Note that for a given real exchange rate there is an additional force, $-\alpha\theta_v$ (which we term the liquidity effect), working towards nominal appreciation in response to a resource boom: the effect of the resource boom on real income increases the demand for money and hence tends to cause e to fall. Thus a long-run real appreciation in response to a resource boom is sufficient (but not necessary) to also ensure a nominal appreciation.

The determination of the long-run nominal exchange rate is illustrated in Figure 3-1. Given the determination of the real exchange rate as described in the previous sections, monetary equilibrium deter-

FIGURE 3-1

MONETARY EQUILIBRIUM AND THE NOMINAL EXCHANGE RATE



mines the nominal prices of traded goods, e , and of non-traded goods, $p_S = e - \underline{\pi}$. Money is neutral, as can be seen by the unitary-coefficient of m in equation (3.5). Further, that neutrality obtains even in the short run; an increase in the money supply causes no change in the real exchange rate and so leads to an immediate equi-proportionate change in e and p_S . This, of course, is because the only dynamics in the system result from the need to reallocate capital, and monetary policy creates no incentives to do so even in the short run.¹⁴

Real Shocks and Monetary Dynamics

Real shocks such as a resource boom will give rise to dynamics in e - i space which reflect those in k_M - $\underline{\pi}$ space illustrated in Figure 2-3. Using equation (3.4) to eliminate i from equation (3.1), the evolution of the exchange rate can be written as follows:

$$(3.6) \quad \dot{e} = \delta(e + \alpha\theta_V v - m - \beta\pi) - i^f$$

Using the long-run solutions in (2.13) and (3.5) this can be written as

$$\dot{e} = \delta(e - e^*) + \delta\beta(\pi^* - \pi)$$

Using the fact that $\underline{\pi}^* = -(b_1/b_2)k_M^*$, we rewrite this in what will prove to be the more convenient form

$$(3.7) \quad \dot{e} = \delta(e - e^*) + (\delta\beta\lambda_L/\epsilon)(k_M - k_M^*)$$

The complete dynamic system is therefore obtained by writing

equations (2.11) and (3.7) in matrix form:

$$(3.8) \quad \begin{bmatrix} \dot{k}_M \\ \dot{e} \end{bmatrix} = \begin{bmatrix} -\phi_1 & 0 \\ \delta\beta\lambda_L/\epsilon & \delta \end{bmatrix} \begin{bmatrix} k_M - k_M^* \\ e - e^* \end{bmatrix}$$

Denote the transition matrix as A; since the determinant of A (equal to $-\delta\phi_1$) is negative, the system exhibits generalized saddle-path stability, as illustrated in Figure 3-2. The nominal exchange rate, e, is a jump variable which for stability takes on an initial value to place the economy on the stable arm. It is straightforward in this system to generate an explicit solution for e, using a method outlined by Dixit (1980).

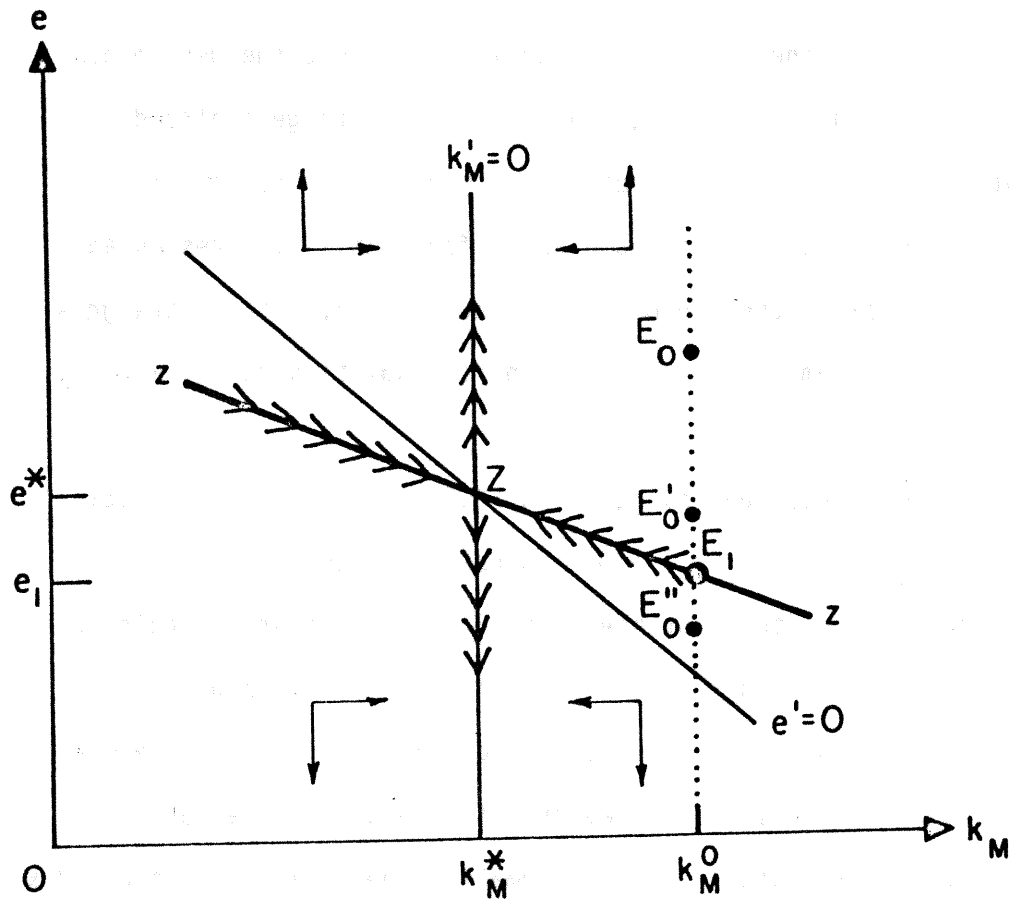
The system described by equation (3.8) has two characteristic roots: $\underline{\mu}_1 = -\phi_1 < 0$ and $\underline{\mu}_2 = \underline{\delta} > 0$. Choosing the stable arm amounts to suppressing the unstable root, $\underline{\delta}$. As Dixit shows, this can be done by choosing the initial value of the jump variable proportional to the value of the predetermined variable (k_M^0), where the factor of proportionality is derived from the left eigen-vector corresponding to the unstable root. Formally, the deviations of e and k_M from their new equilibrium values are related throughout the adjustment period by:

$$(3.9) \quad (e - e^*) = q(k_M - k_M^*)$$

where q is chosen by solving the matrix equation:

FIGURE 3-2

DYNAMIC ADJUSTMENT OF MANUFACTURING CAPITAL STOCK AND THE NOMINAL EXCHANGE RATE



$$(3.10) \quad [q \quad -1][-A+\delta I] = [0 \quad 0].$$

Straightforward calculation yields

$$(3.11) \quad q = -\delta\beta\lambda_L / \varepsilon(\phi_1 + \delta) < 0$$

The stable arm, zz , is therefore negatively sloped but flatter than the $\dot{e} = 0$ locus, as shown in Figure 3-2. From any of the possible initial equilibrium positions (E_0 , E_0' , or E_0''), on impact the system moves to point E_1 from which it converges monotonically to Z .

To find the initial value of e required for stability following a disturbance which changes the long-run equilibrium to (k_M^*, e^*) , substitute into equation (3.9) for q , e^* and k_M^* to yield:

$$(3.12) \quad e_1 = e_0 + \sigma v$$

where e_0 , the initial equilibrium value of the exchange rate, equals $m + \delta^{-1}i^f + qk_M^0$ and where $\underline{\sigma}$, the short-run elasticity of the nominal exchange rate with respect to the natural resource, is given by:

$$(3.13) \quad \sigma \equiv a^{-1}(qb_1 + \beta b_2) - \alpha\theta_V \gtrless 0$$

The sign of $\underline{\sigma}$ obviously determines whether e rises or falls on impact. If $\underline{\sigma}$ is negative, e falls on impact and the initial equilibrium must be at either E_0 or E_0' in Figure 3-2. If $\underline{\sigma}$ is positive, e rises

on impact and the initial equilibrium must be at E_0 ". In equation (3.13) the term in brackets is negative, and hence $\underline{\sigma}$ is negative, provided (b_2/a) , the long-run response of the real exchange rate, is not large positive. If b_2 is negative (i.e., if the resource boom generates a long-run real appreciation) then $\underline{\sigma}$ is negative and on impact e falls.¹⁶ In the international capital mobility case, recall that $\underline{\pi}^* = \underline{\pi}_0$; b_2 is effectively zero and hence the nominal exchange rate must fall in the short run.

The long-run response of the nominal exchange rate is given by:

$$(3.14) \quad e^* = e_0 + \sigma'v$$

where $\underline{\sigma}'$, the long-run elasticity, is given by

$$(3.15) \quad \sigma' = \beta b_2/a - \alpha\theta_V \gtrless 0.$$

It is clear that since $\underline{\sigma}' = \underline{\sigma} - qb_1a^{-1} > \underline{\sigma}$, on impact the exchange rate is below its long-run value.¹⁷ There are three possible cases.

(1) If $\beta b_2 < \alpha\theta_V$, then $\underline{\sigma}$ and $\underline{\sigma}'$ are both negative. This includes both model 1 (the international capital mobility case) where b_2 is zero, and the more plausible outcome in model 2 (the intersectoral capital mobility case) where b_2 is negative and there is long-run real appreciation. The short-run elasticity of the nominal exchange rate is larger than the long-run elasticity in absolute value; there is short-run overshooting, and the initial equilibrium must have been like E_0 in Figure 3.2.

(2) If $\alpha\theta_V < \beta b_2 < \alpha\theta_V - qb_1$, then $\underline{\sigma}$ is negative

but $\underline{\sigma}'$ is positive. The exchange rate falls on impact but ultimately rises, as would occur from an initial equilibrium like E_0' .

(3) If $\underline{\beta}b_2 > a\underline{\alpha}\theta_v - qb_1$, then $\underline{\sigma}$ and $\underline{\sigma}'$ are both positive; the exchange rate rises on impact and continues to rise during the dynamic adjustment, as would occur from an initial equilibrium like E_0'' .

In order to examine the dynamics in e-i space, substitute equation (3.11) into (3.7), which yields

$$(3.16) \quad \dot{e} = \phi_1(e^* - e)$$

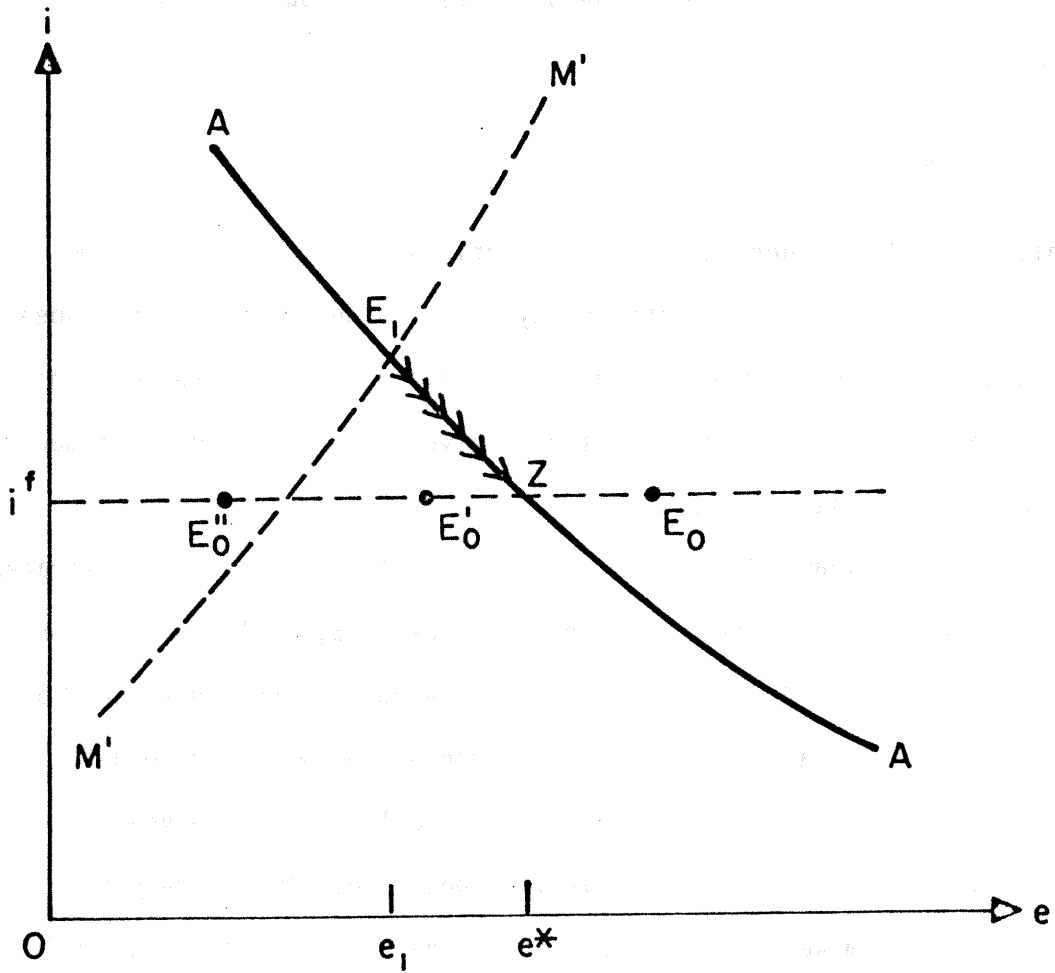
This shows that under rational expectations the speed of adjustment of the capital stock towards its steady-state value determines the speed of adjustment of the exchange rate towards its equilibrium value. This follows from the fact that the system is recursive since the transition matrix in equation (3.8) is triangular.

The dynamics of the monetary variables can now be illustrated in Figure 3-3. On impact the economy moves to E_1 while the new long-run equilibrium is at Z ; E_0 , E_0' and E_0'' correspond to the three possible initial equilibria discussed above in connection with Figure 3-2.

As in Figure 3-1, money market equilibrium for given $\underline{\pi}$ and v is depicted by a positively sloped line. Immediately following a resource boom we know from section II that the real exchange rate is below its long-run equilibrium value, and hence from equation (3.4) that the money market equilibrium locus cuts i^f to the left of the new long-run equilibrium, as shown by $M'M'$ in Figure 3-3.

The negatively sloped AA curve is derived by substituting the

FIGURE 3-3
MONETARY DYNAMICS IN RESPONSE TO A
RESOURCE BOOM



equilibrium exchange rate adjustment equation (3.16) into the asset arbitrage condition (3.1) to get

$$(3.17) \quad i + ae = i^f + ae^*.$$

Note that AA always passes through the long-run equilibrium position; a boom shifts it right or left depending upon the long-run effect on e .

The initial equilibrium could be any one of E_0 , E_0' or E_0'' . The resource boom shifts the long-run equilibrium to Z with $e = e^*$. On impact the boom raises the domestic interest rate above i^f and causes the nominal exchange rate to jump to e_1 less than e , as can be seen by the fact that MM shifts to the dashed line M'M'. If the initial equilibrium is E_0 , with e^* less than e_0 , this corresponds to the first possibility indicated above; there is overshooting of the nominal exchange rate. If the real exchange rate rises by enough to offset the liquidity effect (which works in favour of a nominal appreciation), the initial equilibrium is E_0'' -- the last of the three possibilities -- and the nominal exchange rate rises both on impact and in the long run; further, the short-run response of the nominal exchange rate is smaller than the long-run response. If the real exchange rate rises but not by enough to offset the liquidity effect--the middle possibility-- then e falls on impact but rises in the long run, as from an initial equilibrium E_0' .

IV. CONCLUSIONS

This paper has stressed the implications for the dynamics of the real and nominal exchange rates of a Marshallian distinction between short- and long-run supply responses in the face of an exogenous disturbance. Marshall's partial-equilibrium analysis stressed the overshooting of a relative price due to short-run factor fixity. Our analysis derives this result in a general-equilibrium context, although in that context it is possible that the long-run price response is perverse and so, rather than overshooting, the short-run relative price response is actually in the "wrong direction".

We then extend the framework to incorporate the behaviour of money prices in the face of these changing relative prices. The model focuses on monetary equilibrium combined with rational speculation; the dynamic behaviour of the nominal exchange rate exhibits a straightforward dependence on that of the real exchange rate.¹⁸ But the latter is independent of monetary equilibrium and, in particular, of any speculative behaviour; any influence of speculators on the nominal exchange rate gives rise to identical movements in the equilibrium price of services. It is interesting to note that in our model the dynamics of the nominal exchange rate in response to a real shock are qualitatively equivalent to those generated by Dornbusch's analysis, built on the assumption of domestic price rigidity and focussing on the role of monetary disturbances.

One obvious weakness of the current analysis is the asymmetric nature of expectations formation. Agents are "rational forecasters" when formulating money demands but not when making investment or resource extraction decisions. A useful extension would thus be to incorporate "rational accumulators" into the analysis, drawing on Mussa (1978), van Wijnbergen (1981), or Hayashi (1982) as extended to the open economy by Bruno and Sachs (1981). We have also abstracted throughout from the wealth dynamics inherent in the current account imbalances that will arise in the adjustment in Section III; analysing the feedback onto exchange-rate dynamics is another obvious extension.

Our emphasis has been on the real effects of real disturbances where the dynamics of the system stem from real criteria. While we have shown that these dynamics will also have implications for the behaviour of the nominal exchange rate, in our model nominal disturbances which influence the nominal exchange rate would not have any effects on resource allocation or other real variables. This asymmetry would vanish if a nominal rigidity were included in the specification; these issues are explored in Neary-Purvis (1981).

FOOTNOTES

1. This might be termed "rationalized expectations". Domestic monetary policy determines the domestic interest rate which in turn, given uncovered interest parity, dictates the expected rate of change of the exchange rate. The actual current exchange rate then changes so as to "rationalize" those expectations.
2. In Neary and Purvis (1981), where we also employ this real structure, we relate it to alternative models used in the analysis of the "Dutch Disease", e.g., Buiters and Purvis (1981) and Corden and Neary (1981).
3. Note also that output of benzine is a predetermined variable while output of manufacturing and services can adjust on impact since the allocation of labour can respond instantaneously.
4. Unless otherwise noted, all variables are in logarithmic form and all coefficients are positive. In principle the compensated elasticities $\underline{\epsilon}_B$ and $\underline{\epsilon}_M$ can be positive or negative; we assume in what follows that all commodities are net substitutes so $\underline{\epsilon}_B$ and $\underline{\epsilon}_M$ are positive.
5. Changes in the terms of trade can of course also create income effects. Elsewhere (Neary and Purvis, 1981) we have analysed the consequences of such disturbances in the presence of domestic price rigidities.
6. In this paper labour is treated as being in perfectly inelastic supply; elsewhere (in Neary and Purvis, 1981), we treat the full employment level of employment as the 'natural' level about which actual employment can fluctuate.
7. LL can equivalently be thought of as the locus of points which cor-

respond to equilibrium in the services sector, $c_S = x_S$, where x_S is the supply of services derived by using (1.5) in the full-employment condition (1.6) to yield

$$x_S \equiv \underline{l}_S = -\underline{\lambda}_L k_M - \underline{\lambda}_L \underline{\lambda}_M \pi$$

Equating this to c_S given in (1.4) yields (1.10). The simplifying assumption that only labour is used in services, which allows us to illustrate the model in π - k_M space has been adopted from Kouri.

8. In what follows, the initial equilibrium will be denoted by a subscript zero, the new short-run equilibrium by a subscript one, and the new long-run equilibrium by an asterisk. The latter two are expressed as deviations from the former, or, equivalently, all variables are normalized so that their values at the initial equilibrium are zero.
9. Recall that both P_M and P_B equal e , which is assumed to be fixed.
10. As Mussa (1978) argues, an ad hoc specification such as (2.2) tends to overstate speeds of adjustment by implicitly assuming that current yields will persist indefinitely.
11. Note that the shift in the K_B schedule is permanent, and independent of further domestic demand repercussions. However the adjustment process will generate income effects which will operate through the services sector to have further repercussions on the demand for manufacturing capital. The adjustment of the sectoral capital stocks will raise real national income. We abstract from these in what follows; this can be interpreted as assuming that those income effects are anticipated and hence capitalized into the initial real income response $\underline{\theta}_v$. Other possible income effects will depend in part on domestic savings behaviour since with capital mobility the usual

distinction between national output -- production located in the economy -- and national income -- production owned by the economy -- arises. In what follows, these income effects are also ignored.

12. It also is easily shown that if b_2 is negative so that the long-run effect is a fall in the real exchange rate, that fall is less than the short-run effect given by (1.8).
13. If π rises in the long run, then rather than overshooting, the short-run response is in the wrong direction.
14. In Neary and Purvis (1981) we explore the dynamics which arise when both the capital stock and the price of services adjust sluggishly.
15. Substitution of (3.12) into (3.4) thus gives the short-run value of the domestic interest rate, i .
16. These results illustrate how the structural characteristics of an economy may influence the response of nominal variables to exogenous shocks, a point also made by Jones and Purvis (1981).
17. Equation (3.15) can be rewritten as

$$e^* = e_1 - (qb_1/a)v > e_1$$

which establishes that the exchange rate on impact is below its long-run value, as dictated by the negative slope of the saddle-path zz .

18. As Jeffrey Sachs has pointed out, a solution for $e(t)$ in terms of the time paths of exogenous variables and of the real exchange rate can be found by explicitly solving the differential equation (3.6) to yield

$$e(t) = \int_t^{\infty} [\delta(m + \beta\pi - \alpha\theta_V) + i^f] \exp(-\rho\tau) d\tau$$

Hence the path of $e(t)$, given the constancy of the exogenous variables, is fully described by that of $\pi(t)$.

REFERENCES

- Bruno, M., and Sachs, J. 1981. "Input Price Shocks and the Slowdown in Economic Growth", mimeo, (L.S.E. Centre for Labour Economics).
- Buiter, W.H., and Purvis, D.D. 1981. "Oil, Disinflation, and Export Competitiveness: A Model of the 'Dutch Disease'", in J. Bhandari and B. Putnam (eds.): The International Transmission of Economic Disturbances under Flexible Exchange Rates, (forthcoming, MIT Press).
- Corden, W.M., and Neary, J.P. 1981. "Booming Sector and De-Industrialization in a Small Open Economy", mimeo.
- Dixit, A. 1980. "A Solution Technique for Rational Expectations Models with Applications to Exchange Rate and Interest Rate Determination", mimeo.
- Dornbusch, R. 1978. "Expectations and Exchange Rate Dynamics", Journal of Political Economy 84: 1161-1176.
- Hayashi, F. 1982. "Tobin's Marginal q and Average q: A Neoclassical Interpretation", Econometrica 50: 213-224.
- Jones, R. and Purvis, D.D. 1981. "International Differences in Response to Common External Shocks: The Role of Purchasing Power Parity", presented to the Vth Paris-Dauphine Conference, "Money and

International Monetary Problems".

Kouri, P. 1979. "Profitability and Growth in a Small Open Economy",
in A. Lindbeck (ed.), Inflation and Employment in Open Economies,
Amsterdam: North-Holland, 129-142.

Mayer, W. 1974. "Short-run and Long-run Equilibrium for a Small Open
Economy", Journal of Political Economy, 82, 955-968.

Mussa, M. 1974. "Tariffs and the Distribution of Income: The
Importance of Factor Specificity, Substitutability, and Intensity in
the Short and Long Run", Journal of Political Economy 82: 1191-1204.

_____. 1978. "Dynamic Adjustment to Relative Price Changes in the
Heckscher-Ohlin-Samuelson Model", Journal of Political Economy 86:
775-991.

Neary, J.P. 1978. "Short-run Capital Specificity and the Pure Theory
of International Trade", Economic Journal 88: 488-510.

Neary, J.P. and Purvis, D.D. 1981. "Sectoral Shocks in a Dependent Economy:
Short-Run Accommodation and Long-Run Adjustment", Scandinavian Journal
of Economics, forthcoming.

van Wijnbergen, S. 1981. "Optimal Investment and Exchange Rate Management in
Oil Exporting Countries: A Normative Analysis of the Dutch Disease" mimeo.