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Exchange Rate Uncertainty and Economic Growth in Latin America

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I. Introduction

Perceptions of how real exchange rate movements affect real economic activity vary substantially across regions. In the OECD countries the effect of exchange rate fluctuations on employment, inflation and trade balances has generally been less than expected.[1] In developing countries, on the other hand, the ability of real exchange rates to swing trade balances is rarely questioned. However, considerable attention has been focused on the negative side effects of devaluation on inflation and output.[2] Several economists have advanced explanations for the apparently contractionary effects of devaluation in the 1980s. One hypothesis is that the size and frequency major exchange rate movements matters. Edwards (1989) and Morley (1992) for example study a number of "major devaluation episodes." Edwards finds large devaluations tend to be contractionary and inflationary, while Morley suggests a sharp devaluation induced fall in investment typically dominates depreciation's other expansionary effects.

Others have offered direct empirical evidence on the effects of exchange rate uncertainty. Faini and de Melo (1990) include a proxy for exchange rate uncertainty in their cross section study of output growth and find it has negative impacts on investment

[1]Krugman (1989) refers to these muted effects "on anything real" in the larger OECD countries as "the dog that didn't bark." But more recently he argued that exchange rate driven external adjustment seems to have worked as expected in the United States (albeit with a lag) but not in Germany and perhaps Japan (see Krugman 1992).

[2]The potentially negative effects of exchange rate depreciation on employment was a subject of some debate in the 1970s. Recent empirical evidence from the debt crisis period, however, lends more support "contractionary devaluation" hypothesis (see Edwards (1986, 1989), Faini and de Melo (1990), Morley (1992) or Serven and Solimano (1992)).

in LDCs. Similarly, McLeod and Basu (1992) find that terms of trade instability tends to decrease output growth in Latin America. Pindyck and Solimano (1993) and Serven and Solimano (1992) also provided some evidence that real exchange rate uncertainty reduces investment.

These empirical studies raise the question of why real exchange rate uncertainty should reduce output and investment. Is there any theoretical reason to expect exchange rate uncertainty to reduce output? Or conversely is there any reason to believe smaller and less frequent exchange rate changes may foster more rapid growth and investment?

This question is addressed by Corbo and Caballero (1989) from the point of view of monopolistic export firm. They examine the effect of exchange rate uncertainty on exports from a number of Latin American countries.[3] Taking other input prices as given, they examine the effect of real exchange rate uncertainty on the profits of the firm. Confirming the earlier results of Hartman(1972), Abel (1976), Pindyck (1989), they find that a mean preserving spread in the real exchange rate increases expected profits and therefore should increase exports. Only by assuming exporters are risk averse are they able to obtain the negative relationship between exports and uncertainty suggested by their empirical results. Similarly Pindyck and Solimano (1993) add irreversible investment to provide a theoretical rationale for the negative relationship between uncertainty and investment or output growth. Neither study, however, challenges the

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[3]They examine the effect of exchange rate uncertainty on exports from a number of Latin American countries. Their work builds on the earlier results of Coes (1979) who shows that the institution of the crawling peg in Brazil after 1968 reduced real exchange rate uncertainty.

basic convexity of the profit function with respect to real exchange rate variations.

This paper examines the output effects of real exchange rate uncertainty in the context of familiar Salter-Swan or dependent economy model. In this two-sector, small open economy model the real exchange rate serves as the relative price of traded versus nontraded goods. In other words, we explore the real exchange rate and external adjustment story most common in the small open and developing economy literature. It differs from the two studies just discussed, however. Both Corbo and Caballero (1989) and Pindyck and Solimano (1993) treat the real exchange rate as the relative price of imports or exports faced by an individual firm.

In the Salter-Swan model real exchange rate movements play a critical role in the external adjustment mechanism of the economy. Changes in the real exchange rate alter the factor rewards and the terms of trade between the two sectors and induce a reallocation of factors between them. If real exchange rate movements are to be effective in restoring external balance, factor prices must change in both sectors, especially during the disequilibrium adjustment process.

An important result of this paper is that if factor prices change in response to real exchange rate changes, then expected profits of traded and nontraded goods producing firms can be concave with respect to fluctuations in the real exchange rate. Under these conditions a mean preserving spread in the real exchange rate will *lower* rather than raise expected profits. Thus even without risk averse investors or irreversible investment increased uncertainty can lower output and investment in both sectors. The driving force behind this result is the real exchange rate role as the economy-wide price of nontradables.

After developing a simple example which illustrates this basic story, the next section generalize these results to an open economy endogenous growth model. Although it is difficult to obtain definitive results, we show that for a range of plausible parameter values, the short and long term effects of an increase in real exchange rate uncertainty is to reduce investment and output growth. The last section of the paper provides some empirical evidence regarding the effects of real exchange rate uncertainty on output growth in six Latin American countries.

II. The Implications of Real Exchange Rate Uncertainty

There are two widely used definitions of the real exchange rate. The more popular definition for the OECD countries, sometimes referred to as the purchasing power parity (PPP) approach, simply uses the nominal exchange rate to compare foreign and domestic (consumer) price levels (CPIs). The most common approach in the development and small open economy literature, however, divides the economy into two sectors: tradeables and nontradables. In this context the real exchange rate is the relative price of these two broadly defined groups of goods and services.

With the PPP definition, the real exchange rate has a ready micro and macroeconomic interpretation. For the typical firm it determines the price of imported inputs and export or import competing output prices. As the relative price of tradable to nontradables, however, the real exchange rate becomes an economy wide relative price with important macroeconomic implications, much like the real wage rate or the terms of trade for agriculture. The real exchange rate is a particularly important macroeconomic variable in economies where restoring "external balance" is an common policy problem.

The definition of the real exchange rate has important implications for how uncertainty affects output growth. Most of the classic results regarding investment under uncertainty are derived for price taking firms. Oi (1961) demonstrates that a firm's indirect profit function is convex in output and factor prices while Abel (1983), Hartman (1976) and Pindyck (1988) show the marginal revenue product of capital is convex in the price of output for all linearly homogenous production functions. By simple application of Jensen's inequality, this convexity implies that a mean preserving spread in output or input prices will *increase* the expected present value of future profits leading to rising levels of investment and output growth.

That a more uncertain economic environment will lead to increased investment seems counterintuitive and inconsistent with recent experience with commodity price and real exchange rate instability in LDCs.[4] This has led a number of author's to reconsider the investment process works. As Pindyck (1991) emphasizes in his survey, irreversible investment introduces an important asymmetry in the firm's decision making process; investing today forecloses option of investing tomorrow with better information. Krugman's (1988) model of the decision to invest in traded versus nontraded goods sectors in the face an uncertain real exchange rate draws on this same insight. Contrary to the Jensen's inequality literature, more variable real exchange rates increase the

[4]Of course, accumulating wealth or stocks seems a logical response to fluctuating income streams. However, the rise in expected profits is counterintuitive.

value of waiting and discourage movement of capital between the two sectors.[5]

The model developed below incorporates several of these elements. However, it is mainly the Salter-Swan view of the real exchange rate that can reverse the impact of exchange rate uncertainty on output. To elaborate the key differences between the two approaches to the real exchange and to motivate the more complex growth model that follows we begin with a simple model very similar to that of Corbo and Caballero (1989). Their exporting firm faces a downward sloping isoelastic demand curve and an uncertain exchange rate so that supply (X^s) and demand (X^d) for exports,

$$X^d = A_d(P_x)^{-\eta}, \quad X^s = AL^{\gamma}K^{1-\gamma} \tag{1}$$

depends on the P_x, the dollar price of exports, and η, the export price elasticity of demand. The real exchange rate, R_t, is exogenous and stochastic. Firms take the real wage rate, w_t as given. The exporter's profit function is thus,

$$\pi_t^T = R_t P_{tx} L_t^{\gamma} K_t^{1-\gamma} - w_t L_t \tag{2}$$

Using the demand function to replace P_x with A_d and X_t and assuming the capital stock is fixed, they use the first order condition for labor to solve for L_t and then show

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[5]Caballero (1991) emphasizes the importance of imperfect competition to the classic results: if today's investment affects future prices the relationship between uncertainty and investment may again become negative. Larger initial investment increases the likelihood of a "bad" shock and firms hedge by decreasing present investment. Pindyck (1993) and Caballero and Pindyck (1992) study industry wide uncertainty arguing that irreversibility prevents the industry as whole from avoiding bad outcomes, while new entry partially dissipates the gains from good outcomes leading to concave rather than convex profit functions.

that profits depend on R_t raised to the power $1/(1-\gamma\mu) > 1$ where $\mu = (\eta - 1)/\eta$. This implies that profits are always a *convex* function of the R_t, so that greater uncertainty regarding R_t will increase investment in that sector. This result is quite robust. Even if the firm uses some or only imported inputs, π_t is a convex function of R_t. Given the results discussed above this is not a surprising finding. Caballero and Corbo proceed to assume risk averse exporters.

How does real exchange rate uncertainty affect output in the Salter-Swan model? The key difference is that movements in R now change profits in a broad class of "tradeables" industries (exports or import competing goods) relative to other "nontraded" goods and services. One purpose of changes R then is to facilitate an economy-wide transfer of resources between these two sectors. This generally implies some intersectoral factor movements. Since labor is the mobile factor in this context, the real wage must be fluctuate to attract labor to one sector or the other.

To see this process, consider market for nontraded goods defined analogously to the traded goods sector described previously,

$$N_t^d = A_d(1/R_t)^{-\eta}, \quad N_t^s = L_{tN}^{\alpha}K_{tN}^{1-\alpha}, \quad L = L_{tN} + L_{tX} \tag{3}$$

where R_t now represents the price of tradeables over nontradeables. Setting $N^d = N^s$ in this context is sufficient to take care of the market for exports (best left competitive for this example).

The total supply of labor, L, is fixed but it can be reallocated between the two sectors. Writing out the profit function N we follow the same procedure discussed above except that we replace w_t with the marginal revenue product of labor in each sector (which must be equalized after each realization of R_t). So in this case we can replace w_t with

$$w_t = (\alpha \mu N^{\mu}) \tag{4}$$

where again $\mu = (\eta - 1)/\eta$.

The demand curve can be used to eliminate the price of nontradeables, $1/R_t$. Now substitute this expression into the profit function and write profits as a function of R_t,

$$\pi_t^N = (1 - \alpha\mu) A_d^{\mu} R_t^{\eta-1}. \tag{5}$$

Now for a plausible range of demand elasticities ($1< \eta < 2$), π_t is a concave function of R_t implying that a mean preserving spread R_t will reduce expected profits in nontraded goods production. In general we find that total GDP and even tradeables production are likely to fall as well. The key difference between the two cases is evidently the endogeneity of the real wage. Real wage changes in response to movements in R_t serve to facilitate the reallocate labor between the two major sectors, especially during the disequlibrium adjustment process.

The switch from partial to general equilibrium reflects the special role of the real exchange rate in small open economies. It plays an intersectoral allocation and a macroeconomic role similar to the agricultural terms of trade in low income countries. No individual or firm expects changes in real exchange rates to affect only their own

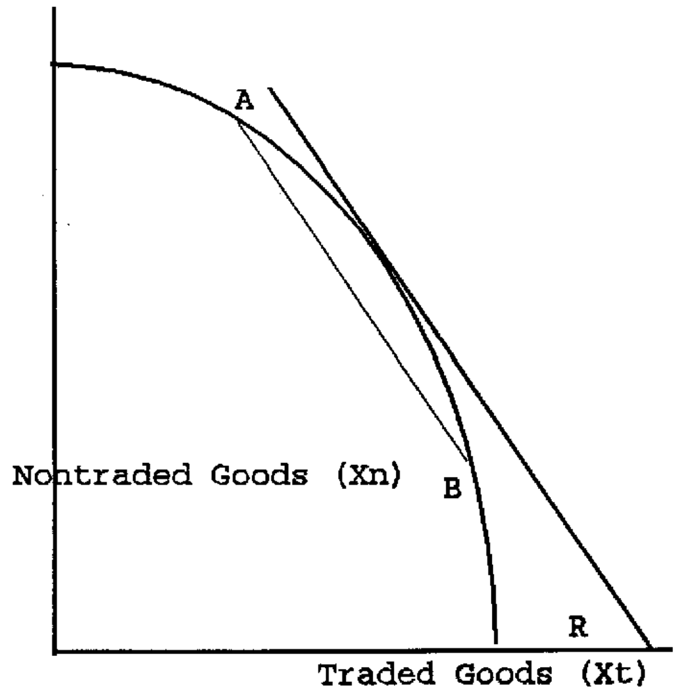


Figure 1

prices. It is the economy wide effects of the real exchange rate that distinguishes it from other commodity prices.

The effect of exchange rate uncertainty on output levels can easily be visualized using the usual transformation frontier for traded and nontraded goods. Gains from a jump in R for traded goods producers are tempered by diminishing returns to fixed inputs (a swing toward point B in Figure 1) while profit downswings are accentuated by the loss of more and more productive workers (movements toward B). Expected losses from symmetric movements in R outweigh the gains, leading to a fall in expected ouput if exchange rate uncertainty increases.

III. Uncertainty and Economic Growth

To explore the effects of real exchange rate uncertainty on growth and investment, we develop a small open economy endogenous growth model. There is no fixed labor supply. Instead in the tradition of the "AK" model of Barro (1990) and Rebelo (1991) we include human capital and fixed capital in one aggregate stock K_t. Exports are used to import intermediate imports or foreign machinery and equipment that enhance the productivity of domestic human and physical capital. In the dependent economy tradition the economy consists of two sector, both using Cobb Douglas technologies to produce traded goods, X_t, and nontraded goods, N_t.

$$N_t = V_{Nt}^{\alpha} K_{Nt-1}^{(1-\alpha)}, \quad X_t = V_{Xt}^{\gamma} K_{Xt-1}^{(1-\gamma)} \tag{6}$$

Intermediate imports, V_t, are freely available in world markets at constant dollar prices. GDP can be invested (I_t) or consumed (C_t) but only traded goods can be exported to obtain intermediate imports. This leads to the national resource constraint,

$$C_t + I_t = N_t + R_t(X_t - V_t) \tag{7}$$

where $R_t = e_t P_{Tt}/P_{Nt}$. P_{Tt} is the exogenous price of traded goods set in international markets while P_N is the price of nontraded goods which is used as the numeriare (that is $P_N = 1$). Finally e_t is an i.i.d. random variable subject to exogenous shocks, perhaps arising from shifts in domestic monetary policy. The key decisions involve the allocation of intermediate imports and capital between the traded and nontraded goods sectors.

These are modeled using the share parameters,

$$V_{Nt} = \lambda_t V_t, \quad V_{Xt} = (1-\lambda_t)V_t, \quad K_{Nt} = h_t K_t, \quad K_{Xt} = (1-h_t)K_t \tag{8}$$

where λ_t and h_t are the shares of intermediate inputs and capital used nontraded goods production.

The decision sequence is as follows. At time t, agents observe R_t and can freely reallocate imports inputs, V_t between the two sectors. For a given allocation of $K_{t-1,}$ the choice of λ_t is a temporal optimization problem similar to the labor allocation problem discussed in the previous section. The allocation of capital between sectors or the choice of h_t, on the other hand, is an intertemporal optimization problem based on the firms expectation of R_{t+1}. Note that asset shares chosen at date t will become effective and irreversible in period t+1. A mean preserving spread in R_t thus affects both the choice of λ_t, and decisions regarding h_t. For a given realization of R_t the choice of λ_t depends on the models closure rule. Initially we assume trade is balanced so that in equilibrium $X_t = V_t$. Given an exogenous shock to R_t, firms reallocate intermediate inputs to restore the equality of marginal revenue product of V in both sectors. This is equivalent to staying on the PPF, as discussed in the previous section. To solve this temporal allocation problem, we plug (1) and (3) into the first order condition,

$$(1-\lambda_t)N_t = (\gamma/\alpha)\lambda_t R_t X_t \tag{9}$$

and then use the resulting version of (9) to solve for V_t as a function of the total capital stock K_{t-1},

$$V_t = \phi_t(\lambda_t, h_{t-1}, R_t)K_{t-1} \tag{10}$$

where,

$$\phi_t = [\lambda_t^{1-\alpha}(1-\lambda_t)^{\gamma-1}(1-h_{t-1})^{1-\gamma}h_{t-1}^{\alpha-1}(\gamma/\alpha)R_t]^{1/(\alpha-\gamma)}. \tag{11}$$

If one input were fixed in supply, equation (10) would be sufficient to solve for λ given a realization of R_t. We can now rewrite the resource constraint as

$$C_t + I_t = \Omega_t K_{t-1} \tag{12}$$

where,

$$\Omega_t = [h_{t-1}^{\alpha}(\lambda_t\phi_t)^{\alpha} + R_t(1-\lambda_t)^{\gamma}\phi_t^{\gamma}(1-h_{t-1})^{1-\gamma} - R_t\phi_t)] \tag{13}$$

Before proceeding to the intertemporal aspect of the problem (the choice of C and I), we can explore the effect of unanticipated shocks to R_t. The choice of λ_t is a temporal optimization problem constrained by the existing allocation of capital and the trade balance constraint. Subject to these constraints imported inputs are reallocated among sectors until the MRP of V_t is equal in both sectors. Inspection of the expression for ϕ_t suggests it will be difficult to obtain a closed form solution for λ_t as a function of

R_t. For our purposes, however, a numerical solution will be sufficient to reveal the key properties of the model. For a given R_t, we can use (7) and the balanced trade constraint to solve for λ_t given the previous year's capital stock and h_{t-1}. Figure 2 shows a set of equilibrium solutions for a range of R_t. Real GDP and the output of both sectors are concave functions of R_t. If $\alpha = \gamma$ there is no solution for λ (we have a one sector economy).

The concavity property does not depend on the relative import intensity of the two sectors. This is not easy to prove, but can be demonstrated. We solved the model for a variety of α,γ combinations ranging from .2 to .5 with different orderings of factor intensity. In every case, traded sector and total output was concave in R_t. Nontraded output tended to be concave for low values of R_t and then became convex. As discussed in the previous section the source of this concavity is the diminishing returns to V_t added to the temporarily fixed capital stock in both sectors. Figure 2 reveals another key property of the real exchange rate in this model. For any given capital stock there is an "optimal" real exchange rate. Depending on the initial exchange rate the short term effects can be expansionary or contractionary.

IV. Growth and Investment

We want to extend the model to an intertemporal setting instead of closing the model through a trade balance restriction. To model the evolution of the sectoral output levels over time, we can solve the portfolio choice problem for the country as whole.
Following Brock (1982) and Craine (1990) we solve the social planner's problem (which

in this context turns out to be the same as the decentralized market solution). The basic portfolio choice problem is similar to that of Krugman (1988). Investors must choose between holding capital in the nontraded goods sector (K_{Nt}) or the traded goods sector (K_{Xt}). For one period this decision is irreversible. Once the investment level and portfolio shares h_t are chosen capital stocks evolve in the usual fashion,

$$K_{Nt} = h_t I_t + (1-\delta)K_{Nt-1}, \quad K_{Xt} = (1-h_t)I_t + (1-\delta)K_{Xt-1} \tag{14}$$

The social planner's problem is to maximize expected utility

$$E_{t=0}\sum_{t=1}^{\infty} \beta^t U(C_t) \tag{15}$$

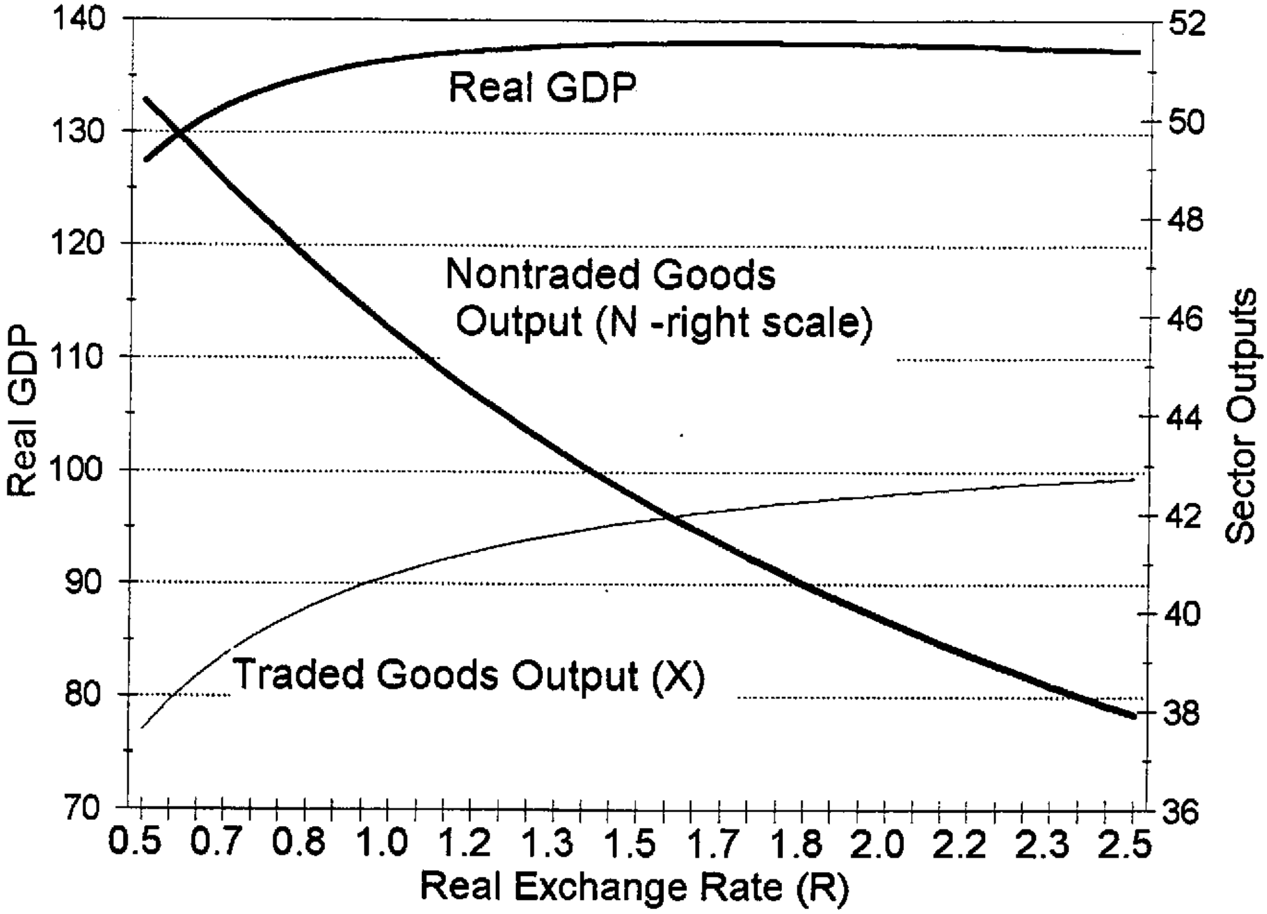
by choosing h_t and total investment subject to the resource constraint (7). A logarithmic utility function ($U_t = \log(C_t)$) considerably simplifies this maximization problem as total wealth W_t (= K_t in this model) will evolve as βY_t (where β reflects the rate of time preference). In order to solve for the portfolio share h_t we need to define the gross rates of return on both types of capital,

$$\rho_t = 1 - \delta + (1 - \gamma)R_t[(1 - \lambda_t)(1 - h_{t-1})^{-1}\phi_t]^{\gamma} \tag{16}$$

$$\Psi_t = 1 - \delta + (1 - \alpha)[\lambda_t h_{t-1}^{-1}\phi_t]^{\alpha} \tag{17}$$

where ρ_t and ψ_t are the returns to capital in the traded and nontraded goods sector respectively. Given the assumption of logarithmic utility and the asset returns (10), the

Figure 2



140
130
120
110
100
90
80
70
52
50
48
46
44
42
40
38
36
Real GDP
Nontraded Goods
Output (N -right scale)
Traded Goods Output (X)
0.5 0.7 0.8 1.0 1.2 1.3 1.5 1.7 1.8 2.0 2.2 2.3 2.5
Real Exchange Rate (R)
Sector Outputs

optimal portfolio problem reduces to maximizing (see Appendix A)

$$Max \quad E_t \log(h_t \phi_{t+1} + (1 - h_t)\rho_{t+1}) \tag{18}$$

Hence, the optimal linear allocation rule h_t that satisfies the first order conditions

$$E_t\left[\frac{\rho_{t+1}}{\omega_{t+1}}\right] = E_t\left[\frac{\Psi_{t+1}}{\omega_{t+1}}\right] = 1 \tag{19}$$

where ω_t is the total return on the country portfolio or $\omega_t = (1\text{-}h_{t-1})\rho_t + h_{t-1}\psi_t$. As long as R_t is i.i.d., asset returns are serially uncorrelated. $E_t(R_{t+1})$ affects returns to investment in both sectors via its impact on ϕ_{t+1}. An exogenous change in exchange rate uncertainty affects total and sectoral investment by changing the expected return in date t+1 capital stocks held at time t. If the expected return to traded goods $E_t(\rho_{t+1})$ increases, the share of total wealth held as that sector's capital stock will increase.

The growth rate of the capital stock responds to the choice of h_t with a lag. Using the optimal accumulation rule for logarithmic utility and equation (12) above we can obtain the growth equation for K_t,

$$K_{t+1} = [1 - \delta + \Omega_t]\beta K_t \tag{20}$$

where we have assumed the depreciation rate, δ, is the same in both sectors and Ω_t is defined in equation (7).

Figure 3 shows the effect of fluctuations in R_t on the return to both assets and the whole portfolio. In this example, if $E_t(R_{t+1})$ is about 1.6, no reallocation of capital will occur and the expected net return on capital (e.g., $\rho_{t+1} - 1 - \delta$) will be about .45. In every case we simulated, a mean preserving spread in R_t reduced the expected return to investment in the traded goods sector (i.e., ρ_{t+1} is concave in R_t). Similarly the return to investment as a whole is concave in R_t (this was the case in every simulation we examined). This implies that increases in real exchange rate uncertainty reduces overall growth because the expected return to capital falls.

Note that the parameter set for Figure 3 produces a hysteresis effect, similar to that found by Krugman (1988). A mean preserving spread in the real exchange rate increases the expected return on nontraded goods, but reduces it for traded goods. This makes investors more reluctant to move into the traded goods sector even at real exchange rates that would have attracted investment before uncertainty increased. One effect of uncertain is that it raises the real exchange rate or the rate of devaluation required to shift resources into the traded goods sector.

Another set of parameter values are illustrated in Figure 3A. In this case a mean preserving spread in R_t lowers the expected return in both sectors, reducing overall investment unambiguously. Note that these results are for sectoral capital stocks. Because we have assumed logarithmic utility, uncertainty has no effect on the overall rate of wealth accumulation (to see this note that the expect growth rate $(K_{t+1} - K_t)$ does not depend on R_{t+1}). Increasing risk does cause capital to be reallocated between sectors

Figure 3

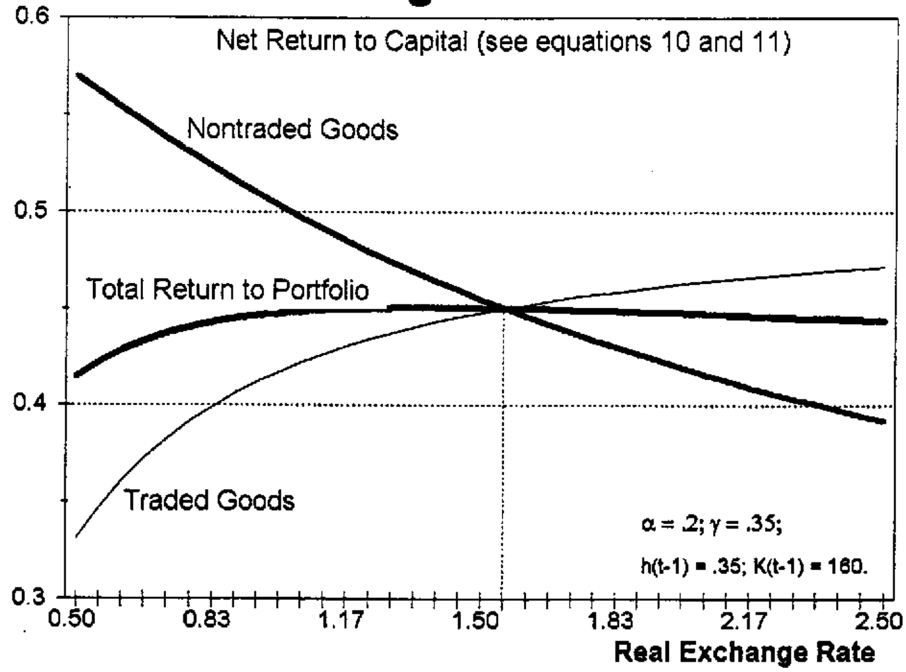
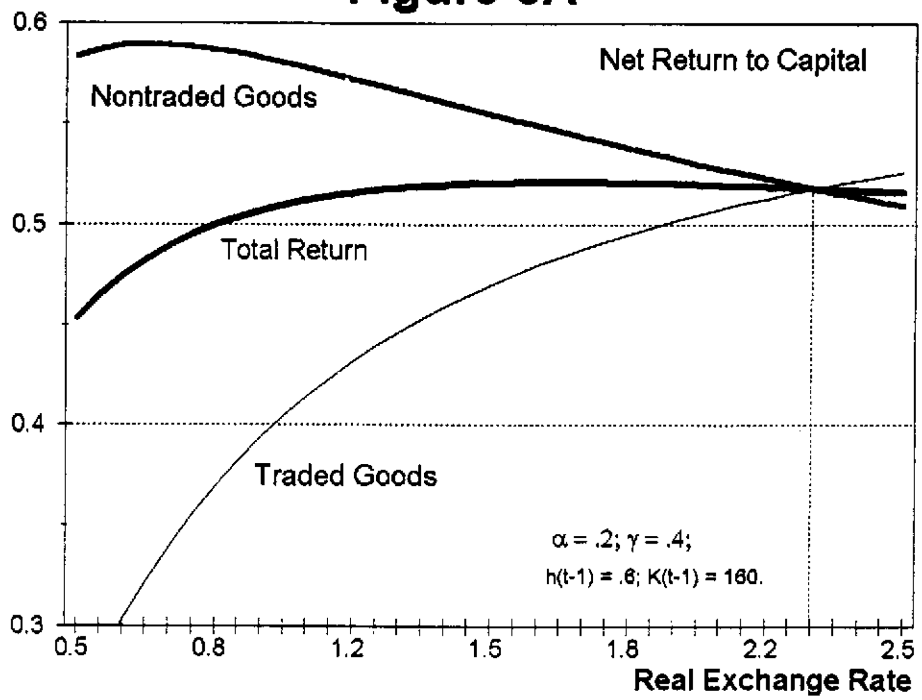


Figure 3A



(that is the portfolio share parameter h_t does depend on expecions of R_{t+1}). To make some statements about how real exchange rate undertainty affects overall GDP growth growth rate condition on R_t we can add a foreign asset.

V. GDP Growth with Foreign Assets

Given the extent of the "capital flight" problem during the 1980s, investors in LDCs clearly have the option of switching to foreign assets. Suppose we allow investors to choose a portfolio including three assets, traded and nontraded sector capital stocks and foreign bonds, B_t. The national resource constraint now becomes

$$C_t + I_t + R_t B_t = \Omega_t K_{t-1} + \frac{R_t}{R_{t-1}}(1 + r^*)B_{t-1} \tag{21}$$

and total wealth is now,

$$W_t = R_t B_t + K_t \tag{22}$$

Generalizing to three assets is straight forward. We need only define two assets shares such that $h_{Bt} + h_{Nt} + h_{Xt} = 1$ where h_{Bt}, h_{Nt}, and h_{Xt} are the shares of foreign bonds, nontraded goods, and traded goods capital. The first order conditions become

$$E_t\left(\frac{\rho_{t+1}}{\omega_{t+1}}\right) = 1; \quad E_t\left(\frac{\Psi_{t+1}}{\omega_{t+1}}\right) = 1; \quad E_t\left(\frac{\Theta_{t+1}}{\omega_{t+1}}\right) = 1 \tag{23}$$

where $\theta_t = (R_t/R_{t-1})(1 + r^*)$. The only substantive change in the problem is the serial correlation introduced in the asset returns by the lagged value of R_t. Asset returns are no longer i.i.d. but as long as R_t is i.i.d. the solution strategy goes through.[6]

Since the return to bonds, θ_t, is always linear or convex in R_t, concavity in the returns to domestic capital are sufficient to predict a shift from domestic to foreign assets and thus a fall in GDP growth. Note that because of logarithmic utility, GNP growth is still unaffected by increases in uncertainty. For most of the parameter values considered, both returns to traded and nontraded capital were concave in R_t over the relevant range of the real exchange rate. The other possibility, illustrated in Figure 3, is that a mean preserving spread in R_t creates a portfolio shift from nontraded goods into both nontraded and foreign bonds.

Because we cannot analytically sign these relationships, whether such concavity exists is an empirical issue. We now try to discern whether real exchange rate uncertainty has the hypothesized affects on output growth in Latin America.

VI. Real Exchange Rates and Output Growth in Six Latin American Countries

This section reviews some empirical evidence on the relationship between real exchange rates and output growth for six major Latin American countries. Following the basic approach of Edwards (1986 and 1989), we use an aggregate growth equation which includes various proxies for domestic monetary and fiscal policy as well as external

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[6]See Brock (1982), Craine (1988) and Basu and McLeod (1992a and 1992b) for examples of how to solve this portfolio problem.

variables such as output growth in the OECD countries and terms of trade changes. As in Edwards (1989) we used both anticipated and unanticipated money growth as proxies for monetary policy and various measures of government consumption expenditures as fiscal policy proxies.

Our estimation strategy involved estimating separate times series regressions for the six major Latin American countries (Brazil, Chile, Colombia, Mexico, and Venezuela) and then to test for homogeneity across regions by constraining set of SUR estimates various grouping three countries. Tests for both the real exchange rate coefficient and for other policy variables rejected these cross-equation restrictions decisively, suggesting that in particular the impact of real exchange rate changes varies substantially among even this group of Latin American economies..

Since panel estimation could not be justified, Table 1 presents three-stage least-squares results for the two groups of countries using annual data. The coefficients reported are the sums of the coefficients for all significant lags of the right hand side variables.[7] These SUR estimates can improve the efficiency of the coefficient estimates in the presence of correlated shocks to output across countries. Since the real exchange rate and some of the monetary policy proxies are endogenous (they depends in part on nontraded goods prices) an instrumental variables estimation technique was used as well. Tests for real exchange rates and output levels suggest both series were difference but not trend stationary (see also McLeod and Basu (1992) for evidence using longer time

[7]The lags varied from 0 year to 2 years depending on their significance. A full set of estimation results is available from the authors upon request.

series) so in every case the log GDP growth rate is the dependent variable. Similarly the exchange rate variable in log change in the trade weighted real exchange rate (in constructing these real exchange rate indices we used the same weights as Edwards (1989:124-25)).

The affects on output growth of real devaluation, terms of trade changes, changes in interest rates on foreign debt, money growth, money growth surprises, and foreign output growth are presented in Table 1. Real exchange rate devaluation has a positive effect on real output growth in Argentina, Brazil, Colombia, and Venezuela but not in Chile and Mexico. But in every country our variance proxy (the real exchange rate squared) has a significant negative effect on output. In fact, in Mexico and Argentina adding the variance proxy tended to reduce the significance or even reverse the sign of the real exchange rate.

Because we included a quadratic term as a proxy for real exchange rate uncertainty, we can calculate the critical real devaluation rate which make devaluation contractionary (Table 2). The magnitude of real devaluations which will not affect output growth is different across these three countries. This rate is the critical magnitude of real devaluation in that real devaluations greater than this rate will cause output growth to fall while smaller devaluations increase output growth. Most importantly, however, we find that small devaluations increase output growth and large devaluations decrease output growth in Argentina, Brazil, Colombia, and Venezuela. And any size devaluation is contractionary in Chile and Mexico.

Terms of trade shocks significantly affect the output of all these countries. In

Chile, Mexico, and Venezuela, an unexpected deterioration in the terms of trade decreases output growth. Terms of trade changes have no effect on output growth in Argentina, Brazil, and Colombia.[8] The results presented above show that the effects of small terms of trade shocks can be mitigated with small devaluations in all countries except Chile and Mexico. Output growth in all of these countries, however, cannot be maintained by devaluation with the occasion of large terms of trade shocks.

VII. Conclusions

Focusing on a widely used two sector model of a small open economy, this paper explored the impact of real exchange rate variability on growth and investment. Defining the real exchange rate as the price of tradables relative to nontradables implies that the main purpose of real exchange rate movements is to reallocate resources between these two sectors. This reallocation requires changes in factor prices, such as real wages or import prices. For a given stock of capital, additions of the variable input to either sector result in diminishing returns to input use. Reductions in input use on the other hand become increasingly costly as the marginal physical product of labor or import inputs increases. This asymmetry in returns creates a concavity of output with respect to the real exchange rate. An increase in risk or a mean preserving spread of R_t thus reduces expected output.

In the long run it is possible to model growth in this context as a sequence of

[8]Terms of trade changes do not affect Brazilian output growth in any of the regressions we performed which are available upon request.

portfolio decisions allocating capital between traded and nontraded goods production. In this context an increase in real exchange rate uncertainty also reduces the expect return to investment in tradables sector and often to nontradables. Adding a foreign asset to the economy's portfolio yields implies that an increase in terms of trade uncertainty lowers long run GDP growth (but not GNP growth). These results are consistent with our empirical findings.

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Table 1
Effects of Real Devaluation, Terms of Trade Shocks, and Money Growth on Output Growth

Dependent Variable: Log Changes in Real Output (Δy),Three-Stage Least Squares for two groups: Southern Cone (Argentina, Brazil, and Chile) and Oil and Fuel Exporters (Colombia, Mexico, and Venezuela)[(a)]

Variable/ Country	const.	Δrer	Δrer^2	Δtt	Δm	Δmr	Δy^*		Godfrey-Pagan Test
Southern Cone									
Argentina (1965-88)	1.66* (1.167)	0.112*** (0.036)	-0.00118*** (0.00048)	0.0628 (0.079)		-0.012 (0.0229)	0.439** (0.2055)	DW=1.99 $Q_{(11)}=9.63$	$\chi^2_{(2)}=3.74$
Brazil (1965-88)	8.29*** (0.919)	0.131** (0.057)	-0.0136*** (0.0027)		-0.0463*** (0.011)	0.177*** (0.0420)	0.411*** (0.113)	DW=1.74 $Q_{(11)}=8.6$	$\chi^2_{(2)}=0.286$
Chile (1965-88)	2.76** (1.23)	-0.039 (0.086)	-0.00756*** (0.00302)	0.076** (0.053)		0.065** (0.042)	0.798*** (0.198)	DW=2.09 $Q_{(11)}=7.46$	$\chi^2_{(2)}=4.62^{*}$
Oil and Fuel Exporters									
Colombia (1965-89)	3.92*** (0.365)	0.0786** (0.0315)	-0.00785*** (0.0028)	0.0385 (0.024)		0.105$^{**(b)}$ (0.066)	0.317*** (0.076)	D.W.=1.989 $Q_{(12)}=5.30$	$\chi^2_{(2)}=3.66$
Mexico (1965-89)	5.76*** (0.378)	-0.0145 (0.0216)	-0.01082*** (0.0012)	0.278*** (0.033)		0.1116*** (0.0237)	0.175** (0.0746)	DW=1.89 $Q_{(12)}=7.88$	$\chi^2_{(2)}=2.01$
Venezuela (1965-89)	2.95*** (0.870)	0.288*** (0.063)	-0.0095*** (0.0020)	-0.0478*** (0.0175)		0.223$^{**(b)}$ (0.109)	0.209 (0.235)	DW=2.023 $Q_{(12)}=6.94$	$\chi^2_{(2)}=3.94$

Notes: (a) All coefficients are the sums of the coefficients on 0 to 2 lags of the variables.
Variables: Δrer = log change in real trade weighted exchange rate, Δtt = log change in the terms of trade, Δy=log change in real GDP, Δm = log change in reserve money as a percentage of GDP, Δne = log changes of nominal trade weighted exchange rate, Δy^* = log change in real foreign GDP as proxied by U.S. real GNP growth (Mexico and Venezuela) or OECD industrial production growth (Argentina, Brazil, Chile, Colombia) depending on the importance of trading partners, i = the nominal interest rate on new external debt commitments, Δm = growth in money (M_1), Δmr = money surprises as measured as the residuals from a regression of money (M_1) growth on lagged money growth, lagged changes in the terms of trade, lagged foreign debt interest rates, lagged government spending, lagged changes in nominal exchange rates, and lagged U.S. inflation.

Instruments: Different lags of Δrer, Δtt, Δm, Δy^*, and Δne.

(b) The variable Δmr was lagged one period in these estimates and are thus subject to the potential inference problems associated with lagged generated regressors (Pagan 1984).

* indicates 10% significance, ** indicates 5% significance, and *** indicates 1% significance

Table 2
Real Rates of Devaluation Which the Change in Real Output Growth to Fall (Δrer^*)

	Δrer^*
Argentina	47.5%
Brazil	4.83%
Chile	0.00%
Colombia	5.00%
Mexico	0.00%
Venezuela	15.2%

Appendix A

In this appendix, we show the solution method of the central planner in solving the optimal portfolio and growth problem. More precisely, we show that the maximization problem reduces to the maximization of equation (18) in the text.

The recursive solution follows Brock (1982), Craine (1989), and Basu and McLeod (1992). Since the capital stock cannot be adjusted in the current period, the country must take W_t as given for a given realization of the real exchange rate R_t. Therefore, the social planner choses only the shares of capital allocated to each sector, h_t. The social planner optimizes equation (15) subject to equation (12) which are reproduced here as equation (A1) and (A2)

$$E_0 \sum_{i=1}^{\infty} \beta^t U(C_t) \tag{A1}$$

$$y_t = C_t + I_t = \Omega_t K_{t-1} \tag{A2}$$

Proposition 1: If $U(C_t) = \ln(C_t)$, total wealth[1] evolves as $W_t = \beta y_t$ and there exists a linear allocation rule, h_t, satisfying the first order conditions

$$E_t\left[\frac{\rho_{t+1}}{\omega_{t+1}}\right] = E_t\left[\frac{\Psi_{t+1}}{\omega_{t+1}}\right] = 1 \tag{A2}$$

where ω_t is the total return on the country portfolio or $\omega_t = (1-h_{t-1})\rho_t + h_{t-1}\psi_t$.

Proof: The value function can be characterized by Bellman's equation

[1]Notice that in this model, wealth merely equals the sum of capital used in the nontradables sector and capital used in the tradables sector.

$$V(y_t,R_t) = \max\left[\log(y_t - W_t) + \beta E_t V(y_{t+1},R_{t+1}\right] \tag{A4}$$

Using the method of undetermined coefficients, we conjecture that there exists some linear allocation rule

$$K_{Nt} = h_t K_t, \quad K_{Xt} = (1-h_t)K_t \tag{A5}$$

and a value function of the form

$$V(\cdot) = \pi_o + \pi_{1t} + \pi_2 \log(y_t) \tag{A6}$$

Substituting equations (A6) and (A5) into (A4) yields

$$\pi_o + \pi_{1t} + \pi_2 \log(y_t) =$$
$$\max\left[\log(y_t - W_t) + \beta\pi_0 + \beta E_t(\pi_{1,t+1}) + \beta\pi_2 E_t \log(h_t \Psi_{t+1} + (1 - h_t)\rho_{t+1}) + \beta\pi_2 \log W_t\right] \tag{A7}$$

Now the social planner chooses wealth to maximize equation (7). The first order conditions reveal

$$W_t = \frac{\beta\pi_2}{(1 + \beta\pi_2)} y_t \tag{A8}$$

Substituting this solution into equation (A7) yields

$$\pi_o + \pi_{1t} + \pi_2 \log(y_t) =$$

$$\max[\pi_0 + \beta\pi_2 \log(\beta\pi_2) + \beta\pi_2 \log(h_t \Psi_{t+1} + (1 - h_t)\rho_{t+1}) + \beta E_t[\pi_{1,t+1}] + (1 + \beta\pi_2)\log(y_t) - (1 + \beta\pi_2)\log(1 + \beta\pi_2)] \tag{A9}$$

By matching coefficients on the left and right sides of equation (A9) we get

$$\pi_2(1 - \beta) = 1 \tag{A10}$$

$$\pi_o = \left[\frac{\beta\pi_2 \log(\beta\pi_2) - (1 + \beta\pi_2)\log(1 + \beta\pi_2)}{(1 - \beta)}\right] \tag{A11}$$

$$\pi_{1t} = \left[\beta E_t[\pi_{1,t+1}] + \left(\frac{\beta}{(1 - \beta)}\right) E_t \log(h_t \Psi_{t+1} + (1 - h_t)\rho_{t+1})\right] \tag{A12}$$

Finding the exact closed form solution to this mapping entails rewriting the last term of (A9) as

$$f(R_t) = E_t \log(h_t \Psi_{t+1} + (1 - h_t)\rho_{t+1}) \tag{A13}$$

We assume that R_t is an element of a compact set. Then this term is a continuous and bounded function of the real exchange rate R_t where the share h_t is conditional on R_t.

Since R_t remains in a compact set, then by the fixed point theorem for contractions[2], there exists a unique solution of (A9) mapping R_t into π_{1t}, confirming the initial conjecture about the form of V(·).

Now we conjecture that

$$\pi_{1t} = \lambda_0 + \lambda_1 f(R_t) \tag{A14}$$

Substituting equation (14) into equation (12) yields

$$\lambda_0 + \lambda_1 f(R_t) = \beta\lambda_0 + \beta\lambda_1 E_t[f(R_{t+1})] + \left(\frac{\beta}{(1-\beta)}\right)f(R_t) \tag{A15}$$

Assuming that R_t is i.i.d., $E_t f(R_t)$ is independent of the conditioning set which allows us to use the method of undetermined coefficients. Solving for λ_o and λ_1 yields

$$\lambda_0 = \left(\frac{\beta}{(1-\beta)}\right)\lambda_1 E_t[f(R_t)] \tag{A16}$$

$$\lambda_1 = \left(\frac{\beta}{(1-\beta)}\right) \tag{A17}$$

---

[2]By definition, If f has a domain D(f) contained in R^p and range in R^q, f satisfied a Lipschitz condition if there exists a constant A > 0 such that

$$\|f(x) - f(u)\| \leq A\|x - u\|$$

for all points x, u in D(f). If A < 1, then the function is called a contraction.

Fixed Point Theorem for Contractions or the Contraction Mapping Theorem: Let f be a contraction with domain R^p and range contained in R^p. Then f has a unique fixed point. For proof see Bartle (1976:162) and Sargent (1987:343-344).

Substituting the relations (A10), (A11), (12), into (A13) then with (A16) and (A17) into (A6) yields

$$V(y_t,R_t) = \pi_o + \left[\frac{\beta}{(1-\beta)}\right]^2 E_t[f(R_{t+1}) + \left[\frac{\beta}{1-\beta}\right]f(R_t) + \left[\frac{1}{(1-\beta)}\right]\log(y_t) \quad \text{(A18)}$$

The only term in equation (A18) which involves h_t is $f(R_t)$. Therefore, the maximization collapses to maximizing

$$Max\ E_t\log(h_t\Psi_{t+1} + (1-h_t)\rho_{t+1}) \quad \text{(A19)}$$

as hypothesized in the text. Therefore the solution is

$$E_t\left[\frac{\rho_{t+1}}{\omega_{t+1}}\right] = E_t\left[\frac{\Psi_{t+1}}{\omega_{t+1}}\right] = 1 \quad \text{(A20)}$$

To see that this return is equal to 1 notice that $h_tE_t(\rho_{t+1}/\omega_{t+1}) + (1\text{-}h_t)E_t(\Psi_{t+1}/\omega_{t+1}) = 1$. Since $h_t + (1\text{-}h_t) = 1$, each of these expected relative return must equal 1.

Finally, to see if our solution conforms to the well known result that wealth evolves as a fraction ß of real income y_t or $W_t = ßy_t$, we substitute equation (A10) into equation (A8) we see that

$$W_t = K_t = \beta y_t \quad \text{(A21)}$$

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