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On Exchange Rates, Nominal and Real

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ABSTRACT

In the post-Bretton Woods period, both nominal and real exchange rates have varied widely and, on occasion, wildly. As bi-lateral real exchange rates measure, in a common currency, the price level of one country relative to that of another, the large movements in those real exchange rates often are offered as evidence against purchasing power parity (PPP). In this paper it is argued that bi-lateral real exchange rates are so highly contaminated with measurement error that they are irrelevant to the PPP debate.

As the nominal exchange rate logically precedes real exchange rates, the paper first develops a "commodity currency" model of nominal exchange rate determination. While extremely frugal, the model is rich enough to admit tests of PPP, independence of monetary policy, foreign exchange market efficiency, and the effect of the terms of trade on a floating exchange rate. The definitions of the "true" and bi-lateral real exchange rates are grafted onto the nominal exchange rate model, and tests are developed to determine whether the two real exchange rates are indeed "real" variables, and the degree to which they respond to the external terms of trade. It is demonstrated that the bi-lateral real exchange rate between a pair of countries X and Y is a faithful proxy for the true (or multi-lateral) real exchange rate of either country only when no third countries can significantly influence the external prices of goods traded by countries X and Y.

Both the nominal and real exchange rate models are tested extensively on Swiss time series data for the post-Bretton Woods period. Switzerland is one of the few small countries that has floated its exchange rate for the entire post-Bretton Woods period, has not participated in joint floats (e.g., the "snake" and the EMS), has eschewed both quantitative controls and intervention in the foreign exchange market, and has had a stable commercial policy throughout the period. As such, the Swiss franc exchange rate is ideal for examining the behavior of both the nominal and the two real exchange rates.

An estimate of the nonlinear "commodity-currency" model by the generalized method of moments (GMM) fits the behavior of the Swiss franc exchange rate *vis à*

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vis both the dollar and the major European currencies very well. As the Swiss exchange rate insulates domestic prices from external shocks, neither PPP nor independence of Swiss monetary policy is rejected. Foreign exchange market efficiency also is not rejected. GMM estimates of the nonlinear real exchange rate models indicate that, whereas the "true" real exchange rate is determined principally by the external terms of trade, the Swiss bi-lateral real exchange rate *vis à vis* both the U. S. and the major European countries is strongly influenced by shocks to exogenous *nominal* variables. In the Swiss case at least, the bi-lateral real exchange rate is far too heavily contaminated with measurement error to be a useful proxy for the true real exchange rate or a reliable indicator of inappropriate macro-economic policies.

I. INTRODUCTION

Since the collapse of the Bretton Woods monetary system in the early 1970s, both nominal and bi-lateral real exchange rates (BRER) have exhibited great variability; as the bilateral real exchange rate typically measures, in a common currency, the price level of one country relative to that of another, the large movements in that real exchange rate are offered as evidence against the validity of the purchasing power parity doctrine (PPP), at least in the short run. In describing the "prevailing conventional wisdom" concerning PPP, Jones and Purvis (1983) conclude that:

> "(1) PPP does *not* hold in the short run.
> (2) There are strong tendencies towards PPP so that it does hold in the long run" [page 34].

In linking PPP to the real,exchange rate, it is essential to distinguish between the bi-lateral and the "true" (or multi-lateral) real exchange rate; the latter refers to the internal prices of traded goods relative to the prices of non-traded goods while the former, which is employed in nearly all empirical contexts, uses a second-country price level (measured in the home-country currency) as a proxy for the internal prices of internationally-traded goods. As such, the bi-lateral real exchange rate captures not only movements in the true real exchange rate but also measurement errors in the *nominal* exchange rate domestic price index for traded goods is eliminated by using the identity $PTF \equiv PT - EX$, and PNT is solved out when obtaining the deterministic component of the reduced form. In simplified notation, that component is:

(3) $\alpha(L)\cdot EX_t = \beta(L)\cdot PTF_t + \gamma(L)\ ytt_t$,

where $\alpha(L) = 1-A(L)\cdot C(L)$, $\beta(L) = A(L)\cdot C(L)+B(L)$, and $\gamma(L) = A(L)\cdot D(L)$; α_0 is normalized to unity by dividing the entire equation by $(1-a_0\cdot c_0)$.

Since available traded-goods price data usually report import and export price indices separately, the PT variable will be defined as a weighted average of IMP and EXP; moreover, as PT is intended to capture only the *substitution* effects arising from external price shocks, the weights of that average must be correct in order that equation (2) satisfy the homogeneity postulate. The proper weight for EXP in the traded goods price index can be expressed as $\delta PT/\delta EXP = (\delta PNT/\delta EXP)_s/(\delta PNT/\delta PT)_s$ and, using the homogeneity postulate, $\delta PT/\delta EXP = (\delta PNT/\delta EXP)_s$.

Consider now a comparative statics exercise in which, holding the exchange rate constant, commercial policy is used to alter import prices by $\delta IMP = \varepsilon_I$ and export prices by $\delta EXP = \varepsilon_E$, with the ε_J being chosen to leave the price index for non-traded goods unaffected: $(\delta PNT/\delta IMP)_s\cdot\varepsilon_I + (\delta PNT/\delta EXP)_s\cdot\varepsilon_E = 0$. As $(\delta PNT/\delta IMP)_s+(\delta PNT/\delta EXP)_s= 1$, $(\delta PNT/\delta EXP)_s= \varepsilon_I/(\varepsilon_I-\varepsilon_E) \equiv \Phi_P$ is the proper (but not necessarily positive) weight for EXP in defining PT.[8] As the weight for imports obviously is $(1-\Phi_P)$, PT and PTF are defined as follows:

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[8] The sign and magnitude of Φ_P are determined by substitution effects. In the absence of complementarity, the ε_J are of opposite sign, and hence Φ_P is a positive fraction. However, if exports are complements with non traded goods, then $(\delta PNT/\delta EXP)_s < 0$ but, as the homogeneity postulate indicates that the substitution effect dominates, $(\delta PNT/\delta IMP)_s + (\delta PNT/\delta EXP)_s > 0$. Moreover, as $\varepsilon_E/\varepsilon_I = -(\delta PNT/\delta IMP)_s/(\delta PNT/\delta EXP)_s > 1$, ε_I and ε_E are of the same sign and $|\varepsilon_E| > |\varepsilon_I|$ so $\Phi_P = \varepsilon_I/(\varepsilon_E-\varepsilon_I)$ is negative. If imports and home goods are complements, then $|\varepsilon_I| > |\varepsilon_E|$ and Φ_P is positive and exceeds unity.

$$PT = \Phi_p \cdot EXP + (1-\Phi_p) \cdot IMP$$
$$= IMP + \Phi_p \cdot TT, \text{ and}$$

$$PTF = IMPF + \Phi_p \cdot TT,$$

and the modified structural equations and reduced form are:[9]

(1′) $EX_t = A(L) \cdot PNT_t + B(L) \cdot (IMPF_t + \Phi_p \cdot TT_t)$,

(2′) $PNT_t = C(L) \cdot (IMP_t + \Phi_p \cdot TT_t) + D(L) \cdot ytt_t$,

(3′) $\alpha(L) \cdot EX_t = \beta(L) \cdot (IMPF_t + \Phi_p \cdot TT_t) + \gamma(L) \cdot ytt_t$.

As Φ_p is a free parameter when equation (3′) is estimated by nonlinear least squares, the homogeneity restriction, $C(1) = 1$, is expressly assumed to hold on both equation (2′) and the reduced form.[10]

Purchasing Power Parity versus Monetary Independence

It was argued earlier that the PPP doctrine can reasonably be interpreted as a relationship among (a) the exchange rate, (b) the prices of *non-traded* goods, and (c) foreign currency prices of *traded* goods; in other words, PPP should be associated with the true (multi-lateral) rather than the bi-lateral

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[9] Equation (2′) is very similar to the "omega" equation introduced by Sjaastad (1980) to measure the incidence of protection:

$$PNT - EXP = \omega \cdot (IMP - EXP),$$

where $\delta PNT/\delta IMP = \omega$ is the "incidence" parameter capturing the substitution effect noted by Dornbusch (1974). From equation (2′) and the homogeneity restriction, $\delta PNT/\delta IMP = C(1) \cdot (1-\Phi_p) = 1-\Phi_p$, so $\omega \equiv 1-\Phi_p$. Note also that equation (2′) avoids the need for a non-traded goods price index. Estimates of ω usually exceed 0.5; a number of those estimates are reported in Clements and Sjaastad (1984).

[10] It will be argued later that ytt and TT have endogenous components, an issue will be resolved by the use of instrumental variables. Note further that the reduced form can be written in a number of different ways; e.g.:

$$\alpha(L) \cdot IMP_t = [\alpha(L)+\beta(L)] \cdot IMPF_t + [\Phi_p \cdot \beta] \cdot TT_t + \gamma(L) \cdot ytt_t,$$

but equation (3′) is preferable as it excludes IMP, which may be corrupted by measurement error. While import price indices are often quoted in domestic currency, the original data (for small countries, at least) undoubtedly were denominated in foreign currencies—as is IMPF. Consequently, IMPF reflects the actual transaction prices of imports whereas IMP may not.

real exchange rate. In terms of the exchange rate model, that interpretation identifies PPP with the restriction that equations (1) and (1′) be homogeneous of degree zero in PNT and PTF; i.e., $A(1)+B(1) = 0$. The homogeneity and PPP restrictions together imply $\beta(1) = 0$ in equations (3) and (3′), which provides a direct test of purchasing power parity.

An *independent* monetary policy normally means that domestic monetary authorities neither accommodate external inflation nor intervene in the foreign exchange market; that is, the exchange rate is endogenous and the domestic price level is exogenous with respect to external prices. Purchasing power parity, as interpreted in this paper, is a prerequisite for independence of monetary policy. Suppose, for example, that a rise in the prices of non-traded goods (caused by domestic monetary expansion) fortuitously coincided with an equal percentage increase in external prices of traded goods. If PPP failed, these two price changes would require an adjustment in the exchange rate, which would impact on the internal prices of traded goods and hence the price level itself. Since the exchange-rate induced change in the price level would then require monetary accommodation, an independent monetary policy is logically impossible in the absence of PPP. Monetary independence and PPP are, however, conceptually distinct, as the latter does not imply the former.

While a well-defined exchange rate rule obviously is incompatible with monetary independence, a money-supply rule does not necessarily guarantee it; the evidence must be found in the data. Although no monetary variables appear in the exchange rate model, an important inference about the independence of domestic monetary policy can be made from the relationship between the exchange rate and external prices of traded goods. As monetary independence requires the domestic price level to be invariant (in the long run) to permanent and identical shocks to IMPF and EXPF, those shocks must generate a reaction in

EX of exactly the same magnitude *but in the opposite direction*; in terms of equations (1) and (1′), B(1) must be minus unity. While homogeneity *cum* PPP requires only $A(1) = -B(1)$, homogeneity *cum* PPP *cum* monetary independence imposes a stronger restriction: $[A(1) = -B(1) = 1] \Rightarrow [\alpha(1) = \beta(1) = 0]$, which are readily tested on an estimate of the reduced form equation (3′).[11]

Satisfaction of the $\alpha(1) = \beta(1) = 0$ restrictions on the model, while necessary, are not sufficient as a test for monetary independence; a third restriction is required, one that can be found only in the reduced form itself. Holding the terms of trade constant, monetary independence causes that the deterministic component of the exchange rate to completely neutralize permanent shocks to the external prices: $\delta EX/\delta PTF = -1$. But from the deterministic component of reduced form equation (3), $\delta EX/\delta PTF = \lim_{L\to 1} \beta(L)/\alpha(L)$, so the third restriction clearly is $\lim_{L\to 1} \beta(L)/\alpha(L) = \left(\lim_{L\to 1} \beta(L)\right)/\left(\lim_{L\to 1} \alpha(L)\right) = -1$.[12] However, if the α and β restrictions are met, $\lim_{L\to 1} \alpha(L) = \lim_{L\to 1} \beta(L) = 0$, so the third restriction must be obtained from the l'Hôpital rule of limits:

$$(4) \qquad \lim_{L\to 1} \beta(L)/\alpha(L) = \beta'(L)/\alpha'(L)\Big|_{L=1} = \left(\beta_1 + 2\cdot\beta_2 + \cdots + K_b\cdot\beta_{K_b}\right)/\left(\alpha_1 + 2\cdot\alpha_2 + \cdots + K_a\cdot\alpha_{K_a}\right) = -1,$$

and $\Phi_M \equiv \beta'(L)/\alpha'(L)\Big|_{L=1}$ is the *coefficient of monetary independence*. Thus the following restrictions are *sufficient* for monetary independence:

$$(5) \qquad \begin{cases} \alpha(1) = 0 \text{ (the } \alpha \text{ restriction)}, \\ \beta(1) = 0 \text{ (the } \beta \text{ restriction), and} \\ \beta'(L)/\alpha'(L)\Big|_{L=1} \equiv \Phi_M = -1 \text{ (the l'Hôpital rule)}, \end{cases}$$

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[11] Note that the $\alpha(1) = \beta(1) = 0$ restrictions on equations (3) and (3′) also are the conditions for EX and PTF to be cointegrated.

[12] It is assumed throughout that the reduced form is stable.

and a joint chi-square test of the three restrictions will be referred to as the *monetary independence* test.[13] Alternatively, Φ_M itself can be estimated by embedding the α and β restrictions and equation (4) into the reduced form.

Terms-of-Trade Neutrality

If the terms-of-trade income effect induces a change in the price of tradeables relative to non tradeables, it will be effected through the exchange rate. With a slight modification, the monetary independence test can be used to analyze that effect. As the impact of a permanent change in the terms of trade on the exchange rate is $\delta EX/\delta ytt = \lim_{L \to 1} \gamma(L)/\alpha(L)$, merely replace $\beta(L)$ in expression (4) with $\gamma(L)$ and replace the β restriction with the $\gamma = 0$ restriction; if the α and γ restrictions are met, the long run exchange rate response to a (permanent) change in the terms of trade is:

$$(4') \qquad \delta EX/\delta ytt = \left(\gamma_1 + 2\cdot\gamma_2 + \cdots + K_g\cdot\gamma_{K_g}\right)/\left(\alpha_1 + 2\cdot\alpha_2 + \cdots + K_a\cdot\alpha_{K_a}\right) = \lambda_N,$$

where λ_N, which is expected to be negative, is the *nominal terms-of-trade coefficient* that measures the response of the price index for tradeables to an improvement in the terms of trade. If $\lambda_N = 0$, the terms of trade are neutral; sufficient conditions for that neutrality are:

$$(5') \qquad \begin{cases} \alpha(1) = 0 \text{ (the } \alpha \text{ restriction)}, \\ \gamma(1) = 0 \text{ (the } \gamma \text{ restriction), and} \\ \gamma'(L)/a'(L)\Big|_{L=1} \equiv \lambda_N = 0 \text{ (the l'Hôpital rule).} \end{cases}$$

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[13] In the original notation, $\beta(L)/\alpha(L) = [A(L)\cdot C(L)+B(L)]/[1-A(L)\cdot C(L)]$; if $\alpha(1) = 0$, the limit of that ratio will be minus unity if $B'(1) = -1$. Moreover, it is now evident why $\alpha(1) = \beta(1) = 0$ is necessary but not sufficient for monetary independence: under a *fixed* exchange rate, which clearly precludes monetary independence, equation (3) degenerates to $EX_t = EX_{t-1}$; two conditions are satisfied but the third is not.

The *terms-of-trade neutrality* test consists of a joint chi-square test of the three restrictions in (5′); again, λ_N can be estimated directly.

Foreign Exchange Market Efficiency

Once foreign-exchange-market agents perceive that monetary policy is independent, B(1) = -1, the exchange rate must *immediately* neutralize shocks to foreign-currency prices of traded goods; in terms of equation (1), b_0 must be minus unity. If not, then for $i \geq 1$, at least one b_i must be nonzero, resulting in a *systematic* lag in the exchange rate response rate to external shocks. If such a lag exists, the market is inefficient as information that could enhance exchange rate forecasts is being ignored.

To test for (weak) foreign-exchange market efficiency, note that with α_0 normalized to unity, $\beta_0 = (a_0 \cdot c_0 + b_0)/(1 - a_0 \cdot c_0)$ and $b_0 = \beta_0 - a_0 \cdot c_0 \cdot (1+\beta_0)$, so it follows that $(\beta_0 = -1) \Rightarrow (b_0 = -1)$. The test consists, then, of the monetary independence test augmented by the $\beta_0 = -1$ restriction.

III. THE REAL EXCHANGE RATE MODEL

It is tautological that a *real* exchange rate must be independent of *nominal* variables, at least in the long run. The main objective at this point is to determine minimal conditions under which real exchange rates will obey that tautology, and to devise an empirical test for those conditions. The two real exchange rates under consideration are the *bi-lateral*, which is defined on two currencies and two price levels, and the true (or *multi-lateral*) real exchange rate, which refers to the internal relative price of traded goods.

Properties of the True Real Exchange Rate

The multi-lateral real exchange rate for country X is usually written as $MRER_X = PT_X - PNT_X$; for practical purposes, it will be defined on the more easily observed variables PT_X and P_X (both in natural logarithms):

(6) $$MRER_X \equiv PT_X - P_X = w_X \cdot (PT_X - PNT_X),$$

where w_X, the factor of proportionality, is the weight of non-traded goods in P_X. Since equation (6) exactly reflects the internal relative price structure in the economy in question, it is symmetric with our interpretation of PPP in the sense that, if $MRER_X$ is a "real" variable, PPP will be preserved.

The validity of the *real-exchange-rate independence* tautology that, in the long run, a *real* exchange rate is independent of *nominal* variables, is readily ascertained by replacing PNT_X in equation (6) with equation (2):

(6′) $$MRER_{X,t} = w_X \cdot \Big([1-C(L)] \cdot PT_{X,t} - D(L)\ ytt_{X,t}\Big).$$

As $PT_X = EX_X + PTF_X$, shocks to the exchange rate and external prices of traded goods may impact on the multi-lateral real exchange rate in the short run but, by the homogeneity restriction, $C(1) = 1$, there will be no long run effect.

The Bi-Lateral Real Exchange Rate: A Case of Measurement Error?

In analytical contexts, the real exchange rate is usually identified with the multi-lateral real rate but the empirical counterpart of the MRER is normally some variant of the *bi-lateral* real exchange rate in which the price level of a second country serves as a proxy for the actual prices of traded goods.[14] The common bilateral real exchange rate of country X *vis à vis*, say, country Y is normally written (in natural logarithms) as:

(7) $$BRER_X^Y \equiv EX_X^Y + P_Y - P_X,$$

where EX_X^Y is the price of currency Y in terms of currency X; note that

[14] Thus Edwards (1989), for example, defines the real exchange rate as the ratio of the foreign-currency price of traded goods to the domestic-currency price of non traded goods. But in his empirical analysis, the real exchange rate becomes the bi-lateral version, with the obligatory apology "unfortunately, it is not possible to find an exact empirical counterpart to [the multi-lateral] analytical construct" [page 87].

$BRER_Y^X \equiv -BRER_X^Y$. With P_X and P_Y replaced by their traded and non-traded goods components, $BRER_X^Y$ can be expressed in terms of $MRER_X$ and $MRER_Y$:

(7') $$BRER_X^Y = MRER_X - MRER_Y + (PT_Y - PTF_X),$$

where PTF_X is measured in the currency of country Y.[15] Obviously, $BRER_X^Y$ picks up disturbances to the true real exchange rates of *both* countries as well as differences in the composition of the foreign trade of the two countries.

However, if (a) $w_X = w_Y = w$, if (b) equation (2) is identical for the two countries, and if (c) countries X and Y trade only with one another, equation (7') reduces to a function of the nominal exchange rate and ytt:

$$BRER_{X,t}^Y = w\cdot\left([1-C(L)]\cdot EX_{X,t}^Y - D(L)\cdot(ytt_{X,t} - ytt_{Y,t})\right).$$

When these three genuinely heroic assumptions are satisfied, the homogeneity restriction implies that the bi-lateral real exchange rate will be independent of the nominal rate in the long run (though not necessarily in the short).

A simple but key relationship between the two real exchange rates is readily seen by subtracting equation (6) from (7) and rearranging the result:

(8) $$BRER_X^Y = MRER_X + P_Y - PTF_X.$$

The collinearity between the true real exchange rate and its empirical proxy $BRER_X^Y$ depends on the collinearity between the foreign-currency price index for country X's *traded goods* and the price level of country Y; if PTF_X and P_Y differ *systematically* over time, $BRER_X^Y$ will be subject to measurement error. In the context of equation (8), there are at least two reasons why P_Y may not dominate PTF_X; the first relates to the fact that, even in a world of two

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[15] Equation (7') above is similar to Frenkel's (1981) equation (7):

$$\ln S_t = \alpha + \beta\cdot\ln\left[(P_T/P_N)/(P_T^*/P_N^*)\right]_t + \ln(P/P^*)_t + u_t,$$

where S is the spot exchange rate, $\beta = w_{US} = w_{CH}$, P is the general price level, P_J is the price level in the J^{th} sector (traded and non traded), "*" indicates the foreign country, and u is the disturbance term.

dominate PTF_X; the first relates to the fact that, even in a world of two countries, the goods traded internationally by country X constitute but a small subset of the goods produced and/or consumed in country Y and hence PTF_X can rise or fall in relation to P_Y whenever relative prices change.[16]

A second—and equally important—source of measurement error arises from the possibility that third countries can influence the world prices of country X's traded goods. In a world of M open economies, the various national price levels and exchange rates jointly determine the world prices of all traded goods; the exact manner in which this may occur has been suggested by Sjaastad (1992) and is briefly summarized in Appendix I. Equation (II-1) of that appendix poses a simple relationship between a foreign-currency price index for country X's traded goods and the M national price levels:

$$(9) \qquad PTF_X = \sum_{j=1}^{M} \Theta_X^j \cdot PF_j + G(Z_X),$$

where the Θ_X^j are non-negative fractions reflecting the relative price-making power of country j in the world market for country X's traded goods and which have the property that $\sum_{j=1}^{M} \Theta_X^j = 1$, PF_j is the price level of country j *measured in the currency of country* Y, and Z_X is a vector of all other variables—the "global fundamentals"—which will be ignored in what follows.

The exact nature of the second source of measurement error in $BRER_X^Y$ is illuminated by combining equations (8) and (9) to obtain:

$$(8') \qquad (1-\Theta_X^X)\cdot BRER_X^Y = MRER_X + \left(1-\Theta_X^X-\Theta_X^Y\right)\cdot P_Y - \sum_{j\neq X,Y}^{M} \Theta_X^j \cdot PF_j,$$

in which PF_X has been solved out of the right hand side. Evidently, the two real exchange rates will be exactly collinear only if $\Theta_X^X + \Theta_X^Y = 1$ so that

[16] Saidi and Swoboda (1983) dealt extensively with this issue. They observe that "...different weights (in national price indices) for different commodity groups, whether traded or non traded, induce deviations from PPP when relative prices change; these variations will be persistent as long as relative prices changes persist" [page 13]. See their appendix for further details.

proxy for $MRER_X$ only *when no third countries can influence the external prices of goods traded internationally by country Y.* This result explains why bi-lateral real exchange rates behave so differently according to the reference country; as that choice determines the magnitude of Θ_X^Y, it also determines the degree to which $BRER_{X,Y}$ is contaminated with measurement error.

A Short Digression:

Throughout this section the true real exchange rate has been identified as multi-lateral, and the rationale for doing so is now readily demonstrated by combining equations (6) and (9) and using the identity $EX_X^j \equiv EX_Y^j - EX_Y^X$:

$$(6'') \qquad MRER_X = PTF_X - PF_X$$
$$= \sum_j^M \Theta_X^j \cdot BRER_X^j + G(Z_X);$$

the "global fundamentals" term, $G(Z_X)$, has been resurrected in equation (6″). Although the true real exchange rate is clearly a weighted average of all bi-lateral real exchange rates, the usual bi-lateral approach sets one weight equal to unity and the remaining ones to zero. Occasionally, however, the bi-lateral real exchange rate is given a multi-lateral flavor by defining it as a weighted average $BRER_X = \sum_s \nu_s \cdot BRER_X^s$, where the ν_s are arbitrary weights (e.g., SDR or trade) that sum to unity. Even neglecting the absence of the $G(Z_X)$ term, this "multi" bi-lateral rendition is not necessarily an improvement over the more common variety. In equation (6″), the Θ_X^k ensure that the the measurement errors present in $BRER_X^k$ *exactly* cancel out but, as the Θ_X^k bear no logical relationship to the ν_s, that cancellation will occur only by chance in $BRER_X$.

Independence of the Real Exchange Rates: Global vs. Local

The precise characteristics of the real exchange rates are easily exposed using reduced-form equations in which endogenous variables have been solved out. Equations (2), (3), (6), (8) and (9) combine into the following reduced forms:

(9′) $\alpha_R(L)\cdot PTF_{X,t} = \alpha(L)\cdot PTF^{*}_{X,t} - \theta^{X}_{X}\cdot\gamma_R(L)\cdot ytt_{X,t}$,

(10A) $\alpha_R(L)\cdot MRER_{X,t} = \beta_R(L)\cdot PTF^{*}_{X,t} + \gamma_R(L)\cdot ytt_{X,t}$,

(10B) $\alpha_R(L)\cdot BRER^{Y}_{X,t} = \big(\beta_R(L)-\alpha(L)\big)\cdot PTF^{*}_{X,t} + \alpha_R(L)\cdot P_{Y,t} + \big(\gamma_R(L)/(1-\Theta^{X}_{X})\big)\cdot ytt_{X,t}$,

where $PTF^{*}_{X} = \sum_{k\neq X}^{M}\theta^{k}_{X}\cdot PF_{k}$ is a simple variant of PTF_X that excludes the price level of country X. The weights, $\theta^{k}_{X} \equiv \Theta^{k}_{X}/(1-\Theta^{X}_{X})$, which are proportional to the Θ^{k}_{X}, also sum to unity and measure the relative market power of country k *excluding the market power possessed by country X.*[17] In terms of the earlier notation, $\alpha(L) = 1-A(L)\cdot C(L)$ (as was defined above), $\alpha_R(L) = \alpha(L) + \theta^{X}_{X}\cdot\beta_R(L)$, $\beta_R(L) = w_X\cdot\big(1+B(L)\big)\cdot\big(1-C(L)\big)$, and $\gamma_R(L) = w_X\cdot\big(A(L)-1\big)\cdot D(L)$.

The restrictions that were derived for the nominal exchange rate are also relevant to the real exchange rate reduced forms. It is evident that the homogeneity restriction requires that $\beta_R(1) = 0$ and monetary independence implies $\alpha(1) = \alpha_R(1) = \gamma_R(1) = 0$. If the foreign exchange market is efficient, $B(L) = -1$ and hence $\beta_R(L) \equiv 0$; in that case $MRER_X$ is *strongly* independent as it depends only on ytt_X in both the short run and the long.

Equations (9′), (10A) and (10B), while too cumbersome for estimation, do shed light on the nature of real exchange rate independence, of which there are two types: *global* and *local*. Global independence, which holds when there is no long run response of the real exchange rate to a permanent shock to *any* variable appearing explicitly or implicitly in PTF^{*}_{X}, is defined by $\delta(MRER_X)/\delta PTF^{*}_{X} = 0$ and $\delta(BRER^{Y}_{X})/\delta PTF^{*}_{X} = 0$. *Local* independence is defined with respect to a specific currency; the real exchange rates are locally independent *vis à vis* currency k when $\delta(MRER_X)/\delta PF_k = \delta(BRER^{Y}_{X})/\delta PF_k = 0$.[18]

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[17] The unit-sum proof is quite simple: $\sum_{k\neq X}^{M}\theta^{k}_{X} = \sum_{k\neq X}^{M}\Theta^{k}_{X}/(1-\Theta^{X}_{X}) = (1-\Theta^{X}_{X})/(1-\Theta^{X}_{X}) = 1$.

[18] Because real exchange rate independence refers to long run responses to shocks to *exogenous* variables, it is meaningless to test it against EX^{Y}_{X}.

Global Independence:

The reduced form equations (10A) and (10B) lend themselves to direct tests of global independence. It follows directly from those equations that:

$$\begin{aligned} \delta(MRER_X)/\delta PTF^*_X &= \lim_{L\to 1} \beta_R(L)/\alpha_R(L) \\ &\equiv \Phi^G_{RM}, \text{ and:} \\ \delta(BRER^Y_X)/\delta PTF^*_X &= \lim_{L\to 1} \big(\beta_R(L)-\alpha(L)\big)/\alpha_R(L) \\ &= \lim_{L\to 1} \big((1+\theta^X_X)\cdot\beta_R(L)-\alpha_R(L)\big)/\alpha_R(L) \\ &= (1+\theta^X_X)\cdot\Phi^G_{RM} - 1 \\ &\equiv \Phi^G_{RB}, \end{aligned}$$

where Φ^G_{RM} and Φ^G_{RB} are the *global dependence coefficients*, which are zero if global independence holds. As $(1+\theta^X_X)\cdot\Phi^G_{RM} = 1+\Phi^G_{RB}$, *both real exchange rates can be globally independent only in the degenerative case in which* $\theta^X_X \to \infty$ (i.e., $\Theta^X_X \to 1$); otherwise, $\Phi^G_{RM} = 0 \Rightarrow \Phi^G_{RB} = -1$, and $\Phi^G_{RB} = 0 \Rightarrow \Phi^G_{RM} = 1/(1+\theta^X_X)$.

If the homogeneity postulate holds, sufficient conditions for global independence of $MRER_X$ clearly are:

$$(5'')\quad \begin{cases} \alpha_R(1) = 0 \text{ (the } \alpha_R \text{ restriction)}, \\ \beta_R(1) = 0 \text{ (the } \beta_R \text{ restriction), and} \\ \beta'_R(L)/\alpha'_R(L)\big|_{L=1} = 0 \text{ (the l'Hôpital rule)}, \end{cases}$$

and similarly for bi-lateral global independence, except that the final restriction becomes $\beta'_R(L)/\alpha'_R(L)\big|_{L=1} = 1/(1+\theta^X_X)$. However, it is *logically impossible* for bi-lateral real exchange rates to be globally independent in a systematic manner; the proof is by contradiction. If that independence held, then $(1+\theta^X_X)\cdot\lim_{L\to 1} \beta_R(L)/\alpha_R(L) = 1$, but since $\alpha_R(L) = \alpha(L) + \theta^X_X\cdot\beta_R(L)$, this condition can be written as $\lim_{L\to 1} \big((1+\theta^X_X)\cdot\beta_R(L)\big)/\big(\alpha(L)+\theta^X_X\cdot\beta_R(L)\big) = 1$. If the homogeneity postulate does not hold, then $\lim_{L\to 1} \beta_R(L) \neq 0$ and hence $\Phi^G_{RB} = 0$ implies $\beta_R(1) = \alpha(1)$, which would occur only by chance. If the homogeneity postulate holds, then $\lim_{L\to1} \beta_R(L) = 0$, so $\lim_{L\to1} \alpha_R(L) = \lim_{L\to1} \left(\alpha'(L)+\theta^X_X\cdot\beta'_R(L)\right) = 0$ is required as well, and hence $\left((1+\theta^X_X)\cdot\beta'_R(L)\right)/\left(\alpha'(L)+\theta^X_X\cdot\beta'_R(L)\right)\Big|_{L=1} = 1$. The implication is that $\beta'_R(1) = \alpha'(1)$, which also would occur only by chance.[19]

Local Independence:

The test for local independence is based on the long run responses of the real exchange rates to a permanent shock to a country-specific variable such as EX^Y_k. From equations (10A) and (10B) and $PTF^*_X = \sum_{k\neq X}^{M} \theta^k_X\cdot\left(P_k - EX^Y_k\right)$, the effects of, say, an appreciation of currency Y *vis a vis* any third currency k are $\delta(MRER_X)/\delta EX^Y_k \equiv \Phi^{L,k}_{RM} = -\theta^k_X\cdot\Phi^G_{RM}$ and $\delta(BRER^Y_X)/\delta EX^Y_k \equiv \Phi^{L,k}_{RB} = -\theta^k_X\cdot\Phi^G_{RB}$. While global independence implies local independence, in the absence of the former, real exchange rates will be locally independent *vis à vis* currency k if and only if $\Theta^k_X = \theta^k_X = 0$. But if multi-lateral global independence holds (i.e., $\Phi^G_{RM} = 0$ and hence $\Phi^G_{RB} = -1$), then $\Phi^{L,k}_{RB} = \theta^k_X$, and at least one $\theta^k_X \neq 0$.

Real Exchange Rates and the Terms of Trade

The responses of $MRER_X$ and $BRER^Y_X$ to the external terms of trade are obviously $\delta(MRER_X)/\delta ytt_X = \lim_{L\to1} \gamma_R(L)/\alpha_R(L) \equiv \lambda_{RM}$ and $\lambda_{RB} = \lambda_{RM}/(1-\Theta^X_X)$, where λ_{RM} and λ_{RB} are the *real terms-of-trade coefficients*. Unless the country is a "price taker" ($\Theta^X_X = 0$), the bi-lateral real exchange rate clearly reacts more strongly to the terms of trade than does the multi-lateral real rate. Moreover, if the $\gamma_R(1) = \alpha_R(1) = 0$ restrictions are met, $\lambda_{RM} = \gamma'_R(L)/\alpha'_R(L)\Big|_{L=1}$.

IV. EMPIRICAL RESULTS: THE SWISS FRANC CASE

All data are quarterly and cover the period 1972:1—1991:4. The (seasonally-adjusted) Swiss franc price indices for Swiss imports and exports are from the TIME SERIES DATA EXPRESS data base (EconData Pty Ltd. of Canberra,

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[19] In terms of the original notation and using the homogeneity postulate, $\alpha'(1) = -C'(1)\cdot A(1)$ and $\beta'_R(1) = -w_X\cdot[1+B(1)]\cdot C'(1)$, so if $\beta'_R(1) = \alpha'(1)$, then $A(1) = w_X\cdot[1+B(1)]$, which can be true in general.

Australia) and all remaining data are from the ESTIMA RATS-OECD data base.[20] Three measures of price levels were used: the GDP deflator (DEF), the consumer price index (CPI), and the producer price index (PPI). The European price level data, which are used in some estimates, are based on the four major countries (France, Germany, Italy and the U.K.) and were obtained by converting the GDP and price level data for each country into a common currency (the DM) and then aggregating across the four countries, quarter by quarter, using relative GDPs as weights. The resulting price index was converted to a U.S. dollar index using the dollar/DM exchange rate.[21]

An exchange rate between the U.S. dollar and a basket of the same four European currencies also was constructed using relative GDPs as weights. The weights of the basket, which will be referred to as the "mini-ECU", are such that, on average, its U.S. dollar price is unity. The actual variable employed in what follows, EUROX, was defined as the natural logarithm of the European currency basket price of the U.S. dollar.[22]

Table 1 reports the results of Dickey-Fuller unit root tests using four lags (the results for other lags are similar) on all basic data using ESTIMA RATS DFUNIT.SRC; a trend was used in all tests on variables in level form. The

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[20] The EXP and IMP variables are in the DXDATA\OECD\NACC file of the TIME SERIES DATA EXPRESS and are identified as CHE.SA.EXPIPI and CHE.SA.IMPIPI.

[21] As French and Italian producer price indices were not available for the entire period, the CPIs for those countries were substituted for producer prices.

[22] The basket was defined such that its U.S. dollar price during period t is:

$$ex^{ECU}_{\$,t} = \Big(GDP_{FRA,t}\cdot(ex^{FF}_{\$,t}/\bar{ex}^{FF}_{\$}) + GDP_{DEU,t}\cdot(ex^{DM}_{\$,t}/\bar{ex}^{DM}_{\$})$$
$$+ GDP_{ITA,t}\cdot(ex^{LIT}_{\$,t}/\bar{ex}^{LIT}_{\$}) + GDP_{UK,t}\cdot(ex^{£}_{\$,t}/\bar{ex}^{£}_{\$})\Big)\Big/\Big(GDP_{EUR,t}\Big),$$

where $\bar{ex}^{j}_{\$}$ is the period average U.S. dollar price of the j^{th} currency, GDP_j is the gross domestic product of the j^{th} country expressed in a common currency (the DM), and GDP_{EUR} is the combined GDP of the four countries, again measured in DM. For each quarter, every currency in the basket is weighted by the relative GDP of that quarter for the country in question.

TABLE 1

DICKEY-FULLER TESTS ON ALL BASIC DATA: 1972:1-1991:4*

VARIABLE	LEVELS			FIRST DIFFERENCES		
	BETA	t STAT**	P-VALUE	BETA	t STAT**	P-VALUE
EX	0.9030	-2.3964	0.0097	0.2705	-3.6705	0.0002
EUROX	0.9345	-1.9690	0.0265	0.4599	-3.1006	0.0014
IMP	0.9278	-2.9233	0.0024	0.7335	-3.1986	0.0010
EXP	0.9250	-2.5043	0.0073	0.6631	-3.0791	0.0015
U.S. DEF	0.9608	-2.2502	0.0138	0.7112	-2.6318	0.0053
U.S. CPI	0.9597	-2.3284	0.0114	0.7618	-2.2946	0.0124
U.S. PPI	0.9689	-1.6396	0.0529	0.6634	-2.2647	0.0134
Swiss DEF	0.9616	-1.8559	0.0339	0.7739	-2.3172	0.0118
Swiss CPI	0.8699	-4.0660	0.0001	0.7074	-2.0585	0.0217
Swiss PPI	0.8953	-3.3625	0.0006	0.5563	-3.9507	0.0001
European DEF	0.8822	-2.7953	0.0034	0.3434	-3.5730	0.0003
European CPI	0.9124	-2.4369	0.0087	0.4311	-3.2020	0.0010
European PPI	0.9084	-2.3732	0.0102	0.3844	-3.3201	0.0007

*Computed using the RATS DFUNIT.SRC procedure with 4 lags.

**Test is against unity.

null hypothesis of a unity root is rejected at the five per cent significance level for the variables in level form in all cases except for U.S. PPI, where the P-value was 5.29 per cent. The unit-root null hypothesis is rejected at the two per cent level of significance for all first-differenced variables except for one case — the Swiss CPI, where the P-value was 2.17 per cent.

Estimates of the Nominal Exchange Rate Model

The objective at this point is to evaluate the performance of the nominal exchange rate model and to test the restrictions imposed by purchasing power parity, monetary independence, foreign exchange market efficiency, and terms-of-trade neutrality. Using the property that, for any polynomial $A(L) = \sum_{i=0}^{N} a_i \cdot L^i$ and any time series Y_t, we can write $A(L)\cdot Y_t = \sum_{i=0}^{N-1}\left(\sum_{j=0}^{i} a_j\right)\cdot \Delta Y_{t-i} + A(1)\cdot Y_{t-N}$, equation (3′) was reparameterized and estimated in the following form:

$$(3'') \qquad \Delta EX_t = -\sum_{i=1}^{N-1}\left(\sum_{j=0}^{i}\alpha_j\right)\cdot \Delta EX_{t-i} + \sum_{i=0}^{N-1}\left[\left(\sum_{j=0}^{i}\beta_j\right)\cdot\left(\Delta IMPF_{t-i} + \Phi_P\cdot \Delta TT_{t-i}\right) + \left(\sum_{j=0}^{i}\gamma_j\right)\cdot \Delta ytt_{t-i}\right]$$

$$+ \alpha(1)\cdot EX_{t-N} + \beta(1)\cdot\left(IMPF_{t-N} + \Phi_P \cdot TT_{t-N}\right) + \gamma(1)\cdot ytt_{t-N}.$$

The reparameterization facilitates those tests as any combination of the α, β, and γ restrictions can be imposed by simply dropping one or more of the last three terms of equation (3″).

The Swiss Franc/U.S. Dollar Case:

With EX defined as the Swiss franc price of the U.S. dollar and with IMPF denominated in dollars, equation (3″) was estimated using ESTIMA RATS nonlinear least squares (NLLS) employing White's (1980) "robust errors" routine to obtain consistent estimates of the standard error; lags were added until the estimates of $\alpha(1)$, $\beta(1)$ and $\gamma(1)$ stabilized. The equation was re-estimated by Hansen's (1982) generalized method of moments (GMM) using NLLS with very similar point estimates but smaller standard errors.[23] The complete estimates, including the tests on the various restrictions, are reported in Table 2 for both the NLLS and GMM estimates.[24]

The standard error of estimate is a mere 0.63 *(0.66)* per cent, and the point estimate of Φ_P, 0.52 *(0.52)*, is tight despite a very high correlation between ytt and TT. Since the estimate of the coefficient of $IMPF_t$, -1.02 *(-1.01)* is not significantly different from minus unity [the t statistic is -1.35 *(-0.93)*], it is clear that external price shocks are very quickly neutralized by the Swiss exchange rate; this result also is consistent with the

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[23] All estimation was by ESTIMA RATS386 version 4.01. When using robust errors, the "damp" factor was set at the lowest level consistent with a positive definite variance-covariance matrix but, when using the generalized method of moments, that factor was set equal to 1.0 to produce Newey-West estimates.

[24] GMM estimation was used because of evidence (presented in Appendix II) that ytt and TT are endogenous. The instruments for the GMM estimation included a constant, lagged values of EX, the log of the ratio of the U.S. to the European price levels, and the residuals from a regression of ytt and TT on IMPF as an instrument for IMPF. TT and ytt served as their own instruments.

TABLE 2

SWISS FRANC/U.S. DOLLAR EXCHANGE RATE, 1974:1-1991:4

NLLS & GMM-NLLS ESTIMATES OF EQUATION (3″)

VARIABLE	LAG	COEFFICIENT		t STATISTIC*		P-VALUE	
		NLLS	GMM	NLLS	GMM	NLLS	GMM
$\hat{\Phi}_P$	-	0.5175	0.5215	4.592	5.7276	0.0000	0.0000
ΔEX	1	1.1965	1.1916	10.5953	15.5518	0.0000	0.0000
"	2	-1.1009	-1.1069	-6.2021	-8.0898	0.0000	0.0000
"	3	0.7994	0.8088	4.4796	5.6218	0.0000	0.0000
"	4	-0.4068	-0.4327	-4.0172	-4.8092	0.0001	0.0000
EX	5	0.0062	0.0212	0.5778	1.3315	0.5634	0.1830
ΔIMPF	0	-1.0206	-1.0116	-66.9753	-81.0866	0.0000	0.0000
"	1	1.1960	1.1873	11.0133	16.0493	0.0000	0.0000
"	2	-1.0911	-1.0930	-6.0384	-7.8180	0.0000	0.0000
"	3	0.7895	0.8060	4.3554	5.5542	0.0000	0.0000
"	4	-0.3827	-0.3912	-3.6773	-4.3452	0.0002	0.0000
IMPF	5	-0.0037	0.0228	-0.3397	1.4851	0.7416	0.1375
Δytt	0	-1.0664	-1.2892	-3.0305	-4.3929	0.0024	0.0000
"	1	0.8333	0.8878	2.6605	3.4036	0.0078	0.0006
"	2	-1.1795	-1.4181	-3.4453	-4.7450	0.0006	0.0000
"	3	1.1151	0.9303	3.0067	2.7707	0.0026	0.0056
"	4	-0.8359	-0.9635	-2.9758	-3.7531	0.0029	0.0002
ytt	5	-0.0023	-0.1275	-0.0385	-1.5377	0.9693	0.1241

$\bar{R}^2$ = 0.9888 (0.9878); SEE = 0.0063 (0.0066); D-W = 1.7628 (1.6670)

$Q_{(18)}$ = 34.7888 (32.9632), P-Value = 0.0100 (0.0167)

Chi-square Tests on Restrictions

RESTRICTIONS	χ^2		NDF	P-VALUE	
α and β	0.7518	2.5118	2	0.6868	0.2848
α and γ	0.8293	2.3749	2	0.6606	0.3050
α, β, and γ	0.8325	2.5182	3	0.8417	0.4720
Monetary Independence	0.9253	2.7774	3	0.8193	0.4272
Market Efficiency	4.2416	6.9435	4	0.3743	0.1389
Terms-of-Trade Neutrality	29.1828	36.1390	3	0.0000	0.0000

* Robust standard errors computed with 4 lags and a damp factor of 0.85 for NLLS and 1.0 for GMM.

hypothesis of monetary independence *cum* foreign exchange market efficiency. Purchasing power parity is not rejected as the estimate of $\beta(1)$ is both very small and quite insignificant, and the α, β and γ restrictions are not rejected either individually or collectively. While neither independence of monetary policy nor foreign exchange market efficiency can be rejected, terms of trade neutrality is very decisively rejected by both estimates.

The α, β and γ restrictions were imposed on equation (3″) by deleting all level variables (EX, IMPF, TT and ytt), and expressions (4) and (4′) for Φ_H and λ_N were embedded in that equation, which was re-estimated by NLLS and GMM-NLLS (using the same instruments). The results, reported in Table 3, are nearly identical with the unrestricted estimates; as first differencing is totally benign, there clearly is no stationarity issue.

Again the precision of the fit is quite extraordinary for first-differenced

TABLE 3

SWISS FRANC/U.S. DOLLAR EXCHANGE RATE, 1974:1-1991:4

RESTRICTED NLLS & GMM-NLLS ESTIMATES OF EQUATION (3″)

VARIABLE	LAG	COEFFICIENT		t STATISTIC*		P-VALUE	
		NLLS	GMM	NLLS	GMM	NLLS	GMM
$\hat{\Phi}_P$	–	0.5329	*0.5268*	4.6970	*5.2840*	0.0000	*0.0000*
$\hat{\Phi}_H$	–	-1.0036	*-1.0004*	-23.6623	*-27.5543*	0.0000	*0.0000*
$\hat{\lambda}_N$	–	-2.3236	*-2.2509*	-5.0716	*-5.8794*	0.0000	*0.0000*
ΔEX	1	1.1975	*1.1657*	10.8306	*14.1969*	0.0000	*0.0000*
"	2	-1.1055	*-1.0396*	-6.1032	*-6.6015*	0.0000	*0.0000*
"	3	0.8099	*0.7447*	4.5107	*4.8720*	0.0000	*0.0000*
"	4	-0.4134	*-0.3820*	-3.8368	*-4.3285*	0.0001	*0.0000*
ΔIMPF	0	-1.0220	*-1.0228*	-68.5680	*-93.6221*	0.0000	*0.0000*
"	1	1.1965	*1.1556*	11.1363	*14.4757*	0.0000	*0.0000*
"	2	-1.0966	*-1.0332*	-6.0140	*-6.5025*	0.0000	*0.0000*
"	3	0.7988	*0.7414*	4.3604	*4.8218*	0.0000	*0.0000*
"	4	-0.3901	*-0.3524*	-3.5570	*-4.0247*	0.0004	*0.0001*
Δytt	0	-1.0647	*-1.0835*	-3.5153	*-4.0398*	0.0004	*0.0001*
"	1	0.8038	*0.9782*	2.4727	*3.8721*	0.0134	*0.0001*
"	2	-1.1710	*-1.3251*	-3.2624	*-4.3545*	0.0011	*0.0000*
"	3	1.0923	*1.0630*	3.0243	*3.3158*	0.0025	*0.0009*
"	4	-0.8489	*-0.7832*	-2.8935	*-3.0088*	0.0038	*0.0026*

$\bar{R}^2$ = 0.9893 *(0.9891)*; SEE = 0.0061 *(0.0062)*; D-W = 1.7645 *(1.7212)*

$Q_{(18)}$ = 33.9947 *(33.9454)*, P-Value = 0.0126 *(0.0128)*

* Robust standard errors computed with 4 lags and a damp factor of 0.70 for NLLS and 1.0 for GMM.

data — the standard error of estimate is 0.61 *(0.62)* per cent. The restricted estimate of Φ_P, 0.53 *(0.53)*, whose t statistic against zero is 4.70 *(5.28)*, differs only slightly from the unrestricted estimate, and the estimate of Φ_M, -1.00 *(-1.00)*, is not significantly different from minus unity [the t statistic against minus unity is -0.08 (*-0.01*)]; monetary independence *vis à vis the U.S. cannot be rejected.* This result, together with the chi-square tests from Table 2, indicates that Swiss monetary policy *alone* is responsible for the modest — but persistent — Swiss inflation since 1973. Foreign exchange market efficiency is not rejected as the estimate of b_0, -1.02 *(-1.02)*, does not differ significantly from minus unity [the t statistic being -1.48 *(-2.09)*].

The results are quite different with respect to the nominal terms-of-trade coefficient. The point estimates of λ_N indicate that a one per cent rise in real income due to improved terms of trade leads to a 2.32 *(2.25)* per cent revaluation of the Swiss franc, and those estimates are highly significant.

The Swiss Franc/Mini-ECU Case:

The entire exercise was repeated with the U.S. dollar replaced by the mini-ECU (the basket of the four major European currencies described above).[25] The results of unrestricted NLLS and GMM-NLLS estimates of equation (3″) and tests of the various restrictions are briefly summarized in Table 4; the only significant difference with the franc/dollar results reported in Table 2 was that an additional lag was required on the EX variable in order to satisfy the alpha *cum* beta restriction. As none of the relevant restrictions were rejected by either estimate (at the 5 per cent significance level), the α, β, and γ

[25] As the variables are in natural logarithms, the new EX is the old EX *minus* EUROX, where EUROX is the European-currency-basket price of the U.S. dollar, and the new IMPF is the old IMPF *plus* EUROX. The TT and ytt variables are unchanged.

TABLE 4

SWISS FRANC/MINI-ECU EXCHANGE RATE, 1974:1-1991:4

Summary of Unrestricted NLLS & GMM-NLLS Estimates of Equation(3″)*

$\bar{R}^2$ = 0.9583 *(0.9563)*; SEE = 0.0063 *(0.0064)*; D-W = 1.8465 *(1.8971)*
Q(18) = 36.9217 *(34.3576)*, P-Value = 0.0054 *(0.0114)*

Chi-square Tests of Restrictions:

Restrictions:	χ^2		NDF	P-Value	
α	2.1604	*0.0742*	1	0.1416	*0.7854*
β (PPP)	0.9818	*0.0187*	1	0.3218	*0.8911*
γ	0.0685	*0.0404*	1	0.7936	*0.8408*
α and β	5.8903	*5.7150*	2	0.0526	*0.0574*
α and γ	2.2839	*0.2655*	2	0.3192	*0.8757*
α, β, and γ	5.9701	*6.1435*	3	0.1131	*0.1048*
Monetary Independence	5.9987	*6.4294*	3	0.1118	*0.0925*
Market Efficiency	6.2309	*7.6374*	4	0.1826	*0.1058*
Terms-of-Trade Neutrality	24.5473	*28.6836*	3	0.0000	*0.0000*

* Robust standard errors computed with 4 lags and a damp factor of 0.85 for NLLS and 1.0 for GMM.

restrictions were imposed and the complete results are reported in Table 5.[26]

Overall, the results are remarkably similar to those obtained using the Swiss franc/U.S. dollar exchange rate and prices denominated in dollars. The fit is very good with a standard error of estimate of only 0.62 *(0.63)* per cent, and the restricted estimate of Φ_P, 0.52 *(0.51)*, whose t statistic against zero is 3.86 *(4.06)*, is very similar to the estimate reported in Table 3. Monetary independence *vis à vis* the four major European countries is not rejected as the estimate of Φ_M, -0.95 *(-0.94)*, is not significantly different from minus unity [the t statistic against minus unity is 0.49 *(0.67)*]. Foreign exchange market efficiency is not rejected: the estimate of b_0, -1.01 *(-1.00)* does not differ significantly from minus unity as the t statistic for that test is -0.25 *(0.19)*. Finally, the estimates of λ_N are

[26] The instruments for the GMM-NLLS estimate were the same as in the case of the U.S. dollar/Swiss franc estimates reported in Table 3.

TABLE 5

SWISS FRANC/MINI-ECU EXCHANGE RATE, 1974:1-1991:4

RESTRICTED NLLS & GMM-NLLS ESTIMATES OF EQUATION (3″)

VARIABLE	LAG	COEFFICIENT		t STATISTIC*		P-Value	
		NLLS	GMM	NLLS	GMM	NLLS	GMM
$\hat{\Phi}_P$	-	0.5215	*0.5093*	3.8570	*4.0636*	0.0001	*0.0000*
$\hat{\Phi}_M$	-	-0.9542	*-0.9435*	-10.2586	*-11.2179*	0.0000	*0.0000*
$\hat{\lambda}_N$	-	-2.4414	*-2.4261*	-5.9559	*-5.7288*	0.0000	*0.0000*
ΔEX	1	1.2198	*1.2755*	12.0582	*13.3222*	0.0000	*0.0000*
"	2	-1.1681	*-1.2281*	-6.6520	*-8.2080*	0.0000	*0.0000*
"	3	0.8430	*0.8517*	5.3238	*5.3440*	0.0000	*0.0000*
"	4	-0.4563	*-0.4828*	-5.1828	*-5.4091*	0.0000	*0.0000*
"	5	0.0387	*0.0506*	1.4675	*2.3602*	0.1423	*0.0183*
ΔIMPF	0	-1.0081	*-0.9953*	-31.1138	*-40.6325*	0.0000	*0.0000*
"	1	1.2500	*1.3149*	12.2022	*14.1403*	0.0000	*0.0000*
"	2	-1.1582	*-1.2246*	-6.5879	*-8.2570*	0.0000	*0.0000*
"	3	0.8557	*0.8660*	5.3970	*5.2500*	0.0000	*0.0000*
"	4	-0.4385	*-0.4640*	-4.8372	*-5.2274*	0.0000	*0.0000*
Δytt	0	-1.0894	*-1.0215*	-3.0930	*-2.8199*	0.0020	*0.0048*
"	1	0.7370	*0.8216*	1.8525	*1.9827*	0.0640	*0.0474*
"	2	-1.2611	*-1.4153*	-3.1595	*-3.5779*	0.0016	*0.0003*
"	3	1.1104	*1.1792*	2.3471	*2.7354*	0.0189	*0.0062*
"	4	-0.7734	*-0.8573*	-2.2156	*-2.8532*	0.0267	*0.0043*

$\bar{R}^2$ = 0.9589 *(0.9578)*; SEE = 0.0062 *(0.0063)*; D-W = 1.7939 *(1.8608)*

$Q_{(18)}$ = 36.9530 *(35.3555)*, P-Value = 0.0053 *(0.0085)*

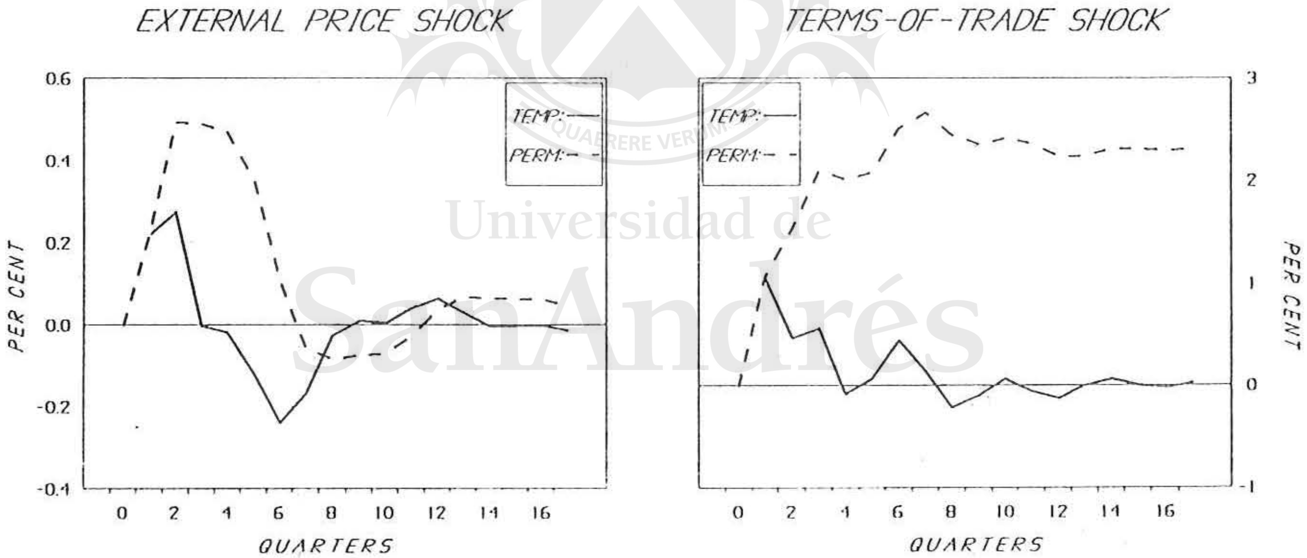
* Robust standard errors computed with 4 lags and a damp factor of 0.80 for NLLS and 1.0 for GMM.

highly significant and very similar to those reported in Table 3; a one per cent rise in real income due to the terms of trade causes a 2.44 *(2.43)* per cent revaluation of the franc.

The most striking aspect of the results for both the franc/dollar and franc/mini-ECU exchange rates is the degree to which the Swiss franc behaves as a "commodity" currency rather than a financial asset. The very large movements in the dollar/franc exchange rate since 1973 have failed to destabilize the Swiss price level; to the contrary, those movements have been *systematic* response to fluctuations in the external prices of Swiss traded goods. Indeed, PPP has been preserved rather than violated by those responses.[27]

Two simulations in which foreign-currency prices of traded goods are subjected to shocks are presented in Figure 1; in both cases, the simulations are based on the restricted NLLS estimate of equation (3′) reported in Table 3, and the shocks occur during quarter 1. The left panel depicts the response of the Swiss franc/dollar exchange rate to a temporary (one period) and a permanent rise of 10 per cent in PTF; a positive value indicates a real appreciation (i.e., the fall in the exchange rate exceeds the rise in PTF). Both shocks induce a small initial real appreciation, but the exchange rate recovers from the temporary shock within two quarters and then experiences small but prolonged oscillations. The permanent shock initially leads to a 0.5 per cent real

FIG. 1: REAL APPRECIATION OF SWISS FRANC IN RESPONSE TO:



[27] The overall results strongly contradict Krugman's (1989) cavalier assertion that "It is only because there seems to be some kind of delinking of exchange rates and the real economy that exchange rates can be as volatile as they have been. That is, *exchange rates can move so much precisely because they seem to matter so little*" [page 39; emphasis in original]. In the Swiss case, the exchange rate matters a great deal, as it stabilizes the internal price level.

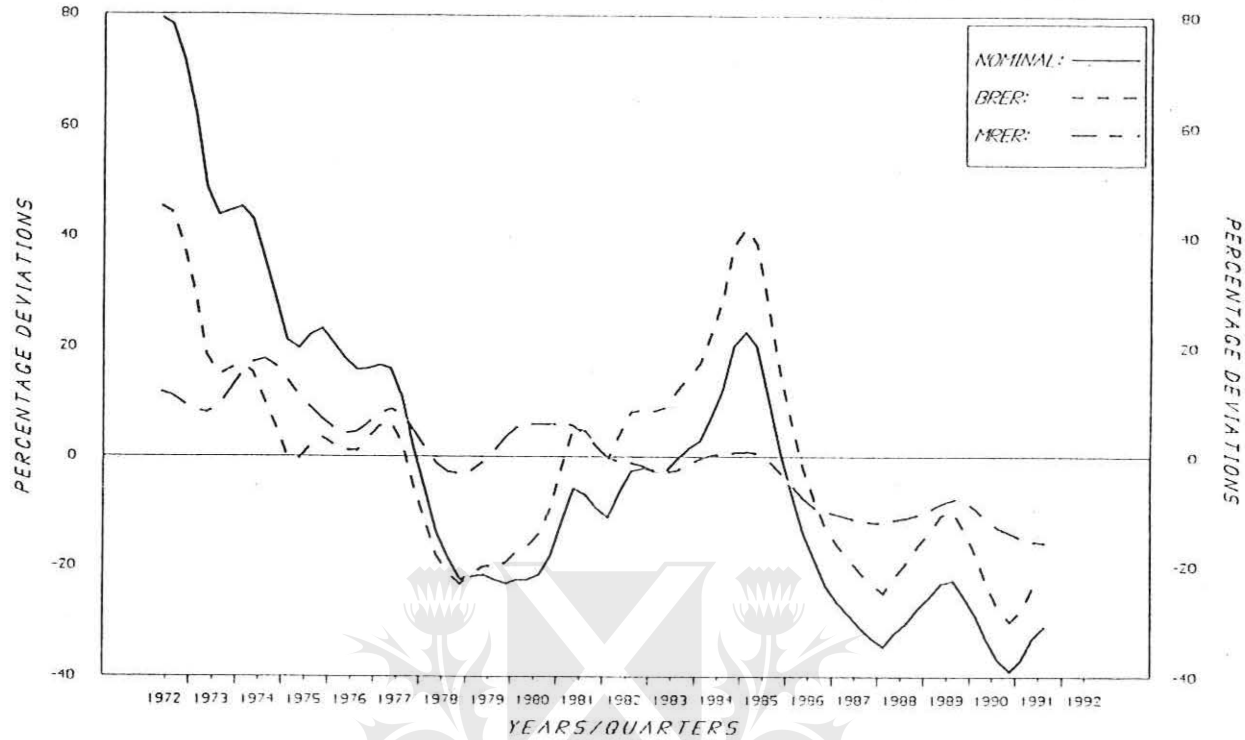
appreciation and, after some minor oscillations, that appreciation settles down to a statistically insignificant 0.04 per cent. The right panel of Figure 1 presents the simulated responses of the exchange rate to temporary and permanent improvements in the terms of trade equivalent to one per cent of Swiss real national income (0.4 standard deviations of ytt). The temporary shock induces an immediate real appreciation—an increase in the relative price of non-traded goods—of one per cent, and that effect last for nearly a year but the "echoes" persist much longer. When the shock is permanent, more than two years are required to approach the final real appreciation of 2.3 per cent.

The Behavior of the Swiss Real Exchange Rates: An Overview

Before to turning to estimates of equations (10A) and (10B), we first examine the secular behavior of the nominal and real Swiss exchange rates *vis à vis* the U.S. dollar since 1972; the departures of the nominal and real exchange rates from their period averages are portrayed in Figure 2. The real exchange rates were defined on GDP deflators and all exchange rates were filtered by a three-quarter centered moving average to improve clarity. That the $BRER_{CH}^{US}$ is far more volatile than the $MRER_{CH}$ is evident; its sample variance is more than five times and its maximum deviations are nearly three times those of $MRER_{CH}$. It also is evident from Figure 2 that the nominal and real exchange rates, the bi-lateral rate particularly so, are quite highly correlated. The simple correlations between nominal and real exchange rates, with the real exchange rates being defined on GDP deflators (DEF), consumer (CPI) and producer (PPI) prices, were computed for both levels and first differences, and are presented in the left panel of Table 6. Except in the case of producer prices, the correlations between nominal and real exchange rates are very high; in the case of $MRER_{CH}$, however, that correlation is mainly trend as first differencing substantially reduces it. In contrast, first differencing *increases* the

FIGURE 2: SWISS EXCHANGE RATES

NOMINAL, BI-LATERAL AND MULTI-LATERAL REAL VERSIONS



correlations between the nominal and bi-lateral real exchange rates, suggesting that the nominal rate dominates $BRER^{US}_{CH}$ in the short run.[28]

Even more interesting are the correlations in the right panel of Table 6, which are between the various exchange rates and the residuals (RES) from simple regressions of P_{US} on PTF_{CH}. As RES is orthogonal with P_{US}, it captures the influence of all other factors, such as price levels of other countries, on PTF_{CH}. While the correlations between $MRER_{CH}$ and RES are insignificant and those between EX^{US}_{CH} and RES are moderate, those between

[28] The high short-run correlation between nominal and bi-lateral real exchange rates is well known. Mussa (1986), for example, in describing his "second important regularity" observed that "during sub periods when the nominal exchange rate is floating, there is strong correlation between short-term movements in the real exchange rate and short-term movements in the nominal exchange rate." [page 131].

TABLE 6

CORRELATIONS AMONG REAL AND NOMINAL EXCHANGE RATES: SWITZERLAND/U.S.

EXCHANGE RATES:	LEVELS	FIRST DIFFERENCES	VARIABLES:	LEVELS	FIRST DIFFERENCES
EX & BRER:			EX & RES:		
DEF	0.8684	0.9805	DEF	-0.5721	-0.5277
CPI	0.7935	0.9717	CPI	-0.5779	-0.5460
PPI	0.5806	0.9384	PPI	-0.5577	-0.5195
EX & MRER:			BRER & RES:		
DEF	0.7956	0.4468	DEF	-0.8497	-0.9679
CPI	0.8480	0.3143	CPI	-0.9325	-0.9729
PPI	-0.4601	0.2658*	PPI	-0.9808	-0.9834
BRER & MRER:			MRER & RES:		
DEF	0.6104	0.4821	DEF	-0.1519*	-0.2685*
CPI	0.5064	0.3816	CPI	-0.1838*	-0.2027*
PPI	-0.0235*	0.3074	PPI	0.0882*	-0.1373*

*Not significant at the one per cent level.

$BRER^{US}_{CH}$ and RES are very high, indicating that those factors strongly affect both the nominal and the bi-lateral real exchange rate at least in the short run. Thus the "noise" captured by RES is transmitted to the bi-lateral real exchange rate via the nominal rate—and corrupts it thoroughly in the process.

Global Independence Tests of the Multi-Lateral Real Exchange Rate

The definitive measure of the relative merits of MRER and BRER lies in the *real exchange rate independence* attribute—the *long run* responses of real exchange rates to shocks imposed on external nominal variables—the tests of which involve the parameters of equations (10A) and (10B). The first step was a test of the homogeneity restriction $\left(C(1) = 1 \Rightarrow \beta_R(1) = 0\right)$, a necessary but not sufficient condition for global independence of the true real exchange rate. As has been noted, equation (10A) is too cumbersome to estimate, so the restriction was tested on a *semi*-reduced form that was derived from equation (10A) and which involves the same key parameters but a reduced number of variables:

(10A') $\alpha(L)\cdot PF_{CH,t} = \big(\alpha(L)-\beta_R(L)\big)\cdot PTF_{CH,t} - \gamma_R(L)\cdot ytt_{CH,t}$.

The homogeneity postulate, which implies $\alpha(1) = \big(\alpha(1)-\beta_R(1)\big)$, was imposed on GMM estimates (with five lags) of equation (10A') for each of the three price level measures and was not rejected in any case, nor was the more stringent restriction that $\alpha(1) = \big(\alpha(1)-\beta_R(1)\big) = 0$; the results are reported in the first two rows of panel A, Table 7. Moreover, the *strong* version of global multilateral independence, $\beta_R(L) \equiv 0$, was tested by imposing the six $\alpha_i = (\alpha_i-\beta_{R_i})$ restrictions together with the $\alpha(1) = 0$ restriction; as is reported in the third row of panel A, Table 7, that joint restriction was not rejected at the 15 per cent level of significance in any of the three cases.[29]

The next step involved estimation of the global dependence coefficient using a second *semi*-reduced form also derived from equation (10A):

(10A") $\alpha(L)\cdot MRER_{CH,t} = \beta_R(L)\cdot PTF_{CH,t} + \gamma_R(L)\cdot ytt_{CH,t}$,

in which the true global dependence coefficient, $\Phi^G_{RM} = \lim_{L\to1} \big(\beta_R(L)/\alpha_R(L)\big)$, is replaced by a proxy, $\phi^G_{RM} \equiv \lim_{L\to1} \big(\beta_R(L)/\alpha(L)\big) = \Phi^G_{RM}\cdot\big(1+\theta^X_X\cdot\phi^G_{RM}\big)$.[30] Equation (10A"), which was reparameterized in the same way as equation (3"), was estimated simultaneously for all three price levels (with four lags) by GMM using RATS nonlinear system (NLSYSTEM); the results are summarized in panel B in Table 7.[31] The joint α, β_R, and γ_R restriction was not rejected at the 40 per cent

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[29] The instruments include a constant, PTF, and the price levels for the U.S. and Europe (both in U.S. dollars). Since ytt is well correlated with PTF, the residuals of a regression of ytt on PTF were an instrument for ytt.

[30] As $\phi^G_{RM} = \lim_{L\to1} \beta_R(L)/\alpha(L) = \big(\lim_{L\to1} \beta_R(L)/\alpha_R(L)\big)\cdot\big(\lim_{L\to1} \alpha_R(L)/\alpha(L)\big) = \Phi^G_{RM}\cdot\big(1+\theta^X_X\cdot\phi^G_{RM}\big)$, ϕ^G_{RM} is a biased proxy unless $\theta^X_X = 0$. However, by dividing the entire expression by θ^X_X, we obtain $\phi^G_{RM}/\theta^X_X = \Phi^G_{RM}\cdot(\phi^G_{RM} + 1/\theta^X_X)$ so, apart from the irrelevant case when $\Theta^X_X \to 1 \Rightarrow \theta^X_X \to \infty$, it follows that $\phi^G_{RM} = 0 \Leftrightarrow \Phi^G_{RM} = 0$. Accordingly, equation (10A") can be used to test for $\Phi^G_{RM} = 0$.

[31] The instruments included a constant, EUROX, (BRER-MRER), PTF, the residuals of a regression of ytt on PTF, and ytt itself (with six lags).

TABLE 7

GLOBAL INDEPENDENCE TEST OF SWISS TRUE REAL EXCHANGE RATE: 1974:1-1991:4

A. Test of the Homogeneity Postulate on GMM Estimates of Equation (10A′)

Restriction:	Test:	PRICE LEVEL MEASURES			
		DEF	CPI	PPI	ALL
1: $\beta_R(1)$.	$\chi^2(1)$:	0.2029	2.0266	0.0024	---
	Signif:	0.6524	0.1546	0.9611	---
2: α & $(\alpha-\beta_R)$.	$\chi^2(2)$:	0.9700	2.0789	0.2809	---
	Signif:	0.6157	0.3537	0.8690	---
3: (2) and $\beta_R(L) \equiv 0$.	$\chi^2(7)$:	6.0964	5.0624	10.6087	---
	Signif:	0.5285	0.6524	0.1566	---

B. Generalized Method-of-Moments Estimates of Equation (10A″)

Restriction:	Test:	DEF	CPI	PPI	ALL
1: α, β_R & γ_R.	$\chi^2(3)$:	2.7564	2.0292	1.4580	4.2470
	Signif:	0.4307	0.5664	0.6920	0.8944
2: $\phi^G_{RM} = 0$.	$\chi^2(3)$:	5.2452	5.4883	1.0649	13.2669
	Signif:	0.1547	0.1393	0.7856	0.1510
3: $\beta_R(L) \equiv 0$.	$\chi^2(5)$:	2.5574	2.7988	5.5066	19.3798
	Signif:	0.7678	0.7310	0.3572	0.1970

GMM-NLSYSTEM Regression Results:

	DEF	CPI	PPI	ALL
$\bar{R}^2$(α, β_R & γ_R Restrictions Imposed):	0.6590	0.5349	0.3684	---
Standard Error of Estimate:	0.0092	0.0095	0.0074	---
Durbin-Watson Statistic:	1.1043	1.1110	2.2626	---
Q(18) Statistic:	66.8559	42.3229	34.0543	---
P-Value:	0.0000	0.0010	0.0124	---
Restricted Estimate of ϕ^G_{RM}:	-0.0429	0.0155	0.0091	-0.0048
Standard Error:	0.0802	0.0677	0.0470	0.0405
t Statistic (against zero):	-0.5340	0.2290	0.1932	-0.1179
P-Value:	0.5933	0.8189	0.8468	0.9062
t Statistic (against unity):	-12.9956	-14.5443	-21.0723	-24.7946
P-Value:	0.0000	0.0000	0.0000	0.0000
χ^2 Signif. of Restriction that ϕ^G_{RM} Estimates are Equal:	---	---	---	0.5185
Restricted Estimate of λ_{RM}	-2.4191	-2.0294	-0.7976	---
Standard Error:	0.5799	0.4640	0.4412	---
t Statistic (against zero):	-4.1714	-4.3734	-1.8077	---
P-Value:	0.0000	0.0000	0.0706	---
χ^2 Signif. of Restriction that λ_{RM} Estimates are Equal:	---	---	---	0.0373

level in any single equation *or* in all three collectively, and neither weak nor strong global independence ($\phi^G_{RM} = 0$ and $\beta_R(L) \equiv 0$, respectively) is rejected at the 10 per cent level, even with the restrictions imposed collectively.

Finally, the joint α, β_R, and γ_R restriction was imposed by deleting all level variables from equation (10A″), and the following expressions were embedded to permit estimates of ϕ^G_{RM} and λ_{RM} by the l'Hôpital rule:

$$(4'') \quad \begin{cases} \phi^G_{RM} = \left(\beta_{R,1} + 2\cdot\beta_{R,2} + 3\cdot\beta_{R,3} + 4\cdot\beta_{R,4}\right)/\left(\alpha_1 + 2\cdot\alpha_2 + 3\cdot\alpha_3 + 4\cdot\alpha_4\right) \\ \lambda_{RM} = \left(\gamma_{R,1} + 2\cdot\gamma_{R,2} + 3\cdot\gamma_{R,3} + 4\cdot\gamma_{R,4}\right)/\left(\alpha_1 + 2\cdot\alpha_2 + 3\cdot\alpha_3 + 4\cdot\alpha_4\right) \end{cases}$$

The results of the restricted GMM-NLSYSTEM estimates of ϕ^G_{RM} are summarized in the middle part of panel B, Table 7. Despite the first differencing of all variables, the standard errors of estimate are less than one per cent and all estimates of ϕ^G_{RM} grossly insignificant--even though the standard errors are small. As a chi-square test on the three estimates of ϕ^G_{RM} indicated no significant differences among them, the equality restriction was imposed and the pooled estimate, reported in the final column of panel B in Table 7, is virtually zero, with a very small standard error. Global independence of the Swiss multi-lateral real exchange rate clearly cannot be rejected.

The estimates of the real terms-of-trade coefficient, λ_{RM}, appear in the lower part of panel B, Table 7. The estimates made using the GDP deflator and consumer prices, -2.42 and -2.03, respectively, do not differ significantly from one another and also are quite similar to the estimates of λ_N (-2.32 and -2.25) reported in Table 3, which provides an insight into the targets of Swiss monetary policy.[32] It follows from equation (6) that $\lambda_{RM} = \delta(PT_{CH} - P_{CH})/\delta ytt_{CH}$, but as $\delta(PT_{CH})/\delta ytt_{CH} = \delta(EX^{US}_{CH})/\delta ytt_{CH} \equiv \lambda_N$, we have $\lambda_{RM} = \lambda_N - \delta(P_{CH})/\delta ytt_{CH}$.

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[32] The estimate of λ_{RM} based on producer prices is significantly smaller than the other two in absolute magnitude, which implies that $\delta(PPI_{CH})/\delta ytt_{CH} < 0$. Since the PPI is a narrowly-based index covering mainly traded goods, and as $\delta(PT_{CH})/\delta ytt_{CH} < 0$, that implication is certainly plausible.

If the monetary authorities successfully target the price of non-traded goods (i.e., wages), then $\mathcal{E}\left(\delta(PNT_{CH})/\delta ytt_{CH}\right) = 0$, where $\mathcal{E}$ is the expected value operator, and hence $\mathcal{E}\left(\delta(P_{CH})/\delta ytt_{CH}\right) = (1-w_{CH})\cdot\lambda_N$, and $\lambda_{RM} = w_{CH}\cdot\lambda_N < \lambda_N$. But if the authorities target the overall price level, then $\mathcal{E}\left(\delta(P_{CH})/\delta ytt_{CH}\right) = 0$ and $\lambda_{RM} = \lambda_N$, which would appear to be the case.

Local Independence Tests of the Bi-Lateral Real Exchange Rate

Since the joint null hypothesis $\{\Phi^G_{RM} = 0,\ \Phi^G_{RB} = -1\}$ has not been rejected, formal testing of the bi-lateral real exchange rate for global independence is pointless; at best, the $BRER^{US}_{CH}$ can be *locally* independent. Recalling that $\Phi^G_{RB} = -1 \Rightarrow \delta BRER^{US}_{CH}/\delta EX^{US}_{EUR} = \theta^{EUR}_{CH}$, a test for local independence *vis à vis* the dollar/mini-ECU nominal exchange rate can be based on an estimate of the reduced form for PTF [equation (9′)]. To simplify that process, the assumption that world markets for Swiss traded goods are dominated, together with the Swiss, by the U.S.-dollar and European-currency blocs was tested on that reduced form. With $\Theta^{CH}_{CH} + \Theta^{EUR}_{CH} + \Theta^{US}_{CH}$ (and hence $\theta^{EUR}_{CH} + \theta^{US}_{CH}$) set equal to unity, $PTF^*_{CH} = \left(\theta^{EUR}_{CH}\cdot PF_{EUR} + \theta^{US}_{CH}\cdot P_{US}\right)$, where PF_{EUR} and P_{US} are the price levels of the four major European countries and the U.S., respectively, both in U.S. dollars. Using that assumption and the strong multi-lateral global independence result obtained earlier $[\beta_R(L) \equiv 0]$, equation (9′) becomes:

$$(9'') \qquad \alpha(L)\cdot PTF_{CH,t} = \alpha(L)\cdot\left(\theta^{EUR}_{CH}\cdot PF_{EUR,t} + \theta^{US}_{CH}\cdot P_{US,t}\right) - \left(\theta^{CH}_{CH}\cdot\gamma_R(L)\right)\cdot ytt_{CH,t}.$$

Equation (9″) was estimated by GMM-NLLS (with five lags) for each price level measure.[33] All estimates of θ^{EUR}_{CH} and θ^{US}_{CH} were significantly different from zero at the 0.87 per cent level (or less) and, while the sum of the estimates of θ^{EUR}_{CH} and θ^{US}_{CH} exceeded unity in all three case, the unit-sum

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[33] The instruments include a constant, PTF, the U.S. and European price levels (both in U.S. dollars), the three versions of MRER, and the residuals of a regression of ytt on the U.S. and European price levels.

restriction was not rejected at the 40 per cent level; these results are reported in panel A of Table 8. Equation (9″) was then re-estimated with that restriction imposed; the preliminary estimates of θ_{CH}^{EUR}, reported in panel A of Table 8, range from 0.64 to 0.75 and all are significantly different from zero at the 0.00 per cent level and from unity at the 1.23 per cent level. These preliminary results suggest that the Swiss/U.S. bi-lateral real exchange rate is not locally independent *vis à vis* the dollar/mini-ECU exchange rate.

A more general test was based on equation (10B), the reduced form for the bilateral real exchange rate. The $\theta_{CH}^{EUR} + \theta_{CH}^{US} = 1$ and $\beta_R(L) \equiv 0$ restrictions radically simplify that reduced form, permitting a direct estimate of θ_{CH}^{EUR}; with those restrictions imposed, equation (10B) becomes:

$$(10B') \quad \alpha(L)\cdot BRER_{CH,t}^{US} = \left(\theta_{CH}^{EUR}\cdot\alpha(L)\right)\cdot BRER_{EUR,t}^{US} + \left(\gamma_R(L)/(1-\Theta_{CH}^{CH})\right)\cdot ytt_{CH,t},$$

where $BRER_{EUR}^{US} = P_{US} - PF_{EUR}$ is the bi-lateral real exchange rate between the four major European countries and the U.S. Since shocks to $BRER_{EUR}^{US}$ reflect either a shock to the dollar/mini-ECU nominal exchange rate or a price level shock in the U.S. and/or Europe, $\Phi_{RB}^{L,ECU} \equiv \delta(BRER_{CH}^{US})/\delta(BRER_{EUR}^{US}) = \theta_{CH}^{EUR}$ is the local Swiss bi-lateral dependence coefficient *vis à vis* any of those variables; accordingly, an estimate of θ_{CH}^{EUR} is the key to a definitive test of local independence of the Swiss franc/U.S. dollar real exchange rate.

The first step in that process was to attempt a further simplification of equation (10B′); the joint $\alpha(1) = \theta_{CH}^{EUR}\cdot\alpha(1) = \gamma_R(1) = 0$ restriction was tested on a simultaneous estimate of equation (10B′) for the three price level measures by GMM-NLSYSTEM.[34] Chi-square tests, reported in panel B of Table 8, indicate

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[34] Equation (10B′) was reparameterized (with four lags) in the same way as equation (3″). In estimating that equation, the instruments consisted of a constant, EUROX, PTF, the three versions of $BRER_{EU}^{US}$, and the residuals a regression of ytt on the three versions of $BRER_{EU}^{US}$.

TABLE 8

LOCAL INDEPENDENCE TEST OF SWISS BI-LATERAL REAL EXCHANGE RATE: 1974:1-1991:4

A. Test of Unit-Sum Restriction: GMM Estimates of Equation (9″)

GMM-NLLS Regression Results:	PRICE LEVEL MEASURES			
	DEF	CPI	PPI	ALL
Sum of Estimated θ_{CH}^{EUR} & θ_{CH}^{US}:	1.0579	1.0319	1.0822	---
Standard Error of Sum:	0.0885	0.1186	0.0986	---
t Statistic (against unity):	0.6539	0.2693	0.8341	---
P-Value:	0.5163	0.7888	0.4084	---
Restricted Estimates of θ_{CH}^{EUR}:	0.6401	0.7533	0.6660	---
t Statistic (against zero):	5.9240	7.9352	13.0496	---
P-Value:	0.0000	0.0000	0.0000	---
t Statistic (against unity):	-3.3305	-2.5989	-6.5449	---
P-Value:	0.0017	0.0123	0.0000	---

B. Generalized Method-of-Moments Estimates of Equation (10B′)

Restriction:	Test:	DEF	CPI	PPI	ALL
α, $\theta_{CH}^{EUR}\cdot\alpha$ & γ_R.	$\chi^2(3)$:	4.9124	3.3080	4.0801	11.9002
	Signif:	0.1783	0.3465	0.2529	0.2190

GMM-NLSYSTEM Regression Results:	DEF	CPI	PPI	ALL
R^2(Above Restrictions Imposed):	0.6718	0.6599	0.5948	---
Standard Error of Estimate:	0.0343	0.0341	0.0365	---
Durbin-Watson Statistic:	1.9936	1.8942	1.9544	---
Q(18) Statistic:	14.8939	14.1610	15.2372	---
P-Value:	0.6692	0.7185	0.6456	---
Restricted Estimates of θ_{CH}^{EUR}:	0.6710	0.7021	0.6019	---
Standard Error:	0.0428	0.0459	0.0438	---
t Statistic (against zero):	15.6811	15.2885	13.7364	---
P-Value:	0.0000	0.0000	0.0000	---
t Statistic (against unity):	-7.6887	-6.4877	-9.0846	---
P-Value:	0.0000	0.0000	0.0000	---
χ^2 Signif. of Restriction that θ_{CH}^{EUR} Estimates are Equal:	---	---	---	0.0000
Restricted Estimates of λ_{RB}:	-5.2834	-4.9384	-4.3413	---
Standard Error:	1.2669	1.1126	1.0796	---
t Statistic (against zero):	-4.1704	-4.4386	-4.0212	---
P-Value:	0.0000	0.0000	0.0001	---
χ^2 Signif. of Restriction that λ_{RB} Estimates are Equal:	---	---	---	0.0021

that the joint restriction is not rejected at the 15 per cent significance level. With that joint restriction imposed, equation (10B′) can be written in a way that which involves only first-differenced variables and permits θ^{EUR}_{CH} to be estimated directly without resorting to the l'Hôpital rule of limits:

$$\Delta BRER^{US}_{CH,t} = \theta^{EUR}_{CH} \cdot \Delta BRER^{US}_{EUR,t} + \sum_{j=1} \alpha_j \cdot \left(\theta^{EUR}_{CH} \cdot \Delta BRER^{US}_{EUR,t-j} - \Delta BRER^{US}_{CH,t-j}\right)$$
$$+ \left(1/(1-\Theta^{CH}_{CH})\right) \cdot \sum_{j=0} \gamma_{R,j} \cdot \Delta ytt_{CH,t-j}.$$

This final version of equation (10B′) was estimated by GMM-NLSYSTEM and the results are reported in panel B of Table 8.[35] Given that all variables were first differenced, the restricted fits are quite good with standard errors of estimate of less than four per cent. The GMM-NLSYSTEM estimates of θ^{EUR}_{CH}, which range from 0.60 to 0.70, are very tight and differ significantly from *both* zero and unity at the 0.00 per cent level of significance; moreover, they are highly consistent with the single equation GMM-NLLS estimates of θ^{EUR}_{CH} reported in panel A of Table 8, the differences being only about one standard error in each case. As the four major European countries appear to have the dominant (but less than total) power in the world markets for Swiss traded goods, local independence of the Swiss franc/U.S. dollar real exchange rate *vis à vis* the U.S. and European price levels as well as the dollar/mini-ECU nominal exchange rate is definitively rejected.[36]

Moreover, the bi-lateral real exchange rate between Switzerland and its European neighbors *also fails* the local independence test. By subtracting

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[35] The instruments consisted of a constant, EUROX, PTF, $BRER^{US}_{EU}$, the residuals a regression of ytt on $BRER^{US}_{EU}$, and TT (with four lags).

[36] Had Edwards (1989) included the Swiss case in his survey, he may well have found episodes of serious "real exchange rate misalignment" which presumably would have been attributed to "inconsistent" Swiss macro-economic policy when, in fact, no such misalignments seem to have occurred.

$\alpha(L)\cdot BRER^{US}_{EUR}$ from both sides of equation (10B′), we obtain the reduced form for that real exchange rate:

$$\alpha(L)\cdot BRER^{EUR}_{CH,t} = -\left((1-\theta^{EUR}_{CH})\cdot\alpha(L)\right)\cdot BRER^{US}_{EUR,t} + \left(\gamma_R(L)/(1-\Theta^{CH}_{CH})\right)\cdot ytt_{CH,t}.$$

Since $\left(1-\theta^{EUR}_{CH}\right) = \theta^{US}_{CH}$, the estimates of θ^{EUR}_{CH} based on equation (10B′) provide implicit estimates of the response of the *Swiss-European* bi-lateral real exchange rate to, say, a depreciation of the ECU *vis à vis* the dollar, and hence a test for local independence of that real exchange rate. As the estimates of θ^{EUR}_{CH} differ significantly from unity at the 0.00 per cent level, $\left(1-\theta^{EUR}_{CH}\right)$ also is significantly different from zero; the Swiss/European bi-lateral real exchange rate is not independent of the ECU-dollar exchange rate.

Finally, equation (10B′) was reparameterized to permit estimation of the real terms-of-trade coefficient, λ_{RB}, using the l'Hôpital rule. The estimates, which are reported in the lower part of panel B in Table 8, range from -4.34 to -5.28 and are highly significant; again the estimate using producer prices is significantly smaller (in absolute value) than those obtained using the GDP or CPI deflators. The fact that $\lambda_{RB} \equiv \lambda_{RM}/(1-\Theta^{CH}_{CH})$ and that the magnitudes of the estimates of λ_{RB} are about double those of λ_{RM} reported in Table 6 suggests that Θ^{CH}_{CH} may be as large as 0.5, indicating that the Swiss may have substantial influence over the external prices of their own traded goods (presumably exports, in this case). In any case, the large swings in the external terms of trade experienced by the smaller countries, together with the sheer magnitude of the estimates of λ_{RB}, indicate that the terms of trade can be a quantitatively important—but often neglected—source of instability in bi-lateral real exchange rates.

Overall, $BRER^{US}_{CH}$ performs quite badly while $MRER_{CH}$ does extremely well, indeed. While the Swiss multi-lateral real exchange rate has been found to be independent of external nominal variables in both the short and the long run, about two-thirds of permanent shocks to the U.S. and/or European prices levels and the dollar/mini-ECU nominal exchange rate are *forever* incorporated into the Swiss/U.S. bi-lateral real exchange rate. That the bulk of the variance in that real exchange rate consists of pure and simple measurement error is reflected in the importance of the external price level variables in both the short and the long run, and also by the fact that the standard errors of estimate of the $BRER_{CH}^{US}$ equations are from four to five times those for the $MRER_{CH}$ equations.

Concluding Comments

The strong response of the bi-lateral real exchange rate to external price level shocks provides a key to the apparent paradox posed by the highly variable bi-lateral real exchange rate and the inability to reject purchasing power parity. The explanation lies in (a) the fact that dollar prices of Swiss traded goods are significantly affected but not totally dominated by either the U.S. or the European price level and (b) the Swiss nominal exchange rate adjusts quickly and fully to changes in external prices of Swiss traded goods. Consequently, shocks to, say, the U.S. price level, which enters directly into the numerator of $BRER_{CH}^{US}$, are only partially offset by the exchange rate. *Accordingly, the Swiss bi-lateral real exchange rate does not reflect the Swiss internal relative price structure but rather measures the external prices of Swiss imports and exports relative to the external (i.e., U.S. or European) price level.* A decline, for example, in that real exchange rate merely reflects a rise in external prices of Swiss traded goods *relative* to the external price level; in short, the Swiss bi-lateral real exchange rate *vis à vis* both the U.S. and the major European countries is hopelessly contaminated by measurement error.

The main findings for the Swiss case can be summarized as follows:

- Despite extremely large fluctuations in the Swiss bi-lateral real exchange rate since 1973, the null hypothesis of purchasing power parity *cannot* be rejected in the Swiss case.

- The Swiss exchange rate reacts quickly to changes in external prices of traded goods, which are fully neutralized in both the short run and the long. The exchange rate response is about the same for export and import prices; a ten per cent increase in either import or export prices results in an immediate revaluation of about five per cent.

- The hypothesis that the Swiss monetary policy has been independent of external inflation cannot be rejected; the modest Swiss inflation since 1973 is strictly a domestic phenomenon. Moreover, the empirical findings are consistent with foreign exchange market efficiency.

- The evidence quite strongly suggests that Switzerland has considerable power over the external prices of her own traded goods. The source of this power is presumably on the export side where many Swiss goods enjoy patent protection (e.g., pharmaceuticals) and/or the status of specialty items for which close substitutes are not available.

- The major European countries and the U.S. possess the remainder of the market power over the prices of Swiss tradeables, with the European countries having by far the largest share; the influence of the "rest of the world" is quite negligible.

- The multi-lateral real exchange rate (i.e., the price of Swiss traded goods relative to those of traded goods) is highly sensitive to the external terms of trade, and the bi-lateral real exchange rate is even more so; indeed, the terms of trade have been the dominant source of disturbances to the Swiss internal relative price structure. An improvement in the terms of trade equal to one per cent of national income causes the multi-lateral (bi-lateral) real exchange rate to fall by more than two (four) per cent.

- It is evident on theoretical grounds that the bi-lateral real exchange rate is, in general, a poor proxy for the true real exchange rate. Just how well it can serve as a substitute depends upon the degree to which the two countries dominate the world market for their traded goods. If that domination is only partial (as in the case of both the Swiss/U.S. and the Swiss/European bi-lateral real exchange rates), severe measurement error results.

- While the *multi-lateral* Swiss real exchange is *globally* independent of permanent shocks to nominal variables, those shocks are *permanently* embodied in both the Swiss/U.S. and Swiss/European bi-lateral real exchange rates. As those bi-lateral real exchange rates are not even *locally* independent, they are "real" in name only and, as such, are unreliable for analytical purposes and misleading in the context of macro-economic policy evaluation.

What is true for the Swiss case may not, of course, hold universally; one does not expect all true real exchange rates to be globally independent and surely cases must exist where the bi-lateral real exchange rate is independent at least locally. But the conclusions of *existing* research based on the bi-lateral real exchange rates are, at best, questionable and, at worst, grossly misleading. Indeed, the inordinate emphasis on the bi-lateral real exchange rate in certain policy circles as an indicator of success or failure of macro-economic policy makes one to wonder just how much serious mischief has been wrought by sheer and simple measurement error.

APPENDIX I: Exchange Rates and Prices of Traded Goods

Ignoring transport costs, tariffs and other barriers to trade, the "law of one price" for internationally-traded good q states that:

$$(I-1) \qquad P^i_q = P^j_q + EX^j_i,$$

where P^i_q is the (natural logarithm of the) price of good q in currency i, and EX^j_i is the (natural logarithm of the) price of currency j in terms of currency i.[37] With no loss of generality, set $i = X$; i.e., the currency of country X will be the *reference* currency.[38] The *excess* demand for good q in country j, $D^{j,q}$, is a function of its *real* price and a vector, Z^j_q, of all other relevant variables (i.e., the market "fundamentals" in country j):

$$(I-2) \qquad D^{q,j} = D^{q,j}\left((P^j_q - P_j), Z^j_q\right)$$
$$= D^{q,j}\left((P^X_q - EX^j_X - P_j), Z^j_q\right)$$

where P_j is the (natural logarithm of the) price level in country j. As:

$$P^X_q - EX^j_X - P_j = (P^X_q - P_X) - (EX^j_X + P_j - P_X)$$
$$\equiv P^{X,R}_q - BRER^j_X,$$

the excess demand for good q in country j can be written as a function of the natural logarithm of the ratio of its *real* price in country X to the bi-lateral *real* exchange rate between countries X and j:

$$D^{q,j} = D^{q,j}\left((P^{X,R}_q - BRER^j_X), Z^j_q\right).$$

Market clearing requires that the M excess demands sum to zero:

$$\sum_j^M D^{q,j}\left((P^{X,R}_q - BRER^j_X), Z^j_q\right) = 0.$$

The summation is then differentiated totally and rearranged:

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[37] To the best of the author's knowledge, this approach was first used by Ridler and Yandle (1972) to analyze the effect of exchange rates on commodity prices. The model presented here first appeared in L. A. Sjaastad, "Exchange Rate Regimes and the Real Rate of Interest," in Connolly and McDermott (1985). A somewhat similar approach has been developed by Dornbusch (1987).

[38] As our interest is in currency *blocs* rather than countries, there is no one to one correspondence between countries and currencies.

$$dP^{X,R}_{q} = \sum_{j}^{M} \left(D^{q,j}_{1}/D^{q}_{1}\right)\cdot d\left(BRER^{j}_{X}\right) - \left(D^{q,j}_{2}/D^{q}_{1}\right)\cdot dZ^{j}_{q},$$

where $D^{q,j}_{1} \equiv \partial\left(D^{q,j}\right)/\partial\left((P^{X,R} - BRER^{j}_{X}\right)$, $D^{q,j}_{2} = \partial\left(D^{q,j}\right)/\partial Z^{j}_{q}$, and $D^{q}_{1} \equiv \sum_{j}^{M} D^{q,j}_{1}$.[39] A local linear approximation relating the *real* price of good q to bi-lateral real exchange rates is obtained by integration:

$$\text{(I-3)} \qquad P^{X,R}_{q} = \sum_{j}^{M} \rho^{q}_{j}\cdot BRER^{j}_{X} + F(Z_{q}),$$

where $\rho^{q}_{j} \equiv D^{q,j}_{1}/D^{q}_{1}$ and $F(Z_{q})$ is the integral of $-\sum_{j=1}^{M}\left(D^{q,j}_{2}/D^{q}_{1}\right)\cdot dZ^{j}_{q}$. The excess demands [equations (I-2)] may be either positive or negative but, as all $D^{q,j}_{1}$ are non-positive, the ρ^{q}_{j} are non-negative fractions that sum to unity. $F(Z_{q})$ captures the Z^{j}_{q} vectors (the global fundamentals) and that term is explicitly assumed to be orthogonal to the $BRER^{j}_{X}$. The fundamentals include all factors (including expectations) that influence the global demand for and supply of good q other than exchange rates.

The structure of the world market for good q is *completely summarized* by the ρ^{q}_{j} in equations (I-3), as those parameters measure the *relative market power* possessed by each participating country. In the limiting case of $\rho^{q}_{j} = 0$, country j is a *price taker* in the world market for good q as any change in its real exchange rate *vis à vis* reference currency X will have no effect on the real price of good q in currency X. At the other extreme, if $\rho^{q}_{j} = 1$, country j is a *price maker* in that market as any change in its real exchange rate will be fully reflected in an equi-proportionate change in the real price of good q country X. Moreover, the magnitudes of the ρ^{q}_{j} have no logical relation to existing patterns of international trade.

The expression for the price of good q can be generalized to an index of the real prices of any set of traded goods (e.g., imports, exports, all traded goods) denominated in currency X; that index is defined as $PT^{R}_{X} \equiv \sum_{q}^{N} \Omega^{q}_{X}\cdot P^{X,R}_{q}$,

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[39] The *excess* demand in country j is $D^{j} \equiv D^{j} - S^{j}$, where D^{j} and S^{j} are domestic demand and supply, respectively. The slope of the excess demand function is $D^{j}_{1} = (D^{j}/P^{j,R}_{q})\cdot\eta_{j} - (S^{j}/P^{j,R}_{q})\cdot\varepsilon_{j}$, where $\eta_{j} \le 0$ and $\varepsilon_{j} \ge 0$ are elasticities of domestic demand and supply, respectively, with respect to the real price of the commodity in country j. The D^{j}_{1} clearly are non-positive.

where the Ω_X^q is a set of "appropriate" non-negative weights that sum to unity. Combining that index with the above expression for $P_q^{X,R}$ results in:

$$PT_X^R \equiv \sum_q^N \Omega_X^q \cdot \left(\sum_j^M \rho_j^q \cdot BRER_X^j + F(Z_q) \right)$$

$$= \sum_q^N \left(\sum_j^M (\Omega_X^q \cdot \rho_j^q) \cdot BRER_X^j \right) + G(Z_X),$$

where $G(Z_X) \equiv \sum_q^N \Omega_X^q \cdot F(Z_q)$ captures the global fundamentals for the set N of traded goods. Moreover, as the $\sum_q^N \Omega_X^q \cdot \rho_j^q$ terms are non-negative and sum to unity, PT_X^R can be written as a weighted average of the $BRER_X^j$:

(I-4) $$PT_X^R = \sum_j^M \Theta_X^j \cdot BRER_X^j + G(Z_X),$$

where $\Theta_X^j \equiv \sum_q^N \Omega_X^q \cdot \rho_q^j$. The Θ_X^j have the same interpretation as the ρ_j^q; they measure the relative market power possessed by country j over the prices of the *set* N of goods traded internationally by country X. Note, of course, that the Θ_X^j will not be the same for different sets (e.g., imports *versus* exports) of internationally-traded goods, but the PT_X^R index can be tailored to refer to any subset of tradeables for any country by choosing the Ω_X^q to correspond to that subset.

Equation (I-4) can be converted into an index defined on nominal prices simply by adding P_X to both sides of equation (I-4):

$$PT_X = \sum_j^M \Theta_X^j \cdot (EX_X^j + P_j) + G(Z_X).$$

Moreover, PT_X can be expressed in the currency of, say, country Y by using the identity $EX_X^j - EX_X^Y \equiv EX_Y^j$ and the property that $\sum_j^M \Theta_X^j = 1$:

(I-5) $$PTF_X = \sum_j^M \Theta_X^j \cdot PF_j + G(Z_X),$$

where PTF_X and PF_j are expressed in terms of currency Y. It is this expression that appears as equation (9) in the text.

APPENDIX II: Terms-of-Trade Endogeneity

From Appendix I it is evident that equation (I-5), which expresses the external prices of traded goods in terms of the price levels in the major countries, can be decomposed into two equations, one for imports another for exports. As the θ's for imports and exports are not unlikely to be identical, the terms of trade may be a function of the PF_j variables, which can lead to bias in the estimates of the reduced forms, such as equations (3′), (10A) and (10B), where ytt_{CH} and/or TT_{CH} appear.

To determine if ytt_{CH} is *endogenous*, the price levels for the four major European countries, the U.S., and Switzerland, all expressed in U.S. dollars, were regressed on ytt_{CH} but as those price levels all exhibit strong positive time trends, they were first detrended to prevent a common time trend from dominating the regression. The *ad hoc* equation was parameterized as follows (where italics indicate detrended variables) in which the time trend in ytt_{CH} was captured by a trend variable:

$$\text{(II-1)}\quad \Delta ytt_{CH,t} = \sum_{i=1}^{3}\left[\left(\sum_{j=0}^{1} a_j\right)\cdot\Delta ytt_{CH,t-i} + \left(\sum_{j=0}^{1} b_j\right)\cdot\Delta P_{US,t-i} + \left(\sum_{j=0}^{1} c_j\right)\cdot\Delta PF_{EU,t-i} + \left(\sum_{j=0}^{1} a_j\right)\cdot\Delta CHPLF_{t-i}\right] + a(1)\cdot\Big(ytt_{CH,t-4} - \psi_{US}\cdot P_{US,t-4} - \psi_{EU}\cdot PF_{EU,t-4} - \psi_{CH}\cdot PF_{CH,t-4} - \psi_T\cdot T\Big),$$

and where ψ_k measures the (long run) response of ytt_{CH} to a permanent shock to variable k $\big($e.g., $\psi_{US} = b(1)/a(1)\big)$. Equation (II-1) was estimated by NLLS for each price level measure (DEF, CPI and PPI) and the results are summarized in Table II-1.

The estimates indicate that the Swiss terms of trade are indeed endogenous with respect to the European, U.S. and Swiss prices levels. That is, all three "countries" possess positive but *differential* market power over the U.S. dollar prices of Swiss importables and exportables; a positive shock to either the U.S. or the European price level worsens the Swiss terms of trade, while a positive shock to the Swiss price level improves them. This is as expected; owing to its small size, Switzerland is highly unlikely to have significant power over *import* prices, those markets being dominated by the large economies (e.g., Europe and the United States). As Swiss *exports*, however, are quite specialized (and often enjoy patent protection), the Swiss may well possess non-negligible power in those markets. By the same reasoning, the U.S. and Europe are likely to have a greater influence over prices of Swiss imports than over those of Swiss exports.

TABLE II-1

ENDOGENEITY TESTS ON ytt; SWITZERLAND, 1974:1-1991:4

U.S. Price Level:	ψ_{US}	t Statistic*	Significance
GDP Deflator	-0.1294	-7.0941	0.0000
Consumer Prices	-0.0904	-4.0609	0.0002
Producer Prices	-0.1048	-9.8176	0.0000
European Price Level:	ψ_{EU}	t Statistic*	Significance
GDP Deflator	-0.0323	-1.9861	0.0524
Consumer Prices	0.0032	0.1768	0.8604
Producer Prices	-0.0397	-3.2448	0.0021
Swiss Price Level:	ψ_{CH}	t Statistic*	Significance
GDP Deflator	0.0458	3.0776	0.0034
Consumer Prices	0.0274	1.7064	0.0940
Producer Prices	0.0619	4.5007	0.0000

* Computed using robust standard errors with 4 lags and a damp factor of 0.75 for the GDP deflator, and 0.85 for consumer and producer prices.

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