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Anticipated Real Exchange-Rate Changes and the Dynamics of Investment

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Unanticipated changes in the real exchange rate affect investment through their impact on the desired capital stock, whose direction depends on a number of factors and is in general ambiguous. In contrast, anticipated changes can also have an important effect on the optimal timing of investment, in a direction that depends on the financial openness of the economy and on the import content of capital goods. This issue is explored using a simple macroeconomic model.

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The impact of permanent real depreciation on a country's capital stock is uncertain. Whether total capital stock rises or falls depends on how depreciation affects aggregate demand, the real interest rate, and especially the import content of capital goods. In the long run, the capital stock can be expected to rise in traded goods and fall in nontraded goods.

Despite this long-run ambiguity, anticipated (as opposed to unanticipated) changes in real exchange rate have a predictable effect on the dynamics of capital accumulation. They provide an incentive for speculative reallocation of investment over time, so they can greatly distort the timing of investments.

In the framework Serven presents, the time profile of investment is related to how financially open an economy is and to the import content of capital goods.

When a real depreciation is expected, an investment boom is likely to develop if the import content of capital goods is high relative to the degree of capital mobility: the anticipated depreciation promotes flight into foreign goods. Conversely, with high capital mobility, the opposite investment pattern is likely to emerge, as the anticipated depreciation promotes flight into foreign assets.

In the first case, the investment boom will be followed by a slump when the depreciation actually takes place, as it amounts to removing a transitory subsidy to investment. In the second case, the predepreciation slump will give way to

a boom, since the depreciation amounts to removing a tax.

Such a pattern could lead the uninformed observer to conclude that the real depreciation is "contractionary" in the first case and "expansionary" in the second. In fact, the sharp change in the investment trend could largely reflect the elimination of the transitory (positive or negative) investment incentive. These speculative investment swings will be larger the smaller the adjustment costs associated with capital accumulation.

These results agree broadly with the experiences of Chile and Uruguay in the late seventies and early eighties. The exchange-rate-based disinflation attempted in both countries led to a real overvaluation and growing expectations of real depreciation. Chile — which had a relatively closed capital account and a high import content of investment — witnessed an investment boom. Uruguay, on the other hand, which is financially fairly open, experienced an investment slump.

Similar results apply to consumers' spending on durable goods. These spending fluctuations simply reflect changes in the optimal timing of consumption and investment — but they obviously have a strong destabilizing potential. This suggests the importance of real exchange rate stability to avoid persistent over- or undervaluations. When exchange rate action is justified, it should be undertaken immediately to prevent distortions in the intertemporal allocation of spending.

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by
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1 - Introduction

With real depreciation being a key component of most macroeconomic adjustment programs, the possibility that it may have an adverse effect on investment (and hence on growth) has recently attracted some attention. Different reasons for such anti-investment bias have been pointed out: first, the high import content of investment goods in most LDCs implies that the real cost of new capital goods will rise with a real depreciation, thereby discouraging investment¹; second, the adverse real income effect of a real depreciation may depress aggregate demand and thus reduce firms' desired capacity²; third, without monetary accomodation, exchange depreciation may result in a liquidity squeeze that raises interest rates and thus the cost of capital, also depressing investment.

Obviously, all these arguments are concerned with the impact of a real depreciation on the desired capital stock, and thus they are subject to the criticism that the response of the latter will be very different in the tradable and nontradable sectors, with the effect on aggregate investment being in principle uncertain³. Moreover, these arguments do not provide any insight on the dynamics of investment, that is, the path along which the desired capital stock will be reached. For that purpose, the distinction between anticipated and unanticipated real depreciations is crucial.

Anticipated real exchange rate changes can have a substantial impact on

¹ This has been pointed out by Branson (1986) and Buffie (1986).

² This follows from the 'contractionary devaluation' literature; see e.g. Krugman and Taylor (1978). If the private sector is a net debtor in foreign currency, then a real depreciation would also have an adverse wealth effect, which could similarly lead to reduced investment ((Easterly, (1989)).

³ This has been emphasized by Lizondo and Montiel (1989).

the timing of investment -- quite apart from their effect on the optimal capital stock. There are two reasons for this. The first one is the well-known fact that anticipated real exchange rate changes will be reflected to some extent in the real interest rate; for example, pending a perfectly anticipated real depreciation the real interest rate and the user cost of capital are temporarily high, and investment must be temporarily low. The second reason is that anticipated real exchange rate changes affect the expected time path of the real cost of new capital goods, again due to their import content; pending a real depreciation, investment goods imports are transitorily cheap and thus investment must be transitorily high⁴. The combination of these two factors determines the optimal allocation of investment over time. Through this mechanism, anticipated real exchange rate changes can lead to wide investment swings, whose precise direction depends on the import content of capital goods and on the degree to which real interest rates incorporate exchange rate expectations --or, in other words, on the degree of financial openness of the economy.

Hence, the import content of capital goods and the degree of capital mobility are two key ingredients in determining the effect of anticipated real exchange rate changes on investment. The third ingredient is of course the evolution of the optimal capital stock. In this paper we use a simple model to examine the role of each of these factors in shaping the time path of investment. The paper is organized as follows. First, in Section 2 we provide an illustration of the behavior of investment in two historical episodes of transitory real appreciation and anticipated depreciation. In Section 3 we set up the formal model, and we use it to explore the role of the different determinants of investment and to analyze the dynamics of investment under alternative expected

⁴This argument was first proposed by Dornbusch (1985).

real exchange rate trajectories. Finally, Section 4 concludes.

2 - Anticipated real exchange rate changes and investment: two stylized cases

An interesting illustration of the behavior of investment under expectations of real exchange rate changes can be found in the transitory real appreciation episodes associated with exchange rate based stabilizations⁵. In these policy experiments, the rate of nominal depreciation is reduced to slow down inflation; since the latter displays substantial inertia in the short run (due to backward-looking wage indexation, or to the slow adjustment of expectations), the result is a real appreciation. The latter is very likely to be perceived as a transitory phenomenon, that will be reversed by the eventual fall in inflation (if the stabilization succeeds) or by a return to a higher rate of devaluation (if the stabilization fails). Thus, such experiments represent clear-cut cases of transitory real appreciation and anticipated depreciation.

Two stylized examples are provided by the stabilization attempts of the late seventies in Chile and Uruguay. In order to fight inflation, both countries adopted a policy of preannounced devaluation (the 'Tablita'), according to which the rate of nominal depreciation was gradually reduced. In Chile, the preannouncement scheme was introduced in February 1978; in June 1979, the rate of depreciation was reduced to zero, and thus the nominal exchange rate was left unchanged until June 1982. As documented by Corbo (1985), the combination of a fixed nominal exchange rate with wage indexation to lagged inflation led to a growing real appreciation. By 1981, the cumulative real appreciation was close to 30 percent (Chart 1), and doubts about the sustainability of the exchange rate

⁵ This is a particular case of the 'expenditure cycle' associated with exchange rate based stabilizations, which has been documented by Kiguel and Liviatan (1989).

were widespread.

During this real appreciation stage, an expenditure boom developed. The major ingredient was the spectacular expansion of private investment, which in real terms more than doubled in 1978-81, and as a ratio of real GDP rose over ten percentage points in these years.

In Uruguay, the preannounced depreciation strategy was adopted in October 1978. The regime lasted until November 1982, when the exchange rate was finally allowed to float. As inflation proved stubborn, the result again was a persistent real appreciation -- which by late 1982 exceeded 30 percent -- along with increasing expectations of real depreciation. However, in sharp contrast with the case of Chile, the overvaluation was accompanied by a private investment slump: the share of private investment in real GDP rose initially in 1979 and then fell about 4 percentage points in 1980-81 (Chart 2).

Although the performance of private investment in these two episodes undoubtedly was the result of a number of factors, it seems clear that the evolution of the real exchange rate must have played an important role⁶. As argued above, there are two main mechanisms (not mutually exclusive) through which the transitory real appreciation may have affected investment. The first one emphasizes the 'desired' capital stock as the force driving investment. It would imply that in Chile the real appreciation contributed to increase the optimal capital stock, due perhaps to its strong favorable effect on the real cost of capital goods imports, and maybe also to a favorable aggregate demand

⁶ The trade liberalization measures adopted by both countries (especially Chile) in the seventies may be another factor in the observed investment performance, as the mounting real overvaluation could have raised the expectation of a reversal of the trade reforms.

effect⁷. However, in Uruguay these factors would have operated in the opposite direction.

The second mechanism follows from the impact of anticipated real exchange rate changes on the timing of investment. If the real appreciation is perceived as transitory, its persistence will lead to increasing expectations of future real depreciation -- and thus to the anticipation that the real cost of investment goods imports will rise in the future. At the same time, the ex-ante real interest rate will also rise to reflect the anticipated depreciation. Depending on the relative strength of these two factors, their combined effect can be an investment boom or a recession. To verify if this argument can contribute to reconcile the contrasting performances of private investment in these two historical episodes, we need to define it more precisely -- a task to which we now turn.

3 - The model

To explore these issues more formally, we use a simple investment model which explicitly incorporates the import content of capital goods, and allows for the effect of real exchange rate expectations on the real interest rate. First, following the standard cost of adjustment approach (see e.g. Hayashi (1982)), investment is assumed to depend on the market value of existing capital relative to its replacement cost:

$$(1) \quad I = K \cdot \phi \cdot [(V \cdot P / P_K) - 1] + \delta K \quad \phi > 0$$

⁷ For the case of Chile, the strong effect on investment of a reduction in the real cost of new capital goods has been empirically confirmed by Solimano (1990). His results also indicate that a real appreciation expands output in the short run, and reduces it over the longer term.

where I is gross real investment, K is the capital stock and δ its rate of depreciation, V is the real market value in terms of domestic goods of one unit of installed capital (i.e., the real price of equity), P is the domestic price level, and P_K is the price of new investment goods. The parameter ϕ can be related to the adjustment cost technology implicit in the investment equation (1). Broadly speaking, the more rapidly adjustment costs increase with investment, the lower ϕ .⁸

The rate of capital accumulation is given by

$$(2) \quad \dot{K} = I - \delta K$$

Hence, net capital accumulation will cease when $V=P_K/P$, that is, when the market value of installed capital and its replacement cost are equalized; then $I = \delta K$. In turn, the price of new capital goods is a weighted average of the prices of domestic goods and imports:

$$(3) \quad P_K = P^\gamma \cdot e^{1-\gamma} \quad 0 < \gamma < 1$$

where e is the nominal exchange rate (the foreign price level is assumed constant and equal to one), and $1-\gamma$ is the unit import content of capital.

The economy produces one single good, which can be sold domestically or exported; the level of output is demand determined. We use a semi-reduced form relating output to the real exchange rate and investment demand:

$$(4) \quad Y = Y(e/P, I) \quad Y_1, Y_2 > 0$$

⁸ For investment to be proportional to the capital stock, as in (1), the adjustment cost function has to be assumed linearly homogeneous in I and K . We could easily dispense with this assumption.

where Y is real output, and e/P is the real exchange rate⁹.

Since monetary considerations are not our main concern here, we will drastically simplify portfolio behavior. We assume that the anticipated rate of return on capital r , to which we shall refer as the 'domestic real interest rate', depends on both domestic and foreign factors:

$$(5) \quad r = \rho \cdot [r^* + E(\dot{e}/e - \dot{P}/P)] + (1-\rho) \cdot j(Y, V \cdot K) \quad 0 \leq \rho \leq 1; j_1, j_2 \geq 0$$

where the operator $E(Z)$ denotes the expected value of the variable Z . Equation (5) can be viewed as the equilibrium condition in the equity market, inverted to solve for r . The latter is expressed as a weighted average of the foreign real interest rate adjusted for anticipated real depreciation, and of 'domestic conditions' in the equity market, summarized by real output and the outstanding real equity stock. The respective weights are given by ρ and $1-\rho$, where ρ can be interpreted as a direct measure of the degree of capital mobility: at one extreme, with perfect capital mobility, $\rho=1$, so that the domestic and the depreciation-adjusted foreign real interest rate must be equal. At the other end, with a closed capital account, $\rho=0$, and the domestic real interest rate depends only on domestic real output and on the outstanding stock of equity¹⁰; an

⁹ Equation (4) could be obtained from the goods market equilibrium condition

$$Y = C(e/P, Y) + I + X(e/P) - (e/P) \cdot [M_C(e/P, C) + M_I(e/P, I)]$$

where C is real consumption, X are exports, and M_C and M_I are imports of consumption and investment goods, respectively. Solving for Y , we would get an expression similar to (4).

¹⁰ Reduced-form interest rate equations similar to (5) have been widely used to analyze the implications of alternative degrees of financial openness; see e.g. Edwards (1986), Blejer and Gil-Diaz (1986). One important difference is that these authors relate the real interest rate to conditions in the domestic money market, rather than in the equity market used here; our approach amounts to assuming that, with a closed capital account, equity market equilibrium can just be expressed as $VK = g(r, Y)$, with $g_1 > 0$, $g_2 < 0$.

increase in either of these variables creates an incipient excess supply in the market and leads to an increase in the real interest rate.¹¹

An alternative rationalization of equation (5) is provided by the existence of rationing in the domestic credit market¹². Suppose that firms can finance their investment with credit or with foreign indebtedness; assume further that the interest rate on credit is administratively fixed below the market-clearing level, and that the total amount of credit available to each firm is subject to a ceiling. At any given time, the credit ceiling will be binding for some firms, while others will still have access to additional credit. For the former group, the interest rate relevant for investment decisions is given by the depreciation-adjusted interest rate on foreign debt (which represents the marginal source of financing), while for the latter group it would equal the interest rate on credit. In the aggregate, the relevant interest rate would be a weighted average of these two (with the weights depending on the fraction of firms in each financial regime), similarly to what is assumed in (5).

The anticipated rate of return on capital is the sum of profits plus anticipated capital gains on equity.

On the other hand, one possible criticism to (5) is that under imperfect capital mobility it allows domestic and foreign real interest rates to be different even in the long run. An alternative specification would be to express the rate of change of the domestic interest rate as a function of its deviation from interest parity (Edwards and Kahn (1985) Browne and McNelis (1990)). Perfect capital mobility would then amount to an infinite speed of adjustment of the domestic interest rate, and in the long run interest parity would hold regardless of the degree of capital mobility. However, the resulting investment dynamics would not be qualitatively very different from those in the paper; thus, we shall ignore this complication here.

¹¹ The implicit rationale for an increase in real output to reduce the excess demand for equity is that it would raise the transactions demand for more 'liquid' assets.

¹² For a more detailed exposition, see Serven (1990).

$$(6) \quad E(\dot{V}/V) + (F/V) - \delta = r$$

where F are gross real profits (including depreciation) per unit of capital. Equation (6) can be integrated forward to express the market value of capital V as the present discounted value of expected future profits, with the discount rate equal to $r+\delta$. In long run equilibrium, profits and the user cost of capital must be equal, i.e., $F = (r+\delta)V$. In turn, real profits are an increasing function of the output/capital ratio (or the rate of capacity utilization):

$$(7) \quad F = F(Y/K) \quad F' > 0$$

It will be useful to denote the real exchange rate as $X \equiv e/P$. Hence, we can write the relative price of capital goods in terms of domestic goods as

$$(8) \quad P_K/P = X^{1-\gamma}$$

Thus the real cost of new capital goods rises with the real exchange rate. Similarly, we define Tobin's Q as the market value of capital relative to its replacement cost:

$$(9) \quad Q \equiv V \cdot P/P_K = V/(X^{1-\gamma})$$

where we have used (8). Also, we can define the real interest rate in terms of capital goods as

$$(10) \quad r_K \equiv r + E(\dot{P}/P - \dot{P}_K/P_K) = r - (1-\gamma) \cdot E(\dot{X}/X)$$

Thus, r_K differs from r due to the anticipated change in the relative price of capital goods, which (from (8)) is proportional to the anticipated rate of real depreciation; in the long run, with a constant real exchange rate, $r=r_K$.

From (8), (9) and (10), it follows that the anticipated rate of change of Tobin's Q is just

$$(11) \quad E(\dot{Q}/Q) = r_K + \delta - F/(Q \cdot X^{1-\gamma})$$

In turn, from (1) and (9) the rate of capital accumulation is

$$(12) \quad \dot{K} = K \cdot \Phi \cdot [Q-1]$$

Combining (4), (5), (7), (8), (11) and (12), the model can be reduced to a system of two dynamic equations in Tobin's Q and the capital stock, with the real exchange rate and its anticipated rate of change as the forcing variables. However, to complete the model we need two additional elements. First, we have to specify how the real exchange rate is determined. Since for our purposes the precise form in which real exchange rate changes are generated is not directly relevant, it will be convenient to assume throughout that the real exchange rate is set exogenously. This can be viewed as resulting from the combination of a managed nominal exchange rate and some source of nominal rigidity in the economy (e.g. incomplete wage indexation)¹³. Hence, we shall not concern ourselves with the separate determination of domestic prices and the nominal exchange rate.

Finally, we must specify how expectations are formed. We shall assume that

¹³ For example, the model could be completed with a price equation of the type

$$P = s_0 \cdot W^s \cdot e^{1-s}$$

where s_0 is a parameter, W is the nominal wage and s the share of labor in variable costs. This can be rewritten

$$X = (e/P) = (1/s_0) \cdot (W/e)^{-s}$$

Thus, with such pricing behavior, a real depreciation amounts to a cut in the real wage in terms of foreign goods. In turn, this could be implemented either through a nominal wage cut with a given nominal exchange rate or, perhaps more realistically, through a nominal depreciation accompanied by a less than proportionate (or zero) nominal wage adjustment.

expectations are rational; hence the expected and actual values of the variables in the model can differ due only to the arrival of unanticipated information - that is, at times of unanticipated shocks.

In order to solve the dynamic system under rational expectations, it is important to note that the capital stock is a predetermined variable, while Tobin's Q is not. At any given instant, the capital stock is given by past investment decisions, and cannot jump in response to new information about the paths of the exogenous variables. In contrast, Q is free to jump instantaneously in reaction to unanticipated information about the present and/or future values of the forcing variables.

To facilitate the manipulation of the model, it is convenient to linearize it around the steady state (see Appendix A). As shown by Buiter (1984), the linearized system has a unique solution if and only if it possesses saddlepoint stability. This amounts to the requirement that the two eigenvalues of the transition matrix have opposite signs. In economic terms, such requirement is met if and only if an increase in the capital stock raises profits per unit of capital by less than the user cost of capital. In particular, a sufficient condition for this to hold is that an increase in the capital stock raise output less than proportionately, so that the output/capital ratio (and hence unit profit) falls. Under such condition¹⁴, the dynamic system has a unique solution, which is 'forward looking' in the sense that Tobin's Q will depend on the past only through its effect on the capital stock.

3.1 - The long run

¹⁴ Under perfect capital mobility ($\rho=1$), this condition is also necessary. See Appendix B.

To understand the dynamics of investment in this model, we need to examine first the long-run effects of real exchange rate changes. These are straightforward: in the long run, the level of the real exchange rate affects the optimal capital stock directly through its effect on the real cost of new capital goods, and indirectly through its impact on real output and the real interest rate.

In the steady state the capital stock, Q , and the real exchange rate are constant. From (12), Q must equal unity, while from (11) real profits per unit of capital must equal the user cost of capital. Replacing (5), (7) and (8) into the long-run version of (11), it follows that

$$(11') \quad [\rho \bar{r}^* + (1-\rho) \cdot j(Y(\bar{X}, \bar{K} \cdot \Phi[\bar{Q}-1]), \bar{Q} \cdot \bar{X}^{1-\gamma} \cdot \bar{K}) + \delta] \cdot (\bar{Q} \cdot \bar{X}^{1-\gamma}) \\ = F(Y(\bar{X}, \bar{K} \cdot \Phi[\bar{Q}-1])/\bar{K})$$

where we have denoted the long-run values of the variables by an overbar.

The steady state is depicted in Figure 1 as the intersection at point A of the horizontal line drawn for $Q=1$ and the qq line that represents equation (11'). The latter can be upward or downward sloping depending on whether an increase in Tobin's Q , given the capital stock, raises real unit profits (the right-hand side of (11')) by more or by less than the user cost of capital (the left-hand side). Following Blanchard (1981), we label these alternatives the 'good news' and 'bad news' cases; they are respectively depicted in Figure 1(a) and 1(b). In the good news case, a higher Q must be matched by a higher capital stock, in order to restore the equality between profits per unit of capital and its real user cost; hence, the qq schedule must be upward sloping. In the bad news case, the opposite happens. In particular, perfect capital mobility ($\rho=1$) is sufficient for the good news case to obtain.

The consequences of a change in the long-run real exchange rate can be easily illustrated. Consider first the case when domestic conditions have no effect on the real interest rate ($\rho=1$); then the real depreciation raises the real cost of capital only due to its import content. At the same time, it raises profits through its expansionary effect on output. Hence, the net result is ambiguous: intuitively, if the import content of capital is small relative to the impact of the depreciation on output and profits, then a real depreciation raises the steady-state capital stock. Graphically, the qq schedule shifts to the right. In the alternative case, it shifts to the left, and the long run capital stock falls (Figure 2).

Consider now the general case of imperfect capital mobility ($\rho < 1$). Then the real depreciation also raises the real cost of capital through its positive effect on the interest rate, due to the increase in output and in the real value of installed capital in terms of domestic goods, which raises the real supply of equity. Through this additional channel, the long run capital stock tends to fall. For it to rise, the direct impact on profits must now be sufficient to outweigh both the adverse interest rate effect and the import content effect.

Formally, the change in the steady state capital stock can be approximated, using (11'), as

$$(13) \quad (\Delta \bar{K} / \bar{K}) = (1/D) \cdot [(\bar{r} + \delta) \cdot \alpha \sigma - (\bar{r} + \delta) \cdot (1 - \gamma) - (1 - \rho) \cdot (\alpha \epsilon + (1 - \gamma) \Omega)] \cdot (\Delta \bar{X} / \bar{X})$$

where $\alpha > 0$ is the elasticity of output with respect to the real exchange rate (i.e., $\alpha \equiv Y_1(e/P)/Y$); $\beta > 0$ is the investment multiplier ($\beta \equiv Y_2$); $\sigma > 0$ is the elasticity of unit profit with respect to the output/capital ratio (i.e., $\sigma \equiv (Y/K)F'/F$); $1 > s_1 > 0$ is the output share of investment; ϵ and Ω respectively denote the semi-elasticities of the real interest rate with respect

to output and to the real equity stock (both assumed non-negative); and D is a parameter combination which is positive if and only if the dynamic model is saddlepoint stable.

The term in square brackets in this expression captures the three effects described above. First, the profitability effect is the positive direct impact on output (via α) and thus on profits (through σ) of the real depreciation; second, the adverse impact on the real cost of capital goods due to their import content is captured by the term $(1-\gamma)$; third, the interest rate effect is the combined impact on the equity market of the output increase (through ϵ) and of the higher value of equity in terms of domestic goods (which raises the interest rate through Ω).

The net impact on the capital stock is therefore uncertain. Clearly, the larger the import content of capital $1-\gamma$, the more likely a reduction in the capital stock. Note in particular that the ambiguity persists even in the case of perfect capital mobility, in which the real interest rate is constant across steady states. The relevant condition for the long run capital stock to rise then is that the profitability effect $\alpha\sigma$ exceed the unit import content of investment $1-\gamma$. If the latter is nil, then the capital stock must rise.

It is clear that, even if the long run capital stock falls, long-run output may rise due to the direct impact of the real exchange rate on demand. The long run output change is given by

$$(14) \quad (\Delta\bar{Y}/\bar{Y}) = \alpha(\Delta\bar{X}/\bar{X}) + \beta s_I (\Delta\bar{K}/\bar{K}) \\ = (1/D) \cdot \alpha [\Omega(1-\rho) + \sigma(\bar{r} + \delta)] - \beta s_I (1-\gamma) [\Omega(1-\rho) + \bar{r} + \delta] \cdot (\Delta\bar{X}/\bar{X})$$

Thus, if capital goods have zero import content, then output must rise in

the long run with a real depreciation¹⁵. The larger the import content of investment $1-\gamma$, the more unlikely a real depreciation is to result in output expansion¹⁶.

3.2 - Anticipated Exchange rate Changes and The Timing of Investment

The long run analysis above illustrates the effect of the real exchange rate on the long-run capital stock. However, in the model the anticipated time path of the real exchange rate also affects the optimal investment path or, in other words, the time profile of the accumulation process by which the optimal capital stock will be reached.

This is apparent from equation (11), which expresses the anticipated time path of Tobin's Q in terms of the real interest rate and the profit rate, both in terms of capital goods. For a given profit rate, a high (low) r_K implies a rising (falling) path for Tobin's Q and hence also for investment. From (5) and (10), the effect on r_K of a change in the anticipated rate of depreciation is just

$$(15) \quad \frac{\partial r_K}{\partial E(\dot{X}/X)} = \rho - (1-\gamma)$$

which summarizes the two opposing effects described earlier. First, the capital gain effect $1-\gamma$, through which an increase in the anticipated rate of

¹⁵ Notice also that if the impact of a real depreciation on noninvestment demand is contractionary (i.e., $a < 0$) then both output and the capital stock must fall in the long run.

¹⁶ Again, the distinction between the tradable and nontradable sectors would reveal a very different behavior of sectoral investment. In particular, in the tradable sector the relative price of new capital goods in terms of final goods would fall; the likely result would be an increase in investment. In the nontradable sector, the opposite result would be likely.

depreciation reduces r_K and stimulates current investment, due to the import content of capital goods: if a real depreciation is anticipated, the real cost of imported capital goods is expected to rise and thus the real interest rate in terms of capital is low. Second, there is the conventional asset substitution effect ρ that raises the real interest rate and discourages current investment: the anticipated real depreciation increases the expected return on foreign assets and, to an extent determined by the degree of capital mobility, also the required return on equity; this is reflected in a corresponding increase in the real interest rate in terms of capital.

Although the net result is in general ambiguous, in our framework the critical condition is just whether the unit import content of investment ($1-\gamma$) exceeds or falls short of the degree of capital mobility as measured by ρ . With high capital mobility ρ is close to 1, an anticipated depreciation raises the real interest rate in terms of capital, and investment must fall relative to the future. The expected depreciation encourages flight into foreign assets and acts like a transitory tax on investment. Conversely, with low capital mobility and a high import content of investment ($1-\gamma > \rho$), the expected depreciation reduces r_K , and investment must rise relative to the future. The depreciation thus promotes flight into foreign goods, and amounts to a transitory subsidy to investment. Thus, the precise direction in which investment is intertemporally reallocated depends on institutional features of goods and assets markets.

Notice the contrast with the case of an anticipated future increase in tariffs on investment goods. It is clear that in such case there is no asset substitution effect, and the anticipated tariff increase would just amount to an anticipated capital gain (of magnitude $1-\gamma$) on early investment. Hence, it would unambiguously result in a transitory investment boom.

How does this agree with the empirical facts? We can return to the two episodes of transitory real appreciation and anticipated real depreciation in Chile and Uruguay that we described earlier. In Chile, the degree of openness of the capital account of the Balance of Payments in the late seventies and early eighties was limited; empirical equations similar to (5) yield an estimate¹⁷ of the degree of openness ρ below 1/4. In contrast, the import content of investment averaged about 40 percent in 1977-81; in particular, about 90 percent of machinery and transport equipment was purchased abroad in that period¹⁸. Thus, our model suggests that in the case of Chile an anticipated real depreciation should reduce the ex-ante real interest rate in terms of capital goods and thus promote a transitory investment boom -- which seems in broad agreement with the observed pattern¹⁹.

In contrast, the financial liberalization of the late seventies had left Uruguay's capital account very open. Domestic and depreciation-adjusted foreign interest rates moved closely together in 1978-82; in fact, the corresponding empirical estimates of the degree of capital mobility ρ are very close to unity²⁰, exceeding the import content of investment by a wide margin. Under such

¹⁷ See Edwards (1986).

¹⁸ See Banco Central de Chile (1986). These figures refer to total investment; the import content would probably be much higher in the case of private investment, since a large portion of public investments take the form of construction and public works, whose import content is nil.

¹⁹ Again, the suspicion that the trade liberalization of 1977-79 might be just a transitory phenomenon and could be followed by tariff increases may have played also an important role in the investment boom. As noted in the text, an expected tariff rise would unambiguously reduce r_K -- adding also to the transitory investment boom.

²⁰ The results reported by Blejer and Gil Diaz (1986) yield a value of ρ equal to one. Hanson and De Melo (1985) reach the same result for the long run; however, their short-run estimate of ρ is only .43. Nevertheless, even this latter value appears substantially larger than the import content of aggregate

conditions, it follows that the ex-ante real interest rate in terms of capital must rise when a real depreciation is anticipated; pending the anticipated depreciation, there should be an investment slump -- which again does not seem to disagree with the observed investment performance²¹.

3.3 - The Dynamics of an Anticipated Real Depreciation

This discussion can be formalized solving the model for the time paths of the capital stock and Tobin's Q, for a given time path of the real exchange rate. The dynamics of investment will reflect the combination of the two factors described earlier: the 'desired' capital stock at each instant, and the optimal timing of investment. Formally, let $\hat{K}(t)$ denote the capital stock that would obtain in the long run if the real exchange rate were to equal $X(t)$ forever; in other words, $\hat{K}(t)$ is the optimal capital stock associated with the constant real exchange rate $X(t)$ (thus, in particular, $\hat{K}(\infty)=\bar{K}$). Then the time path of K can be written²²

$$(16) \quad \dot{K}(t) = \lambda \cdot [K(t) - \int_t^{\infty} h(t, \tau) \cdot E_t[\hat{K}(\tau)] \cdot d\tau] \\ + (\Phi/\mu) \cdot (1-\gamma-\rho) \cdot [\int_t^{\infty} h(t, \tau) \cdot E_t[\dot{K}(\tau)] \cdot d\tau]$$

where $\lambda < 0$ and $\mu > 0$ respectively are the stable and unstable roots of the dynamic

investment, which for 1978-82 averaged about 15% (World Bank (1988)).

²¹ Obviously, while the observed facts are in line with our analytical results, we are not trying to imply that the investment performance in Chile or Uruguay can be explained exclusively by the time path of the real exchange rate; in both cases, other factors played an important part. However, the real appreciation undoubtedly had a major role. More complete descriptions of the macroeconomic events of the late seventies and early eighties in Chile and Uruguay can be respectively found in Corbo (1985) and Hanson and De Melo (1985).

²² Details are given in Appendix B.

system. The first line of (16) is the desired capital stock component; it causes the capital stock to change in proportion to its deviation from a weighted average of expected future optimal capital stocks, with the weights given by the function $h(t, \tau)^{23}$. Loosely speaking, it depends only on the discrepancy between the actual and optimal capital stocks. The second line in (16) is the speculative or intertemporal reallocation effect; it relates the rate of change of the capital stock to a weighted average of future anticipated rates of real depreciation. In particular, it is completely unrelated to the discrepancy between the current capital stock and its future optimal value.

To examine in more detail the dynamics of an anticipated permanent real depreciation, let us consider first the case of a gradual real depreciation. Specifically, assume that, starting from long run equilibrium at time zero, the rate of real depreciation becomes positive, and the real exchange rate is continuously depreciated until time T ; from instant T on, the real exchange rate stays constant. Thus, in the interval between 0 and T there is a perfectly anticipated real depreciation; for simplicity, we further assume that the latter proceeds at a constant rate.

It may be instructive to separate the two factors determining investment. Consider first the case of no speculative effect, that is, $\gamma + \rho = 1$ (thus the second line in (16) vanishes). Then the real interest rate in terms of capital goods is unaffected by the anticipated rate of depreciation, and the dynamics depend only on the change in the optimal capital stock. This is illustrated in Figure 3, which reflects the case of an expansionary long-run effect on the capital stock (the contractionary case is analogous). Starting from the long run

²³ The weights are given by $h(t, \tau) = \mu \exp\{\mu(t - \tau)\}$; thus they are positive and (exponentially) declining in τ , with $\int_t^{\infty} h(t, \tau) d\tau = 1$.

equilibrium A at time zero, there is an upward jump in Q to Q(0), which immediately raises investment and output. In Appendix B we show that Q(0) is given by

$$(17) \quad Q(0) = 1 + H \cdot (1 - e^{-\mu T}) T^{-1} \mu^{-2} \cdot (\Delta \bar{X} / \bar{X})$$

where $H \equiv \{(\bar{r} + \delta) \cdot [a\sigma - (1 - \gamma)] - (1 - \rho) \cdot (a\epsilon + (1 - \gamma)\Omega)\}$ is just the term in square brackets in (13), and hence it is positive (negative) if and only if the desired capital stock rises (falls) with a higher real exchange rate; and $\Delta \bar{X}$ is the long-run real exchange rate change (thus $T^{-1}(\Delta \bar{X} / \bar{X})$ approximately equals the percentage rate of real depreciation in the interval between zero and T). Hence, given the magnitude of the depreciation and its impact on the long run capital stock, the initial jump in Q is smaller the longer the time interval T over which the depreciation takes place, and also the larger the unstable root of the system.

After the initial jump in Q and investment, two adjustment patterns are possible. If the increase in Q raises profitability by more than the real interest rate (i.e., in the good news case, depicted in panel (a) of Figure 3), then following its initial jump Q must be falling, and capital accumulation is decelerating. In the bad news case (Figure 3(b)), Q keeps rising (and investment increasing) for some time, with the length of this expansionary phase increasing with that of the depreciation stage T; however, Q and investment must start declining before time T. When the rate of depreciation returns to zero at instant T, the system must be at point A_T on the ss schedule in Figure 3a, which describes the unique trajectory along which the model will converge to the new long run equilibrium at A'. In both the good news and bad news cases, Q keeps falling and K rising after instant T towards their long-run values. Hence,

throughout the adjustment Q remains above, and K below, the steady state level. In other words, the adjustment is monotonic, and, in particular, the capital stock cannot overshoot its long-run level. Obviously, in the absence of any incentives to the intertemporal reallocation of investment, there is no reason for overaccumulating capital.

Let us now turn to the more interesting case of no effect on the desired capital stock, but a non-zero speculative effect. Throughout, the desired capital stock remains unchanged, and the anticipated depreciation affects only the time path of investment (i.e., the first line of (16) is zero). Thus, investment will initially rise or fall depending on the sign of the intertemporal reallocation effect. The initial value of Q is now

$$(17') \quad Q(0) = 1 + [1 - \gamma - \rho] \cdot (1 - e^{-\mu T}) \cdot (\mu T)^{-1} \cdot (\Delta \bar{X} / \bar{X})$$

Hence, as argued above, if the unit import content of capital $1 - \gamma$ exceeds (falls short of) the degree of capital mobility as measured by ρ , Tobin's Q and investment must rise (fall) initially. Of course, the reason is that the initial effect of the anticipated depreciation is to reduce (raise) the real interest rate in terms of capital goods. From (17'), the jump in Q is proportional to the magnitude of the intertemporal reallocation term $1 - \gamma - \rho$; again, it is smaller the longer the depreciation interval T and the larger the unstable root of the system μ .

The two alternatives are depicted in Figure 4(a) and 4(b) respectively. Since their dynamics are analogous, we focus on Panel (a), which corresponds to the case of high import content relative to the degree of capital mobility. The initial rise in Q (to $Q(0)$) is followed by a gradual decline; net investment slows down and, eventually, becomes negative before T. Thus, there is a clockwise

movement from A_0 to A_T . At instant T , the system must be at a point such as A_T on the original saddle path, with the capital stock exceeding its initial (and final) level; the excess capital is then gradually eliminated.

What about the general case of nonzero long-run effect and nonzero intertemporal effect? It is clear that the dynamics will be a mixture of the two polar cases just examined. In the long run, the optimal capital stock may rise or fall with the real depreciation; regardless of this, if the import content of capital is high (low) relative to the degree of capital mobility, then investment will be relatively higher before (after) instant T . Formally, the condition for a transitory investment boom can be expressed in terms of the initial change in Q , which is given by

$$(18) \quad Q(0) = 1 + [(H/\mu) + 1 - \gamma - \rho] \cdot (1 - e^{-\mu T}) \cdot (\mu T)^{-1} \cdot (\Delta \bar{X} / \bar{X})$$

Hence, even if the capital stock falls in the long run ($H < 0$), there can be an initial investment boom if the speculative effect is strong enough, so that the term in square brackets in (18) is positive. This is illustrated in Figure 5, in which Tobin's Q and investment rise initially, so that the capital stock moves away from its (lower) long-run value. The initial boom is gradually reversed as the system moves from A_0 to A_T ; at time T , the capital stock must exceed its initial level. Thereafter, the excess capital is decumulated.

It is important to notice in (18) that the weight of the long-run effect H in determining the short-run investment outcome is inversely related to μ , the unstable root of the system. In turn, for given values of all the other parameters, μ can be shown to increase with ϕ -- that is, to decrease with the magnitude of the adjustment costs associated with investment. Intuitively, the smaller the adjustment costs, the cheaper it is to reverse the over- or

underaccumulation of capital; thus, the speculative component $1-\gamma-\rho$ becomes relatively more important in determining the short-run investment response. In other words, Φ provides a measure of the intertemporal substitutability of investment²⁴.

The above results correspond to the case of an anticipated gradual real depreciation. What happens in the case of a perfectly anticipated discrete real exchange rate change²⁵? Assume that starting from equilibrium at time 0, it becomes known that at time T the real exchange rate will be permanently raised by the amount $\Delta\bar{X}$. Hence, the instantaneous rate of depreciation is zero both before and after T, and is unbounded at time T. This implies that if the speculative factor $1-\gamma-\rho$ is not zero, then at instant T the ex-ante real interest rate in terms of capital goods r_K is also unbounded -- as both the instantaneous return on foreign assets and the rate of change of the relative price of new capital goods become infinite; thus, Tobin's Q must exhibit a discrete jump at time T. It is important to note that this is not a violation of market efficiency; on the contrary, such discontinuity is required for the arbitrage equation (11) to hold²⁶ at time T.

²⁴ Of course, this implies that the speculative component will be specially important for those types of investment for which adjustment (or installation) costs are small.

²⁵ An anticipated discrete change in the real exchange rate seems to create a technical problem, since the instantaneous rate of real depreciation \bar{X} becomes unbounded at the time of the real exchange rate change. However, such technicality can be easily resolved (see Appendix B).

²⁶ The same applies to the real price of equity V. With an unbounded anticipated rate of depreciation at time T, the instantaneous rate of return on foreign assets is also unbounded; thus, from (6), V must jump to provide the capital gains required to match it. Such capital gains are perfectly anticipated, but imply no violation of market efficiency. Notice that, with a closed capital account ($\rho=0$), V would not jump, but Tobin's Q would continue to do so due to

Hence, the main difference with the previous case of gradual depreciation is the working of the reallocation effect. The initial value of Q is now

$$(19) \quad Q(0) = 1 + [(H/\mu) + 1 - \gamma - \rho] \cdot e^{-\mu T} \cdot (\Delta \bar{X} / \bar{X})$$

The dynamics are represented in Figure 6, which, for the purpose of illustration, again assumes no effect on the desired capital stock (hence $H=0$ in (19)). As before, if the import content of capital goods is high relative to the degree of capital mobility, there will be an initial boom, caused by the decline in the ex-ante real interest rate in terms of capital. In this case, however, the boom induced by the intertemporal reallocation of investment must last until the instant of the depreciation²⁷, at which Tobin's Q will show a discrete downward jump, investment will fall, and the elimination of the excess capital will begin. It is interesting to note that to the outside observer the real depreciation may appear to exert an overly 'contractionary' effect on investment demand (and perhaps also on real output), which in reality is just the counterpart to the speculative pre-depreciation boom.

Interestingly, these results indicate that, contrary to conventional wisdom, it is possible for an anticipated future depreciation to result in higher present investment than an unanticipated, immediate depreciation. As an extreme

the instantaneous jump in the real cost of imported capital goods.

On the other hand, with a more disaggregated asset structure, the long-term interest rate (rather than the short-term one) could be the relevant one to determine the required rate of return on equity. With both rates linked by an arbitrage equation (as e.g., in Blanchard (1984)), the long rate would remain bounded at instant T; however, it would have to jump at that moment as the short rate would become unbounded. The behavior of Tobin's Q and investment would then be similar to those analyzed in the 'gradual depreciation' case in the text.

²⁷ Moreover, in the bad news case (i.e., when a higher Q reduces profitability relative to the cost of capital) the initial expansion will proceed at an accelerating pace, with Q, investment and output continuously rising. In the good news case the expansion must slow down before instant T.

example, consider again the case in which the depreciation leaves the desired capital stock unchanged; then an unanticipated depreciation will have no effect whatsoever on investment. However, if the import content of capital is high relative to the degree of financial openness, we have just seen that an anticipated future depreciation (whether gradual or discrete) must lead to an initial investment boom. Moreover, if adjustment costs are not too high, then the same result can obtain even if the capital stock has to fall in the long run.

An application: transitory real appreciation and anticipated depreciation

Finally, we can return to our starting point and explore the more realistic case of a transitory real appreciation of uncertain duration. To simplify as much as possible, assume that the appreciation is known to be purely transitory; thus, the long-run exchange rate and capital stock remain unaffected. Further, we assume that investors expect the real appreciation to be eliminated by a jump depreciation that will restore the original real exchange rate; however, the exact timing of such depreciation is unknown.

Specifically, suppose that at any given instant there is a fixed probability $(1-\pi)$ that the appreciation will continue -- for simplicity, at a constant pace -- and an instantaneous probability π that it will be eliminated by a real depreciation. Provided the real depreciation has not yet happened at time t , the rate of depreciation that at such instant individuals will expect for time $t+\tau$ can be shown to equal²⁸

$$(20) \quad E_t[\dot{X}(t+\tau)] = \theta \cdot e^{-\pi\tau} \cdot [\pi \cdot (t+\tau) - 1] \quad \text{for } \tau > 0$$

where θ is the (constant) rate of real appreciation. Hence, exchange rate

²⁸ See Appendix B.

expectations will evolve as shown in Figure 7. The solid line represents the expectations prevailing at a given instant t_0 about the future path of the rate of depreciation; the dotted lines correspond to the expectations that will be held at later instants $t_2 > t_1 > t_0$ provided the depreciation has not yet taken place. Notice that the first two schedules reflect an initial stage of anticipated real appreciation (that is, the anticipated depreciation is initially negative), followed by depreciation; however, the length of this expected appreciation stage is shorter for t_1 than for t_0 , and at a later time t_2 no further appreciation is expected anymore. This follows from the fact that as time passes and the appreciation goes on, the cumulated real appreciation rises, so that the real depreciation required to restore the original real exchange rate grows larger -- eventually becoming the dominant factor. Thus, although initially investors may expect the ongoing real appreciation to continue for some time, they eventually will come to expect an increasingly large real depreciation²⁹.

As should be clear from our previous discussion, such real exchange rate path can generate substantial investment fluctuations. Again, let us focus on the intertemporal reallocation effect. As before, the initial impact on investment through this channel depends on the degree of capital mobility relative to the import content of capital goods. Consider first the low capital mobility case. Intuitively, at time zero investors anticipate an initial period (of uncertain duration) of real appreciation; thus, if capital mobility is low relative to the import content of capital goods, the ex-ante real interest rate in terms of capital rises; Q and investment will initially jump down. However, as shown in the previous figure, the anticipated appreciation is followed by

²⁹Observe that this happens despite the fact that the instantaneous probability of a real depreciation is constant. If, perhaps more realistically, the latter were increasing over time, then this effect would be reinforced.

increasing expected real depreciation, so that immediately after its initial jump r_K is falling and Q must be rising. As time passes and the anticipated depreciation fails to materialize, expected future real exchange rates are continuously being revised upward, leading to a growing investment boom and to an increasing overaccumulation of capital (Figure 8); moreover, the higher the probability of instantaneous depreciation, the earlier the boom will develop, and the more rapidly Q and investment will be rising.

Of course, these results are reversed if capital mobility is high. In that case, there will be an initial investment rise, followed by an increasingly deep recession as the growing anticipation of real depreciation leads to continuous increases in the ex-ante real interest rate in terms of capital goods.

The other factor affecting investment is the change in the optimal capital stock due to the changing level of the real exchange rate. Of course, in the long run this effect vanishes (as the steady state real exchange rate is unchanged), but in the short run it affects profits and the real interest rate, and hence the desired capital stock at each instant is changing. As before, the joint impact of the intertemporal reallocation effect and the desired capital stock change on investment is in general ambiguous. Formally, the initial value of Tobin's Q can be shown to equal

$$(21) \quad Q(0) = 1 - (\mu + \pi)^{-2} \cdot \mu \cdot [(H/\mu) + (1 - \gamma - \rho)] \cdot (\theta/\bar{X})$$

Notice that the larger θ and the smaller the instantaneous probability of depreciation π , the greater the size of the initial jump in Q ; the reason is that both factors increase the 'effective' anticipated appreciation rate. The direction of the jump again depends on the weighted sum of the intertemporal effect and the optimal capital stock effect.

4 - Concluding Remarks

Our results can be easily summarized. We have seen that in general the impact of a permanent real depreciation on the desired capital stock is uncertain; whether the aggregate capital stock rises or falls depends on the effects of the depreciation on aggregate demand and on the real interest rate, and, in particular, on the import content of capital goods. Moreover, the long-run capital stock can be expected to rise in the traded goods sector and to fall in the nontraded goods sector.

In spite of this long-run ambiguity, we have seen that anticipated real exchange rate changes have a predictable effect on the dynamics of capital accumulation. This is so because they provide an incentive for a speculative reallocation of investment over time -- quite apart from their effects on the optimal capital stock --, thus introducing potentially large distortions in the timing of investment.

In our framework, the time profile of investment can be easily related to the degree of financial openness of the economy and to the import content of capital goods: when a real depreciation is expected, an investment boom is likely to develop if the import content of capital goods (measured by the parameter $1-\gamma$ in the model) is high relative to the degree of capital mobility (which in the model is summarized by the parameter ρ) -- the anticipated depreciation then promotes flight into foreign goods; conversely, with high capital mobility the opposite investment pattern is likely to emerge, as the anticipated depreciation promotes flight into foreign assets. In the former case, the investment boom will be followed by a slump when the depreciation actually takes place, as it amounts to the removal of a transitory subsidy to investment; in the latter case, the

pre-depreciation slump will give way to a boom -- since the depreciation amounts to the removal of a tax. Such pattern could lead the uninformed observer to the (incorrect) conclusion that the real depreciation is 'contractionary' in the first case and 'expansionary' in the second -- while in fact the sharp change in the investment trend could to a large extent reflect the elimination of the transitory (positive or negative) investment incentive. Also, these speculative investment swings will be larger the higher the intertemporal substitutability of investment -- or, in other words, the smaller the adjustment costs associated with capital accumulation.

These results seem in broad agreement with the experiences of Chile and Uruguay in the late seventies and early eighties. The exchange rate-based disinflation attempted in both countries led to a real overvaluation and growing expectations of real depreciation. In the process, Chile -- which had a relatively closed capital account and a high import content of investment -- witnessed an investment boom; in contrast, Uruguay, characterized by a high degree of financial openness, experienced an investment slump.

Although in the paper we have focused on investment, it is clear that similar results would apply to consumers' expenditure on durable goods. Through both channels, transitory real exchange rate changes lead to an intertemporal reallocation of real expenditures and can generate large swings in real absorption. While these expenditure fluctuations simply reflect changes in the optimal timing of consumption and investment, they obviously have a strong destabilizing potential. For example, the unjustified perception that a real depreciation is imminent can lead to an expenditure boom -- causing a deterioration of the external accounts that in fact forces the real depreciation to be undertaken. From the viewpoint of macroeconomic and exchange rate policy,

this suggests that a stable real exchange rate path, avoiding persistent over- or undervaluations, can play a major role in stabilizing expenditure and output. Our results also support the view that, when the economic fundamentals warrant exchange rate action, it should be undertaken immediately -- to prevent the distortionary consequences that expectations of real exchange rate changes may have on the timing of consumption and investment.

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CHART 1

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CHILE: Private Investment (% of GDP) and Real Exchange Rate (1980 = 100)

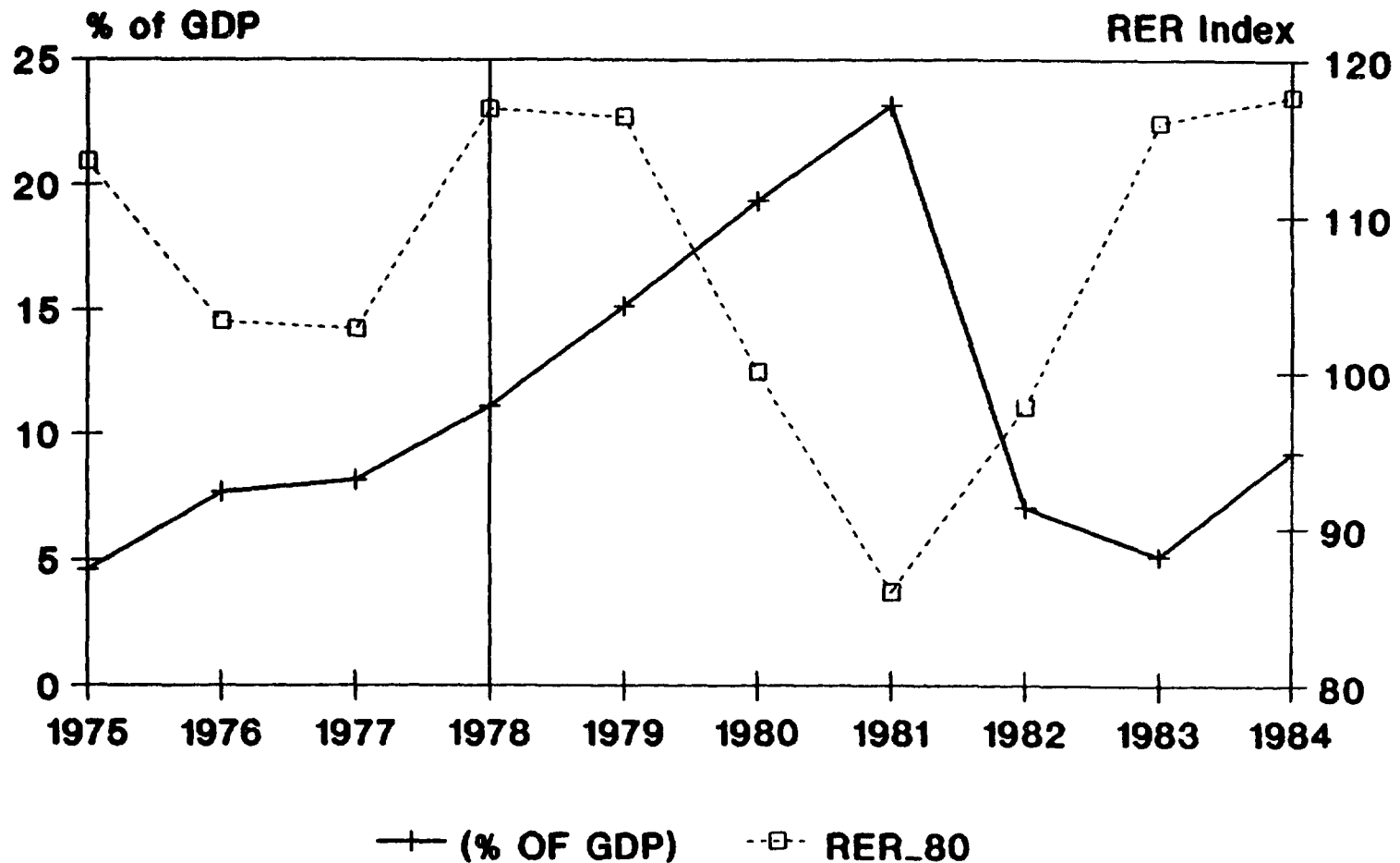


CHART 2

URUGUAY: Private Investment (% of GDP) and Real Exchange Rate (1980 = 100)

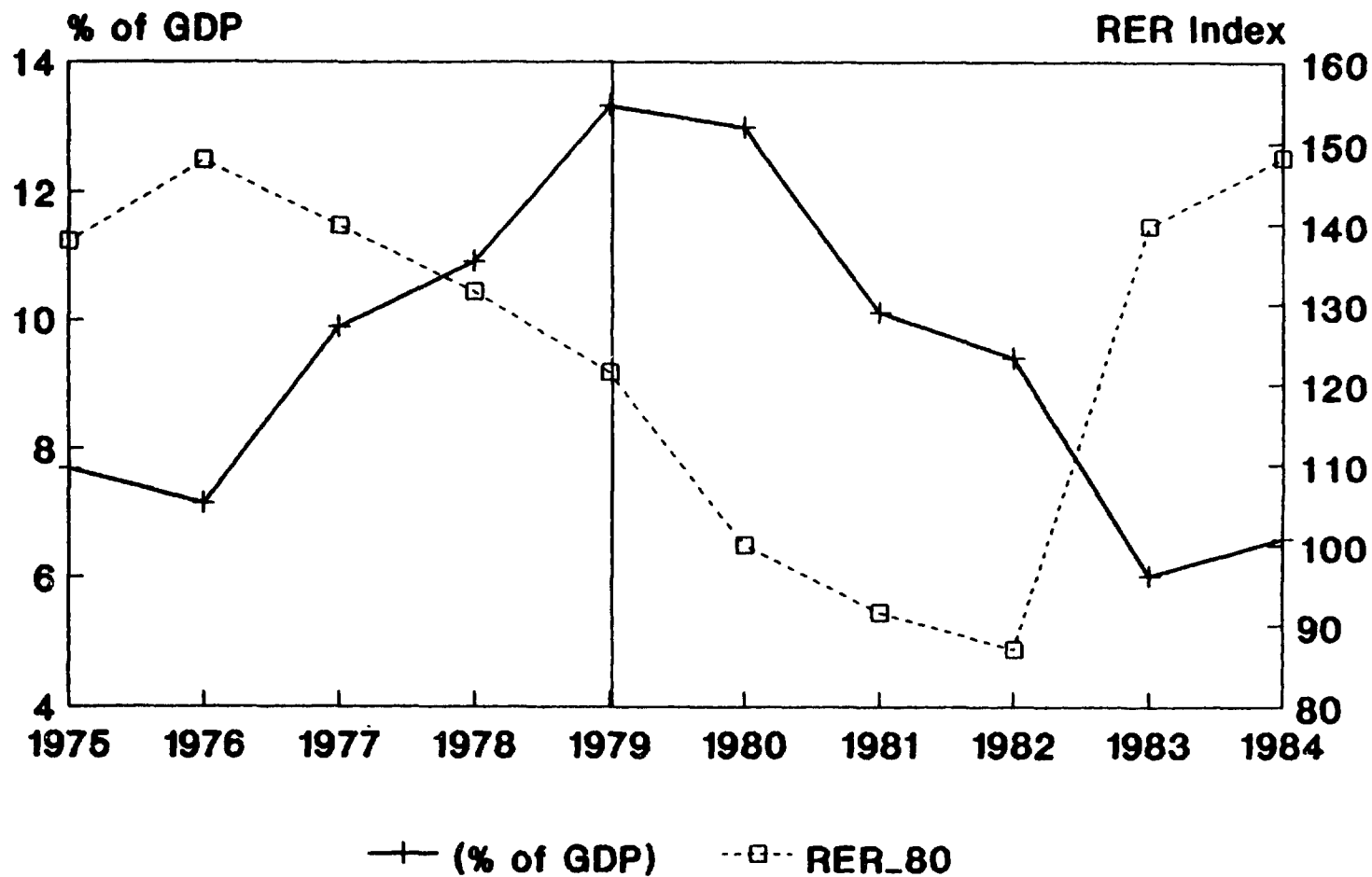


Figure 1

The steady state

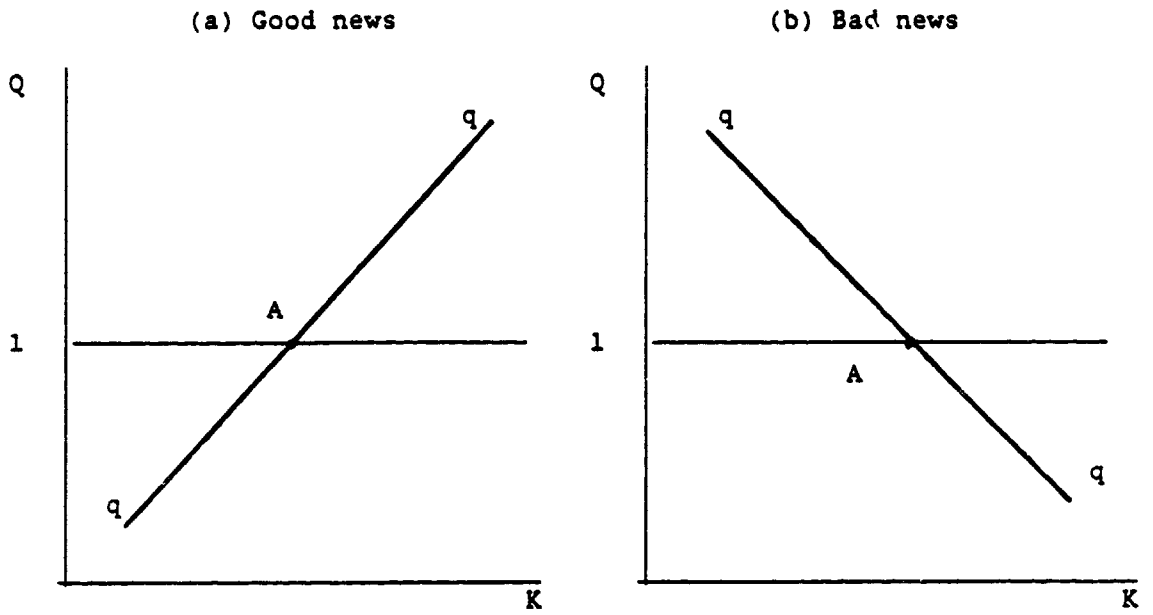


Figure 2

Long-run effect of a real depreciation (good news case)

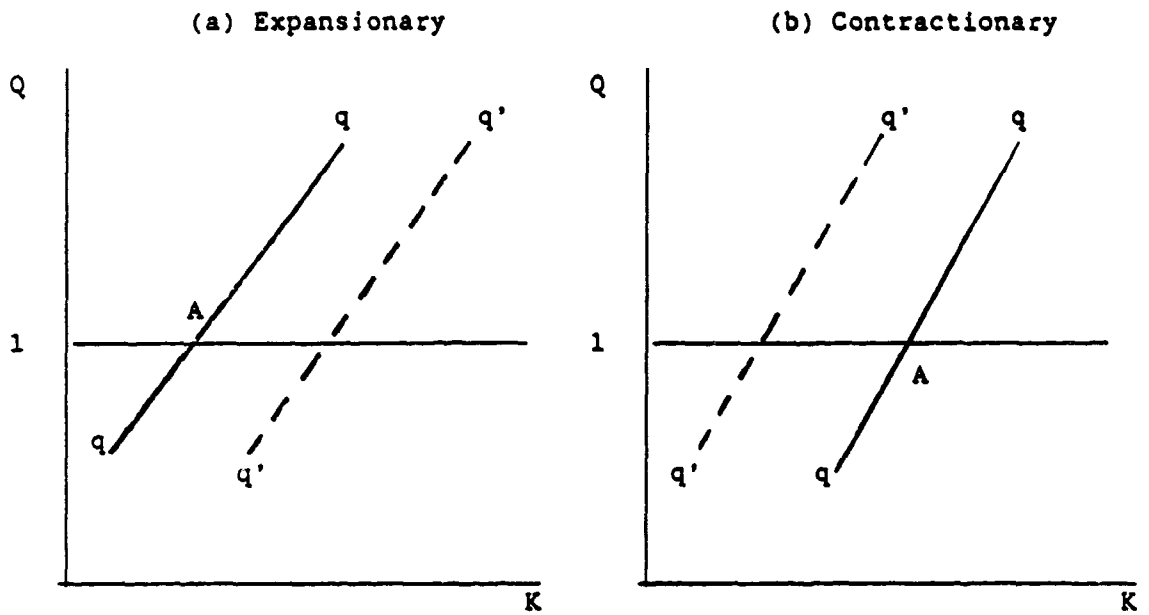


Figure 3

Anticipated gradual depreciation
(Expansionary case, no intertemporal effect)

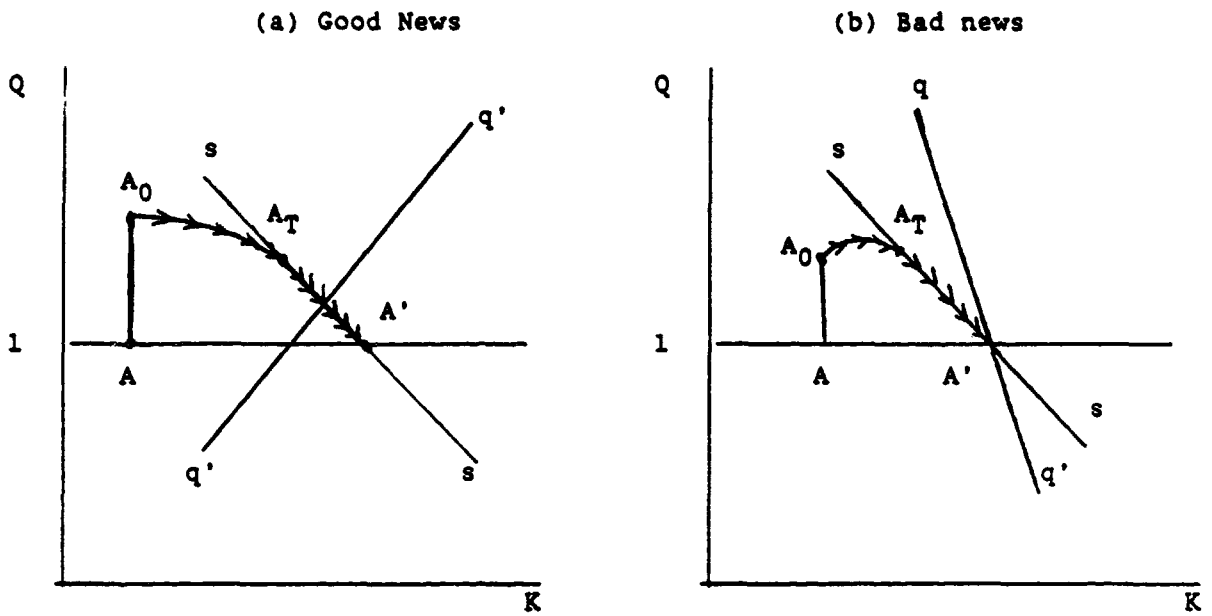
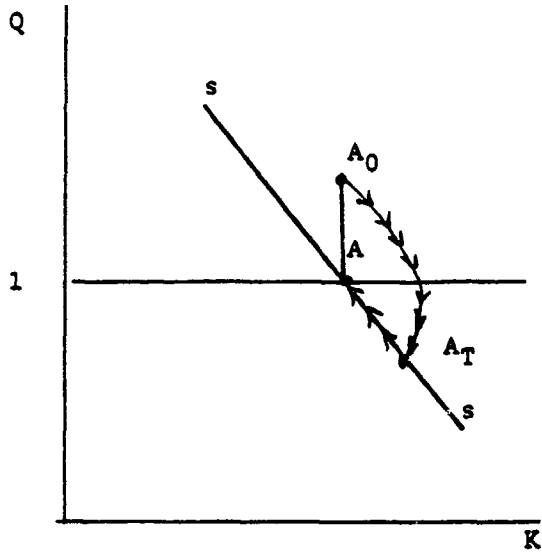


Figure 4

Anticipated gradual depreciation
(No capital stock effect)

(a) Low capital Mobility



(b) High capital mobility

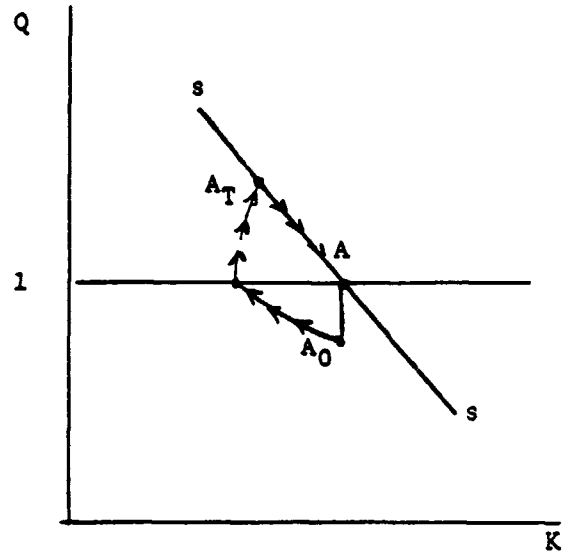


Figure 6

Anticipated jump depreciation

No capital stock effect

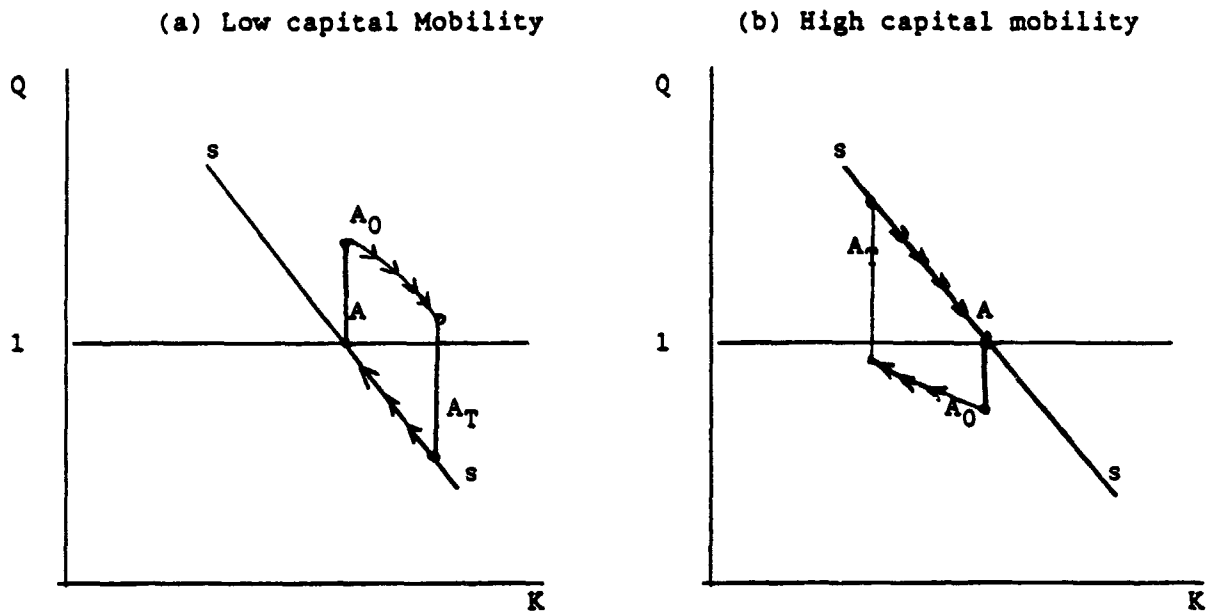


Figure 7
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Anticipated Rate of Change of Real Exchange Rate

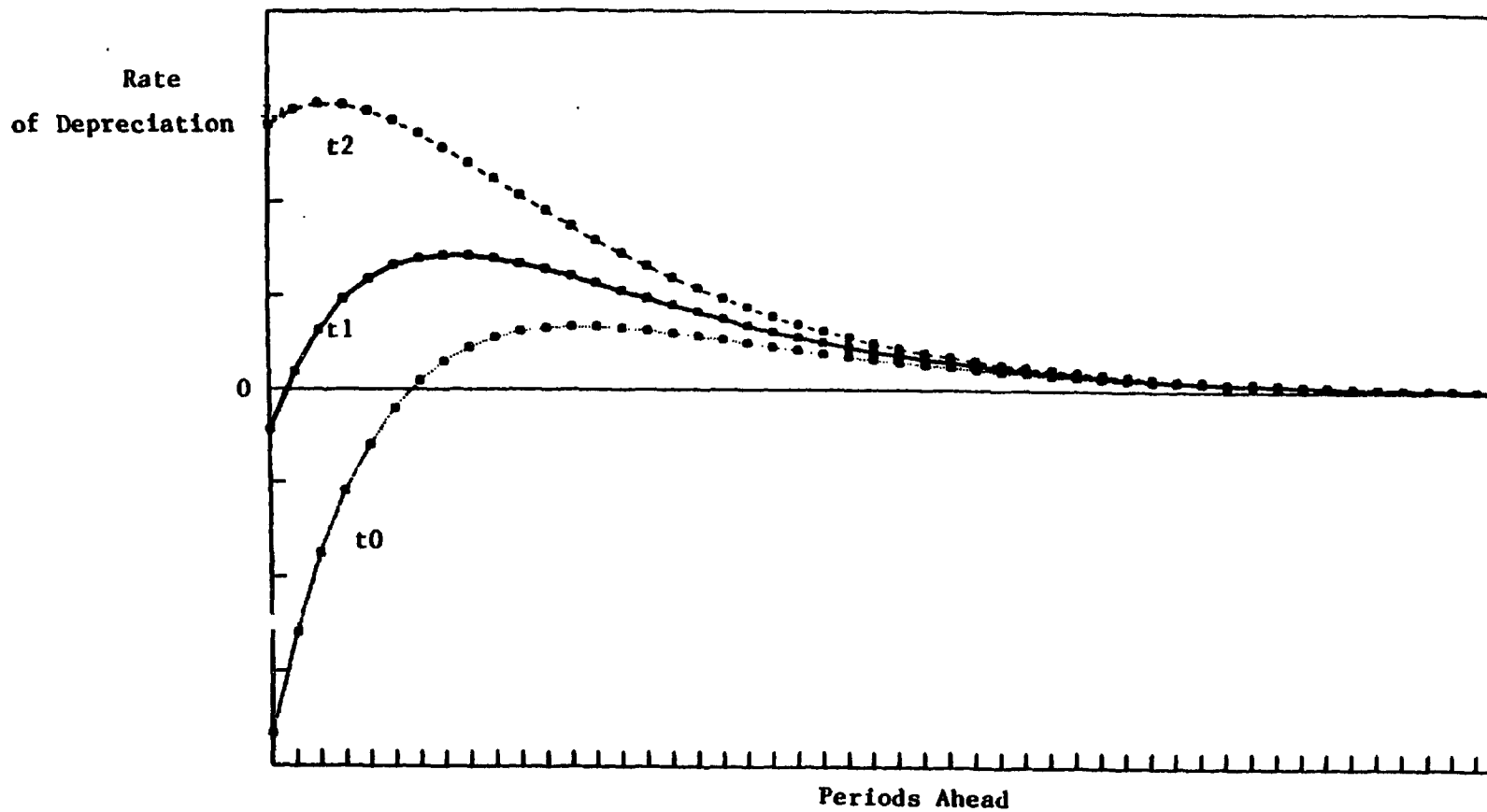
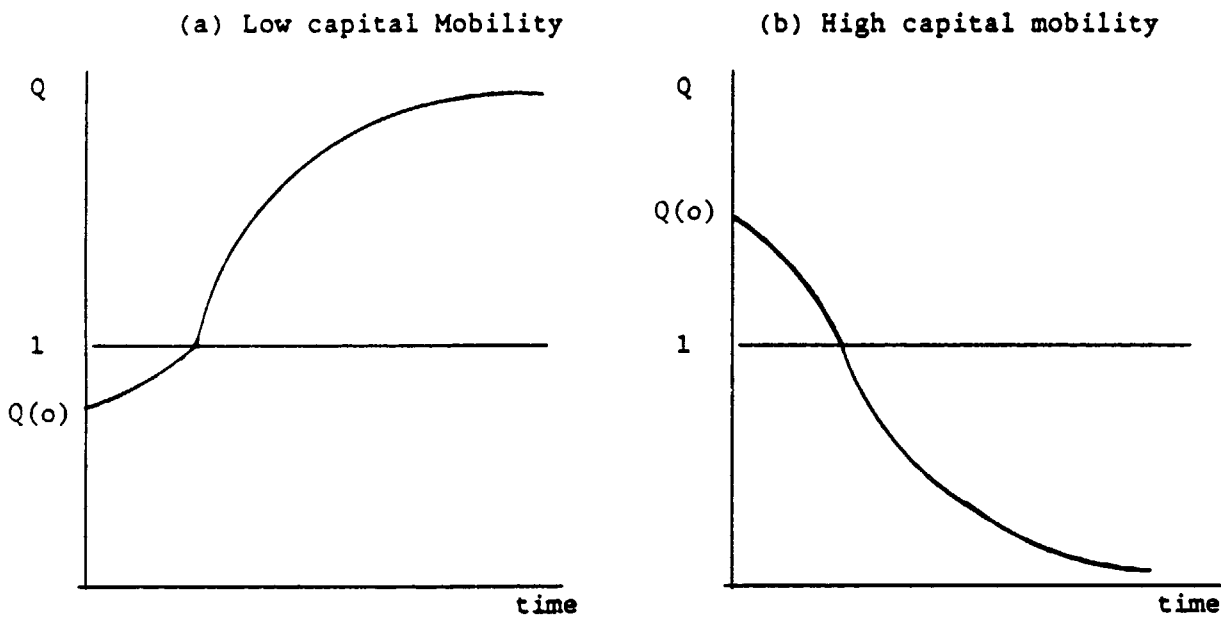


Figure 8

Transitory real appreciation

No capital stock effect



Appendix AThe dynamic model

The dynamics of the capital stock are given by (12) in the text. To obtain a dynamic equation for Tobin's Q in terms Q, K and the real exchange rate, we proceed as follows. First, replacing (1) into (4) and using the definition of Q, we have

$$(A1) \quad Y = Y(X, K \cdot \phi \cdot [Q-1] + \delta K)$$

and thus profits can be expressed

$$(A2) \quad F = F(Y(X, K \cdot \phi \cdot [Q-1] + \delta K) / K)$$

Combining these expressions with (5) and (10) in the text, the real interest rate in terms of capital goods can be rewritten

$$(A3) \quad r_K = (1-\rho) \cdot j(Y(X, K \cdot \phi \cdot [Q-1] + \delta K), Q \cdot X^{1-\gamma} \cdot K) - (1-\gamma-\rho) \cdot E(\dot{X}/X)$$

Thus the anticipated rate of change of Q (11) can be written

$$(A4) \quad E(\dot{Q}) = Q \cdot \left[\delta + \rho r^* + (\rho + \gamma - 1) \cdot E(\dot{X}/X) + (1-\rho) \cdot j(Y(X, K \cdot \phi \cdot [Q-1] + \delta K), Q K X^{1-\gamma}) \right] - F(Y(X, K \cdot \phi \cdot [Q-1] + \delta K) / K) \cdot X^{\gamma-1}$$

Thus the dynamic system consists of (A4) and (12) in the text. Linearizing around the long-run equilibrium, we get

$$(A5) \quad \begin{bmatrix} \dot{K} \\ E(\dot{Q}) \end{bmatrix} = A \cdot \begin{bmatrix} K - \bar{K} \\ Q - \bar{Q} \end{bmatrix} + B \cdot \begin{bmatrix} X - \bar{X} \\ E(\dot{X}) \end{bmatrix}$$

where we have defined the matrices

$$A \equiv \begin{bmatrix} 0 & \phi \\ \bar{K}^{-1} \{ (\epsilon \beta s_I + \Omega) (1-\rho) + \sigma (\bar{r} + \delta) (1-\beta s_I) \} & (\epsilon \beta s_I \phi / \delta + \Omega) (1-\rho) - (\bar{r} + \delta) \sigma \beta s_I \phi / \delta \end{bmatrix}$$

$$B \equiv \begin{bmatrix} 0 & 0 \\ \bar{X}^{-1} \{ (\epsilon \alpha + \Omega) (1-\gamma) \} (1-\rho) + (\bar{r} + \delta) (1-\gamma - \alpha \sigma) & \bar{X}^{-1} \{ \rho + \gamma - 1 \} \end{bmatrix}$$

Appendix B

Solution of the model

The determinant of the matrix A in (A5) is

$$(B1) \quad |A| = -\Phi[(\epsilon\beta s_T + \Omega)(1-\rho) + \sigma(\bar{r} + \delta)(1-\beta s_T)] \cdot \bar{K}^{-1}$$

Hence, $\beta s_T < 1$ is sufficient (but not necessary) for saddlepoint stability. We let λ and μ respectively denote the stable (negative) and unstable (positive) eigenvalues of A (i.e., $\lambda\mu = |A|$). Simple but tedious manipulations confirm that, for given values of the other parameters, $(\partial\mu/\partial\Phi) > 0$, $(\partial\lambda/\partial\Phi) < 0$. On the other hand, the 'good news' case is defined by $(\lambda + \mu) < 0$ (i.e., $a_{22} < 0$ in the transition matrix A); the 'bad news' case is the opposite. The expression D used in the equations in the text is just $D = -(K/\Phi) \cdot |A|$.

Using the results in Buiter (1984), the solution trajectory for Q can be written

$$(B2) \quad Q(t) - \bar{Q} = (\lambda/\Phi)[K(t) - \bar{K}] \\ + \int_t^{\infty} e^{\mu(t-\tau)} \cdot \bar{X}^{-1} \cdot \left[HE_{\tau}(X(\tau) - \bar{X}) + (1-\gamma-\rho)E_{\tau}(\dot{X}(\tau)) \right] d\tau$$

where H was defined in the text, $\bar{Q} = 1$, and $E_s(X(u))$ denotes the expected value of $X(u)$ conditional on the information available at time s. The saddle path SS in the diagrams is the locus defined by the equality in the first line of (B2).

Similarly, the solution for K is

$$(B3) \quad K(t) - \bar{K} = e^{\lambda t} [K(0) - \bar{K}] \\ + \Phi \int_0^t e^{\lambda(t-s)} \cdot \bar{X}^{-1} \left[\int_s^{\infty} e^{\mu(s-\tau)} [HE_s(X(\tau) - \bar{X}) + (1-\gamma-\rho)E_s(\dot{X}(\tau))] d\tau \right] ds$$

The final form equation for Q can be computed by replacing (B3) into (B2). From (A5) and (B1), the long-run change in the capital stock resulting from a change $\Delta\bar{X}$ in the real exchange rate can be written

$$(B4) \quad K(0) - \bar{K} = (\lambda\mu)^{-1} \cdot \Phi H \cdot (\Delta\bar{X}/\bar{X})$$

Also, defining

$$\hat{K}(\tau) \equiv \bar{K} - (\lambda\mu)^{-1} \Phi H \cdot (1/\bar{X}) \cdot (X(\tau) - \bar{X})$$

we can use (B2) and (B3) to write

$$\dot{K}(t) = \lambda[K(t) - \int_t^{\infty} \mu e^{\mu(t-\tau)} E_{\tau} \hat{K}(\tau) d\tau] \\ + \Phi(1-\gamma-\rho) \cdot \bar{X}^{-1} \cdot \left[\int_t^{\infty} e^{\mu(t-\tau)} E_{\tau} \dot{X}(\tau) d\tau \right]$$

which is (16) in the text.

Anticipated gradual depreciation

Assume that, starting at time zero, the rate of real depreciation becomes positive; it then stays at its new value until time T, when it is returned to zero. Then we have

$$\begin{aligned}\dot{\bar{X}}(t) &= T^{-1} \cdot \Delta \bar{X} && \text{for } 0 < t < T \\ &= 0 && \text{for } t > T\end{aligned}$$

where $\Delta \bar{X}$ is the change in the real exchange rate between instants 0 and T. Thus,

$$\begin{aligned}X(t) - \bar{X} &= T^{-1} \cdot (t - T) \cdot \Delta \bar{X} && \text{for } 0 < t < T \\ &= 0 && \text{for } t > T\end{aligned}$$

Replacing these expressions into (B2) and (B3), and assuming perfect foresight, we can write the final form equations for q and K as

$$\begin{aligned}\text{(B5a)} \quad Q(t) - \bar{Q} &= [\mu T (\mu - \lambda)]^{-1} \cdot \left[(1 - \gamma - \rho) [(\mu - \lambda) e^{\lambda t} + \lambda e^{\lambda t - \mu T} - \mu e^{\mu(t - T)}] \right. \\ &\quad \left. + (\lambda \mu)^{-1} \cdot H \cdot [\mu^2 (e^{\lambda t} - 1) + \lambda^2 e^{\lambda t} (e^{-\mu T} - 1) + \lambda \mu (1 - e^{\mu(t - T)})] \right] \cdot (\Delta \bar{X} / \bar{X}) \quad \text{for } t < T;\end{aligned}$$

$$\begin{aligned}\text{(B5b)} \quad &= \lambda (\mu T)^{-1} \cdot e^{\lambda t} \cdot \left[(1 - \gamma - \rho) \cdot [\lambda^{-1} (1 - e^{-\lambda T}) - (\mu - \lambda)^{-1} (e^{-\lambda T} - e^{-\mu T})] \right. \\ &\quad \left. + H \cdot [\lambda^{-2} (1 - e^{-\lambda T}) - \mu^{-1} (\mu - \lambda)^{-1} (e^{-\lambda T} - e^{-\mu T}) - (\mu \lambda)^{-1} (e^{-\lambda T} - 1)] \right] \cdot (\Delta \bar{X} / \bar{X}) \quad \text{for } t > T.\end{aligned}$$

$$\begin{aligned}\text{(B6a)} \quad K(t) - \bar{K} &= \Phi (\mu T)^{-1} \cdot \left[(1 - \gamma - \rho) \cdot [\lambda^{-1} (e^{\lambda t} - 1) - (\mu - \lambda)^{-1} e^{-\mu T} (e^{\mu t} - e^{\lambda t})] \right. \\ &\quad \left. + H \cdot [\lambda^{-1} (T - t) + \lambda^{-1} (e^{\lambda t} - 1) (\lambda^{-1} + \mu^{-1}) - \mu^{-1} (\mu - \lambda)^{-1} e^{-\mu T} (e^{\mu t} - e^{\lambda t})] \right] \cdot (\Delta \bar{X} / \bar{X}) \\ &\quad \text{for } t < T;\end{aligned}$$

$$\begin{aligned}\text{(B6b)} \quad &= \Phi (\mu T)^{-1} \cdot e^{\lambda t} \cdot \left[(1 - \gamma - \rho) \cdot [\lambda^{-1} (1 - e^{-\lambda T}) - (\mu - \lambda)^{-1} (e^{-\lambda T} - e^{-\mu T})] \right. \\ &\quad \left. + H \cdot [\lambda^{-2} (1 - e^{-\lambda T}) - \mu^{-1} (\mu - \lambda)^{-1} (e^{-\lambda T} - e^{-\mu T}) - (\mu \lambda)^{-1} (e^{-\lambda T} - 1)] \right] \cdot (\Delta \bar{X} / \bar{X}) \\ &\quad \text{for } t > T.\end{aligned}$$

Letting $t=0$ in (B5a), we get expression (18) in the text, which, for $H=0$ and $1-\gamma-\rho=0$, reduces to (17') and (17), respectively.

Using (B5) and (B6), we can verify the features of the adjustment path mentioned in the text. First, when $1-\gamma-\rho=0$, so that no intertemporal reallocation occurs, it is easy to see from (B5a) that the sign of $(Q-\bar{Q})$ is the same as that of H ; also, for $t<T$,

$$\text{sgn}(\dot{Q}(t)) = \text{sgn} \{ [(\mu^2 - \lambda^2)e^{\lambda t} \cdot (1 - e^{-\mu T}) + \mu^2 e^{-\mu T} (e^{\lambda t} - e^{\mu t})] \cdot H \cdot (\Delta \bar{X} / \bar{X}) \}$$

In the good news case $(\mu + \lambda) < 0$, the expression in square brackets is always negative, so that for $H > 0$ Q declines continuously, as assumed in the diagram; in the bad news case, it is positive up to instant t^* , defined by

$$t^* = (\mu - \lambda)^{-1} \ln [\mu^{-2} (\mu^2 - \lambda^2) e^{\mu T} - \mu^{-2} \lambda^2]$$

Thus t^* is increasing in T . To see that in either case the capital stock cannot overshoot its long-run level, it is enough to recall that for $t < T$, $(Q-1)$ cannot change sign; thus, if at any instant there is overshooting, there must also be at time T . But, from (B6a), it is easy to see that

$$\text{sgn}(K(T) - \bar{K}) = - \text{sgn} \{ H \cdot \Delta \bar{X} \} = \text{sgn} \{ K(0) - \bar{K} \}$$

where the second equality follows from (B4). Hence, there cannot be overshooting.

Let us now focus on the reallocation effect. For $H=0$, it can be seen from (B5a) that

$$\text{sgn}(Q(t) - \bar{Q}) = \text{sgn} \{ [(\mu - \lambda)e^{\lambda t} + \lambda e^{\lambda t - \mu T} - \mu e^{\mu(t-T)}] \cdot (1 - \gamma - \rho) \cdot (\Delta \bar{X} / \bar{X}) \}$$

for $t < T$. The expression in square brackets is positive at $t=0$, and negative at $t=T$; it is always decreasing between 0 and T . The sign change occurs at

$$t^* = (\mu - \lambda)^{-1} \ln [\mu^{-1} e^{\mu T} (\mu - \lambda) + (\lambda / \mu)]$$

Thus, the larger T , the longer the interval during which the capital stock will be moving away from its long-run level.

Anticipated discrete depreciation

The difficulty with this case is that $\dot{X}(T)$ approaches infinity. A simple way to overcome this problem is to represent the rate of depreciation in terms of the impulse function $\delta(T)$ (also called Dirac's delta), which is defined by

$$\delta(t) = 0 \quad \text{for } t \neq T$$

and

$$\int_{-\infty}^{\infty} \delta(s) ds = 1$$

Thus, the function $\delta(T)$ represents a unit impulse taking place at time $t=T$. Further, it can be shown that, for any continuous function f ,

$$\int_{-\infty}^{\infty} \delta(s) f(s) ds = f(T)$$

Using these results, in our case the time path of $\dot{X}(t)$ can be expressed as

$$\dot{X}(t) = \delta(T) \cdot \Delta \bar{X}$$

that is, as the product of the impulse function and the magnitude of the impulse. In turn, the real exchange rate is

$$\begin{aligned} X(t) - \bar{X} &= -\Delta \bar{X} & \text{for } t < T \\ &= 0 & \text{for } t > T \end{aligned}$$

Using again (B2) and (B3), and the perfect foresight assumption, we can solve for the trajectories of K and q :

$$(B7a) \quad Q(t) - \bar{Q} = (\mu - \lambda)^{-1} e^{-\mu T} (\mu e^{\mu t} - \lambda e^{\lambda t}) \cdot [(H/\mu) + 1 - \gamma - \rho] \cdot (\Delta \bar{X} / \bar{X}) \quad \text{for } t < T;$$

$$(B7b) \quad Q(t) - \bar{Q} = (\mu - \lambda)^{-1} e^{\lambda t} [(\mu e^{-\lambda T} - \lambda e^{-\mu T}) \cdot (H/\mu) + \lambda (e^{-\lambda T} - e^{-\mu T}) (1 - \gamma - \rho)] \cdot (\Delta \bar{X} / \bar{X})$$

for $t > T$.

$$(B8a) \quad K(t) - \bar{K} = \Phi \left[\begin{aligned} &[\lambda^{-1} - (\mu - \lambda)^{-1} e^{-\mu T} (e^{\lambda t} - e^{\mu t})] \cdot (H/\mu) \\ &+ (\mu - \lambda)^{-1} e^{-\mu T} (e^{\mu t} - e^{\lambda t}) \cdot (1 - \gamma - \rho) \end{aligned} \right] \cdot (\Delta \bar{X} / \bar{X}) \quad \text{for } t < T;$$

$$(B8b) \quad K(t) - \bar{K} = \Phi (\mu - \lambda)^{-1} e^{\lambda t} \left[\begin{aligned} &\lambda^{-1} (\mu e^{-\lambda T} - \lambda e^{-\mu T}) \cdot (H/\mu) \\ &+ (e^{-\lambda T} - e^{-\mu T}) \cdot (1 - \gamma - \rho) \end{aligned} \right] \cdot (\Delta \bar{X} / \bar{X}) \quad \text{for } t > T.$$

Comparing (B7a) and (B7b), it is clear that $Q(t)$ has a discontinuity at $t=T$. More precisely, at time T it must jump by the amount $(1 - \gamma - \rho)(\Delta \bar{X} / \bar{X})$, reflecting the simultaneous impulse in the rate of depreciation. Of course, this is not a violation of market efficiency; on the contrary, it results from the fact that at $t=T$ the real interest rate in terms of capital is unbounded; hence Q must jump to provide the required rate of return.

Letting $t=0$ in (B7a), we get (19) in the text. Also, from (B7a) it is clear that between 0 and T , $Q-1$ cannot change sign, so that the initial expansion (or

contraction) must last until T. To see if it may proceed at an ever-accelerating pace, we can let $H=0$ in (B7a) and compute

$$\text{sgn}(\dot{Q}(t)) = \text{sgn}\{ [\mu^2 e^{\mu t} - \lambda^2 e^{\lambda t}] \cdot (1-\gamma-\rho) \cdot (\Delta\bar{X}/\bar{X}) \} \quad \text{for } t < T$$

In the good news case $\mu^2 > \lambda^2$, so that there will be a continuous acceleration. In the bad news case, there will be an initial acceleration, that may be followed by a slowdown starting at time t^* if

$$t^* \equiv 2 (\mu - \lambda)^{-1} \ln(\lambda/\mu) < T.$$

Transitory appreciation and anticipated depreciation

Finally, we examine the case of a gradual real appreciation accompanied by anticipated depreciation. Assume that if no depreciation has yet taken place, then the (constant) rate of instantaneous real appreciation is θ ; hence if no depreciation has yet occurred the actual real exchange rate path is

$$\dot{X}(\tau) = -\theta$$

or $X(\tau) = \bar{X} - \tau\theta$

In turn, there is an instantaneous probability π of a real depreciation that will return the real exchange rate to its initial value \bar{X} . Thus, if at any instant the depreciation has not yet occurred, the probability that it will not occur within the next τ instants is just

$$\text{Pr} [\text{another } \tau \text{ instants of appreciation}] = e^{-\pi\tau}$$

As τ grows, the probability approaches zero, so that the long run real exchange rate is known to be unchanged at \bar{X} . Hence, pending the depreciation, the anticipated real exchange rate can be expressed

$$(B9) \quad E_t[X(t+\tau)] = \bar{X} - \theta \cdot (t+\tau) \cdot e^{-\pi\tau} \quad \text{for } \tau > 0$$

and its anticipated rate of change is

$$(B10) \quad E_t[\dot{X}(t+\tau)] = \theta \cdot e^{-\pi\tau} \cdot [\pi(t+\tau) - 1] \quad \text{for } \tau > 0$$

which is (20) in the text. Letting $\tau^*(t) \equiv (1/\pi) - t$, it follows that for $\tau < \tau^*(t)$ there are expectations of real appreciation, while for $\tau > \tau^*(t)$ real depreciation is expected. As t grows, the expectation of real depreciation becomes dominant; eventually, for $t > \pi^{-1}$ only real depreciation would be anticipated.

Proceeding as before, we find that if the real depreciation has not yet occurred at time t , the paths of Q and K are

$$(B11) \quad Q(t) - \bar{Q} = -(\mu + \pi)^{-1} \cdot (\theta/\bar{X}) \cdot \lambda^{-1} \cdot$$

$$\cdot \left[(H/\mu) [(\mu + \pi)^{-1} \mu \lambda e^{\lambda t} - \mu(1 - e^{\lambda t})] + (1 - \gamma - \rho) [(\mu + \pi)^{-1} \mu \lambda e^{\lambda t} + \pi(1 - e^{\lambda t})] \right]$$

$$(B12) \quad K(t) - \bar{K} = \lambda^{-1} \cdot (\mu + \pi)^{-1} \cdot \phi \cdot (\theta / \bar{X}) \cdot \\ \cdot \left[H[t + (1 - e^{\lambda t}) \{\lambda^{-1} + (\mu + \pi)^{-1}\}] + (1 - \gamma - \rho) [(1 - e^{\lambda t}) \{\mu(\mu + \pi)^{-1} - \lambda^{-1} \pi\} - \pi t] \right]$$

Letting $t=0$ in (B11), we get (21) in the text. For $(1 - \gamma - \rho) = 0$, it can be seen from (B11) that Q will remain below (above) unity throughout the real appreciation stage if and only if H is positive (negative); thus the capital stock will be falling (rising). In turn, for $H=0$ it can be seen that

$$\text{sgn}(Q(t) - 1) = \text{sgn} \{ (1 - \gamma - \rho) \cdot [\pi(\mu + \pi)(1 - e^{\lambda t}) + \lambda \mu e^{\lambda t}] \}$$

$$\text{and} \quad \text{sgn}(\dot{Q}(t)) = \text{sgn}(1 - \gamma - \rho)$$

Thus with low (high) capital mobility, Q will initially jump down (up) and then rise (fall) continuously; $Q-1$ will change sign at time t^* , given by

$$t^* \equiv \lambda^{-1} \cdot \{ \ln[\pi(\mu + \pi)] - \ln[\pi(\mu + \pi) - \lambda \mu] \}$$

which is a decreasing function of the instantaneous probability of depreciation.

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