

THE CURRENT EXPERIENCE OF FLEXIBLE EXCHANGE RATES:
EMPIRICAL EVIDENCE
FOR TEN INDUSTRIAL COUNTRIES

by

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I. GENERAL INTRODUCTION

The widespread adoption of managed floating exchange rate regimes (among the major currencies) in recent years has made it increasingly important for monetary authorities to be able to isolate those aggregate economic variables which play major roles in influencing exchange rate behavior. For an open, developed economy, an understanding of these factors is important for the pursuit of a balanced external financial policy and a compatible domestic economic policy.

Many hypotheses of exchange rate determination have been advanced in the past few years and just as many have been resurrected and modified from previous periods of academic interest in flexible exchange rates. Recent contributions tend to emphasize that the exchange rate is the relative price of two national monies, and hence is primarily determined by factors affecting the relative supplies and demands for these monies. The analysis of the exchange rate is thus removed from the partial framework of the trade sector and conducted in the general framework of the world economy. Short of analyzing exchange rates in the context of large scale multicountry econometric models, appropriate simplifying

assumptions must be made about the nature of elements "left out" of scaled-down, single equation models, and quite often the fundamental distinction between competing views rests on the very nature of these assumptions. Although a single equation is put forward as the center of analysis, it must be remembered that the exchange rate is but one element in a complex world economy of interrelated markets, and is determined in concert with many other variables in that economy.

Of the single equation models currently in use, the basic monetary model (or, more generally, the asset market model) is particularly attractive as a basis for empirical investigation because its assumptions of the validity of the Purchasing Power Parity and Interest Rate Parity doctrines, as well as the existence of stable money demand functions lead to a specification of the exchange market that is simple in both concept and estimation.

This paper evaluates the empirical validity of a particular variant of the monetary model for the U.S. dollar exchange rates of ten industrial countries (Group of Ten -- excluding the U.S. -- plus Switzerland), and the performance of a modified Purchasing Power Parity

model for the same group of countries. Its main purpose is to test particular hypotheses of empirical regularity between exchange rates and certain specified economic variables in an attempt to ascertain whether, for a diverse group of currencies, the monetary and Purchasing Power Parity models obtain results consistent with current beliefs on the speed of adjustment of the exchange rate and with previous studies on the demand for money -- its purpose is not to provide elaborate discourses on the market behavior of individual currencies.

Section II of this paper provides a brief review of recent advances in the theory of flexible exchange rates. This is followed by Section III which focuses on Purchasing Power Parity and alternative measures for the relative price components of the ten exchange rates selected for study. Section IV lays out and estimates a simple monetary model and a short-run Purchasing Power Parity model for the ten exchange rates and, finally, Section V provides a summary and conclusions.

II. REVIEW OF RECENT DEVELOPMENTS

"Why have floating rates behaved differently from the way we were promised?"¹

A. INTRODUCTION

The current experience of floating exchange rates among the major currencies has led to a careful reappraisal of prevailing theories of exchange rate determination. Traditional theory after World War II² focused primarily on flow equilibrium in goods markets, equating the demand for foreign exchange with domestic expenditure on imports and the supply with foreign expenditure on domestic exports. Such emphasis on goods market equilibrium asserted an accommodating adjustment in the capital account via either interest-induced or politically controlled capital flows. As Lindbeck³

1. Comment by Robert Aliber during general discussion on "Flexible Exchange Rates and Stabilization Policy," Stockholm, August 26-27, 1975.

2. Prior to World War II, it was generally believed that long-term capital movements were determined by differing rates of return on physical assets and that the current account adjusted to the predetermined capital account through changes in relative prices, income and exchange rates.

3. Assar Lindbeck, "Approaches to Exchange Rate Analysis -- An Introduction," The Scandinavian Journal of Economics, Vol. 78, No. 2, (1976), pp. 133-145.

points out, however, it is important to remember that this theory was spawned in an era of strictly controlled capital flows, largely inconvertible currencies, and perhaps most important (for contrast with the current literature), stocks of foreign financial assets that were very small relative to the magnitude of trade flows.

Recent contributions to the theory of exchange rate determination continue to view the adjustment to equilibrium in goods markets as the dominant force influencing the exchange rate in the long run, yet stress the analytical advantage of focussing on the supply and demand for stocks of financial assets denominated in various currencies when discussing exchange rate behavior in the short run.

B. PURCHASING POWER PARITY

The long-run analysis is almost invariably couched in terms of relative Purchasing Power Parity (PPP), perhaps the most often resurrected model of exchange rate determination. Largely because of its

analytical simplicity, PPP has enjoyed several periods of renewed interest, recurrent criticism, and eventual desuetude, a feature suggesting at least a historical consensus that "the useful insights we derive from theoretical structures are inversely related to their complexity."⁴ Simply stated, the main tenet of relative PPP theory is that if all countries produce the same goods, if all goods are tradable, and if there is free trade, the law of one price will prevail to ensure that goods arbitrage equates the relative price levels of any two countries with their currencies' exchange rate.⁵ As interpreted by Holmes⁶ and elaborated by

4. Comment by Rudiger Dornbusch during general discussion at Stockholm conference on "Flexible Exchange Rates and Stabilization Policy," August 26-27, 1975. For a comprehensive review of the theory of PPP see Lawrence H. Officer, "The Purchasing-Power-Parity Theory of Exchange Rates: A Review Article," IMF, Staff Papers, Vol. 23, No. 1, (March 1976), pp. 1-60.

5. The PPP rate is usually defined as the product of the actual exchange rate (in a base period when it is "equal" to PPP) and the relative price ratio (set equal to "1" at the base date).

6. J. M. Holmes, "The Purchasing Power Parity Theory: In Defense of Gustav Cassel as a Modern Theorist," Journal of Political Economy, Vol. 75, No. 5, (October 1967), pp. 686-695.

Knight⁷ a supplementary proposition of PPP is that the relationship between the nominal money supply and real money demand is the principal determinant of each country's domestic price level. Knight observes that Cassel's theory of exchange rates, if viewed in this light, depends not only on the 'law of one price' but also on a proposition fundamental to all modern monetary theory -- the long-run neutrality of money.

Despite its continued popularity as a theory of exchange rate determination, there exist no convincing empirical analyses to support the contention that causality runs uniquely from relative price changes to changes in the exchange rate. Indeed, a recent study by Brillembourg⁸ dismisses the causal interpretation of PPP in favor of an equilibrium view. Under this view, exchange rates and prices are seen to be determined simultaneously in a general equilibrium

7. Malcolm Knight, "Output, Prices and the Floating Exchange Rate in Canada: A Monetary Approach," (Unpublished, IMF, December 1976).

8. Arturo Brillembourg, "Purchasing Power Parity Tests of Causality and Equilibrium," (Unpublished, IMF, December 1976).

context. Brillembourg contends that if we accept the equilibrium interpretation of PPP, and also accept that PPP is not the major determinant of the short-run exchange rate, that further effort might concentrate on investigating the "other influences" affecting short-run adjustment.

C. THE ASSET MARKET APPROACH

The Asset Market Approach (AMA), as the short-run behavioral analysis has come to be known, stresses the importance of the supply and demand for existing stocks of financial assets as the principal factor influencing short-term exchange rate variability. The AMA is relevant for countries that have well-developed financial markets and, in a limiting sense, only for those whose markets are not characterized by excessive controls on international financial transactions. A major advantage of the AMA is its more realistic treatment of the importance of financial markets and deemphasis of the role of goods markets in the short-run adjustment process:

New unexpected financial developments leading to desired portfolio readjustments occur continuously, and they may at times cause sharp exchange rate changes. In

contrast, changes in current account positions (apart from their effect on expectations) play a more subdued role in the short run, both because prices in goods markets usually change more gradually, and because longer lags operate in the adjustment of trade and invisible flows to price changes. Also, expectational factors play a more limited role in determining trade and service flows. Thus, over any short period the potential demand for a currency resulting from changes in desired stocks of financial assets will be large relative to the flow demand arising from current balance-of-payments transactions and will be more important in determining the short-run equilibrium value of the exchange rate.⁹

Both Frenkel¹⁰ and Myhrman¹¹ trace the major building blocks of the AMA back at least one hundred years, characterizing its current emergence more as an

9. Jacques R. Artus and Andrew D. Crockett, Floating Exchange Rates and the Need for Surveillance, Princeton Essays in International Finance, No. 127, (New Jersey: Princeton University, May 1978).

10. Jacob Frenkel, "A Monetary Approach to the Exchange Rate: Doctrinal Aspects and Empirical Evidence," The Economics of Exchange Rates: Selected Studies, eds. Jacob A. Frenkel and Harry G. Johnson, (Reading, Mass.: Addison-Wesley Publishing Co., 1978), pp. 1-25.

11. Johan Myhrman, "Experiences of Flexible Exchange Rates in Earlier Periods: Theories, Evidence and a New View," The Scandinavian Journal of Economics, Vol. 78, No. 2, (1976), pp. 169-196.

evolutionary growth of theory accommodating the shortcomings of traditional analysis rather than as a revolutionary change of views. Frenkel even points out that Cassel's original formulation of PPP was in terms of relative quantities of money rather than relative price levels. There is a fundamental difference, however, between the classical proponents of a monetary view on the one hand, and modern writers on the other. The classical authors stress the indirect effects of monetary changes on the exchange rate through their impact on domestic commodity prices.

In contrast, current literature focuses on the direct effects of these changes on both the exchange rate and the balance of payments. Thus, while classical writers trace the impact of an excessive increase in the growth rate of the money supply through its effect on domestic prices which in turn influence the exchange rate via relative price adjustments, current writers see the excess money balances immediately spilling over into either the current account as an excess demand for commodities, or the capital account as an excess demand for financial assets. This latter approach is based on an analytical formulation wherein the foreign asset and

commodity prices for any single country are parametrically given, implying that at least in the short run, a country may not be able to effectively insulate itself from external developments simply by floating its exchange rate.¹²

There are essentially two strands of literature on the AMA -- one emphasizing general portfolio balance and the other focusing solely on the demand for and supply of money. The latter can be viewed as both a pedagogical and empirical simplification of the former. A few of the basic propositions of the AMA are:

1. The existing stock of securities held domestically can only change, with time, by net flows of savings.
2. The amount of domestically held foreign exchange can only be changed (net), with time, by trade and/or service flows.¹³

12. This theme is explored theoretically by Rudiger Dornbusch, "The Theory of Flexible Exchange Rate Regimes and Monetary Policy," The Economics of Exchange Rates: Selected Studies, eds. Jacob A. Frenkel and Harry G. Johnson, pp. 27-46, and Donald J. Mathieson, "Monetary Interdependence Under Flexible Exchange Rates," (Unpublished, IMF, March 1976). In these works, much consideration is given to the role of expectations.

13. This follows from the observation that (theoretically) under freely floating exchange rates, movements in international reserves and corresponding changes in the foreign component of the monetary base are zero.

3. The capital account must balance the predetermined current account, therefore the existing stocks of financial assets must be held.

A feature of the AMA not yet touched on is the special role played by expectations in determining the exchange rate in the short run. The demand for any type of financial instrument is naturally dependent, in part, on the expected yield to be gained from holding it. Thus, it should be expected that if both domestic and foreign securities (or money) are potential portfolio investments, the current exchange rate must incorporate, to some degree, the expectations of market participants.

A succinct statement of the AMA is provided in the previously cited work by Artus and Crockett.¹⁴ To paraphrase them, the demand for financial assets denominated in the currency of a given country is assumed to be determined by their expected yield relative to the expected yield on assets of other currency denominations. Relative yield expectations reflect both the interest rate differentials and expected exchange rate changes. The change in demand

14. Jacques R. Artus and Andrew D. Crockett, op. cit., pp. 4-5.

during a given period is the (net) private capital flow, and must equal, ex post, the residual sum from current account transactions, official capital flows, and (net) official exchange market intervention. Expectations, which play such a leading role in short-run portfolio analysis, are nevertheless significantly influenced by the potential balance of payments disequilibria represented by changing relative prices in the goods markets, and even though such disequilibrating flows may be small relative to existing stocks of financial assets during some short time span, they can eventually lead to a significant disequilibrium in stocks. Hence, to avoid possible exchange losses, exchange market participants will try to maintain an exchange rate that they believe will sustain some level of current account balance -- a rate presumably dictated (or at least suggested) by PPP theory.

D. REVIEW OF PAST AND PRESENT MODELS

As mentioned earlier, the AMA was developed primarily to account for exchange rate fluctuations that could not be explained solely by factors affecting flow equilibrium in the goods markets. Typically, papers using this approach supplement their analysis with Purchasing Power Parity and provide some sort of adjustment mechanism so that the exchange rate will tend -- over time -- to approximate the equilibrium suggested by relative PPP.

In the papers of Dornbusch¹⁵ and Mathieson,¹⁶ portfolio shifts are allowed to exert short-term influence on an exchange rate otherwise determined by PPP. Figure 1 illustrates the short-term adjustment path of these papers as (a)-(f)-(h)-(j), and the underlying equilibrium trend is implicitly defined by path (b)-(i)-(j). Both of these papers stress that flexible exchange rates do not provide complete insulation from

15. Dornbusch, "Theory of Flexible Exchange Rate Regimes," op. cit.

16. Mathieson, "Monetary Interdependence," op. cit.

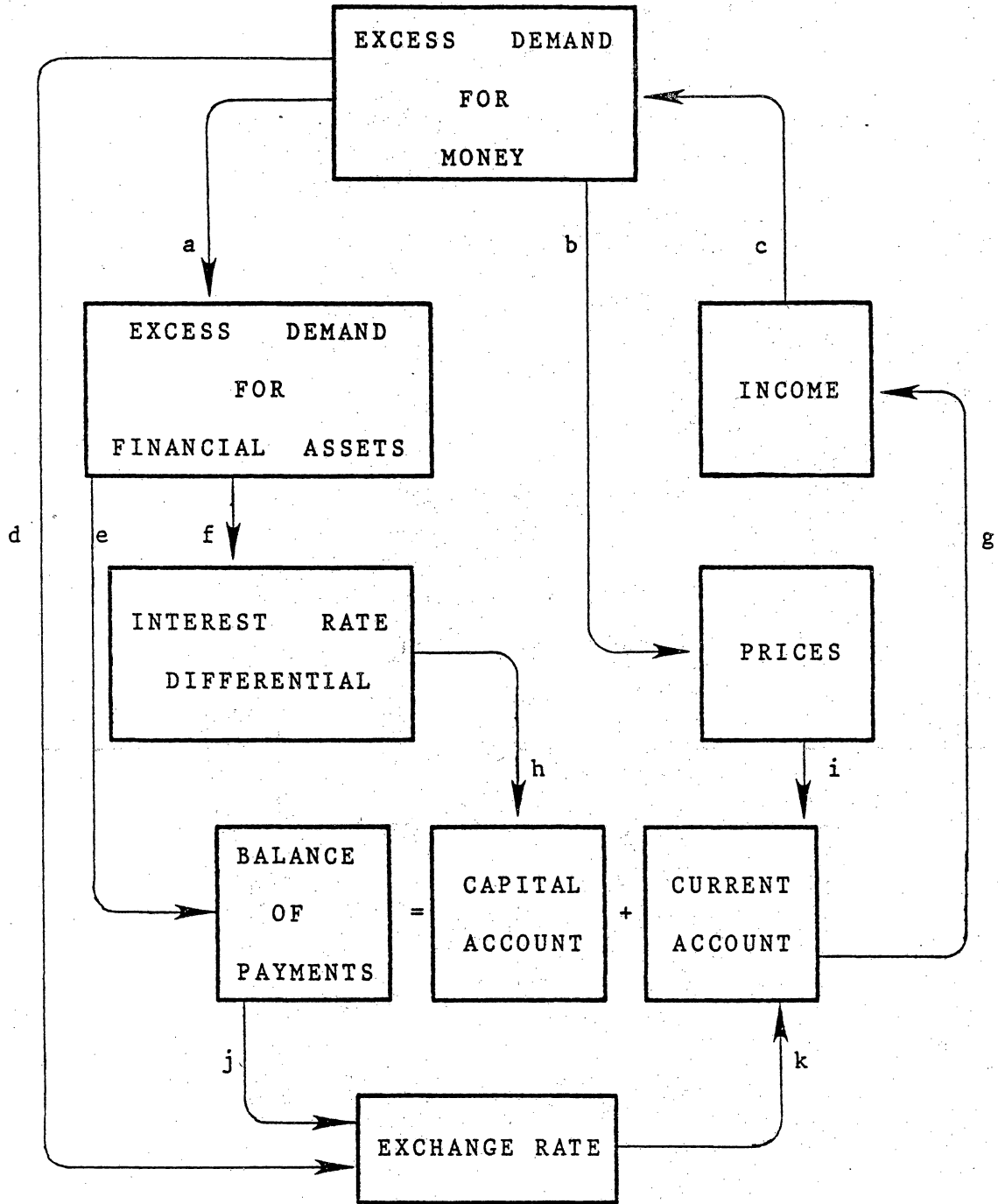


FIGURE 1

Paths of Exchange Rate Adjustment

foreign monetary disturbances so long as prices and/or expectations are slow to adjust in the short run. Furthermore, Dornbusch departs from the traditional Keynesian approach (that maintains all goods are traded and economies specialize in production) and distinguishes between "traded" and "non-traded" goods, thereby obviating the need to identify the exchange rate with the terms of trade. Although Isard¹⁷ also follows an (a)-(f)-(h)-(j) approach, he provides for an interaction over time between the exchange rate and wealth depending on the extent to which funds in domestic asset portfolios are allocated to foreign financial instruments. Wealth enters into the analysis of the models of Kouri¹⁸ and Genberg and Kierzkowski¹⁹

17. Peter Isard, Exchange-Rate Determination: A Survey of Popular Views and Recent Models, Princeton Studies in International Finance, No. 42. (New Jersey: Princeton University, May 1978).

18. Pentti J. K. Kouri, "The Exchange Rate and the Balance of Payments in the Short Run and in the Long Run: A Monetary Approach," The Scandinavian Journal of Economics, Vol. 78, No. 2, (1976) pp. 280-304.

19. Hans Genberg and Henryk Kierzkowski, Short Run, Long Run, and Dynamics of Adjustment Under Flexible Exchange Rates, (Geneva: Graduate Institute of International Studies, 1975).

in another vein. In these studies the adjustment follows the recursive loop (a)-(e)-(j)-(k)-(g). The exchange rate is determined in the assets market (given the stock of wealth and the supply of assets denominated in various currencies). The exchange rate then affects the current account, which in turn (through its repercussions on income, prices and wealth) influences the exchange rate. The Genberg-Kierzkowski model goes further by offering an analysis of shifts in production between traded and non-traded goods following exchange rate changes.

In his empirical investigation of the Deutsche Mark/Pound Sterling rate, Bilson²⁰ blends the major links of paths (c)-(a)-(f)-(h)-(j) and (b)-(i)-(j) into one estimating equation that combines relative money demand functions with a partial adjustment mechanism that provides for the adjustment of the actual exchange rate to the "equilibrium" rate.

20. John F.O. Bilson, "The Monetary Approach to the Exchange Rate: Some Empirical Evidence," Staff Papers, Vol. 25, No. 1, (March 1978), pp. 48-75.

Bigman²¹ explains the short-run variation of the Pound Sterling/U.S. dollar rate with an estimating equation incorporating paths (f)-(h)-(j) and (i)-(j) in conjunction with two inflation expectations hypotheses, using the effective²² exchange rate and the actual exchange rate as alternative response variables.²³

Frenkel greatly simplifies his investigation by directly linking money and the exchange rate, (d). This rudimentary specification is well-suited to his subject of the German hyperinflation in the early 1920's. He feels that the "...episode is of special interest since it provides an opportunity to examine the assets approach to a situation in which it is clear that the

21. David Bigman, "Exchange Rate Determination in the Short-Run," (Unpublished, IMF, May 1978).

22. The weights used for deriving the effective rate in Bigman's paper were taken from the IMF Multilateral Exchange Rate Model (MERM). For information on MERM see Jacques R. Artus and Rudolph R. Rhomberg, "A Multilateral Exchange Rate Model," Staff Papers, Vol. 20, No. 3, (November 1973), pp. 591-611, and Rudolf R. Rhomberg, "Indices of Effective Exchange Rates," IMF, Staff Papers, Vol. 23, No. 1, (March 1976), pp. 88-112, especially Appendix I, p. 103.

23. Bilson, op. cit., pp. 62-63, also estimates a short-run PPP model, which we will discuss in Section IV, below.

source of disturbances is monetary."²⁴ In another paper, Frenkel and Clements,²⁵ like Bilson, employ a model incorporating paths (c)-(a)-(f)-(h)-(j) and (b)-(i)-(j), although in implicitly assuming a sufficiently rapid adjustment of the actual exchange rate to its equilibrium level, they find it unnecessary to apply the partial adjustment hypothesis.

Finally, Suss²⁶ stresses that for the current period of flexible exchange rates the monetary model is more appropriately cast within the context of managed floating. Beginning with the basic Bilson-Frenkel-Clements structure, she extends the model to allow for the effect of reserve changes on the exchange rate, and she simultaneously determines the exchange rate, the level of reserves, and the change in the interest rate differential.

24. Frenkel, op. cit., p. 205.

25. Jacob A. Frenkel and Kenneth W. Clements, "Exchange Rates in the 1920's: A Monetary Approach," NBER Working Paper Series, National Bureau of Economic Research, No. 290, October 1978.

26. Esther Suss, "A Short-Run Model of the Trade-Off Between Exchange Rate and Reserve Changes," (mimeographed, IMF, forthcoming).

Perhaps the current literature can best be placed in the proper perspective by comparing it with what came before. Classical writers, (primarily Cassel, Hume and Ricardo) were concerned almost exclusively with the loop (b)-(i)-(j)-(k)-(g), although some studies began with a change in the capital account precipitated by some exogenous stimulus.²⁷ Later studies dating from the end of World War II started on one hand by analyzing the effects of changes in income on the current account (via the propensity to import) and on the other by investigating the impact of interest rate changes on the capital account (via interest rate parity). These are illustrated by paths (f)-(j) and (h)-(j), respectively.

The preceding paragraphs by no means offer an exhaustive review of current literature. They primarily serve to highlight a few contributions, some of which provide the foundation for the models we will develop in Section IV.

27. Lindbeck, op. cit., p. 140, mentions two such stimuli: war reparations and a change in the relative return on physical assets.

In the following section we will review the alternative measures of PPP that will subsequently be used in the empirical testing of our modified PPP model.

III. MEASUREMENT OF PURCHASING POWER PARITY

A. INITIAL CONSIDERATIONS

In his review article, Lawrence Officer²⁸ concluded that the principal limitations of PPP theory fall into three categories: 1) PPP is subject to random error in its predictions; 2) PPP calculations may be subject to systematic bias, over time, as a measure of the equilibrium exchange rate, and 3) other variables may play an important role in exchange rate determination.

It is probably safe to say that most economic theories are afflicted with the first weakness. As for the second, upon exploring the empirical basis of one theoretically potent bias Officer concluded (in another article) that:

On balance, the productivity bias does not survive empirical tests of its existence... What are the implications for the validity of the PPP theory of exchange rates? An alleged powerful bias -- one

28. Officer, "Review," op. cit., pp. 51-52.

that overwhelmed the theory and constrained its applicability -- has been shown to have little empirical foundation.²⁹

In the present study we will assume that systematic bias, of any type, is not a subject for undue concern, not only due to Officer's findings on the productivity bias, but also because we will be looking at a time period of sufficiently short length to ensure

29. Lawrence H. Officer, "The Productivity Bias in Purchasing Power Parity: An Econometric Investigation," IMF, Staff Papers, Vol. 23, No. 3, (November 1976), p. 575. The analytic argument in favor of the productivity bias is summarized by Officer in his "Review" article, pp. 18-19 as follows:

"A high-income country is more productive technologically than a low-income country; but the efficiency advantage of the former country is not uniform over all industries. Rather, it is greater for traded goods... than for non-traded goods... prices of traded goods are equalized across countries (abstracting from trade restrictions and transport costs); but this is not so for non-traded goods. With the wage rate higher in the more productive (higher-income) country and with wages equalized domestically across all industries, the internal price ratio must be higher in the higher-income country. The prices of non-traded goods... are not directly relevant for balance of payments equilibrium. Therefore, a price parity calculated from general price levels yields an exchange value of the high-income country's currency that is lower than its true long-run equilibrium value, and this systematic bias increases with the overall productivity difference... between the countries involved."

that any potential bias is not allowed ample time to develop a serious magnitude.

The concern that other variables may play an important role in exchange rate determination can be largely mollified by a generous blending of PPP theory with other lines of analysis, a subject which we will touch upon in Section IV.

In addition to the above-mentioned theoretical reservations, there are two subsidiary problems that normally need to be addressed before an actual "calculation" of PPP series is undertaken: 1) the choice of a base period; and 2) the selection of relevant price indices. The selection of an appropriate base period -- a point in time when PPP is equal to the exchange rate -- is primarily important only in studies attempting to assess the "overvaluation" or "undervaluation" of the exchange rate at specific points in time. Since our analysis will not be concerned with this subject, but rather with the movement of the exchange rate relative to the movement of PPP, a base period need not be defined, per se, for its only effect would be to set the value of the intercept term in an estimating equation. Theoretically, given the relative PPP equation in its

most basic form, the intercept should not differ significantly from "0."

Extreme views on the selection of appropriate price indices are 1) the prices should relate to traded goods, only and 2) they should pertain to the broadest spectrum of commodities. While proponents of traded goods indices emphasize the role of commodity arbitrage, advocates of general price indices stress the importance of asset market equilibrium in the determination of exchange rates. Recent theoretical literature focuses on the traded goods index and analyzes asset market implications (as well as the implications of internal differential price changes) separately. This approach, while holding that conditions in asset markets play a major role in exchange rate fluctuations, maintains that relative price changes of (only those) goods actually entering the international market are important in assessing the long-term development of the exchange rate.³⁰

30. The attitude expressed by focusing on the prices of only traded goods is implicit in an observat-

Our investigation will focus on three different price indices as potential measures of PPP: the indices of consumer prices (CP), wholesale prices (WP), and export prices (EP). Of these, CP is the broadest measure, usually incorporating the costs of both goods and services -- not all of which reasonably can be expected to be traded internationally, regardless of exchange rate developments over time. The second, WP, has come under attack because its formulation appears unable to preclude the measurement of any given commodity's price at several stages of the production process. Although the degree of error imparted by such double counting is difficult to ascertain, it is nevertheless significant enough to beg the question as to what well-defined sectors of the economy WP is representing in a value-added sense at any point in time. EP offers an approximation of a traded goods index, although "traded goods" refers to a different

30. (continued) -ion made several years ago by Paul Samuelson: "Patently, I cannot import cheap Italian haircuts nor can Niagara-Falls honeymoons be exported." (Paul Samuelson, "Theoretical Notes on Trade Problems," Review of Economics and Statistics, Vol 46, No. 2, (1964), p. 148.)

basket of commodities for each country. A comprehensive look at the comparative merits of alternative price indices can be found in an excellent review article by Goldstein and Officer.³¹ Doctrinal and further analytical aspects of competing indices are covered by Frenkel³² and Artus,³³ respectively. The reader is referred to these papers for supplemental discussion.

B. MEASUREMENT AND COMPARISON

Our prospective measures of PPP are simple ratios of the price data discussed above. Leaving aside the question as to whether PPP might more appropriately be specified as a distributed lag model, we calculate monthly PPP series as direct ratios of their respective monthly price components. Furthermore, we restrict

31. Morris Goldstein and Lawrence H. Officer, "The Tradeable/Nontradable Dichotomy: A Review of the Literature and Suggested New Measures," (Unpublished, IMF, July 1977).

32. Frenkel, "A Monetary Approach to the Exchange Rate: Doctrinal Aspects and Empirical Evidence," op. cit.

33. Jacques R. Artus, "Methods of Assessing the Longer-Run Equilibrium Value of an Exchange Rate," Finance and Development, Vol. 15, No. 2, (June 1978), pp. 26-28.

ourselves to bilateral price ratios rather than composite ratios based on weighted averages of a country's major trading partners. This approach, although implicitly assuming that third-country disturbances affect partner countries homologically, is nevertheless intuitively appealing in that it clearly defines the exchange rate between two currencies in terms of prices in their respective monetary areas.

Figure 2 provides a visual track of how closely the alternative measures of PPP approximate the actual exchange rate. The charts are semi-logarithmic and each series crosses the base line (100) at March 1973.

Under the null hypothesis that the "distribution" of relative prices illustrated in Figure 2 agrees with the "distribution" of exchange rates over the sample period, we employ the Chi-square goodness-of-fit test to arrive at the results given in Table I. Since the critical value of Chi-square with 63 degrees of freedom and a 5 percent risk of a Type I error is greater than 80, we are unable to reject the null hypothesis on the basis of this (crude) test, alone.

In addition to illustrating the closeness in trend of exchange rate and relative price series, Figure

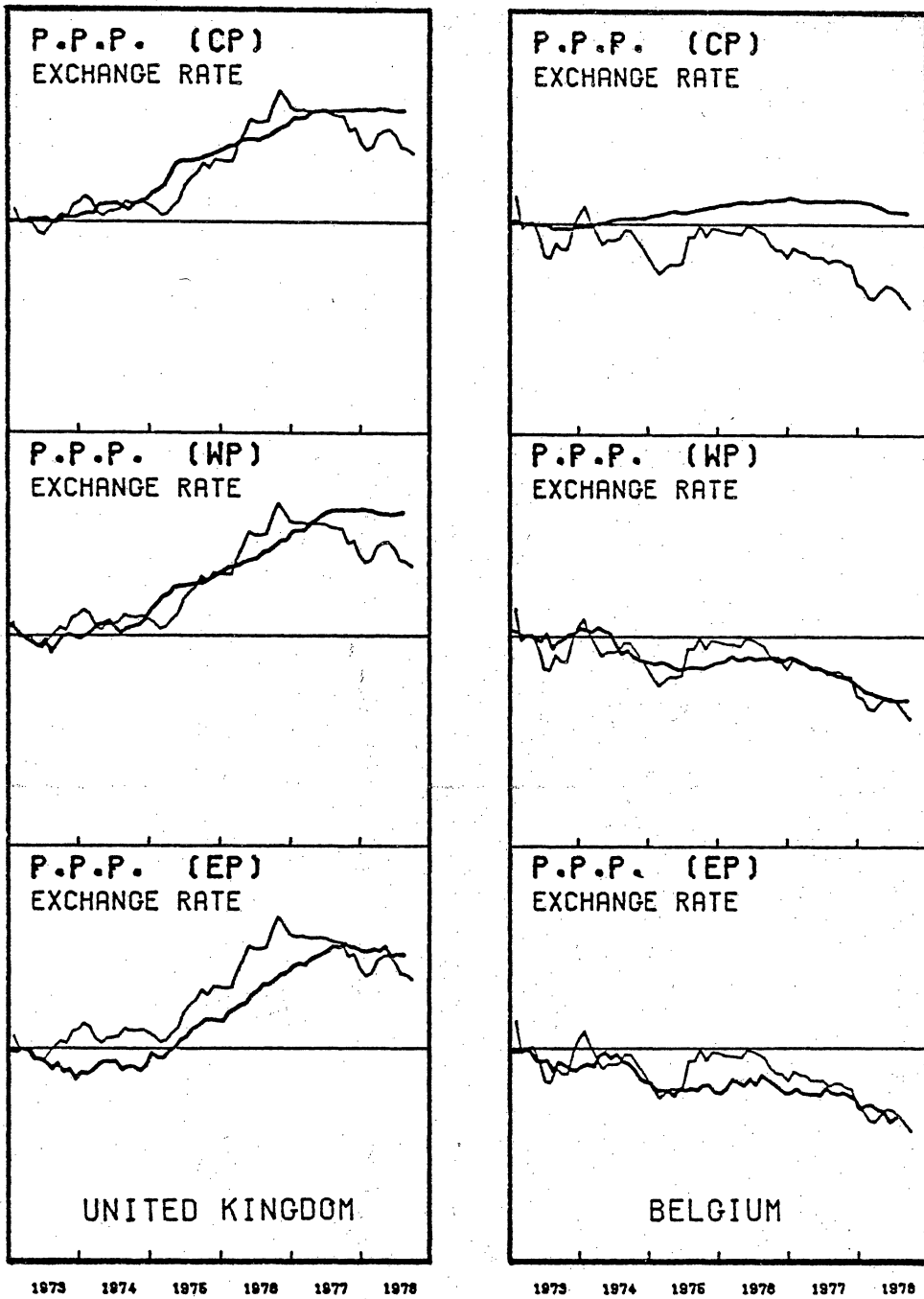


FIGURE 2

Measures of Purchasing Power Parity

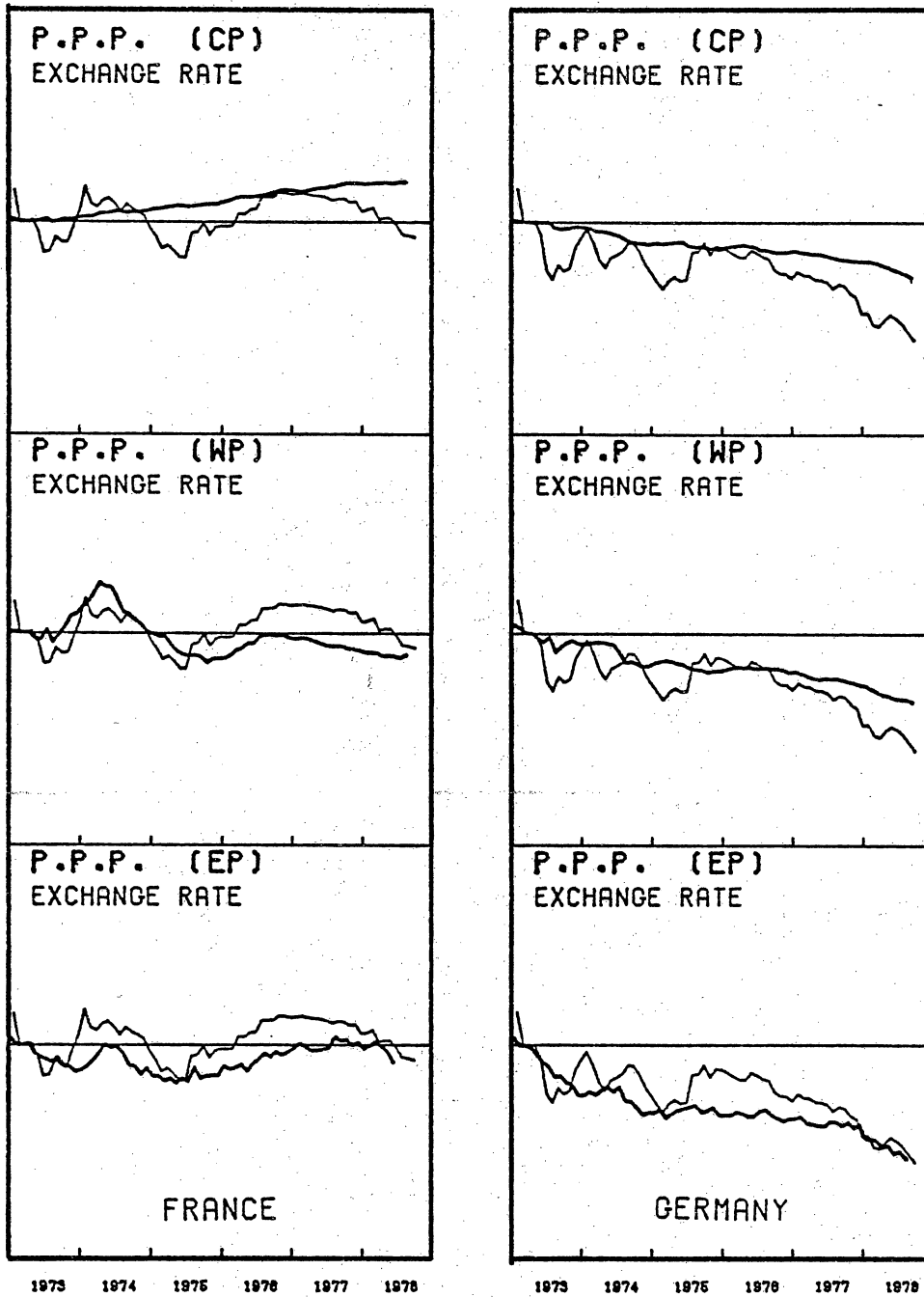


FIGURE 2 - Continued

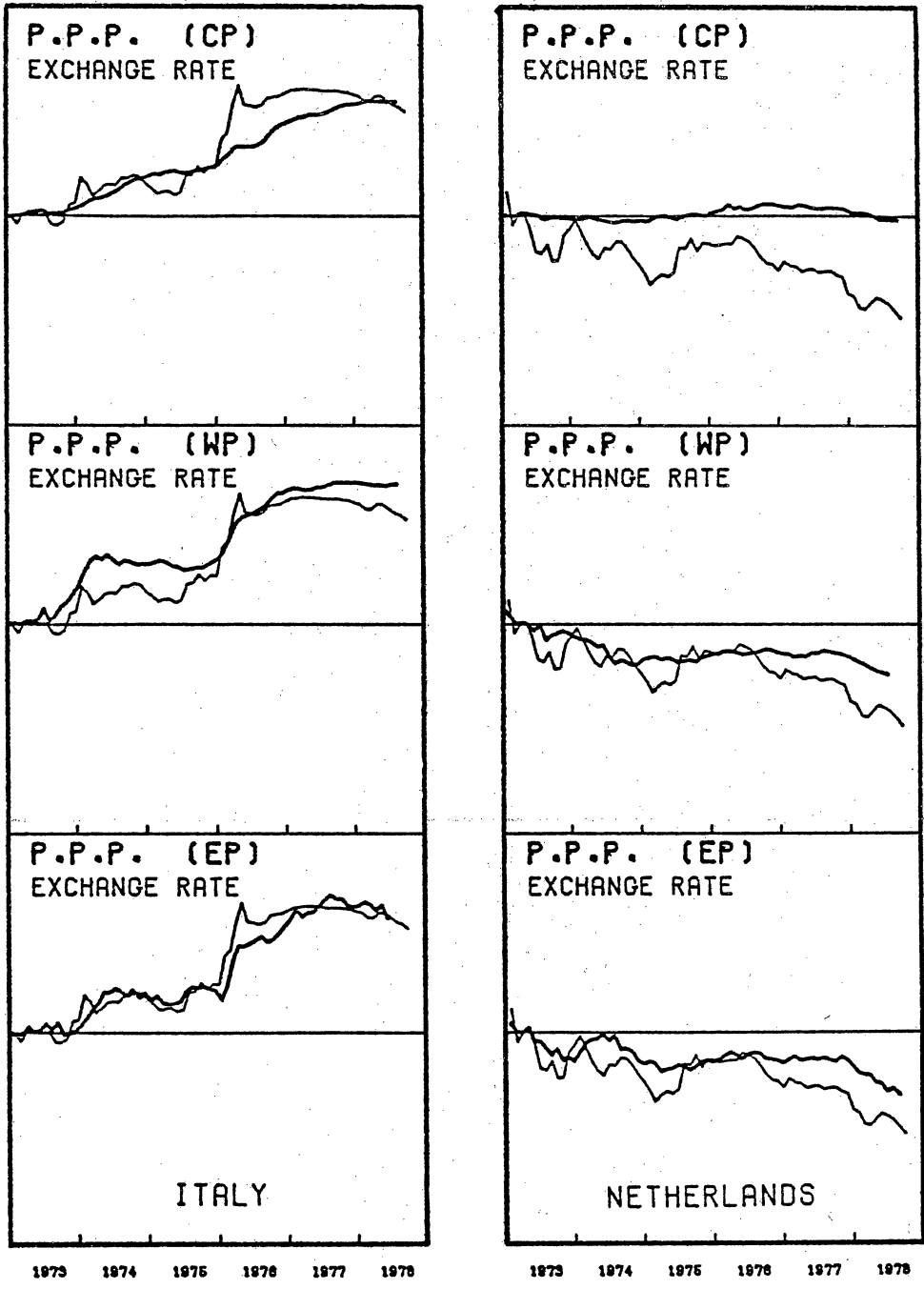


FIGURE 2 - Continued

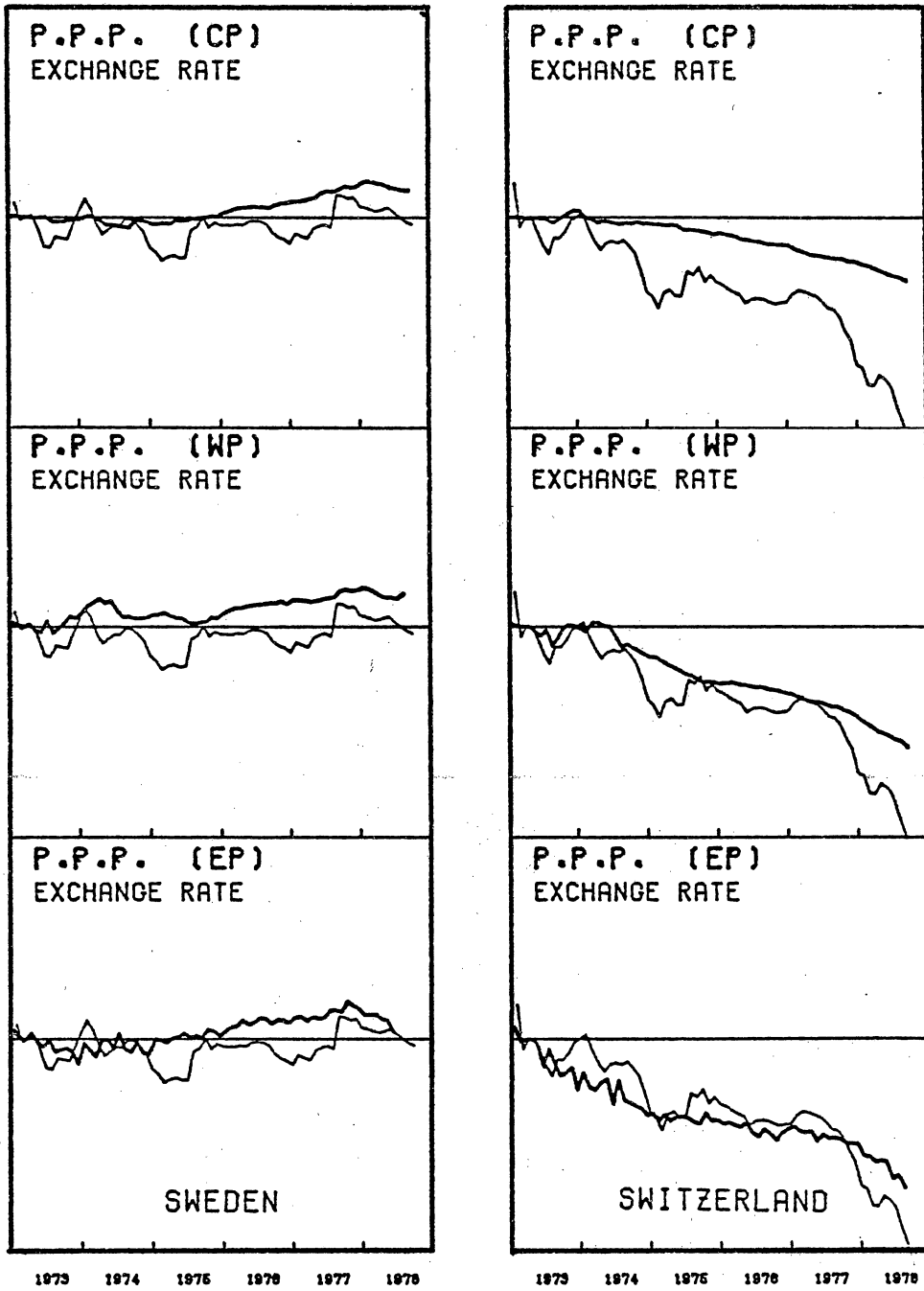


FIGURE 2 - Continued

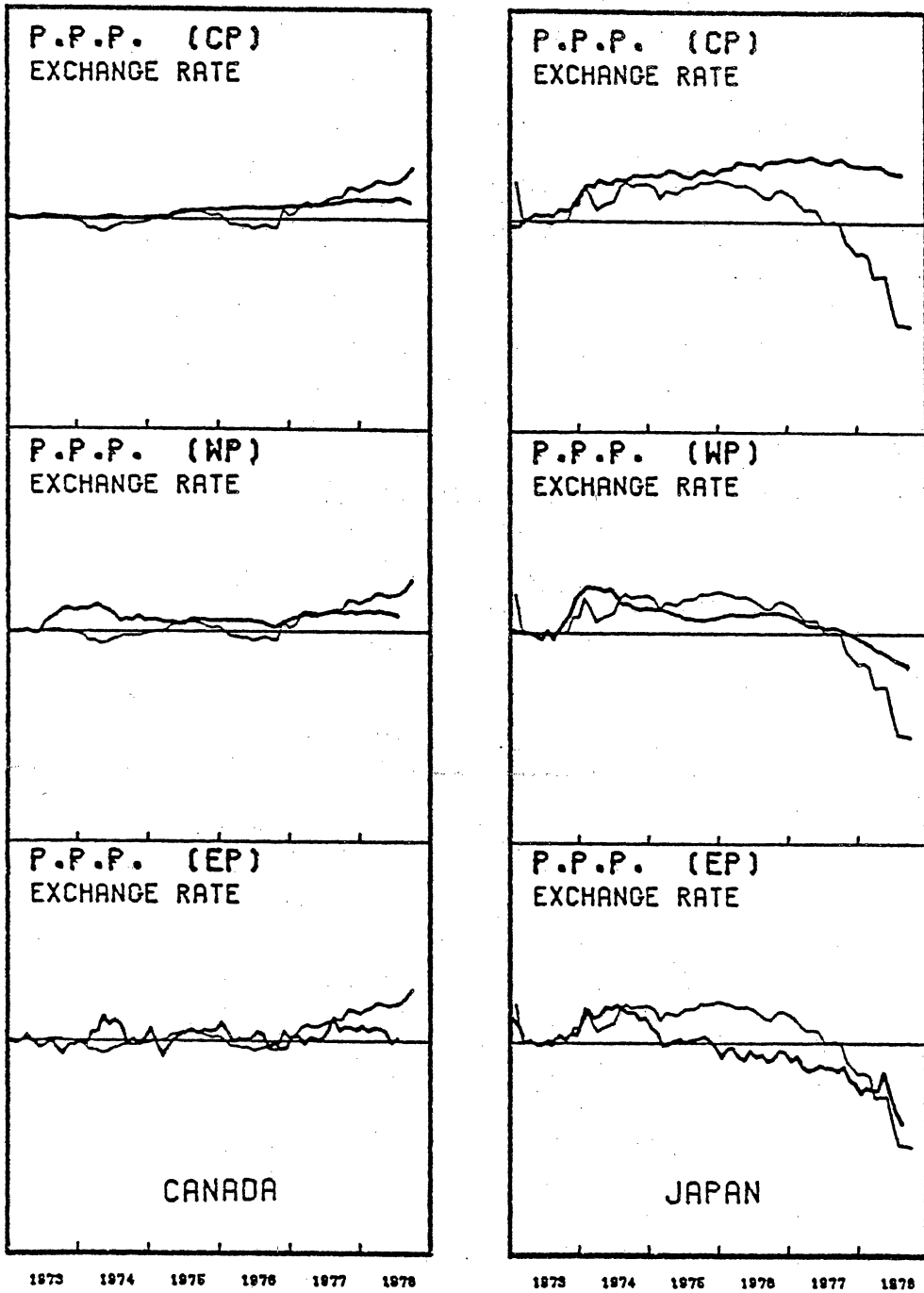


FIGURE 2 - Continued

TABLE I

Goodness-of-Fit (Chi-square) Values for Alternative
Measures of PPP against the Exchange Rate
(March 1973 through June 1978)

Country	Measures of Purchasing Power Parity		
	(CP)	(EP)	(WP)
United Kingdom.....	.98	3.09	1.36
Belgium.....	6.56	1.10	.67
France.....	1.54	2.01	1.95
Germany.....	2.74	1.90	1.58
Italy.....	1.53	.73	1.44
Netherlands.....	8.11	1.80	1.71
Sweden.....	1.53	1.86	2.93
Switzerland.....	11.06	1.72	2.81
Canada.....	.32	.65	.80
Japan.....	6.55	2.56	1.16

2 highlights one of the foremost problems connected with applying unaugmented PPP theory to the current period of flexible exchange rates. Relative price ratios invariably show substantially less variability than do exchange rates. This, coupled with the fact that the two series often display a relatively low measure of covariance, tends to seriously undermine the explanatory power of relative prices as sole determinants of the exchange rate (in the short run).

Artus and Crockett offer a more specific illustration of this phenomenon in their charts (for seven of the countries included in the present study) showing deviations of exchange rates and relative consumer price indices from their respective thirteen-month centered moving averages, concluding that: "During the first few years of floating exchange rates among the major industrialized countries, short-run exchange rate movements have been far greater than the corresponding movements in domestic price levels."

34. Artus and Crockett, *Floating Exchange Rates and the Need for Surveillance*, *op. cit.*, pp. 3-4.

In consideration of the above, the general proclivity of current literature, and the evidence presented by Brillembourg,³⁵ we will proceed under the assumption that PPP represents the long-run equilibrium exchange rate, and formulate our monetary and PPP models, accordingly.

35. Brillembourg, "Purchasing Power Parity Tests of Causality and Equilibrium," op. cit., pp. 10-14.

IV. ALTERNATIVE EXCHANGE RATE MODELS

Calculate a time series of relative PPP during a period when the exchange rate is floating and compare it with the corresponding time series of the floating rate. PPP theory asserts that there is a tendency for the short-run equilibrium exchange rate, that is, a freely floating rate, to equal the PPP. Noticeable divergences between the actual rate and PPP are then explained in terms of other influences on the rate.³⁶

A. BASIC MONETARY MODEL

The model we are about to lay out is labelled "monetary" because it selects money from the wide spectrum of financial assets addressed in the Assets Market Approach and places the money market in the "center of analysis."³⁷ Furthermore, it assumes the

36. Officer, "Review," op.cit., p. 39.

37. Rudiger Dornbusch, "General Discussion: What Have We Learned? Where are the Fundamental Conflicts of Opinion?" ed. Lars Calmfors and Clas Wihlborg, The Scandinavian Journal of Economics, Vol. 78, No. 2, (1976), p. 389. Dornbusch's perspective on the apparent agreement shown during the Stockholm conference is summarized under four points:

"(1) In principle the exchange rate is determined by the general equilibrium, stock and flow, of the relevant model.

(2) Specifically, asset markets are important.

(3) Among the asset markets it is unobjectionable to single out the money market as the center of analysis.

(4) Independent of school of thought, capital mobility and expectations are of critical importance in the determination of exchange rates."

validity of the PPP doctrine as well as the existence of stable money demand functions for each of the countries in our study. The latter assumption is carried over from the monetary approach to the balance of payments,³⁸ and is the heart of our model.

We begin by assuming that the correct specification of the demand for money in country 1 is given by an adaptation of the Cagan³⁹ functional form:

$$(1) \quad M_1 / P_1 = k e^{(-a_1) y_1} b_1$$

where "M" is the index of the money supply, "P" is the index of the price level, "y" is the index of real

38. For a sampling of the literature see The Monetary Approach to the Balance of Payments, International Monetary Fund, Washington, D.C., 1977, and The Monetary Approach to the Balance of Payments, eds. Jacob A. Frenkel and Harry G. Johnson, University of Toronto Press, Toronto, 1976.

39. Philip Cagan, "The Monetary Dynamics of Hyperinflation," Studies in the Quantity Theory of Money, ed. Milton Friedman, pp. 25-117, especially pp. 27-35. The Cagan functional form has served (either explicitly or implicitly) as the foundation for many recent contributions on exchange rates, including the previously cited works by Bilson, Frenkel and Clements, and Suss.

income (for which we will substitute the index of industrial production as a proxy), "b" is the income elasticity of demand for money, "i" is the rate of interest, and "a," "c," and "k" are parameters.

As real income increases, individuals will not only need larger balances to conveniently meet transactions requirements, but will also be more willing to forego part of the interest they might earn by holding wealth in the form of relatively illiquid assets. As the rate of interest rises, individuals will tend to substitute interest-earning assets for part of their cash balances.

Thus the demand for real cash balances changes in the same direction as real income, and the opposite direction to changes in returns on financial assets. Solving (1) for P, we get:

$$(2) \quad P = M \frac{k^{-1} (ai)^{-1} e^{-1} y^{-b}}{1 \quad 1 \quad 1 \quad 1}$$

If we next assume that country 2 has an identical money demand function, and invoke PPP:

$$(3) \quad ER^* = P_1 / P_2$$

Upon dividing equation (2) by its counterpart for country 2 we arrive at the solution for the long-run equilibrium exchange rate (ER*):

$$(4) \quad ER^* = \left(\frac{M_1}{M_2} \right) k_1^{-1} e^{a(i_1 - i_2)} \left(\frac{y_1}{y_2} \right)^{-b}$$

Expressing (4) in log-linear form, we get:

$$(5) \quad \log ER^* = -\log\left(\frac{k_1}{k_2}\right) + \log\left(\frac{M_1}{M_2}\right) - b[\log\left(\frac{y_1}{y_2}\right)] \\ + a(i_1 - i_2)$$

The "shift factor,"⁴⁰ is specified to allow for an exogenous trend in the relative demand for the two currencies:

$$(6) \quad \log\left(\frac{k_1}{k_2}\right) = k + dt$$

40. Adopted from Bilson, op. cit., p. 55.

where "t" is a simple time trend, "k" is a constant, and "d" is the relative rate of growth in money demand. Hence, an exogenous trend increase in the demand for Deutsche marks relative to U.S. dollars would produce a negative coefficient for "t" in the exchange rate equation for Germany.

We next draw on interest parity theory to express the interest rate differential as the forward premium (or discount) on foreign exchange. Frenkel and Clements⁴¹ emphasize that this characterizes the interest rate differential as an expectations variable inasmuch as it draws on the assumption that capital markets are fully integrated so that nominal interest rate differentials can be viewed as a reflection of differences in expected rates of inflation. For our purposes, we will nevertheless assume that the role is somewhat mixed, for as Fleming observed: "Perhaps during hyperinflation the forward rate will be a perfect indicator of expectations, because interest arbitrage is almost non-existent. But in quieter times interest arbi-

41. Frenkel and Clements, op. cit., p. 4.

trage seems to dominate especially if there is no trend in exchange rates."⁴²

Finally, we assume that the exchange rate adjusts to the long-run equilibrium rate according to a modified partial adjustment process:⁴³

$$(7) \quad \Delta \log ER = m[\log ER^* - \log ER(-1)] - n(\Delta \log R)$$

where " Δ " is the difference operator, "ER" is the current exchange rate, "R" is the current level of net official reserves,⁴⁴ and "m" and "n" are parameters.

42. J. Marcus Fleming, "General Discussion: What Have We Learned? Where are the Fundamental Conflicts of Opinion?" ed. Lars Calmfors and Clas Wihlborg, The Scandinavian Journal of Economics, Vol. 78, No. 2, (1976), pp. 408-409.

43. The basic partial adjustment model is widely used in economic literature. For a brief discussion of its mechanics and applications see: G.S. Maddala, Econometrics, (New York: McGraw-Hill Book Co., 1977), pp. 142-146.

44. "Net official reserves" is defined to be monetary authorities gross international reserves (expressed in U.S. dollars) including gold, special drawing rights, reserve position in the IMF, and foreign exchange minus foreign liabilities (including use of IMF credit). The previously cited work by Suss incorporates a (gross) reserves variable by minimizing a cost function based on the assumption that monetary authorities attempt to minimize the costs of adjustment on their domestic policy goals by choosing an appropriate combination of reserves and exchange rate changes.

The rationale behind the incorporation of the reserves measure in the partial adjustment specification is that under a managed floating exchange rate regime, monetary authorities may affect the normal adjustment process through intervention aimed at either stabilizing erratic exchange rate movements or moderating the speed of adjustment in any given direction. Hence, the reserves variable is intended as a proxy for exchange market intervention, and it is hoped that its inclusion in the model might detect evidence of any "leaning against the wind,"⁴⁵ or "smoothing and braking"⁴⁶ that could account for adjustment periods which might be considered longer than normal within the context of a monetary

45. Peter J. Quirk, "Exchange Rate Policy in Japan: Leaning Against the Wind," Staff Papers, Vol. 24, No. 3, (November 1977), pp. 642-664.

46. A description of various intervention strategies monetary authorities might follow is given in Richard N. Cooper, "IMF Surveillance Over Exchange Rates," The New International Monetary System, eds. Robert A. Mundell and Jacques J. Polak, (New York: Columbia University Press, 1977), pp. 69-83. The reserves change specification is in part based on Cooper's observation (p. 79) that "Direct intervention in spot exchange markets implies a gain or loss of international reserves, and the cumulative gain or loss in reserves indicates the degree of one-sidedness in intervention over the corresponding period."

model. As we will be working with monthly data, however, it is possible that a very active intervention policy directed solely at dampening erratic fluctuations may go undetected through incorporation of a reserves variable. This would happen, for example, if there were no net cumulative change in reserves as a result of such intervention. Another problem is that intervention does not necessarily have the same impact at different points in time, and thus the estimated regression parameter might have a very high variance.⁴⁷

Solving (7) for the exchange rate, we get:

$$(8) \quad \log ER = m(\log ER^*) + (1-m)\log ER(-1) - n(\Delta \log R)$$

Upon combining the results of equations (5), (6), and (8), and adding an error term, we arrive at the

47. Writing about the U.S. Federal Reserve Bank, Wilson Schmidt maintains that not only the time of day is an important factor in determining the impact that Fed intervention has on the market, but also "whether and how well it is known the Fed is intervening." (Wilson E. Schmidt, "Foreign Exchange Intervention by the Federal Reserve Bank of New York: Some Questions," Exchange Rate Flexibility, eds. Jacob S. Dreyer, Gottfried Haberler, and Thomas D. Willett, (Washington, D.C.: American Enterprise Institute, 1978), p. 99.)

final estimating equation for the monetary model:

$$\begin{aligned}
 (9) \quad \log ER = & B_0 + B_1 t + B_2 [\log(M_1 / M_2)] + B_3 [\log(y_1 / y_2)] \\
 & + B_4 (i_1 - i_2) + B_5 (\Delta \log R) \\
 & + B_6 \log[ER(-1)] + u
 \end{aligned}$$

where $B_0 = mk$; $B_1 = md$; $B_2 = m$; $B_3 = -mb$;
 $B_4 = ma$; $B_5 = -n$; and, $B_6 = 1-m$.

From the parameter estimates listed above, we derive the following measures:

(1) the average long-run trend in the relative demand for the two currencies, in percent per annum:

$$= 12[B_1 / (1 - B_6)]$$

(2) the long-run homogeneity coefficient for nominal variables:

$$= B_2 / (1 - B_6)$$

(3) the long-run income elasticity of demand for money:

$$= -\frac{B}{3} / (1 - \frac{B}{6})$$

(4) the long-run interest rate semi-elasticity of demand for money:

$$= -\frac{B}{4} / (1 - \frac{B}{6})$$

(5) the long-run reserves ratio elasticity of the exchange rate:

$$= \frac{B}{5} / (1 - \frac{B}{6}), \text{ and}$$

(6) the partial adjustment coefficient relating the exchange rate to its long-run equilibrium level:

$$= 1 - \frac{B}{6}$$

The "reserves ratio elasticity" is so designated because of the equivalence of the expressions:

$$\frac{B}{5} [\Delta \log R] \quad \text{and} \quad \frac{B}{5} \log[R/R(-1)]$$

To derive some tangible meaning from this elasticity, we will later derive the average dollar amount of change in reserves associated with a one percent change in the reserves ratio (i.e., the average over the sample period). From this we will find the average dollar amount ($\$ \Delta R$) required to effect a 1 percent change in the exchange rate by dividing through by the elasticity:

$$\$ \Delta R = \left(\frac{1}{B} \right) \left(\frac{1}{n} \right) \sum_{t=1}^n \frac{\Delta R}{\% \Delta [R/R(-1)]}$$

B. PURCHASING POWER PARITY MODEL

A second type of model we will look at is a variant of Bilson's sophisticated version of PPP⁴⁸ which is based (in spirit) on Brillembourg's observation

48. Bilson, op. cit., pp. 62-63.

that if PPP should be accepted as the equilibrium exchange rate, further attention could be directed at determining what factors affect the adjustment of the actual exchange rate in the short run. Upon combining the PPP equilibrium postulate:

$$(10) \quad \log ER^* = \log(P_1 / P_2)$$

with the partial adjustment mechanism given in equation (7), and extending the model to incorporate the interest rate differential as an additional factor affecting short-term adjustment, we obtain:

$$(11) \quad \Delta \log ER = m[\log(P_1 / P_2) - \log ER(-1)] \\ - n(\Delta \log R) + p(i_1 - i_2)$$

which we can simplify to

$$(12) \quad \log ER - \log(P_1 / P_2) = (1-m)[\log ER(-1) - \log(P_1 / P_2)] \\ - n(\Delta \log R) + p(i_1 - i_2)$$

Equation (12) states that the equilibrium exchange rate is equal to the relative price ratio (PPP), yet certain short-term factors (summarized by monetary authority exchange market intervention and the interest rate differential) may cause temporary deviation from equilibrium. As in the earlier monetary approach, the coefficient on the interest rate is expected to be positive, i.e., an increase in domestic interest rates is associated with a depreciation in the exchange rate.

Upon adding a constant term⁴⁹ and an error term, we may state the estimating form of our PPP model as follows:

$$(13) \log ER - \log(PPP) = Q_0 + Q_1 [\log ER(-1) - \log(PPP)] \\ + Q_2 (\Delta \log R) + Q_3 (i_1 - i_2) + u$$

where $Q_1 = 1 - m$; $Q_2 = -n$; and, $Q_3 = p$.

49. As there is no provision for a constant term in a PPP specification, it is expected that the coefficient estimates will not differ significantly from zero.

From these coefficient estimates we can derive:

(1) the partial adjustment coefficient relating the exchange rate to the long-run equilibrium rate:

$$= 1 - Q_1$$

(2) the long-run reserves ratio elasticity of the exchange rate:

$$= Q_2 / (1 - Q_1), \text{ and}$$

(3) the long-run semi-elasticity of the interest rate with respect to the exchange rate (which, by invoking the homogeneity postulate can be viewed as (minus) the interest semi-elasticity of demand for money):

$$= Q_3 / (1 - Q_1)$$

C. ESTIMATION METHODS

As Bilson⁵⁰ points out, if we were to know the actual values of the various income elasticities, interest elasticities, adjustment coefficients, and

50. Bilson, op. cit., p. 56.

other parameters, it would be a matter of applying a simple F-test to determine whether our estimation results are consistent with them, but since a fairly wide range of estimates might be considered acceptable, we must employ an entirely different procedure. The method we will follow is a technique developed by Theil and Goldberger⁵¹ in the early 1960's. Their "mixed estimation" method permits the analyst to use extraneous information to develop prior judgements concerning the values of certain regression parameters. The prior information takes the form of specified confidence intervals within which these parameters are expected to lie. Mixed estimation is preferable to Bayesian inference (for our purposes) because it does not require a prior distribution of all parameters in the regression equation but rather permits us to concentrate on those that we feel we know something about. "Essentially, the

51. H. Theil and A.S. Goldberger, "On Pure and Mixed Statistical Estimation in Economics," International Economic Review, Vol. 2, No. 1, (January 1961). For a brief description of the method, see Henri Theil, Principles of Econometrics, (New York: John Wiley and Sons, Inc., 1971), pp. 346-352; also see Appendix A.

mixed estimation procedure consists of using the sample to modify one's prior judgements."⁵²

A test as to whether the estimation results are consistent with our hypotheses concerning the parameters now becomes a test as to whether the sample and prior information are compatible with one another. Based on certain normality assumptions regarding the error terms in the sample and prior distributions, Theil⁵³ offers a "compatibility statistic" to determine whether the prior information is contradicted by sample evidence. The test statistic is distributed according to Chi-square with "k" degrees of freedom (k being the number of prior restrictions on the regression parameters), and is essentially a test to determine whether, after adjusting for disparities in parameter estimates due to differences in the respective covariance matrices of the sample and prior information sets, the remaining squared

52. Theil, op. cit., p. 348.

53. Henri Theil, "On the Use of Incomplete Prior Information in Regression Analysis," Journal of the American Statistical Association, Vol. 58, (June 1963), pp. 401-414.

differences are significant.

Ordinary Least Squares (OLS) estimation is capable of providing a good measure of the overall fit for regression equations having highly collinear explanatory variables, yet it is unable to distinguish the influence of individual variables on the exchange rate. Mixed estimation, through restrictions on selected parameters produces more precise estimates of these, as well as for some of the unrestricted parameters.

In implementing the mixed estimation method we will assume the following statements⁵⁴ are consistent with the nominal homogeneity postulate, previous studies on the demand for money,⁵⁵ and the notion of rapid adjustment of the exchange in response to changing money market conditions:

54. Numbers 2 and 3 are taken from Bilson, op. cit., p. 56.

55. Stephen M. Goldfeld, "The Demand for Money Revisited," Brookings Papers on Economic Activity, No. 3, 1973, pp. 577-638, is cited by Frenkel and Clements, and Bilson.

(1) The long-run homogeneity coefficient relating the exchange rate to the money supply has a 95 percent confidence interval of (.90, 1.10).

(2) The long-run income elasticity of demand for money has a 95 percent confidence interval of (.50, 1.50).

(3) The interest rate semi-elasticity of demand for money has a 95 percent confidence interval of (0.00, -3.00).

(4) The partial adjustment coefficient for the exchange rate has a 95 percent confidence interval of (.16, .50), which translates to a prior specification on the time to so called "complete adjustment" ranging from 2 to 6 months.⁵⁶

Application of the two-sigma rule⁵⁷ to the above confidence intervals gives the following approximate standard errors for the prior specification:

56. Bilson's prior on this variable allows up to 12 months for total adjustment. Since the literature contains specifications even at the extreme of continuous equilibrium, (e.g., the previously cited work by Dornbusch) we have somewhat narrowed the range of acceptable values.

57. The two-sigma rule is the proposition that the interval obtained by adding and subtracting twice the standard error to the estimated coefficient contains that coefficient apart from a probability of .046.

(1) Homogeneity coefficient:	s = .0500
(2) Income Elasticity:	s = .2500
(3) Interest semi-elasticity:	s = .7500
(4) Partial adjustment coefficient:	s = .0850

D. EMPIRICAL RESULTS

The requisite data for the exercise of testing the monetary and PPP models are described in Appendix B. Results of the regression analysis are given in Table II. The table is broken down so that the results for each of the ten countries are reported on a separate page (beginning page 56). Subheadings indicate the names of the variables while the equations given above -- numbers (9) and (13) -- indicate whether a log transformation was made to the variables before estimation. Coefficient estimates are listed along with their standard errors.

The equations, identified in the table with Roman numerals, were estimated using both OLS and mixed estimation, and correspond to the text equations as follows:

TABLE II
 Testing Alternative Models of the Exchange Rate:
 Monetary and Augmented Purchasing Power Parity Specifications
 United Kingdom

RESPONSE	EXPLANATORY VARIABLES							SUMMARY STATISTICS						
	CONSTANT	TIME	(M/M) _{1 2}	(Y/Y) _{1 2}	(I-I) _{1 2}	RESERVES	ER(-1)	ER(-1)/P	R2	S.E.E.	F	D-W	TC	SH
I. ER	.2781 (.7137)	-.0003 (.0006)	.1881 (.0669)	-.0893 (.0951)	.3281 (.0967)	-.0240 (.0275)	.8382 (.0642)		.98	.0206	499	2.47*	[0LS]**	
	.6817 (.3783)	-.0002 (.0002)	.2117 (.0450)	-.1491 (.0756)	.3849 (.0832)	-.0134 (.0263)	.7856 (.0431)		.98	.0207	461	2.73*	1.65 S:80 P:10	
	-.0202 (.0074)				-.3994 (.0857)	-.0378 (.0255)	-.8086 (.0593)		.88	.0205	140	1.52	[0LS]**	
II. ER/CP	-.0251 (.0065)				.3417 (.0796)	-.0315 (.0251)	.7619 (.0482)		.85	.0206	116	1.42	.82 S:91 P:9	
	-.0119 (.0084)				.7539 (.1037)	-.0564 (.0261)	-.8944 (.0651)		.90	.0210	181	1.56	[0LS]**	
III. ER/EP	-.0212 (.0071)				-.3554 (.0937)	-.0504 (.0259)	-.8088 (.0512)		.87	.0221	136	1.39	1.74 S:90 P:10	
	-.0120 (.0077)				.2406 (.0936)	-.0547 (.0260)	-.8994 (.0544)		.91	.0216	197	1.58	[0LS]**	
IV. ER/WP	-.0200 (.0068)				.3173 (.0859)	-.0484 (.0258)	-.8303 (.0455)		.88	.0219	140	1.42	2.61 S:92 P:8	

Standard errors are shown in parentheses under each coefficient.

* The Durbin H-Statistic (due to lagged response variable).

TC - Theil's Compatibility Statistic.

SH - Share of sample (S) and prior (P) information in posterior precision of estimate.

** The TC and SH summary statistics are not applicable in OLS estimation.

TABLE II - Continued

Belgium

RESPONSE	EXPLANATORY VARIABLES						SUMMARY STATISTICS					
	CONSTANT	TIME (M/M)	(y/y) 1 2	(1-1) 1 2	RESERVES ER(-1)	ER(-1)/P	R2	S.E.E.	F	D-W	IC	SH
I. ER	-6672 (.7165)	.1276 (.1134)	.1233 (.0937)	-.2684 (.1256)	-.3037 (.1353)	.8923 (.0713)	.86	.0261	59	2.38*	[OLS]**	
	-.1024 (.3932)	.1739 (.0344)	.0239 (.0814)	-.1404 (.1149)	-.2895 (.1315)	.8250 (.0503)	.84	.0266	49	2.64*	4.55 S:76 P:24	
II. ER/CP	-.0032 (.0061)			-.2289 (.0891)	-.3081 (.1336)	.9649 (.0401)	.91	.0266	201	1.61	[OLS]**	
	-.0098 (.0057)			-.2140 (.0878)	-.3216 (.1334)	.9118 (.0359)	.86	.0269	124	1.48	7.52 S:94 P: 6	
III. ER/EP	-.0010 (.0040)			-.1980 (.0932)	-.3236 (.1343)	.9145 (.0734)	.75	.0264	61	1.56	[OLS]**	
	-.0038 (.0038)			-.1449 (.0903)	-.3512 (.1333)	.8130 (.0546)	.68	.0269	43	1.40	2.60 S:88 P:12	
IV. ER/MP	-.0034 (.0037)			-.1968 (.0891)	-.3199 (.1306)	.8607 (.0740)	.71	.0260	50	1.51	[OLS]**	
	-.0044 (.0036)			-.1628 (.0872)	-.3282 (.1303)	.7838 (.0547)	.65	.0262	38	1.39	2.20 S:88 P:12	

Standard errors are shown in parentheses under each coefficient.

* The Durbin H-Statistic (due to lagged response variable).

IC = Theil's Compatibility Statistic.

SH = Share of sample (S) and prior (P) information in posterior precision of estimate.

** The IC and SH summary statistics are not applicable in OLS estimation.

TABLE II - Continued

France

RESPONSE	EXPLANATORY VARIABLES										SUMMARY STATISTICS				
	CONSTANT	TIME	(M/M)	(Y/Y)	(I-I)	RESERVES	ER(-1)	ER(-1)/P	R2	S.E.E.	F	D-W	IC	SH	
I. ER	1.1261 (.8153)	-.0005 (.0006)	.1219 (.1105)	-.1571 (.1323)	.4409 (.2181)	-.1813 (.0825)	.7891 (.0740)		.84	.0255	52	.46*	[OLS]**		
	1.0088 (.4899)	-.0011 (.0003)	.2379 (.0555)	-.2182 (.1037)	.4805 (.1838)	-.1679 (.0818)	.7573 (.0516)		.84	.0257	48	.50*	.79 S:73 P:27		
II. ER/CP	-.0086 (.0058)				.2289 (.1762)	-.2204 (.0799)		.8539 (.0662)	.80	.0256	80	1.84	[OLS]**		
	-.0124 (.0053)				.3187 (.1530)	-.2171 (.0799)		.7825 (.0317)	.75	.0259	61	1.70	1.12 S:88 P:12		
III. ER/EP	-.0066 (.0052)				.2739 (.2035)	-.2013 (.0824)		.8409 (.0916)	.74	.0260	56	1.83	[OLS]**		
	-.0067 (.0048)				.4005 (.1746)	-.1863 (.0816)		.7471 (.0615)	.69	.0262	46	1.71	.39 S:84 P:16		
IV. ER/MP	-.0039 (.0061)				.0988 (.1630)	-.2020 (.0841)		.9393 (.0463)	.88	.0263	146	1.88	[OLS]**		
	-.0089 (.0037)				.1481 (.1571)	-.1754 (.0836)		.8757 (.0404)	.82	.0267	93	1.70	4.70 S:92 P:8		

Standard errors are shown in parentheses under each coefficient.
 * The Durbin H-Statistic (due to lagged response variable).
 IC = Theil's Compatibility Statistic.
 SH = Shares of sample (S) and prior (P) information in posterior precision of estimate.
 ** The IC and SH summary statistics are not applicable in OLS estimation.

TABLE II - Continued

Germany

RESPONSE	EXPLANATORY VARIABLES						SUMMARY STATISTICS							
	CONSTANT	TIME	(M/N)	(Y/Y)	(I-I)	RESERVES	ER(-1)	ER(-1)/P	R2	S.E.E.	F	D-W	TC	SH
I. ER	-.1129 (.7226)	-.0017 (.0007)	.2771 (.1303)	-.0321 (.1437)	-.1038 (.2183)	-.5431 (.1206)	.8035 (.0635)		.91	.0256	93	2.68*	[0.6]**	
	.6134 (.4988)	-.0018 (.0004)	.2446 (.0353)	-.1332 (.1056)	-.1506 (.1827)	-.5305 (.1190)	.7600 (.0498)		.89	.0258	73	2.80*	1.28	8:73 P:27
II. ER/CP	-.0055 (.0049)				-.1093 (.1801)	-.5826 (.1206)		.8679 (.0370)		.0260	86	1.52	[0.6]**	
	-.0049 (.0047)				-.0487 (.1700)	-.5748 (.1202)		.8081 (.0467)		.0263	64	1.41	2.41	8:89 P:11
III. ER/EP	-.0014 (.0051)				-.0486 (.1845)	-.6132 (.1213)		.8627 (.0397)		.0260	92	1.53	[0.6]**	
	.0010 (.0049)				-.0321 (.1734)	-.6210 (.1206)		.7990 (.0484)		.0263	70	1.42	1.91	8:89 P:11
IV. ER/VP	-.0026 (.0049)				-.1418 (.1771)	-.6007 (.1193)		.8445 (.0587)		.0257	80	1.49	[0.6]**	
	-.0008 (.0048)				-.0894 (.1672)	-.5981 (.1188)		.7918 (.0473)		.0259	62	1.40	2.18	8:89 P:11

Standard errors are shown in parentheses under each coefficient.

* The Durbin H-Statistic (due to lagged response variable).

TC - Theil's Compatibility Statistic.

SH - Share of sample (S) and prior (P) information in posterior precision of estimate.

** The TC and SH summary statistics are not applicable in OLS estimation.

TABLE II - Continued

Italy

RESPONSE	EXPLANATORY VARIABLES							SUMMARY STATISTICS					
	CONSTANT	TIME	(M/H) 1 2	(y/y) 1 2	(I-I) 1 2	RESERVES	ER(-1)	ER(-1)/P	R2	S.E.E.	F	D-W	TC	SH
I. ER	.5003 (.5972)	.0004 (.0009)	.0305 (.1127)	-.0220 (.0755)	.1368 (.1672)	-.0354 (.0374)	.8833 (.0861)	.98	.0272	371	1.77*		[0.18]**
	.3354 (.3359)	-.0005 (.0003)	.1859 (.0594)	-.0642 (.0686)	.2676 (.1276)	-.0584 (.0369)	.8073 (.0555)	.97	.0277	355	1.99*	2.58	8.76 P:24
	.0053 (.0062)			.0422 (.1019)		-.0596 (.0365)	.9328 (.0813)	.82	.0268	91	1.71		[0.18]**
II. ER/CP	-.0002 (.0057)			-.1561 (.0888)		-.0532 (.0363)	.8054 (.0580)	.77	.0274	66	1.45	1.48	8.87 P:13
	.0086 (.0076)			-.0202 (.0842)		-.0633 (.0365)	1.0090 (.0946)	.71	.0270	48	1.83		[0.18]**
III. ER/EP	-.0026 (.0064)			.0653 (.0781)		-.0612 (.0364)	.8209 (.0619)	.61	.0279	31	1.45	1.77	8.85 P:13
	.0066 (.0060)			-.0048 (.0770)		-.0615 (.0365)	.9580 (.0831)	.71	.0269	48	1.75		[0.18]**
IV. ER/MP	.0014 (.0056)			.0385 (.0748)		-.0565 (.0364)	.8179 (.0582)	.61	.0276	32	1.46	1.99	8.07 P:13

Standard errors are shown in parentheses under each coefficient.

* The Durbin H-Statistic (due to lagged response variable).

TC = Theil's Compatibility Statistic.

SH = Shares of sample (S) and prior (P) information in posterior precision of estimate.

** The TC and SH summary statistics are not applicable in OLS estimation.

TABLE II - Continued

Netherlands

RESPONSE	EXPLANATORY VARIABLES						SUMMARY STATISTICS							
	CONSTANT	TIME	(M/H) _{1 2}	(Y/Y) _{1 2}	(I-I) _{1 2}	RESERVES	ER(-1)	ER(-1)/P	R2	S.E.E.	F	D-W	TC	SH
I. ER	-.3504 (.5716)	-.0010 (.0005)	.0894 (.0642)	.0081 (.0826)	-.0669 (.1191)	-.0731 (.0796)	.8263 (.0754)		.86	.0284	57	2.58*	[OLS]**	
	.1750 (.3598)	-.0013 (.0004)	.1618 (.0464)	-.0253 (.0721)	-.0013 (.1144)	-.0614 (.0791)	.8257 (.0452)		.87	.0289	66	2.30*	4.15 S:78 P:22	
	-.0083 (.0056)			-.1513 (.1084)		-.0908 (.0798)		.9545 (.0488)		.86	.0289	128	1.58 [OLS]**	
II. ER/CP	-.0142 (.0051)			-.1197 (.1061)		-.0854 (.0798)		.8841 (.0419)		.80	.0294	81	1.44 5.43 S:92 P: 8	
	-.0094 (.0066)			-.1525 (.1082)		-.0914 (.0798)		.9289 (.0785)		.70	.0289	47	1.56 [OLS]**	
III. ER/EP	-.0172 (.0054)			-.1178 (.1059)		-.0869 (.0798)		.8128 (.0566)		.61	.0294	32	1.39 2.46 S:87 P:13	
	-.0048 (.0037)			-.1417 (.1080)		-.0856 (.0794)		.9112 (.0654)		.76	.0287	65	1.54 [OLS]**	
IV. ER/MP	-.0050 (.0037)			-.1041 (.1055)		-.0769 (.0793)		.8238 (.0510)		.69	.0291	45	1.38 2.85 S:89 P:11	

Standard errors are shown in parentheses under each coefficient.

* The Durbin H-Statistic (due to lagged response variable).

TC - Theil's Compatibility Statistic.

SH - Shares of sample (S) and prior (P) information in posterior precision of estimate.

** The TC and SH summary statistics are not applicable in OLS estimation.

TABLE II - Continued

Sweden

RESPONSE	EXPLANATORY VARIABLES							SUMMARY STATISTICS					
	CONSTANT	TIME	(M/H) 1 2	(y/y) 1 2	$(I-I)$ 1 2	RESERVES	ER(-1)	ER(-1)/P	R2	S.E.E.	F	D-W	TC	SH
I. ER	1.7970 (.5875)	.0010 (.0008)	-.0855 (.0986)	-.0291 (.0853)	-.3122 (.1281)	.0293 (.0519)	.7219 (.0865)	.76	.0268	31	2.43*		[OLS]**
	-.8959 (.3310)	-.0012 (.0005)	-.1853 (.0552)	-.1749 (.0690)	-.1221 (.1199)	-.0342 (.0512)	-.7971 (.0524)	.80	.0288	37	1.44*	2.51	8:78 P:22
II. ER/CP	-.0055 (.0049)				-.2000 (.1140)	-.0229 (.0511)	-.7573 (.0817)	.69	.0269	44	1.57		[OLS]**
	-.0069 (.0047)				-.1917 (.1043)	-.0218 (.0500)	-.7316 (.0566)	.66	.0269	39	1.53	1.85	8:86 P:14
III. ER/EP	-.0102 (.0058)				-.1959 (.1143)	-.0280 (.0509)	-.8080 (.0665)	.78	.0270	71	1.62		[OLS]**
	-.0132 (.0053)				-.2042 (.1058)	-.0235 (.0501)	-.7677 (.0506)	.75	.0271	59	1.56	2.33	8:89 P:11
IV. ER/WP	-.0017 (.0043)				-.3657 (.1309)	-.0320 (.0484)	-.6610 (.0919)	.72	.0260	53	1.54		[OLS]**
	-.0022 (.0043)				-.3049 (.1087)	-.0391 (.0478)	-.6943 (.0591)	.72	.0260	52	1.57	2.28	8:84 P:16

Standard errors are shown in parentheses under each coefficient.

* The Durbin H-Statistic (due to lagged response variable).

TC = Theil's Compatibility Statistic.

SH = Shares of sample (S) and prior (P) information in posterior precision of estimate.

** The TC and SH summary statistics are not applicable in OLS estimation.

TABLE II - Continued

Switzerland

RESPONSE	EXPLANATORY VARIABLES						SUMMARY STATISTICS							
	CONSTANT	TIME	(M/H) 1 2	(y/y) 1 2	(1-1) 1 2	RESERVES	ER(-1)	ER(-1)/P	R2	S.E.E.	F	D-W	TC	SH
I. ER	1.5311 (.9529)	-.0021 (.0007)	.1379 (.1212)	-.3020 (.1191)	.5183 (.1830)	-.0718 (.0347)	.8391 (.0637)	.97	.0266	301	1.89*	[OLS]**		
	1.3089 (.6620)	-.0022 (.0005)	.2033 (.0477)	-.2725 (.0948)	.5661 (.1681)	-.0686 (.0338)	.7929 (.0435)	.96	.0269	243	2.19*	1.90 S:76 P:24		
II. ER/CP	-.0041 (.0076)				.1898 (.1658)	-.0895 (.0364)	.9699 (.0410)	.92	.0289	227	1.56	[OLS]**		
	-.0090 (.0072)				.2623 (.1572)	-.0934 (.0364)	.9112 (.0367)	.87	.0294	136	1.42	6.84 S:93 P:7		
III. ER/EP	.0005 (.0068)				.3743 (.1923)	-.0866 (.0354)	.8729 (.0664)	.85	.0281	113	1.52	[OLS]**		
	.0012 (.0066)				.4978 (.1712)	-.0858 (.0354)	.7944 (.0518)	.81	.0285	84	1.43	1.52 S:88 P:12		
IV. ER/FP	-.0034 (.0070)				-.2007 (.1601)	-.0895 (.0360)	.9218 (.0643)	.80	.0286	81	1.52	[OLS]**		
	-.0053 (.0067)				.2658 (.1519)	-.0919 (.0360)	.8273 (.0507)	.73	.0292	55	1.36	2.25 S:88 P:12		

Standard errors are shown in parentheses under each coefficient.

* The Durbin H-Statistic (due to lagged response variable).

IC = Theil's Compatibility Statistic.

SH = Shares of sample (S) and prior (P) information in posterior precision of estimate.

** The IC and SH summary statistics are not applicable in OLS estimation.

TABLE II - Continued

Canada

RESPONSE	EXPLANATORY VARIABLES						SUMMARY STATISTICS							
	CONSTANT	TIME	(M/M) _{1 2}	(Y/Y) _{1 2}	(I-I) _{1 2}	RESERVES	ER(-1)	ER(-1)/P	R2	S.E.E.	F	D-W	TC	SH
I. ER	.6053 (.3817)	.0004 (.0001)	-.0420 (.0427)	.0067 (.0370)	-.1745 (.0963)	-.1674 (.0226)	.9022 (.0523)		.97	.0083	267	-.96*	[OLS]**	
	-.0178 (.2031)	.0003 (.0001)	-.0368 (.0326)	-.0238 (.0347)	-.1645 (.0814)	-.1626 (.0221)	.9341 (.0323)		.98	.0086	382	-.50*	10.7 5:03 P: 17	
II. ER/CP	.0013 (.0012)			.0130 (.0623)		-.1784 (.0223)		1.0091 (.0405)	.93	.0087	261	2.00	[OLS]**	
	.0012 (.0012)			-.0296 (.0608)		-.1711 (.0224)		.9454 (.0339)	.88	.0089	149	1.81	9.1 5:94 P: 6	
III. ER/EP	.0013 (.0012)			-.0102 (.0564)		-.1793 (.0221)		1.0155 (.0243)	.97	.0087	589	2.03	[OLS]**	
	.0010 (.0012)			.0042 (.0560)		-.1759 (.0221)		.9883 (.0233)	.94	.0088	322	1.92	13.5 5:98 P: 2	
IV. ER/MP	-.0004 (.0018)			-.0083 (.0557)		-.1798 (.0219)		1.0299 (.0261)	.96	.0087	526	2.07	[OLS]**	
	.0012 (.0017)			-.0065 (.0554)		-.1772 (.0219)		.9976 (.0248)	.93	.0088	281	1.97	14.2 5:97 P: 3	

Standard errors are shown in parentheses under each coefficient.

* The Durbin H-Statistic (due to lagged response variable).

TC - Theil's Compatibility Statistic.

SH - Shares of sample (S) and prior (P) information in posterior precision of estimate.

** The TC and SH summary statistics are not applicable in OLS estimation.

TABLE II - Continued

Japan

RESPONSE	EXPLANATORY VARIABLES						SUMMARY STATISTICS							
	CONSTANT	TIME	(M/N) 1 2	(Y/Y) 1 2	(I-I) 1 2	RESERVES	ER(-1)	ER(-1)/P	RZ	S.E.E.	F	D-W	IC	SH
I. ER	.0389 (.7166)	-.0003 (.0005)	.0217 (.1039)	-.0502 (.1156)	.0830 (.1680)	-.2522 (.0697)	1.0201 (.0649)		.95	.0205	193	.01*	[0LS]**	
	.6760 (.4560)	-.0009 (.0004)	.1114 (.0545)	-.1664 (.0957)	.3117 (.1322)	-.2465 (.0692)	.8881 (.0501)		.92	.0213	115	1.10*	4.5 S:76 P:24	
	-.0019 (.0057)		.1602 (.1226)			-.2649 (.0662)	1.0233 (.0354)		.97	.0202	564	1.96	[0LS]**	
II. ER/CP	-.0093 (.0053)		.2423 (.1174)			-.3097 (.0652)	.9694 (.0326)		.94	.0206	311	1.79	11.2 S:95 P: 5	
	-.0041 (.0031)		.2234 (.1059)			-.2678 (.0614)	.9606 (.0401)		.92	.0201	238	1.87	[0LS]**	
III. ER/FP	-.0024 (.0030)		.2730 (.1031)			-.2448 (.0609)	.9054 (.0361)		.88	.0205	145	1.75	6.6 S:94 P: 6	
	-.0051 (.0029)		.2455 (.1144)			-.2873 (.0591)	.9479 (.0521)		.90	.0201	179	1.86	[0LS]**	
IV. ER/VP	-.0050 (.0028)		.3279 (.1088)			-.2919 (.0591)	.8690 (.0441)		.85	.0205	115	1.71	4.2 S:92 P: 8	

Standard errors are shown in parentheses under each coefficient.

* The Durbin B-Statistic (due to lagged response variable).

IC = Theil's Competitiveness Statistic.

SH = Shares of sample (S) and prior (P) information in posterior precision of estimate.

** The IC and SH summary statistics are not applicable in OLS estimation.

- I. The monetary model, equation (9).
- II. The PPP model, equation (13), using relative CP.
- III. The PPP model, equation (13), using relative EP.
- IV. The PPP model, equation (13), using relative WP.

The following information is relevant to the interpretation of the reported summary statistics:

For the monetary model:

(1) The critical values of the Durbin H-statistic with a 5 percent probability of committing a Type I error are plus or minus 1.65; for a 1 percent probability, the values are plus or minus 2.33.

(2) The critical value of the Theil compatibility statistic at the 5 percent level of significance is 9.49; at the 1 percent level it is 13.28.

For the PPP models:

(1) The lower and upper bounds of the 5 percent points of the Durbin-Watson statistic are 1.50 and 1.70, respectively; the corresponding bounds of the 1 percent points are 1.35 and 1.53, respectively.

(2) The critical value of the Theil compatibility statistic at the 5 percent level of significance is 5.99; at the 1 percent level it is 9.21.

Additional measures reported for the mixed estimation results are the relative contributions of sample and prior information in the posterior precision

of the estimate.⁵⁸

Out of the 150 parameter estimates of the Theil-Goldberger application, 81 meet the joint criteria of compatibility of sample and prior information at the 5 percent level and significance at the 95 percent level.⁵⁹ Translations into the long-run values for these 81 coefficients are presented in Table III, where it can be seen that:

(1) The exogenous shift in demand from U.S. dollars to domestic currency ranged from 5.25 percent per year for the French franc to 12.69 percent per year for the Swiss franc.

(2) The long-run homogeneity coefficients all fall within the two-sigma range of our prior specification.

58. These are reported as scalar measures indicating percentage shares, and are based on a decomposition of the joint variance-covariance matrix. For their derivation see: Theil, "On the Use of Incomplete Prior Information in Regression Analysis," *op. cit.*, pp. 409-412.

59. Due to evidence of positive autocorrelation in some of the disturbance terms, sampling variances may be somewhat understated and summary statistics such as R-squared and F correspondingly overstated.

TABLE III

Implicit Long-Run Coefficient Estimates*

Country and Model	Demand Shift % per annum	Homogeneity Coefficient	Income Elasticity	Interest Elasticity**	Reserve Ratio Elasticity**	Adjustment % per month***
United Kingdom						
I	....	.99	.70	-.18	....	21.44
II				-.14	....	23.81
III				-.19	....	19.12
IV				-.19	....	16.97
Belgium						
I	-6.21	.99	....	....	-1.65 (96)	17.50
II				....	....	....
III				....	-1.88 (84)	18.70
IV				....	-1.52 (104)	21.62
France						
I	-5.25	.98	.89	-.19	-.69 (198)	26.27
II				-.14	-1.00 (137)	21.75
III				-.16	-.74 (185)	25.29
IV				....	-1.41 (97)	12.43 (74.58)
Germany						
I	-8.81	1.02	....	....	-2.21 (236)	26.00
II				....	-3.00 (174)	19.19
III				....	-3.09 (169)	20.10
IV				....	-2.87 (182)	20.82
Italy						
I	....	.97	....	-.14	....	19.27
II				....	....	19.46
III				....	....	17.91
IV				....	....	16.21

* Four leaders (....) indicate failure of estimate to satisfy dual criteria as mentioned in text.

** The interest rate differential is set at 10 percent.

*** Figures in parentheses indicate intervention amount (millions of U.S. dollars) required to effect

a 1 percent change in the exchange rate.

**** Figures in parentheses indicate percentage adjustment in six months, if less than 100.

TABLE III - Continued

Country and Model	Demand Shift % per annum	Homogeneity Coefficient	Income Elasticity	Interest Elasticity**	Reserves Ratio Elasticity***	Adjustment % per month****
Netherlands						
I	-9.24	.93	....	....	....	17.43
II				....	....	11.59 (69.54)
III				....	....	18.72
IV				....	....	17.62
Sveden						
I	-6.99	.91	.86	....	....	20.29
II				....	....	26.84
III				....	....	23.23
IV				.10	....	30.57
Switzerland						
I	-12.69	.98	1.32	-.27	-.33 (313)	20.71
II				....	....	....
III				-.24	-.42 (246)	20.56
IV				....	-.53 (195)	17.27
Canada						
I	....	....	....	....	....	....
II				....	....	....
III				....	....	....
IV				....	....	....
Japan						
I	-9.72	1.00	....	-.28	-2.20 (47)	11.19 (67.14)
II				....	....	....
III				....	....	....
IV				-.25	-2.23 (47)	13.11 (78.66)

* Four leaders (....) indicate failure of estimate to satisfy dual criteria as mentioned in text.

** The interest rate differential is set at 10 percent.

*** Figures in parentheses indicate intervention amount (millions of U.S. dollars) required to effect a 1 percent change in the exchange rate.

**** Figures in parentheses indicate percentage adjustment in six months, if less than 100.

(3) The few significant estimates of the income elasticity of demand for money fall within the two-sigma interval of our prior specification.

(4) The interest rate semi-elasticities of demand for money (except for Sweden's which has the wrong sign) all fall within the two-sigma range of our prior specification.

(5) The reserves ratio elasticities indicate that on average, over the sample period, amounts ranging from \$47 million (monetary and wholesale price PPP models, Japan) to \$313 million (monetary model, Switzerland) was associated with a 1 percent change in the exchange rate.⁶⁰

(6) The adjustment coefficients indicate monthly adjustment rates of exchange rates to their equilibrium levels ranging from 11.19 percent (monetary model, Japan) to 30.57 percent (wholesale price PPP model, Sweden). Consistency with our prior specification on this coefficient would require adjustment speeds of at least 16.67 percent per month, which is the case for 28 of the 32 estimates reported. Furthermore, the relationship between these and the reserve impact coefficients is well-ordered: the higher reserves impact coefficients in general being associated with the lower monthly percentage adjustments in the exchange rate.

60. The formula for deriving these amounts was given on page 47.

The fact that not one of the models for Canada withstood the dual criteria test of compatibility and significance is probably attributable to the powerful linkages between the Canadian and U.S. economies, or more specifically to the fact that many of the U.S. variables are direct determinants of their Canadian counterparts, which would suggest the appropriateness of a different specification for modeling the Canadian experience.⁶¹

There are at least two reasons for poor coefficient estimates for some of the relative income variables in the monetary models. First, as pointed out by Frenkel and Clements,⁶² and Suss,⁶³ the phenomenon of currency substitution may lead to imprecise parameter estimates because the estimated specification bases money demand functions on domestic variables only. They

61. Knight has much greater success, for example, using a more general equilibrium approach in his paper "Output, Prices and the Floating Exchange Rate in Canada: A Monetary Approach," op. cit.

62. Frenkel and Clements, "Exchange Rates in the 1920's: A Monetary Approach," op. cit.

63. Suss, "A Short-Run Model of the Trade-Off Between Exchange Rate and Reserve Changes," op. cit.

suggest a richer formulation based on both domestic and foreign components of money demand. Second, as stressed by Bilson, the very nature of the data may lead to imprecise parameter estimates. Indices of industrial production are used as proxies for income levels, and the "income" elasticities of demand for money based on these proxies "must consequently also take account of the possibility that the elasticity of real income with respect to industrial production is not exactly unity."⁶⁴

Problems with coefficient estimates on the interest rate differential stem from another aspect of our analysis. The inclusion of this variable as well as its partial designation as an expectational measure was implicitly based on the assumption of perfect capital mobility. In fact, the actual degree of mobility for any given country may be very far from this extreme, and, over the sample period, this degree may have changed considerably.

64. Bilson, op. cit., p. 56.

V. CONCLUSION

A. SUMMARY AND CONCLUSIONS

From the perspectives of Purchasing Power Parity and the monetary approach to the exchange rate we examined the evidence of ten industrial countries over the sample period March 1973 through June 1978. We began by developing a simple monetary model based on the hypothesis that the equilibrium exchange rate, viewed as the relative price of two monies, is a function of the factors determining the supplies and demands for those two monies, and that the exchange rate adjusts to equilibrium, over time, according to a partial adjustment mechanism that incorporates changes in official reserves holdings as a possible dampening element on an otherwise free adjustment.

We next discussed a modified PPP model based on the notion that relative prices define the equilibrium exchange rate while deviations from equilibrium can largely be explained by short-term influences on the exchange rate caused by such factors as exchange market intervention and changing interest rate differentials.

The models were estimated using ordinary least squares, as well as mixed estimation, which permitted us to combine the sample information with prior information derived from the homogeneity postulate, known characteristics of the demand for money, and a somewhat arbitrary rule of thumb regarding the speed of adjustment.

The simplicity of the models, as well as their appurtenant degree of abstraction from reality make the drawing of a detailed set of conclusions inappropriate. Although our findings are broadly consistent with the properties of the models estimated, the evidence is far from conclusive in endorsing the validity of either.

Both models, however, underscore the notion that under a system of flexible exchange rates, domestic monetary growth and the exchange rate are strongly associated, and any policy action aimed at modifying one can be expected to correspondingly affect the trend rate of growth of the other. This is most clearly seen in the case of the monetary model, where the equilibrium exchange rate is defined in terms of relative money supplies, so the calculation of the monetary expansion (contraction) necessary to move the exchange rate to some target level is a simple matter.

Long-run homogeneity between the exchange rate and relative money forcefully emphasizes the fact that in order to maintain the value of its currency, a country must choose the appropriate rate of domestic monetary expansion. If France (for example) would wish to maintain a relatively fixed exchange rate between the franc and the U.S. dollar, French authorities would have to equate (as closely as possible) the rate of monetary expansion in France with the rate in the U.S. Although most of the equations estimated provided measures of fairly rapid adjustment, the effects of any such policy action are completely worked out only after some time. For the case of France, in terms of the monetary model, the period of adjustment would be somewhere in the neighborhood of four months (see Table III).

It should be stressed that the homogeneity postulate also has implications for intervention. Barring sterilization measures, intervention cannot sustain an exchange rate inconsistent with relative rates of monetary expansion because the associated reserves changes impinge on these relative rates through their impact on the foreign component of the monetary base.

A country attempting to maintain a stable relationship between its domestic monetary policy and the exchange rate has at least two avenues it can follow:

(1) It can modify its domestic rate of monetary expansion to accommodate a desired level (or trend rate of growth) of the exchange rate, or

(2) It can steadfastly maintain a target rate of monetary expansion and accept the consequential rate of growth of the exchange rate.

The particular avenue, or combination of avenues that a country chooses to follow depends, inter alia, on preceding and current circumstances surrounding payments imbalances, political uncertainties, the current climate of private expectations, and perhaps more fundamentally, the vulnerability of the traded goods sector to changes in exchange rates (in terms of the costs involved in a gradual reallocation of productive resources), and the degree to which the authorities wish to limit this vulnerability.

B. AREAS FOR POSSIBLE IMPROVEMENT

Perhaps the most serious weakness of the models in this paper is their failure to take into account the endogeneity of interest rates. A more appropriate specification (given a system of flexible exchange rates) would determine interest rates and exchange rates, simultaneously. This, in fact, is precisely the route already taken by Suss.⁶⁵

In terms of the appropriate specification for an interest rate equation, it would be useful to be able, in some way, to devise a formulation that would permit different interpretations depending on the degree of freedom of capital mobility as well as the changes in this degree over time. Although no suggestion is offered for treating the first problem, a possible means of approaching the second may be Cooley and Prescott's⁶⁶

65. Suss, "A Short-Run Model of the Trade-Off Between Exchange Rate and Reserve Changes," op. cit.

66. T. Cooley and E. Prescott, "Varying Parameter Regression: A Theory and Some Applications," Annals of Economic and Social Measurement, October 1973, pp. 463-473. For a brief explanation of the method see G.S. Maddala, op. cit., pp. 396-399.

varying-parameter regression which permits a "drift" in specific parameters over the range of the estimation period.

An area which deserves considerable attention is improvement in the definition of the intervention variable as well as the functional representation whereby this variable is included in the exchange rate equation. Any refinement in the variable's definition that effectively eliminates changes in reserves due to factors other than intervention is a step in the right direction. The correction for any known changes corresponding to swaps with domestic banks is one example of this sort of refinement.⁶⁷

As for functional form, an intriguing line for exploration might be one that embraces both a policy reaction function and a "market response" function that attempts to quantify market reaction due to the magnitude of market intervention and to the public's perception of the genuineness of this intervention.

67. I am thankful to Mr. John C. O'Connor for suggesting this correction.

Finally, it should be noted that even working within the limitations of the monetary model of equation (9), one might improve the efficiency of both OLS and mixed estimation by taking advantage of the identity restriction:

$$B_2 + B_6 = 1$$

It is interesting to note that even without this restriction, 8 of the 10 OLS estimates for these coefficients sum to values within the interval (.90, 1.10).

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APPENDIX A. THEIL-GOLDBERGER ESTIMATION METHOD

This appendix summarizes the main features of the mixed estimator and its pertinent summary statistics.

In addition, it directs the reader to relevant sources containing further detail.

A. THE ESTIMATOR

Suppose the $n \times 1$ vector of observations on the response variable, y , is generated according to:

$$(A1) \quad y = XB + u$$

where X is an $n \times K$ observation matrix of explanatory variables (including the constant term), B is the $K \times 1$ coefficient vector, and u is the $n \times 1$ disturbance vector.

Furthermore, assume that $E(u) = 0$, and $E(uu')$ = σU .

U is a positive definite $n \times n$ matrix, and is a generalization of $U = I$, the case of the standard linear model.

If there exists prior information on some of the parameters in the form of q linear combinations of the coefficients:

$$(A2) \quad r = RB + v$$

where R is a known $q \times K$ matrix (of rank q), and v is the error component of the prior estimate, r , this information can be combined with (A1) to produce:

$$(A3) \quad \begin{bmatrix} y \\ r \end{bmatrix} = \begin{bmatrix} X \\ R \end{bmatrix} B + \begin{bmatrix} u \\ v \end{bmatrix}$$

which is formulated under the assumption that the sample and prior information are independent. Noting that:

$$E \begin{bmatrix} u \\ v \end{bmatrix} = 0, \text{ and } V \begin{bmatrix} u \\ v \end{bmatrix} = \begin{bmatrix} \sigma^2 U & 0 \\ 0 & V \end{bmatrix}$$

where V is the covariance matrix of the prior distribution, the Aitken principle can be applied to (A3) to derive the mixed estimator of B :

$$(A4) \quad \beta = \left[\begin{array}{cc} 2 & -1 \\ (1/\sigma^2) X'U & X + R'V \end{array} \right]^{-1} \left[\begin{array}{c} -1 \\ -1 \\ (1/\sigma^2) X'y + R'V r \end{array} \right]$$

B. THE COMPATIBILITY STATISTIC

To test whether the prior information is contradicted by sample evidence, Theil suggests a test procedure based on the sample estimate of B , $(\tilde{\beta})$, and the prior estimate, r . The prior specification states

that $r - RB$ is a vector of mean "0" and covariance matrix V . The compatibility test is based on whether the difference $r - R\tilde{\beta}$ is too large to fit these mean and covariance specifications.

The statistic is developed as follows: First, we note that:

$$(A5) \quad V(r - R\tilde{\beta}) = \sigma^2 R(X'U'X)^{-1} R' + V$$

The quadratic form of $r - R\tilde{\beta}$ whose matrix is the inverse of (A5) is:

$$(A6) \quad (r - R\tilde{\beta})' [\sigma^2 R(X'U'X)^{-1} R' + V]^{-1} (r - R\tilde{\beta})$$

Under the assumption that u and v are normally distributed, (A6) is distributed Chi-square(q), with the null hypothesis that sample and prior information are compatible. (" q " is the number of prior coefficient restrictions.)

C. RELATIVE CONTRIBUTIONS OF ESTIMATES

The precision of the mixed estimate, β , is given by the covariance matrix in equation (A4):

$$(A7) \quad V(\beta) = [(1/\sigma^2)X'UX + R'VR]^{-1}$$

In an attempt to determine the relative shares of sample and prior information in the precision of the estimate, Theil breaks apart (A7) according to:

$$(A8) \quad A = (1/\sigma^2)X'UX \quad \text{and}$$

$$(A9) \quad B = R'VR$$

He then states the problem as one of solving for a function g to measure the share of A (or B) in the matrix $(A + B)$. After restricting the problem by requiring:

$$(1) \quad g(A,B) + g(B,A) = 1 \quad (\text{adding up criterion})$$

$$(2) \quad g(0,B) = 0; \quad g(A,0) = 1 \quad (\text{zero-unit criterion})$$

$$(3) \quad g(K'AK, K'BK) = g(A,B) \quad (\text{The invariance criterion for nonsingular linear transformations, which ensures against changes in shares being caused by changes in units of account.})$$

$$(4) \quad g(pA_1 + qA_2, pB_1 + qB_2) = pq(A_1, B_1) + pq(A_2, B_2)$$

(linearity criterion).

Theil then shows that the only function satisfying these four criteria is:

$$(A10) \quad g(A, B) = (1/K) \text{trace } A(A + B)^{-1}$$

which, in terms of (A7), gives the sample and prior shares in precision as:

$$(A11) \quad \text{Sample: } (1/K) \text{trace} [(1/\sigma^2) X'X + R'V^{-1}R]$$

$$(A12) \quad \text{Prior: } (1/K) \text{trace } R'V^{-1}R [(1/\sigma^2) X'X + R'V^{-1}R]$$

D. ADDITIONAL INFORMATION

A more detailed treatment of each of the topics discussed above can be found as follows:

(1) For additional material on the method of mixed estimation see Theil and Goldberger, "On Pure and Mixed Statistical Estimation in Economics," previously cited.

(2) For further detail on the derivation of the compatibility statistic, see Theil,

Principles of Econometrics, previously cited, pp. 350-351.

(3) For a more complete development of the relative shares measures see Theil, "On the Use of Incomplete Prior Information in Regression Analysis," previously cited, pp. 409-412.

APPENDIX B. SAMPLE DATA: DESCRIPTION AND SOURCE

The data base consists of 64 monthly observations on each variable covering the period March 1973 through June 1978. The basic data are available through the Data Fund Division, Bureau of Statistics, International Monetary Fund, and most are published each month (for a current string of dates) in International Financial Statistics (IFS).⁶⁸

Specific time series for each of the ten countries (as well as for the U.S. for money, income, and price relatives) are as follows:

(1) The end-of-month spot exchange rate expressed in units of national currency per U.S. dollar (IFS line "ae") transformed into an index,

(2) The narrow definition of the money supply (IFS line "34") transformed into an index,⁶⁹

68. Data for the entire sample period are available on the monthly IFS tape.

69. Strictly speaking, the model calls for data on money demand, but as Cagan, op. cit., p. 33 points out: "The assumption made... is that desired real cash balances are equal to actual real cash balances at all times. This means that any discrepancy that may exist between the two is erased almost immediately by movements in the price level."

(3) The index of industrial production (IFS line "66..b" or line "66..c"), as a proxy for real income.

(4) The three-month forward exchange rate (IFS line "b") transformed using (1), above, into a premium or discount. Data for the Italian lira were not available for the entire time period of this study. Hence, for Italy, the interest rate differential was taken as the difference between Italy's interbank rate and the United States' three-month primary market rate on large negotiable certificates of deposit. These two series are published in the Federal Reserve Bulletin.

(5) The series for gross official reserves (IFS line "1..d") less short term foreign liabilities (IFS line "4..d"), and Use of IMF Credit (IFS line "2e.d"), if significant. In the case of the United Kingdom, an unpublished Data Fund time series, line "16c..zF" was converted into U.S. dollars and used as the foreign liabilities series.

(6) Indices of consumer prices (IFS line "64"), export prices (IFS line "74"), and wholesale prices (IFS line "63").

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THE CURRENT EXPERIENCE OF FLEXIBLE EXCHANGE RATES:
EMPIRICAL EVIDENCE FOR TEN INDUSTRIAL COUNTRIES

by

Ronald Frederick Pearson

(ABSTRACT)

The theories of Purchasing Power Parity and the monetary approach to the exchange rate were empirically tested for ten industrial countries over the sample period March 1973 through June 1978.

Purchasing Power Parity (PPP) was held to represent the long-run equilibrium exchange rate, and the PPP model was designed to focus on factors affecting short-term disequilibrium such as changing interest rate differentials and foreign exchange market intervention.

The monetary model was based on the hypothesis that the equilibrium exchange rate, viewed as the relative price of two monies, is a function of the factors determining the supplies and demands for those monies.

The models were estimated using both ordinary least squares and mixed estimation. The latter method permitted the combination of sample and prior

information, and in general provided improved individual coefficient estimates in the presence of a highly collinear data set. Prior information was derived from the homogeneity postulate and known characteristics of the demand for money.

The empirical results broadly supported the models estimated, yet did not strongly endorse the validity of either.

It was suggested that further research should be directed at improving data definition and variable specification, with particular emphasis on the measure for intervention. Also mentioned was the fact that a simultaneous equations model appears to be particularly well suited to the exposition of the monetary approach.