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Wong, Kin Wah, Ph.D.

Iowa State University, 1993

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The theory of generalized purchasing power parity:
Multivariate cointegration and dynamic analysis of cointegrating systems

by

Kin Wah Wong

A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of the

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1993

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CHAPTER I. INTRODUCTION

Purchasing power parity (PPP) is an important feature of most models of exchange rate determination. It is generally believed that short-run PPP does not hold. However, there is some controversy about the validity of PPP in the long-run. While numerous recent studies find that long-run PPP does not seem to hold, there are some other studies which find results consistent with long-run PPP. Most of these studies have employed Engle and Granger (1987) cointegration techniques to test for long-run PPP. Recently, Baillie and Selover (1987), Corbae and Ouliaris (1988), Enders (1988), Enders and Hurn (1991), Kim and Enders (1991), Patel (1990), and Taylor (1988) all find evidence against long-run PPP.

Nevertheless, Enders (1989) and McNown and Wallace (1989) find evidence that PPP performs well for high inflation countries while Abuaf and Jorion (1990), Edison (1987), and Kim (1990) find some evidence that long-run PPP may hold over a long period. We notice that long-run PPP holds over a long time span or for countries experiencing high inflation, but it fails to hold for the large industrialized western economies such as the U.S. and the U.K in general. One will wonder that long-run PPP holds under some special cases.

Although the empirical studies of PPP provide mixed results, they do not contradict most of the structural exchange rate models. For instance, in the Dornbusch (1976) overshooting model, real shocks (e.g., real income shocks) are responsible for the departures from long-run PPP so that the real exchange rate is non-stationary. However, nominal shocks just have short-run effects on PPP. By long-run money neutrality, nominal shocks do not have any permanent effects on PPP. Thus, if results are in favor of long-run PPP, it may be due to nominal shocks. On the other hand, if results reject long-run PPP, the real shocks must dominate the nominal shocks. Recently, most studies find evidence against long-run PPP, so real exchange rate is non-stationary. It is possibly due to the presence of real shocks (e.g., real income shocks).

However, Enders and Hurn (1991a, b) recognize that if the non-stationary real shocks (e.g., real income shocks) share common trends, real exchange rates will share the same common trends. Thus, the various real exchange rates themselves will be cointegrated. Based on this observation, Enders and Hurn (1991a, b) develop the theory of Generalized Purchasing Power Parity (Generalized-P.P.P). They indicate that if the non-stationary real macroeconomic variables (i.e., real income) share common trends, the non-stationary bilateral real exchange rates will share the same trends. As a result, the various bilateral real exchange rates will be cointegrated among themselves. This is a general concept of Generalized-PPP. Actually, Generalized-PPP is a general form of PPP, and so PPP is just a special case of Generalized-PPP.

The primary aim of this paper is to investigate the existence of Generalized-PPP for the Asian countries. Rapid growth of economic potential in Asia makes it interesting to study the existence of Generalized-PPP. To obtain the underlying background of Generalized-PPP, we review literature on PPP and discuss some empirical studies in Chapter II. Chapter III examines the existence of unit roots for real exchange rates by the augmented Dickey-Fuller tests and the Phillips-Perron tests. In Chapter IV we present the theory of Generalized-PPP and illustrate the concept with a four-country version of Dornbusch (1976) overshooting model. After discussing Johansen (1988) multivariate cointegration techniques, we present empirical tests for Generalized-PPP for the Asian countries studied (i.e., India, Indonesia, Korea, the Philippines, Singapore, and Thailand), and cases of each of the specified Asian countries with the three larger countries (i.e., the U.S., Germany, and the U.K.). Chapter V presents error correction models and shows how the resulting impulse response functions trace out the time paths of the Asian countries' real exchange rates in response to shocks from themselves and the three large countries. Chapter VI is the concluding remarks.

CHAPTER II. LITERATURE REVIEW

Since purchasing power parity (PPP) is inadequate to explain the movements of price and exchange rate in many studies, it is necessary to provide a remedy for its inadequacy. Recently, Enders and Hurn (1991a, 1991b) developed the theory of Generalized Purchasing Power Parity (Generalized-PPP) to generalize the concept of PPP. Accordingly, PPP is only a special case of Generalized-PPP. The emergence of Generalized-PPP is due to the weakness of PPP theory. To review literature on PPP, thus, will provide a first insight into Generalized-PPP.

In this chapter, we review the theory of PPP and discuss its problems in its absolute and relative formulations. Then we present the recent empirical studies for PPP. Lastly, a two-country version of Dornbusch (1976) overshooting model is presented to illustrate short-run and long-run effects of real and nominal shocks on PPP.

Formulations for Purchasing Power Parity

PPP theory was developed by the Swedish economist Cassel (1918) who argued that the exchange rate is determined by the ratio of price levels in the two countries. Thus, if the domestic price level rises (falls), the value of the domestic currency will fall (rises) in the same proportion. Regardless of the places and the types of currencies to make the purchases, PPP ensures that each country's currency has an identical real purchasing power.

There are absolute and relative versions of PPP theory. In its absolute version, PPP is primarily justified by the law of one price, which is the most traditional way. If there are no barriers of trade and transportation costs, and both countries produce a tradeable homogeneous good, then the law of one price postulates that:

$$P_{it} = P_{it}{}^{*}E_t \qquad (2.1)$$

where P_{it} and $P_{it}{}^{*}$ are the prices of good i in the domestic country and the foreign country in period t; E_t is the nominal exchange rate or the domestic price of foreign currency in period t.

Commodity arbitrage is assumed to ensure that the equality in equation (2.1) holds. Equation (2.1) states that in terms of domestic currency, the price of good i in the domestic country is equal to the price of good i in the foreign country. If equation (2.1) holds for all goods, and if national price levels are constructed using the same weights and the same goods for both domestic and foreign countries, then absolute PPP can be obtained as:

$$E_t = P_t / P_t{}^{*} \qquad (2.2)$$

Equation (2.2) states that the nominal exchange rate is equal to the ratio of the domestic price level and the foreign price level. Thus, an increase in the domestic price level or a decrease in the foreign price level will result in an equiproportionate increase in the nominal exchange rate or a depreciation of the domestic currency. Likewise, a fall in the domestic price level or a rise in the foreign price level will lead to the same proportional decrease in the nominal exchange rate or an appreciation of the domestic currency.

If absolute PPP holds, then it implies the real exchange rate, $E_tP_t^* / P_t$, will equal unity. Thus, from equation (2.2), the real exchange rate can be written as:

$$E_tP_t^* / P_t = 1 \qquad (2.3)$$

Equation (2.3) states that the real exchange rate is expressed by the ratio of the foreign price level measured in the domestic currency and the domestic price level. Clearly, if the real exchange rate is equal to one, the purchasing power of money in both the domestic country and the foreign country will be the same. Thus, if the real exchange rate is greater than one, it means a real depreciation of the domestic currency. That is, more domestic goods are needed in exchange for one unit of foreign goods. In the same manner, if the real exchange rate is less than one, it implies a real appreciation of the domestic currency. That is, it requires less domestic goods in exchange for one unit of foreign goods. Only when equation (2.3) holds, it implies absolute PPP holds, and the real exchange rate is in equilibrium.

One important implication of equation (2.3) is that the real exchange rate allows for the inflation differentials between the domestic country and the foreign country. That is, the nominal exchange rate responds to the differentials in inflation rates between the two countries.

Absolute PPP is the strong version of PPP theory. If strong assumptions of absolute PPP are relaxed, it will become the weak or relative version of PPP. That is, transportation costs and barriers of trade such as tariffs and quotas, which are constant over time, are permitted; non-tradeable goods are allowed and their relative prices are also constant overtime. Under these weaker assumptions, relative PPP is more realistic. In this light, if absolute PPP holds, relative PPP will also hold. However, when relative PPP holds, absolute PPP does not necessarily hold.

Relative PPP postulates that the change in the nominal exchange rate over time is proportional to the relative change in the price levels in the domestic country and the foreign country over the same time period such that:

$$\frac{E_{t+1}}{E_t} = \frac{P_{t+1} / P_t}{P_{t+1}^* \; / P_t^*} \tag{2.4}$$

where subscripts t and t+1 denote period t and period t+1.

Thus, if the domestic price level increases (decreases) by 10 percent while the foreign price level does not change from period t to period t+1, the nominal exchange rate will also increase (decrease) by 10 percent from period t to period t+1. That is, the domestic currency will depreciate (appreciate) by 10 percent from period t to period t+1. On the other hand, if the domestic price level does not change from period t to period t+1 while the foreign price level rises (falls) by 10 percent, the nominal exchange rate will decrease (increase) by 10 percent (i.e., the domestic currency will appreciate (depreciate) by 10 percent) from period t to period t+1.

Relative PPP implies that the differential in inflation rates between the domestic country and the foreign country is bridged by the change in the nominal exchange rate. Consider the domestic inflation rate π_t and the foreign inflation rate π_t^* are:

$$\pi_t = \frac{dP_t / dt}{P_t} = \frac{P_{t+1} - P_t}{P_t} \tag{2.5}$$

$$\pi_t^* = \frac{dP_t^* / dt}{P_t^*} = \frac{P_{t+1}^* - P_t^*}{P_t^*} \tag{2.6}$$

and the change in the nominal exchange rate is:

$$\hat{E}_t = \frac{dE_t / dt}{E_t} = \frac{E_{t+1} - E_t}{E_t} \tag{2.7}$$

Hence, equation (2.4) can be rewritten as:

$$\hat{E}_t = \frac{\pi_t - \pi_t^*}{1 + \pi_t^*} \tag{2.8}$$

If the foreign inflation rate π_t^* is small enough, equation (2.8) will be reduced as:

$$\hat{E}_t = \pi_t - \pi_t^* \tag{2.9}$$

Equation (2.9) shows that the change in the nominal exchange rate is equal to the inflation differential between the domestic country and the foreign country.

Thus, when the domestic inflation rate is higher than the foreign inflation rate, the nominal exchange rate will increase or the domestic currency will depreciate from period t to period t+1. Likewise, if the foreign inflation rate is higher than that of the domestic country, the nominal exchange rate will decrease or there is an appreciation of the domestic currency from period t to period t+1.

In its relative version, PPP is usually justified by money neutrality. By the neutrality of money, money does not have any effect on relative prices. That is, if money doubles, price levels of all goods will double. As a result, relative prices will be the same as before, and hence the nominal exchange rate will not be affected.

In addition, the relative version of PPP can also be justified by the Fisher hypothesis. The Fisher hypothesis postulates that the domestic real interest rate is equal to the foreign real interest rate such that:

$$1 + R_t = \frac{1 + i_t}{P_{t+1} / P_t} = \frac{1 + i_t^*}{P_{t+1}^* / P_t^*} = 1 + R_t^* \qquad (2.10)$$

where R_t, R_t^* are the domestic and the foreign real interest rates in period t while i_t and i_t^* are nominal interest rates in the domestic country and the foreign country in period t.

Equation (2.10) implies that the domestic real interest rate equals the foreign interest rate if anticipated inflation rates in both countries are taken into account in estimating their nominal interest rates. Also, the uncovered interest rate parity is known as:

$$1 + i_t = (1 + i_t^*) \frac{E_{t+1}}{E_t} \qquad (2.11)$$

Thus, relative PPP can be obtained by combining equations (2.10) and (2.11) (i.e., equation (2.4) can be obtained by combining equations (2.10) and (2.11)).

Problems in Estimating Purchasing Power Parity

The validity of PPP theory is a big controversy in open economy macroeconomics. Both the absolute version and the relative version of PPP face many difficulities. To examine the difficulties of PPP would help us to develop the theory of Generalized-PPP.

PPP theory postulates that the nominal exchange rate is determined by the relative price between two countries, but the nominal exchange rate does not affect the relative price. Obviously, this is incorrect. In fact, the nominal exchange rate and the relative price can affect each other in the real world. Let us consider a simple example. Suppose there is a depreciation of the domestic currency for some reasons. Then the domestic exports are relatively cheaper than that of the foreign country. In this case, the domestic exporters may try to increase their prices in order to make more profit. Thus, the depreciation of domestic currency will raise the domestic prices and so does the relative price between the domestic country and the foreign country. In this light, PPP is not really the theory of exchange rate determination.

Instead, PPP postulates the equilibrium relationship between the exchange rate and relative price.

Regardless of whether PPP is the theory of exchange rate determination or whether it specifies the equilibrium relationship between the exchange rate and prices, it is rare to believe that PPP holds at all time spans. Even the proponents of PPP believe it holds in the long-run but not in the short-run.

In its relative version, PPP primarily relies on the neutrality of money. Although long-run money neutrality is generally accepted, short-run money neutrality may not be true. In the real world, the response of prices of goods to monetary shocks is slow due to imperfect information and the institutional rigidities, which in turn affects movements in the real exchange rate. In addition, Dornbusch (1976) has argued that the goods market adjusts slowly relative to exchange and assets markets. Thus, monetary shocks have real effects on relative prices and the real exchange rate in the short-run, and hence PPP does not hold in the short-run. At the end of this chapter, a two-country version of Dornbusch (1976) overshooting model will be used to illustrate short-run effects of monetary shocks on PPP in more detail.

In equations (2.2) and (2.4), we need price levels in calculations of absolute PPP and relative PPP. In the real world, however, there are many different goods and hence a number of prices. It is obvious that not all prices enter into the calculation of the general price level. In practice, the general price level is approximated by the price index, and so the components of the price index will influence the response of the nominal exchange rate to the change in the relative price. Thus, an inappropriate price index may yield misleading PPP estimates, and may affect the movements in real exchange rates.

On the one hand, the use of consumer price index includes the prices of tradeable and non-tradeable goods and services, but the prices of non-tradeable goods are not equalized by international trade between countries. On the other hand, the wholesale price index excludes all manufacturing goods and services. If the cost of living index is used, the commodities (e.g., rent) which are irrelevant to international trade will also be included. The use of relative export price index is also suggested, but Samuelson (1964) argued that the use of this index in calculation of PPP would imply the terms of trade between countries' exports to be a universal constant. Also, costs of production are suggested rather than prices in PPP calculation. One popular way is to use the wage index since wages are the primary cost of all forms of goods and services. But if wages are lower in the goods and services exported than that in domestic consumption, then the wage index will not be a good guide to the movements in the price level. Since each price index has its own advantages and drawbacks, the selection of the price index in calculation of PPP is a big controversy so far.

The existence of non-tradeable goods and services also leads to problems with PPP. The transportation costs of non-tradeable goods such as cement and bricks are too high for them to have international trade. Houses may be cheaper in the foreign country than the domestic country, but no one would want to import houses from abroad. Most services such as hair cuts and car repairs do not enter international trade. According to the theory of international trade, the prices of tradeable goods and services are equalized among countries by international trade, but the prices of non-tradeable goods and services tend not to be equalized by international trade. However, the general price index includes prices of tradeable and non-tradeable goods and services, and prices of non-tradeable goods and services are not equalized among countries, so PPP theory misleadingly estimates nominal exchange rates.

Balassa (1964) has pointed out that the ratio of the price of non-tradeable goods and services to the price of tradeable goods and services is relatively higher in developed countries than in developing countries. The reason may be that technology of non-tradeable goods and services such as hair cuts is quite similar in developed and developing countries while it is not in the sector of tradeable goods. In order to retain labor in the non-tradeable goods and services sector in the developed countries, wages must be relatively higher than those in the tradeable goods and services sector. It follows that prices of non-tradeable goods and services are much higher in developed countries than in developing countries. Since the use of the general price index includes the prices of both tradeable and non-tradeable goods and services, and prices of the latter are not equalized across countries by international trade but are relatively higher in developed countries, PPP will lead to an underestimation of the value of currencies for developed countries and an overestimation of the value of currencies for developing countries. The distortions will be greater if the technological gap between developed and developing countries is getting larger.

PPP theory emphasizes the importance of the monetary factors. However, Balassa (1964) has argued that structural changes are as important as the monetary factors. Thus, changes in supply and demand relationships will lead to the misleading PPP estimates. For instance, if the domestic country is in full employment, positive demand shocks will cause increases in prices of domestic goods. As a result, there are deviations from PPP which are caused by the non-monetary factors in the process of price adjustment.

An illustrative model of non-traded goods

Note that non-traded goods cause many problems in PPP formulation. In order to illustrate the role of non-traded goods in PPP formulation, it is useful to develop a model of non-traded goods. As illustrated in the previous section, if commodity arbitrage holds for all goods, and national price levels are constructed using the same weights, then PPP will hold. However, PPP fails if one of the conditions is violated.

Consider a model such as the Dependent Economy Model developed by Salter (1959) with two categories of goods: traded goods and non-traded goods. Then the domestic price level is constructed as a weight average of prices of traded goods and non-traded goods:

$$P_t = P_{Tt}^{\alpha} P_{Nt}^{1-\alpha} \qquad (2.12)$$

where P_T and P_N are prices of traded goods and non-traded goods respectively; α is a weight which is a positive constant.

Similarly, for the foreign country, its price level is constructed in the same way. For simplicity, assume $\alpha = \alpha^*$ since we focus on the issue of non-traded goods so that:

$$P_t^* = P_{Tt}^{*\alpha} P_{Nt}^{*1-\alpha} \tag{2.13}$$

In this model, commodity arbitrage is assumed in traded goods only, but not in non-traded goods such that:

$$P_{Tt} = E_t P_{Tt}^* \tag{2.14}$$

Rewriting equations (2.12) and (2.13) as:

$$P_t = P_{Tt} (\rho_t)^{1-\alpha} \tag{2.15}$$

and $$P_t^* = P_{Tt}^* (\rho_t^*)^{1-\alpha} \tag{2.16}$$

where $\rho = P_{Nt} / P_{Tt}$ and $\rho* = P_{Nt}^* / P_{Tt}^*$ are relative prices of non-traded goods in the domestic country and the foreign country respectively.

Combine equations (2.14) to (2.16) to obtain the following relationship:

$$P_t / (E_t P_t^*) = (\rho_t / \rho_t^*)^{1-\alpha} \tag{2.17}$$

Equation (2.17) implies that the validity of PPP depends on the relative prices of non-traded goods in the domestic and foreign countries (i.e., ρ_t and ρ_t^*). If $\rho_t = \rho_t^*$ in equation (2.17), absolute PPP holds. In general, however, $\rho_t \neq \rho_t^*$ so that absolute PPP does not hold generally. On the other hand, if the domestic and foreign relative prices of non-traded goods (i.e., ρ_t and ρ_t^*)

are constant over time, the relative version of PPP will hold. If there are real shocks (e.g., productivity shocks) in the domestic and foreign countries, ρ_t and ρ_t* will change. Thus, ρ_t and ρ_t* are not constant over time, so the relative PPP does not hold. In particular, if ρ_t / ρ_t* is non-stationary, then the real exchange rate will also be non-stationary and PPP will fail as a long-run relationship.

Empirical Evidence on Purchasing Power Parity

Absolute PPP is mainly justified by the spatial arbitrage of the law of one price. However, the existence of transportation costs, tariffs, quotas, and other trade impediments in reality will violate the required arbitrage conditions. Kravis and Lipsey (1978) have examined commodity arbitrage on disaggregate manufactured goods and have found evidence that the commodity arbitrage view of PPP is hard to accept since commodity arbitrage does not even hold for traded goods. Meanwhile, Richardson (1978) uses regression analysis for disaggregated commodity arbitrage between the U.S. and Canada and concludes that even if commodity arbitrage takes place, it is never perfect. As reported in Table A-1, Isard (1977) finds evidence that disparities between the common currency prices of different countries are systematically correlated with exchange rates, rather than randomly fluctuating over time. Thus, he argues, from the most disaggregated product lists for which domestic and foreign prices can be matched, the relative price effects in different countries mark the manufactured goods as differentiated goods rather than near-perfect substitutes. Therefore, it is impossible to construct the aggregate price index which is expected to follow the law of one price.

The choice of an appropriate price index is a primary problem for measuring PPP. Thygesen (1978) has examined four main price indices for the European Community. The four candidates are export prices, wholesale prices, unit labor costs, and consumer prices. He has pointed out some difficulties in applying the four price indices for measuring PPP. For the export prices, little direct information about long-run equilibrium is given by observation of the law of one price, and prices of import-competing goods are completely omitted. The use of the wholesale price index gives a significant weight to domestic cost elements. Hence, conformity to a parallel price trend in different countries cannot be interpreted as the result of commodity arbitrage. Unit labor costs just give information on the major factor of products but not on total factor costs. Finally, the consumer price index includes not only tradeable goods and services but also non-tradeable goods and services, which lead to a biased measurement of PPP. His findings have indicated that the wholesale price index has performed almost as well as export prices for measuring PPP. Conversely, the use of the consumer price index is the worst. Because of the statistical defects of export prices (i.e., narrow coverage and lack of direct information on prices), Thygesen (1978) suggests to use the wholesale price index in measuring PPP.

In addition, Kim (1990) and McNown and Wallace (1989) have used the wholesale price index and the consumer price index in testing PPP. Both studies have been applied the cointegration technique. Kim (1990) has found that the hypothesis of no cointegration between the exchange rate and the price ratio is more likely rejected for the industrialized countries when the wholesale price index is used than when the consumer price index is used. He concludes that the consumer price index gives a substantial weight to non-tradeable goods, and hence PPP is not easy to hold.

McNown and Wallace (1989) have found evidence in support of PPP in the high inflation economies for the wholesale price index, but not for the consumer price index. Their explanation is that greater weight of tradeable goods is given to the wholesale price index relative to the consumer price index. Also, trade liberalization policies in these high inflation countries allow the law of one price to work well for tradeable goods. Thus, PPP in terms of wholesale price index performs well. Both the findings of Kim (1990) and McNown and Wallace (1989) support Balassa's (1964) argument that structural deviations from PPP arises when the price of non-tradeable goods rises relative to the price of tradeable goods with productivity growth biased toward tradeable goods.

Genberg (1978) has examined the performance of PPP under fixed and flexible exchange rates for fourteen industrialized countries which is reported in Table A-2. His findings indicate that deviations from PPP are both smaller and less prolonged under a fixed exchange rate regime than under a flexible exchange rate regime. He has also found evidence to show that the actual exchange rates will not be too far apart from their PPP levels if there is an appropriate adjustment for structural changes.

One early popular way of testing PPP is to run the simple regression (i.e., ordinary least squares equation). For example, Frenkel (1976) has tested PPP by using the following regression form:

$$\ln E_t = \alpha + \beta \ln(P_t / P_t^*) + u_t \tag{2.18}$$

where u_t is a disturbance term.

Using equation (2.18), PPP holds if $\alpha = 0$, and $\beta = 1$. However, α does not need to be zero if price indices rather than price levels are used. Using 1970's data to test PPP, Frenkel (1976) has used price indices to run the regression form of equation (2.18). He finds evidence inconsistent with PPP since β is not even close to one.

Krugman (1978) has pointed out that testing PPP by simply regressing equation (2.18) is inappropriate since both prices and the exchange rate are endogenous. He solves the problem of simultaneity by using an instrumental variable technique. Thus, he includes a time trend as an instrumental variable in equation (2.18). His results are shown in Table A-3. For all the cases (except the Mark/Dollar), it is not possible to reject the null hypothesis of $\beta = 1$ at the 5% significance level, so he finds results more favorable to PPP.

Instead of using the simple regression tests, most researchers tend to use the Engle and Granger (1987) cointegration technique to test long-run PPP recently. If the exchange rate and the relative prices are cointegrated in equation (2.18), the disturbance term u_t should be stationary, and hence long-run PPP should hold. In this context, the stationarity of u_t can be tested by the augmented Dickey-Fuller tests. For example, Enders (1989), McNown and Wallace (1989) and Patel (1990) has employed the methodology of cointegrating regressions to examine PPP.

Enders (1989) has expressed the PPP relationship (i.e., equation (2.18)) in terms of the real exchange rate:

$$r_t = (E_t P_t^*) / P_t = \beta + u_{1t} \qquad (2.19)$$

where u_{1t} is a stochastic disturbance.

The augmented Dickey-Fuller tests are used to test the stationarity of the dollar/pound real exchange rate during the U.S. greenback and gold-standard periods. His results are reported below:

	Greenback period	Gold-standard period
No lag	-4.558	-4.307
Four lags	-4.569	-4.725

At the 5% significance level, the critical value is -2.93 so that it is possible to reject the null hypothesis of a unit root. Thus, the unit root tests indicate that the real exchange rate was stationary in these two periods, and hence PPP performed well in the pre-World War I period.

McNown and Wallace (1989) have argued that tests of high inflation countries might offer findings favorable to PPP. For the four high inflation countries, Argentina, Brazil, Chile, and Israel, they found cointegration between the exchange rate and the wholesale price index in Argentina, Chile, and Israel during the 1970s and 1980s as shown in Table A-4. In addition,

Table A-5 shows that real exchange rates for Argentina and Chile are also found to be stationary. The results appear to have more support for PPP. They have argued that monetary shocks dominate real shocks for countries experiencing high rates of inflation, and hence evidence favorable to PPP would be more likely.

Patel (1990) has examined the following log-linear PPP relation:

$$e_t = \beta_1 p_t - \beta_2 p_t^* + \varepsilon_t \qquad (2.20)$$

where ε_t is a stochastic disturbance.

He asserts that the traditional constraint that β_1 and β_2 in equation (2.20) should be unity is relaxed since different countries use different weights to construct price indices. Using the Engle-Granger two-step methodology, he has found that the null hypothesis of no cointegration cannot be rejected for twelve out of fifteen country-pairs; the results are shown in Table A-6. Hence, these results do not support a long-run PPP relation.

Note that in the trivariate case for PPP (i.e., equation (2.20)), there may be two cointegration vectors since there are three variables, e_t, p_t, and p_t^*. Using the Engle-Granger methodology, Patel (1990) can, at most, estimate only one cointegration vector. This might be the reason that he finds evidence inconsistent with PPP. Recently, a new multivariate cointegration approach has been developed by Johansen (1988). The methodology is superior to the traditional Engle-Granger approach because it estimates all the cointegration vectors in the multivariate case. The Johansen methodology is discussed in Chapter V in more detail.

MacDonald (1991) has utilized the Johansen methodology to examine the PPP concept for the industrialized countries. For most cases, he finds evidence of a cointegration vector, but the proportionality restrictions of the exchange rate to relative prices are not satisfied, which are shown in Table A-7. He has argued that such restrictions are rejected because of factors such as measurement error and transportation costs. Thus, results support only "weak-form" P.P.P.

Two-Country Version of Dornbusch (1976) Overshooting Model

The two-country version of Dornbusch (1976) overshooting model is presented to illustrate the effects of nominal shocks and real shocks on P.P.P. The model is formulated under perfect capital mobility, perfect foresight, and the assumption that goods markets and prices adjust slower than the asset markets and exchange rates respectively.

For simplicity, both the domestic and foreign countries are considered with identical structural parameters. The model is illustrated in the relative form:

$$i_t = i_t^* + \theta\,(e^{LR} - e_t) \qquad (2.21)$$

$$(m_t - m_t^*) - (p_t - p_t^*) = \phi\,(y_t - y_t^*) - \lambda\,(i_t - i_t^*) \qquad (2.22)$$

$$(D_t - D_t^*) = \delta\,(e_t - p_t + p_t^*) + \gamma\,(y_t - y_t^*) - \sigma\,(i_t - i_t^*) \qquad (2.23)$$

$$(p_{t+1} - p_{t+1}^*) - (p_t - p_t^*) = \pi\,[(D_t - D_t^*) - (y_t - y_t^*)] \qquad (2.24)$$

where i is the interest rate, e^{LR}, e, m, p, y, and D are the natural logarithms of long-run exchange rate, spot exchange rate, money stock, price level, real income and excess demand respectively; t and t+1 are time subscripts, parameters are positive constants and asterisks denote foreign counterparts.

Equation (2.21) is the uncovered interest rate parity. Domestic interest rate equals the foreign interest rate with expected rate of appreciation of the currency. Equation (2.22) is the relative real money market equilibrium condition. Relative real money supply is equal to relative money demand which is positively related to the relative income and negatively related to the interest differential. Equation (2.23) is the relative demand for goods. It is positively related to the relative income and the real exchange rate, and negatively related to the interest differential. Equation (2.24) represents the price adjustment which is positively related to the relative excess demand for goods.

Combining equations (2.21) and (2.22), the relative asset market equilibrium is given by:

$$(m_t - m_t^*) - (p_t - p_t^*) = \phi\,(y_t - y_t^*) - \lambda\theta\,(e^{LR} - e_t) \qquad (2.25)$$

Since $e_t = e^{LR}$ and $(p_t - p_t^*) = (p^{LR} - p^{LR*})$ in the long-run, long-run relative equilibrium price level $(p^{LR} - p^{LR*})$ can be found from equation (2.25) to be:

$$(p^{LR} - p^{LR*}) = (m_t - m_t^*) - \phi\,(y_t - y_t^*) \qquad (2.26)$$

From equations (2.22), (2.23), (2.24) and (2.26), it follows that:

$$(p_{t+1} - p_{t+1}^{*}) - (p_t - p_t^{*}) = \pi [\delta (e_t - p_t + p_t^{*}) - (1 - \gamma) (y_t - y_t^{*}) + (\sigma / \lambda) [(p^{LR} - p^{LR*}) - (p_t - p_t^{*})] \quad (2.27)$$

but $(p_{t+1} - p_{t+1}^{*}) - (p_t - p_t^{*}) = 0$; $(p_t - p_t^{*}) = (p^{LR} - p^{LR*})$ and $e_t = e^{LR}$ in the long-run. Hence, from equation (2.27), long-run equilibrium exchange rate is given by:

$$e^{LR} = (p^{LR} - p^{LR*}) + [(1 - \gamma) / \delta] (y_t - y_t^{*}) \quad (2.28)$$

Now, let us first show the effects of nominal shocks for PPP in both the long-run and the short-run.

From equation (2.26), the effect of an increase in the domestic money supply on long-run relative price level is given by:

$$\frac{d(p^{LR} - p^{LR\,*})}{dm_t} = 1 \quad (2.29)$$

On substituting equation (2.26) into equation (2.28) the effect of money shock on long-run exchange rate is found to be:

$$\frac{de^{LR}}{dm_t} = 1 \quad (2.30)$$

Real exchange rate r_t is expressed as $r_t = e_t - p_t + p_t^*$. Hence, by combining equations (2.29) and (2.30) the effect of nominal shocks on long-run real exchange rate will be:

$$\frac{dr^{LR}}{dm_t} = \frac{de^{LR}}{dm_t} = \frac{d(\, p^{LR} \; - \; p^{LR*}\,)}{dm_t} = 0 \qquad (2.31)$$

From equation (2.31) the nominal shock does not have any effect on long-run real exchange rate. It means that long-run PPP holds under nominal shocks.

Noting that $d(p^{LR} - p^{LR*}) = de^{LR} = dm_t$, from equation (2.25) the effect of money supply shock on short-run spot exchange rate is given by:

$$\frac{de_t}{dm_t} = 1 + 1 \,/\, (\lambda\theta) \qquad (2.32)$$

Equation (2.32) states that the exchange rate overshoots by $1 \,/\, (\lambda\ \theta)$ in the short-run. Under the assumption of short-run sticky prices, it is obvious that there is a temporary depreciation of real exchange rate. That is,

$$\frac{dr_t}{dm_t} = \frac{de_t}{dm_t} - \frac{d(\, p_t - p_t^*\,)}{dm_t} = 1 + 1 \,/\, (\lambda\theta) \qquad (2.33)$$

Now, let us consider the presence of real shocks. From equation (2.25), short-run effect of the productivity shock on the exchange rate is given by:

$$\frac{de_t}{dy_t} = \frac{-\,\phi}{\lambda\theta} \qquad (2.34)$$

As prices are sticky in the short-run, short-run real exchange rate is given by:

$$\frac{dr_t}{dm_t} = \frac{de_t}{dm_t} - \frac{d(p_t - p_t^*)}{dm_t} = \frac{-\phi}{\lambda\theta} \tag{2.35}$$

Equation (2.35) shows that the real exchange rate appreciates in the short-run.

From equation (2.26), the effect of productivity shock on long-run relative price level is given by:

$$\frac{d(p^{LR} - p^{LR*})}{dy_t} = -\phi \tag{2.36}$$

On substituting equation (2.26) into equation (2.28), the effect of productivity shock on long-run exchange rate is:

$$\frac{de^{LR}}{dy_t} = \frac{(1-\gamma)}{\delta} - \phi \tag{2.37}$$

Thus, by combining equations (2.36) and (2.37), the effect of real shock on long-run real exchange rate is found to be:

$$\frac{dr^{LR}}{dy_t} = \frac{de^{LR}}{dy_t} - \frac{d(p^{LR} - p^{LR*})}{dy_t} = \frac{(1-\gamma)}{\delta} \tag{2.38}$$

From equation (2.38), there is a depreciation of long-run real exchange rate. It implies that real shocks can cause permanent deviations from PPP.

CHAPTER III. UNIVARIATE TESTS FOR UNIT ROOTS IN REAL EXCHANGE RATES

Univariate Unit Root Tests

Chapter II discusses many different empirical studies and tests for PPP. In this chapter, two popular univariate tests ---- the augmented Dickey-Fuller (1979, 1981) tests and the Phillips-Perron (1988) tests ---- for unit roots in the bilateral real exchange rates are employed.

The bilateral real exchange rate was defined as:

$$r_{1it} = e_{1it} + p_{it} - p_{1t} \qquad (3.1)$$

where r_{1it} is the bilateral real exchange rate between country 1 and country i in period t; e_{1it} is the bilateral nominal exchange rate between country 1 and country i in period t; and p_{jt} is the wholesale price index of country j. All variables are in natural logarithms.

PPP implies that the bilateral real exchange rate in equation (3.1) is a stationary process. In order to test PPP, we can test the stationarity of the bilateral real exchange rate by using the unit root tests.

Tests for unit roots are performed using the augmented Dickey-Fuller tests and the Phillips-Perron tests. The tests involve the estimation of the following two equations:

$$r_{1it} = \mu^* + \alpha^* r_{1it-1} + u_t^* \qquad (3.2)$$

$$r_{1it} = \mu' + \beta' t + \alpha' r_{1it-1} + u_t' \qquad (3.3)$$

Equation (3.2) is the first order autoregression with a constant term while equation (3.3) is the first order autoregression with a constant term and a deterministic time trend.

The Phillips-Perron tests allow for weakly dependent and heterogeneously distributed error terms. The test statistics involve testing the null hypothesis of a unit root (i.e., H_0: $\alpha^* = 1$ in equation (3.2), and H_0: $\alpha' = 1$ in equation (3.3)) against the alternative that it does not.

The Dickey-Fuller methodology assumes that the disturbances in equations (3.2) and (3.3) are i.i.d. If the disturbances in equations (3.2) and (3.3) are serially correlated, the lags of r_{1it} will be included in order to guarantee serially uncorrelated disturbances. Thus, equations (3.2) and (3.3) become:

$$r_{1it} = a_o + a_1 r_{1it-1} + a_2 r_{1it-2} + \dots\dots\dots + a_{n+1} r_{1it-(n+1)} + \varepsilon_t \qquad (3.4)$$

$$r_{1it} = a_o' + \theta t + a_1' r_{1it-1} + a_2' r_{1it-2} + \dots\dots\dots + a_{n+1}' r_{1it-(n+1)} + \varepsilon_t' \qquad (3.5)$$

The augmented Dickey-Fuller tests consist of rewriting equations (3.4) and (3.5) as:

$$\Delta r_{1it} = a_o + \rho r_{1it-1} + \sum_{j=1}^{n} b_j \Delta r_{1it-j} + \varepsilon_t \qquad (3.6)$$

$$\Delta r_{1it} = a_o' + \theta t + \rho' r_{1it-1} + \sum_{j=1}^{n} b_j' \Delta r_{1it-j} + \varepsilon_t' \qquad (3.7)$$

where $\rho = \sum_{i=1}^{n} a_i - 1$; $b_j = -\sum_{i=1}^{n} a_{i+1}$ $\qquad \rho' = \sum_{i=1}^{n} a_i' - 1$; $b_j = -\sum_{i=1}^{n} a_{i+1}'$

If ρ in equation (3.6) and ρ' in equation (3.7) are significantly different from zero, then the null hypothesis of a unit root will be rejected. Both the augmented Dickey-Fuller tests and the Phillips-Perron tests require the substantially negative values of test statistics to reject the null hypothesis of a unit root. Critical values for the two unit root tests are tabulated in Fuller (1976) and are presented with the following results.

Unit Root Tests for Real Exchange Rates

We obtained monthly wholesale prices and monthly nominal exchange rates from the IMF data tapes over the period January 1973 to December 1989 (i.e., the post Bretton Woods period representing flexible exchange rates) for the following countries: Germany, India, Indonesia, Japan, Korea, the Philippines, Singapore, Thailand, the United Kingdom, and the United States. Unfortunately, we do not have monthly wholesale prices for Hong Kong, Malaysia, and Taiwan. Note also that the price series for Singapore runs from January 1974 to December 1989 while the price series for Indonesia runs from January 1973 to April 1986. We then used wholesale prices and nominal exchange rates to construct real exchange rates in equation (3.1). In our empirical studies, we use Japan as the base country (i.e., country 1 in equation (3.1) is Japan). Those bilateral real exchange rates were then normalized to zero for the first period (i.e., the bilateral real exchange rates in January 1973 equal zero, except the bilateral real exchange rate for Singapore, which is equal to zero in January 1974). The time paths of the nine real exchange rates are shown in Figures 3-1 through 3-9.

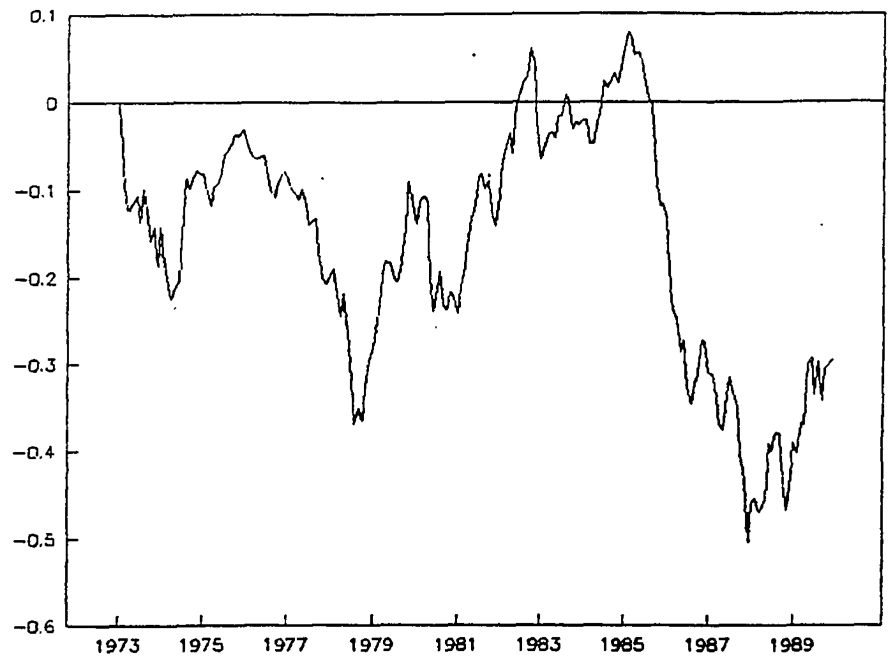

Figure 3-1. The U.S. real exchange rate

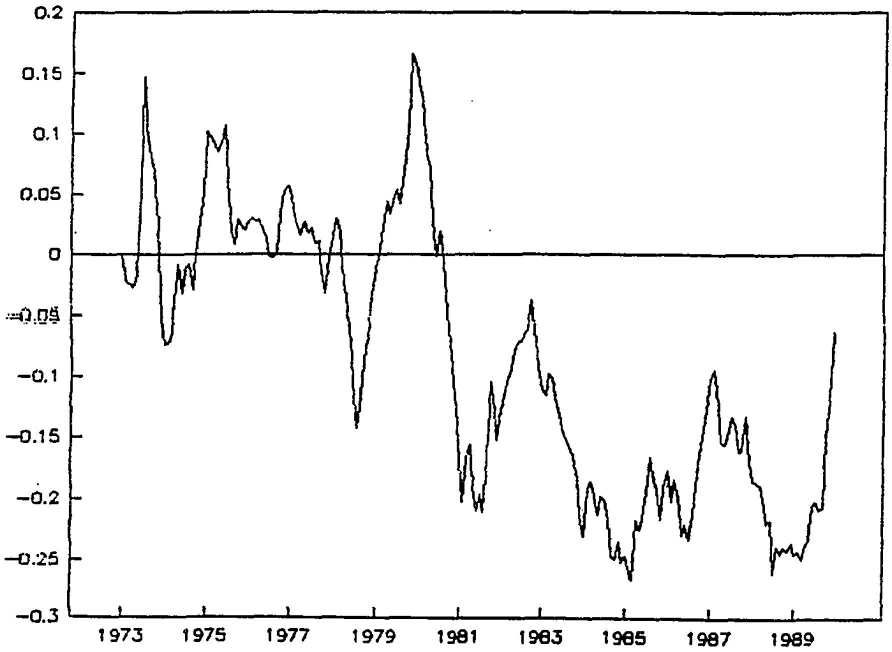

Figure 3-2. The German real exchange rate

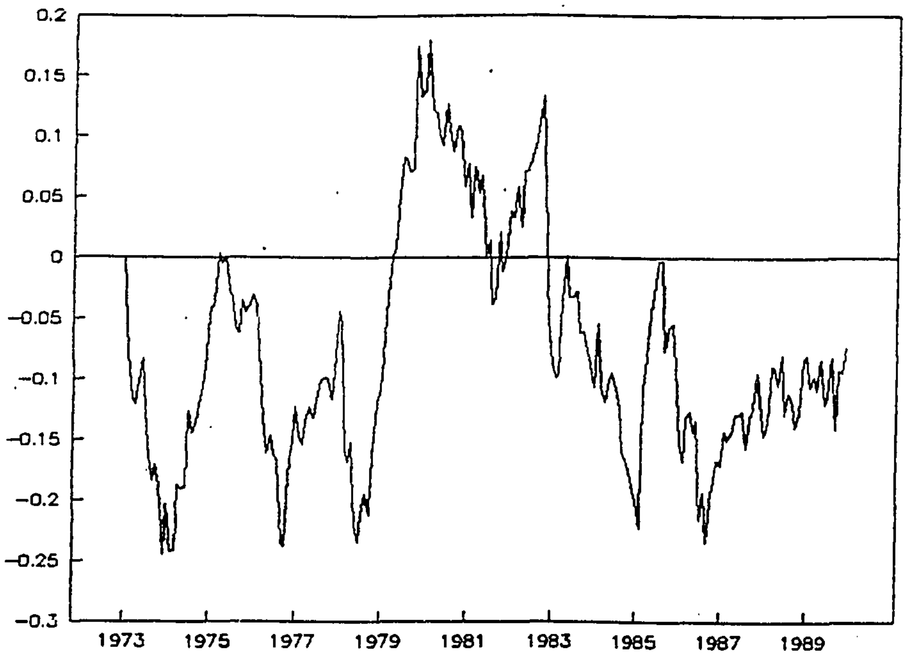

Figure 3-3. The U.K. real exchange rate

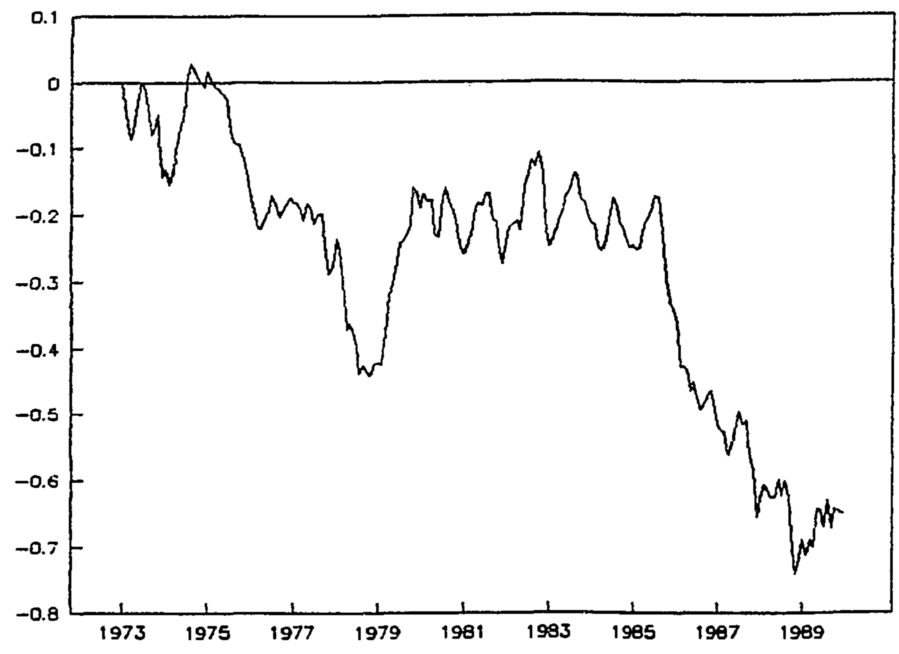

Figure 3-4. The Indian real exchange rate

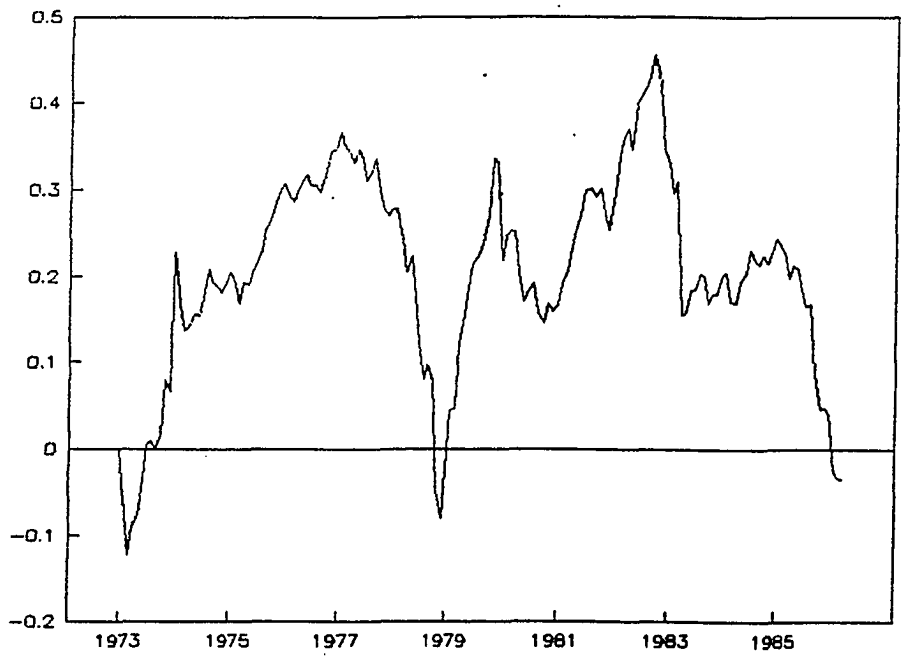

Figure 3-5. The Indonesian real exchange rate

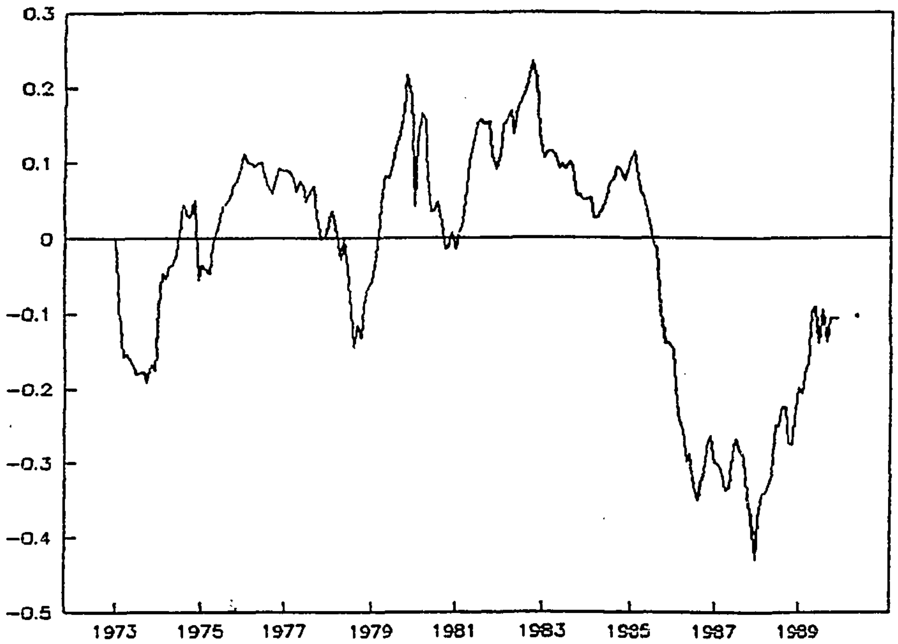

Figure 3-6. The Korean real exchange rate

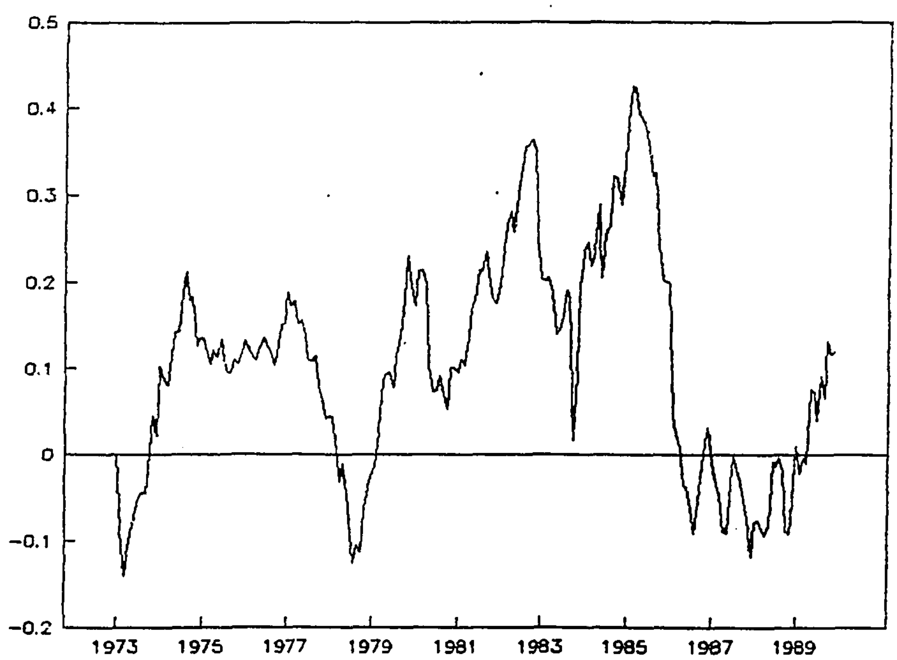

Figure 3-7. The Philippine real exchange rate

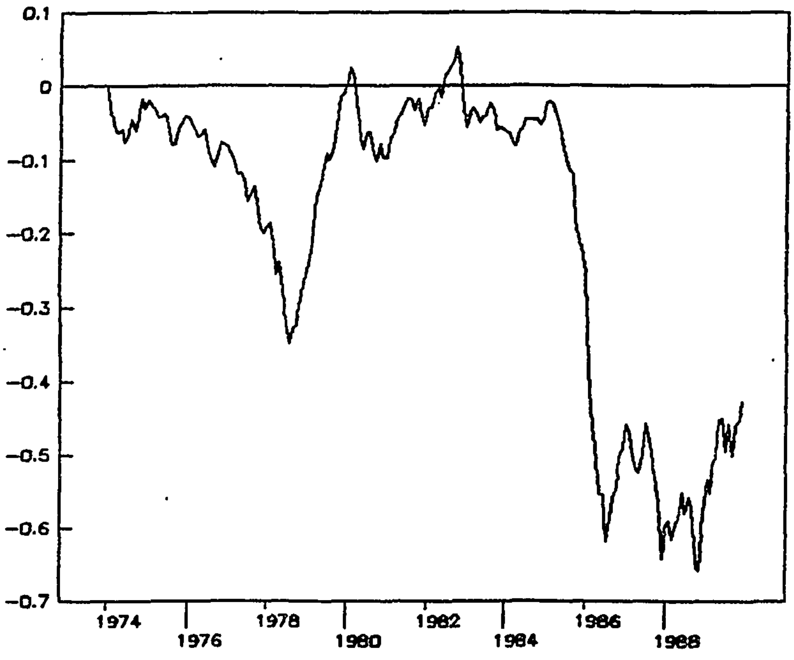

Figure 3-8. The Singapore real exchange rate

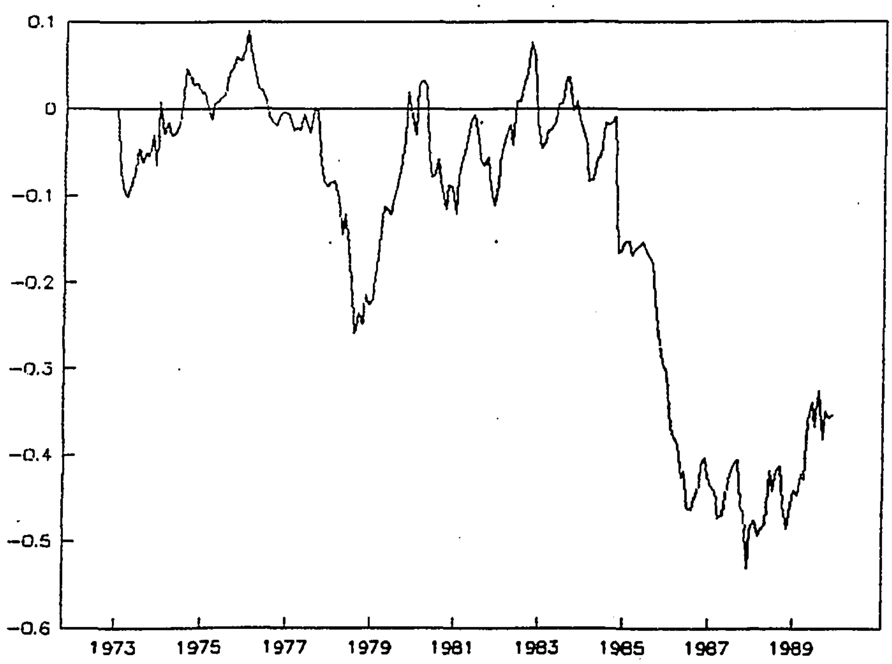

Figure 3-9. The Thai real exchange rate

Table 3-1 reports results of the augmented Dickey-Fuller tests and the Phillips-Perron tests. Each test included twelve lags in order to reflect the use of monthly data. With 100 (250) observations at the 5% significance level, the critical values are -2.89 (-2.88) for the two tests without time trend, and -3.45 (-3.43) for the two unit root tests with a deterministic trend. For the augmented Dickey-Fuller tests, the reported test statistics indicate that the null hypothesis of a unit root cannot be rejected at the 5% significance level for all cases except for the German/Japanese bilateral real exchange rate with a deterministic trend. Turning to the Phillips-Perron tests, with the exception of the U.K./Japanese bilateral real exchange rate without trend, the null

Table 3-1. Univariate tests for unit roots in real exchange rates

	Dickey-Fuller		Phillips-Perron	
	No trend	Trend	No trend	Trend
Germany	-1.89	-3.72*	-2.04	-2.91
India	-0.63	-1.91	-0.81	-1.85
Indonesia	-1.58	-1.43	-2.27	-1.87
Korea	-1.71	-2.39	-1.82	-2.05
Philippines	-2.67	-2.67	-2.59	-2.58
Singapore	-1.43	-1.94	-1.27	-1.82
Thailand	-1.32	-2.15	-1.09	-2.00
U. K.	-2.64	-2.67	-2.90*	-2.08
U. S.	-2.14	-2.43	-1.95	-2.08

Note: 12 lags are included for each test.

* indicates statistical significance at the 5% level.

Critical values at the 5% significance level:

	No trend	Trend
100 observations	-2.89	-3.45
250 observations	-2.88	-3.43

hypothesis that the bilateral real exchange rate has a unit root cannot be rejected for all cases.

Examining German/Japanese and the U.K./Japanese bilateral real exchange rates in more detail, one would question the stationarity of these two real rates. As shown in Figures 3-2 and 3-3, both real rates look to be non-stationary. Also, the German/Japanese real rate shows evidence of a unit root in the absence of a deterministic trend. Even though it is tested to be stationary with including a deterministic trend at the 5% significance level by the augmented Dickey-Fuller test, the null hypothesis of a unit root cannot be rejected at the 1% significance level. With 100 (250) observations at the 1% significance level, the critical value is -4.04 (-3.99). Furthermore, the null hypothesis of a unit root in the presence of a trend is rejected by using the Phillips-Perron test.

In the case of the U.K./Japanese bilateral real rate, the null hypothesis of a unit root in the absence of a deterministic trend is just barely rejected at the 5% significance level by using the Phillips-Perron test. In addition, the real rate is shown to have a unit root by the other test statistics.

Figures 3-10 to 3-18 show the first differences of the nine real exchange rates. It seems that all the real rates appear to be stationary. In order to make sure whether each bilateral real exchange rate has a unit root, we test for a unit root in the first differences of the bilateral real exchange rates. Table 3-2 reports results for the augmented Dickey-Fuller tests and the Phillips-Perron tests with twelve lags on the first differences of the bilateral real exchange

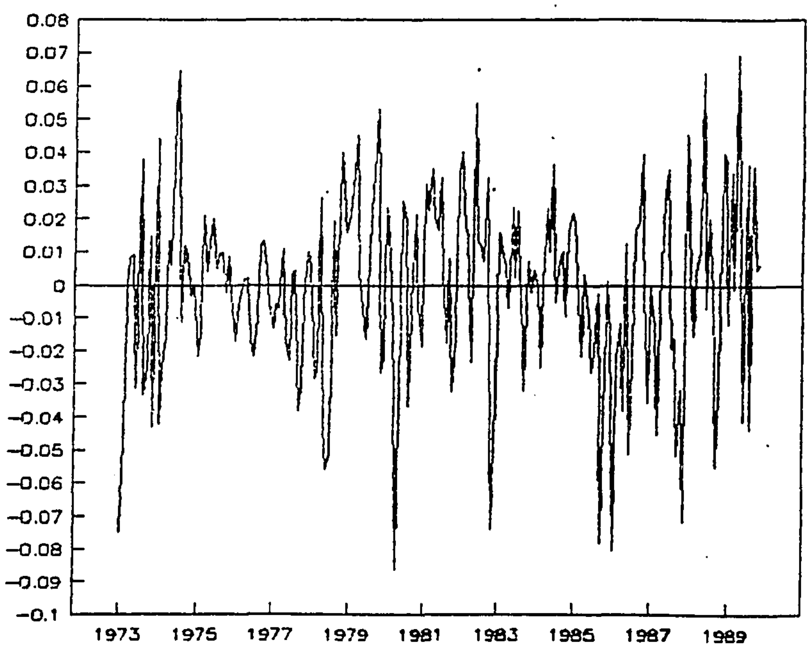

Figure 3-10. The first-differenced U.S. real exchange rate

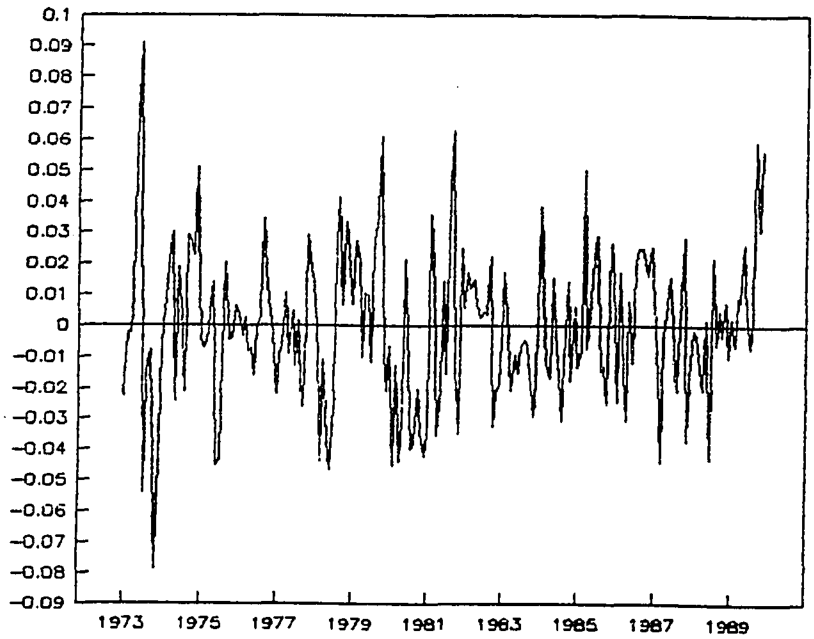

Figure 3-11. The first-differenced German real exchange rate

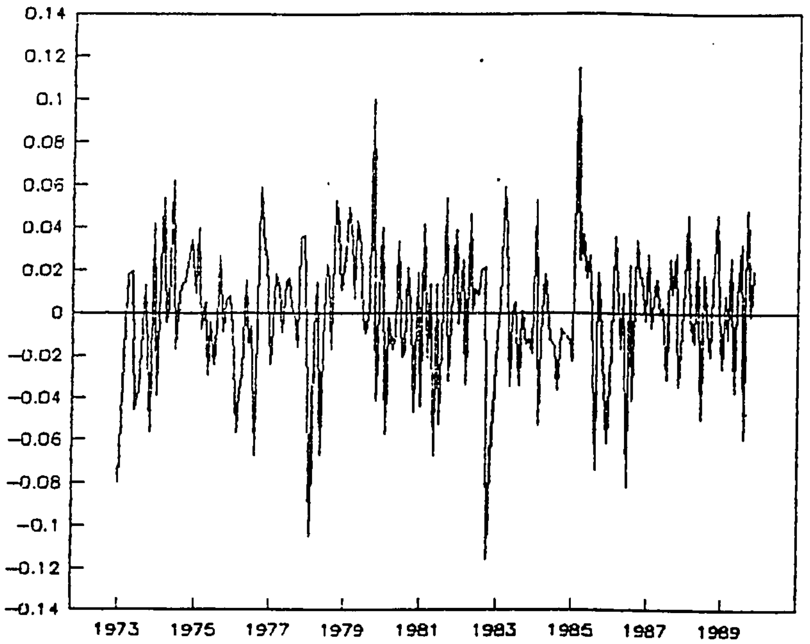

Figure 3-12. The first-differenced U.K. real exchange rate

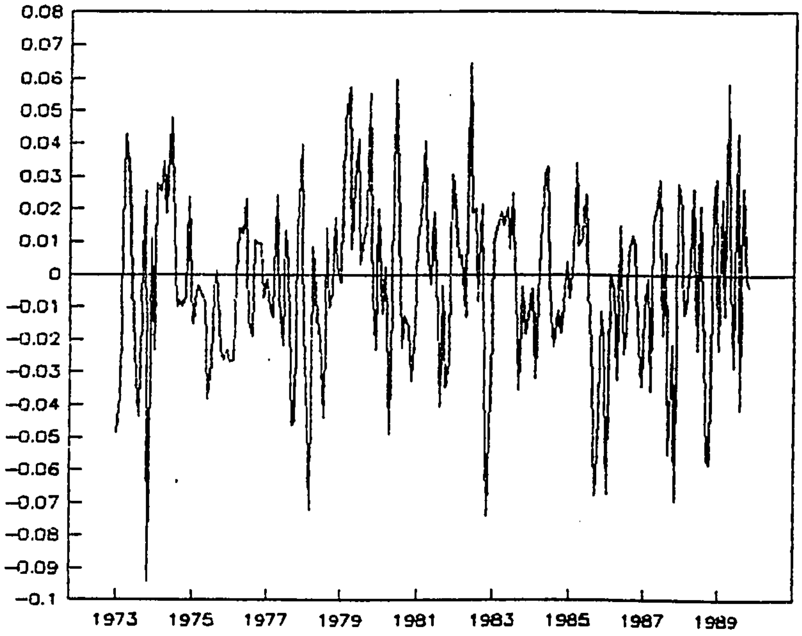

Figure 3-13. The first-differenced Indian real exchange rate

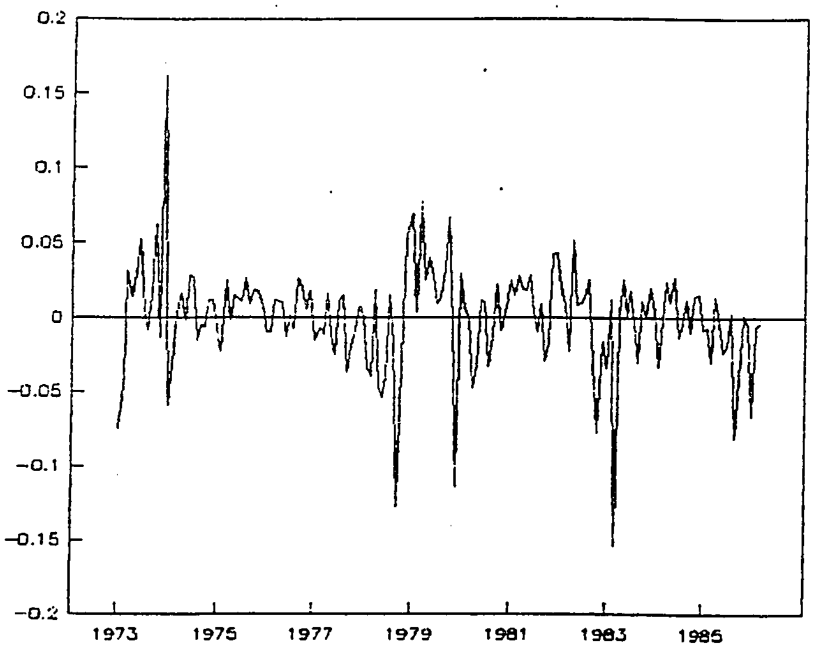

Figure 3-14. The first-differenced Indonesian real exchange rate

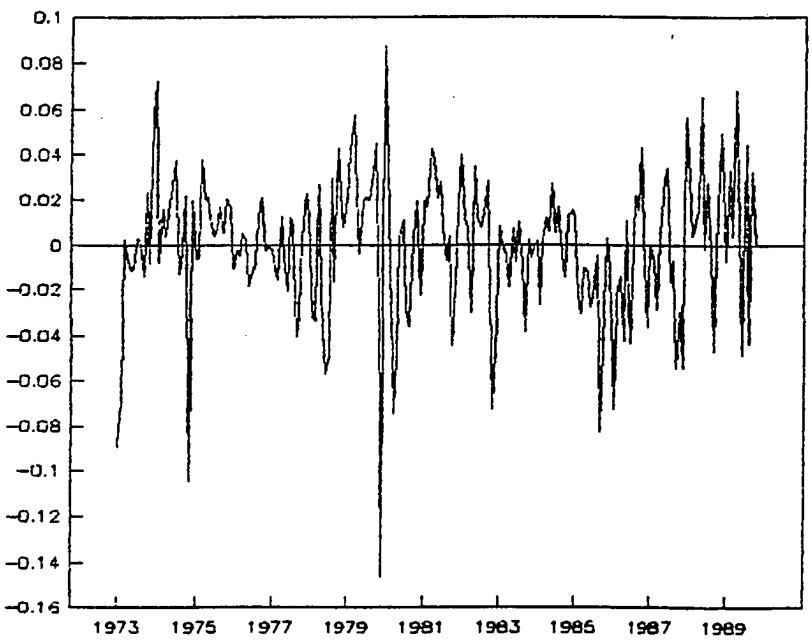

Figure 3-15. The first-differenced Korean real exchange rate

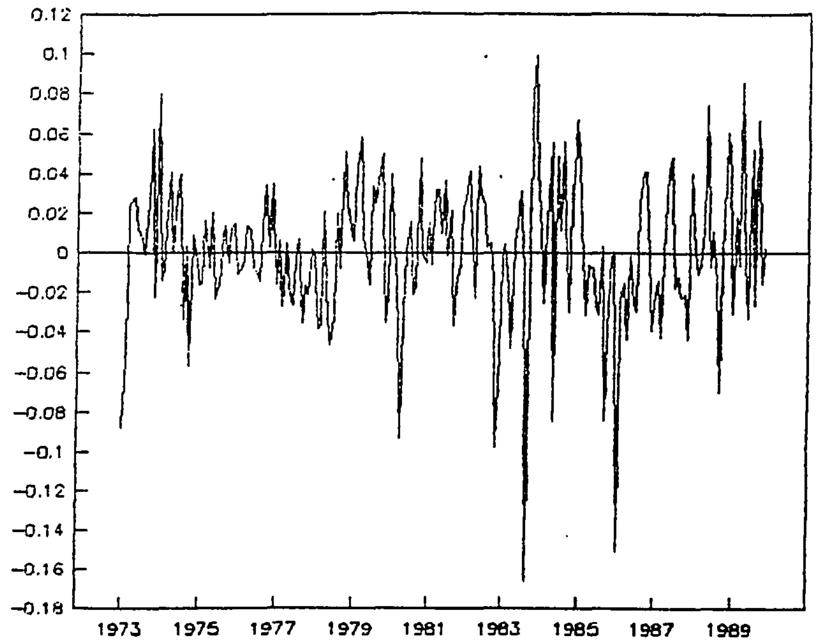

Figure 3-16. The first-differenced Philippine real exchange rate

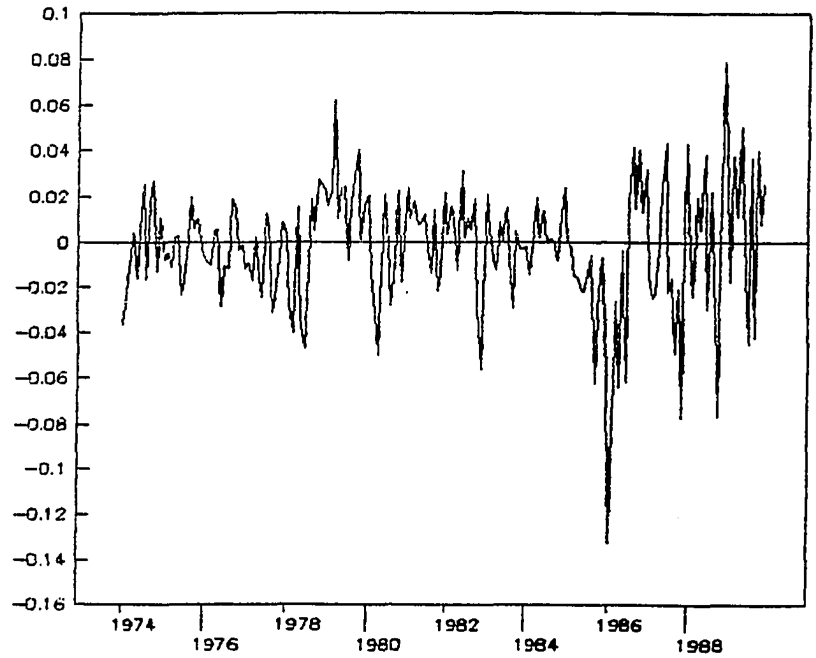

Figure 3-17. The first-differenced Singapore real exchange rate

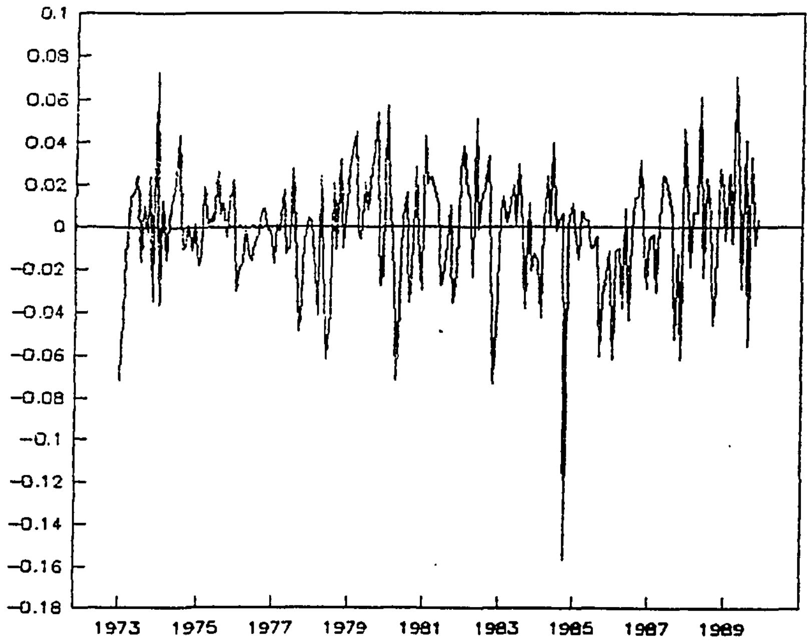

Figure 3-18. The first-differenced Thai real exchange rate

rates. For all countries except Thailand, the null hypothesis of a unit root is rejected for the bilateral real exchange rates using differenced data at the 5% significance level. For most cases, this null can be strongly rejected at the 1% significance level. Notice, however, that the stationarity in the first-differenced Thailand/Japanese bilateral real rate is only borderline insignificant at the 5% level using the augmented Dickey-Fuller test with including time trend. In the absence of such a trend, however, the null hypothesis that the first-differenced bilateral real rate for Thailand has a unit root is rejected even at the 2.5% significance level using the augmented Dickey-Fuller test. With sample size 100 (250) at the 2.5% significance level,

Table 3-2. Univariate tests for unit roots in the first differences of the real exchange rates

	Dickey-Fuller		Phillips-Perron	
	No trend	Trend	No trend	Trend
Germany	-3.80**	-3.78*	-9.99**	-10.00**
India	-4.05**	-4.16**	-11.24**	-11.24**
Indonesia	-3.70**	-3.97**	-11.53**	-11.68**
Korea	-3.82**	-3.83*	-12.13**	-12.15**
Philippines	-4.16**	-4.11**	-12.89**	-12.89**
Singapore	-3.72*	-3.69*	-10.90**	-10.89**
Thailand	-3.43*	-3.40	-13.69**	-13.71**
U. K.	-4.67**	-4.70**	-14.69**	-14.68**
U. S.	-3.72**	-3.75*	-12.00**	-11.99**

Note: 12 lags are included for each test.

* and ** indicates statistical significance at the 5% and 1% levels respectively.

Critical values:	5% significance level		1% significance level	
	No trend	Trend	No trend	Trend
100 observations	-2.89	-3.45	-3.51	-4.04
250 observations	-2.88	-3.43	-3.46	-3.99

the critical value is -3.17 (-3.14). In addition, the two Phillips-Perron statistics for the Thailand case are the substantially negative values so that they lead to the rejection of the null hypothesis of a unit root at the 1% significance level. Meanwhile, the first-differenced Thai real rate looks stationary in Figure 3-18. In fact, the Phillips-Perron statistics for all countries are the substantially negative values, and thus the null hypothesis of non-stationarity is strongly rejected at the 1% significance level for all of the first-differenced bilateral real exchange rates.

These results confirm the previous results. All the bilateral real exchange rates have a unit root, and each bilateral real rate is a non-stationary series. Furthermore, there is no unit root in the first differences of bilateral real exchange rates. Hence, bilateral real exchange rates are integrated of order one, and are stationary in first differences.

Concluding Remarks

Visual inspection shows that real exchange rates of Germany, India, Indonesia, Korea, the Philippines, Singapore, Thailand, the U.K., and the U.S. are first-differenced stationary. Using the formal tests, the augmented Dickey-Fuller tests and the Phillips-Perron tests, the null hypothesis of a single unit root in the real exchange series cannot be rejected for any country. Thus, all the real exchange rates are non-stationary, and hence PPP receives no support from the data.

CHAPTER IV. GENERALIZED PURCHASING POWER PARITY AND THE EMPIRICAL TESTS

Generalized Purchasing Power Parity

Most studies find that long-run PPP does not hold in general so that bilateral real exchange rates are generally non-stationary. Even though bilateral real exchange rates are individually non-stationary, certain groups of bilateral real exchange rates may be stationary if their fundamental factors (e.g., the real income processes) are closely interrelated. Following the above argument, Enders and Hurn (1991a,b) develop the theory of Generalized Purchasing Power Parity (Generalized-PPP). According to Generalized-PPP, the bilateral real exchange rates are generally non-stationary because the real fundamentals (i.e. the real macroeconomic time series), such as the real income processes, of the bilateral real exchange rates are, in general, non-stationary. However, if the real fundamentals themselves are closely interrelated and exhibit the existence of common trends, then a certain group of bilateral real exchange rates will be stationary. In other words, if the real fundamentals share common trends among themselves, the various bilateral real exchange rates themselves will be cointegrated. Meanwhile, there will exist at least one stationary linear combination of the various bilateral real exchange rates.

If Generalized-PPP holds, the countries involved will constitute an optimum currency area as defined by Mundell (1961). In an optimum currency area, member countries will experience the same type of real macroeconomic shocks and share common trends. Hence, there exists a linear combination of bilateral real exchange rates for the member countries which is stationary; this will be illustrated in the next section. This stationary linear combination of the various bilateral real exchange rates implies the existence of a long-run equilibrium relationship between bilateral real exchange rates of the members of the currency area. Thus, Generalized-PPP is defined as:

$$r_{12t} = \beta_{10} + \beta_{13} r_{13t} + \beta_{14} r_{14t} + \beta_{15} r_{15t} + \ldots + \beta_{1n} r_{1nt} + \varepsilon_t \quad (4.1)$$

where r_{1it} are the logarithms of the bilateral real exchange rates between country 1 and country i in period t; ε_t is a stationary white noise process with zero mean. Note that parameters in equation (4.1) constitute the cointegration vector.

In fact, a traditional PPP relation is a special case of Generalized-PPP. It is easy to see the relation by considering the antilogarithmic form of equation (4.1):

$$(e_{12t}p_{2t})/p_{1t} = \exp^{\beta 10}[(e_{13t}p_{3t})/p_{1t}]^{\beta 13}[(e_{14t}p_{4t})/p_{1t}]^{\beta 14} \ldots\ldots [(e_{1nt}p_{nt})/p_{1t}]^{\beta 1n}\omega_t \quad (4.2)$$

where e_{1it} are nominal exchange rates between country i and country 1 in period t; p_{it} are price levels of country i in period t; ω_t is the antilog of the white noise process ε_t in equation (4.1).

If all the β_{1i} in equation (4.2) equal zero, equation (4.2) will become a usual PPP relation ($e_{12t} = p_{1t} / p_{2t}$). Using the same notations as in Chapter II, that will be $e_t = p_t / p_t^*$.

Dornbusch Overshooting Model: Four-Country Version

In order to illustrate the theory of Generalized-PPP, a four-country version of Dornbusch (1976) overshooting model is developed to show how the concepts work. In this four-country case, we allow different structural parameters for the four countries. All the other assumptions will remain the same as those of the two-country version in Chapter II.

For the four-country version of Dornbusch (1976) overshooting model, country j's money market equilibrium:

$$m_{jt} - p_{jt} = \phi_j y_{jt} - \lambda_j i_{jt} \qquad ; \quad j = 1, 2, 3, 4 \qquad (4.3)$$

In the money market equilibrium condition, real money supply is equal to money demand which is positively related to the domestic income and negatively related to the domestic interest rate.

Country j's aggregate demand for goods:

$$D_{jt} = \eta_{jk} r_{jkt} + \eta_{jh} r_{jht} + \eta_{jn} r_{jnt} + c_j y_{jt} + f_{jk} y_{kt} + f_{jh} y_{ht} + f_{jn} y_{nt} - \sigma_j i_{jt}$$
$$; \quad j = 1, 2, 3, 4; \qquad j \neq k \neq h \neq n \quad (4.4)$$

In equation (4.4) the aggregate demand for domestic goods is positively related to the domestic income and foreign income levels, and relative prices of foreign to domestic goods (i.e., the real exchange rates), and inversely related to the domestic interest rate.

Country j's price adjustment equation:

$$p_{jt+1} - p_{jt} = \pi_j [D_{jt} - y_{jt}] \qquad (4.5)$$

In equation (4.5) if there is an excess demand (supply), the price level will rise (fall).

Uncovered interest rate parity condition:

$$i_{1t} = i_{kt} + E_t[e_{1kt+1} - e_{1kt}] \qquad ; \quad k = 2, 3, 4 \qquad (4.6)$$

In equation (4.6), the domestic interest rate is equal to the foreign interest rate with the expected rate of appreciation of the currency.

where m_{jt} = country j's money stock;

p_{jt} = country j's price level;

y_{jt} = country j's real income;

i_{jt} = country j's interest rate;

D_{jt} = country j's aggregate demand for goods;

r_{jkt} = the real exchange rate between countries j and k;

e_{jkt} = the nominal exchange rate between countries j and k;

all the above variables are in natural logarithms;

ϕ, λ, η, c, f, σ, π = positive constants;

E_t = expectation operator.

Real exchange rates are defined as before, such that:

$$r_{jkt} = e_{jkt} + p_{kt} - p_{jt} \qquad (4.7)$$

As $r_{jkt} = -r_{kjt}$ and $r_{jht} = r_{jkt} - r_{hkt}$, then only three independent real exchange rates are determined in the four-country model. By the same token, there are three independent nominal exchange rates since $e_{jkt} = -e_{kjt}$ and $e_{jht} = e_{jkt} - e_{hkt}$.

From equation (4.3), there are four money market equilibrium conditions. Substituting equation (4.4) into equation (4.5) gives another four equations. From equation (4.6) and equation (4.7), we have three uncovered interest rate parity conditions and three independently determined real exchange rates. Thus, a unique solution exists since there are fourteen independent equations which can be used to solve fourteen variables (i.e., 3 real exchange rates, 3 nominal exchange rates, 4 interest rates, and 4 price levels). By the given initial conditions, the solution will be linear in terms of income and money processes so that the solution for the three real exchange rates will be:

$$\begin{bmatrix} r_{12t} \\ r_{13t} \\ r_{14t} \end{bmatrix} = \begin{bmatrix} a_{11}(L) & a_{12}(L) & a_{13}(L) & a_{14}(L) \\ a_{21}(L) & a_{22}(L) & a_{23}(L) & a_{24}(L) \\ a_{31}(L) & a_{32}(L) & a_{33}(L) & a_{34}(L) \end{bmatrix} \begin{bmatrix} y_{1t} \\ y_{2t} \\ y_{3t} \\ y_{4t} \end{bmatrix} + \begin{bmatrix} b_{11}(L) & b_{12}(L) & b_{13}(L) & b_{14}(L) \\ b_{21}(L) & b_{22}(L) & b_{23}(L) & b_{24}(L) \\ b_{31}(L) & b_{32}(L) & b_{33}(L) & b_{34}(L) \end{bmatrix} \begin{bmatrix} m_{1t} \\ m_{2t} \\ m_{3t} \\ m_{4t} \end{bmatrix} \quad (4.8)$$

where $a_{ij}(L)$ and $b_{ij}(L)$ are polynomials in the lag operator of order p.

In the long run, the sum of elements for each $b_{ij}(L)$ in equation (4.8) is zero by long-run money neutrality. It implies that money does not have any permanent effects on real exchange rates. Thus, the general long-run solution for real exchange rates in equation (4.8) depends only on real income processes which are generally non-stationary. Since real income processes are in general non-stationary, real exchange rates will also tend to be non-stationary.

In equation (4.8), $a_{ij}(L)$ are not arbitrary, but are constituted by the aggregate demand parameters in the goods market. In order to illustrate that $a_{ij}(L)$ are not arbitrary, we assume the case where π_j tend to be infinity. In the long-run, goods market always clears, and nominal exchange rates will be the same in all time periods such that:

$$E_t\,[e_{1kt+1} - e_{1kt}] = 0 \qquad ; \qquad k = 2, 3, 4$$

and $$y_{jt} = D_{jt} \qquad ; \qquad j = 1, 2, 3, 4$$

Thus, from the four goods market equilibrium conditions, the long-run solution for the real exchange rates and interest rate will be:

$$\begin{bmatrix} \eta_{12} & \eta_{13} & \eta_{14} & -\sigma_1 \\ -(\eta_{21}+\eta_{23}+\eta_{24}) & \eta_{23} & \eta_{24} & -\sigma_2 \\ \eta_{32} & -(\eta_3+\eta_{32}+\eta_{34}) & \eta_{34} & -\sigma_3 \\ \eta_{42} & \eta_{43} & -(\eta_{41}+\eta_{42}+\eta_{43}) & -\sigma_4 \end{bmatrix} \begin{bmatrix} r_1 \\ r_2 \\ r_3 \\ i \end{bmatrix} = \begin{bmatrix} (1-c_1) & -f_{12} & -f_{13} & -f_{14} \\ -f_{21} & (1-c_2) & -f_{23} & -f_{24} \\ -f_{31} & -f_{32} & (1-c_3) & -f_{34} \\ -f_{41} & -f_{42} & -f_{43} & (1-c_4) \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix}$$

or

$$\begin{bmatrix} r_1 \\ r_2 \\ r_3 \\ i \end{bmatrix} = \begin{bmatrix} \eta_{12} & \eta_{13} & \eta_{14} & -\sigma_1 \\ -(\eta_{21}+\eta_{23}+\eta_{24}) & \eta_{23} & \eta_{24} & -\sigma_2 \\ \eta_{32} & -(\eta_{31}+\eta_{32}+\eta_{34}) & \eta_{34} & -\sigma_3 \\ \eta_{42} & \eta_{43} & -(\eta_{41}+\eta_{42}+\eta_{43}) & -\sigma_4 \end{bmatrix}^{-1} \begin{bmatrix} (1-c_1) & -f_{12} & -f_{13} & -f_{14} \\ -f_{21} & (1-c_2) & -f_{23} & -f_{24} \\ -f_{31} & -f_{32} & (1-c_3) & -f_{34} \\ -f_{41} & -f_{42} & -f_{43} & (1-c_4) \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} \qquad (4.9)$$

Note that the time subscript is dropped for the long-run solution, and the long-run interest rate is denoted by i since $i_1 = i_2 = i_3 = i_4$ in the long-run.

Obviously, from equation (4.9) the three long-run real exchange rates are linear in the four real income processes, such as:

$$r_{12} = d_{11}y_1 + d_{12}y_2 + d_{13}y_3 + d_{14}y_4 \qquad (4.10)$$

$$r_{13} = d_{21}y_1 + d_{22}y_2 + d_{23}y_3 + d_{24}y_4 \qquad (4.11)$$

$$r_{14} = d_{31}y_1 + d_{32}y_2 + d_{33}y_3 + d_{34}y_4 \qquad (4.12)$$

where d_{ij} ($i = 1, 2, 3$; $j = 1, 2, 3, 4$) contains the goods market demand parameters for the four countries.

If the four income processes share a common trend, denoted y_t, the system of equations (4.10) - (4.12) becomes:

$$\begin{bmatrix} r_{12} \\ r_{13} \\ r_{14} \end{bmatrix} = \begin{bmatrix} d_{11} + d_{12} + d_{13} + d_{14} \\ d_{21} + d_{22} + d_{23} + d_{24} \\ d_{31} + d_{32} + d_{33} + d_{34} \end{bmatrix} y_t \qquad (4.13)$$

From equation (4.13), we can obtain two linear combinations of the three real exchange rates:

$$r_{12} = \beta_{10} + \beta_{13}r_{13} + \beta_{14}r_{14} \qquad (4.14)$$

and $$r_{12} = \beta_{10}' + \beta_{13}'r_{13} + \beta_{14}'r_{14} \qquad (4.15)$$

where $\beta_{10} = -(d_{31} + d_{32} + d_{33} + d_{34})(d_{11} + d_{12} + d_{13} + d_{14})$

$\beta_{13} = (d_{11} + d_{12} + d_{13} + d_{14}) / (d_{21} + d_{22} + d_{23} + d_{24})$

$\beta_{14} = d_{11} + d_{12} + d_{13} + d_{14}$

and $\beta_{10}' = -(d_{21} + d_{22} + d_{23} + d_{24})(d_{11} + d_{12} + d_{13} + d_{14})$

$\beta_{13}' = d_{11} + d_{12} + d_{13} + d_{14}$

$\beta_{14}' = (d_{11} + d_{12} + d_{13} + d_{14}) / (d_{31} + d_{32} + d_{33} + d_{34})$

The key is that if all nonstationary income processes share common trend(s), the corresponding bilateral real exchange rates which are non-stationary will share the same trend(s) in the currency area. Thus, if the non-stationary bilateral real exchange rates are cointegrated, there will exist at least one stationary linear combination of the bilateral real exchange rates. In our particular case, there are two stationary linear combinations for the three bilateral real exchange rates (i.e., equations (4.14) and (4.15)). Equation (4.14) shows a long-run equilibrium relationship between the various bilateral real exchange rates in which the cointegrating parameters, $\beta_{1i,}$ are the functions of the aggregate demand parameters. Like equation (4.14), equation (4.15) is another long-run equilibrium relationship. Thus, there is no unique long-run equilibrium relationship in this specific case. Furthermore, the long-run equilibrium relationship between the various bilateral real exchange rates can be generalized as the form of equation (4.1).

Multivariate Cointegration Methodology

The augmented Dickey-Fuller and the Phillips-Perron tests can be used to test for the existence of a cointegration vector (or scalar) between the nominal exchange rate and the relative price on a bilateral basis. Since there may exist more than one cointegration vector between the various bilateral real exchange rates, the univariate tests will not be appropriate in this context. Instead of using the univariate methodology, multivariate cointegration approach due to Johansen (1988) will be employed to test for Generalized-PPP.

Johansen (1988) and Johansen and Juselius (1990) use the method of maximum likelihood to develop multivariate cointegration technique. The methodology not only offers tests for the number of cointegration vectors, but also estimates parameters of all the cointegration vectors.

In order to briefly discuss the Johansen (1988) methodology, let us consider the following typical VAR representation:

$$X_t = \sum_{i=1}^{k} \Pi_i X_{t-i} + \varepsilon_t \qquad (4.16)$$

where ε_t is the white noise process.

Since macroeconomic time series are generally non-stationary, rewrite equation (4.16) in first-differences such that:

$$\Delta X_t = \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-k} + \varepsilon_t \tag{4.17}$$

where $\Gamma_i = -I + \sum_{j=1}^{k-1} \Pi_j$, and $\Pi = -I + \sum_{i=1}^{k} \Pi_j$

Notice that a nxn matrix Π in equation (4.17) plays a key role in the Johansen (1988) methodology since its rank provides information for the stationarity of the variables in the nx1 vector X_t. If the matrix Π has full rank (i.e., rank(Π) = n), then the vector process X_t will be stationary. If the matrix Π is the null matrix (i.e., rank(Π) = 0), the vector X_t will be first-differencing stationary. Thus, equation (4.17) will be reduced to the usual first-differencing VAR system. Finally, if $0 < \text{rank}(\Pi) < n$, then there will be at least one but at most n-1 stationary linear combinations of the variables in the vector X_t. In this case the rank of the matrix Π, thus, equals the number of cointegration vector r (i.e., $0 < \text{rank}(\Pi) = r < n$); it implies that there are two nxr matrices α and β such that:

$$\Pi = \alpha \beta' \tag{4.18}$$

The rows of the matrix β' are the cointegration vectors so that there are r cointegration vectors. Thus, $\beta' X_t$ (i.e., the cointegration vectors times the non-stationary vector X_t) is stationary. As a result, equation (4.17) can be interpreted as an error correction model with the elements of the matrix α as the speed of adjustment towards the long-run equilibrium.

By regressing the following two equations in order to obtain residuals ε_{0t} and ε_{1t}:

$$\Delta X_t = \sum_{i=1}^{k-1} \Phi_{0i} \Delta X_{t-i} + \varepsilon_{0t} \quad (4.19)$$

$$X_{t-k} = \sum_{i=1}^{k-1} \Phi_{1i} \Delta X_{t-i} + \varepsilon_{1t} \quad (4.20)$$

Then, the squared canonical correlations between residuals ε_{0t} and ε_{1t} from equation (4.19) and equation (4.20) are used to calculate the two likelihood ratio test statistics:

$$\text{trace} = -T \sum_{i=r+1}^{n} \ln (1 - \lambda_i^*) \quad (4.21)$$

$$\lambda\text{max} = -T \ln (1 - \lambda^*_{r+1}) \quad (4.22)$$

where $\lambda^*_{r+1} > \lambda^*_{r+2} > ...... > \lambda^*_n$ are the n-r smallest squared canonical correlations between ε_{0t} and ε_{1t}.

The trace statistic in equation (4.21) tests the null hypothesis of at most r cointegration vectors against a general alternative. The maximal eigenvalue statistic λmax in equation (4.22) tests the null hypothesis of r cointegration vectors against the alternative hypothesis of r+1 cointegration vectors.

Empirical Tests

We are now in a position to examine the existence of Generalized-PPP. Since most Asian countries show rapid economic growth rates, it is interesting to find the Generalized-PPP relationship in Asia. If Generalized-PPP holds for the countries of Asia, it will then imply the existence of a currency area for the Asian countries.

In the following study, we use the same data as in Chapter III. The selection of a base country is arbitrary. However, Japan still acts as the base country since Japan is the strongest economic power in Asia, which will be necessary in our second study. Tests for cointegration for the various bilateral real exchange rates are performed by using the Johansen approach with twelve lags since the monthly data are used.

<u>Asian Countries Alone</u>

Since the rapid growth rate in Asia is most remarkable, we first investigate whether the Asian countries themselves constitute a currency area in the sense implied by Generalized-PPP. Tests for cointegration for real exchange rates among the Asian countries are presented in Table 4-1. For the six bilateral real exchange rates of the Asian countries investigated, we group any five of the bilateral real rates in different combinations to examine whether there exist cointegration relationships among those bilateral real exchange rates.

For the trace test, the null hypothesis of no cointegration (i.e., $r = 0$) can be rejected for groups 1, 3, 4, and 5 at the 5% and even 1% significance levels. We can reject the null of no cointegration (i.e., $r = 0$) for group 2, but not for group 6, at the 10% significance level. The critical value for the trace

Table 4-1. Tests for cointegration for the Asian real exchange rates

Group [a]	Trace					λmax				
	r=0	r≤1	r≤2	r≤3	r≤4	r=0	r=1	r=2	r=3	r=4
1	86.58	41.49	15.26	6.07	0.06	45.09	26.23	9.18	6.01	0.06
2	68.29	34.89	20.32	6.22	0.19	33.40	14.57	14.10	6.03	0.19
3	87.93	48.06	16.81	6.53	0.23	39.87	31.25	10.28	6.29	0.23
4	98.71	56.64	28.49	5.40	0.01	42.08	28.15	23.08	5.40	0.01
5	92.25	49.52	21.00	9.74	0.14	42.73	28.52	11.27	9.59	0.14
6	65.01	40.55	19.12	5.82	0.48	24.46	21.43	13.30	5.34	0.48

[a]Each group contains five bilateral real exchange rates out of the six real rates for India, Indonesia, Korea, the Philippines, Singapore, and Thailand such as: Group 1 excludes India; group 2 excludes Indonesia; group 3 excludes Korea; group 4 excludes the Philippines; group 5 excludes Thailand; group 6 excludes Singapore.

Critical values:

	Trace					λmax				
	r=0	r≤1	r≤2	r≤3	r≤4	r=0	r=1	r=2	r=3	r=4
5%	69.98	48.42	31.26	17.84	8.08	33.26	27.34	21.28	14.60	8.08
2.5%	73.03	51.80	34.06	19.61	9.66	35.70	29.60	23.36	16.40	9.66
1%	77.91	55.55	37.29	21.96	11.58	38.86	32.62	26.15	18.78	11.58

statistic at the 10% significance level is 65.96. For the λmax test, the null hypothesis of r = 0 against the alternative r = 1 can be rejected for all groups except group 6 at the 5% significance level. In fact, the null can be rejected for groups 1, 3, 4, and 5 at the 1% significance level. Up to this point, we know that cointegration relationships exist in groups 1 to 5.

As shown in Table 4-1, it is a little complicated to determine the number of cointegration vectors for some groups. Since the trace test for the hypothesis r ≤ 1 and the λmax test for the null of r = 1 against the alternative r = 2 cannot be rejected for groups 1 and 2 at the 5% significance level, both tests indicate that both groups have one cointegration vector. For groups 3, 4, and 5, however, there is some ambiguity about the number of cointegration vectors. For group 3, the λmax statistic for the null hypothesis of r = 1 against the alternative r = 2 can be rejected at the 5% significance level, but not at the 1% significance level; however, the trace statistic for the null hypothesis of r ≤ 1 cannot be rejected at the 5% significance level. At the 5% significance level, the null hypothesis of r ≤ 1, and the null of r = 1 against the alternative r = 2 can be rejected by using the trace and the λmax tests for groups 4 and 5. Nevertheless, at the 2.5% significance level, the λmax test indicates one cointegration vector for group 4, and both tests indicate one cointegration vector for group 5 as well. Given the difficulties in the interpretation of multiple cointegration vectors, groups 3, 4, and 5 are considered to have one cointegration vector in our results. Regardless of the number of cointegration vectors, the key is that there exists cointegration relationships for groups 1 to 5.

The results of cointegration tests for the bilateral real exchange rates among the Asian countries indicate that there is no cointegration vector for group 6, and there exists one cointegration vector for other five groups (i.e., groups 1 to 5). Therefore, we conclude that Generalized-PPP holds for groups 1 to 5, but not for group 6. Notice, however, that Singapore is the only country not included in group 6, but appears in all the other five groups (i.e., groups 1 to 5). Perhaps, the real exchange rate of Singapore is the main linkage for such cointegration relationship.

Rather than simply saying that the Singapore real exchange rate is the main linkage for the existence of Generalized-PPP among the Asian countries, we confirm this interpretation by formal tests. Table 4-2 lists results of the tests for cointegration for real exchange rates in the Asian countries examined without including Singapore. For all the five groups, neither the trace nor λmax tests indicate that the null hypothesis of no cointegration (i.e., $r = 0$) can be rejected at the 5% significance level. Thus, there is no cointegration relationship in each group, and Generalized-PPP does not hold for these five groups. Therefore, we conclude that real exchange rates of these Asian countries are cointegrated only when the Singapore real rate is included; thus, Generalized-PPP does not hold among these countries without including Singapore. It follows that these results confirm the interpretation that the Singapore real exchange rate is the main linkage for the existence of cointegration relationships among those Asian countries' real rates.

Table 4-2. Tests for cointegration for the Asian real exchange rates without including Singapore real rate

Group [a]	Trace				λmax			
	r=0	r≤1	r≤2	r≤3	r=0	r=1	r=2	r=3
1	47.24	22.93	6.38	1.47	24.31	16.55	4.91	1.47
2	40.23	22.29	7.37	1.69	17.94	14.92	5.68	1.69
3	39.74	16.05	5.31	0.28	23.69	10.74	5.03	0.28
4	38.01	20.56	9.67	0.29	17.46	10.88	9.39	0.29
5	38.61	19.38	7.39	0.02	19.23	11.99	7.37	0.02

[a]Group 1: Indonesia, Korea, the Philippines, and Thailand.
Group 2: India, Korea, the Philippines, and Thailand.
Group 3: India, Indonesia, the Philippines, and Thailand.
Group 4: India, Indonesia, Korea, and Thailand.
Group 5: India, Indonesia, Korea, and the Philippines.

Critical values:

	Trace				λmax			
	r=0	r≤1	r≤2	r≤3	r=0	r=1	r=2	r=3
5%	48.42	31.26	17.84	8.08	27.34	21.28	14.60	8.08

As the real rate of Singapore plays a key role in Generalized-PPP in Asia, we examine Singapore in more detail. Singapore is a tiny country which relies heavily on international trade. Its economy is easily influenced by larger countries. On the other hand, because of its flexibility, Singapore can react and adapt to the events of larger countries with ease. Therefore, we expect that the real rate of Singapore is sensitive to the changes of the other countries' (especially larger countries) real exchange rates. In order to examine this interpretation, the long-run equilibrium relationships for groups 1 to 5 are presented in Table 4-3.

In each group, there is a linear combination of the various bilateral real exchange rates which is stationary. In order to examine the responses of the Singapore/Japanese bilateral real rate to the other Asian countries' bilateral real exchange rates, the estimated cointegration vectors are normalized on the Singapore/Japanese bilateral real exchange rate such that:

$$r_{12t} = \beta_{13} r_{13t} + \beta_{14} r_{14t} + \beta_{15} r_{15t} + \beta_{16} r_{16t} + \varepsilon_t \qquad (4.23)$$

where r_{12} is the natural logarithm of the Singapore/Japanese bilateral real exchange rate; r_{13}, r_{14}, r_{15}, and r_{16} respectively, refer to the natural logarithms of the bilateral real exchange rates of the various Asian countries; ε_t is a stationary stochastic disturbance term.

Table 4-3. Long-run equilibrium relationship among the Asian real exchange rates

Group	India	Indonesia	Korea	Philippines	Thailand
1		8.511	-10.956	5.978	-3.645
2	1.052		1.016	0.121	-0.747
3	0.394	0.649		1.093	-0.843
4	0.773	-0.445	1.576		-0.450
5	1.098	-1.486	2.723	-0.770	

Equation (4.23) is the Generalized-PPP representation for each of the five groups, and the coefficients can be interpreted as the long-run elasticities. As shown in Table 4-3, the absolute values of most coefficients are quite large, especially the coefficients for group 1. In group 1, the Singapore/Japanese bilateral real exchange rate changes by 8.511%, 10.956%, 5.978%, and 3.645% respectively in response to a one percent change in the Indonesian, Korean, Philippine, and Thai bilateral real exchange rates with Japan. Moreover, it exhibits the greatest response to the Korean real rate. For other groups, we obtain similar results. This may be that Korea is the "largest" country in these groups. Therefore, the results seem to support our finding that the Singapore real rate is sensitive in response to the changes of other real rates.

Finally, Johansen and Juselius (1990) interpret α as the speed of adjustment towards the long-run equilibrium. This is the weight with which the Singapore real exchange rate reacts to a deviation from Generalized-PPP. The values of α for the five groups are listed as follows:

Group	1	2	3	4	5
α	0.016	0.161	0.088	0.102	-0.102

For all groups except group 1, the Singapore real rate makes a reasonable adjustment in response to a deviation from Generalized-PPP since their speed of adjustment coefficients are not low. Hence, any deviation from Generalized-PPP can be eliminated in a relatively short period.

Influences of Larger Countries

The Asian countries investigated are relatively small in comparison with large countries such as the U.S., Germany, and the U.K. Usually, the behavior of such large countries will have certain effects on small countries. Thus, it is natural to think that the time paths of the real exchange rate of small Asian countries are influenced by events in large countries. Enders and Hurn (1991b) show that real exchange rates of small Pacific Rim countries follow a time path dictated by events in larger countries. Following their work, we examine whether there are cointegration vectors among real exchange rates of the large countries (i.e., the U.S., Germany, and the U.K. in this context) with the real exchange rate of each of the Asian countries.

The results of the cointegration tests are reported in Table 4-4. For the trace test, the null hypothesis of no cointegration (i.e., $r = 0$) can be rejected for all groups except the group with India at the 2.5% significance level. Indeed, the null of $r = 0$ for the groups with Korea, the Philippines, Thailand, and Singapore can be rejected at the 1% level. Moreover, there appears to be a single cointegration vector for each group (except India) since the null hypothesis of $r \leq 1$ cannot be rejected for all groups at the 2.5% significance level.

Turning to the λmax test , the null hypothesis of no cointegration (i.e., $r=0$) against the alternative $r = 1$ cannot be rejected for the group with India at the 2.5% and even 5% significance levels. The critical value for the 5% significance level is 27.34. This result is consistent with the result from the

Table 4-4. Tests for cointegration for the real exchange rates of large countries with the Asian country

Group [a]	Trace				λmax			
	r=0	r≤1	r≤2	r≤3	r=0	r=1	r=2	r=3
India	46.49	22.65	9.23	0.28	23.84	13.43	8.95	0.28
Indonesia	55.43	23.80	5.88	0.83	31.63	17.93	5.04	0.83
Korea	56.93	27.17	8.98	2.81	29.76	18.20	6.16	2.81
Philippines	63.11	26.37	11.08	2.11	36.74	15.29	8.97	2.11
Singapore	64.25	33.53	13.82	3.71	30.72	19.71	10.11	3.71
Thailand	56.91	32.55	16.00	2.85	24.35	16.56	13.14	2.85

[a]In addition to the Asian country listed, each group also contains the U.S., Germany, and the U.K.

Critical values:

	Trace				λmax			
	r=0	r≤1	r≤2	r≤3	r=0	r=1	r=2	r=3
2.5%	51.80	34.06	19.61	9.66	29.60	23.36	16.40	9.66
1%	55.55	37.29	21.96	11.58	32.62	26.15	18.78	11.58

trace test that no cointegration vector exists for the group with India. For the group with Indonesia, Korea, the Philippines, and Singapore, the null hypothesis of no cointegration (i.e., r = 0) against the alternative r = 1 can be rejected while the null hypothesis of r = 1 against the alternative r = 2 cannot be rejected at the 2.5% significance level. These results correspond to the trace test that these four groups have one cointegration vector. For the group with Thailand, however, the null hypothesis of no cointegration (i.e., $r = 0$) against the alternative $r = 1$ cannot be rejected at the 2.5% significance level. This result is inconsistent with the result from the trace test that this group has a single cointegration vector. Nevertheless, we consider that the group with Thailand has one cointegration vector since the trace statistic is significant at the 1% level, and the λmax statistic is just slightly insignificant at the 10% level. The critical value for the 10% significance level is 24.92 for the λmax test.

Table 4-5 reports the following long-run equilibrium relationship for each group (except India since no cointegration exists):

$$r_{act} = \beta_{us} r_{ust} + \beta_{ge} r_{get} + \beta_{uk} r_{ukt} + \varepsilon_t \qquad (4.24)$$

where r_{ac} represents the natural logarithm of the bilateral real exchange rate for each of the Asian countries; r_{us}, r_{ge}, and r_{uk} are the natural logarithms of the bilateral real rates of the U.S., Germany, and the U.K.; ε_t is a stationary stochastic disturbance term.

We normalized the bilateral real exchange rate of each of the small Asian countries in equation (4.24) to show how each of these small countries responds to the changes in the real rates of the large countries. As shown in Table 4-5, most coefficients have quite large absolute values. For each group, the absolute value of the U.S. coefficient is, in general, relatively larger than other coefficients. This may be that the U.S. is the largest country and so has

Table 4-5. Long-run equilibrium relationship among the real exchange rates of the large countries with the Asian country

Group	U.S.	Germany	U.K.	α
Indonesia	1.513	1.389	1.750	-0.041
Korea	-0.497	1.443	-0.995	-0.050
Philippines	0.720	-0.352	0.253	-0.450
Singapore	1.173	0.681	0.638	0.066
Thailand	0.986	0.893	0.383	0.052

more influence on the small Asian countries.

In this study, however, the values of α, the speed of adjustment coefficients, are low for all groups except the group with the Philippines. Thus, any deviation from Generalized-PPP, the adjustment towards the long-run equilibrium is, in general, slow. However, Philippine real exchange rate can achieve a rapid adjustment (-0.45) in response to any deviation from Generalized-PPP.

Concluding Remarks

Using the Johansen procedure, we show that Generalized-PPP holds between the Asian countries only when Singapore is included. Thus, the real exchange rate of Singapore serves as the main linkage for the existence of Generalized-PPP in Asia.

In the second study, we also show that Generalized-PPP holds for each of the Asian countries (except India) and the large countries examined. It follows that each of these Asian countries is small, and the real fundamental variables (e.g., the real income processes) of their real exchange rates are influenced by events in the larger countries. Thus, the movements in real exchange rates of these small Asian countries may be influenced by shocks in real exchange rates of these larger countries. In Chapter V, this issue is investigated in the VAR framework.

CHAPTER V. ERROR CORRECTION MODELS AND IMPULSE RESPONSES

The existence of a cointegration vector between the various bilateral real exchange rates implies that Generalized-PPP holds between the countries involved. It also implies that there exists an error correction model of the form:

$$A(L)\ \Delta X_t = \alpha\ E_{t-1} + v_t \qquad (5.1)$$

where A(L) is a nxn matrix polynomial in the lag operator of order p with A(0) = I; the nxr matrix α is the speed of adjustment; $E_{t-1} = \beta' X_{t-1}$, and elements in the rx1 vector E_{t-1} are the error correction terms which are stationary; v_t are the white noise process.

From the results reported in Chapter IV, Generalized-PPP holds for each of the Asian country's real exchange rate (except India) and the real exchange rates of the large countries. Since the real exchange rate of each Asian country is affected by the real rates of the large countries, it is interesting to estimate their error correction models. Using this autoregressive model, it is possible to see the effects of shocks in the real exchange rates of the large countries on each real rate of the Asian countries.

Consider the following error correction model for each of the five cases (i.e., Indonesia, Korea, the Philippines, Singapore, and Thailand):

$$\begin{bmatrix} \Delta rus_t \\ \Delta rge_t \\ \Delta ruk_t \\ \Delta rac_t \end{bmatrix} = \begin{bmatrix} A_{11}(L) & A_{12}(L) & A_{13}(L) & A_{14}(L) \\ A_{21}(L) & A_{22}(L) & A_{23}(L) & A_{24}(L) \\ A_{31}(L) & A_{32}(L) & A_{33}(L) & A_{34}(L) \\ A_{41}(L) & A_{42}(L) & A_{43}(L) & A_{44}(L) \end{bmatrix} \begin{bmatrix} \Delta rus_{t-1} \\ \Delta rge_{t-1} \\ \Delta ruk_{t-1} \\ \Delta rac_{t-1} \end{bmatrix} + \alpha E_{t-1} + v_t \qquad (5.2)$$

where rus, rge, and ruk respectively refer to the logarithms of the bilateral real exchange rates of the U.S., Germany, and the U.K., and rac represents the logarithm of the bilateral real exchange rate of the Asian country in each case. In the following five cases, rindo, rko, rph, rsi, and rti respectively refer to the logarithms of the real exchange rates of Indonesia, Korea, the Philippines, Singapore, and Thailand.

A four-equation system was estimated equation by equation using OLS in which each real exchange rate is specified with 12 lags in order to reflect monthly data used. However, we do not need to concern ourselves with the problem of exogenous variables and endogenous variables in this kind of vector autoregression (VAR) framework. Nevertheless, there is a major difference between our system and the usual VAR analysis in first-differences. Since there exists a cointegration vector in our model, an error correction vector must be included; otherwise, the model will be misspecified.

Once having the error correction models, it is easier to use the impulse response functions to trace out the time paths of the bilateral real exchange rates of the Asian countries in response to shocks emanating in the large countries. The impulse response function or moving average representation is derived by inverting the autoregressive representation (i.e., the error correction model in this context) to express all the variables in terms of innovations. Given the error correction model, typical shocks are one standard deviation changes in error terms in each equation. Note that the error terms in the error correction model are contemporaneously correlated. After inverting from the error correction model, the impulse response function still contains contemporaneous correlated error terms, in which all contemporaneous covariance terms equal zero and the variance of each element is normalized to equal one.

In order to have orthogonalized error terms, the triangularization of the error correction model is necessary. In this triangularized system, real exchange rates are ordered from that of the largest economy to that of the smallest economy for reflecting the importance of the country's currency. Thus, the large country's real exchange rate innovations enter the small country's real exchange rate equation. In other words, the large country's real exchange rate innovations influence all real exchange rates while the smallest country's real exchange rate innovations affect only itself but not the other countries' real exchange rates. In our five cases, the variables are ordered as Δrus, Δrge, Δruk, and Δrac. Thus, the largest country, the U.S., is ordered the first. The smallest country, the Asian country, is placed last. Germany is assumed to be larger than the U.K. Reversing the order of Germany and the U.K. does not affect the results reported below.

Using the impulse response function, the variance decomposition of the various bilateral real exchange rates can also be constructed. The degree of the exogeneity to a set of the bilateral real exchange rates can be estimated by calculating the percentage of the k-period-ahead forecast error variance of a variable produced by an innovation in one variable. Hence, if a variable is exogenous, this variable itself will fully explain its own forecast error variance. That is, if this variable is perfectly exogenous, its forecast error variance will be 100% explained by itself. Also, the importance of one real exchange rate to another real exchange rate can be estimated by the variance decomposition. In this context, it is interesting to know whether the movements in the small country's real exchange rate is influenced by shocks in the large countries' real exchange rates.

The Indonesian Case

Estimated error correction model

Table 5-1 reports the error correction model for the case of Indonesia. Four variables Δrus, Δrge, Δruk, and Δrindo are the first differences in the real exchange rates of the U.S., Germany, the U.K., and Indonesia respectively. E is the error correction term. Examining the estimated standard errors, we notice that the volatility of the U.K. real exchange rate is the highest in the system. As the German real exchange rate shows the lowest volatility, the variability in the real exchange rate of the U.S. is less than that of Indonesia.

Since there are more than hundreds of parameters in the error correction model, it is not surprising that most of the parameters are insignificant. The estimated coefficients show an oscillatory pattern, and the

Table 5-1. Error correction model: Indonesia

Equation	Variable	1	2	3	4	5	6
Δrus	Δrus	0.321[b]	-0.072	0.026	0.173[a]	0.065	-0.089
	Δrge	0.012	-0.008	0.057	-0.087	0.020	-0.041
	Δruk	0.136[a]	-0.072	0.022	0.074	0.042	-0.090[a]
	Δrindo	-0.103[a]	0.060	0.001	-0.021	-0.029	0.086
	E	0.035					
Δrge	Δrus	0.051	-0.167[a]	0.089	0.030	-0.074	0.081
	Δrge	0.298[b]	-0.068	0.068	-0.090	-0.073	0.110
	Δruk	0.056	0.006	0.018	0.021	0.136[a]	-0.102[a]
	Δrindo	-0.087	0.083	-0.063	0.020	0.047	0.140[a]
	E	-0.008					
Δruk	Δrus	0.099	-0.121	0.199[a]	-0.149	0.080	0.169
	Δrge	-0.054	0.236[a]	-0.065	0.357[a]	-0.305[a]	0.191
	Δruk	0.119	-0.066	-0.004	-0.005	-0.027	-0.170[a]
	Δrindo	-0.243[a]	0.212[a]	-0.086	-0.094	0.077	0.026
	E	-0.033					
Δrindo	Δrus	0.228[a]	-0.115	0.129	0.149[a]	0.101	-0.271[a]
	Δrge	-0.059	-0.113	0.159[a]	-0.141	0.204[a]	-0.007
	Δruk	0.179[a]	-0.054	0.031	0.082	0.102[a]	-0.185[b]
	Δrindo	-0.007	0.076	-0.012	0.049	0.169[a]	0.204[a]
	E	-0.043[a]					

Note: a and b indicate t-statistics between 1 and 2, and greater than 2 in absolute value respectively.

7	8	9	10	11	12	S.E.
0.013	-0.025	-0.104	0.106	0.156[a]	0.116	0.0248
-0.161[a]	-0.083	-0.031	0.080	0.033	-0.024	
-0.063	-0.009	0.118[a]	-0.091[a]	-0.129[a]	-0.010	
-0.004	0.070	0.049	0.086[a]	0.089[a]	0.089	
0.001	0.011	-0.137[a]	0.038	0.035	0.075	0.0230
-0.017	0.089	-0.039	0.111	-0.049	-0.168[a]	
-0.181[b]	0.007	-0.005	-0.066	-0.023	0.002	
0.017	0.021	0.191[b]	-0.195[b]	-0.118[a]	0.021	
-0.194[a]	0.290[a]	-0.257[a]	-0.159	-0.023	0.011	0.0372
-0.066	0.156	0.088	0.100	-0.005	0.090	
-0.036	-0.101	-0.057	-0.045	-0.053	-0.042	
0.032	-0.035	0.110	-0.088	0.046	-0.086	
0.169[a]	-0.056	-0.153[a]	-0.182[a]	0.300[b]	0.144[a]	0.0270
-0.039	-0.117	-0.056	0.174[a]	0.007	-0.154[a]	
-0.114[a]	0.047	0.097[a]	-0.092[a]	-0.212[b]	0.148[a]	
-0.165[a]	0.071	0.001	-0.117[a]	-0.174[a]	-0.121[a]	

near multicollinearity and the cross-equation feedbacks are also in the model. Thus, the usefulness of the error correction model reduces sharply. Using this autoregressive system, however, we can have the impulse response function to obtain a more reasonable interpretation. Unlike the usual VAR representation, an important result can be obtained from the error correction model. That is, the error correction model contains an error correction vector which indicates whether deviations from Generalized-PPP can be eliminated. Note that only the error correction term in the Δrindo equation is significant so that only the real exchange rate of the small country, Indonesia, is a response to deviations from Generalized-PPP.

Table 5-2 gives the F-statistics for Granger causality tests on the lagged variables. A significant F value tends to reject the null hypothesis that all lags of a specified variable have zero coefficients. It is interesting that lags of all the four real exchange rates are not significant in the Δrus, Δrge, and Δruk equations at conventional significance levels. Thus, it seems that no real exchange rates in the system and even their own lags can explain the movements in the real exchange rates of the U.S., Germany, and the U.K. We would question whether the movements in these three real exchange rates are affected by other variables.

In the Δrindo equation, however, lags of Δrindo itself are significant at the 10% significance level. Also, lags of Δrus and Δruk are significant in forecasting the Indonesian real exchange rate at the 5% significance level; the marginal significance levels for Δrus and Δruk are 0.045 and 0.029

Table 5-2. F-statistics for causality tests: Indonesia

	Variable			
Equation	Δrus	Δrge	Δruk	Δrindo
Δrus	1.343 (0.207)[a]	0.452 (0.937)	0.970 (0.483)	0.703 (0.745)
Δrge	0.386 (0.966)	1.342 (0.208)	1.091 (0.376)	1.387 (0.185)
Δruk	0.688 (0.759)	0.638 (0.805)	0.397 (0.962)	0.594 (0.842)
Δrindo	1.879 (0.046)	0.827 (0.622)	2.030 (0.029)	1.614 (0.100)

[a]Marginal significance levels are in parentheses.

respectively. On the other hand, the marginal significance level for Δrge is 0.622 which is insignificant. Thus, there is evidence that the movements of the Indonesian real exchange rate are explained not only by its own past, but also are influenced by the real exchange rates of the large countries, the U.S. and the U.K.

Unlike the usual VAR representation, however, there is an error correction vector in this error correction model. The above results which are based on the traditional Granger causality tests ignore the error correction term. Thus, our results may be misleading.

Variance decomposition and impulse response functions

Table 5-3 reports the variance decomposition for the case of Indonesia. At 1, 6, and 36 months, the U.S. real exchange rate account for 100%, 93%, and 76% of its forecast error variance, and the German real exchange rate explains 91%, 86%, and 72% of its own variance. Since most of their forecast error variance are explained by their own innovation, the real exchange rates of the U.S. and Germany are considered to be exogenous in this model. In contrast, the real exchange rates of the U.K. and Indonesia explain only 59% and 39% of their own forecast error variance.

The innovation in the real exchange rates of Germany, the U.K., and Indonesia account for 8%, 11%, and 5% of the forecast error variance in the U.S. real exchange rate. Similarly. the real exchange rates of the U.S., the U.K., and Indonesia account for a small proportion of the forecast error variance in the German real exchange rate; each accounts for only 11%, 10%, and 7% of the variability of the German real exchange rate. It implies that there are only small feedbacks from other real exchange rates into the real exchange rates of the U.S. and Germany.

Fourteen percent and 22% of the forecast error variance in the U.K. real exchange rate is explained by the real exchange rates of the U.S. and Germany. This shows significant feedbacks from the real exchange rates of the U.S. and Germany to the U.K. real exchange rate. At the same time, about 70% of the forecast error variance in the Indonesian real exchange rate is divided nearly equally between the U.S. real exchange rate and itself. It

Table 5-3. Variance decomposition: Proportion of forecast error (Indonesia)

Forecast error in	k month ahead error produced by each innovation					
	k	S.E.	Δrus	Δrge	Δruk	Δrindo
Δrus	1	0.0202	1.00	0.00	0.00	0.00
	3	0.0217	0.96	0.01	0.02	0.01
	6	0.0227	0.93	0.02	0.04	0.01
	12	0.0248	0.78	0.08	0.11	0.03
	24	0.0255	0.76	0.08	0.11	0.05
	36	0.0256	0.76	0.08	0.11	0.05
Δrge	1	0.0187	0.09	0.91	0.00	0.00
	3	0.0201	0.10	0.89	0.01	0.00
	6	0.0205	0.10	0.86	0.03	0.01
	12	0.0221	0.10	0.75	0.09	0.06
	24	0.0230	0.11	0.72	0.10	0.07
	36	0.0230	0.11	0.72	0.10	0.07
Δruk	1	0.0302	0.12	0.21	0.67	0.00
	3	0.0310	0.12	0.20	0.65	0.03
	6	0.0321	0.13	0.22	0.61	0.04
	12	0.0333	0.14	0.22	0.60	0.04
	24	0.0339	0.14	0.22	0.59	0.05
	36	0.0339	0.14	0.22	0.59	0.05
Δrindo	1	0.0220	0.30	0.00	0.00	0.70
	3	0.0234	0.33	0.01	0.04	0.62
	6	0.0267	0.39	0.07	0.06	0.48
	12	0.0303	0.35	0.07	0.19	0.39
	24	0.0317	0.34	0.09	0.18	0.39
	36	0.0319	0.34	0.09	0.18	0.39

reflects that there is a strong feedback from the U.S. real exchange rate to the Indonesian real exchange rate. In addition, another 18% of the forecast error variance in the Indonesian real rate is explained by the U.K. real rate. Thus, it indicates a quite important feedback from the U.K. real exchange rate to the Indonesian real rate.

Note that the Indonesian real exchange rate only accounts for about 5% of the forecast error variance in each of the real exchange rates of the U.S., Germany, and the U.K. respectively. This result shows that insignificant effects of the Indonesian real exchange rate on the movements in the real exchange rates of the larger countries. (i.e., the U.S., Germany, the U.K.). On the other hand, as the results show above, movements in the Indonesian real exchange rate are affected by the real exchange rates of the larger countries, especially the U.S.

Figure 5-1 plots the impulse response functions of the Indonesian real exchange rate to a typical shock in the real exchange rates of the U.S., Germany, the U.K., and Indonesia respectively. A one standard deviation shock in each of the real exchange rates has different effects on the Indonesian real exchange rate. As can be seen, the effects of the innovations in the real exchange rates of Indonesia and the U.S. on the Indonesian real exchange rate are larger than that of other two real exchange rates in the first month. However, the Indonesian real exchange rate will eventually go back to zero in response to all four real exchange rate shocks. Figures 5-2 to 5-5 illustrate the responses of the Indonesian real exchange rate to each shock separately.

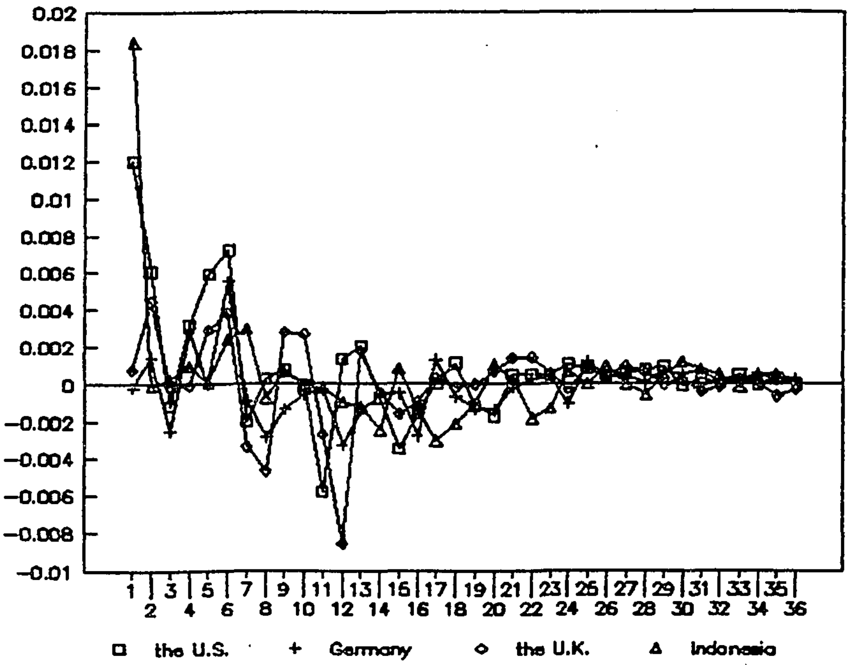

Figure 5-1. Responses of Δrindo to a shock in Δrus, Δrge, Δruk, and Δrindo

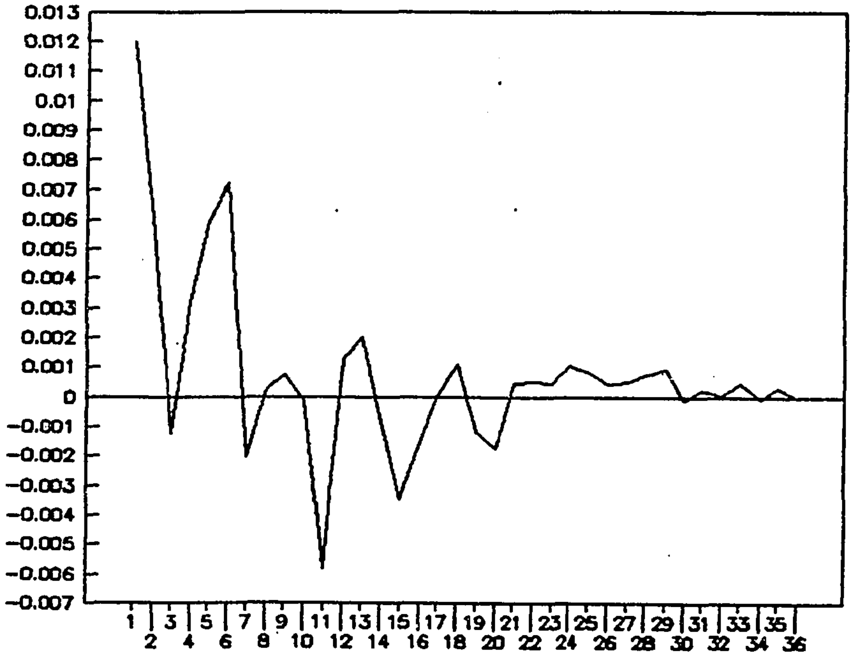

Figure 5-2. Responses ofΔrindo to a shock in Δrus

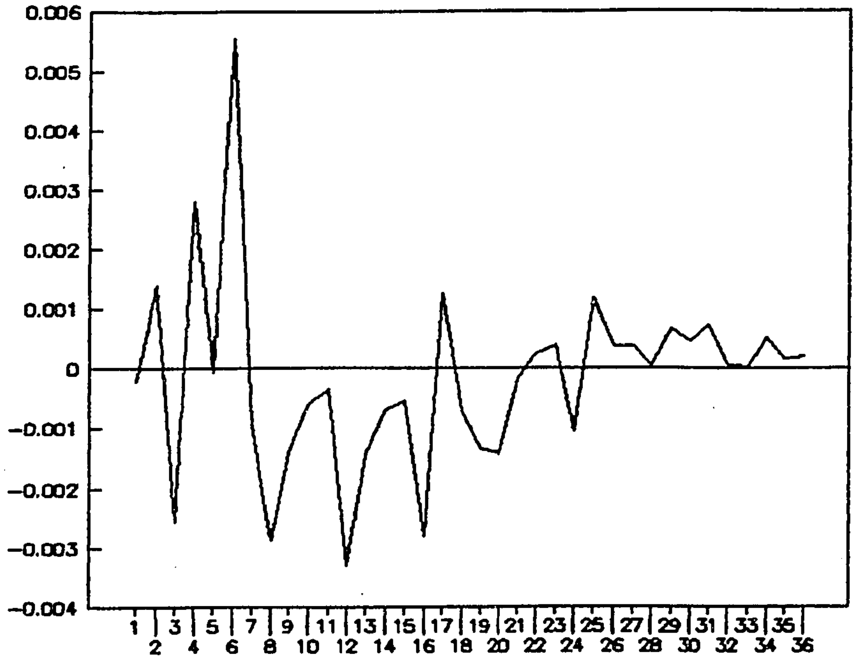

Figure 5-3. Responses of Δrindo to a shock in Δrge

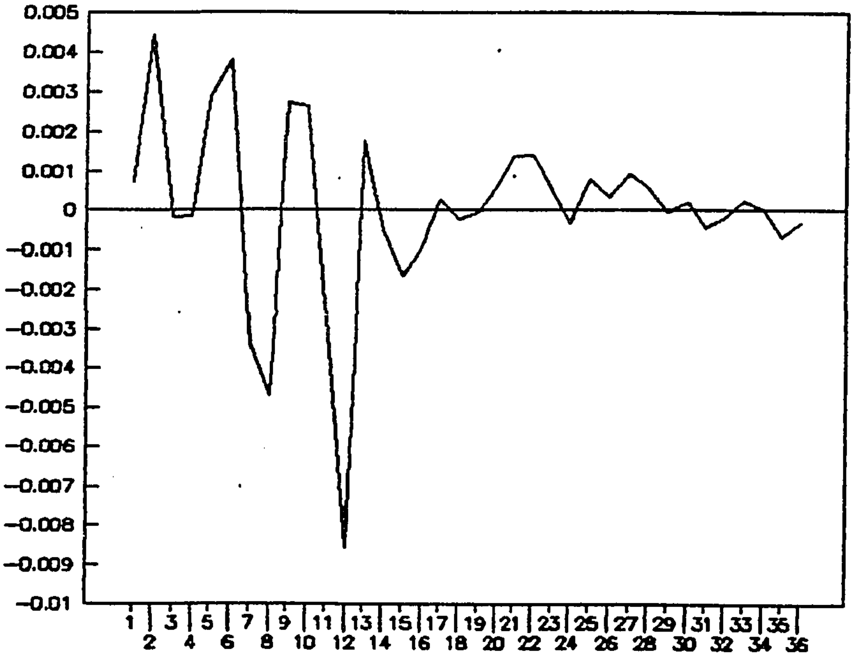

Figure 5-4. Response of Δrindo to a shock in Δruk

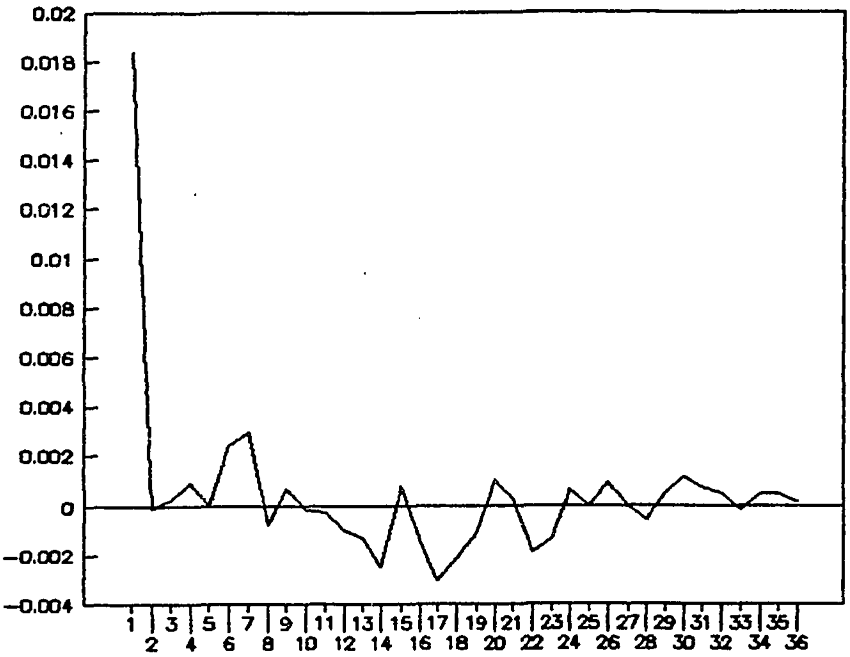

Figure 5-5. Responses of Δrindo to a shock in Δrindo

Figure 5-2 shows the response of the Indonesian real exchange rate to a one standard deviation shock in the U.S. real exchange rate. Following a shock in the U.S. real exchange rate, the Indonesian real exchange rate is generally positive for the first nine months. Then the Indonesian real exchange rate fluctuates between positive and negative values from months 10-20, but finally converges to zero.

As displayed in Figure 5-3, the Indonesian real exchange rate shows oscillatory behavior for the first six months following a shock in the German real rate. Then the Indonesian real exchange rate is, in general, negative up to the twenty-first month. At this point, the real exchange rate of Indonesia begins to return to its original level.

The response of the Indonesian real exchange rate to a typical shock in the U.K. real exchange rate is shown in Figure 5-4. Unlike the shocks in the real exchange rates of the U.S. and Germany, the behavior of the Indonesian real exchange rate is oscillatory for all time horizons. The fluctuations of the Indonesian real rate are large for the first thirteen months and reach a negative peak in the twelfth month; then its fluctuations gets smaller and smaller until go back to zero.

In response to its own shock, the Indonesian real exchange rate shoots up sharply during the first month, which is shown in Figure 5-5. Then the Indonesian real exchange rate quickly drops down to its initial level in the second month. From month two on, the Indonesian real rate starts to move up and down, but converges to zero finally.

The Korean Case

Estimated error correction model

The results of estimating the error correction model for Δrus, Δrge, Δruk, and Δrko are given in Table 5-4. In this four-equation system, only the error correction term in the Δruk equation is significant. Hence, the U.K. real exchange rate, but not the real exchange rates of the U.S., Germany, and Korea, seems to make the adjustment to any deviations from Generalized-PPP.

As in the case of Indonesia, the volatility of the German real exchange rate is the lowest. However, the highest volatility is with the Korean real

Table 5-4. Error correction model: Korea

Equation	Variable	1	2	3	4	5	6
Δrus	Δrus	0.194[a]	0.005	-0.035	0.036	0.026	-0.184[a]
	Δrge	-0.028	-0.071	0.177[a]	-0.194[a]	0.071	-0.026
	Δruk	0.102[a]	-0.048	0.036	0.108[a]	0.029	-0.068
	Δrko	0.068	-0.082[a]	-0.021	-0.009	0.042	0.066
	E	0.036					
Δrge	Δrus	0.017	-0.039	-0.042	0.018	-0.032	0.118[a]
	Δrge	0.350[b]	-0.087	0.142[a]	-0.098	0.013[a]	0.065[a]
	Δruk	-0.007	-0.013	-0.030	0.018	0.091	-0.100
	Δrko	-0.051	0.021	0.013	0.019	0.016	-0.093[a]
	E	0.024					
Δruk	Δrus	-0.008	0.142	0.150[a]	-0.249[a]	0.034	-0.035
	Δrge	-0.068	0.202[a]	-0.018	0.266[a]	-0.174[a]	-0.021
	Δruk	0.059	-0.016	-0.013	0.054	-0.013	-0.093
	Δrko	-0.130[a]	-0.027	-0.099[a]	0.003	0.091	-0.015
	E	0.061[a]					
Δrko	Δrus	0.270[a]	-0.018	0.066	-0.047	0.038	0.028
	Δrge	0.037	-0.301[a]	0.148	-0.278[a]	0.064	0.001
	Δruk	0.116	-0.081	0.117	0.243[b]	0.045	-0.231[a]
	Δrko	0.132[a]	-0.031	-0.119[a]	-0.171[a]	0.096	0.087
	E	-0.051					

Note: a and b are t-statistics between 1 and 2, and greater than 2 in absolute values respectively.

7	8	9	10	11	12	S.E.
0.133[a]	0.021	-0.092	0.045	0.033	0.060	0.0263
-0.188[a]	-0.010	-0.121[a]	0.159[a]	-0.096	0.065	
-0.034	-0.044	-0.072	-0.111[a]	-0.082[a]	-0.065	
-0.145[b]	0.126[a]	0.034	-0.012	0.121[a]	-0.084	
0.011	-0.072	0.054	-0.224[b]	0.008	0.028	0.0227
-0.040[a]	0.035	0.028	0.143[a]	-0.071	-0.014	
-0.077	-0.050	0.015	-0.031	-0.024	-0.071[a]	
0.082[a]	0.060	0.034	0.014	0.116[a]	-0.062	
0.054	0.014	-0.122	-0.238[a]	0.067	-0.102	0.0337
-0.016	0.066	0.195[a]	0.119	-0.107	0.147[a]	
0.069	-0.086	-0.115[a]	0.015	-0.012	-0.040	
-0.066	0.183[a]	0.014	0.077	0.090	-0.063	
-0.166[a]	0.045	-0.316[a]	0.253[a]	-0.118	0.131	0.0404
-0.347[b]	0.247[a]	-0.141	0.216[a]	-0.203[a]	0.104	
0.027	-0.008	0.117[a]	-0.124	-0.149[a]	0.018	
0.025	0.202[a]	-0.017	0.043	0.052	-0.105	

exchange rate. Although some parameters are significant, individual coefficients do not mean much due to the multicollinearity in the variables and the complicated cross-equation feedbacks. As discussed in the previous case, a convenient way to summarize and interpret the results is to use the moving average representation (or the impulse response function) which is derived from the error correction model.

The results of Granger causality tests are reported in Table 5-5. It shows that lags of all the four real exchange rates are completely insignificant in the four equations. It means that even their own lags in the four real exchange rates do not explain the movements in themselves. It seems that movements in these real exchange rates are influenced by other variables. Nevertheless, as mentioned in the previous case, results from Granger causality tests do not reflect any effect from the error correction vector in the model. Thus, results look strange to us and may not be correct.

Variance decomposition and impulse response functions

Table 5-6 shows the variance decomposition of the real exchange rates of the U.S., Germany, the U.K., and Korea. Like the case of Indonesia, both the real exchange rates of the U.S. and Germany account for most of their own forecast error variance. Each accounts for 100%, 93%, and 80% and 87%, 85%, and 75% of their own forecast error variance at 1, 6, and 36 months respectively. However, about 60% of the forecast error variance in the U.K. real exchange rate is due to its own innovation, and only a half of the

Table 5-5. F-statistics for causality tests: Korea

Equation	Variable			
	Δrus	Δrge	Δruk	Δrko
Δrus	0.703	0.883	0.995	1.490
	(0.746)[a]	(0.565)	(0.457)	(0.135)
Δrge	0.813	1.564	0.670	0.900
	(0.637)	(0.109)	(0.777)	(0.549)
Δruk	0.728	1.021	0.406	0.795
	(0.722)	(0.433)	(0.959)	(0.656)
Δrko	1.169	0.908	1.244	1.327
	(0.311)	(0.541)	(0.259)	(0.210)

[a]marginal significance levels are in parentheses.

forecast error variance in the Korean real exchange rate is explained by itself. It appears that the degree of exogeneity of the U.S. real rate is stronger than the German rate while the real exchange rates of the U.K. and Korea are not exogenous.

Examining Table 5-6 in more detail, the German, U.K., and Korean real exchange rates explain very little (about 5-8% each) of the forecast error variance in the U.S. real rate. For the German real rate, the U.S. real rate explains 14% while the U.K. and Korean rates account for 4% and 7% of its forecast error variance. Thus, there is only moderate feedback from the U.S. real rate into the German real exchange rate. Considering the U.K. real exchange rate, one-third of its forecast error variance is explained by both the

Table 5-6. Variance decomposition: Proportion of forecast error (Korea)

Forecast error in	k	S.E.	Δrus	Δrge	Δruk	Δrko
	k month ahead error produced by each innovation					
Δrus	1	0.0226	1.00	0.00	0.00	0.00
	3	0.0239	0.97	0.01	0.01	0.01
	6	0.0245	0.93	0.02	0.03	0.02
	12	0.0265	0.82	0.05	0.06	0.07
	24	0.0272	0.81	0.05	0.07	0.07
	36	0.0273	0.80	0.05	0.08	0.07
Δrge	1	0.0195	0.13	0.87	0.00	0.00
	3	0.0207	0.13	0.87	0.00	0.00
	6	0.0210	0.13	0.85	0.01	0.01
	12	0.0223	0.13	0.77	0.04	0.06
	24	0.0227	0.14	0.75	0.04	0.07
	36	0.0227	0.14	0.75	0.04	0.07
Δruk	1	0.0290	0.11	0.16	0.73	0.00
	3	0.0296	0.12	0.16	0.70	0.02
	6	0.0307	0.13	0.18	0.66	0.03
	12	0.0322	0.14	0.18	0.62	0.06
	24	0.0328	0.15	0.18	0.60	0.07
	36	0.0329	0.15	0.18	0.60	0.07
Δrko	1	0.0348	0.41	0.01	0.00	0.58
	3	0.0371	0.44	0.03	0.01	0.52
	6	0.0389	0.42	0.03	0.04	0.51
	12	0.0419	0.40	0.05	0.07	0.48
	24	0.0428	0.39	0.06	0.07	0.48
	36	0.0429	0.39	0.06	0.07	0.48

real rates of the U.S. (15%) and Germany (18%). This shows important feedbacks from the U.S. and German real rates to the U.K. real exchange rate.Finally, each of the German and U.K. real rates account for only 6-7% of the forecast error variance in the Korean real rate; however, about 40% of the variance is explained by the U.S. real exchange rate. It reveals that there is a strong feedback from the U.S. real rate to the Korean real rate.

Clearly, the real rates of the U.K. and Korea do not explain the movements in the real exchange rates other than themselves. Nevertheless, for Germany, the U.K., and especially Korea, real exchange rate movements are heavily influenced by the U.S.

Figure 5-6 displays the Korean real exchange rate responses to a typical shock in each of the real exchange rate for the U.S., Germany, the U.K., and Korea. As in the case of Indonesia, the Korean real exchange rate shows a large positive jump in response to the shocks in the U.S. real rate and itself for the first month. For each shock, however, the Korean real exchange rate will eventually return to its original level. In order to provide a more clear interpretation, the responses of the Korean real rate to each shock are presented in individual figures (i.e., Figures 5-7 to 5-10).

Figure 5-7 shows the response of the Korean real exchange rate to a typical shock in the U.S. real exchange rate. For the first thirteen months, the Korean real rate fluctuates above and below the origin level after a shock in the U.S. rate. Then the Korean real exchange rate returns to its original level.

As shown in Figure 5-8, the Korean real exchange rate shows big

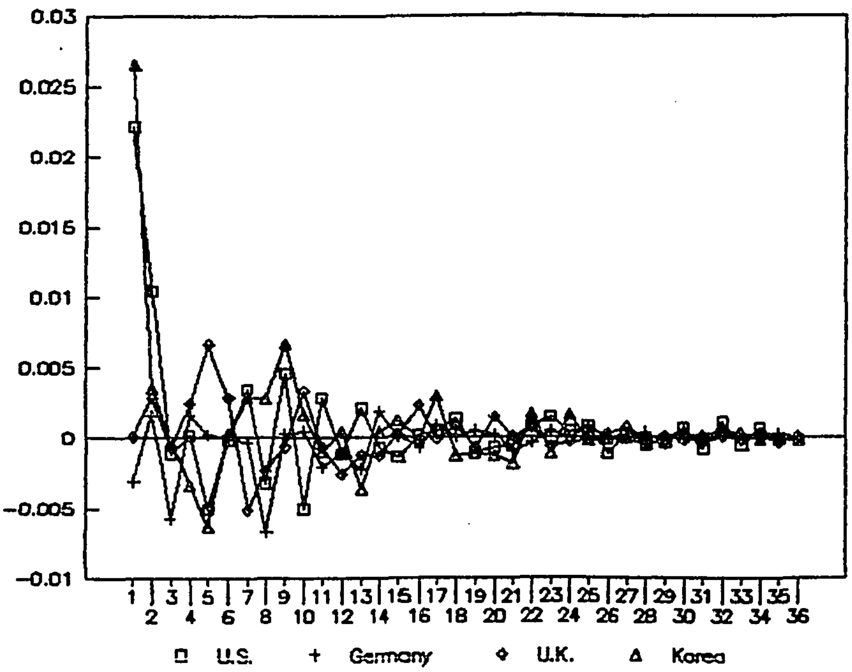

Figure 5-6. Responses of Δrko to a shock in Δrus, Δrge, Δruk, and Δrko

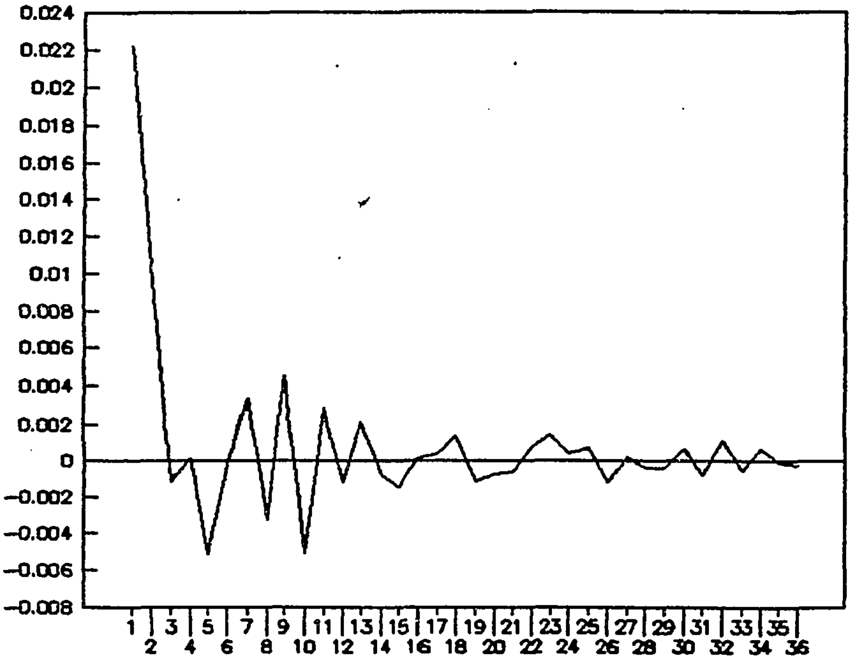

Figure 5-7. Responses of Δrko to a shock in Δrus

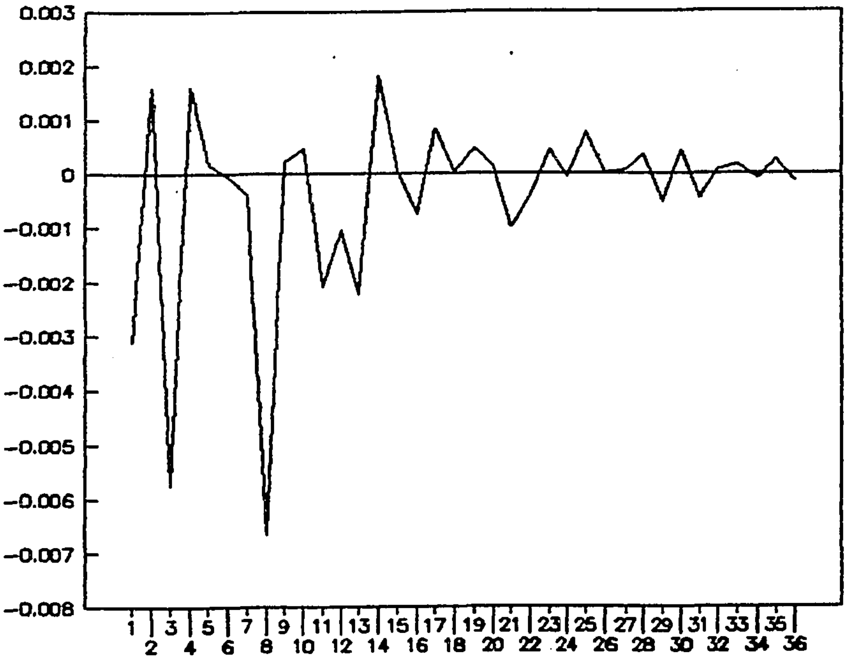

Figure 5-8. Responses of Δrko to a shock in Δrge

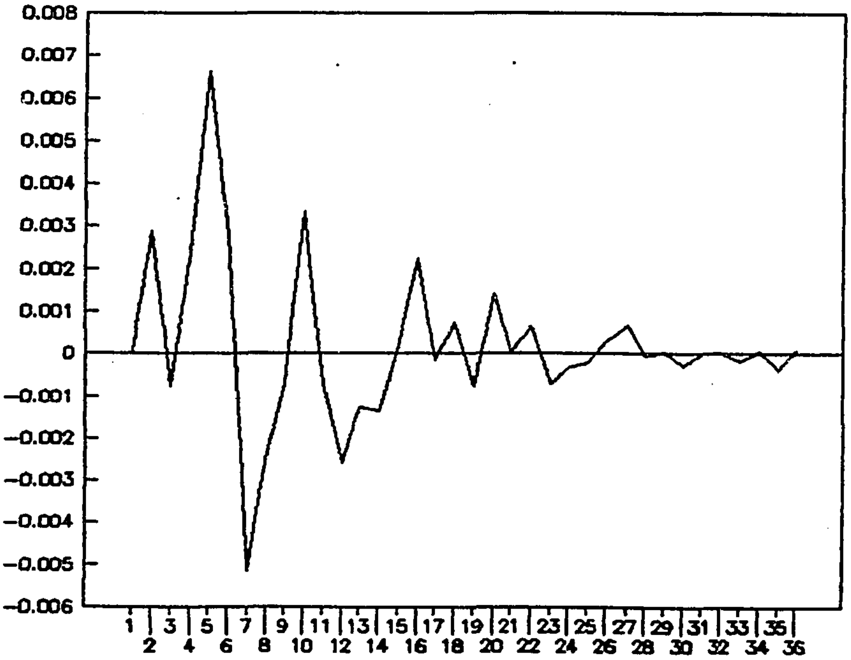

Figure 5-9. Responses of Δrko to a shock in Δruk

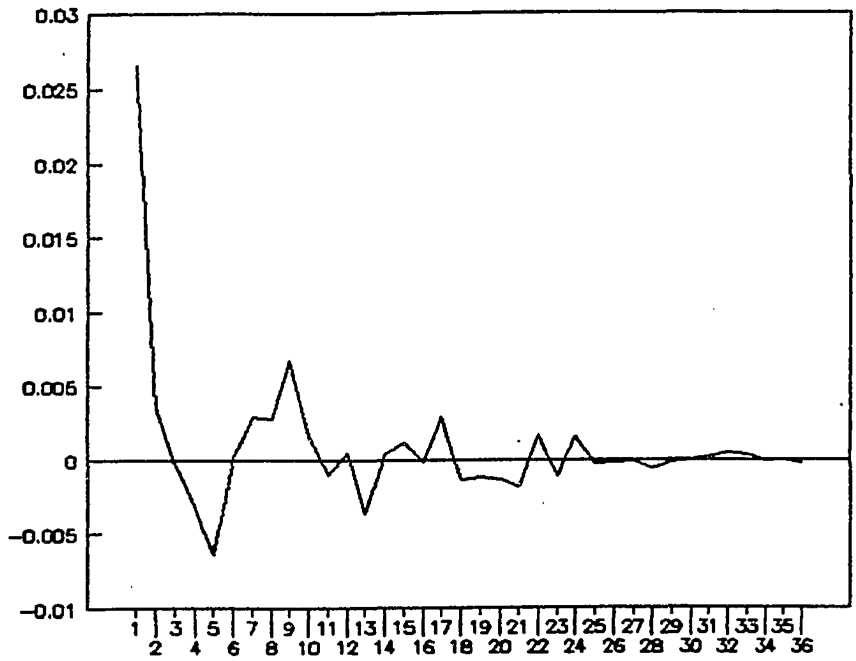

Figure 5-10. Responses of Δrko to a shock in Δrko

fluctuations in the first nine months following a shock in the German real exchange rate; it attains a negative peak at the eighth month. Then the fluctuations of the Korean rate become small, and it finally reverts to its initial level.

After a shock in the U.K. real exchange rate, the Korean real exchange rate is generally positive for the first six months; it reaches a positive peak at the fifth month as shown in Figure 5-9. Then the Korean real rate is generally negative from the seventh month to the fourteenth month and returns to its original level afterwards. Thus, an unanticipated depreciation of the U.K. real exchange rate is associated with a depreciation of the Korean real exchange rate for the first six months and then an appreciation of the Korean real rate in the following eight months.

Figure 5-10 illustrates the response of the Korean real exchange rate to its own shock. After its own shock, the Korean real rate is positive for the first two months, negative for the next three months, positive again for months 6-10, and then converges to zero.

The Philippine Case

Estimated error correction model

Table 5-7 presents the estimated error correction model for Δrus, Δrge, Δruk, and Δrph. Like the case of Korea, the volatility of the German real exchange rate is the lowest while the Philippine real rate is the highest. Also, the results of the model are difficult to interpret due to the multicollinearity in each equation and the cross-equation feedbacks. All these characteristics are similar to the case of Korea.

Unlike the cases of Indonesia and Korea, however, the error correction terms in the four real exchange rate equations are all significant. Thus, the U.S., German, U.K., and Philippine real exchange rates appear to be responsive to deviations from Generalized-PPP.

Strikingly, the results of Granger causality tests which are shown in Table 5-8 are also the same as the Korean case. None of the four real exchange rates are significant in the four real exchange rate equations at conventional significance levels; movements in the four real exchange rates

Table 5-7. Error correction model: The Philippines

Equation	Variable	1	2	3	4	5	6
Δrus	Δrus	0.262[a]	0.038	-0.164[a]	0.125	-0.063	-0.236[a]
	Δrge	0.048	-0.069	0.103	-0.093	-0.015	0.075
	Δruk	0.104[a]	-0.099[a]	0.030	0.069	0.013	-0.103[a]
	Δrph	-0.080	-0.028	0.093	-0.108[a]	0.198[b]	0.080
	E	0.043[a]					
Δrge	Δrus	-0.017	-0.139[a]	-0.083	0.151[a]	0.019	-0.047
	Δrge	0.286[b]	-0.074	0.098	-0.099	-0.038	0.124[a]
	Δruk	0.000	-0.003	0.002	0.005	0.103[a]	-0.087[a]
	Δrph	0.035	0.134[a]	0.099[a]	-0.087[a]	-0.009	0.058
	E	-0.042[a]					
Δruk	Δrus	-0.101	0.205[a]	-0.089	0.060	0.081	-0.193[a]
	Δrge	-0.039	0.100	-0.001	0.170[a]	-0.213[a]	-0.007
	Δruk	0.097	0.017	0.004	0.063	-0.032	-0.073
	Δrph	-0.042	-0.006	0.124[a]	-0.215[a]	-0.126[a]	0.136[a]
	E	-0.081[b]					
Δrph	Δrus	0.240[a]	0.040	-0.212[a]	0.217[a]	-0.081	-0.167
	Δrge	-0.040	-0.070	0.176[a]	-0.277[a]	0.149	-0.054
	Δruk	0.155[a]	-0.122[a]	-0.014	0.098	-0.085	-0.085
	Δrph	-0.290	-0.084	0.102	-0.075	0.322[b]	-0.017
	E	0.048[a]					

Note: a and b are t-statistics between 1 and 2, and greater than 2 in absolute values respectively.

7	8	9	10	11	12	S.E.
0.141[a]	0.039	0.054	-0.068	0.262[a]	-0.095	0.0273
-0.177[a]	-0.082	-0.037	0.054	-0.047	0.060	
-0.021	-0.063	0.084[a]	-0.104[a]	-0.116[a]	-0.078[a]	
-0.035	-0.007	-0.045	0.035	-0.030	0.017	
0.118[a]	0.049	0.134[a]	-0.118[a]	-0.042	-0.061	0.0224
-0.070	0.055	-0.041	0.156[a]	-0.117[a]	-0.035	
-0.055	-0.026	0.021	-0.055	0.000	-0.012	
-0.068	-0.051	-0.022	-0.017	0.091[a]	0.045	
0.173[a]	0.137	0.003	-0.151	0.122	-0.124	0.0333
-0.040	-0.036	0.174[a]	0.027	-0.147[a]	0.112	
0.086	-0.051	-0.063	0.025	0.004	0.010	
-0.126[a]	0.046	-0.072	0.003	0.070	-0.037	
0.383[b]	-0.194	0.167	-0.051	0.343[b]	-0.342[b]	0.0351
-0.139	-0.207[a]	0.101	0.004	0.162[a]	0.088	
-0.039	-0.035	0.065	-0.110[a]	-0.179[a]	-0.143[a]	
-0.214[a]	0.180[a]	-0.144[a]	0.070	-0.161a	0.082	

Table 5-8. F-statistics for causality tests: The Philippines

Equation	Variable			
	Δrus	Δrge	Δruk	Δrph
Δrus	1.191	0.582	1.089	0.644
	(0.295)[a]	(0.854)	(0.374)	(0.801)
Δrge	0.977	1.339	0.541	0.972
	(0.474)	(0.203)	(0.885)	(0.479)
Δruk	0.572	0.708	0.324	0.831
	(0.862)	(0.742)	(0.984)	(0.619)
Δrph	1.456	1.019	1.096	1.317
	(0.148)	(0.435)	(0.368)	(0.215)

[a]Marginal significance levels are in parentheses.

may be explained by other variables. Also, it may be that the error correction terms are not taken into account in applying Granger causality tests. Thus, results from Granger causality tests do not fully capture lags of all real exchange rates; especially, all error correction terms are significant in this model.

Variance decomposition and impulse response functions

Table 5-9 gives the variance decomposition of the U.S., German, U.K., and Philippine real exchange rates. Strikingly, the results are similar to the previous two cases.

As in the cases of Indonesia and Korea, both the U.S. and the German

Table 5-9. Variance decomposition: Proportion of forecast error (the Philippines)

	k month ahead error produced by each innovation					
Forecast error in	k	S.E.	Δrus	Δrge	Δuk	Δrph
Δrus	1	0.0234	1.00	0.00	0.00	0.00
	3	0.0245	0.97	0.01	0.02	0.00
	6	0.0250	0.94	0.02	0.02	0.02
	12	0.0266	0.85	0.05	0.06	0.04
	24	0.0272	0.84	0.05	0.07	0.04
	36	0.0272	0.84	0.05	0.07	0.04
Δrge	1	0.0193	0.13	0.87	0.00	0.00
	3	0.0203	0.14	0.85	0.00	0.01
	6	0.0208	0.14	0.81	0.01	0.04
	12	0.0217	0.15	0.76	0.03	0.06
	24	0.0221	0.16	0.73	0.04	0.07
	36	0.0222	0.16	0.73	0.04	0.07
Δruk	1	0.0286	0.13	0.12	0.75	0.00
	3	0.0292	0.15	0.12	0.73	0.00
	6	0.0303	0.16	0.13	0.68	0.03
	12	0.0315	0.17	0.13	0.65	0.05
	24	0.0319	0.17	0.14	0.63	0.06
	36	0.0319	0.17	0.14	0.63	0.06
Δrph	1	0.0302	0.61	0.00	0.00	0.39
	3	0.0314	0.61	0.00	0.02	0.37
	6	0.0326	0.59	0.02	0.03	0.36
	12	0.0347	0.54	0.05	0.06	0.35
	24	0.0358	0.54	0.05	0.08	0.33
	36	0.0358	0.53	0.05	0.09	0.33

real exchange rates explain the main proportion of their own forecast error variance. For example, at 1, 6, and 36 months, the U.S. real rate accounts for 100%, 94%, and 84% of its forecast error variance, and the German real rate explains 87%, 81%, and 73% of its variance. In contrast, the U.K. real rate accounts for only 63% of its forecast error variance and the Philippine real rate explains even less proportion, only one-third, of its variance. These observations have the same implications with the case in Korea.

Clearly, the innovations in the real rates of Germany, the U.K., and the Philippines just explain 5%, 7%, and 4% of the forecast error variance in the U.S. real exchange rate. This result implies the U.S. real exchange rate is exogenous. For the German real rate, 16%, 4%, and 7% of its forecast error variance are accounted for by the innovations in the U.S., U.K., and Philippine real rates respectively. It shows that a significant feedback to the German real rate is from the U.S. real rate. The innovations in the U.S. and German real rates explain 17% and 14% of the forecast error variance in the U.K. real exchange rate. Thus, there are important feedbacks from the U.S. and the German real rates into the U.K. real rate. Finally, it is surprising that more than a half of the forecast error variance in the Philippine real exchange rate is explained by the innovation in the U.S. real rate. Hence, there is a strong feedback from the U.S. real rate to the Philippine real rate.

Strikingly, the U.S. real exchange rate not only affects the movements in the German and the U.K. real exchange rate, but also dominates over the Philippine real exchange rate movement as well. On the other hand, the U.K.

and the Philippine real exchange rates do not have too much influence on the movements in other real rates. For the German real rate, only the U.K. real exchange rate movement is affected by it.

Figure 5-11 presents the impulse response functions of the Philippine real exchange rate to a typical shock in the U.S., German, U.K., and Philippine real exchange rates respectively. As in the previous two cases, the Philippine real exchange rate rises sharply for the first month after a shock in the U.S. and the Philippine rates respectively. However, the effect of the U.S. rate shock is larger than that of the Philippines in this case. Indeed, a shock in the U.S. real rate has greater effects than other real rate shocks at all time horizons, as can be seen in Figure 5-11. As before, effects of each real exchange rate shock on the Philippine real rate are independently shown in Figures 5-12 through 5-15.

Figure 5-12 shows the response of the Philippine real exchange rate to a one standard deviation shock in the U.S. real rate. A shock in the U.S. real rate leads to a positive peak effect on the Philippine real rate for the first month. Moreover, the Philippine rate shows fluctuations between positive and negative values for the first eighteen months. At this point, the Philippine real rate returns to its original level.

As shown in Figure 5-13, the Philippine real exchange rate fluctuates for the first six months following a shock in the German real rate. Then the Philippine real rate is negative for the next five months, and it reaches a negative peak in the month eight. After this period, the Philippine real rate

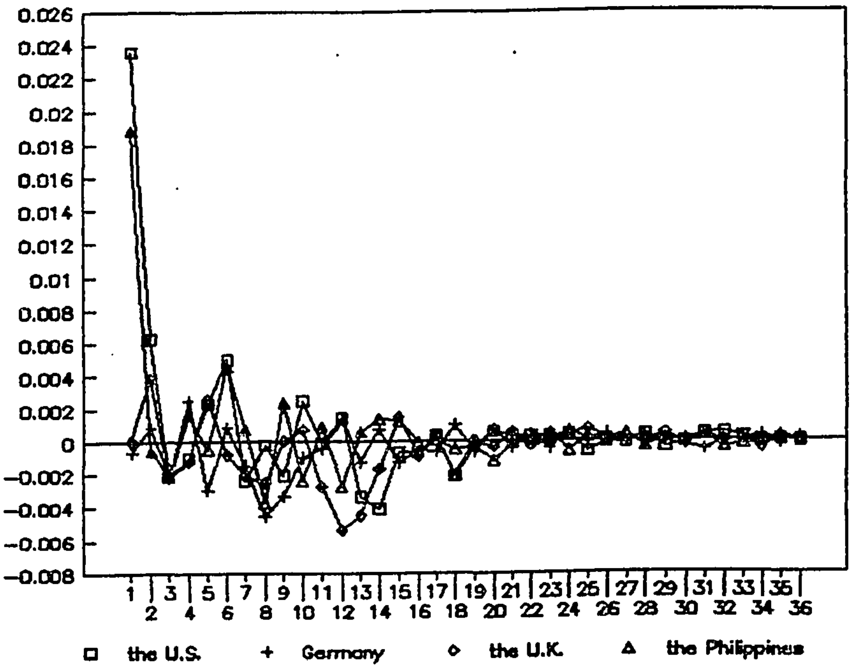

Figure 5-11. Responses of Δrph to a shock in Δrus, Δrge, Δruk, and Δrph

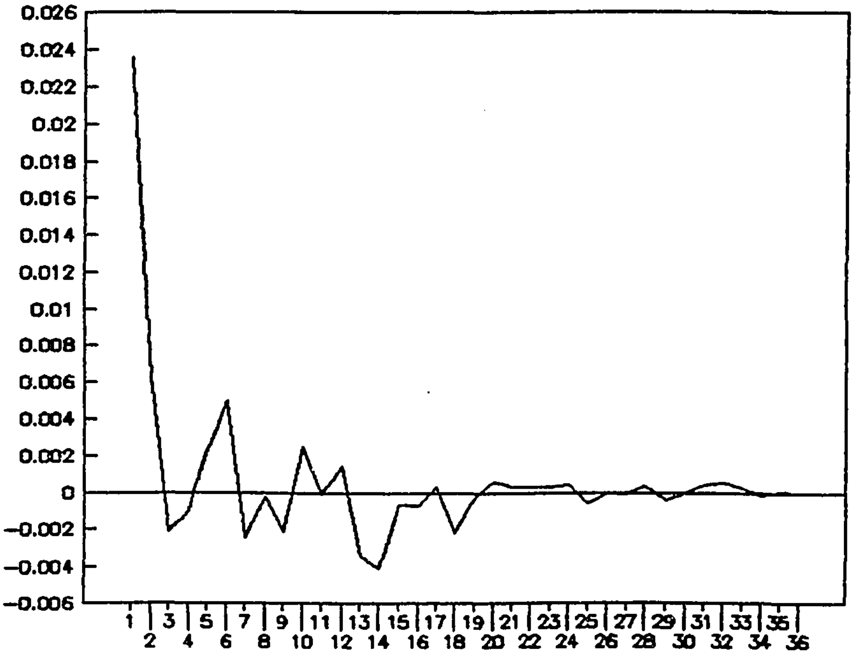

Figure 5-12. Responses of Δrph to a shock in Δrus

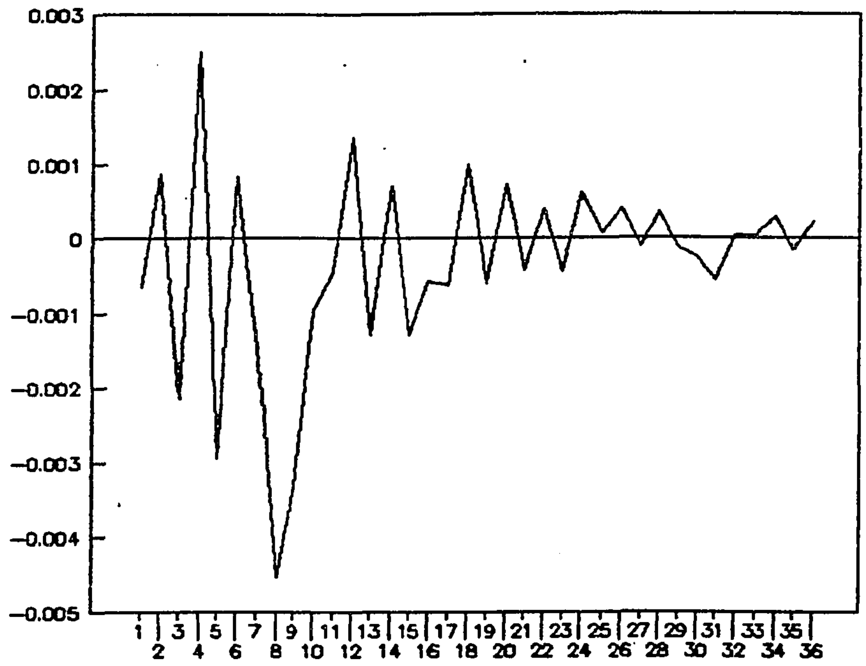

Figure 5-13. Responses of Δrph to a shock in Δrge

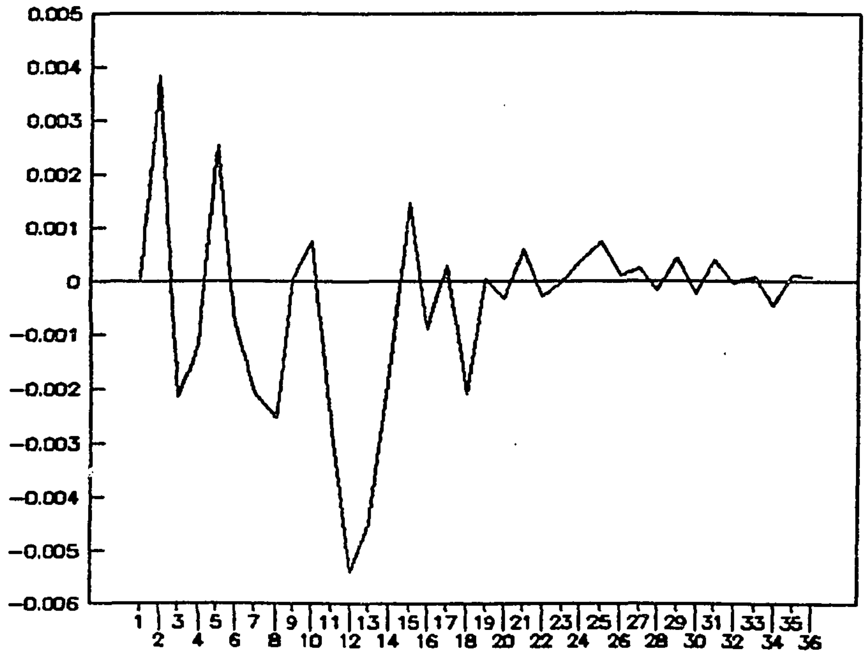

Figure 5-14. Responses of Δrph to a shock in Δruk

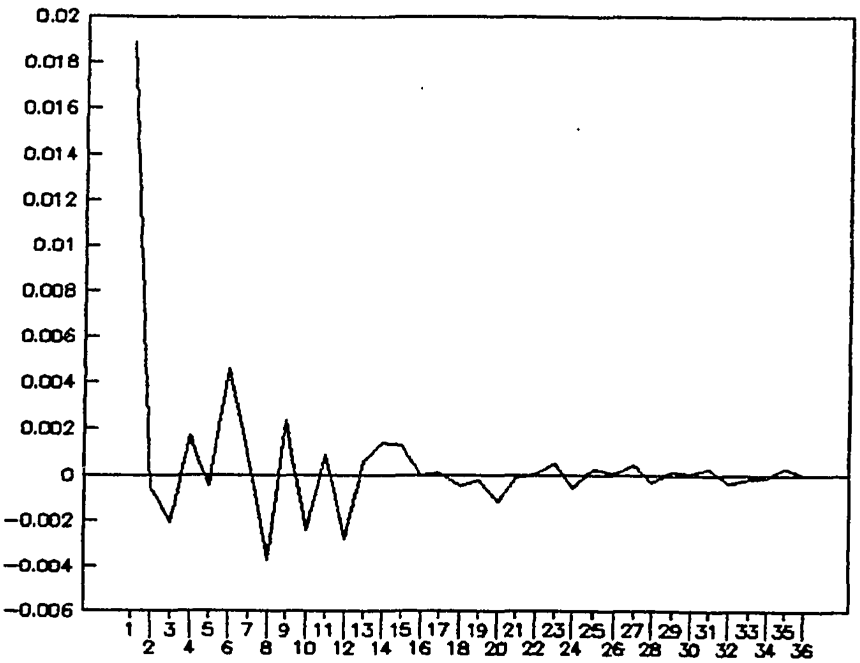

Figure 5-15. Responses of Δrph to a shock in Δrph

shows small fluctuations but converges to zero.

In Figure 5-14, a shock in the U.K. real rate causes further bigger fluctuations in the Philippine real exchange rate than the German real rate shock; it has a positive peak effect at the second month and has a negative peak effect at the twelfth month. In addition, the fluctuations of the Philippines real exchange rate not only are large, but also are persistent; the fluctuations end at the nineteenth month, and then the Philippine rate begins to return to its initial level.

As shown in Figure 5-15, a one standard deviation shock in the Philippine real exchange rate has the largest effect on itself at the first month.

Then, like the other three real rate shocks, the Philippine real exchange rate shows oscillatory behavior and returns to the original level after fifteen months.

The Singapore Case

Estimated Error Correction Model

The error correction model for the real exchange rates of the U.S., Germany, the U.K., and Singapore is presented in Table 5-10. As indicated by the estimated standard errors, the volatility of the real exchange rate of the U.K. is the highest while the German real exchange rate is the lowest. Most of the parameters are not significant since this is an over-parameterized model. There is no such a clear pattern for each OLS equation as signs of the estimated coefficients change randomly. The near multicollinearity of variables and the cross-equation feedbacks also exist in the system, so it makes us look more harder to interpret the results. In the next section, the impulse response function, or moving average representation, which is transformed from the error correction model, will give us a reasonable interpretation. Nevertheless, the error correction term, E_{t-1}, in each equation except the second equation (i.e., Δrge) is significant. Thus, the real exchange rates of the U.S., the U.K., and Singapore are responsive to deviations from Generalized-PPP.

Table 5-11 gives the F-statistics for Granger causality tests on the lagged variables. Obviously, no F-statistics are significant in equations Δrus, Δrge,

Table 5-10. Error correction model: Singapore

Equation	Variable	1	2	3	4	5	6
Δrus	Δrus	0.125	-0.160	0.217[a]	-0.030	0.105	-0.202[a]
	Δrge	0.059	-0.051	0.116	-0.065	-0.037	-0.061
	Δruk	0.133[a]	-0.095[a]	0.053	0.089[a]	0.046	-0.060
	Δrsi	0.055	0.273[a]	-0.312[a]	0.021	0.004	0.091
	E	0.147[b]					
Δrge	Δrus	0.016	-0.140	0.190[a]	-0.085	0.050	0.060
	Δrge	0.372[b]	-0.126[a]	0.106	-0.005	-0.040	-0.153[a]
	Δruk	0.007	-0.040	-0.013	-0.011	0.099[a]	-0.082[a]
	Δrsi	-0.031	0.187[a]	-0.246[a]	0.160	-0.100	-0.040
	E	0.029					
Δruk	Δrus	-0.002	-0.260[a]	0.516[b]	-0.583[b]	0.185	-0.018
	Δrge	0.113	0.138	0.188[a]	0.279[a]	-0.089	0.077
	Δruk	0.093	-0.078	-0.065	0.009	-0.063	-0.104[a]
	Δrsi	-0.235[a]	0.569[b]	-0.592[b]	0.470[a]	-0.087	-0.041
	E	0.149[b]					
Δrsi	Δrus	-0.248[a]	-0.080	0.191[a]	-0.054	0.083	-0.121
	Δrge	-0.004	-0.026	0.082	-0.066	-0.039	0.122
	Δruk	0.126[a]	-0.087[a]	0.035	0.016	0.069	-0.047
	Δrsi	0.426[b]	0.179[a]	-0.164	0.076	0.008	-0.069
	E	0.079[a]					

Note: a and b indicate t-statistics between 1 and 2, and greater than 2 in absolute values respectively.

7	8	9	10	11	12	S.E.
0.159	0.103	-0.033	-0.006	0.322[a]	-0.127	0.0267
-0.050	0.080	0.083	0.113	0.056	0.144[a]	
-0.052	-0.096[a]	0.094[a]	-0.115[a]	-0.124[a]	-0.082[a]	
-0.082	-0.163	-0.056	0.059	-0.138	0.017	
0.024	0.257[a]	0.037	-0.083	0.046	-0.036	0.0228
-0.095	0.168[a]	-0.022	0.846	0.006	-0.025	
-0.115[a]	-0.034	-0.006	-0.034	-0.015	-0.059	
0.134	-0.382[b]	0.040	0.003	-0.004	0.033	
-0.103	0.172	-0.051	-0.376[a]	0.150	-0.214[a]	0.0329
0.058	0.166[a]	0.272[a]	0.023	0.009	0.240[a]	
0.008	-0.150[a]	-0.090	-0.004	-0.063	-0.073	
0.176	-0.081	-0.201	0.385[a]	-0.034	-0.003	
0.203[a]	0.067	-0.045	-0.023	0.246[a]	-0.283[a]	0.0258
-0.106	0.099	0.035	0.089	-0.055	0.215[a]	
-0.055	-0.135[a]	0.075[a]	-0.101[a]	-0.150[b]	-0.155[b]	
0.042	-0.161	0.003	0.080	-0.088	0.134	

Table 5-11. F-statistics for causality tests: Singapore

Equation	Variable			
	Δrus	Δrge	Δruk	Δrsi
Δrus	0.773 (0.677)[a]	0.440 (0.958)	1.296 (0.228)	0.743 (0.707)
Δrge	0.728 (0.722)	1.378 (0.184)	0.665 (0.782)	0.911 (0.538)
Δruk	1.375 (0.186)	1.271 (0.243)	0.596 (0.842)	1.251 (0.256)
Δrsi	1.249 (0.257)	0.492 (0.916)	1.590 (0.102)	1.241 (0.262)

[a]Marginal significance levels are in parentheses.

Δruk, and Δrsi. In other words, no variable is important in each equation; even the lagged values of each real exchange rate do not explain the movement in itself. Probably, there are some other variables which explain the movements in the four real exchange rates. On the other hand, it is not surprising to have these awful results since influences of error correction terms are not detected by Granger causality tests. Thus, results from Granger causality tests may be misleading.

Variance Decomposition and Impulse Response Functions

Table 5-12 shows the variance decomposition of the real exchange rates for the three large countries (i.e., the U.S., Germany, and the U.K.) and

Table 5-12. Variance decomposition: Proportion of forecast error (Singapore)

Forecast error in	k month ahead error produced by each innovation					
	k	S.E.	Δrus	Δrge	Δruk	Δrsi
Δrus	1	0.0226	1.00	0.00	0.00	0.00
	3	0.0239	0.95	0.01	0.02	0.02
	6	0.0245	0.92	0.03	0.03	0.02
	12	0.0261	0.84	0.04	0.08	0.04
	24	0.0270	0.79	0.05	0.10	0.06
	36	0.0272	0.78	0.06	0.10	0.06
Δrge	1	0.0193	0.10	0.90	0.00	0.00
	3	0.0207	0.10	0.90	0.00	0.00
	6	0.0210	0.10	0.87	0.02	0.01
	12	0.0223	0.12	0.78	0.05	0.05
	24	0.0227	0.12	0.76	0.06	0.06
	36	0.0228	0.12	0.76	0.06	0.06
Δruk	1	0.0279	0.08	0.16	0.76	0.00
	3	0.0294	0.10	0.16	0.70	0.04
	6	0.0312	0.10	0.21	0.63	0.06
	12	0.0326	0.12	0.21	0.61	0.06
	24	0.0334	0.13	0.22	0.58	0.07
	36	0.0335	0.13	0.22	0.58	0.07
Δrsi	1	0.0219	0.72	0.02	0.00	0.26
	3	0.0234	0.66	0.02	0.03	0.29
	6	0.0240	0.66	0.03	0.03	0.28
	12	0.0256	0.61	0.05	0.09	0.25
	24	0.0268	0.57	0.07	0.12	0.24
	36	0.0270	0.57	0.07	0.12	0.24

Singapore. Both the real exchange rates of the U.S. and Germany account for most of their own forecast error variance. In this instance, the U.S. real exchange rate account for 92%, 84%, 79%, and 78%, and the German real rate explains 87%, 78%, 76%, and 76% of their own forecast error variance at 1/2, 1, 2, and 3 years respectively. On the other hand, the real exchange rates of the U.K. and Singapore account for more than 58% and only about 24% of their own forecast error variance. This result indicates that the movements in the real exchange rates of the U.S. and Germany are both explained by their own innovations. Therefore, it appears that the real exchange rates of the U.S. and Germany are exogenous in this system since most of the forecast error variance is attributable to their own innovations respectively.

The innovations in the U.S. real exchange rate account for 12%, 13%, and more than 57% of the forecast error variance in the real exchange rates of Germany, the U.K. and Singapore respectively. The German real rate explains 6%, 22%, and 7% of the forecast error variance in the U.S., the U.K., and Singapore real rates respectively. The U.K. real exchange rate accounts for 10%, 6%, and 12% of the forecast error variance in the U.S., German, and Singapore real exchange rates respectively. On the contrary, the Singapore real exchange rate explains only 6% to 7% of the forecast error variance in the U.S., German, and the U.K. real exchange rates respectively.

The results above indicate that there is a strong feedback from the U.S. real exchange rate into the real exchange rates of Germany, the U.K., and especially Singapore. On the other hand, the feedback from the Singapore real rate to the other three real exchange rates is extremely small. Notice that the Singapore real exchange rate has about 69% of its forecast error variance accounted for by the U.S. (57%), and the U.K. (12%) real exchange rates. In fact, the U.S. real exchange rate explains the greater proportion (more than 57%) of the Singapore's forecast error variance at all time horizons.

In short, the real exchange rate movement in the small country (Singapore) is mainly caused by the real exchange rate of the larger country (the U.S.). However, the real exchange rate movements in the large countries (the U.S., Germany, and the U.K.) are not caused by the small country's (Singapore) real exchange rate shock. In fact, the real exchange rate of the "super large" country, the U.S., can also have moderate effects on the real exchange rate movements in the other large countries, Germany and the U.K.

Figure 5-16 shows the impulse response functions of the Singapore real exchange rate to a typical shock in the four (the U.S., German, the U.K., and Singapore) real exchange rates. Obviously, the U.S. (the largest country) real exchange rate shock has the biggest effect on the Singapore real exchange rate for the first month. In fact, a shock in the U.S. real exchange rate plays a key role for the time path of the Singapore real exchange rate. A shock in each of the other two countries' (Germany and the U.K.) real exchange rates also has certain effects on the Singapore real exchange rate at all time horizons.

Figures 5-17 to 5-20 illustrate the responses of the Singapore real exchange rate to a typical shock in the U.S., German, the U.K., and Singapore

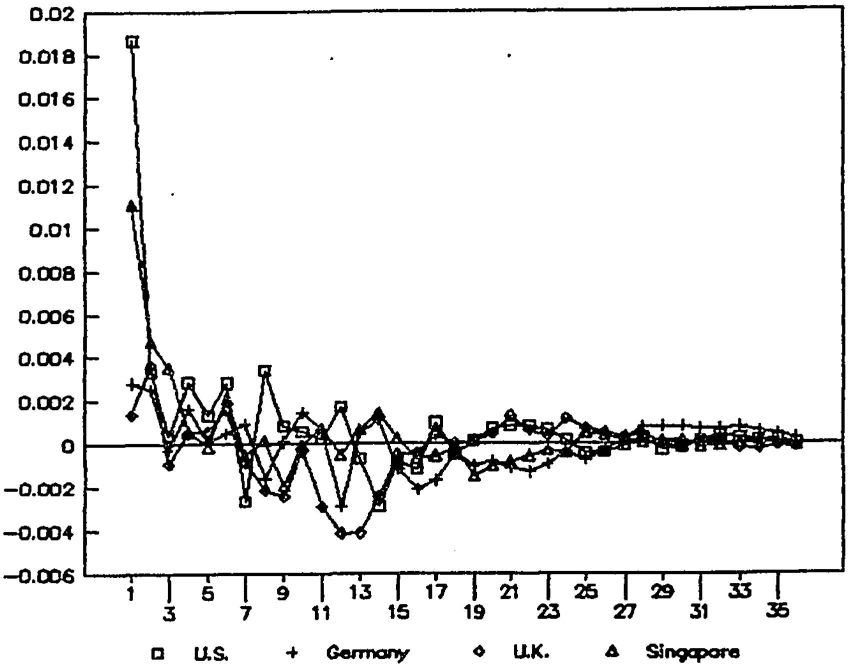

Figure 5-16. Responses of Δrsi to a shock in Δrus, Δrge, Δruk, and Δrsi

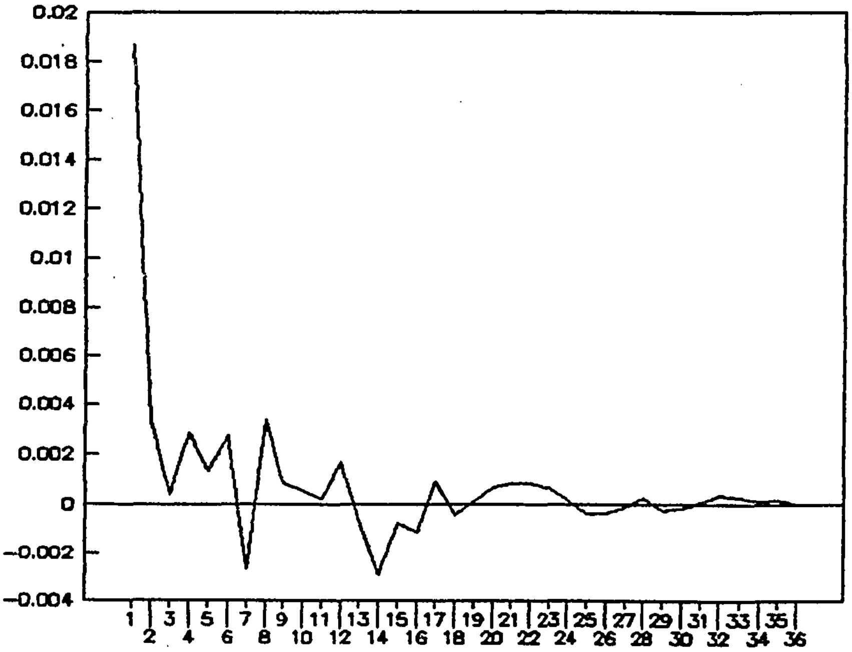

Figure 5-17. Responses of Δrsi to a shock in Δrus

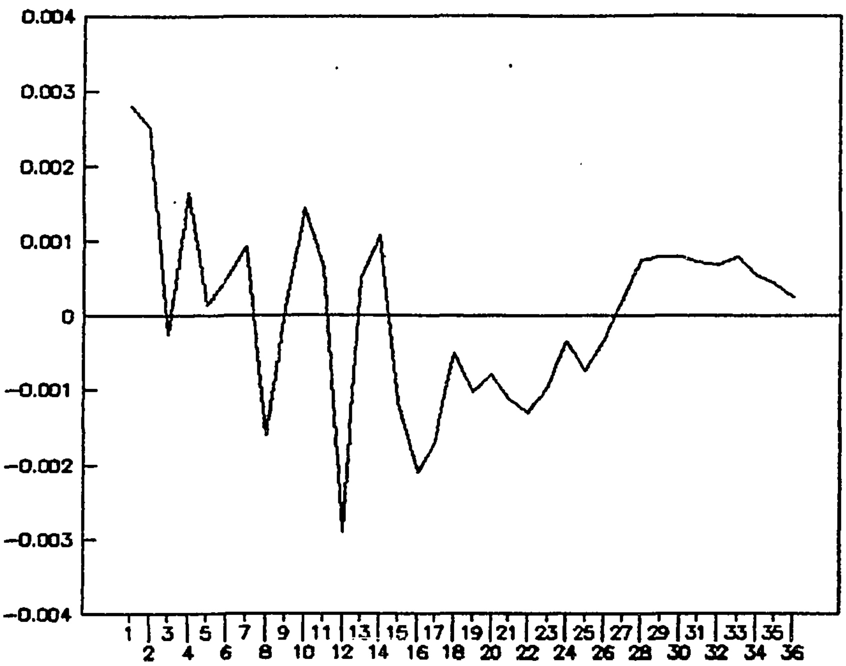

Figure 5-18. Responses of Δrsi to a shock in Δrge

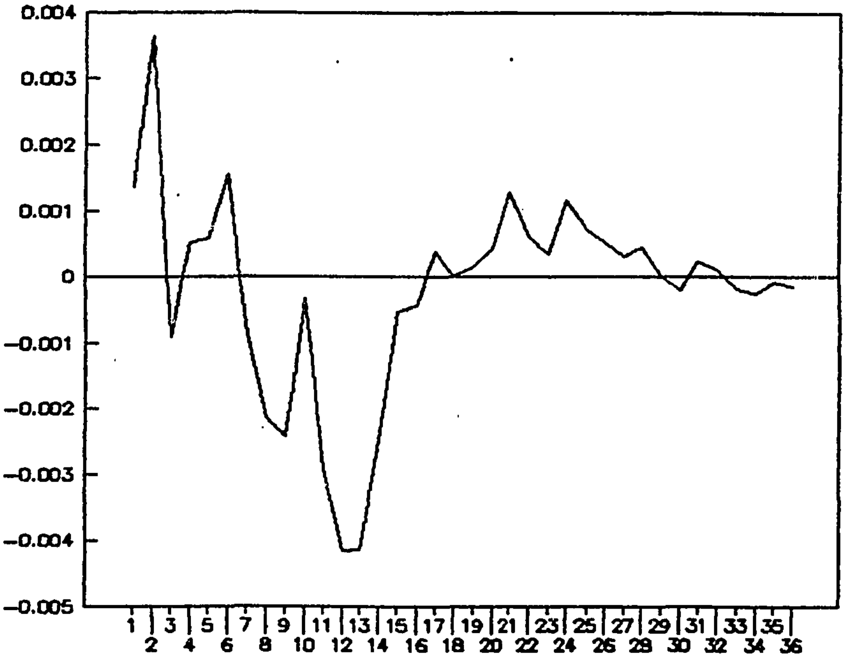

Figure 5-19. Responses of Δrsi to a shock in Δruk

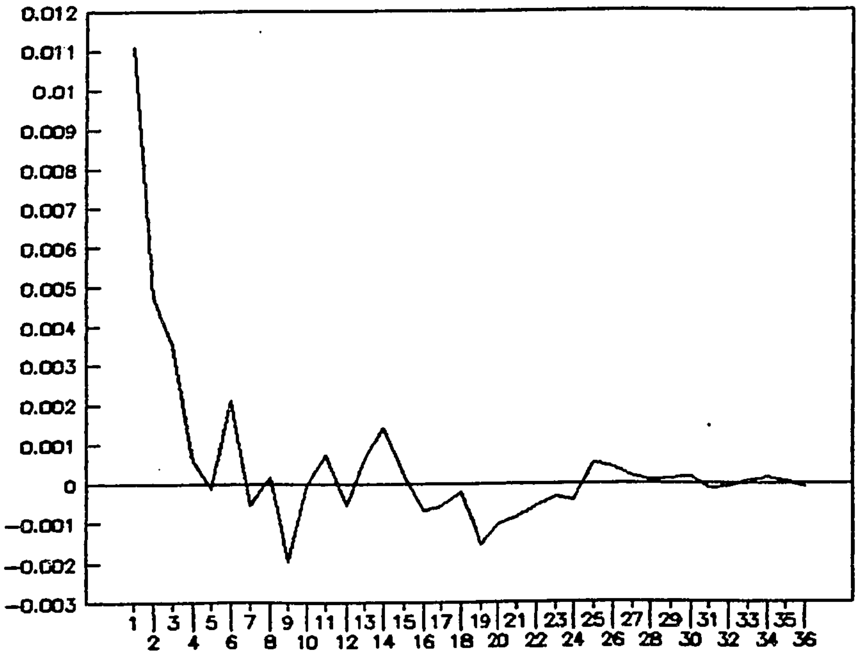

Figure 5-20. Responses of Δrsi to a shock in Δrsi

individually. These figures provide a thorough analysis. Figure 5-17 shows the response of the Singapore real exchange rate to a typical shock in the U.S. real exchange rate. The Singapore real exchange rate is generally positive for the first twelve months following the U.S. real exchange rate shock. Then the Singapore real rate begins to return to its initial level. Thus, an unanticipated depreciation of the U.S. real exchange rate leads to a depreciation of the Singapore real exchange rate as well.

As shown in Figure 5-18, the response of the Singapore real exchange rate to a typical shock in the German real exchange rate is, in general, positive for the first fourteen months. Then it declines for twelve months and rises afterwards. Although the impulse response of the Singapore real exchange rate to the German real rate shock is more persistent, it still returns to its original level.

The U.K. real exchange rate shock has different effects on the Singapore real exchange rate. In Figure 5-19, the Singapore real exchange rate rises generally for the first six months in response to the U.K. real rate shock. It then falls below the initial level for ten months and increases again, eventually returning to the original level.

Unlike the shocks in the real rates of the large countries (the U.S., Germany, and the U.K.), the Singapore real exchange rate is positive for the first four months following its own shock as shown in Figure 5-20. Then the Singapore real rate shows small fluctuations and reverts to its original level.

The Thai Case

Estimated error correction model

We are now going to analyze the last case, the case of Thailand. Not surprisingly, the results of the estimated error correction model are similar to the previous four cases, which are shown in Table 5-13. There are no clear implications to draw from the autoregressive coefficients because of the multicollinearity in the variables and the cross-equation feedbacks. As indicated by standard errors, the U.K. real exchange rate shows the highest volatility, and the German real rate is the lowest. Additionally, the error correction terms in equations Δrus and Δruk are significant. Therefore, the

Table 5-13. Error correction model: Thailand

Equation	Variable	1	2	3	4	5	6
Δrus	Δrus	0.360[b]	0.129	0.048	0.013	0.009	-0.014
	Δrge	0.016	0.024	0.213[a]	-0.055	-0.001	0.172[a]
	Δruk	0.164[b]	-0.085[a]	0.068	0.160[b]	0.059	-0.085[a]
	Δrti	-0.235[a]	-0.144[a]	-0.227[a]	-0.051	0.158[a]	-0.215[a]
	E	0.111[b]					
Δrge	Δrus	0.019	-0.041	0.198[a]	-0.143[a]	0.106	0.022
	Δrge	0.420[b]	-0.082	0.099	0.012	-0.027	0.097
	Δruk	-0.026	0.007	-0.011	-0.020	0.117[a]	-0.098[a]
	Δrti	-0.065	-0.019	-0.164[a]	0.152[a]	-0.133[a]	0.036
	E	0.039					
Δruk	Δrus	-0.273[a]	0.310[a]	0.076	0.119	0.164	0.080
	Δrge	0.085	0.175[a]	0.042	0.356[b]	-0.214[a]	0.045
	Δruk	0.039	-0.026	-0.001	0.037	0.069	-0.071
	Δrti	0.035	-0.166	-0.075	-0.417[b]	-0.074	-0.121
	E	0.072[a]					
Δrti	Δrus	0.093	0.253[a]	-0.016	-0.044	0.140	-0.120
	Δrge	-0.020	-0.053	-0.206[a]	-0.128	-0.141[a]	0.262[a]
	Δruk	0.233[b]	-0.042	0.055	0.195[b]	0.122[a]	-0.138[a]
	Δrti	-0.092	-0.153	-0.126	-0.076	0.092	-0.121
	E	0.036					

Note: a and b are t-statistics between 1 and 2, and greater than 2 in absolute values respectively.

7	8	9	10	11	12	S.E.
0.060	-0.066	-0.021	0.124	0.153[a]	-0.177[a]	0.0263
-0.170[a]	0.003	0.027	0.175[a]	-0.105	0.122[a]	
0.061	-0.061	-0.098[a]	-0.094[a]	-0.078[a]	-0.079[a]	
-0.069	0.138[a]	-0.001	-0.213[a]	0.113	0.125	
-0.007	0.096	0.090	-0.162[a]	0.162[a]	-0.091	0.0229
-0.030	0.117[a]	-0.017	0.152[a]	-0.066	-0.013	
-0.098[a]	-0.035	0.000	-0.034	0.002	-0.044	
0.064	-0.160[a]	0.011	0.007	-0.128[a]	-0.081	
0.014	0.227[a]	-0.190[a]	-0.290[a]	0.270[a]	-0.266[a]	0.0339
-0.029	0.103	0.138	0.160[a]	-0.051	0.150[a]	
0.097	-0.073	-0.081	-0.008	-0.041	-0.023	
-0.019	-0.152	0.171	0.107	-0.100	-0.100	
0.138	-0.101	-0.094	0.073	0.118	-0.266[a]	0.0284
-0.055	-0.015	-0.027	0.229[a]	-0.027	0.090	
0.062	-0.028	0.041	-0.032	-0.145[a]	-0.098[a]	
-0.211[a]	0.197[a]	0.146	-0.179[a]	0.120	0.229	

U.S. and the U.K. real rates make the adjustment to deviations from Generalized-PPP.

Table 5-14 reports the results of Granger causality tests. Lags of all the four real exchange rates are not significant in the Δrus equation at conventional significance levels. Note that even though the marginal significance level of Δruk is 0.102 in the Δrus equation, it is still not considered to be significant at the 10% significant level. This result means that no real exchange rates explain the movements in the U.S. real exchange rate.

For the German real exchange rate, however, lags of Δrge are significant in forecasting Δrge at the 10% significance level. This reveals that

Table 5-14. F-statistics for causality tests: Thailand

	Variable			
Equation	Δrus	Δrge	Δruk	Δrti
Δrus	1.115	0.917	1.586	1.379
	(0.353)[a]	(0.532)	(0.102)	(0.183)
Δrge	0.637	1.758	0.681	0.755
	(0.808)	(0.061)	(0.767)	(0.696)
Δruk	1.429	1.108	0.310	0.853
	(0.160)	(0.358)	(0.987)	(0.596)
Δrti	0.804	0.970	1.954	1.160
	(0.646)	(0.480)	(0.033)	(0.318)

[a]Marginal significance levels are in parentheses.

the movements in the German real exchange rate are explained by its own past. In contrast, none of the real exchange rates are significant in explaining the movements in the U.K. real exchange rate at conventional significance levels. At this point, we would question whether the movements in the U.S. and the U.K. real rates are affected by other variables.

In the Δrti equation, Δrus, Δrge, and Δrti are not significant at conventional significance levels; however, lags of Δruk are significant at the 5% significance level. Thus, there is evidence that the U.K. real exchange rate affects the real exchange rate of Thailand.

Like the previous four cases, the above results may be questionable due to error correction terms in the model. Since lagged real exchange rates are embedded in each error correction term, results from Granger causality tests do not take these terms into account and thus may be misleading.

Variance decomposition and impulse response functions

Table 5-15 reports the variance decomposition of the real exchange rates of the U.S., Germany, the U.K., and Thailand. As in the previous four cases, both the U.S. and the German real exchange rates account for most of their forecast error variance. For instance, the U.S. real rate accounts for 100%, 82%, and 86% while the German real rate explains 86%, 84%, and 77% of their own forecast error variance at 1, 6, and 36 months. On the other hand, the U.K. real rate explains only more than a half of its forecast error variance. For the Thai real rate, even a smaller proportion (only 25%)

Table 5-15. Variance decomposition: Proportion of forecast error (Thailand)

	k month ahead error produced by each innovation					
Forecast error in	k	S.E.	Δrus	Δrge	Δruk	Δrti
Δrus	1	0.0226	1.00	0.00	0.00	0.00
	3	0.0241	0.93	0.01	0.03	0.03
	6	0.0258	0.82	0.08	0.04	0.06
	12	0.0274	0.76	0.09	0.08	0.07
	24	0.0279	0.75	0.09	0.09	0.07
	36	0.0279	0.75	0.09	0.09	0.07
Δrge	1	0.0197	0.14	0.86	0.00	0.00
	3	0.0212	0.13	0.87	0.00	0.00
	6	0.0217	0.13	0.84	0.02	0.01
	12	0.0228	0.14	0.78	0.05	0.03
	24	0.0231	0.14	0.77	0.06	0.03
	36	0.0231	0.14	0.77	0.06	0.03
Δruk	1	0.0291	0.15	0.16	0.69	0.00
	3	0.0299	0.17	0.17	0.66	0.00
	6	0.0316	0.17	0.20	0.59	0.04
	12	0.0330	0.18	0.21	0.57	0.04
	24	0.0336	0.18	0.21	0.56	0.05
	36	0.0336	0.18	0.21	0.56	0.05
Δrti	1	0.0244	0.71	0.00	0.00	0.29
	3	0.0255	0.66	0.01	0.05	0.28
	6	0.0268	0.61	0.05	0.07	0.27
	12	0.0284	0.57	0.07	0.10	0.26
	24	0.0288	0.56	0.07	0.11	0.26
	36	0.0288	0.56	0.07	0.12	0.25

of its forecast error variance is explained by its own innovation. Therefore, the degrees of the exogeneity of the U.S. and German real exchange rates are higher than the U.K. and Thai real exchange rates.

For the German, U.K., and Thai real exchange rates, each rate explains 7-9% of the forecast error variance in the U.S. real exchange rate. Thus, the feedbacks from these three real rates to the U.S. real rate are negligible. The German real exchange rate has about 14%, 6%, and 3% of its forecast error variance accounted for by the U.S., U.K., and Thai real exchange rates respectively. It implies that an important feedback is from the U.S. real rate to the German real rate. For the U.K. real exchange rate, about 40% of its forecast error variance is divided almost equally between the real rates of the U.S. and Germany. This result implies that there are significant feedbacks from both the U.S. and the German real rates into the U.K. real rate. Finally, about 70% of the forecast error variance in the Thai real exchange rate is due to the innovations in both the U.S. and the U.K. real rates; in particular, 56% of the variance is explained by the U.S. real rate. Hence, this result shows that the feedback from the U.S. real rate into the Thai real rate is much stronger than that of the U.K. real rate.

As in the previous four cases, the U.S. real exchange rate affects the movements in the three other real exchange rates, especially the Thai real rate. However, the Thai real exchange rate does not have many explanations in movements in other real exchange rates and even itself.

Figure 5-21 plots the impulse response functions of the Thai real exchange rate to a typical shock in the U.S., German, U.K., and Thai real exchange rates respectively. As in the previous four cases, both the U.S. and the Thai real exchange rate shocks show a larger positive effect than that of the German and the U.K. real rates at the first month respectively. In fact, in response to a shock in the U.S. real rate, the Thai real rate shoots up higher than its own shock. Although each real rate shock has different effects on the Thai real rate, the Thai real rate converges to zero for just more than a year. Figures 5-22 to 5-25 show the responses of the Thai real exchange rate to each real rate shock independently.

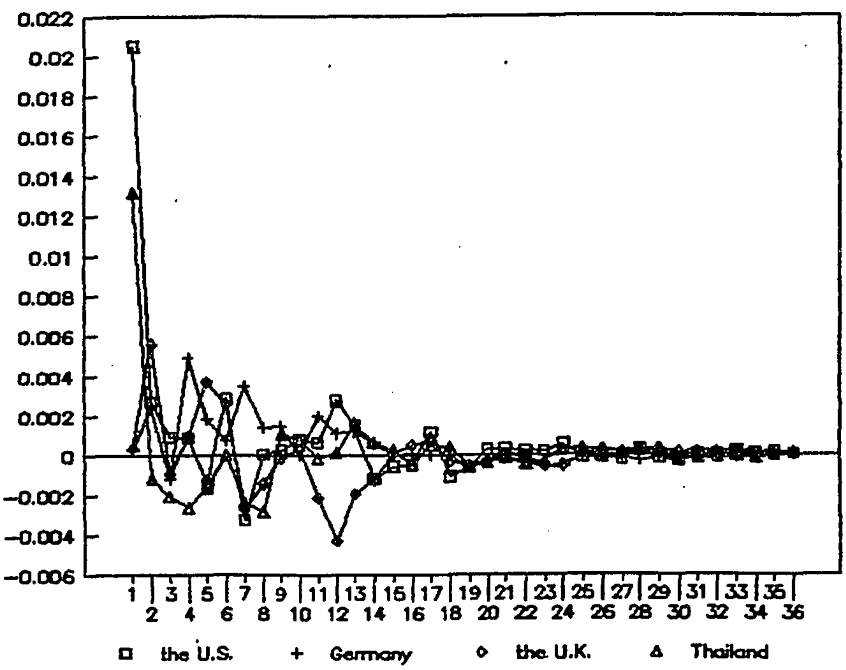

Figure 5-21. Response of Δrti to a shock in Δrus, Δrge, Δruk, and Δrti

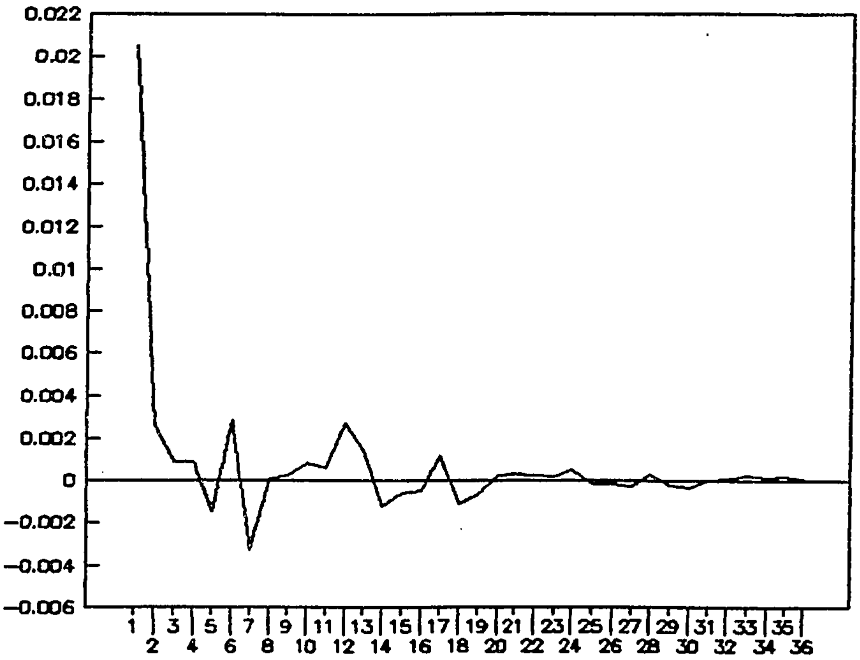

Figure 5-22. Responses of Δrti to a shock in Δrus

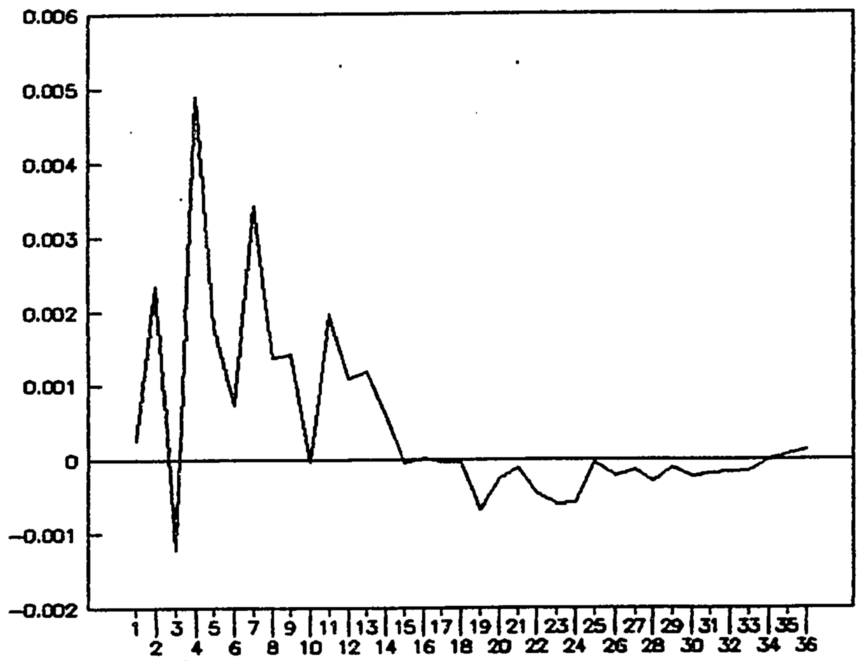

Figure 5-23. Responses of Δrti to a shock in Δrge

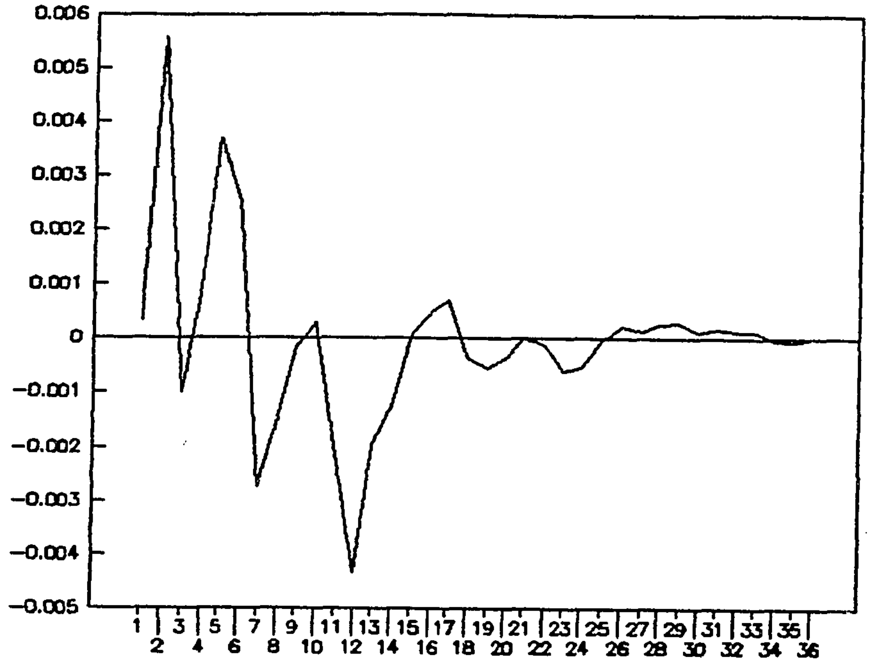

Figure 5-24. Responses of Δrti to a shock in Δruk

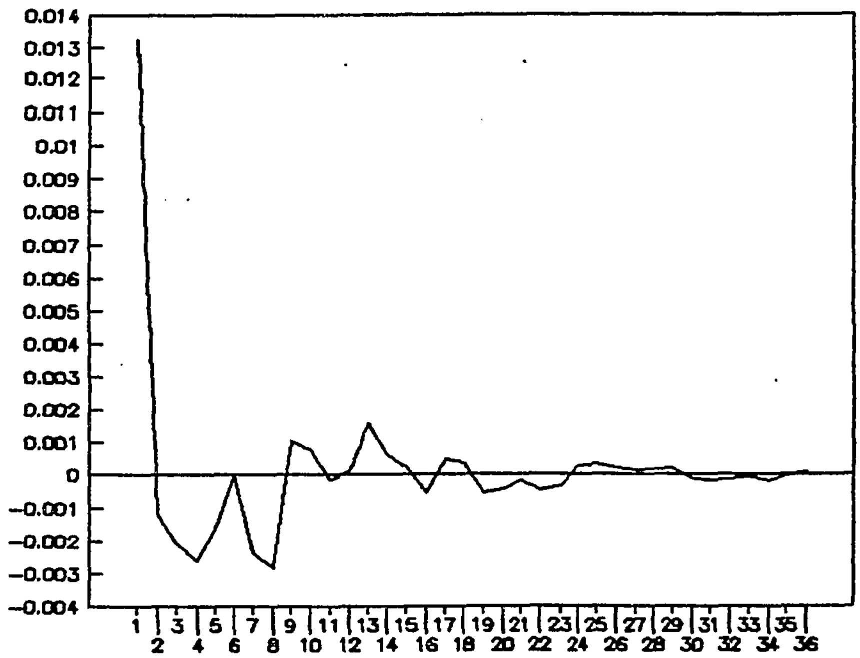

Figure 5-25. Responses of Δrti to a shock in Δrti

Figure 5-22 shows the effects of a one standard deviation shock in the U.S. real rate on the Thai real exchange rate. After a shock in the U.S. real rate, the Thai real exchange rate is generally positive for the first thirteen months and then begins to revert to its original level. There is some evidence that an unanticipated depreciation of the U.S. real exchange rate causes a depreciation of the Thai real exchange rate.

In Figure 5-23, in response to the German real rate shock, the Thai real exchange rate generally increases for the first fourteen months and then returns to its initial level. In this period, the Thai real rate attains a positive peak at the fourth month. Thus, an unanticipated depreciation of the German real exchange rate is associated with a depreciation of the Thai real exchange rate as well.

As shown in Figure 5-24, the Thai real exchange rate is generally positive for the first six months following a shock in the U.K. real exchange rate; also it reaches a positive peak at the second month. However, the behavior of the Thai real rate changes after this period. From the seventh month to the fourteenth month, the Thai real exchange rate generally declines and attains a negative peak at the twelfth month, and then it starts to revert to its original level. It is likely that an unanticipated depreciation of the U.K. real exchange rate raises the Thai real exchange rate (i.e., a depreciation of the Thai real exchange rate) for the first half year and then decreases the Thai real rate (i.e., an appreciation of the Thai real rate) subsequently.

In Figure 5-25, a shock in the Thai real rate leads the Thai real rate shooting up for the first month, and then generally falling from months 2-8. After this period, the Thai real rate fluctuates above zero and then converges to zero.

Concluding Remarks

The results of Granger causality tests from the five cases indicate the movements in most real exchange rates are almost completely unexplained by their own past and other real exchange rates. It is not surprising to have this result. In the usual VAR system, Granger causality tests on the lagged variables are appropriate. However, in our error correction models, these terms may be inappropriate since the existence of error correction terms. Therefore, results from Granger causality tests may be misleading in our study. Moreover, in Chapter IV, we examined the theory of Generalized-PPP and showed that real exchange rates are influenced by some fundamental variables, such as real income and government expenditure. As these fundamental variables do not appear in our model, we, of course, have these kinds of results.

In all the cases, the movements in the real exchange rates of the small Asian countries are influenced by shocks in the real exchange rates of the larger countries, especially the largest country, the U.S. Conversely, the movements in the U.S., German, and U.K. real exchange rates are not affected by the real exchange rates of the small Asian countries.

CHAPTER VI. SUMMARY AND CONCLUSIONS

Unit root tests, the augmented Dickey-Fuller and the Phillips-Perron tests, indicate that the bilateral real exchange rates of six small Asian countries (India, Indonesia, Korea, the Philippines, Singapore, and Thailand) and three larger countries (Germany, the U.K., and the U.S.) are not stationary, and each has a unit root over the period January 1973 to December 1989 (i.e., a period of flexible exchange rates). This result does not support purchasing power parity (PPP).

The theory of Generalized Purchasing Power Parity (Generalized-PPP) is developed due to the failure of PPP. Generalized-PPP states that the bilateral real exchange rates are, in general, non-stationary since the real fundamental variables are generally non-stationary. If the real fundamental variables of some countries share common trends, these countries' real exchange rates will share the same common trends. By sharing the common trends, these countries' real exchange rates are cointegrated, and there exists at least one stationary linear combination of the real exchange rates. Indeed, PPP is just a special case of Generalized-PPP.

Tests for the performance of Generalized-PPP by the Johansen multivariate cointegration methodology are presented. There is evidence in support of Generalized-PPP for the Asian countries as long as the Singapore real exchange rate is included. It is likely that the Singapore real exchange rate is the main linkage for the existence of Generalized-PPP in Asia. On the other hand, Generalized-PPP does hold for each of the small Asian countries (except India) with the three large countries (Germany, the U.K., and the U.S.).

The existence of Generalized-PPP implies that there is an error correction model. Using this model, it is possible to use the resulting impulse response functions to trace out the time paths of the various small Asian countries' real exchange rates for shocks in the real exchange rates of larger countries. Both the results of variance decomposition and the impulse response functions indicate that the real exchange rate movements in the small Asian countries are influenced by the shocks in large countries' real exchange rates, especially the largest country, the U.S. However, no movements in the real exchange rates of the large countries are caused by the small Asian countries.

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APPENDIX. ADDITIONAL TABLES

Isard's Findings

Table A-1. Exchange rates and relative export price indexes for selected machinery categories

	1970	1971	1972	1973	1974	1975
Exchange rate	100	103.4	114.6	140.9	143.9	155.2
Internal combustion engines	100	104.1	119.8	155.5	147.7	148.1
Agricultural tilling machinery	100	108.9	116.6	136.2	138.1	122.5
Office calculating machines	100	110.3	114.4	139.3	146.0	147.7
Metalworking machinery	100	110.4	125.2	153.8	144.3	141.8
Pumps	100	106.2	121.2	144.7	151.7	139.3
Forklift trucks	100	111.1	125.6	159.7	145.1	139.1

Note: Relative export price indexes are defined as German dollar export price per U.S. dollar export price.

Genberg's Findings

Table A-2. Average absolute percentage deviations from purchasing power parity[a]

	Fixed exchange rate period: 1957-1966	Include flexible exchange rate period: 1957-1976
Austria	1.3	2.0
Belgium	1.4	2.1
Canada	2.0	3.3
Denmark	1.3	2.0
France	2.5	3.0
Germany	1.3	2.7
Italy	1.2	5.8
Japan	1.9	3.8
Netherlands	0.5	1.7
Norway	0.9	2.9
Sweden	0.7	0.7
Switzerland	0.7	0.7
U.K.	0.5	3.8
U.S.	1.2	3.8
Average	1.2	3.2

[a]Regression residuals from: $\log(E_{ijt}P_{it} / P_{jt}) = a + bt + u_t$ where t is a time trend and u is residual term which represents deviations from purchasing power parity.

Krugman's Findings

Table A-3. Tests of purchasing power parity, instrumental variables technique

Exchange rate	α	β	SEE	R2
Pound/Dollar	-0.084 (0.017)[a]	0.856 (0.125)	0.023	0.949
French Franc/Dollar	0.002 (0.057)	1.053 (0.122)	0.046	0.979
Mark/Dollar	0.089 (0.055)	0.168 (0.427)	0.034	0.740
Lira/Dollar	0.070 (0.066)	1.651 (0.460)	0.025	0.965
Swiss Franc/Dollar	0.059 (0.032)	0.817 (0.208)	0.049	0.660
Pound/Dollar	0.038 (0.044)	1.405 (0.268)	0.029	0.954

[a]Numbers in parentheses are standard errors.

Findings of McNown and Wallace

Table A-4. Tests for cointegration

Country	α	β	Dickey-Fuller	Augmented Dickey-Fuller
Argentina	-8.44	1.05	-3.66**	N/A[a]
Brazil	-3.21	1.05	-2.52	N/A
Chile	3.98	0.98	-4.11**	-3.34
Israel	-5.34	1.02	-3.26*	N/A

[a]Since no lag terms are significant, no augmented Dickey-Fuller test statistic is reported.

* and ** indicate statistical significance at the 5% and 10% levels respectively.

Table A-5. Tests of the real exchange rate

Country	Dickey-Fuller	Augmented Dickey-Fuller
Argentine	-2.63*	N/A[a]
Brazil	-1.81	N/A
Chile	-4.00**	-3.03**
Israel	-2.53	N/A

[a]Since no lag terms are significant, no augmented Dickey-Fuller test statistic is reported.

* and ** indicate statistical significance at the 5% and 10% levels respectively.

Patel's Findings

Table A-6. Tests for cointegration

Country Pair	β_1	β_2	Argumented Dickey-Fuller
U.S. U.K.	1.7	1.4	-1.64
U.S. Canada	0.3	0.4	-2.38
U.S. Germany	2.7	5.0	-3.73*
U.S. Netherlands	1.5	1.7	-1.85
U.S. Japan	1.0	1.6	-1.90
U.K. Canada	0.7	1.0	-1.48
U.K. Germany	1.0	2.0	-2.52
U.K. Netherlands	0.8	0.8	-2.73
U.K. Japan	1.4	2.8	-2.86
Canada Germany	3.8	7.5	-2.54
Canada Netherlands	1.0	1.0	-1.34
Canada Japan	1.2	1.9	-4.41**
Germany Netherlands	0.3	0.4	-3.69
Germany Japan	2.4	2.0	-5.44**
Netherlands Japan	1.4	2.0	-1.70

* and ** indicate statistical significance at the 5% and 10% levels respectively.

MacDonald's Findings

Table A-7. Multivariate cointegration results and tests of homogeneity restrictions

	Trace		λmax		β_1	β_2	χ^2
	r=0	r<1	r=0	r=1			
Canada	32.37*	9.79	22.58**	6.79	1.016	0.805	14.96 (0.00)[a]
France	18.29	9.18	28.62**	10.32	1.211	0.799	14.04 (0.00)
Germany	34.61	7.71	26.90**	6.97	65.980	37.594	19.27 (0.00)
Japan	17.32	6.87	25.08**	7.67	2.403	1.753	11.52 (0.00)
U.K.	42.72**	17.47	25.25**	11.72	0.403	1.353	15.08 (0.00)

Note: Only the results in terms of the wholesale price index is reported. As indicated by the χ^2 test, the homogeneity restrictions are rejected in all cases.

[a]Numbers in parenthesis are marginal significance levels.

* and ** denote statistical significance at the 5% and 1% levels respectively.