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9 Real Exchange Rates in the 1970s

Louka T. Katseli

9.1 Introduction

There is by now a substantive literature and a growing consensus on the failure of the purchasing power parity (PPP) doctrine to explain exchange rate movements in the 1970s. With the advent of floating exchange rates, PPP was rediscovered and presented as a simple and potentially powerful theory of exchange rate determination. Then it was reburied under a strong wave of criticism. The main objections were equivalent to those which had been raised in the 1920s,[1] and included the tenuous empirical validity of perfect commodity arbitrage and the noncomparability of general price indices due to weighting and/or productivity differences. Critics pointed to the predominance of nonmonetary disturbances that can substantially alter the equilibrium terms of trade among countries; they finally highlighted the role of expectations, and potentially asymmetric behavior of governments and/or private market participants in asset and good markets whose actions can produce "overshooting" phenomena.[2]

This latest round of debate on the theoretical and empirical validity of PPP has raised a number of interesting and still unresolved questions that focus explicitly on the role of the real exchange rate in macroeconomic adjustment.

Real exchange rates have moved differently across countries as a consequence of both structural differences and policy responses. The origin of the shocks has also varied. In some cases the predominant shocks originated in

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1. For a review of the most recent round of debates on PPP, see Katseli-Papaefstratiou (1979*a*) and Frenkel (1981).

2. This point was first raised and elaborated by Dornbusch (1976).

the home country: increases in domestic costs of production due to growing government budget deficits adversely affected international competitiveness through real appreciation of the exchange rate. Careful management of the nominal exchange rate through a policy of minidevaluations has in some instances mitigated these effects. Alternatively, in countries with open financial markets, the real appreciation of the currency has occasionally been dampened due to actions of private market participants who diversified internationally in light of expected nominal depreciation of the currency.[3]

In other cases the origin of the disturbance was external to the particular economy: confronted with rising foreign prices, some central banks appreciated their effective nominal exchange rates in an attempt to insulate the domestic economy from external inflationary pressures. Nominal appreciation of the exchange rate in the face of external price increases could also be consistent with private market behavior where agents perceive the deterioration of the terms of trade as a permanent improvement in international competitiveness. More often, however, at least among smaller European countries, increases in foreign prices have been transmitted to domestic prices through substitution and income effects in consumption or production. This process could even be accompanied by exchange rate depreciation if the rise of internal prices exceeds that of traded goods.[4] Finally, changes in nominal exchange rates among hard currencies have led to changes in effective exchange rates which have in turn been transmitted to domestic prices and, in the case of countries with market power, to the foreign currency price of exports.[5]

Thus real exchange rate movements reflect different economic processes which result from the interaction of private market participants and policy authorities. Even in those cases where real exchange rates have remained roughly constant, it is interesting to analyze the economic forces behind the process of real exchange rate determination. Such analysis can highlight the effectiveness of exchange rate policy and can illuminate the fundamental reasons for alternative targets in the exercise of exchange rate policy. Thus in a country where nominal exchange rate devaluation quickly raises domestic prices by the full extent of the devaluation, an active exchange rate policy can only become an instrument of anti-inflation policy rather than balance of payments adjustment. Alternatively, if the speed of adjustment is low, nominal exchange rate policy can potentially become a useful instrument of external balance.

3. Increases in domestic cost conditions could also be associated with a drop in foreign prices due to labor market behavior in the foreign country (Branson and Rotemberg 1980) or the presence of intermediate goods (Katseli and Marion 1982).

4. For a discussion of overshooting of internal prices of home goods, see Corden and Jones (1976) and Katseli-Papaefstratiou (1979*b*).

5. If the demand elasticity for exports is not infinite, devaluation by the home country reduces the foreign price of exports.

In countries where nominal exchange rates are market determined, the transmission from nominal exchange rate movements to relative prices and from prices to exchange rates can highlight the role of the current account in the process of exchange rate determination. In a rational expectations framework, the instantaneous adjustment of the nominal exchange rate following a given disturbance will critically depend on expectations about the movement of relative prices. Similarly, the dynamic path of the nominal exchange rate to its new equilibrium level will depend on the actual and expected movement of the real exchange rate which determines the current account and hence the rate of accumulation of foreign assets.[6]

In light of these considerations, this paper presents a comparative analysis of the implied linkages between nominal exchange rates and relative prices for 13 industrialized countries during the 1974–80 period of floating rates. Section 9.2 highlights the theoretical differences between two commonly used indices of real exchange rate movements, namely, the terms of trade and the relative price of traded to nontraded goods. This is done in a pure two-country, four-good trade model following the work by Bruno (1976), Jones (1979), Katseli (1980), and more recently Srinivasan (1982). The model is solved for the equilibrium terms of trade and relative price of nontraded goods in response to a number of disturbances in the home or foreign country. Even in the context of this stark framework, it can be readily seen that the movement of the two indices is not analytically equivalent so that the choice of index becomes crucially important for empirical work.

Section 9.3 provides a comparative study of the two relative price indices for thirteen OECD countries during the period of floating rates and analyzes their time series properties for that same period. The lack of any systematic correspondence in the movement of the two indices, which is suggested in the theoretical analysis of section 9.2, is also evident in the empirical findings of this section.

In section 9.4, movements in the real exchange rate, defined now as the relative price of nontraded to traded goods, are decomposed into movements of the nominal exchange rate, a foreign price, and a domestic price component. The analysis of their time series properties supports the view that in the floating rate period there has not been a one-to-one correspondence between movements in exchange rates and prices, as a simple PPP view would maintain. Instead exchange rates have generally followed an AR1 process while prices all followed cyclical AR2 processes. This provides partial support to the theoretical argument that the process of exchange rate determination is qualitatively different from the process of relative price determination, and does not contradict the conventional hypothesis that exchange

6. Whether or not news about the current account affects nominal exchange rate movements will depend on the market's expectations about real exchange rate movements (Branson 1977, 1981).

rates are determined in assets markets which clear faster than goods markets. Statistical exogeneity, however, is harder to ascertain.

Section 9.5 investigates different patterns of statistical exogeneity among nominal exchange rates, domestic, and foreign prices and simulates the implied adjustment to unexpected shocks in each of these variables for the OECD countries in the sample. The analysis highlights some of the observed differences of behavior and the appearance of vicious circles.

The last section of the paper summarizes the results.

9.2 The Equilibrium Real Exchange Rate: Alternative Interpretations

In static trade theory long-run equilibrium is usually identified with balance on current account.[7] The equilibrium real exchange rate is thus identified with the vector of relative prices that balances the current account (Katseli 1979*a*).

Depending on the object of the analysis most models of real exchange rate determination have focused either on the terms of trade or the relative price of traded to nontraded goods. In traditional two-country, two-good models, the equilibrium real exchange rate has almost always been identified with the terms of trade.[8] Alternatively in models where nontraded goods play an important role in balance of payments adjustment, the terms of trade are usually assumed to be determined exogenously and traded goods are assumed to be perfect substitutes and thus aggregated into a composite good (Dornbusch 1973; Bruno 1976). Given the importance of nontraded goods and trade in differentiated products in most OECD countries (Krugman 1980), such restrictive assumptions are not necessarily warranted except for analytical purposes. It is important to realize that in the process of adjustment both relative prices are involved, that is, the terms of trade and the relative price of traded to nontraded goods. This fundamental insight goes back to Pearce (1961) if not still earlier to Keynes (1930) and Ohlin (1929*a*, 1929*b*). Introduction of nontraded goods into a simple two-country model where each country is completely specialized in the production of a traded commodity allows the relationship between the two relative price indices in both flow and stock equilibrium to be demonstrated clearly.[9] The effects of different shifts such as technological change in either sector on both equilibrium relative prices can then be easily derived.

This is the structure of the theoretical model that is presented in this section. It is a static trade model where all goods are final and where there is

7. Most analyses at least in the finance literature abstract from long-run structural imbalances that may be planned especially in the context of developing economies with substantial foreign borrowings. Most notable exceptions are the works by Bardhan (1970) and Bruno (1976).

8. Besides most trade theory models one should include in that tradition the work by Branson (1981), Krugman (1981), and Sachs (1981).

9. In the flow equilibrium solutions, the stock of money is held fixed while in stock equilibrium it becomes endogenous as the current account is assumed to be balanced.

only one tradeable private asset, money, that can be accumulated through the trade balance. All these assumptions could in turn be relaxed along the lines of recent papers (Giavazzi 1980; Obstfeld 1981a; Katseli and Marion 1982). The objective here is not to present a complete list of factors that could affect the real exchange rate but rather to highlight the differences between the equilibrium properties of the two relative indices in the simplest general equilibrium model.

Each country is assumed to produce a nontraded good (H and H^*, where a "*" indicates the foreign country) using a fixed amount of sector-specific capital ($\bar{K}_h$ and $\bar{K}_h^*$) and labor (N) which is free to move between the nontraded and traded good sector in each country but not internationally. The two trading countries are assumed to be completely specialized with the home country producing an exportable commodity (X) and importing the foreign country's traded good (M). The assumption of complete specialization can be justified on grounds that each of the major OECD countries produces a different bundle of products. It also makes the model solvable, as it reduces the number of relative prices that need to be endogenously determined to three. Using the home country's exportable price as the numeraire,[10] the relevant relative prices are the home and foreign country's relative prices of nontraded goods (P_h and P_h^*) and the terms of trade (P_m) between the two countries.

The exogenous shifts that are analyzed in the comparative-static exercises are increases in the stock of capital used by different sectors, representing capital-augmenting technical progress; increases in the desired real wage that could be attributed to rising degrees of unionization; changes in the marginal propensity to save which could result either from shifts in intertemporal preferences or from policy; and a money transfer from one country to the other. Money is assumed to be the only asset that constitutes private wealth.[11] Thus saving, which is equal to the trade balance, is also equal to the flow excess demand for money by the private sector. The effects of all disturbances on relative prices will be presented both on impact when the stock of money is given, but there is positive saving or dissaving in each country through the balance of payments, and in the long run where the actual money holdings equal their desired level and hence saving and the trade balance are zero.

The full model is set out and described below and a more detailed explanation of the workings of the labor and goods markets follows.[12] A complete list of symbols is presented in table 9.1.

10. The choice of the numeraire turns out to be important and linked to the homogeneity postulates of the demand functions.

11. The capital stock is assumed to be held by the public sector and profits earned by the government are returned to the public in a lump-sum transfer.

12. The exchange rate is assumed to be held constant or at least to be determined separately in asset markets (Katseli and Marion 1982). This will be shown to be consistent with the empirical findings later on. The model could be significantly enriched if financial markets are introduced and expectations explicitly modeled.

Table 9.1 **Notation**

H = nontraded (home) good.
X = home country's exportable good.
M = foreign country's exportable (home country's importable).
P_h = price of home country's nontraded good relative to exportable.
P_m = terms of trade (an increase in P_m is equivalent to a deterioration in the terms of trade of the home country).
K_i, $i = x, m, h, h^*$ = sector-specific capital used in each sector i.
A = shift parameter of labor supply function in each country.
W = real wage in terms of the exportable commodity.
N_i, $i = x, m, h, h^*$ = employment in each sector.
C = desired real consumption expenditures in terms of the home country's exportable.
λ = speed of adjustment of actual to desired money holdings.
k = inverse of velocity of circulation.
$\lambda k = s$ = marginal propensity to save.
Y = real income in terms of the home country's exportable.
M = real money supply in terms of the home country's exportable.

Note: Asterisks refer to foreign variables denominated in foreign exchange. Subscripts s and d attached to quantities refer to supplies or demands of goods, while subscript $i = x, m, h, h^*$ refers to sector-specific variables.

The Model

(1) $$H_s(P_h, P_m, K_h, A) - H_d(P_h, P_m, C) = 0.$$

(2) $$H_s^*(P_h^*, P_m, K_h^*, A^*) - H_d^*(P_h^*, P_m, C^*) = 0.$$

(3) $$X_s(P_h, P_m, K_x, A) - X_d(P_h, P_m, C) - X_d^*(P_h^*, P_m, C^*) = 0.$$

(4) $$M_s^*(P_h^*, P_m, K_m^*, A^*) - M_d^*(P_h^*, P_m, C^*) - M_d(P_h, P_m, C) = 0.$$

(5) $$C = Y - S.$$

(6) $$C^* = Y^* - S^*.$$

(7) $$Y = P_hH_s + X_s.$$

(8) $$Y^* = P_h^*H_s^* + P_mM_s^*.$$

(9) $$S = \lambda[kY - M].$$

(10) $$S^* = \lambda^*[k^*Y^* - M^*].$$

(11) $$X_s(P_h, P_m, K_x, A) - X_d(P_h, P_m, C) - P_mM_d(P_h, P_m, C) = 0.$$

As in Katseli (1980), equations (1) and (2) specify the equilibrium condition in the nontraded good markets of both countries, while equations (3) and (4) impose the overall equilibrium clearing conditions in the international market for the traded commodities X and M. Equations (3) and (4) together imply that in flow equilibrium one country's deficit should be the other country's surplus.

The specification of the labor markets follows the work by Argy and Salop (1979) and Katseli and Marion (1982), where firms determine the demand for labor by equating the nominal wage to the value of the own marginal product of labor while the supply of labor in each sector is assumed to depend on the nominal wage divided by the expected price level (W/P^e); the expected price level (P^e) is assumed to be a function of the consumer price index. It is due to this assumption that the terms of trade enter the supply function of the nontraded goods. The shift parameter A represents exogenous movements in the supply of labor schedule. Appendix 1 gives a derivation of the functional forms for the supply curves presented in equations (1) and (2) and by extension (3) and (4).

Demand for home goods depends on the own relative price, the terms of trade, and real consumption expenditures, the latter defined by equations (5) and (6). All goods are assumed to be gross substitutes and indifference curves homothetic.

Finally, real output, or income in terms of commodity X, is defined in equations (7) and (8), and real saving in equations (9) and (10). Desired saving is equal to the flow excess demand for money. In the absence of government debt or domestic money creation, the private sector accumulates money through the balance of payments.

The condition for stock equilibrium, characterized by a zero rate of asset accumulation, is equation (11).

By appropriate substitution of equations (5)–(10) in equations (1)–(4), and by invoking Walras's law, the model can be reduced to a system of three equations in three unknowns, namely, the two relative prices of nontraded goods, P_h and P_h^*, and the relative price of imports, P_m. Table 9.1 reports the comparative static effects of percentage changes in each of the exogenous variables, K_h, K_x, K_h^*, K_m^*, A, A^*, on P_h and P_m, holding the stock of money fixed. Table 9.2 also reports the effects on relative prices of a money transfer from the foreign country to the home country (i.e., when $\hat{M}^* = -\hat{M}$) and the effects of a change in the marginal propensities to save in both countries.

Table 9.2 **Effects of Various Disturbances on Relative Prices Holding the Real Money Stock, M, Fixed**

Disturbance	$\hat{K}_h$	$\hat{K}_x$	$\hat{K}_h^*$	$\hat{K}_m^*$	$\hat{A}$	$\hat{A}^*$	$\hat{M}^* (= -\hat{M})$	ds	ds^*
$\hat{P}_h$	–	+	?	–	?	?	?	?	+
$\hat{P}_m$	?	?	?	–	?	?	?	+	+

In Appendix 2 it is shown that a sufficient condition for local stability of the system is that the reduction in the labor supply due to an increase in the expected consumer price relative to the price of the exportable is adequately low.

It can be seen from table 9.2 that with few exceptions the movement of the two relative prices is hard to sign unambiguously. The results depend on the relative size of the structural parameters in the two countries such as the relative own-price and cross-price elasticities of demand and supply for each good and the relative marginal propensities to consume. For the convenience of the reader, Appendix 3 gives a complete listing of the solutions, so that the existing ambiguities can be interpreted more easily.

A few general conclusions can be drawn which can be related to known results:

1. An increase in the capital stock used by the home country's nontraded good sector unambiguously lowers the relative price of nontraded goods. This result is well known from the growth and trade literature and is also derived in Bruno (1976). The opposite can be said for expansion of the capital stock in the home country's traded good sector. The effects of these disturbances on the equilibrium terms of trade are ambiguous, however, depending on the relative size of the income and substitution effects in the demand for the three available goods.

2. Increases in the capital stock of the trading partner's nontraded good have ambiguous effects on P_h and P_m. The reason for this is that the ensuing decrease in the foreign country's relative price of nontraded goods causes substitution away from the traded goods at the same time that foreign income probably increases. It is not clear therefore if overall demand by foreigners for the two traded goods increases or not.

3. Contrary to the previous case, growth of the capital stock in the foreign country's traded good reduces the home country's relative price of nontraded goods and the relative price of importables. Expansion of supply of importables unambiguously reduces their price, causing substitution away from the home country's nontraded and traded goods. Thus, if we define the real exchange rate as the relative price of traded goods and the terms of trade as the relative price of exportables (that is, the inverse of $\hat{P}_h$ and $\hat{P}_m$, respectively), it follows that trade-biased growth in the foreign country causes the home country's real exchange to depreciate and its terms of trade to improve.

4. A push for higher real wages in either country has, as one would expect, ambiguous effects on the relative price of goods. The outcome will depend once again on the relative size of the supply and demand elasticities.

5. The results from the transfer experiment are interesting in light of the Ohlin-Keynes insights and can be studied in conjunction with the *ds* experiment. If the home country's money supply is increased by the same amount as the reduction in the money supply of the trading partner, home saving

falls. As in the case of a reduction in the marginal propensity to save, the ensuing change in P_h depends on the marginal propensities to consume the home and exportable commodities. If m_h is sufficiently larger than m_x, then P_h unambiguously increases. The effects on P_m are harder to ascertain. A reduction in saving unambiguously reduces P_m as consumption of both the nontraded good and the exportable rises in the home country. However, the effects of a transfer which increases M in the home country depend not only on the home country's reaction but also on the foreign country. Hence, as is shown in Appendix 3, the relative size of both the home and foreign marginal propensities to consume is important.

The ambiguities that characterize the flow equilibrium solutions reappear in the stock equilibrium version, which is characterized by a balanced current account and an endogenous money supply. In stock equilibrium the system consists of four equations in four unknowns and can be solved recursively, as is shown in Appendix 4.

From the above, it is evident that both the origin of any given disturbance and the choice of the relative index will determine the effects of any given real shock on what is called the "equilibrium real exchange rate." In the empirical section that follows, the two indices will be approximated first by the relative price of foreign to domestic wholesale prices, a proxy for the relative price of traded goods between countries and hence the terms of trade, and second by the price of traded goods relative to the value-added deflator, a proxy for the relative price of traded to nontraded goods.[13]

9.2 Indices of Real Exchange Rates

An index usually used to describe the real exchange rate in empirical studies is the ratio of foreign to domestic wholesale prices expressed in a common currency (Branson 1981). As wholesale prices exclude services, a major component of nontraded goods, they can be considered proxies for relative traded good prices and thus the terms of trade. Data for the construction of this index (R^w) come from the International Monetary Fund and are based on quarterly observations.[14]

The R^{tn} index, that is, the relative price of traded to nontraded goods, is constructed by deflating the home currency price of traded goods by the value-added deflator which is used as a proxy for the price of nontraded goods. The home currency price of traded goods is calculated by taking a weighted average of export and import unit value indices for each country as these are given by the IMF's *International Financial Statistics*.

13. The relevant wholesale price index was also used in subsequent tests as a proxy for traded good prices. The results are not reported here but are available upon request.

14. The weights used in these calculations are based on trade in manufacturing commodities among 14 countries, 13 of which are included in our sample. (The sole exception is Switzerland.) They can be readily obtained from the author.

Figures 9.1–9.5 plot the two relevant indices for five major industrialized countries, namely, the United States (A), Japan (J), Germany (G), United Kingdom (E), and France (F).

The United States is the only country which has experienced a continuous depreciation of its real exchange rate almost for the whole period, regardless of which index is used. The other countries' experience can be roughly subdivided into three subperiods. During the first period, which ends around the second quarter of 1974, the relative price of traded to nontraded goods increased while domestic wholesale prices rose rapidly. This trend is especially characteristic of Japan and Germany. The second period, roughly extending from 1974 to 1978, is quite dissimilar across countries. The two real price indices stayed roughly constant in the case of the United States and Japan, while they exhibited substantial fluctuations in the other countries. After 1978, France and England experienced real appreciations and the United States and Germany real depreciations. The evidence on Japan is mixed.

Table 9.3 provides some information on the stochastic properties of the two real exchange rate indices for the whole period of the 1970s by comparing the variability of each index around trend and the correlation coefficient between the two for each country. The correlation coefficient between each index and the current account balance is also included, even though

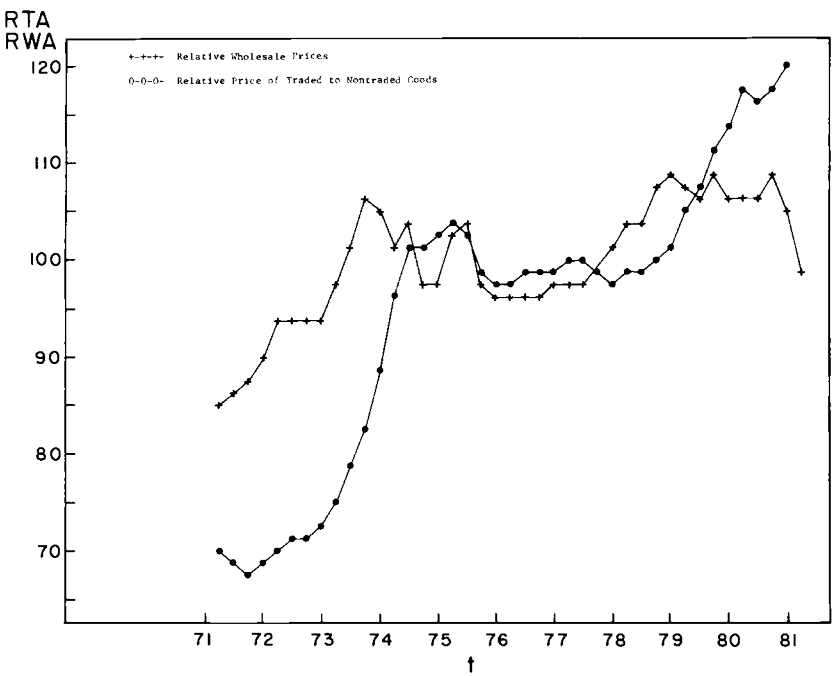

Fig. 9.1 Alternative measures of real exchange rates—United States

Fig. 9.2 Alternative measures of real exchange rates—Japan

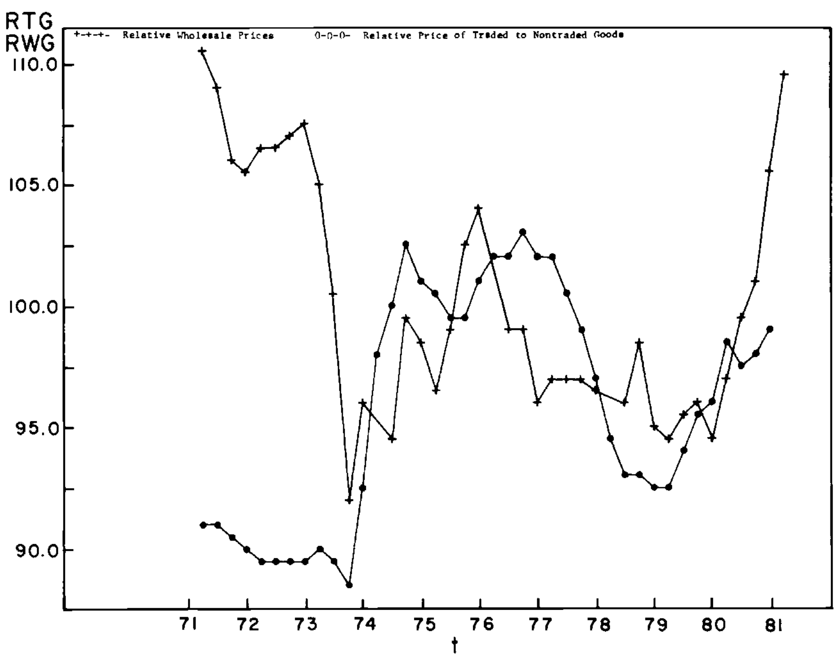

Fig. 9.3 Alternative measures of real exchange rates—Germany

Fig. 9.4 Alternative measures of real exchange rates—United Kingdom

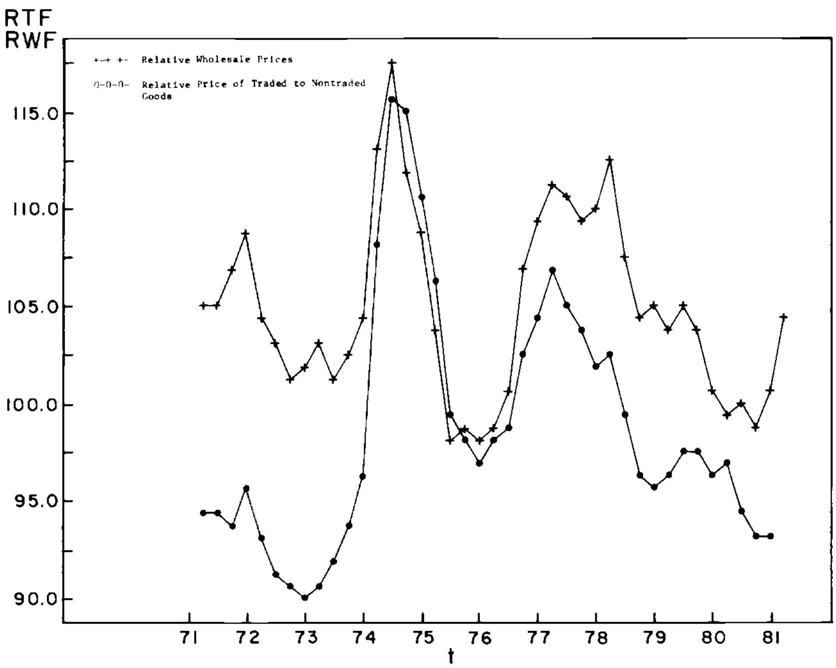

Fig. 9.5 Alternative measures of real exchange rates—France

Table 9.3 **Comparison of Real Exchange Rate Variability and Correlations (1971.1–1980.4)**

	Real Exchange Rates (R)		Correlations		
Countries	$\sigma_{R^{tn}}$	$\sigma_{R^{w}}$	$\rho(R_t^{tn}, R_t^{w})$	$\rho(CA_t, R_t^{tn})$	$\rho(CA_t, R_t^{w})$
United States	7.7	4.3	.307	.559	.258
Canada	3.2	3.6	.141	−.043	.140
Japan	11.1	7.2	.561	−.443	−.239
United Kingdom	6.7	10.3	.784	−.491	−.537
West Germany	4.4	6.4	−.116	.287	−.642
Austria	2.0	3.1	.259	−.069	−.015
Netherlands	5.5	3.3	.420	.103	−.301
Denmark	5.4	5.8	.194	−.177	−.079
Belgium	4.7	4.4	.112	−.330	−.653
France	6.3	4.4	.738	−.417	−.204
Italy	7.7	3.8	.334	−.542	.041
Norway	5.6	5.8	−.124	.351	.639
Sweden	2.4	5.1	−.334	−.518	.383

1. Data are detrended and deseasonalized.
2. Source of all data is the IMF.
3. Both indices are defined as relative prices of foreign to domestic variables; $R^{tn} = \frac{E\,(w_1P^x + w_2P^m)}{P^v}$ and $R^w = \frac{E\,(FP^w)}{P^w}$.

this study will stop short of investigating the properties of current account adjustment. It is interesting to note, however, that ρ is in most cases negative, probably reflecting strong *J* curve effects.

Comparing the standard deviations of the two indices which are used as measures of variability around trend, it is interesting to note that experiences differ across countries even though the underlying reasons for these differences are not apparent in such aggregate analysis. In terms of variability of the R^{tn} index during the floating rate period, Japan has clearly the lead, followed by the United States, Italy, and England. In terms of R^w, the United Kingdom and Japan are the two leading countries. Germany and countries in the deutsche mark currency area have experienced considerably less real exchange rate variability, regardless of the index. In all cases, these developments could be attributed either to private market behavior, to policy, or even to differences in structural characteristics which account for different transmission processes. It is evident, however, that whatever the reason, the real exchange rates of most countries moved sufficiently to contradict a PPP view of exchange rate determination. This is consistent with most available empirical findings (Frenkel, 1981). Section 9.4 below will pursue this line of inquiry further.

The correlation coefficient between the two relative price indices (detrended and deseasonalized) is highest in the case of the United Kingdom (.784) but low and sometimes negative in most other cases. Thus, the choice of the real exchange rate index becomes crucial.

This becomes clearer if the time series properties of the two indices are compared more closely. Given the instability of the international system during the first 3 years of the 1970s, which is evident in figures 9.1–9.5, 1974.2 was chosen as the base period of the empirical investigation.

Table 9.4 presents the autoregressive structure of the two quarterly time series where each variable is regressed on its own past lags. In each regression and in all subsequent tables, a constant and seasonal dummy variables are included while a log-linear trend has been removed. All variables in this and subsequent tables are stated as natural logarithms. Significance at the 5% and 10% levels is indicated by one or two asterisks, respectively.

For each of the thirteen countries in the sample, the fourth-order univariate autoregression (AR4) obtained by least squares fit over the 1974.2–1980.4 period is presented. The lags are subsequently shortened and the results of the appropriate second-order or first-order autoregressive structures are also reported. In all cases the standard errors increase only slightly.

As was expected, the two time series have quite different properties. In all countries except Austria, Norway, and Sweden, R^{tn} exhibits AR2 properties with convergent cyclical responses to disturbances,[15] while R^{w} is in most cases an AR1 stable process. Exceptions are Canada, Japan, France, and Sweden, where R^{w} is a stable AR2 process, and the United Kingdom, where the system could be considered explosive. These differences in the properties of the two time series can be attributed to the relative sluggishness of domestic nontraded good prices which causes a lengthier adjustment process. It should also be noted that the coefficient of R^{w}_{t-1} is in some cases over .90 and in the United Kingdom, Denmark, Norway, and Italy not significantly different from unity. This would make the R^{w} close to a random walk process in which a given disturbance to the system is sustained indefinitely. It is thus evident both from the theoretical analysis of section 9.2 and the empirical evidence provided so far that the two indices do not exhibit similar time series properties.

The analysis of the remaining two sections will be cast in terms of R^{tn}. The choice of the index is influenced by the fact that the properties of R^{w} have received relatively more attention in the recent literature (Branson 1981) and that in the presence of nontraded goods, R^{tn} is a better proxy of overall competitiveness.

Given the choice of R^{tn} as the relevant real exchange rate index, sections 9.4 and 9.5 below investigate further the movements of nominal effective exchange rates, foreign prices of traded goods, and domestic prices, and their interactions.

15. In a second-order difference equation with complex roots convergence requires that the modulus $R(=\sqrt{a_2})$ be smaller than unity.

Table 9.4 **Cross-Country Univariate Regressions of the Real Exchange Rate (1974:2–1980:4)**

	R^m_{t-i}							R^w_{t-i}						
	$t-1$	$t-2$	$t-3$	$t-4$	R^2	SSE	D-W	$t-1$	$t-2$	$t-3$	$t-4$	R^2	SSE	D-W
United States	1.49*	−.39	−.26	.10	.98	.002	2.0	.66*	−.12	.35	−.21	.76	.012	1.9
	1.56*	−.64*			.98	.002	2.3	.61*	.08			.74	.014	1.8
Canada	1.18*	.03	−.50	.05	.96	.002	1.8	1.20*	−.60**	.47	−.35	.96	.005	1.5
	1.49*	−.67*			.94	.003	2.3	1.23*	−.43*			.95	.006	1.9
Japan	1.41*	−.56**	−.03	−.04	.92	.025	1.8	1.07*	−.37	.17	−.35	.85	.020	2.1
	1.49*	−.69			.91	.026	1.9	1.24*	−.54*			.81	.026	2.2
United Kingdom	1.34*	−.51	−.04	−.02	.87	.007	1.9	1.00*	−.04	−.03	−.01	.93	.025	1.9
	1.39*	−.59*			.87	.007	1.9	1.01*	−.08			.93	.025	1.9
West Germany	1.35*	−.41	−.04	−.04	.92	.002	1.8	.96*	−.14	.30	−.48	.67	.008	1.6
	1.45*	−.56*			.92	.002	2.0	.80*	.05			.52	.011	1.6
Austria	.77*	−.03	.13	−.17	.89	.003	2.5	.89*	−.27	.22	−.18	.72	.006	1.5
	.77*	.02			.88	.003	2.4	.79*	−.10			.71	.006	1.6
Netherlands	1.14*	−.24	.07	−.16	.88	.006	2.0	.84*	.20	.31	−.43*	.84	.005	2.0
	1.27*	−.38*			.86	.006	2.2	.79*	.22			.80	.006	2.1
Denmark	1.34*	−.62	.28	−.17	.93	.007	1.7	.97*	−.18	.31	−.23	.85	.007	2.0
	1.31*	−.44*			.93	.007	1.8	.92*	−.00			.85	.008	2.1
Belgium	1.11*	−.28	.32	−.45	.92	.007	1.6	1.05*	−.35	.39	−.51*	.95	.004	1.9
	1.36*	−.47*			.90	.008	2.1	1.18*	−.37			.93	.005	2.1
France	1.18*	−.60*	.05	−.11	.96	.004	2.2	1.14*	−.54**	.32	−.36	.85	.010	2.1
	1.32*	−.69*			.96	.004	2.5	1.24*	−.52*			.82	.012	2.4
Italy	.49*	.05	−.01	−.32*	.74	.013	1.8	.93*	−.35	.23	−.28	.65	.013	1.9
	.91*	−.30**			.61	.020	2.4	.92*	−.26			.63	.014	2.0
Norway	.74*	.31	−.12	−.28	.85	.014	1.9	.89*	−.15	.02	−.15	.89	.009	2.0
	.99*	−.10			.81	.018	2.3	.97*	−.30			.89	.010	2.1
Sweden	.57*	.09	−.34	−.03	.79	.002	1.9	1.13*	−.25	−.16	−.06	.89	.008	1.8
	.76*	−.25						1.26*	−.53*			.88	.009	2.1

Notes: All regressions include a time trend and seasonal dummies.

One asterisk implies that the coefficient is significant at the 5% confidence level. Two asterisks imply that the coefficient is significant at the 10% confidence level.

9.4 Decomposition of R^{tn} and Analysis of Time Series Properties of Its Components

Variability of the real exchange rate, R^{tn}, around trend can be decomposed further. Determination of the principal source of variability, if at all possible, can illuminate the importance and effects of "news" relative to the long-run movement of R^{tn}, which is determined by expected changes in competitiveness due to technological innovations, decreasing money illusion or other factors.

Table 9.5 shows that for most countries much of the R^{tn} variability can be attributed to the detrended foreign price of tradeables index. Its standard deviation is considerably higher than that of either the nominal effective exchange rate or the value added deflator with the exception of the United Kingdom where nominal exchange rate variability is dominant. This is not surprising given the fact that the time period under consideration in table 9.5 includes 1973 and hence the dramatic increase in the prices of all imported intermediate goods, most notably oil. The second point to be noted is that for most countries the standard deviation of the value added deflator is the lowest. Austria, the Netherlands, and Belgium, whose exchange rates have been tied to the deutsche mark, are the only exceptions. Low variability of P^v probably reflects countercyclical policies that have been pursued during the period. Finally, contrasting the results of tables 9.3 and 9.5, real exchange rate variability is consistently higher than nominal exchange rate variability in all countries except Canada, the United Kingdom, Austria, and Sweden. The result runs counter to existing perceptions about real exchange rates which in a PPP world are assumed to stay roughly constant, and at least not to exhibit greater variability than nominal exchange rates.

The correlation analysis presented in table 9.5 sheds some light on the process underlying the variability in the real exchange rate index. Once again, experience is quite varied across countries. Foreign and domestic prices have moved closely together in all countries, especially in Japan (ρ = .909), but in most cases the nominal exchange rate has moved in the opposite direction from foreign and domestic prices. A notable exception is Japan. The Scandinavian countries (Denmark, Norway, Sweden) and Austria exhibit the highest negative correlations between exchange rates and each of the two price indices.

With the exception of Japan and the United Kingdom, where the correlation coefficient between nominal and real exchange rates is relatively high, in most countries it is relatively small. This could be the outcome of a PPP market view of nominal exchange rate determination which is probably unlikely given the high variability of the real exchange rates in most countries, or policy-enforced correlations (positive and negative respectively) among the nominal exchange rate and domestic and foreign prices. As was argued in section 9.1, causality can run either way. With respect to domestic prices,

Table 9.5 **Comparison of Price and Nominal Exchange Rate Variability and Correlation Analysis (1971:1–1980:4)**

	Effective Exchange Rate (*E*) σ_E (× *100*)	Prices (*P*)		Correlation Analysis				
		σ_{P^v}	σ_{FP^t}	$\rho(E, R^{tn})$	$\rho(P^v, R^{tn})$	$\rho(P^v, FP^t)$	$\rho(E, FP^t)$	$\rho(E, P^v)$
United States	4.6	2.7	9.0	.255	.040	.566	−.425	−.487
Canada	4.5	3.2	7.4	.131	.456	.791	.667	−.247
Japan	8.2	5.0	8.6	.938	.581	.909	.538	.469
United Kingdom	10.6	4.7	7.0	.680	.001	.296	−.571	.307
West Germany	4.0	1.5	6.7	−.088	.693	.698	−.564	.017
Austria	2.9	3.2	5.8	−.111	.333	.901	−.771	−.505
Netherlands	2.5	2.8	8.1	−.283	.333	.708	−.618	−.366
Denmark	4.7	2.9	7.8	.200	−.138	.674	−.670	−.731
Belgium	2.2	3.4	6.1	.474	.286	.774	.053	−.140
France	4.1	3.4	7.3	.116	−.223	.297	−.486	.024
Italy	4.8	3.7	9.4	.268	.412	.562	−.152	.347
Norway	5.1	3.0	9.1	−.001	−.130	.629	−.789	−.701
Sweden	5.0	3.3	8.9	−.214	.765	.847	−.814	−.428

$R_t^{tn} = E(w_t P^x + w_2 P^m)/P^v$

Notes: Data are detrended and deseasonalized. Source of all data is the IMF; P^x and P^m series come from the IMF's *International Financial Statistics*. Exchange rates are effective rates, defined as home currency per foreign exchange.

a nominal devaluation could be passed on rapidly to domestic prices or alternatively domestic inflationary pressures could influence authorities or the market to depreciate the nominal exchange rate. This process will be consistent with the evidence on Japan, United Kingdom, and Italy, where the correlation coefficient between E and P^v is positive.

A nominal devaluation can induce a decline in the foreign currency price of traded goods if countries possess market power in traded good markets. Alternatively, an increase in foreign prices might lead monetary authorities to appreciate the nominal exchange rate in order to insulate the economy from external inflationary pressures. This would be consistent with the evidence on most other industrialized countries, especially the Scandinavian countries. Given the observed high variability of the real exchange rate and foreign prices and the relatively low variability of the domestic price index, intervention by the monetary authorities is suspected. Section 9.5 investigates more thoroughly the evidence on causality and the adjustment process of individual countries.

Before proceeding with the analysis, however, a few more points should be raised. Table 9.6 describes the dynamic time series properties of the three indices, the nominal effective exchange rate, the value-added deflator, and the foreign price of traded goods for the period 1974.2–1980.4 after the 1973 major realignment of nominal parities. As with the real exchange rate indices, each variable is regressed against past values of itself in a regression which includes a constant, a time trend and seasonal dummies. Lags are subsequently eliminated successively and the final choice is based on the significance level of the estimated coefficient and the standard error of the restricted equation. The F-test of the joint elimination of the third- and fourth-period lags shows that the three indices generally demonstrate properties of an AR1 or AR2 autoregressive process with the exception of West Germany and the United Kingdom.

With the exception of Canada, Japan, France, and Sweden, the exchange rate can be described as an AR1 process. The process is generally stable except in the cases of the United Kingdom and Italy, where the estimated coefficients of E_{t-1} exceed unity while the second lag coefficient is not significantly different from zero. Also for Norway, one of the smaller European countries, the respective estimates in the restricted equation are 1.12 and $-.32$. The coefficients for some of the other small European countries, especially the Scandinavian countries, are close enough to unity that the nominal exchange rate can be effectively characterized as a random walk. This probably explains why the nominal exchange rate in most of these countries has not been allowed to vary much (see table 9.5).

The two prices can be described effectively on the other hand as AR2 processes. According to the reported F-tests, P^v, in the United Kingdom and Germany exhibit even higher-order autoregressive properties. This underlines the sluggishness of the domestic price index which is probably the

Table 9.6 **Cross Country Univariate Regressions of Exchange Rates and Prices (1974.2–1980.4)**

	E							
	−1	−2	−3	−4	R^2	SEE	D-W	*F*(3,4)
United States	.88*	−.06	.33	−.34	.88	.012	1.6	1.5(.24)
	.82	.03			.86	.014	1.5	
Canada	1.39*	−.75**	.41	−.25	.98	.005	1.6	0.7(.49)
	1.36*	−.52*			.98	.006	1.8	
Japan	1.16*	−.19	−.12	−.21	.95	.002	2.1	2.0(.17)
	1.45*	−.69			.94	.027	2.4	
United Kingdom	1.13*	−.04	−.02	−.09	.93	.023	1.9	0.2(.85)
	1.16*	−.15			.93	.023	2.0	
West Germany	.94*	−.11	.24	−.48*	.97	.009	1.5	3.3(.06)
	.80*	.01			.96	.012	1.5	
Austria	.84*	−.37	.18	−.42*	.97	.004	1.4	2.7(.09)
	.76*	−.27			.96	.005	1.6	
Netherlands	.69*	−.13	.24	−.44	.93	.004	1.5	2.0(.16)
	.67*	−.09			.91	.005	1.7	
Denmark	.94*	−.18	.32	−.24	.83	.007	1.8	0.6(.56)
	.88*	−.00			.82	.007	1.9	
Belgium	.75*	−.05	.25	−.35	.90	.005	1.6	1.0(.39)
	.78*	−.01			.89	.006	1.7	
France	1.05*	−.44	.29	−.37**	.86	.009	2.3	2.0(.16)
	1.13*	−.44*			.82	.010	2.4	
Italy	1.13*	−.43	.24	−.22	.98	.017	1.9	0.4(.65)
	1.11	−.33			.98	.018	2.0	
Norway	.99*	.00	−.13	−.10	.88	.005	2.0	0.9(.44)
	1.12*	−.32			.87	.006	2.2	
Sweden	1.25*	−.44	.01	−.09	.94	.008	1.8	0.3(.78)
	1.32*	−.55*			.94	.008	2.0	

1. All regressions include a constant, seasonal dummies, and a time trend.
2. A "*" indicates the coefficient is significant at the 5% level.
A "**" indicates the coefficient is significant at the 10% level.
3. The source of data is the IMF. FP' was computed by division of the P' index by the effective exchange rate.
4. The *F*-test is conducted under the null hypothesis that the third and fourth-lag coefficients are equal to zero; the number in parenthesis is the significance level at which the null hypothesis can be accepted. Germany and Austria are the only countries for which the *F*-test on the *E* and *P* autoregressions point to an AR3 or AR4 structure.
5. The behavior of the stochastic equations is stable in all cases.
6. For Sweden the FP' autoregression was estimated for the period 1974:2–1979:4.

outcome of pricing or stabilization policies. FP' is generally an AR2 process, except possibly in West Germany and Norway.

The observed differences between the properties of nominal exchange rate time series data and those of relative prices, which have also been noted elsewhere (Branson 1981; Frenkel 1981), would be consistent with the

Table 9.6 (Continued)

	P^v							
	−1	−2	−3	−4	R^2	SEE	D-W	$F(3,4)$
United States	1.30*	−.62	.00	.00	.99	.001	2.0	0.0(.99)
	1.30	−.61			.99	.001	1.9	
Canada	1.49*	−.61**	.16	−.21	1.00	.001	2.2	0.7(.49)
	1.67*	−.78*			1.00	.001	2.3	
Japan	1.19*	−.52**	.49**	−.26	.94	.002	1.4	1.6(.23)
	1.03*	−.16			.93	.002	1.4	
United Kingdom	.90*	−.00	.24	.40*	1.00	.001	1.9	5.7(.01)
	1.37*	−.54*			1.00	.002	2.4	
West Germany	.96*	.08	−.05	−.29**	1.00	.000	1.8	6.4(.01)
	1.45*	−.55			1.00	.000	2.2	
Austria	1.12*	−.73*	.66**	−.39**	.99	.001	1.9	2.1(.15)
	1.03*	−.37*			.99	.001	2.0	
Netherlands	1.00*	−.26	−.02	−.12	.99	.002	2.0	0.4(.65)
	1.11*	−.43*			.99	.002	2.2	
Denmark	1.16*	−.18	−.25	.08	1.00	.001	2.4	0.3(.73)
	1.26*	−.44*			1.00	.001	2.4	
Belgium	1.01*	−.20	−.16	.14	1.00	.001	2.6	0.8(.47)
	1.02	−.23**			1.00	.001	2.2	
France	1.32*	−.14	−.32	−.06	1.00	.002	2.1	1.6(.23)
	1.59*	−.70*			1.00	.002	2.5	
Italy	1.42*	−.97*	.32	−.08	1.00	.002	2.0	0.5(.61)
	1.23*	−.58*			1.00	.002	1.7	
Norway	1.17*	−.45	.17	−.16	1.00	.001	2.3	0.4(.65)
	1.23*	−.47*			1.00	.001	2.4	
Sweden	.94*	−.12	−.23	−.01	1.00	.002	2.0	0.9(.44)
	1.12*	−.47*			1.00	.003	2.3	

hypothesis that exchange rates are determined in assets markets, which clear markedly faster than goods markets. Since price adjustments generally are more sluggish than exchange rate adjustments, nominal exchange rates tend to overshoot their equilibrium value as private market participants respond to new information. This would also be consistent with the observed high real exchange rate variability and would apply particularly well to the United States, the United Kingdom, and Germany among the major hard currency countries. The interaction of exchange rates and prices in the other floating countries—Japan, Canada, and France—is harder to ascertain at least from the evidence presented in table 9.6. Section 9.5 provides some further insights into these cases and into the underlying process of real exchange rate determination in the smaller European countries.

9.5 Statistical Exogeneity and Responses to Unexpected Shocks

Following the work of Sargent (1979), Sims (1980*a*), and Taylor (1980), and more recently of Ashenfelter and Card (1981), the stochastic dynamics

Table 9.6 (Continued)

	−1	−2	−3	−4	R^2	SEE	D-W	$F(3,4)$
United States	1.00*	−.18	.27	−.32*	.98	.013	1.5	2.8(.08)
	1.18*	−.30**			.97	.017	1.8	
Canada	1.38*	−.45	−.05	−.04	.98	.006	2.1	0.2(.81)
	1.49*	−.63*			.98	.007	2.3	
Japan	.89*	−.24	.23	−.27**	.98	.015	2.1	1.9(.18)
	1.04*	−.23**			.97	.018	2.4	
United Kingdom	1.15*	−.19	.05	−.24	.98	.017	2.0	1.1(.35)
	1.34*	−.43*			.98	.019	2.3	
West Germany	.85*	−.30	.13	−.28*	.99	.005	1.5	3.1(.07)
	1.09*	−.54*			.99	.007	2.1	
Austria	.90*	−.19	−.12	−.10	.99	.005	1.8	1.0(.38)
	1.18*	−.54*			.99	.005	2.0	
Netherlands	1.26*	−.51**	.05	−.09	.99	.005	1.9	0.3(.78)
	1.37*	−.53*			.99	.005	2.2	
Denmark	1.02*	−.09	−.14	−.05	.99	.003	1.9	0.8(.46)
	1.20*	−.42*			.99	.004	2.3	
Belgium	1.01*	−.39	.02	−.17	.99	.006	1.8	1.0(.39)
	1.26*	−.64*			.99	.007	2.4	
France	1.06*	−.13	−.06	−.16	.99	.006	1.9	1.4(.26)
	1.32	−.53*			.98	.007	2.4	
Italy	.95*	.04	−.08	−.17	.97	.017	2.0	2.0(.17)
	1.23*	−.36			.96	.021	2.4	
Norway	.83*	.26	−.22	−.22	.98	.015	1.7	4.3(.03)
	1.27*	−.45*			.97	.022	2.5	
Sweden	1.52*	−.86*	.30	−.15	.98	.006	1.7	0.3(.76)
	1.47*	−.66*			.98	.006	1.8	

of the nominal exchange rate and relative price series are investigated further in this section. The objective here is twofold: to estimate the observed adjustment of current nominal exchange rates (and prices) to lagged known values of relative prices (and exchange rates) and, more important, to investigate the response of each time series to unanticipated disturbances. The failure of most well-known models of exchange rate determination to explain the variability of nominal exchange rates in the 1970s suggests that "news" is the main explanatory variable of the observed large swings in exchange rates. News is captured by the error term in vector autoregression systems, which include as independent variables lagged values of all the relevant dependent variables.

In the context of real exchange rate determination, news about the current account position, money supply, or output will affect both nominal exchange rates and prices. Thus, residuals in vector autoregressions which include as independent variables only lagged values of nominal exchange rates and prices will capture unanticipated movements in these two variables due to such news. A high negative correlation coefficient among residuals therefore could imply either that agents move nominal exchange rates and prices in opposite directions as a response to a particular source of news or that nominal exchange rates and prices respond to different sets of news which are themselves negatively correlated.

In light of these considerations, a second-order vector autoregression system is estimated for each country in the sample. The two variables are the nominal effective exchange rate and relative prices defined as the ratio of the value-added deflator to the foreign price of traded goods. Each of the two variables is regressed against lagged values of both variables. All regressions are run on quarterly observations and include a constant, a linear trend, and seasonal dummies. Given the analysis of section 9.4, two lags are used for each variable. The only exception is Germany, for which the vector autoregression is also run with three lags on exchange rates and relative prices.

Each of the estimated equations can be interpreted as a forecasting equation. To determine whether or not inclusion of the other variable improves its explanatory power, F-tests are conducted under the null hypothesis that *(a)* the two lagged relative price terms in the exchange rate equation are zero or *(b)* the two lagged exchange rate terms in the relative price equation are zero. The results are reported in table 9.7 with significance levels in parentheses. Table 9.7 also reports the correlation between the residuals of the two estimated equations, which can be interpreted as the correlation between "innovations." Subject to our previous interpretation, a strong positive correlation between the two residuals would imply that the two series respond similarly to a given source of news (e.g., money supply news) or to different sets of news (e.g., money supply and current account) that are positively correlated.

The results of table 9.7 support the intuitive arguments so far. At a 10% significance level, it is shown that the exchange rate can be considered statistically exogenous or predetermined vis-à-vis relative prices in all cases except the United Kingdom and possibly Denmark, Austria, and Belgium. Past movements of the exchange rate are important expected determinants of the relative price ratio in Japan, Belgium, and Norway. This supports the previous findings of differential speed of adjustment in assets and goods markets and the stronger *expected* transmission linkages in the smaller and more open economies.

The correlation among residuals is positive in all cases but it is around .8 to .9 in the cases of the United States, the United Kingdom, West Germany, and France. This finding is consistent with the hypothesis that, despite relatively low expected transmission from exchange rates to prices and from prices to exchange rates in the hard-currency industrialized countries as compared to smaller and more open economies (tables 9.5 and 9.7), innovations have a similar effect on both nominal exchange rates and domestic prices. In the other smaller countries, relative price and exchange rate movements seem to respond independently to innovations.

Table 9.7 **Correlation of Residuals and Granger Exogeneity Tests in Vector Autoregression System of Exchange Rates and Relative Prices[a] (1974:2–1980:4)**

Countries	$\rho(\hat{V}_E, \hat{V}_{P^v/FP^t})$	$F(P^v/FP^t)^b$	$F(E)^b$
United States	.92	1.09 (.36)	1.82 (.19)
Canada	.73	1.63 (.22)	.95 (.41)
Japan	.62	.25 (.78)	4.80 (.02)*
United Kingdom	.83	3.59 (.05)*	6.99 (.57)
West Germany	.92	.66 (.53)	1.96 (.17)
	.93	.45 (.72)	.81 (.51)
Austria	.72	3.21 (.06)**	.04 (.96)
Netherlands	.16	1.66 (.22)	1.44 (.26)
Denmark	.36	2.75 (.09)**	.70 (.51)
Belgium	.31	2.69 (.09)**	3.95 (.04)*
France	.79	1.23 (.32)	1.77 (.20)
Italy	.45	.66 (.53)	.44 (.65)
Norway	.33	.52 (.60)	2.68 (.09)**
Sweden[c]	.77	.31 (.74)	.46 (.64)

[a]For all countries the vector autoregressions include two lags on all relevant variables, with the sole exception of Germany where the results of the vector autoregression with three lags on E, P^v, and hence P^v/FP^t are also reported.

[b]$F(P^v/FP^t)$ is the F-test under the null hypothesis that $(P^v/FP^t)_{t-1}$ and $(P^v/FP^t)_{t-2}$ are zero in the E equation. Similarly, $F(E)$ is the F-test under the null hypothesis that E_{t-1} and E_{t-2} are zero in the relative price equation. Significance levels are given in parentheses. An asterisk indicates that the null hypothesis can be rejected within a 10% confidence interval.

[c]Sample period: 1974.2–1979.4.

Based on the underlying estimation of the vector autoregression system (VAR), figures 9.6 and 9.7 plot the response of each of the two independent variables to one standard deviation shock in the residual of the cross-equation for France, Germany, Japan, and the United States.[16] Note that the impulse reaction functions presented in these figures reveal substantial cross-country differences in the dynamic path of adjustment to an unexpected disturbance.

16. The impulse reaction functions are run under the assumption that the variance-covariance matrix of the disturbances is in fact diagonal. This assumption is hard to justify in the case of the large industrialized countries where the correlation coefficient of residuals is high. Three factors prompted this choice, however: *(a)* there is no unique way of orthogonalizing the disturbances and thus the only acceptable alternative would have been to investigate all possible orthogonalizations; *(b)* the impulse reactions could be interpreted as a shock to the distinct part of each residual in the VAR system; and *(c)* since there is no a priori reason why the appropriate orthogonalization is different across the chosen subset of countries, cross-country comparisons of impulse reactions are still informative.

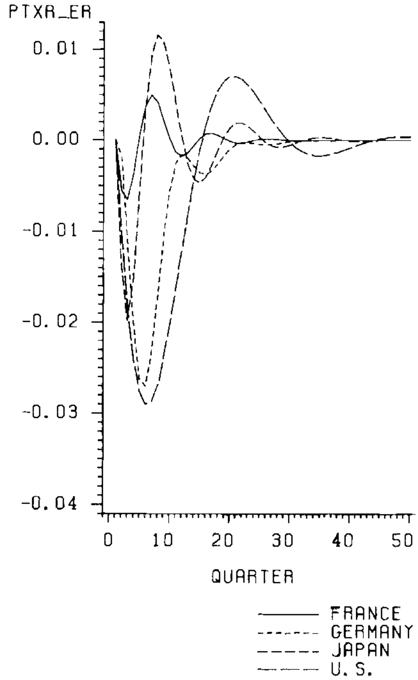

Fig. 9.6 Responses of relative prices, nontraded to traded goods, to shock in exchange rate (period of estimation 1974:2–1980:4).

In all four countries, news that causes an unexpected nominal depreciation induces a decrease in the relative price of nontraded to traded goods. The drop is largest and the adjustment slowest in the case of the United States, which is the least open country in the sample and which possesses a high degree of market power. The system in all cases converges roughly after 50 quarters.

Oscillations of nominal exchange rates in response to an unexpected shock in relative prices are once again larger and more prolonged in the case of the United States. The nominal exchange rate depreciates in value after a short period of small appreciation (two quarters). After 50 quarters it did not converge to its equilibrium value. The dynamic path of adjustment is quite different in the other countries, with adjustment almost monotonic in the case of Germany. The exchange rate converges approximately after 35 quarters. The pronounced nominal and real appreciations probably reflect anti-inflationary policies and possibly, in the case of the European countries, the sluggishness in nominal exchange rate adjustment imposed by monetary arrangements.

In conclusion, the evidence in table 9.7 and figures 9.6–9.7 suggests that even though innovations affect nominal exchange rates and relative prices

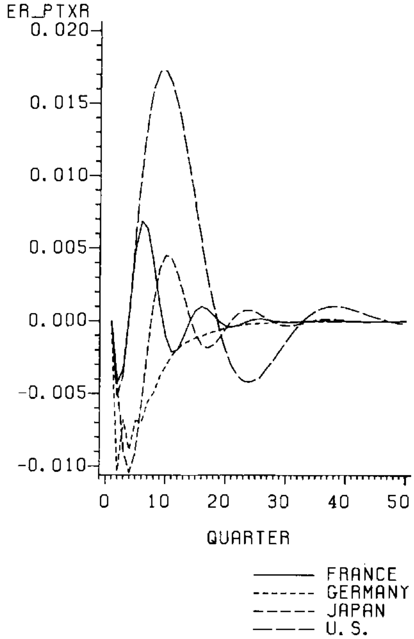

Fig. 9.7 Response of exchange rate to shock in relative prices, nontraded to traded goods (period of estimation 1974:2–1980:4).

symmetrically in the large countries as opposed to the smaller countries, the impulse reaction functions even for these countries are not identical due to differences in structure and policy behavior.

Movements in the relative price index can now be decomposed further into movements of the domestic and foreign price components, and the properties of the system can be analyzed further. Here again each variable in the trivariate autoregression system is regressed against lagged values of all three variables. As with the bivariate VAR, two lags are used in the autoregressive structure. Tables 9.8, 9.9, and 9.10 present estimates of each of the forecasting equations as well as the results of F-tests on the successive elimination of cross variables. The numbers in parentheses under the estimated coefficients report the t-statistics.

Table 9.8 confirms the hypothesis of exogeneity of the nominal exchange rate that was postulated in table 9.7, except in the case of Germany. While in table 9.7 it was reported that current values of the exchange rate do not seem to depend on lagged values of relative prices, the results here indicate that lagged values of P^v independently affect the nominal exchange rate. Furthermore, in the case of Belgium, joint elimination of the two lags on P^v is hard to justify. This gives partial justification for the preoccupation with vicious circles by Belgian economists.

Table 9.8 **Responsiveness of E to Lagged E, P^v and FP^t (1974.2–1980.4)**

	E_{t-1}	E_{t-2}	E_{t-3}	P^v_{t-1}	P^v_{t-2}	P^v_{t-3}	FP^t_{t-1}	FP^t_{t-2}	FP^t_{t-3}	R^2	D-W	$F(P^v)$	$F(FP^t)$
United States	.97	−.50		1.76	−.73		.12	−.58		.92	2.3	2.5	2.2
	(2.3)[a]	(.9)		(2.2)	(2.2)		(.3)	(1.0)				(.11)	(.15)
Canada	1.24	−.35		−.49	−.25		.30	.30		.99	2.1	3.0	2.1
	(4.3)	(1.2)		(.09)	(.4)		(1.2)	(.1)				(0.08)	(.15)
Japan	1.42	−.68		−.41	.59		.29	−.17		.94	2.4	.2	.3
	(7.0)	(3.4)		(0.5)	(.5)		(.8)	(.5)				(.84)	(.70)
United Kingdom	.68	.27		.86	−.38		−.27	.15		.96	1.9	3.0	.2
	(1.6)	(.8)		(1.2)	(.6)		(.7)	(.5)			(0.7)	(.08)	(.80)
West Germany	.71	−.36		−.50	2.11		.41	−.32		.98	1.6	6.4	.7
	(2.1)	(.8)		(.5)	(1.9)		(1.2)	(1.1)				(.01)*[c]	(.50)
	1.43	−1.03	.21	−2.81	6.17	−2.89	.82	−1.01	.44	.99	2.4	7.2	1.1
	(3.3)	(1.5)	(.4)	(2.0)	(3.4)	(2.3)	(1.7)	(1.3)	(1.0)			(.00)*	(.30)
Austria	.91	.25		−.39	−.05		−.14	.56		.98	1.8	.9	3.6
	(3.0)	(.9)		(.8)	(.1)		(.6)	(2.6)				(.42)	(.52)
Netherlands	.44	.08		.16	−.62		−.21	.30		.93	1.9	1.9	2.8
	(1.6)	(.3)		(.4)	(1.5)		(1.2)	(2.0)				(.18)	(.09)
Denmark	.74	.05		−.45	.12		.17	.11		.86	2.1	.6	1.8
	(2.7)	(.2)		(.7)	(.2)		(.5)	(.3)				(.55)	(.19)
Belgium	.49	.35		−.93	.17		−.21	.29		.94	2.4	4.4	1.6
	(1.8)	(1.3)		(1.6)	(.3)		(1.3)	(1.7)				(.03)*	(.23)
France	1.03	−.41		−.80	.84		.38	−.44		.85	2.4	.08	1.2
	(4.6)	(1.9)		(1.2)	(1.1)		(1.1)	(1.5)				(.47)	(.34)
Italy	1.05	−.30		−.43	.30		−.16	.15		.98	2.0	.2	.3
	(4.1)	(1.2)		(.7)	(.6)		(.7)	(.7)				(.74)	(.74)
Norway	.91	−.28		.21	−.41		−.17	.11		.89	2.4	1.2	1.0
	(3.4)	(1.1)		(.6)	(.1.2)		(1.4)	(.9)				(.32)	(.38)
Sweden[b]	1.10	−.36		.12	−.12		−.28	.23		.94	1.9	.0	.2
	(2.5)	(.8)		(.2)	(.2)		(.6)	(.6)				(.98)	(.78)

[a] t-statistics in parentheses. [b] Sample period = 1974:2–1979:4.

[c] Significance level for F-test under null hypothesis that the coefficients of relevant variable are zero. An asterisk indicates that the null hypothesis can be rejected within a 5% confidence interval.

Table 9.9 **Responsiveness of P^v to Lagged P^v, E and FP^t**
(1974:2–1980:4)

	E_{t-1}	E_{t-2}	E_{t-3}	P^v_{t-1}	P^v_{t-2}	P^v_{t-3}	FP^t_{t-1}	FP^t_{t-2}	FP^t_{t-3}	R^2	D-W	$F(E)$	$F(FP^t)$
United States	−.70	.25		.73	−.70		−.10	.32		1.00	2.1	8.6	9.1
	(.7)[a]	(2.0)		(4.0)	(3.8)		(1.0)	(2.5)				(.00)*	(.00)*
Canada	.09	−.01		1.45	−.57		.05	−.03		1.00	2.1	.8	.1
	(.6)	(.1)		(5.1)	(1.8)		(0.4)	(.2)				(.48)	(.91)
Japan	.03	.01		.66	−.22		.16	.04		.97	1.8	1.4	5.0
	(.6)	(.2)		(3.7)	(1.0)		(2.1)	(.6)				(.27)	(.02)*
United Kingdom	−.11	.04		1.18	−.35		−.13	−.07		1.00	2.2	.8	.5
	(.8)	(.3)		(5.3)	(1.6)		(1.0)	(.7)				(.47)	(.60)
West Germany	.05	−.15		1.07	−.10		.17	−.13		1.00	1.9	2.1	3.6
	(.9)	(1.9)		(5.2)	(.5)		(2.7)	(2.3)				(.15)	(.05)*
	.19	−.30	.12	0.86	.52	−.61	.22	−.28	.10	.99	2.3	1.9	2.1
	(2.2)	(2.3)	(1.2)	(3.1)	(1.6)	(2.5)	(2.4)	(1.8)	(1.2)			(.18)	(.15)
Austria	−.01	.19		.79	−.30		.10	.07		.99	2.1	.7	1.0
	(.0)	(1.1)		(3.0)	(1.4)		(.8)	(.6)				(.51)	(.41)
Netherlands	.39	−.21		.85	−.12		.20	−.09		.99	1.9	1.8	1.7
	(1.9)	(1.1)		(3.3)	(.4)		(1.5)	(.8)				(.20)	(.21)
Denmark	−.11	.41		.65	−.07		−.25	.37		1.00	2.3	1.4	8.7
	(1.3)	(1.6)		(3.2)	(.4)		(2.5)	(3.7)				(.28)	(.00)*
Belgium	.03	.09		.81	−.02		−.00	.05		1.00	2.4	1.7	1.4
	(.3)	(.9)		(3.5)	(.1)		(.1)	(.7)				(.21)	(.27)
France	.06	−.02		1.16	−.20		.29	−.25		1.00	2.6	.2	2.7
	(.6)	(.2)		(4.6)	(.7)		(2.1)	(2.2)				(.79)	(.10)
Italy	.17	−.12		.99	−.49		.05	.06		1.00	1.8	2.2	1.2
	(2.1)	(1.5)		(4.8)	(3.2)		(.6)	(.9)				(.14)	(.32)
Norway	−.10	.20		1.12	−.36		−.06	.09		.99	2.3	1.5	1.3
	(.8)	(1.6)		(6.4)	(2.2)		(1.0)	(1.5)				(.25)	(.30)
Sweden[b]	.25	.12		.32	−.21		.44	−.12		1.00	2.1	2.0	2.3
	(1.4)	(.6)		(1.0)	(.9)		(2.1)	(.8)				(.18)	(.14)

[a]t-statistics in parentheses. [b]Sample period = 1974.2–1979.4.

Table 9.10 **Responsiveness of FP^t to Lagged FP^t, E, and P^v (1974:2–1980:4)**

	E_{t-1}	E_{t-2}	E_{t-3}	P^v_{t-1}	P^v_{t-2}	P^v_{t-3}	FP^t_{t-1}	FP^t_{t-2}	FP^t_{t-3}	R^2	D-W	$F(E)$	$F(P^v)$
United States	.43	.15		−2.17	.63		1.34	.12		.98	1.7	5.8	3.4
	(.9)	(.2)		(2.5)	(.7)		(2.7)	(.2)				(.01)*	(.06)
Canada	.06	−.07		.77	−.07		1.11	−.62		.98	2.9	.0	2.7
	(.2)	(.2)		(1.3)	(.1)		(4.0)	(2.0)				(.98)	(.10)
Japan	.42	−.34		.50	.02		.90	−.32		.99	2.2	5.6	.6
	(3.3)	(2.6)		(.9)	(.0)		(4.0)	(1.5)				(.01)*	(.55)
United Kingdom	.33	−.61		−1.24	.95		1.29	−.55		.99	1.7	5.5	3.5
	(1.0)	(2.3)		(2.3)	(1.8)		(4.2)	(2.2)				(.02)*	(.06)
West Germany	.74	−.32		−.24	−.81		1.32	−.55		.99	1.8	5.2	3.7
	(2.7)	(.9)		(.3)	(.9)		(4.8)	(2.3)				(.02)*	(.05)*
	.06	.54	−.45	1.30	−4.03	2.55	.79	.44	−.62	.99	2.3	1.3	5.0
	(.2)	(1.0)	(1.0)	(1.1)	(2.9)	(2.5)	(2.03)	(.7)	(1.7)			(.32)	(.02)*
Austria	−.29	.12		.83	−.60		.90	−.47		.99	2.2	.3	1.4
	(.8)	(.4)		(1.6)	(1.5)		(3.6)	(1.9)				(.71)	(.28)
Netherlands	.53	−.08		−.61	.37		1.53	−.63		.99	2.1	2.3	1.9
	(1.9)	(.3)		(1.8)	(.9)		(9.1)	(4.5)				(.13)	(.18)
Denmark	.22	−.24		.05	−.01		1.29	−.51		.99	2.1	.7	0
	(1.0)	(1.1)		(.1)	(.0)		(5.1)	(2.0)				(.53)	(.98)
Belgium	.39	−.17		.86	−.83		1.14	−.44		.99	2.2	.9	1.0
	(1.2)	(.5)		(1.2)	(1.4)		(5.8)	(2.2)				(.40)	(.38)
France	.30	−.27		.31	−.13		1.30	−.53		.99	2.3	1.5	.2
	(1.6)	(1.5)		(.6)	(.2)		(4.4)	(2.2)				(.26)	(.79)
Italy	.10	−.28		.47	−.70		.99	−.19		.96	2.1	.7	1.3
	(.4)	(1.1)		(.7)	(1.5)		(4.4)	(.8)				(.51)	(.31)
Norway	−.94	1.21		−.28	.23		.95	−.07		.98	2.4	3.5	.1
	(1.9)	(2.6)		(.4)	(.4)		(4.3)	(.3)				(.06)	(.90)
Sweden[b]	−.0	.08		−.38	.21		1.57	−.69		.98	2.0	.0	.2
	(.0)	(.2)		(.5)	(.3)		(3.4)	(2.0)				(.97)	(.86)

[a]t = statistics in parentheses. [b]Sample period-1974:2–1979:4.

Table 9.9 presents the forecasting equation for P^v. Based on the F-test, the domestic price index is clearly responsive to past exchange rate movements only in the case of the United States with an insignificant first-period lag and a significantly positive second-period lag. Based on the estimated equation, the first-period lag (E_{t-1}) has a significantly positive sign in Germany and Italy. The second-period lag is significantly negative in Germany alone.

Past values of the foreign price index for the post-1973–74 oil price increase period are significant determinants of the domestic price index only in the United States, Japan, Germany, and Denmark. The first-period lag is significantly positive also in France and Sweden and surprisingly negative in the case of Denmark. The second-period lag is significantly negative in Germany and France and positive in Denmark and the United States. In general, it can be concluded that current values for P^v do not seem to be as affected by lagged values of E and FP^t as one would expect. This limited backward-looking linkage could be the outcome of domestic price stabilization policies during the 1970s.

Finally, table 9.10 presents the forecasting equation for the price of traded goods in units of foreign exchange. There are two reasons why one could expect past exchange rate and domestic price movements to affect the foreign currency price of traded goods: the possession of market power and a dominant position in international trade. Thus it is not surprising that in the case of the leading countries—the United States, Japan, England, and Germany—lagged values of exchange rates if not domestic prices are important determinants of the foreign price index. This kind of international linkage can work in many directions. An effective nominal devaluation of the dollar, for example, would raise United States domestic prices of home and exported goods (cf. table 9.9). Inflation in the United States will be transmitted to its trading partners and induce an increase in their domestic price despite the initial nominal appreciation of their currency. Eventually it could raise the United States' effective foreign price of traded goods (FP^t). On the other hand, possession of market power on the export and import markets could lower the foreign price of traded goods, at least in the short run.

Finally, an increase in the domestic price of any of the leading countries might induce other nations to establish restrictive policies in an attempt to insulate their economies from the negative transmission effects. The results in table 9.10 are difficult to interpret further without reference to other macroeconomic variables. However, they support the view that there exist sufficiently important negative transmission links between the most developed of the industrialized countries and the rest of the world to require a more careful analysis.

The major findings so far are quite supportive of established theories. *(a)* In most cases (with the possible exception of the United States and

Belgium), the exchange rate can be considered a predetermined variable in domestic price determination. *(b)* Prices of nontraded relative to traded goods are affected by lagged values of exchange rates only in the cases of Japan among "large" countries and Belgium and Norway among "small" countries. In the other large countries, news seems to affect exchange rates and prices in similar patterns even though there are cross-country differences in the speed of adjustment to innovations. *(c)* Again in the case of "large" countries (United States, Japan, United Kingdom, and Germany), the foreign price of traded goods cannot be considered exogenous as it is affected by past exchange rates and domestic prices. *(d)* The domestic price index, P^v, does not seem to depend on lagged exchange rates and/or foreign prices in almost all countries, probably due to stabilization policies.

The correlations of residuals among all pairs in the autoregressive system are presented in table 9.11. For all countries, an innovation in the exchange rate, the predominantly exogenous variable, is associated with a negative innovation in the foreign price index. Once again for the large countries (United States, United Kingdom, and Germany) the correlation coefficient is highly significant (greater than $-.70$). This high negative ρ in the countries with open and developed financial markets would be consistent with a rational expectations asset market view of exchange rate determination where an unexpected increase in foreign prices induces expectations of a

Table 9.11 Correlation of Residuals in Vector Autoregression System of Exchange Rates, Value Added Deflator and Foreign Price of Traded Goods (1974:2–1980:4)

Countries	$\rho(\hat{V}_E, \hat{V}_{P^V})$	$\rho(\hat{V}_E, \hat{V}_{FPt})$	$\rho(\hat{V}_{P^V}, \hat{V}_{FPt})$
United States	−.52	−.91	.55
Canada	−.04	−.58	.53
Japan	−.36	−.73	.39
United Kingdom	−.33	−.87	.47
West Germany	.47	−.83	−.28
	.23[a]	−.75	.07
Austria	.15	−.59	.28
Netherlands	−.20	−.39	.51
Denmark	−.54	−.56	.22
Belgium	.44	−.25	.17
France	−.52	−.88	.62
Italy	.13	−.36	.34
Norway	−.49	−.45	.25
Sweden	−.16	−.79	.40

[a]Correlation of residuals in system of equations estimated with three lags on each independent variable.

current account surplus and thus an immediate appreciation of the exchange rate. In the case of the other countries, the negative correlation probably reflects intervention by authorities in the exchange market.

The correlation coefficient between innovations in the domestic and foreign price indices is positive, as expected, but relatively low. Given all the empirical findings so far, and the low overall variability of the P^v index, it should be concluded that during the 1970s stabilization policies focused on domestic inflation. This finding is also consistent with the mixed evidence on the correlation coefficient between the exchange rate and domestic price residuals. It is positive only in the cases of Germany, Austria, Belgium, and Italy, and negative for all other countries. The results for Belgium and Italy once again give some empirical support to the vicious circle theorizing in connection with these two countries (Basevi and de Grauwe 1977) and sharply contrasts their experience with that of the Scandinavian small and open economies.

In general, it can be concluded that innovations in the two price indices move generally together with causality running from foreign to domestic prices in the smaller countries and usually in both directions in the larger countries. Innovations in exchange rates and foreign prices are negatively correlated. In the case of small countries with managed nominal exchange rates, the negative correlation would be consistent with contemporaneous intervention in the exchange market as a result of innovations in the foreign price level. In the large countries, where both the nominal exchange rate and foreign price level are market determined, the high negative correlation would be consistent with opposite impact responses of the two indices to the same set of news or responses to different sets of news which are negatively correlated. Finally, the evidence on the correlation in innovations between the exchange rate and the domestic price vector is mixed, with positive correlations in the most open economies (Germany, Austria, Belgium, and Italy) and negative correlations elsewhere, probably because of stabilization policies.

These results are only indicative of the complicated nature of the adjustment process and differences across countries which can have their origin in the nature of the unexpected shock, the structural responses to the disturbance, or the policy reaction of the authorities. What is striking is that some systematic patterns emerge.

It could be said that the process of adjustment in the smaller European countries is perhaps the most varied and complicated despite the ''smallness'' of the economy. As an example of differences in behavior, figures 9.8 and 9.9 plot the response of the value-added deflator to unexpected shocks in foreign prices and the exchange rate for three small European countries which follow the deutsche mark closely: Belgium, the Netherlands, and Norway. Here again, substantial differences emerge in the dynamic path of adjustment of the domestic price index. Differences occur,

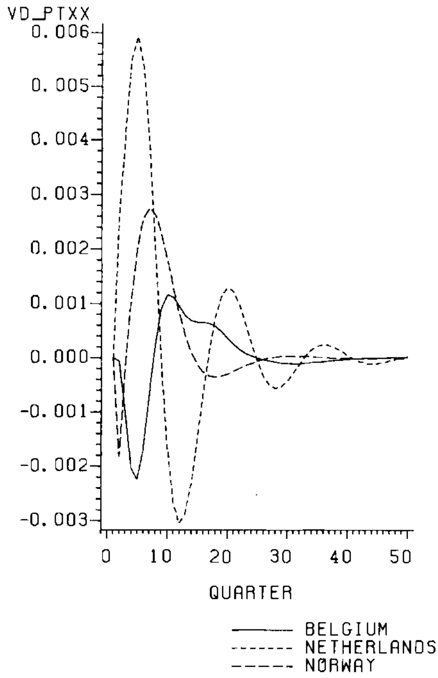

Fig. 9.8 Response of value added deflator to shock in foreign prices of traded goods.

not only in the magnitude of oscillations, the oscillatory path itself, and the speed of convergence, but also in the direction of the short-run impulse response to disturbances.

The response of domestic prices to unexpected shocks in foreign prices for the three countries is presented in figure 9.8. Adjustment is quite varied with an initial decrease in P^v in Belgium and Norway and a sharp increase in the Netherlands, and subsequent oscillations which are damped relatively quickly in the first two countries (in less than 30 quarters) but more slowly in the case of the Netherlands. Figure 9.9 demonstrates the cross-country differences in the response of P^v to innovations in E. The Norwegian response, where the value-added deflator decreases following an unexpected depreciation, could have its origin in the importance of intermediate goods (Katseli 1980) or in the role of policy. Any hypothesis, however, would be only that unless one possesses knowledge of the specific institutional and economic characteristics of the country.

The negative response of domestic prices following an unexpected nominal depreciation induces a larger depreciation of the real exchange rate rel-

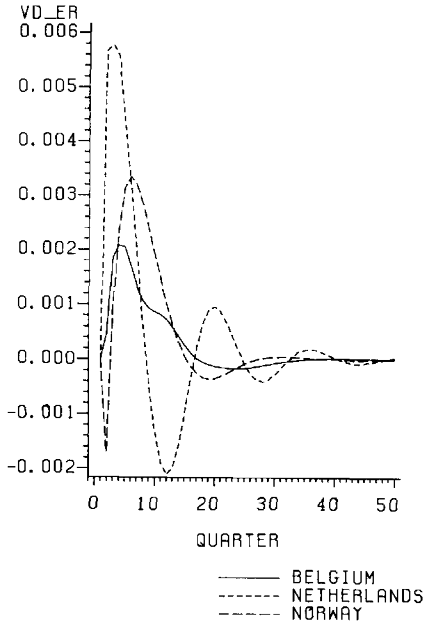

Fig. 9.9 Response of value added deflator to shock in exchange rate

ative to the nominal exchange rate. Interestingly enough, the same pattern is observed in Denmark and Austria. This pattern of response to innovations in exchange rates is quite different in the case of the other small European countries, as can be seen in table 9.12. The induced movement in domestic prices following an unexpected depreciation probably makes real exchange rate adjustment easier in the Scandinavian countries and Austria than in the other small countries of Europe. Given that current account adjustment is dependent on movements in the real rather than the nominal exchange rate, this tentative conclusion suggests that the attainment of external balance requires a greater nominal devaluation in the case of the smaller countries of central Europe than in the case of their northern neighbors.

9.6 Conclusions

The objective of this paper was to study the movements of real exchange rates in the 1970s and to explore some of the inherent complications in the process of real exchange rate determination. Real factors such as technological change, decreasing money illusion, and changes in intertemporal preferences were shown to affect the equilibrium terms of trade and the relative

Table 9.12 Impulse Reaction Functions: Responses of P^y to One Standard Deviation Shock in E (20 quarters)

	Country						
Quarter	Denmark	Sweden[b]	Norway	Austria	Netherlands	Belgium	Italy
1	.0	.0	.0	.0	.0	.0	.0
2	−.20 D-02[a]	.59 D-02	−.17 D-02	−.13 D-03	.56 D-02	.45 D-03	.53 D-02
3	−.13	.11 D-01	.84 D-03	.21 D-02	.57	.19 D-02	.71
4	.43 D-03	.11	.24 D-02	.31	.56	.21	.45
5	.17 D-02	.66 D-02	.31	.39	.43	.21	.33 D-04
6	.23	.33 D-02	.33	.44	.32	.17	−.35 D-02
7	.23	.17	.32	.46	.19	.13	−.51
8	.20	.11	.28	.46	.70 D-03	.11	−.51
9	.14	.76 D-03	.24	.44	−.40	.94 D-03	−.43
10	.70 D-03	.43	.19	.41	−.13 D-02	.88	−.34
11	.94 D-04	.12	.14	.38	−.19	.82	−.26
12	−.38 D-03	−.11	.10	.35	−.21	.73	−.20
13	−.70	−.24	.64 D-03	.33	−.20	.58	−.15
14	−.85	−.29	.32	.32	−.16	.42	−.10
15	−.86	−.28	.62 D-04	.30	−.10	.26	−.60 D-03
16	−.77	−.23	−.13 D-03	.29	−.38 D-03	.12	−.27
17	−.62	−.15	−.26	.28	.19	.16 D-04	−.32 D-04
18	−.44	−.71 D-04	−.33	.26	.62	−.52	.13 D-03
19	−.25	−.11 D-05	−.36	.25	.88	−.95	.21
20	−.96 D-04	.47 D-04	−.35	.24	.95	−.12 D-03	.25

[a]Divided by 100; D-02 applies to all numbers below it. Same for D-01, D-03, D-04.

[b]Sample period of estimation 1974:2–1979:4.

price of traded to nontraded goods differently. Given the latter definition of the real exchange rate, deviations around trend were shown to be quite varied across countries. So were the economic processes that dictated them. Three rough country groupings emerged: the large industrialized countries (with the possible exception of Japan), the Scandinavian countries, and the smaller European countries.

In the major industrialized countries, exchange rates can be considered predetermined with respect to relative prices. Past movements of nominal exchange rates, however, influence foreign prices in a way that is consistent with these countries' possession of market power. There is a strong positive correlation among residuals of nominal exchange rates and relative prices. This would be consistent with economic theorizing where unexpected increases in the money supply or other news cause a depreciation of the nominal exchange rate and an increase in the price of nontraded goods relative to the foreign currency price of traded goods. However, the strong positive correlation between innovations in E and P^v/FP^t cannot be accounted for by a strong positive correlation between innovations in E and P^v. The evidence is rather mixed (table 9.11), but it seems to suggest that this correlation is the outcome of strong negative correlations between innovations in E and FP^t, negative correlations between innovations in E and P^v, and strong positive correlations between innovations in P^v and FP^t. This suggests that one should look more closely at patterns of interdependence among major industrialized countries.

The evidence also suggests that a nondiscriminatory application of the "small country" model to European experiences will be problematic unless one understands internal targets of policy and differences in structural characteristics.

In all small countries, with the exception of Belgium, the nominal exchange rate does not seem to be affected by lagged values of domestic or foreign prices. The foreign price level of traded goods can be considered similarly predetermined. The domestic value-added deflator, however, is strongly influenced by lagged values of foreign prices (tables 9.8–9.10).

Differences across countries come with respect to their adjustment to innovations. "News" that affects nominal exchange rates and domestic prices are positively correlated in Austria, Belgium, and Italy and negatively correlated in the Netherlands and the Scandinavian countries. There is similarly a strong negative correlation of the E and FP^t residuals in the Scandinavian countries as opposed to the other smaller European countries. This could be the outcome of more independent nominal exchange rate policies in the northern countries as opposed to the countries in the European Monetary System. There are also substantial differences in the path of adjustment as a response to innovations. The fundamental economic processes behind these systematic differences are not well understood. They merit closer attention and more careful analysis.

Appendix 1

In each country each sector uses a fixed stock of capital $\overline{K}_i$ and labor N_i which is free to move between sectors. The overall stock of labor is given and there is full employment. In each sector profit maximizing behavior would imply that the nominal wage is equated to the value of the own marginal product of labor. Thus, taking the nontraded goods sector as an example, and using again the exportable as a numeraire,

(A1) $$W = P_h \cdot f(\overline{K}_h, N_h); f_N < 0, f_K > 0,$$

where W = the real wage in terms of the exportable commodity. The supply of labor is assumed to depend on the expected real wage (W/P^e), where the expected price level is itself a function of the consumer price index, and a shift parameter A. Thus,

(A2) $$W = P^e \cdot g(\overline{N}, A); g_N > 0; g_A > 0,$$

where

(A3) $$P^e = h(P); 1 \geq h' \geq 0$$

and

(A4) $$P = \alpha_1 P_h + \alpha_2 + \alpha_3 P_m.$$

Substituting (3′) and (4′) in (2′) and equating the demand and supply of labor in each sector, it follows that

(A5) $$W = P_h \cdot f(\overline{K}_h, N_h) = h(\alpha_1 P_h + \alpha_2 + \alpha_3 P_m) \cdot g(\overline{N}, A).$$

Assuming that all initial prices and hence $g(\overline{N}, A)$, $h(P)$, and $f(\overline{K}_h, N_h)$ are set equal to unity, equation (A5) can be differentiated totally and solved for dN_h. Then,

(A6) $$f_N dN_h = (h'\alpha_1 - 1)dP_h + h'\alpha_3 dP_m + g_A dA - f_K dK_h.$$

From (A6) it follows that employment, and hence output in the nontraded good sector, is a positive function of P_h and K_h and a negative function of A and P_m. These are the assumed signs of the partial derivatives in the supply functions of the model. This is the most general specification of the labor markets that allows explicit consideration of different types of wage rigidities or degrees of money illusion.

Appendix 2

Local stability of a three-by-three system requires that the trace is negative and the determinant is negative. In the present case, sign ambiguities arise in elements a_{32}, a_{13}, and a_{33}, which are defined below. If a_{13} is positive and a_{32} and a_{33} are negative, then stability is guaranteed. This is equivalent to assuming that the cross elasticities of supply, E^*_{mh}, E_{hm}, and E_{xm}, are sufficiently low. In other words, the determinant of the system can be described as follows:

$$|D| = \begin{bmatrix} a_{11} & 0 & a_{13} \\ 0 & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix},$$

where

$$a_{11} = -(B_h - 1) - (1 + E_{hh})[1 - m_h(1 - s)] - (1 - s)m_h \frac{X_s}{P_h H_d} E_{xh} < 0$$

$$a_{21} = 0$$

$$a_{31} = -E_{xh}X_s[1 - m_x \frac{1}{P_x}(1 - s)] - B_{xh}X_d - m_x \frac{1}{P_x} P_h H_s(1 + E_{hh}) < 0$$

$$a_{22} = -(B^*_h - 1) - (1 + E^*_{hh})[1 - m^*_h(1 - s^*)] - m^*_h(1 - s^*)\frac{P_m M^*_s}{P_h H^*_d} E^*_{mh} < 0$$

$$a_{32} = -B^*_{xh}X^*_d - m^*_h \frac{1}{P_x}(1 - s^*)[P^*_h H^*_s(1 + E^*_{hh}) - P_m M^*_s E^*_{mh}]?$$

$$a_{13} = E_{hm} + B_{hm} - m_h(1 - s)\left[E_{hm} + \frac{X_s}{P_h H_d} E_{xm}\right]?$$

$$a_{23} = E^*_{hm}[1 - m^*_h(1 - s^*)] + B^*_{hm} + m^*_h(1 - s^*)\frac{P_m M^*_s}{P^*_h H^*_d}(1 + E_{mm}) > 0$$

$$a_{33} = -E_{xm}X_s - B_{xm}X_d - B^*_{xm}X^*_d + m_x \frac{1}{P_x}(1 - s)(P_h H_s E_{hm} + X_s E_{xm}) + m^*_x \frac{1}{xP_x}(1 - s^*)[P^*_h H^*_s E^*_{hm} - P_m M^*_s(1 + E^*_{mm})]?$$

The elasticities used in the solutions, all converted to be positive numbers, are defined below:

B_h = own-price elasticity of demand for home goods;
B_{ij} = cross-price elasticities of demand where i is the relevant sector and j the relevant price vector;

E_{ii} = own-price elasticity of supply;
E_{ij} = cross-price elasticities of supply;
m_i = marginal propensity to consume goods of sector i.

Appendix 3

Two sets of solutions are presented below. Holding M constant, P_h and P_m can be expressed as functions of all the exogenous variables. The first term in parenthesis is the numerator, and its sign is given above it. Elements from the determinant matrix are presented as elements a_{ij} and their sign is specified in Appendix 2. The determinant, D, is assumed to be negative as required for stability. A complete listing of the elasticity terms is presented in Appendix 2.

$$\hat{P}_h = \overset{+}{\left\{[1 - m_h(1 - s)]E_{h,K_h}(a_{22}a_{33} - a_{32}a_{23}) + m_x\frac{1}{P_x}(1 - s)P_hH_sE_{h,K_h}(-a_{22}a_{13})\right\}}D^{-1}\hat{K}_h < 0$$

$$= \overset{?}{\left\{-[1 - m_h^*(1 - s^*)]E_{h,K_h}^*(-a_{32}a_{13}) + m_x^*\frac{1}{P_x}(1 - s^*)P_h^*H_s^*E_{h,K_h}^*(-a_{22}a_{13})\right\}}D^{-1}\hat{K}_h^*$$

$$= \overset{-}{\left\{-\frac{X_s}{P_hH_d}m_h(1 - s)E_{x,K_x}(a_{22}a_{33} - a_{32}a_{23}) - E_{x,K_x}X_s\left[1 - m_x\frac{1}{P_x}(1 - s)\right](-a_{22}a_{13})\right\}}D^{-1}\hat{K}_x > 0$$

$$= \overset{+}{\left\{-\frac{P_mM_s^*}{P_h^*H_d^*}m_h^*(1 - s^*)E_{m,K_m}^*(-a_{32}a_{13}) + m_x^*\frac{1}{P_x}(1 - s^*)P_mM_s^*E_{m,K_m}^*(-a_{22}a_{13})\right\}}D^{-1}\hat{K}_m^* < 0$$

?

$$= \left(\left\{-[1 - m_h(1 - s)]E_{h,A} + m_h\frac{(1 - s)}{P_hH_d}X^sE_{x,A}\right\}(a_{22}a_{33} - a_{32}a_{23})\right.$$

$$+ \left\{E_{x,A}X_s\left[1 - m_x\frac{1}{P_x}(1 - s)\right]\right.$$

$$\left.\left. - P_hH_sE_{h,A}m_x\frac{1}{P_x}(1 - s)\right\}. (-a_{22}a_{13})\right)D^{-1}\hat{A}$$

?

$$= \left(\left\{[1 - m_h^*(1 - s^*)]E_{h,A}^* - m_h^*(1 - s^*)\frac{P_mM_s^*}{P_h^*H_d^*}E_{m,A}^*\right\}(-a_{32}a_{13})\right.$$

$$- m_x^*\frac{1}{P_x}(1 - s^*)(P_h^*H_s^*E_{h,A}^* + P_mM_s^*E_{m,A}^*)$$

$$\left.(-a_{22}a_{13})\right)D^{-1}\hat{A}^*$$

?

$$= \left[m_h\frac{Y}{P_hH_d}(a_{22}a_{33} - a_{32}a_{23}) - m_x\frac{Y}{P_x}(-a_{22}a_{13})\right]D^{-1}ds$$

$-$

$$= \left[-m_h^*\frac{Y^*}{P_h^*H_d^*}(-a_{32}a_{13}) - m_x^*\frac{Y^*}{P_x}(-a_{22}a_{13})\right]D^{-1}ds^* > 0$$

$$= \left[-m_h\frac{1}{P_hH_d}\lambda M(a_{22}a_{33} - a_{32}a_{23}) - m_h^*\frac{1}{P_h^*H_d^*}\lambda M^*(-a_{32}a_{13})\right.$$

$$+ \left(m_x\frac{1}{p_x}\lambda M - m_x^*\frac{1}{P_x}\lambda^*M^*\right)$$

$$\left.(-a_{22}a_{13})\right]D^{-1}\hat{M}.$$

?

$$\hat{P}_m = \left\{[1 - m_h(1 - s)]E_{h,K_h}(-a_{31}a_{22}) + \right.$$

$$\left. m_x\frac{1}{P_x}(1 - s)P_hH_sE_{h,K_h}(a_{11}a_{22})\right\}D^{-1}\hat{K}_h$$

$$= \left\{ -[1 - m_h^*(1 - s^*)]E_{h,K_h}^*(a_{11}a_{32}) + m_x^*\frac{1}{P_x}(1 - s^*)P_h^*H_s^*E_{h,K_h}^*(a_{11}a_{22}) \right\} D^{-1}\hat{K}_h^*$$

$$?$$

$$= \left\{ -\frac{X_s}{P_hH_d}m_h(1 - s)E_{x,K_x}(-a_{31}a_{22}) - E_{x,K_x}X_s\left[1 - m_x\frac{1}{P_x}(1 - s)\right](a_{11}a_{22}) \right\} D^{-1}\hat{K}_x$$

$$+$$

$$= \left[\frac{P_mM_s^*}{P_h^*H_d^*}m_h^*(1 - s^*)E_{m,K_m}^*(a_{11}a_{32}) + m_x^*\frac{1}{P_x}(1 - s^*)P_mM_s^*E_{m,K_m}^*(a_{11}a_{22}) \right] D^{-1}\hat{K}_m^* < 0$$

$$?$$

$$= \left(\left\{ -[1 - m_h(1 - s)]E_{h,A} + m_h\frac{(1 - s)}{P_hH_d}X^sE_{x,A} \right\}(-a_{31}a_{22}) + \left[E_{x,A}X_s\left(1 - m_x\frac{1}{P_x}(1 - s)\right)\right] - m_x\frac{1}{P_x}(1 - s)P_hH_sE_{h,A}(a_{11}a_{22}) \right) D^{-1}\hat{A}$$

$$?$$

$$= \left\{ [1 - m_h^*(1 - s^*)]E_{h,A}^* - m_h^*(1 - s^*)\frac{P_mM_s^*}{P_h^*H_d^*}E_{m,A}^* \right\} \left[(a_{11}a_{32}) - m_x^*\frac{1}{P_x}(1 - s^*)(P_h^*H_s^*E_{h,A}^* + P_mM_s^*E_{m,A}^*)(a_{11}a_{22}) \right] D^{-1}\hat{A}^*$$

$$-$$

$$= \left[m_h\frac{Y}{P_hH_d}(-a_{31}a_{22}) - m_x\frac{Y}{P_x}(a_{11}a_{22}) \right] D^{-1}ds > 0$$

$$-$$

$$= \left[-m_h^*\frac{Y^*}{P_h^*H_d^*}(a_{11}a_{32}) - m_x^*\frac{Y^*}{P_x}(a_{11}a_{22}) \right] D^{-1}ds^* > 0$$

$$= \left[-m_h \frac{1}{P_h H_d} \lambda M(-a_{31}a_{22}) - m_h^* \frac{1}{P_h^* H_d^*} \lambda M^*(a_{11}a_{32}) \right.$$
$$\left. + \left(m_x \frac{1}{P_x} \lambda M - m_x^* \frac{1}{P_x} \lambda^* M^* \right)(a_{11}a_{22}) \right] D^{-1}\hat{M}$$

Appendix 4

Total differentiation of equation (11) yields the following expression:

$$(1'') \qquad \gamma_1 \hat{P}_h + \gamma_2 \hat{P}_m - \gamma_3 \hat{M} = \delta_1 \hat{K}_x + \delta_2 \hat{K}_h + \delta_3 \hat{A} + \delta_4 ds,$$

where

$$\gamma_1 = -E_{xh}X_s - B_{xh}X_d - B_{mh}P_mM_d$$
$$- (m_x + m_m)(1 - s)[P_hH_s(1 + E_{hh}) - X_sE_{xh}], \quad <0;$$

$$\gamma_2 = -E_{xm}X_s - B_{xm}X_d - P_mM_d(1 - B_{mm})$$
$$+ (m_x + m_m)(1 - s)(P_hH_sE_{hm} + X_sE_{xm})?$$

$$\gamma_3 = -(m_x + m_m)\lambda M, \quad <0$$

$$\delta_1 = -E_{x,K_x}X_s[1 - (m_x + m_m)X_s(1 - s)], \quad <0$$

$$\delta_2 = (m_x + m_m)(1 - s)P_hH_sE_{h,K_h}, \quad >0$$

$$\delta_3 = E_{x,A}X_s - (m_x + m_m)(1 - \lambda k)(P_hH_sE_{h,A} + X_sE_{x,A}), \quad ?$$

$$\delta_4 = -(m_x + m_m)Y, \quad <0.$$

Substituting the flow equilibrium solutions for $\hat{P}_h$ and $\hat{P}_m$ with respect to each of the disturbances (see App. 3), equation (1″) can be solved for $\hat{M}$ as a function of each of the exogenous variables. The effects on the relative prices can then be inferred from the $\hat{P}_h/\hat{M}$ and $\hat{P}_m/\hat{M}$ flow equilibrium solutions. Given the ambiguity of γ_2 and the noted ambiguities in Appendix 3, the relative movements of the two prices are hard to ascertain.

Comment Willem H. Buiter

Introduction

I found this an interesting paper. The first half, containing the theoretical analysis, develops a specification of the real side of an open economy that should become part of the "standard" open macroeconomic model. The empirical second half contains some interesting data description and analysis.

In this paper, as in her earlier work, Louka Katseli emphasizes the importance of differences in economic structure for the way in which external and internal shocks are transmitted through the economy. This attention to the details of economic structure, on both the demand side and the supply side, can also be found in the work of Bruno and Sachs.

Following the paradigm developed by Koopmans and Montias (1971), outcomes are the result of the interaction of the external environment, economic structure and economic policies. Macroeconomists have had quite a bit to say about policy and the external environment while paying scant attention to economic structure. Homogeneous output and inputs and a minimal role for relative prices were the norm until recently. The oil shocks of the seventies have ended this complacency. Those who, like Louka Katseli, combine knowledge of the industrialized capitalist world with an understanding of the semi-industrialized world have been well ahead of the rest of us in appreciating the importance of differences in economic structure.

This does not mean that I agree with all or even most of what is said in the paper. But my comments, even if occasionally critical, should always be footnoted with my appreciation for the general thrust of this research. I certainly learned something by studying this paper.

One general criticism I have is that the paper really is two papers. The theoretical model of the first half does not contribute significantly to our understanding of the empirical analysis contained in the second half. I therefore shall discuss the two parts separately.

The Theoretical Model

The theoretical model is a two-country, four-good model. Each country produces a (possibly distinct) nontraded good and specializes in the production of a single distinct exportable. Both the terms of trade and the relative price of traded and nontraded goods are endogenous. I consider this to be a useful production structure for the analysis of contemporary macroeconomic adjustment problems. For a number of important policy issues, (imported) intermediate inputs will of course have to be incorporated in the model.

The model analyzes a short-run flow equilibrium with static expectations and a stationary, long-run stock equilibrium. If the role of intertemporal prices were brought out explicitly, and if forward-looking, rational expectations were included, the current momentary equilibrium could of course no longer be determined with reference only to current conditions. To be integrated successfully into the open-economy macroeconomics tradition, the roles of intertemporal allocation and of model-consistent expectations formation should be further developed.

As it stands, the model is entirely "real"; it belongs to the pure theory of international trade. Only relative prices are determined. M is identified with "money" but in fact stands for home country nonhuman wealth in terms of the home country's exportable. This misleading identification with money has led to the omission of interest-bearing internationally traded assets and to the loss of the distinction between the trade balance and the current account. Another problem is that while the saving function $S = \lambda(kY - M)$ clearly identifies M with (nonhuman) private wealth, there are other assets in the model: the sector-specific capital stocks. Even if physical capital goods are neither internationally tradable nor shiftable between sectors within a country, the financial ownership claims on these physical capital goods certainly are part of private wealth. In a model with an explicit intertemporal dimension their market values would be endogenous. Along the lines of Tobin's q, sectoral capital formation could then be endogenized.

The current model does not have any international mobility of financial capital in a stock-shift sense. In the absence of public sector deficits and domestic credit creation, the given world stock of M is redistributed between countries through the "flow" trade balance deficit or surplus. Of course, this is a long way removed from the asset market approach to exchange rate determination. In a suitably modified form, however, it may provide a theory of the long-run determinants of the real exchange rate—one of the anchors that helps pin down the behavior of the short- and medium-term adjustment processes that have been the traditional concern of open macroeconomics.

A rather minor comment is that the ambiguities in the comparative statics are probably even worse than reported. Two of the unambiguous results were, first, that an increase in the capital stock used by the home country's nontraded good sector lowers the relative price of the nontraded good and, second, that an expansion of the capital stock in the home country's traded good sector raises the relative price of the nontraded goods. Both these results can be reversed once it is recognized that such additions to the sector-specific capital stocks represent increases in wealth that will affect demand directly.

Finally on the theoretical side, since the model is entirely real, it should be feasible to root it more firmly in optimizing behavior. This would also be the most satisfactory way of introducing expectations explicitly. Analytically, the simplest way to proceed would be to model an infinite-lived consumer (see, e.g., Obstfeld 1981*b*). In view of the rather tenuous empirical status of that hypothesis, an overlapping generations approach may be preferred (see, e.g., Buiter 1981*a*).[1]

1. For a discussion of some of the problems involved in modeling infinite-lived agents, see Matt. 19:16–30.

The Empirical Analysis

As someone interested in the "real exchange rate overshooting" (Dornbusch 1976) phenomenon, I was struck by the dissimilarities in the behavior of the various different real exchange rate and competitiveness indices. Clearly, empirical work aimed at testing the Dornbusch proposition will have to proceed very carefully in selecting an empirical counterpart to the theoretical construct of "competitiveness."

The rest of my comments, on Katseli's empirical work, amount to quite general reflections on modern time series analysis, that is, the vector autoregressions, impulse response functions, and Granger-causality tests that are the bread and butter of so much recent macroeconometric work, including this paper.

Diagnostic Tests of Residuals from Vector Autoregression

Valid use of vector autoregressive models requires that the estimated residuals be not too different from white noise. Even when no lagged dependent variables are present in time series models, the standard Durbin-Watson statistic is strictly only a test against a first-order autoregressive process in the disturbances of a single equation, although its usefulness as a general test of misspecification in linear regression models has been argued by some (e.g., Harvey 1981). It is not an appropriate test for first-order autocorrelation even in univariate autoregressions, because the presence of a lagged dependent variable biases the Durbin-Watson statistic toward 2. Furthermore, in the paper, the Durbin-Watson test is applied equation by equation, and does not therefore provide a test against noncontemporaneous correlations between the disturbances in different equations. What is required is a test that considers the entire autocorrelation and cross-correlation function of the estimated residuals. For a univariate autoregression, the Box-Pierce Q-statistic provides a useful diagnostic, as do tests based on the Lagrange multiplier principle or indeed simple visual inspection of the autocorrelation function. For multivariate autoregressions, the Lagrange multiplier principle may be used to derive an asymptotically valid test for serial correlation when the system of equations is estimated under the null hypothesis that the disturbances are white noise. In principle the alternative hypothesis could be that the disturbances follow any higher-order AR or MA process. Without asking for the moon, it is clearly desirable that the single-equation Durbin-Watson tests be supplemented by more appropriate diagnostics.

Innovation Accounting and Impulse Response Functions

The impulse response function or transfer function analysis performed in the paper and advocated, for example, by Sims (1980*a*, 1980*b*) is often less informative than it seems. The estimation of an unrestricted vector-autoregressive process will ideally yield a representation of the data-generating process as in (1).[2]

$$A(L)\,x(t) = \epsilon_t \tag{1}$$

x_t is an n-vector, $A(L)$ is a matrix polynomical in the lag operator L with $A(0) = I$ and ϵ_t is an n-vector of random disturbances with $\epsilon_t \sim NID(0, \Omega)$. The variance-covariance matrix of the disturbances Ω will not in general be diagonal: the disturbances will tend to be contemporaneously correlated. To be able to answer the question, "What is the dynamic response of the system to a unit impulse in the ith equation?" Sims proposes to transform the residuals ϵ_t in such a way that the transformed residuals have a diagonal variance covariance matrix. To see what this means, consider the moving average representation of (1) given by

$$x_t = [A(L)]^{-1}\epsilon_t = B(L)\epsilon_t = \sum_{i=0}^{\infty} B_i\epsilon_{t-i},\ B_0 = I. \tag{2}$$

Sims (1980*b*) proceeds by premultiplying ϵ_t by a lower-triangular matrix D which has ones along its main diagonal and which transforms ϵ_t into a vector of contemporaneously independent disturbances. That is, let

$$C_i = B_iD^{-1}, \tag{3a}$$

$$r_t = D\epsilon_t, \tag{3b}$$

and

$$E[r_tr_t'] = [\sigma_{r_ir_j}];\ \sigma_{r_ir_j} = 0,\ i \neq j. \tag{4b}$$

This permits us to write (2) as

$$x_t = C(L)r_t = \sum_{i=0}^{\infty} C_ir_{t-i}. \tag{2'}$$

With this representation of the disturbances, we can identify clearly the jth element of r_t, r_{jt}, as the innovation specific to the jth equation. We now can perturb just the jth equation in period t with a unit impulse. While in period t this affects only the jth element of x, in subsequent periods the effects of r_{jt} will spread through the entire system, propagated by the C_i matrices. In the bivariate examples considered in Louka Katseli's paper,

$$\epsilon_t = \begin{bmatrix} \epsilon_{1t} \\ \epsilon_{2t} \end{bmatrix},\ D = \begin{bmatrix} 1 & 0 \\ d_{21} & 1 \end{bmatrix},$$

2. For empirical purposes the order of the autoregression will generally have to be finite. All processes are assumed to be covariance stationary.

and

$$r_t = D\epsilon_t = \begin{bmatrix} \epsilon_{1t} \\ d_{21}\epsilon_{1t} + \epsilon_{2t} \end{bmatrix}.$$

The contemporaneous variance-covariance matrix of r_t is

$$E[r_t r_t'] = \begin{bmatrix} \sigma_{\epsilon_1}^2 & d_{21}\sigma_{\epsilon_1}^2 + \sigma_{\epsilon_1\epsilon_2} \\ d_{21}\sigma_{\epsilon_1}^2 + \sigma_{\epsilon_1\epsilon_2} & d_{21}^2\sigma_{\epsilon_1}^2 + \sigma_{\epsilon_2}^2 + 2d_{21}\sigma_{\epsilon_1\epsilon_2} \end{bmatrix}.$$

This will be a diagonal matrix if and only if $d_{21} = -\sigma_{\epsilon_1\epsilon_2}/\sigma_{\epsilon_1}^2$ in which case

$$D = \begin{bmatrix} 1 & 0 \\ -\dfrac{\sigma_{\epsilon_1\epsilon_2}}{\sigma_{\epsilon_1}^2} & 1 \end{bmatrix}$$

and

$$E[r_t r_t'] = \begin{bmatrix} \sigma_{\epsilon_1}^2 & 0 \\ 0 & \sigma_{\epsilon_2}^2 - \dfrac{(\sigma_{\epsilon_1\epsilon_2})^2}{\sigma_{\epsilon_1}^2} \end{bmatrix}.$$

The problem with this procedure is that there is no unique way of diagonalizing the variance-covariance matrix of the disturbances. In an n-variable system there are $n!$ linearly independent ways of orthogonalizing the disturbances. The impulse response function will be different for different orthogonalizations.

In the bivariate example, we could instead orthogonalize the disturbances by using the upper-triangular matrix $\overline{D} = \begin{bmatrix} 1 & d_{12} \\ 0 & 1 \end{bmatrix}$. In this case we require

$d_{12} = -\dfrac{\sigma_{\epsilon_1\epsilon_2}}{\sigma_{\epsilon_2}^2}$, in which case

$$\overline{D} = \begin{bmatrix} 1 & -\dfrac{\sigma_{\epsilon_1\epsilon_2}}{\sigma_{\epsilon_2}^2} \\ 0 & 1 \end{bmatrix}$$

and

$$E[r_t r_t'] = \begin{bmatrix} \sigma_{\epsilon_1}^2 - \dfrac{(\sigma_{\epsilon_1\epsilon_2})^2}{(\sigma_{\epsilon_2})^2} & 0 \\ 0 & \sigma_{\epsilon_2}^2 \end{bmatrix}.$$

The C_i matrices that propagate the unit impulses will, unless the disturbances are orthogonal to begin with ($\sigma_{\epsilon_1\epsilon_2} = 0$), differ under D and $\overline{D}$ transformations. Unless one performed the full range of orthogonalizations and established that the impulse response functions are similar for all of them, it is difficult to see what interest attaches to a particular orthogonalization.

Testing for Stability

Vector autoregressions are not immune to the Lucas critique. More generally, changes in the stochastic process generating the data may have occurred over the sample period. Stability tests such as the Chow test can be performed if one has prior reason to suspect a break in the data generating process at a given data. Graphical techniques such as the CUSUM and CUSUM SQUARED tests are helpful as are tests of out-of-sample predictive ability.

Granger Causality Tests

My comments under this heading are not so much a specific criticism of Louka Katseli's use of Granger causality or econometric exogeneity tests as a general warning against the widespread misinterpretation of these tests. I do this with little hope that it will have any significant effects as the tide of lemmings rushing toward the sea appears to be almost unstoppable.

For simplicity, my examples will be bivariate. Let $E(\mid .)$ be the conditional expectation operation. For any variable x_t let $X^t \equiv \{x_s, s < t\}$.

Definition 1: x_t is said to Granger cause y_t *in mean* if

(5a) $$E(y_t \mid Y^t, X^t) \not\equiv E(y_t \mid Y^t).$$

x_t fails to Granger cause y_t *in mean* if

(5b) $$E(y_t \mid Y^t, X^t) \equiv E(y_t \mid Y^t).$$

Instead of referring to Granger causality *in mean,* I shall follow common usage and refer to definition 1 as the definition of Granger causality. A stronger form of Granger causality does, however, relate to the entire conditional distribution of random variables instead of merely to their conditional means. For any variable x, let $F(x_t \mid .)$ denote the conditional distribution function of x_t. Then (Granger 1980):

Definition 2: x_t is said to Granger cause y_t *in distribution* if

(6a) $$F(y_t \mid Y^t, X^t) \not\equiv F(y_t \mid Y^t).$$

x_t fails to Granger cause y_t *in distribution* if

(6b) $$F(y_t \mid Y^t, X^t) \equiv F(y_t \mid Y^t).$$

For policy design and evaluation, the following property is essential.

Definition 3: y_t is said to be *invariant in mean* with respect to x_t if changes in the deterministic components of the structural stochastic process governing x_t do not have any effect on the mean of y_t.

A stronger invariance property is

Definition 4: y_t is said to be *invariant in distribution* with respect to x_t if changes in the deterministic components of the structural stochastic process governing x_t do not have any effect on the distribution function of y_t.

Tests of Granger causality are tests of *incremental predictive content* (Schwert 1979, p. 82), they are not tests of invariance. In fact, there is two-way nonimplication between the two properties, "absence of Granger causality" and "invariance." Yet applied economists almost without fail make invariance propositions on the basis of Granger causality tests. The "two-way nonimplication" can be established using two examples.

Example 1: x Granger causes y does not imply y is not invariant with respect to x.

The example is due to Sargent (1976).

(7) $$y_t = \lambda y_{t-1} + \beta_0[x_t - E(x_t \mid I_{t-1})] + \beta_1[x_{t-1} - E(x_{t-1} \mid I_{t-2})] + u_t,$$

(8) $$x_t = \sum_{i=1}^{n} \delta_i x_{t-i} + \epsilon_t.$$

u_t and ϵ_t are white noise disturbances. I_t is the information set in period t conditioning expectations formed in period t. It is easily seen that x_t Granger causes y_t, since

$$E(y_t \mid Y^t, X^t) = \lambda y_{t-1} + \beta_1(x_t - \sum_{i=1}^{n} \delta_1 x_{t-1-i}) \neq E(y_t|Y^t) = \lambda y_{t-1}.$$

However, changes in the deterministic components of the stochastic process governing x, that is, changes in δ_i, $i = 1, \ldots, n$, do not affect the density function of y_t which, for (7) and (8), is given by

(9) $$y_t = \lambda y_{t-1} + \beta_0\epsilon_t + \beta_1\epsilon_{t-1} + u_t.$$

Note, however, that if it is possible to have an instantaneous feedback rule for x_t which makes it a function of some element(s) of I_t, then changes in the deterministic components of the instantaneous feedback rule will in general alter the density function of y.

Example 2: x fails to Granger cause y does not imply that y is invariant with respect to x.

The failure of Granger causality tests always to flag the presence or absence of invariance is due to their inability to detect effects of x on y operating currently (x_t on y_t) and through anticipations of the future

$[E(x_{t-i} \mid I_{t-j})$ on y_t, $i \geq 1$, $j \geq 0]$. Granger causality tests are "backward looking." According to Granger (1980, p. 330), "The past and present may cause the future but the future cannot cause the past." While this is, by definition, correct for Granger causality, it is misleading for causality in the sense of noninvariance, which is the one relevant for policy design and evaluation. The following example shows how current "policy actions" and current and past anticipations of future policy actions can have effects that are not detected by Granger causality tests. This means that Granger causality tests fail to signal the presence or absence of instantaneous feedback rules or automatic stabilizers. Ironically, they also fail to reveal the presence or absence of anticipated future policy actions. Thus the rational expectations revolution is the final nail in the coffin of the idea that Granger causality tests can settle the issue of policy effectiveness or neutrality. Sargent's assertion that "failure of monetary and fiscal policy variables to cause unemployment and other real variables is sufficient to deliver classical policy implications" (Sargent 1976, p.222) is false. (See also Buiter 1981*b*.)

Consider the following:

(10) $$y_t = \alpha_1 y_{t-1} + \alpha_2 E(x_{t+1} \mid I_t) + \alpha_3 x_t + \alpha_4 x_{t-1} + \epsilon_t^y;$$

(11) $$x_t = \beta y_{t-1} + \epsilon_t^x,$$

where ϵ_t^y and ϵ_t^x are mutually serially independently distributed random disturbances. Eliminating $E(x_{t+1} \mid I_t)$, x_t, and x_{t-1} in (10) using (11) we get

(12) $$\begin{aligned} y_t = {} & (1 - \alpha_2\beta)^{-1}(\alpha_1 + \alpha_3\beta)y_{t-1} \\ & + (1 - \alpha_2\beta)^{-1}\alpha_4\beta y_{t-2} + (1 - \alpha_2\beta)^{-1}\alpha_3\epsilon_t^x \\ & + (1 - \alpha_2\beta)^{-1}\alpha_4\epsilon_{t-1}^x + (1 - \alpha_2\beta)^{-1}\epsilon_t^y. \end{aligned}$$

Now,

$$\begin{aligned} E(y_t \mid Y^t) = {} & (1 - \alpha_2\beta)^{-1}(\alpha_1 + \alpha_3\beta)y_{t-1} + (1 - \alpha_2\beta)^{-1}\alpha_4\beta y_{t-2} \\ & + (1 - \alpha_2\beta)^{-1}\alpha_4 E(\epsilon_{t-1}^x \mid Y^t). \end{aligned}$$

Therefore (assuming ϵ^y and ϵ^x to be contemporaneously independent),

(13a) $$\begin{aligned} E(y_t \mid Y^t) = {} & (1 - \alpha_2\beta)^{-1}(\alpha_1 + \alpha_3\beta)y_{t-1} \\ & + (1 - \alpha_2\beta)^{-1}\alpha_4\beta y_{t-2} \\ & + \frac{\alpha_4\alpha_3\sigma_x^2}{(\alpha_3^2 + \alpha_4^2)\sigma_x^2 + \sigma_y^2}(1 - \alpha_2\beta)^{-1}(\alpha_3\epsilon_{t-1}^x \\ & + \alpha_4\epsilon_{t-2}^x + \epsilon_{t-1}^y). \end{aligned}$$

Also,

(13b) $$\begin{aligned} E(y_t \mid Y^t, X^t) = {} & (1 - \alpha_2\beta)^{-1}(\alpha_1 + \alpha_3\beta)y_{t-1} \\ & + (1 - \alpha_2\beta)^{-1}\alpha_4\beta y_{t-2} \\ & + (1 - \alpha_2\beta)^{-1}\alpha_4\epsilon_{t-1}^x. \end{aligned}$$

Comparing (13a) and (13b), we see that x Granger causes y. (It should be obvious that y also Granger causes x.) Since y is obviously not invariant with respect to x (changes in β alter the mean and the higher moments of y_t), the presence of Granger causality from x to y appears to be a good indicator of the presence of noninvariance of y with respect to x. All the Granger test does, however, is pick up the effect of x_{t-1} in (10). If we set $\alpha_4 = 0$ in (10), x affects y_t only through x_t and through $E(x_{t+1} \mid I_t)$. With $\alpha_4 = 0$, inspection of (12) reveals that y again is not invariant with respect to x: changes in β affect all moments of y. Inspection of (13a) and (13b) reveals, however, that with $\alpha_4 = 0$, x fails to Granger cause y: the Granger test cannot reveal current and anticipated future effects. Even if $\alpha_4 \neq 0$ and lagged effects are present, x will not Granger cause y if the function (11) is nonstochastic, that is, if $\sigma_x = 0$. If x is a policy instrument whose value is determined by some nonstochastic feedback rule, $x_t = \beta y_{t-1}$ might well apply. If x is chosen optimally, this will always be the case.

Of course, Granger causality tests do have their uses in time series analysis. The three most important ones are the following.

First, together with the entire modern time series apparatus of vector autoregressive–moving average processes, "innovation accounting," and the analysis of the contemporaneous correlations between the innovations in the various equations, they are an important tool for *data description*. They represent compact and parsimonious ways of representing the dominant time series properties of a data sample. Data-coherent structural models should be consistent with these representations.

Second, in empirical rational expectations models that fall short of being complete general equilibrium models, there frequently is a problem about what to include in the information set conditioning the expectations. The answer would seem to be that anything that Granger causes the variable to be predicted and can reasonably be assumed to be widely available at low cost should be part of the information set.

Third, in structural model estimation heroic assumptions are often made about statistical exogeneity. Systematic use of Granger causality tests will establish whether these exogeneity assumptions are consistent with the data.

What Granger causality tests cannot do is shed light on such issues as whether the authorities can use the money supply to influence the behavior of real output or prices. Granger causality tests may be sophisticated post hoc, ergo propter hoc; using them as the basis for invariance propositions represents a "sophisticated" fallacy.

These critical general observations do not affect my opinion that the data description contained in the empirical part of this paper is informative. Any theory that cannot generate the kinds of stochastic behavior documented in the paper is not worth having.

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